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For: Integrated Beamformer/Modem Architecture

Enclosed are:

New Patent Application including:
22 Pages of Specification;
3 Sheets of Drawings; and

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U.S. Patent Application
Scott Bierly, et al.

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All correspondence regarding this application should be directed to EPSTEIN, EDELL, SHAPIRO, FINNAN & LYTLE, LLC, at the above address, customer number 27896.

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INTEGRATED BEAMFORMER/MODEM ARCHITECTURE

CROSS REFERENCE TO RELATED APPLICATION

This application claims priority from U.S. Provisional Patent Application Serial No. 60/271,961 entitled "Integrated TDMA Beamformer/Modem Architecture," filed February 28, 2001. The disclosure of this provisional patent application is incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to wireless communication transceivers and modems and, more particularly, to the construction of a multi-frequency, multi-channel transceiver system such as might be used in a multi-user base station for terrestrial cellular or fixed-wireless applications.

Description of the Related Art

Directional antennas are widely used in a variety of communications systems to more efficiently transmit and receive radiated signals. Relative to an isotropic antenna, which transmits and receives signals equally in all directions, a directional antenna has an antenna gain pattern that is greater in certain directions than others, typically having a higher-gain main lobe several degrees wide (i.e., an antenna beam). Generally, a greater antenna gain reduces the amount of power required to transmit and receive signals between two communication devices. Thus, steering the main lobe of a transceiver's antenna gain pattern in the direction of another communication device facilitates communication between the two devices.

To be useful in certain applications, it may be necessary to rapidly point the antenna beam of a directional antenna in different directions. For example, base stations employed in cellular or wireless communication systems are required to communicate with several mobile communication devices at once. Often, the cell or region covered by the base station is divided into angular sectors (e.g., three 120° sectors), with certain antennas being responsible for communications with any mobile communication devices in a given sector. To permit virtually instantaneous redirecting of the antenna beam within the sector, an antenna formed of a phased array of independently controllable antenna elements may be used. The antenna

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beam is formed by applying appropriate phase and gain to the individual elements in the array.

More specifically, beamforming is a type of spatial filtering in which an array of sensor elements is controlled with appropriate signal processing to implement a phased array antenna for the purpose of shaping the antenna response over time in a space-varying manner (i.e., steering gain in some directions, while producing attenuation or nulls in other directions). In a radio communications system, a signal arriving at each element of an antenna array will arrive at slightly different times due to the direction of arrival with respect to the antenna array plane (unless the signal has normal incidence to the plane, in which case the signal will arrive at all elements simultaneously). A phased-array receive antenna achieves gain in a particular direction by phase shifting, or time shifting, the signal from each element, and then summing the phase-shifted element signals in a signal combiner. By choosing the relative phasing of each element appropriately, coherence can be achieved for a particular direction of arrival (DOA), across a particular signal bandwidth.

Digital beamforming is analogous to analog beamforming, except that the received signal on each antenna element is independently digitized, and the phasing/combining operation is performed mathematically on the digital samples. The present inventors describe digital beamforming techniques in U.S. Patent Application Serial No. 09/778,854 entitled "Integrated Beam Forming/Rake/MUD CDMA Receiver Architecture", filed February 8, 2001, the disclosure of which is incorporated herein by reference in its entirety. Conventionally, digital beamforming is done on a wideband signal, prior to despreading a CDMA waveform. This forces the computationally intense beamforming to take place at a much higher sampling rate, resulting in more mathematical operations per second, and corresponding increased hardware cost. To address this shortcoming, beamforming can be performed at baseband, as disclosed by Hanson et al. in U.S. Patent No. 6,052,085, the disclosure of which is incorporated herein by reference in its entirety.

Furthermore, digital beamforming is conventionally performed as a separate process, independent of symbol modulation/demodulation, perhaps even as a separate product from the modem. In addition to the resulting inability to support advanced demodulation techniques with this architecture, the cost of the beamforming function is greater as a stand-alone function, compared to the incremental cost of adding the capability to a modem. The largest cost-component of beamforming is the complex multiplication of each sample for each element with the beamforming weights. Thus, whether stand-alone beamformers

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merely point in the direction of the signal of interest, or respond more adaptively to dynamic interference conditions by null-steering, such beamformers still lack the ability to be tightly coupled with potential advanced demodulation techniques.

When combined with the modem, there is potential to absorb the complex multiply required for beamforming into computation already taking place for extremely low incremental cost. In U.S. Patent No. 5,764,187, the disclosure of which is incorporated herein by reference, Rudish et al. disclose an implementation of beamforming using digital direct synthesis (DDS) functions. However, Rudish does not suggest or recognize potential hardware and processing savings in both signal transmission and reception. Specifically, Rudish does not suggest combining demodulation with beamforming or using hardware in a time-shared manner for both transmit and receive. Rudish's architecture is highly parallel and does lend itself to time multiplexing techniques which could potentially reduce hardware requirements.

Accordingly, there remains a need for an efficient, integrated way of incorporating beamforming technology, for both transmit and receive, into base stations or transceiver terminals that process large number of users simultaneously using time division multiple access (TDMA) and/or frequency division multiple access (FDMA) technology. This problem can be extremely computationally burdensome, and architectures for cost-effectively performing this processing are not addressed sufficiently in the prior art.

SUMMARY OF THE INVENTION

Therefore, in light of the above, and for other reasons that become apparent when the invention is fully described, an object of the present invention is to integrate digital beamforming capabilities into baseband processing functions such as modulation and demodulation carrier phase rotation and AGC/power-control scaling functions.

Another object of the present invention is to efficiently implement a digital signal processing architecture for a TDMA and/or FDMA base station transceiver performing digital adaptive beamforming with a multi-element antenna array.

A further object of the present invention is to reduce overall hardware and processing requirements in a multi-user transceiver system employing antenna beam steering.

Yet a further object of the present invention is to share common processing elements between modulation and demodulation functions in a modem.

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A still further object of the present invention is to take advantage of intermediate frequency (IF) to baseband data rate reductions to process parallel signal data in a time-multiplexed manner at baseband to thereby reduce modem hardware requirements.

Another object of the present invention is to reduce the size and weight of transceiver/modem equipment.

Yet another object of the present invention is to maximize the amount of processing performed with a limited hardware resource.

Still another object of the present invention is to implement transceiver/modem processing of multiple signals in a cost-effective manner.

The aforesaid objects are achieved individually and in combination, and it is not intended that the present invention be construed as requiring two or more of the objects to be combined unless expressly required by the claims attached hereto.

In accordance with the present invention, a modulator/demodulator (modem) architecture is presented for TDMA and FDMA applications. In particular, a transceiver configured to simultaneously communicate with multiple users, such as a base station transceiver, employs a phased-array antenna capable of generating a steerable, directed antenna beam for communication with other devices. Rather than implementing the beamforming phase and amplitude control of the antenna elements in the front-end circuitry, the signals from each antenna element are independently processed all the way down to the individual baseband channel level, and digital beamforming is performed at baseband. While this approach would suggest significantly higher processing demands due to the separate processing for each antenna element, the transceiver of the present invention is implemented using a symmetrical processing structure, leveraging the relationship of increasing computational complexity with decreasing computational rate from IF to baseband processing. Specifically, the data rate reduction from IF to baseband permits parallel signal data from multiple antenna elements to be time multiplexed and serially processed at acceptable data rates at baseband with minimal modem hardware requirements.

Further, the approach of the present invention allows the computation of carrier tracking, automatic gain control (AGC)/power-control, and beamforming to be shared by the same processing circuitry for all channels when performed at baseband. The resulting baseband circuitry is only incrementally larger than that already required in the modem for performing carrier tracking and AGC, yet accomplishes independent beamforming for each antenna element on each user channel. For non-simultaneous transmit/receive systems, such

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as time division duplex (TDD), additional savings are realized by sharing wideband digital down-converter (DDC) and digital up-converter (DUC) hardware as well as the baseband beamforming circuitry in a time-multiplexed manner between the demodulator and modulator functions.

The above and still further objects, features and advantages of the present invention will become apparent upon consideration of the following definitions, descriptions and descriptive figures of specific embodiments thereof wherein like reference numerals in the various figures are utilized to designate like components. While these descriptions go into specific details of the invention, it should be understood that variations may and do exist and would be apparent to those skilled in the art based on the descriptions herein.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a functional block diagram of an integrated TDMA/FMDA beamformer/modem architecture in accordance with an exemplary embodiment of the present invention.

Fig. 2 is a functional flow diagram illustrating the signal processing operations associated with transmitting and modulating signals in accordance with the exemplary embodiment of the present invention.

Fig. 3 is a functional flow diagram illustrating the signal processing operations associated with receiving and demodulating signals in accordance with the exemplary embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The following detailed explanations of Figs. 1-3 and of the preferred embodiments reveal the methods and apparatus of the present invention. Fig. 1 is a generalized functional block diagram of an integrated beamformer/modem architecture in accordance with an exemplary embodiment of the present invention. The beamformer/modem architecture of the present invention can be employed in any communication device that transmits or receives signals from other communication devices. As used herein and in the claims, a "communication device" includes any device, mobile or stationary, that is capable of transmitting and/or receiving communication signals, including but not limited to: a handheld or body-mounted radio; any type of mobile or wireless telephone (e.g., analog cellular, digital cellular, PCS or satellite-based); a pager, beeper or PDA device; a radio or

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transceiver carried on, built into or embedded in a ground-based or airborne vehicle; any portable electronic device equipped with wireless reception/transmission capabilities, including multimedia terminals capable of receiving/transmitting audio, video and/or data information; and any device mounted in a fixed location with transmission/reception capabilities. The architecture of the present invention is particularly useful in any transceiver communication device requiring the use of directed antenna beams to transmit signals to and receive signals from a plurality of other communication devices used in transmission of audio, video and/or data information including, but not limited to, base stations of wireless communication systems, mobile communication devices, airborne communication systems, and communications satellites.

Referring to Fig. 1, the transceiver beamformer/modem architecture includes a plurality E of transmit/receive antenna elements 10_1, 10_2, ..., 10_E forming a phased array antenna which is electronically steerable via digital beamforming. Antenna elements 10 may have any hardware configuration suitable for operating at the frequency and bandwidth required by the communication system in which the transceiver is used. In the specific implementation shown in Fig. 1, the transceiver employs time-division duplexing (TDD) in which the transceiver is alternately in a transmit and receive mode, relying on the phased array antenna for both signal transmission and reception. Accordingly, each antenna element 10_i has a corresponding RF switching element 12_i selectively connecting the antenna element to the transmitter system and the receiver system. RF switching elements 12_i can be a RF transmit/receive switches, circulators, diplexers, hybrid splitters or any other device suitable for selective connecting the antenna elements to the transmit and receive circuitry. It should be understood, however, that the invention is not limited to a TDD architecture, and the present invention can be employed with both simultaneous and non-simultaneous transmit/receive schemes.

On the receiver side, each of the antenna elements 10_1, 10_2, ..., 10_E is coupled to a respective bandpass filter 14_1, 14_2, ..., 14_E which attenuates signal frequencies outside the filter's pass band. Each antenna element 10_i can simultaneously receive signals on a plurality of different frequency channels F within the receiver pass band (frequency division multiplexing FDM). Each frequency channel is in turn time-division multiplexed (TDM), such that the system employs both time division multiple access (TDMA) and frequency division multiple access (FDMA) channelizing. The filtered RF signal from each element 10_1, 10_2, ..., 10_E is amplified by a corresponding low-noise amplifier (LNA) 16_1, 16_2, ..., 16_E

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and then processed by an analog RF down-converter (DC) 18_1, 18_2, ..., 18_E which down-converts the RF signal to an intermediate frequency (IF). For each of the E IF signals, a corresponding analog-to-digital (A/D) converter 19_1, 19_2, ..., 19_E digitally samples the IF signal at a wideband input sampling rate Fs_1, and the digital IF signal is received by a bank of digital down-converters (DDC) 20 to perform frequency division multiplexing (FDM) de-channelization.

The DDC bank 20 includes a digital down-converter for each of the F frequency channels of each of the E antenna elements for a total of FxE digital down-converters. In practice, it may be possible under certain circumstances to perform digital down-conversion with fewer than FxE actual DDC devices, as will be explained herein in greater detail. DDC bank 20 down-converts the digital IF signal to a baseband frequency by decimating the digital IF signal and FIR filtering to bring the signal in each frequency channel of each antenna element down to baseband. Specifically, each DDC selects every R^{th} sample for inclusion in the baseband signal while discarding the intervening R-1 samples, such that each DDC produces a decimated signal for a particular element and frequency channel at a sampling rate of

$$Fs_2 = \frac{Fs_1}{R} \qquad (1)$$

The factor R represents the narrowband rate reduction which facilitates multiplexing the multiple elements and frequency channels in order to share baseband processing circuitry. A frequency division multiplexer (FDM) channel numerically controlled oscillator bank 22 comprises F NCOs which are respectively tuned to the center frequency of the F frequency channels. The FDM channel NCO bank 22 supplies the F different frequency signals used by DDC bank 20 to perform the complex multiplying required to bring each of the F frequency channel signals from each of the E antenna elements down to baseband, which are then filtered by FIR filters.

As shown in Fig. 1, each of the digital baseband signals generated in parallel by the FxE DDCs is time multiplexed by multiplexer (MUX) 24 into a serial signal having a rate of

$$Fs_3 = \frac{Fs_1 \cdot E \cdot F}{R} \qquad (2)$$

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The time-multiplexed serial baseband output signal of multiplexer 24 is processed at baseband as described below to detect data symbols for each of C user channels. It should be understood that the various data rates described herein relate to upper limits constrained by the relationships between factors such as the wideband sample rate, the number and bandwidth of frequency and time channels, the decimation/interpolation factor, the number of antenna elements, the number of users channels and input/output symbol rates. Accordingly, a particular architecture can be designed to operate up to particular clock rates in accordance with these relationships. However, these rate relationships do not imply that the hardware must be operated at the maximum designed rate. Thus, for example, while Fs_3 is shown in equation (2) to as "equal to" a particular expression, it will be understood that this expression represents an upper limit on the permissible value of Fs_3; in operation, Fs_3 can be set at an appropriate rate up to the value of this expression.

On the transmitter side, baseband signals are generated at the rate Fs_3 and supplied to a demultiplexer (DEMUX) 26. The serial baseband signal stream includes time-multiplexed signals for each antenna element on each user channel. Demultiplexer 26 converts the serial baseband signal to FxE parallel signals, each having a rate of Fs_2, which are respectively received by FxE digital up-converters (DUC) of a DUC bank 28 which performs FDM channelization of the baseband signals. Receiving the center frequencies of the F frequency channels from FDM channel NCO bank 22, DUC bank 28 performs the complex multiplying required to up-convert E signals (one for each antenna element) on each of the F channel frequencies into E digital IF signals. Further, to bring the sampling rate up to the wideband sampling rate Fs_1 required by the digital-to-analog converters 29_1, 29_2, ..., 29_E corresponding to antenna elements 10_1, 10_2, ..., 10_E, DUC bank 28 interpolates each of the E digital IF signals by the factor of R. After digital-to-analog conversion, the analog IF signal for each of E antenna elements is up-converted to RF by respective analog up-converters 30_1, 30_2, ..., 30_E and amplified by respective power amplifiers 32_1, 32_2, ..., 32_E. With RF switching elements 12_1, 12_2, ..., 12_E positioned to connect the transmit circuitry to respective antenna elements 10_1, 10_2, ..., 10_E, the amplified RF signals are transmitted via the antenna elements in accordance with the beamforming applied in the baseband processing.

Beamforming in a multi-user modem or base station applications in the prior art has principally taken a non-integrated or detached approach. In some cases, beamforming rotation and combining is done in analog in the front-end UC/DC circuitry of the modem. In other cases, beamforming is performed using either analog or digital approaches as a distinct

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external apparatus from the modem. The approach of the present invention is to incorporate beamforming directly into the modem architecture. To accomplish beamforming, the appropriate relative signal phase and amplitude must be applied to the individual antenna elements to form an antenna beam which has a desired shape and points in a particular direction. To support signal modulation and demodulation, baseband processors typically perform the functions of carrier phase tracking (involving carrier phase rotation) and automatic gain control (AGC) (i.e., adjusting the amplitude of the baseband signal to be within the operational range of downstream devices), although baseband processors do not generally process carrier phase and amplitude on an antenna-element-by-antenna-element basis. In accordance with the present invention, beamforming is integrated into baseband processing such that beamforming computations are performed in a manner requiring only additional adders, due to integration with the existing modulation/demodulation carrier phase rotation and the AGC/power-control scaling functions.

An important novel aspect of the present invention is the independent processing of each antenna element all the way from the antenna elements down to individual baseband channel-level processing. While increasing the baseband computational complexity by a factor of the number of antenna elements *E*, this approach affords significant performance advantages to each user channel, permitting completely independent antenna beam patterns to be achieved per channel when receiving, as well as individual contributions to the beam pattern when transmitting.

Baseband processing is described in connection with transmission and reception of data symbols associated with a plurality of users. A flow diagram summarizing the signal processing operations associated with modulating and transmitting data symbols is shown in Fig. 2, while a flow diagram summarizing the signal processing operations associated with receiving and demodulating data symbols is shown in Fig. 3. Referring to Figs. 1 and 2, *C* independent data streams of symbols are received in parallel on *C* user channels at a certain data rate. The input data symbols from the *C* user channels are time multiplexed by multiplexer 34 into a serial signal having a data rate *C* times the input symbol rate, with each user channel receiving the fraction *1/C* of the time slots (operation 100 in Fig. 2). The serial signal is processed by a baseband modulator bank 36 comprising *C* baseband modulators which respectively generate in a time-multiplexed series baseband signals from the input data symbols of the *C* user channels for processing by shared baseband processor 38.

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Since beamforming is to be performed at baseband, for each input data symbol on each user channel, baseband modulator bank 36 must generate E copies of each symbol (operation 102). Consequently, the data rate of the time-multiplexed signal out of baseband modulator bank 36 is the input data symbol rate times the number of user channels C times the number of antenna elements E, and for each input data symbol time slot, baseband modulator bank 36 produces E identical baseband modulated signals in E corresponding time slots. The output of the baseband modulator bank 36, which is supplied to shared baseband processor 38, is serialized in this manner so that shared baseband processor 38 can be implemented with a single complex multiplier and a single automatic gain control element. Shared baseband processor 38 applies different phases and scaling to each of the E copies of each symbol.

Shared baseband processor 38 includes a carrier phase accumulator bank 40 comprising a single numerically controlled oscillator (NCO) controlled in a time-multiplex manner via a memory bank of phase values corresponding to each user channel C (for both modulation and demodulation). The NCO supplies a rolling phase for the respective data channels to a phase adder 42 in a time-multiplexed manner. A bank of beam rotation weights 44 contains beamforming weights in the form of phase rotations for each channel and each antenna element, which are supplied to phase adder 42 channel-by-channel and element-by-element in a time-multiplexed manner. With C independent user channels, E different antenna elements and both transmit and receive beam steering, beam rotation weight bank 44 includes *CxEx2* beamforming phase rotations. Phase adder 42 receives the beamforming rotation weights and adjusts the phase supplied by the carrier phase accumulator bank NCO 40 in accordance with the beamforming phases of the particular antenna elements. A sin/cos lookup table 46 is indexed by the adjusted phase value generated by phase adder 42 and supplies the corresponding sine/cosine multiplicands to a complex multiplier 48 for adjusting the phases of the input time-multiplex baseband signals on a time-slot-by-time-slot basis (operation 104).

The phase-adjusted baseband signal in each time slot is then adjusted in amplitude by a scalar multiplier 50 based on scaling information received from beam scaling and AGC/power control processor 52 (operation 106). Like the bank of beam rotation weights 44, scaling processor 52 applies different scaling on a time-slot basis in accordance with the beam scaling to be applied to a particular antenna element for each user channel and for both signal transmission and reception power control, resulting in *CxEx2* different scaling

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functions. For example, for received signals being demodulated, the automatic gain control adjusts the signal level to be within the operational range of downstream processing, simultaneously taking into account the relative scaling of the different antenna elements for proper beamforming.

By incorporating the individual antenna element phase rotations required to form a beam pattern into baseband signal rotations already required for each channel for carrier tracking, only a modest hardware impact occurs (this impact is shown in Fig. 1 by the dotted box enclosing adder 42 and beam rotation weights 44). This is because the process of carrier tracking already rotates each complex baseband sample by some amount on the unit circle between 0 and 2π radians. The complexity of this rotation is the same, regardless of the amount of rotation. Thus, by adding the desired beamforming rotation to the sample-by-sample desired carrier tracking rotation, a new sum rotation is formed. This sum rotation is then applied to the existing complex multiplier 48, which simultaneously performs carrier tracking and beam phasing, at the incremental cost of the adder 42 used to compute the rotation sum. In the same manner, the magnitude scaling component of beam weighting is incorporated into the existing AGC or power-control scalar multiplication. If the multiplication of the slowly changing beam scaling weight with the slowly changing AGC or power-control factor can be performed in software (which already calculates those individual values), then this second aspect of the beamforming computation is essentially achieved without additional hardware cost.

The phase and gain adjusted serial baseband signal stream produced by shared baseband processor is received by demultiplexer 26 and processed as previously described. Specifically, demultiplexer 26 converts the serial baseband signal to *FxE* parallel signals (operation 108) which are digitally up-converted by DUC bank 28 to produce *E* parallel digital IF signals corresponding to the *E* antenna elements (operation 110), which are then up-converted to RF at the analog front end and transmitted (operation 112).

Ultimately, the TDMA/FDMA transmission scheme must support transmission of the data symbols on each of the *C* user channels. The relationship between the input/output data symbol rate of the *C* user channels and the front end processing rates can be understood as follows. Recall that each of the *F* frequency-multiplexed channels is time division multiplexed (TDM) to support *T* users simultaneously. The instantaneous bandwidth of any one of the *F* frequency-multiplexed channel is equal to the number of TDM users on that channel times the maximum data rate of the users. Thus, for example, if 10 TDM users each

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having at 1 kbps maximum data rate are sharing one FDM channel, then that FDM channel itself is running at a 10 kbps rate. The overall number of user channels C is then related to the number of frequency channels F by the relationship $C = FxT$.

In the TDD example shown in Fig. 1, shared baseband processor 38 can also be used in a time-multiplexed manner to process the baseband signal samples generated from received RF signals. Referring to Fig. 3, wideband RF signals received at each of the E antenna elements are down-converted to IF and digitized (operation 200), digitally down-converted to baseband to form FxE parallel baseband signals (operation 202) and then time multiplexed to form a serial baseband signal stream at FxE the parallel data rate (operation 204) in the manner previously described. Shared baseband processor 38 operates on the serial baseband signal stream on a time-slot-by-time-slot basis to adjust the phase and amplitude of the time-multiplexed baseband samples.

In the receive case, the NCO's of the carrier phase accumulator bank 40 respectively track the carrier phase of the signal in each of the C user channels based on feedback from a phase discriminator within the corresponding baseband demodulator 58. The bank of beam rotation weights 44 supplies beamforming weights for each channel and each antenna element in a time-multiplexed manner to adjust the rolling phase from the carrier tracker via adder 42 in accordance with the receive antenna beam. The sin/cos lookup table 46 is indexed by the adjusted phase value generated by phase adder 42 and supplies the corresponding sine/cosine multiplicands to complex multiplier 48 for adjusting the phases of the received time-multiplexed baseband signals on a time-slot-by-time-slot basis (operation 206). The phase adjusted baseband signal in each time slot is then adjusted in amplitude by multiplier 50 based on the required AGC and antenna element beam scaling (operation 208). Thus, beamforming for both modulation and demodulation can be seen to be implemented using the primarily existing baseband carrier rotation/AGC/power-control computational hardware. The beamformer/demodulator function can be used to compute the direction of arrival (DOA) of each user signal as it is processed. This not only accomplishes tracking of the received beam pattern on the signal, but also provides a known bearing for use during transmit beamforming.

The phase and amplitude adjusted baseband samples are supplied to a beamformer combiner bank 54 which, for each user channel C, combines at baseband the E simultaneously-received antenna element signals. That is, the antenna element signals forming a particular receive antenna beam via their appropriate phase and amplitude

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adjustments are combined to realize the resultant signal received via the particular antenna beam. The serial output data stream from beamformer combiner bank 54 has a data rate of

$$Fs_4 = \frac{Fs_1 \cdot C}{R} \qquad (3)$$

The output of beamformer/combiner bank 54 is supplied to a channel equalizer bank 56 comprising C channel equalizers which perform channel equalization on the C respective user channel signals. The output of channel equalizer bank 56 is supplied to a baseband demodulator 58 which demodulates the baseband signals for each of the C user channels. A demultiplexer 60 serial-to-parallel converts the output of baseband demodulator 58, and the C parallel signals undergo joint detection 62 to produce C soft detect output symbols.

As illustrated in Fig. 1, non-simultaneous transmit/receive cases, such as TDD, allow FDM Channel-NCO-Bank and Beamforming/Carrier-Rotation/AGC/Power-Control functions to be time-shared between modulation and demodulation computation. Identical mathematical functionality is required during both modulation and demodulation, but operating on different signal data and different state information such as FDM frequency channel, carrier frequency offset, NCO phase, beam weights, and AGC/Power-Control values. Thus, the computational hardware is reused in both modes, while appropriate signal data must be routed to the hardware, and appropriate state vectors retrieved from local storage (e.g., random access memory (RAM)) and routed to the hardware. In Fig. 1, signal data is routed at the correct time by synchronizing the switching of the RF switching elements $12_{1\text{-}E}$ as well as closing either switches 64 and 66 to connect the shared baseband processor 38 to the receiver/demodulator circuitry or switches 68 and 70 to connect the shared baseband processor to the modulation/transmitter circuitry; internal state vectors are represented by the boxes that have depth (e.g., carrier phase accumulator bank, which is implemented as a single hardware accumulator connected to a RAM containing *C*2* accumulated phase words).

It is also possible in a TDD-type system to share much of the computational complexity of the DDC bank and DUC bank (for purposes of clarity, this potential sharing is not shown in Fig. 1). In both cases, for instance, *F*E* wideband complex multiplies must be performed for TDM tuning. Furthermore, *F*E* FIR filters must be implemented at the wideband Fs_1 rate, using identical filter coefficients in both cases (for the DDC case, the filter is decimating by a factor of R, and for the DUC case the filter is interpolating by a factor of

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R), essentially the same hardware is required to perform the filtering operation, allowing a single efficient structure to perform both functions.

If non-beamforming prior-art modem architectures were merely extended to support multiple elements, wideband computational complexity would be increased by a factor of *E*. Another important aspect of the present invention is the manner in which this additional signal processing complexity due to beamforming is implemented. By exploiting several architectural innovations that perform this extended processing in a non-obvious manner, the additional capabilities are obtained at reduced implementation cost. Firstly, in the wideband DDC/DUC processing, the prior art (or extrapolation thereof) technique would simply repeat DDC/DUC modules on a per-element basis. According to the present invention, the DDC and DUC modules are broken down into constituent functions of NCO, complex multiplication, and interpolation/decimation FIR filtering. While the state vectors of those functions are unique and must be maintained for each element and frequency, both up-converting and down-converting, the computation is almost identical. Therefore, the present invention shares that processing between elements, frequencies, up-conversion, and down-conversion as is appropriate given the processing required by the input sampling rate Fs_I, and the arithmetic processing rate Fp. For example, if Fp/Fs_I is four, then a single physical DDC/DUC hardware resource can actually be shared across four elements or frequencies. Furthermore, in a time-multiplexed transmit/receive scenario, a single computational hardware implementation can serve as both DDC and DUC. As previously mentioned, in a TDD system, the DDC and DUC NCOs produce the same frequency waveform for a given frequency channel, and can thus be directly shared.

As has already been noted, significant complexity exists in the baseband portion of the beamforming base station modem. This is true for both arithmetic computation, as well as variety and multiple-rates of data operands for frequency bands, channel time slots, and antenna elements. Additional novel features of the present invention specifically address the organization of this complexity, to produce a dataflow architecture that can be effectively implemented on a VLSI, FPGA or ASIC type device. The typically large interpolation/decimation factor *R* is leveraged and used to multiplex/demultiplex the *FxE* streams of complex data from/to the DDC/DUC processing functions. This approach reduces the wiring interconnect complexity compared to other approaches. If *R* is greater than the product *FxE*, the sequential frequency/element data stream can likely be demodulated and beamformed by a single processing unit, as shown in Fig. 1; otherwise, multiple units would

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service the excess computational demand. This also applies to the beamformer/combiner function. In a TDD system, where modulation and demodulation do not occur at the same time, this carrier-tracking/beamforming hardware is also shared for both modulation and demodulation. In an FDD system, twice the capacity would be required, either through *R* being at least *2xFxE*, or through an additional computational block.

As illustrated in Fig. 1, the additional functions of baseband modulation, channel equalizer, baseband demodulation, and detection are achieved through distinct hardware blocks. In the manner just described, a single instance of these processing blocks can handle all *C* user channels, in this case where *R* is greater than or equal to *C*. Since this modem jointly demodulates many (C) users simultaneously, advanced signal processing techniques such as joint detection are readily enabled by the present invention.

Although beamforming on each user channel *C* requires a relatively large amount of beamforming computation to be performed (*E*C* complex multiply-accumulates per sample), this computation is at baseband, thus leveraging the sampling rate reduction of 1/R due to filtering and decimation in the DDC. Consequently, the beamforming computation rate in the share baseband processor is given by

$$Fs_5 = \frac{2 \cdot Fs_1 \cdot E \cdot C}{R} \qquad (4)$$

If *2xExC* can be set to be approximately equal to *R*, then it can be seen that the entire beamforming computation for all user channels, transmit and receive, can be accomplished with a single complex multiply-accumulator running at the input sample rate Fs_1. This example is for the case of transmit/receive multiplexing.

The present invention improves the state of the art by mitigating the growth in wideband hardware complexity due to beamforming through novel restructuring of fundamental transceiver building blocks. At the same time, baseband hardware complexity growth is also minimized. The complex weighting required for beamforming potentially represents the largest impact of all. However, by incorporating the element rotations required to form a beam pattern into baseband signal rotations already required for each channel for carrier tracking, only a modest hardware impact occurs.

One of the principal advantages of the present invention is the potential for dramatically increasing processing capability in applications where there is a limited hardware resource. For example, where the digital signal processing associated with up/down-converting and modulation/demodulation are to be implemented on field

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programmable gate arrays (FPGA), there is a fixed resource and a finite number of processing/memory elements that can be formed on the chip. Consider an example where the signals being processed are voice circuits in a cellular base station, where typical processing rates are 10 to 20 kHz. If modem processing is performed at clock rates on this order, a tremendous waste of expensive hardware resources results, since, regardless of the processing rates, the modem processing requires complex multipliers, random access memories, arithmetic logic, oscillators, and other signal processing hardware to be formed in the FPGA. According to the present invention, by employing time-multiplexing in the modem processing between user channels, antenna elements and modulation/demodulation, and by operating the FPGA at 10 MHz to accommodate the time-multiplex a thousand times more voice signal processing can be performed on a comparable FPGA with roughly the same amount of circuitry therein. Thus, in additional to cost savings, the invention is advantageous in any application where smaller size and weight would be beneficial, such as in handheld or airborne units.

The present invention advantageously permits an element snapshot memory to operate at narrowband sampling rates, allowing an eased implementation for any snapshot operations required. Furthermore, these snapshots occur after narrowband channel filtering, thus containing only received signals of interest for that frequency band.

Further, integration of the beamformer with the demodulator in the present invention allows advanced adaptive algorithms to be implemented that can be enhanced by the feedback of post-demodulation metrics such as carrier-SNR/phase, symbol-SNR/phase, and error control decoding metrics.

In accordance with another aspect of the present invention, the beamformer spatial processing for each user channel is integrated with demodulation functionality, such as adaptive equalization temporal processing, allowing more complex algorithms to be implemented that jointly perform spatial/temporal optimization.

While the present invention has been described in the context of multiple user channels and certain features of the present invention are most advantageously exploited in this context, it will be understood that the present invention is nevertheless useful in the context of a single user channel or only a few user channels, and can be employed in devices such as mobile communication devices serving only a single end-user at a time. Further, the baseband time-multiplexing and shared processing techniques described herein can be employed in systems using only one of TDMA and FDMA, and has applicability in virtually

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any multi-user communication system employing multiplexing, including those employing code division multiple access (CDMA).

The present invention performs demodulation and detection of potentially all visible user channels in the antenna field of view. This capability facilitates the joint detection (rather than individual) of all channels simultaneously, which is known in the prior art to substantially increase cellular capacity. The present invention further enables the combined processing of beamforming, equalization, and joint detection in a single demodulation process.

Having described preferred embodiments of new and improved integrated beamformer/modem architecture, it is believed that other modifications, variations and changes will be suggested to those skilled in the art in view of the teachings set forth herein. It is therefore to be understood that all such variations, modifications and changes are believed to fall within the scope of the present invention as defined by the appended claims. Although specific terms are employed herein, they are used in a generic and descriptive sense only and not for purposes of limitation.

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What is Claimed is:

1. An apparatus for modulating and demodulating signals transmitted and received via an electronically steerable phased array antenna comprising a plurality of antenna elements, the apparatus comprising:

a baseband modulator configured to modulate signals to be transmitted via the phased array antenna;

a baseband demodulator configured to demodulate signals received via the phased array antenna; and

a shared baseband processor configured to receive baseband signals including the modulated signals from said baseband modulator and the signals received via the phased array antenna which are destined for said baseband demodulator, said shared baseband processor adjusting phases of the baseband signals to jointly account for beamforming phase rotation of individual antenna elements and carrier phase rotation, and adjusting amplitudes of the baseband signals to jointly perform power control and antenna element beam scaling.

2. The apparatus of claim 1, wherein said baseband signals received by said shared baseband processor are time multiplexed, and said shared baseband processor operates on said baseband signals on a time-slot-by-time-slot basis.

3. The apparatus of claim 1, wherein said baseband modulator receives data symbols from a plurality of user channels and supplies to said shared baseband processor a time-multiplexed stream of modulated data symbols from said plurality of user channels.

4. The apparatus of claim 3, wherein, for each input data symbol, said baseband modulator generates a plurality of modulated data symbols in the time-multiplexed stream respectively corresponding to the plurality of antenna elements.

5. The apparatus of claim 1, wherein said shared baseband processor comprises:

a numerically controlled oscillator configured to generate a stream of carrier phases for baseband signals of each of a plurality of user channels in a time-multiplexed manner;

a beamforming phase rotator configured to generate a stream of beam rotation phases corresponding to individual antenna elements for each of the plurality of user channels in a time-multiplexed manner;

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a phase adder configured to sum the beam rotation phases and the carrier phases to produce a time-multiplexed stream of combined phase adjustments; and

a complex multiplier configured to adjust phases of a time-multiplexed stream of baseband signals corresponding to the plurality of user channels in accordance with the combined phase adjustments.

6. The apparatus of claim 5, wherein said combined phase adjustments index a sine/cosine lookup table which supplies multiplicands to said complex multiplier.

7. The apparatus of claim 1, wherein said shared baseband processor comprises a multiplier which performs complex multiplication on baseband signals relating to a plurality of user channels in a time-multiplexed manner.

8. The apparatus of claim 1, wherein said shared baseband processor comprises a multiplier which performs complex multiplication on baseband signals associated with a plurality of individual antenna elements in a time-multiplexed manner.

9. The apparatus of claim 1, wherein said shared baseband processor comprises a beam scaling and power control processor configured to generate a time-multiplexed stream of gain control signals for baseband signals corresponding to individual antenna elements for each of a plurality of user channels, the gain control signals jointly accounting for power control and antenna element beam scaling; and

a multiplier configured to adjust amplitudes of a time-multiplexed stream of baseband signals corresponding to the plurality of user channels in accordance with the gain control signals.

10. The apparatus of claim 1, further comprising:

a baseband beamformer configured to receive time-multiplexed baseband signals from said shared baseband processor corresponding to individual antenna elements, said baseband processor forming a combined signal from said time-multiplex baseband signals.

11. The apparatus of claim 1, further comprising:

a plurality of digital down-converters respectively down-converting digitized signals

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received from the plurality of antenna elements to produce parallel streams of sampled baseband signals; and

a multiplexer receiving the parallel streams of sampled baseband signals and supplying a time-multiplexed stream of the sampled baseband signals to said shared baseband processor.

12. The apparatus of claim 11, wherein said plurality of digital down-converters perform decimation to reduce a sampling rate of the digitized signals.

13. The apparatus of claim 11, wherein said plurality of digital down-converters separately down-convert digitized signals for each antenna element for each of a plurality of frequency channels.

14. The apparatus of claim 1, further comprising:

a demultiplexer receiving a time-multiplexed stream of baseband signals from said shared baseband processor and generating parallel streams of baseband signals corresponding to the plurality of antenna elements; and

a plurality of digital up-converters respectively up-converting the parallel streams of baseband signals to produce a plurality of digitized intermediate frequency signals corresponding to the plurality of antenna elements.

15. The apparatus of claim 14, wherein said plurality of digital up-converters perform interpolation to increase a sampling rate of the digitized intermediate frequency signals.

16. The apparatus of claim 14, wherein said plurality of digital up-converters separately up-convert baseband signals for each antenna element for each of a plurality of frequency channels.

17. The apparatus of claim 1, wherein signals are transmitted and received using time division duplex, said apparatus further comprising switching elements to selectively connect said shared baseband processor to said baseband modulator and front-end transmit circuitry for signal transmission and to said baseband demodulator and front-end receive circuitry for signal reception.

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18. The apparatus of claim 1, wherein said apparatus employs time division multiple access (TDMA) to transmit and receive signals.

19. The apparatus of claim 1, wherein said apparatus employs frequency division multiple access (FDMA) to transmit and receive signals.

20. The apparatus of claim 1, wherein said apparatus is a field programmable gate array (FPGA).

21. The apparatus of claim 1, wherein the apparatus is implemented via a very large scale integration (VLSI) circuit or an application specific integrated circuit (ASIC).

22. The apparatus of claim 1, wherein said apparatus is a modem.

23. The apparatus of claim 1, wherein said apparatus is a transceiver.

24. The apparatus of claim 1, wherein said apparatus is a basestation transceiver.

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ABSTRACT OF THE DISCLOSURE

A transceiver employing a steerable phased-array antenna includes a modem architecture in which signals from each antenna element in the array are independently processed down to the individual baseband channel level, and digital beamforming is performed at baseband. The data rate reduction from IF to baseband permits parallel signal data from multiple antenna elements to be time multiplexed and serially processed at acceptable data rates at baseband with minimal modem hardware requirements. Both for transmit signal modulation and received signal demodulation, the computation of carrier tracking, automatic gain control (AGC)/power-control, and beamforming are shared by the same processing circuitry for all channels when performed at baseband. The resulting baseband circuitry is only incrementally larger than that required for carrier tracking and AGC alone, yet accomplishes independent beamforming for each antenna element on each user channel.

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Apple EX1002 Page 24

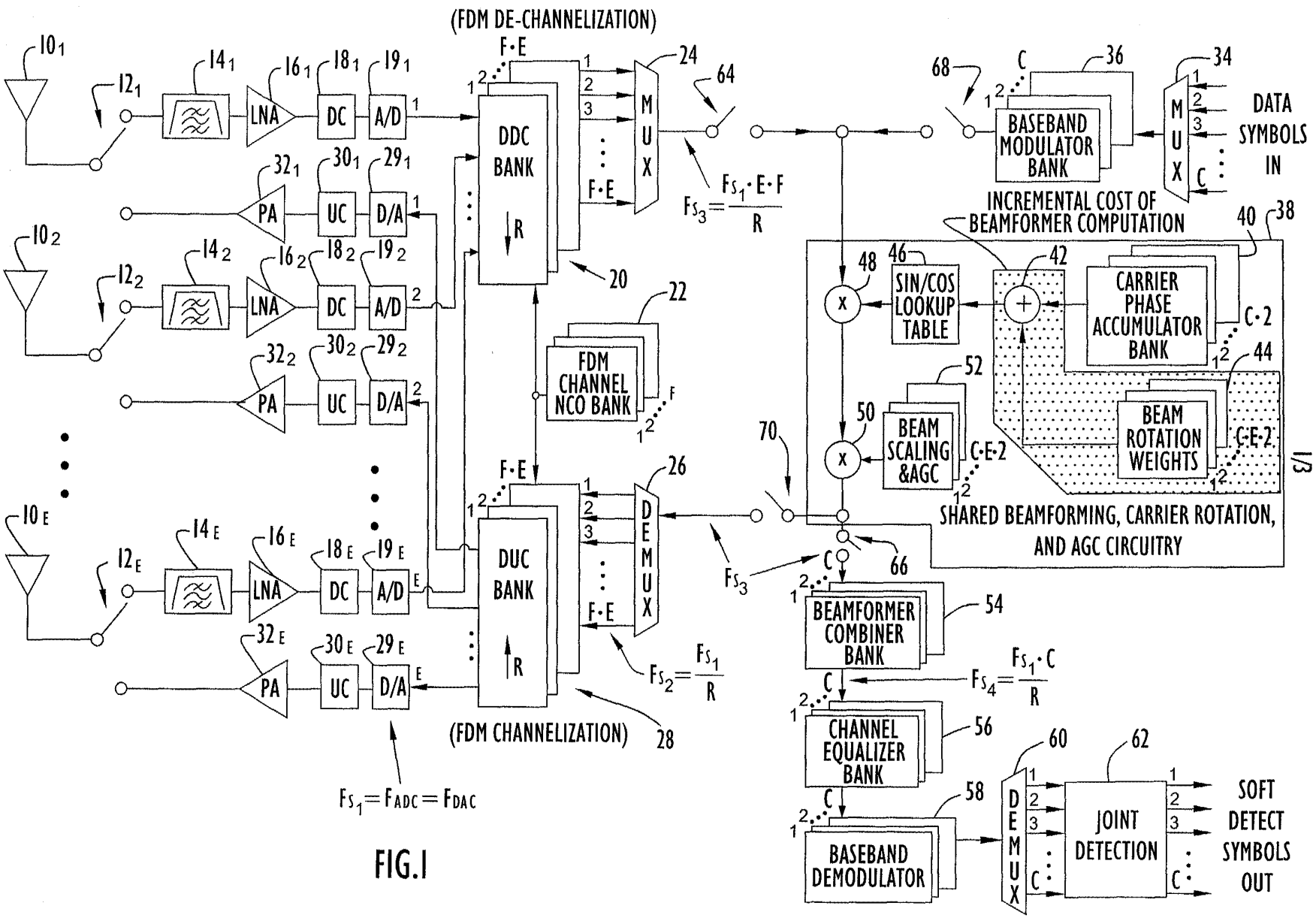

(FDM DE-CHANNELIZATION)
DDC BANK
DUC BANK
FDM CHANNEL NCO BANK
MUX
DEMUX
LNA
DC
A/D
PA
UC
D/A
BASEBAND MODULATOR BANK
DATA SYMBOLS IN
INCREMENTAL COST OF BEAMFORMER COMPUTATION
SIN/COS LOOKUP TABLE
CARRIER PHASE ACCUMULATOR BANK
BEAM SCALING &AGC
BEAM ROTATION WEIGHTS
SHARED BEAMFORMING, CARRIER ROTATION, AND AGC CIRCUITRY
BEAMFORMER COMBINER BANK
CHANNEL EQUALIZER BANK
BASEBAND DEMODULATOR
JOINT DETECTION
SOFT DETECT SYMBOLS OUT
(FDM CHANNELIZATION)
$Fs_1 = F_{ADC} = F_{DAC}$
$Fs_2 = \frac{Fs_1}{R}$
$Fs_3 = \frac{Fs_1 \cdot E \cdot F}{R}$
$Fs_4 = \frac{Fs_1 \cdot C}{R}$

FIG.1

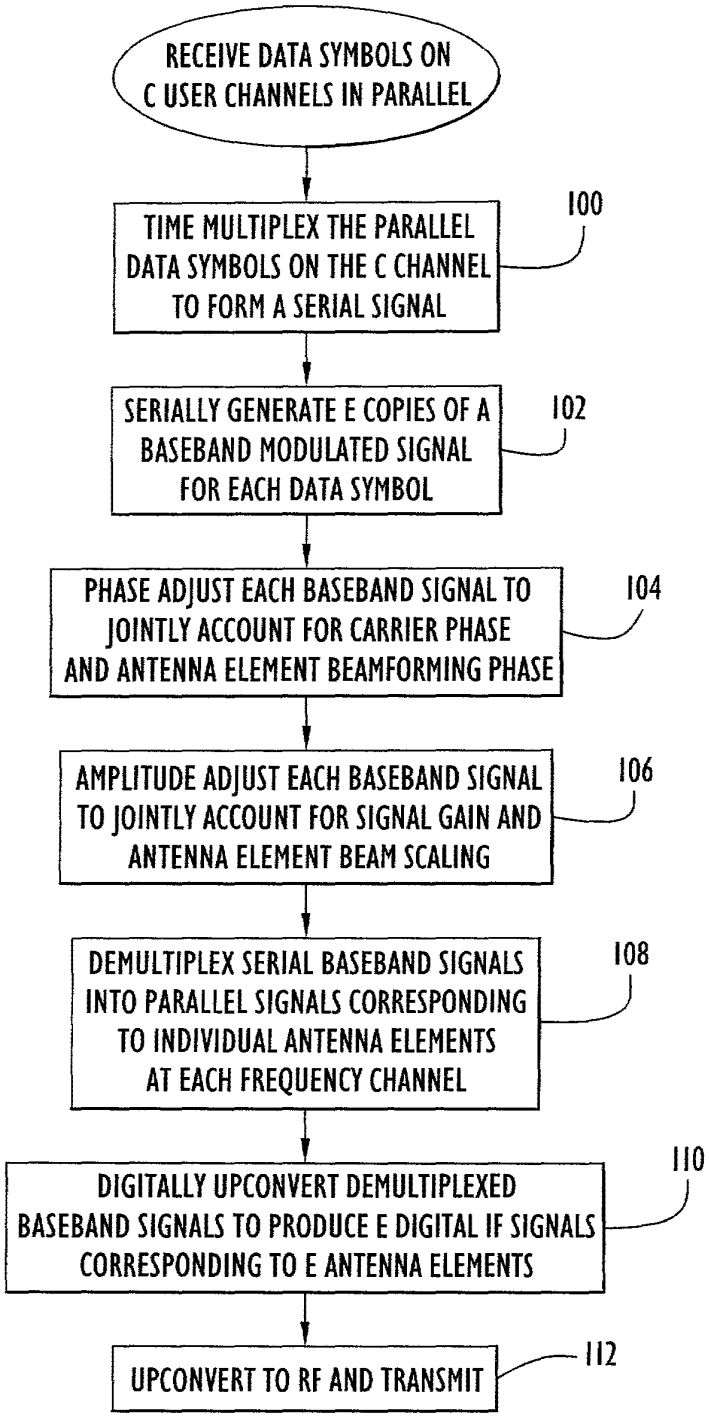

RECEIVE DATA SYMBOLS ON C USER CHANNELS IN PARALLEL
TIME MULTIPLEX THE PARALLEL DATA SYMBOLS ON THE C CHANNEL TO FORM A SERIAL SIGNAL
100
SERIALLY GENERATE E COPIES OF A BASEBAND MODULATED SIGNAL FOR EACH DATA SYMBOL
102
PHASE ADJUST EACH BASEBAND SIGNAL TO JOINTLY ACCOUNT FOR CARRIER PHASE AND ANTENNA ELEMENT BEAMFORMING PHASE
104
AMPLITUDE ADJUST EACH BASEBAND SIGNAL TO JOINTLY ACCOUNT FOR SIGNAL GAIN AND ANTENNA ELEMENT BEAM SCALING
106
DEMULTIPLEX SERIAL BASEBAND SIGNALS INTO PARALLEL SIGNALS CORRESPONDING TO INDIVIDUAL ANTENNA ELEMENTS AT EACH FREQUENCY CHANNEL
108
DIGITALLY UPCONVERT DEMULTIPLEXED BASEBAND SIGNALS TO PRODUCE E DIGITAL IF SIGNALS CORRESPONDING TO E ANTENNA ELEMENTS
110
UPCONVERT TO RF AND TRANSMIT
112

FIG.2

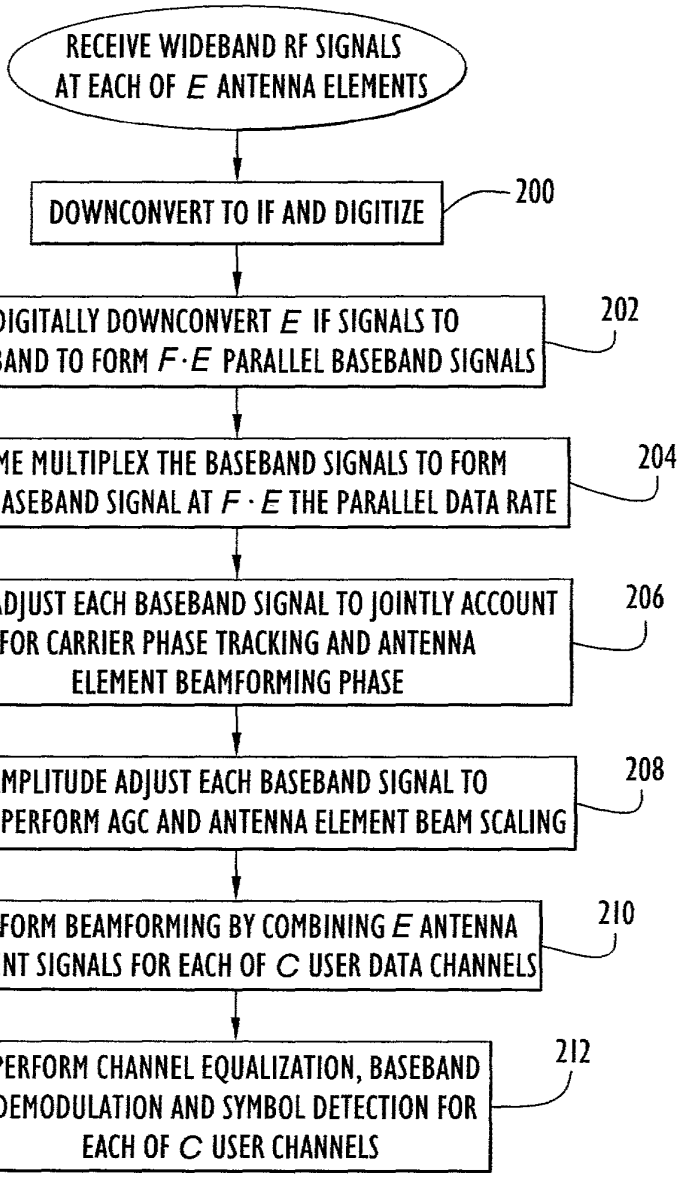

RECEIVE WIDEBAND RF SIGNALS AT EACH OF E ANTENNA ELEMENTS
DOWNCONVERT TO IF AND DIGITIZE
200
DIGITALLY DOWNCONVERT E IF SIGNALS TO BASEBAND TO FORM F·E PARALLEL BASEBAND SIGNALS
202
TIME MULTIPLEX THE BASEBAND SIGNALS TO FORM SERIAL BASEBAND SIGNAL AT F · E THE PARALLEL DATA RATE
204
PHASE ADJUST EACH BASEBAND SIGNAL TO JOINTLY ACCOUNT FOR CARRIER PHASE TRACKING AND ANTENNA ELEMENT BEAMFORMING PHASE
206
AMPLITUDE ADJUST EACH BASEBAND SIGNAL TO JOINTLY PERFORM AGC AND ANTENNA ELEMENT BEAM SCALING
208
PERFORM BEAMFORMING BY COMBINING E ANTENNA ELEMENT SIGNALS FOR EACH OF C USER DATA CHANNELS
210
PERFORM CHANNEL EQUALIZATION, BASEBAND DEMODULATION AND SYMBOL DETECTION FOR EACH OF C USER CHANNELS
212

FIG.3

PATENT APPLICATION FEE DETERMINATION RECORD
Effective October 1, 2001

Application or Docket Number
10081614

CLAIMS AS FILED - PART I

	(Column 1)		(Column 2)
TOTAL CLAIMS	24		
FOR	NUMBER FILED		NUMBER EXTRA
TOTAL CHARGEABLE CLAIMS	24 minus 20=	*	4
INDEPENDENT CLAIMS	1 minus 3 =	*	
MULTIPLE DEPENDENT CLAIM PRESENT			☐

* If the difference in column 1 is less than zero, enter "0" in column 2

SMALL ENTITY TYPE ☐		OR	OTHER THAN SMALL ENTITY	
RATE	FEE		RATE	FEE
BASIC FEE	370.00	OR	BASIC FEE	740.00
X$ 9=		OR	X$18=	72
X42=		OR	X84=	156.00
+140=		OR	+280=	
TOTAL		OR	TOTAL	968.00

CLAIMS AS AMENDED - PART II

AMENDMENT A

	(Column 1)		(Column 2)	(Column 3)
	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA
Total	*	Minus	**	=
Independent	*	Minus	***	=
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM				☐

SMALL ENTITY		OR	OTHER THAN SMALL ENTITY	
RATE	ADDITIONAL FEE		RATE	ADDITIONAL FEE
X$ 9=		OR	X$18=	
X42=		OR	X84=	
+140=		OR	+280=	
TOTAL ADDIT. FEE		OR	TOTAL ADDIT. FEE	

AMENDMENT B

	(Column 1)		(Column 2)	(Column 3)
	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA
Total	*	Minus	**	=
Independent	*	Minus	***	=
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM				☐

RATE	ADDITIONAL FEE		RATE	ADDITIONAL FEE
X$ 9=		OR	X$18=	
X42=		OR	X84=	
+140=		OR	+280=	
TOTAL ADDIT. FEE		OR	TOTAL ADDIT. FEE	

AMENDMENT C

	(Column 1)		(Column 2)	(Column 3)
	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA
Total	*	Minus	**	=
Independent	*	Minus	***	=
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM				☐

RATE	ADDITIONAL FEE		RATE	ADDITIONAL FEE
X$ 9=		OR	X$18=	
X42=		OR	X84=	
+140=		OR	+280=	
TOTAL ADDIT. FEE		OR	TOTAL ADDIT. FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20."
***If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3."
The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

CLAIMS ONLY

SERIAL NO.	FILING DATE
10/084,614	
APPLICANT(S)	

CLAIMS

	AS FILED		AFTER 1st AMENDMENT		AFTER 2nd AMENDMENT	
	IND.	DEP.	IND.	DEP.	IND.	DEP.
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TOTAL IND.	1					
TOTAL DEP.	23					
TOTAL CLAIMS	24					

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100						
TOTAL IND.						
TOTAL DEP.						
TOTAL CLAIMS						

* MAY BE USED FOR ADDITIONAL CLAIMS OR ADMENDMENTS

FORM PTO-2022 (1-98)

U.S.DEPARTMENT OF COMMERCE
Patent and Trademark Office

*U.S. Government Printing Office: 1998 - 333-[illegible]/[illegible]

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Apple EX1002 Page 29

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COMMISSIONER FOR PATENTS
UNITED STATES PATENT AND TRADEMARK OFFICE
WASHINGTON, D.C. 20231
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APPLICATION NUMBER	FILING/RECEIPT DATE	FIRST NAMED APPLICANT	ATTORNEY DOCKET NUMBER
10/084,614	02/28/2002	Scott Bierly	0918.0153C

CONFIRMATION NO. 1621

27896
EPSTEIN, EDELL, SHAPIRO, FINNAN & LYTLE, LLC
1901 RESEARCH BOULEVARD
SUITE 400
ROCKVILLE, MD 20850

FORMALITIES LETTER

OC000000007664935

Date Mailed: 03/19/2002

NOTICE TO FILE MISSING PARTS OF NONPROVISIONAL APPLICATION

FILED UNDER 37 CFR 1.53(b)

Filing Date Granted

An application number and filing date have been accorded to this application. The item(s) indicated below, however, are missing. Applicant is given **TWO MONTHS** from the date of this Notice within which to file all required items and pay any fees required below to avoid abandonment. Extensions of time may be obtained by filing a petition accompanied by the extension fee under the provisions of 37 CFR 1.136(a).

- The statutory basic filing fee is missing.
  Applicant must submit $ **740** *to complete the basic filing fee for a non-small entity. If appropriate, applicant may make a written assertion of entitlement to small entity status and pay the small entity filing fee (37 CFR 1.27).*
- Total additional claim fee(s) for this application is $72.
  - **$72** for **4** total claims over 20.
- The oath or declaration is missing.
  A properly signed oath or declaration in compliance with 37 CFR 1.63, identifying the application by the above Application Number and Filing Date, is required.
- To avoid abandonment, a late filing fee or oath or declaration surcharge as set forth in 37 CFR 1.16(l) of $130 for a non-small entity, must be submitted with the missing items identified in this letter.
- **The balance due by applicant is $ 942.**

A copy of this notice MUST be returned with the reply.

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Initial Patent Examination Division (703) 308-1202
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#31 4P/$

EPSTEIN, EDELL, SHAPIRO, FINNAN & LYTLE, LLC
1901 Research Boulevard
Suite 400
Rockville, Maryland 20850-3164
(301) 424-3640

In re the PATENT application of:

Scott BIERLY, et al.

Serial No.: 10/084,614

Filed: February 28, 2002

For: **Integrated Beamformer/Modem Architecture**

ASSISTANT COMMISSIONER FOR PATENTS
Washington, D. C. 20231

TRANSMITTAL LETTER

Sir:

Transmitted herewith for filing in the subject application are a Response to the Notice to File Missing Parts (2 pages), a Declaration and Power of Attorney (3 pages), Copy of Form PTO-1533, Check #5921 in the amount of $942.00 in payment of the subject application filing fee and surcharge, Four Assignment Documents (1 page each), Assignment Recordation Cover Sheet (3 pages), and Check #5923 in the amount of $40.00 for payment of the Assignment recordation filing fee.

The Commissioner is hereby authorized to charge payment of any additional fees required for the above-identified application or credit any overpayment to Deposit Account No. 05-0460.

Respectfully submitted,

Patrick J. Finnan
Registration No. 39,189

Hand-delivered: May 20, 2002

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MAY 20 2002
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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the PATENT application of

Scott BIERLY, et al.

Serial No.: 10/084,614

Filed: February 28, 2002

For: **Integrated Beamformer/Modem Architecture**

ASSISTANT COMMISSIONER FOR PATENTS
Washington, D. C. 20231

RESPONSE TO NOTICE TO FILE MISSING PARTS

Sir:

In response to the Notice to File Missing Parts of Application dated March 19, 2002, enclosed for filing in the subject application are an executed Declaration and Power of Attorney (3 pages), a copy of Form PTO-1533, and Check #5921 in the amount of $942.00 in payment of the subject application filing fee calculated as shown below.

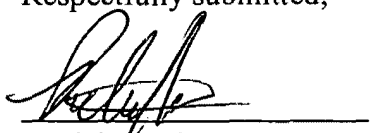
FEE CALCULATION

					BASIC FILING FEE:	$740.00
					SURCHARGE:	$130.00
TOTAL CLAIMS	24	- 20 = 4	Extra 4 x 18	=	$	72.00
INDEPENDENT CLAIMS	1	- 3 = 0	Extra 0 x 80	=	$	0.00
				TOTAL	$	942.00

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Apple EX1002 Page 32

The Commissioner is hereby authorized to charge any additional fees required for the above-identified application or credit any overpayment to Deposit Account No. 05-0460.

Respectfully submitted,



Patrick J. Finnan
Registration No. 38,189

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Hand-delivered: May 20, 2002

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Apple EX1002 Page 33

#3

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APPLICATION NUMBER	FILING/RECEIPT DATE	FIRST NAMED APPLICANT	ATTORNEY DOCKET NUMBER
10/084,614	02/28/2002	Scott Bierly	0918.0153C

CONFIRMATION NO. 1621

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ROCKVILLE, MD 20850

FORMALITIES LETTER

OC000000007664935

Date Mailed: 03/19/2002

NOTICE TO FILE MISSING PARTS OF NONPROVISIONAL APPLICATION

FILED UNDER 37 CFR 1.53(b)

Filing Date Granted

An application number and filing date have been accorded to this application. The item(s) indicated below, however, are missing. Applicant is given **TWO MONTHS** from the date of this Notice within which to file all required items and pay any fees required below to avoid abandonment. Extensions of time may be obtained by filing a petition accompanied by the extension fee under the provisions of 37 CFR 1.136(a).

- The statutory basic filing fee is missing.
  Applicant must submit $ **740** *to complete the basic filing fee for a non-small entity. If appropriate, applicant may make a written assertion of entitlement to small entity status and pay the small entity filing fee (37 CFR 1.27).*
- Total additional claim fee(s) for this application is $72.
  - **$72** for **4** total claims over 20.
- The oath or declaration is missing.
  A properly signed oath or declaration in compliance with 37 CFR 1.63, identifying the application by the above Application Number and Filing Date, is required.
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- **The balance due by applicant is $ 942.**

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02 FC:103 72.00 OP
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#3

Atty. Docket No. 0918.0153C

DECLARATION AND POWER OF ATTORNEY
(Patent, Design or C-I-P Application)

As a below-named inventor, I hereby declare that:
My residence, post office, address and citizenship are as stated below next to my name I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are stated below) of the subject matter which is claimed and for which a patent is sought on the invention entitled Integrated Beamformer/Modem Architecture the specification of which

__is attached hereto
X was filed on February 28, 2002 as Application Serial No. 10/084,614 and was amended on
I hereby state that I have reviewed and understand the contents of the above-entitled specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations §1.56(a).

I hereby claim foreign priority benefits under Title 35 United States Code, §119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed.

COUNTRY	APPLICATION NO.	DATE OF FILING	PRIORITY CLAIMED UNDER 35 U.S.C. 119
			Yes__ No__

LISTING OF FOREIGN APPLICATIONS CONTINUED ON PAGE 2 HEREOF YES __ NO __
I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first page of Title 35, United States Code, §112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56(a) which occurred between the filing date of the prior application and the national or PCT International filing date of this application

(Application Serial No.)	(Filing Date)	(Status)

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith.

I hereby claim the benefit under Title 35, United States Code, 119(e) of any United States provisional application(s) listed below:

60/271,961	February 28, 2001
(Application Serial No.)	(Filing Date)

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Atty. Docket No. 0918.0153C

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(Patent, Design or C-I-P Application)

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

DECLARATION AND POWER OF ATTORNEY

(Patent, Design or C-I-P Application)

Signature of Inventor #1	Signature of Inventor #2
Date: 4/26/02	Date: 5/16/02
Signature of Inventor #3	Signature of Inventor #4
Date: 4/26/02	Date: 5/16/02

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In re the PATENT application of:

Scott BIERLY, et al.

Serial No.: 10/084,614

Filed: February 28, 2002

For: **Integrated Beamformer/Modem Architecture**

INFORMATION DISCLOSURE STATEMENT

Assistant Commissioner for Patents
Washington, D.C. 20231

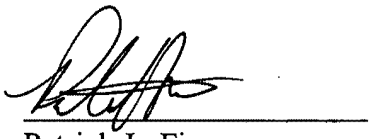
Sir:

Pursuant to the duty imposed by 37 C.F.R. §1.56 to disclose information which may be material to patentability of the above-identified patent application, the Examiner's attention is directed to the documents listed on the enclosed Information Disclosure Citation Form. Copies of the documents listed thereon are enclosed herewith.

Since this Information Disclosure Statement is being filed in compliance with 37 C.F.R. §1.97(b), within three (3) months of the filing date of the above-identified application and/or prior to the mailing date of a first Office Action on the merits, no fee is required in connection with its filing. However, the Commissioner is hereby authorized to charge payment of any fees required for the above-identified application or credit any overpayment to Deposit Account No. 05-0460.

The submission of the listed documents is not intended as an admission that any such document constitutes prior art against the claims of the present application. Applicant does not waive any right to take any action that would be appropriate to antedate or otherwise remove any listed document as a competent reference against the claims of the present application.

Respectfully submitted,



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Sheet 1 of 1

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LIST OF REFERENCES CITED BY APPLICANT(S)
(Use several sheets if necessary)

Date Submitted to PTO:

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ATTY DOCKET NO. 0918.0153C	SERIAL NO. 10/084,614
APPLICANT: Scott Bierly, et al.	
FILING DATE : February 28, 2002	GROUP

U.S. PATENT DOCUMENTS

*EXAMINER INITIAL		DOCUMENT NUMBER	DATE	NAME	CLASS	SUBCLASS	FILING DATE IF APPROPRIATE
		5,764,187	06/09/98	Rudish et al.			
		5,943,010	08/24/99	Rudish et al.			
		6,052,085	04/18/00	Hanson et al.			

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FOREIGN PATENT DOCUMENTS

		DOCUMENT NUMBER	DATE	COUNTRY	CLASS	SUBCLASS	TRANSLATION YES/NO/ OR ABSTRACT
	✓	WO 01/59962	08/16/01				
	✓	WO 00/11800	03/02/00				

OTHER DOCUMENT(S) (Including Author, Title, Date, Pertinent Pages, Etc.)

		✓	Bierly, et al.; Sequential-Acquisition, Multi-Band, Multi-Channel, Matched Filter; U.S. Patent Application Serial No. 09/707,909; filed November 8, 2000.

EXAMINER	DATE CONSIDERED

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609; Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

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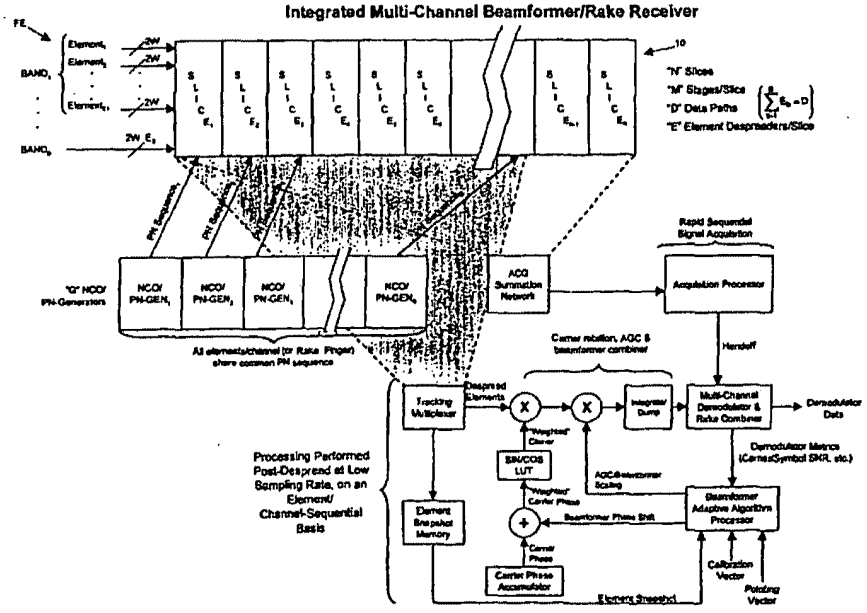
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(54) Title: INTEGRATED BEAMFORMING/RAKE/MUD CDMA RECEIVER ARCHITECTURE



(57) Abstract: A spread-spectrum demodulator architecture (10) is presented which utilizes parallel (Fig. 1) processing to accomplish rapid signal acquisition with simultaneous tracking of multiple channels, while implementing an integrated multi-element adaptive beamformer, Rake combiner, and multi-user detector (MUD). A matched filter computational architecture is utilized, in which common digital arithmetic elements are used for both acquisition and tracking purposes. As each channel is sequentially acquired by the parallel matched filter, a subset of the arithmetic elements are then dedicated to the subsequent tracking of that channel. Additionally, multiple data inputs and delay lines are present, connecting the sampled baseband data streams of numerous RF bands and antenna elements with the arithmetic elements. The matched filter/despreader processing is virtually independent of channel origin or utilization; e.g., CDMA users, RF bands, beamformer elements, or Rake Fingers. Integration of the beamformer weighting computation with the demodulator results in substantial savings by sharing the

[Continued on next page]

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— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

existing circuitry performing carrier tracking and AGC. An optimal demodulator solution can be achieved through unified "space/time" processing, by providing all observables (element snapshots, Rake Fingers, carrier/symbol SNR/phase, etc.), for multiple channels, to a single adaptive algorithm processor that can beamform, Rake, and perform joint detection [14-16].

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INTEGRATED BEAMFORMING/RAKE/MUD CDMA RECEIVER ARCHITECTURE

CROSS REFERENCE TO RELATED APPLICATIONS

The present application is the subject of provisional application No. 60/181,571 filed February 10, 2000 entitled INTEGRATED BEAMFORMING/CDMA-RAKE RECEIVER ARCHITECTURE. This application is also a continuation-in-part application of application Serial No. 09/707,909 filed November 8, 2000.

Reference is also made to Weinberg et al application Serial No. 09/382,202 filed August 23, 1999 and entitled MULTI-BAND, MULTI-FUNCTION, INTEGRATED TRANSCEIVER which is incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates in general to wireless communication receivers. In particular, it relates to the integration of multiple signal types (CDMA, FDMA, CW, etc.), from multiple bands, with each band and signal type potentially containing multiple user channels, and a single receiver processing architecture with multiple antenna elements per band for sequentially acquiring, and simultaneously demodulating these multiple channels,

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utilizing jointly-optimized advanced signal processing techniques of digital beamforming, Rake multipath combining, and joint detection.

2. Description of the Prior Art

Matched Filtering

A matched-filter is typically employed in a spread-spectrum demodulator to remove the effects of PN-spreading and allow the carrier and modulating information to be recovered. The digital implementation of a matched filter can be expressed as an integrate-and-dump correlation process, which is of relatively modest computational burden during signal tracking and demodulation. However, it is computationally and/or time intensive to acquire such a signal, where many such correlations must be performed to achieve synchronization with the transmitted spreading sequence. For each potential code-phase offset to be searched (which typically number in the thousands), sufficient samples must be correlated to ensure that the integrated SNR is sufficient for detection. Performed one at a time, acquisition could easily take several minutes to achieve in typical applications.

For applications requiring rapid signal acquisition (e.g., seconds), a highly parallel matched-filter structure may be used to search many spreading code offsets simultaneously. Typically, this computationally expensive

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apparatus would be underutilized once acquisition is completed, during the much less demanding tracking operation. If the same parallel matched filter is also used for tracking purposes, only perhaps three of its numerous correlation branches (perhaps hundreds) are useful in this instance. Alternatively, it may be simpler to use a separate set of early, on-time, and late integrate-and-dump correlators to take over once acquisition is complete; in this case, the parallel matched filter would go completely unused during tracking.

In implementations evidenced by the prior art, the matched-filtering solution has generally fallen into one of several classes:

1. Slow acquisition by sequential traversal of the search space using only the hardware required for tracking a signal; dedicated hardware per channel.

2. Rapid acquisition by parallel traversal of the search space using a dedicated parallel matched filter, which is idle or shut down when dedicated tracking hardware takes over; dedicated hardware per channel.

3. Either class 1 or 2, but multi-band and/or multi-channel, using a loosely integrated but disparate collection of individual processing resources.

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Beamforming

Beamforming is a form of spatial filtering in which an array of sensor elements are utilized with appropriate signal processing to digitally implement a phased array antenna, for the purpose of shaping the antenna response over time in a space-varying manner (i.e., steering gain in some directions, and attenuation or nulls in other directions). In a radio communications system, a signal arriving at each element of an antenna array will arrive at slightly different times, due to the direction of arrival with respect to the antenna array plane (unless it has normal incidence to the plane, in which case the signal will arrive at all elements simultaneously). A phased array antenna achieves gain in a particular direction by phase-shifting, or time-shifting, the signal from each element, and then summing them in a signal combiner. By choosing the relative phasing of each element appropriately, coherence can be achieved for a particular direction of arrival (DOA), across a particular signal bandwidth.

Digital beamforming is very analogous to this, except that the signal on each antenna element is independently digitized, and the phasing/combining operation performed mathematically on the digital samples. Traditionally, digital beamforming is done on a wideband signal, prior to despreading a CDMA waveform. This forces the

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computationally intense beamforming to take place at a much higher sampling rate, resulting in more mathematical operations per second, and corresponding increased hardware cost (there are examples addressing this shortcoming in the prior art, such as Hanson et al., where beamforming is performed at baseband to avoid this and other issues).

Furthermore, digital beamforming is traditionally done as a separate process, independent of symbol demodulation, perhaps even as a separate product from the demodulator. In addition to the resulting inability to support advanced demodulation techniques with this architecture, the cost of the beamforming function is greater as a stand-alone function, compared to the incremental cost of adding the capability to a demodulator. The largest cost-component of beamforming is the complex multiplication of each sample for each element with the beamforming weights. When combined with the demodulator, the complex multiply can be absorbed into computation already taking place for extremely low incremental cost due to beamforming (there is, for example, an implementation of beamforming using digital direct synthesis (DDS) functions in the prior art, such as Rudish, et al.). Thus, whether stand-alone beamformers merely point in the direction of the signal of interest, or respond more adaptively to dynamic interference conditions by null-steering, they still lack

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the ability to be tightly coupled with potential advanced demodulation techniques.

Rake Combining

Rake combining is a method of mitigating the effects of a multipath interference dominated communications channel, as is adaptive equalization. However, in a typical equalizer, the filter time-span must correspond to the multipath delay spread, and therefore tends to be limited to very close-in multipath, spanning perhaps a few symbols. The Rake, however, exploits the properties of CDMA signals (i.e., during despreading, all other codes become uncorrelated, including copies of the desired code delayed by greater than about half a chip, and are reduced to noise across the entire spread bandwidth) that enables each multipath component (offset by more than about half a chip) to be acquired, tracked, and despread in isolation, and then coherently combined. Much like beamforming, this coherent combining results in increased effective antenna aperture and improved SNR, although using only a single antenna element. This divide-and-conquer approach allows the Rake to span an essentially arbitrary multipath delay spread, applying computational resources based linearly on the number of desired despreader branches, or "Fingers", desired, and not based on the delay spread itself (although acquisition time, and thus dynamic performance, is related

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to the actual delay spread, as this defines the limits of what must be searched).

In the prior art, Rake combining is typically employed as a dedicated function in a fixed CDMA receiver structure. Resources are designed into the receiver to perform some fixed maximum number of Rake Fingers, and those resources are tied up regardless of whether those Fingers are actually utilized or not. What is needed is a more flexible and generalized receiver architecture, which can task resources on more of a demand basis, and furthermore treat diversity information such as Rake Fingers as simply one of several diversity inputs to be jointly optimized in a common process that yields maximum advantage to each desired user signal.

What is needed is the ability to combine potential spatial processing information with other dimensions of information and diversity, both regarding the signal(s) of interest, and the interference environment. To this end, what is needed is a receiver architecture for efficiently processing spatial information (antenna elements), temporal information (coherent signal multipath components; i.e., Rake Fingers), and interference information (noise power estimates, co-channel interfering symbol soft decisions) jointly and efficiently.

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SUMMARY OF THE INVENTION

The present invention applies approaches to achieve rapid acquisition in a multi-band, multi-channel signal environment, by sharing a homogeneous collection of digital processing elements. This is done, in part, by taking maximum advantage of the computational commonality between the acquisition and tracking correlation processes. Furthermore, the mismatch in computational demand between acquisition and tracking is exploited by creating a multi-channel, multi-band integrated receiver. Since only a small percentage of the computational resources are consumed by tracking an individual channel, the remaining resources may be employed to accelerate the acquisition of additional channels. As more resources become dedicated to tracking, fewer remain for acquisition; this has the effect of gradually reducing the number of parallel code offsets that can be searched, gradually increasing acquisition time. In many applications, such as a GPS receiver, this is quite acceptable, as generally additional channels beyond the first four are less urgent, and are used primarily for position refinement, and back-up signals in the event that a channel is dropped. These ideas are the subject of U.S. Patent Application No. 09/707,909, filed November 8, 2000, entitled "Sequential-Acquisition, Multi-Band, Multi-Channel, Matched Filter", and are preserved as features of the present invention.

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The present invention embodies various extensions to the previously disclosed invention, wherein the multi-band capability is evolved to support multiple antenna elements at a common band (as well as other bands), to support digital beamforming; the multi-channel capability is evolved to support multiple Rake Fingers on a common channel (as well as other channels); and the multi-channel demodulator capability is evolved to support computationally efficient, simultaneous processing of all bands, elements, channels, and Rake Fingers. The present invention thus forms an architectural framework capable of hosting a variety of algorithms for joint space-time optimization of individual user channels in a multipath environment, as well as multi-user (joint) detection of multiple user channels limited by co-channel interference. By considering these capabilities together, rather than as independent solutions to problems, considerable efficiencies and improvements are realized by this invention, in comparison to the prior art.

In the first aspect of the present invention, the multi-datapath receiver architecture allows independent automatic-gain control (AGC) between multiple input bands ***B*** or elements ***E***, minimizing inter-band/element interference, and avoiding additive noise compared to schemes that combine the bands/elements into a single signal and data stream.

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To accomplish this, the present invention efficiently processes multiple streams of W-bit complex sampled data (real data is easily processed as well, by adding a complex-to-read conversion to the front of the matched filter), so that multi-band or multi-element receiver signals can be kept spectrally separated. This concept, implemented using *D* data storage paths, supports *D* bands and elements when shifting at the data sampling rate (F_{samp}); alternatively, the same *D* data storage paths can support *D**k bands and elements by multiplexing the multi-band/multi-element streams and shifting the data at the higher sampling rate of k*F_{samp}.

In another aspect of the present invention, the parallel acquisition correlator, or matched-filter, aids in rapid pseudo-noise (PN)-acquisition by simultaneously searching numerous possible PN-code alignments, as compared with a less compute-intensive (but more time-intensive) sequential search. Multiple channels of data may be co-resident in each band/element and sampled data stream using Code Division Multiple Access (CDMA) techniques, and multiple bands/elements and sampled data streams share the common computation hardware in the Correlator. In this way, a versatile, multi-channel receiver is realized in a hardware-efficient manner by time-sequencing the available resources to process the multiple signals, multiple antenna

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elements, and multiple multipath components resident in the data shift registers simultaneously.

In still another aspect of the present invention, the matched filter is organized into *N* "Slices" of *M*-stages/Slice. Each Slice is composed further of *D* data paths supporting multiple bands *B* and/or antenna elements *E*. Each Slice can accept a code phase hand-off the from the PN-Acquisition Correlator and become a PN-tracking de-spreader by providing separate outputs for early, on-time, and late correlations for each element (with spacing depending on the sampling rate; typically half a chip). Slices are handed-off for tracking in the same direction as data flows, and correlation reference coefficients are shifted (for instance, left to right)—this permits shifting data to be simultaneously available for the leftmost Slices that are using the data for tracking, and rightmost Slices that are using the data for acquisition. Each Slice can choose between using and shifting the acquisition reference coefficient stream to the right, or accepting the handoff of the previous acquisition reference coefficient stream and using it to track the acquired signal.

In still another aspect of the present invention, the Acquisition correlator can integrate across all available Slices to produce a single combined output, or the individual Slice integrations can be selectively output for post-processing in the case of high residual carrier

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offsets or high-symbol rates, where the entire *N*M*-stage correlator width cannot be directly combined without encountering an integration cancellation effect. Alternatively, the Acquisition correlator can be configurable to switch from coherent integration to non-coherent integration, by taking the magnitude of I and Q partial integrations within the summer tree, or Slices themselves, at a point appropriate for the signal being acquired.

In yet another aspect, the present invention embodies a Scaleable Acquisition Correlator, which when tracking a maximum of *G* independent channels and/or Rake Fingers, can use the remaining *N-G* Slices to search for new signals for fast re-acquisition of dropped signals, and for continually searching the multipath environment for Rake Fingers to track dynamic channel conditions. Initially, Slices will be allocated sequentially (for instance, from left to right), but after running for some time, with signals alternately being acquired and dropped, the Slice allocation will most likely become fragmented, resulting in inefficient use of the Acquisition Correlator. This can be resolved by implementing a de-fragmentation algorithm that swaps tracking Slices around dynamically to maximize the number of contiguous rightmost Slices, and thus optimize Acquisition.

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In another aspect, the present invention contains *G* independent numerically-controlled oscillator (NCO)-based PN-Code Generators with almost arbitrary code rate tracking resolution (for example, better than .0007 Hertz for a 32-bit NCO clocked at 3 MHz). All NCOs run using a single reference clock which is the same clock that is used for all signal processing in the Matched-Filter and Demodulator. Ultra-precise tracking of PN Code phase is maintained in the *G* independent phase accumulators. Multi-channel NCOs can in one embodiment be efficiently implemented by sharing computational resources and implementing phase accumulation registers in RAM, for the case when the processing rate is in excess of the required NCO sampling rate. Note that while each channel and Rake Finger requires its own PN-NCO, a single NCO is shared across all elements when beamforming.

In still another aspect of the present invention, the incoming wideband element data is made available to all Slices, which allows each element to be independently despread for each channel/Rake Finger using the core matched filter structure. As a result, beamforming is easily performed at narrowband (despread) sampling and processing rates, and with improved potential precision. The present invention is an improvement over the prior art, because in addition to the raw computational savings of narrowband processing, the beamformer hardware is time-

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shared across multiple elements, channels, and Rake Fingers for improved computational efficiency.

In another aspect, the present invention allows the Beamforming computation to be implemented with only additional adders, due to integration with the demodulation carrier phase rotation and the AGC scaling functions.

In yet another aspect, the present invention allows an element snapshot memory to operate at narrowband sampling rates, allowing an eased implementation for any snapshot operations required.

In still another aspect, integration of the beamformer with the demodulator in the present invention allows advanced adaptive algorithms to be implemented that can be enhanced by the feedback of post-demodulation metrics such as PN-SNR/phase, carrier-SNR/phase, symbol-SNR/phase, as well as error control decoding metrics.

In still another aspect of the present invention, the integrated beamforming CDMA Rake receiver exploits both space and time diversity aspects of a multi-path environment by assigning Slices to each Rake Finger, and steering beams that individually optimize along the line-of-sight (DOA) of each multipath reflection (i.e., a potential beam for each Rake Finger).

In another aspect of the present invention, the integrated multi-channel demodulator and Rake combiner make

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coherent complex symbol data for each Rake Finger (potentially for multiple user channels sharing the same frequency band), as well as individual channels not being Raked, available to a single optimization process. This allows the use of advanced multi-user detection (MUD) algorithms (e.g., joint detection) to mitigate co-channel interference that has not been suppressed by beamforming.

In yet another aspect, the present invention's Slice-based data-flow computational architecture permits dynamic, flexible allocation of resources between tracking of multiple input bands, user channels, and Rake Fingers, and acquisition resources for dropped/new channels and continuously monitoring Rake dynamics.

In another aspect, the matched-filter Slice architecture of the present invention contains PN-tracking integrators (i.e., early, on-time, late) for each beamforming element. Furthermore, after all elements are weighted and combined, the demodulator architecture uses the combined early/on-time/late integrations to maintain a single PN-tracking loop for each beamforming channel, or Rake Finger.

In another aspect, the present invention allows each beamforming channel, or Rake Finger, to combine data from all elements and form a composite carrier and symbol discriminator that allows all elements of that channel to

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be tracked with a single carrier loop, and a single symbol loop.

In still another aspect, the present invention's multi-channel architecture allows continuous on-line element calibration capability to take place. Furthermore, calibration can be performed independently on each user channel, and each Rake Finger, closing the calibration loops individually to remove essentially all bias terms.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a generalized functional block diagram of the multi-channel matched filter architecture, illustrating the multiple input bands, the multiple NCO-based PN Generators, and the division of the parallel matched filter into multiple Slices; the matched filter can be seen to have an acquisition output, and a tracking output which sequentially sends despread element data for each channel and each channel's Rake Finger into the integrated multi-channel beamforming demodulator and Rake combiner.

FIG. 2 is a generalized functional block diagram of the matched filter Slice architecture (for the specific embodiment in which RAM structures are utilized to form highly efficient data storage cells, for the case of relatively low sampling rates); note that each Slice shares a single PN chipping stream for despreading, and contains

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"E" computation elements, corresponding to the number of supported beamformer elements; each computation element is shared across all "M" stages/Slice.

FIG. 3 is a functional block diagram showing an example embodiment of the multi-channel, NCO-driven, PN code Generator, using efficient RAM-based state machines.

FIG. 4 is an illustration of the sequential acquisition and handoff to tracking in the matched filter, showing how multiple antenna elements along with multiple signal bands and channels are handled simultaneously, using an example embodiment and a time sequence of resource allocation diagrams.

FIG. 5 is a dataflow diagram showing the complex arithmetic calculations required to weight and combine all beamformer elements for each despread sample coming from the matched filter.

FIG. 6 illustrates how the embodiment in FIG. 3 might produce sequential despread outputs, corresponding to each band, element, and channel (early, on-time, and late), as well as the sequence of carrier NCO outputs and beamformer weight outputs that might be produced during the tracking process; this figure also shows graphically how these sequences flow through computation elements to simultaneously accomplish both the carrier tracking and beamforming functions (no Rake in this example).

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FIG. 7 is an illustration of the sequential acquisition and handoff to tracking in the matched filter (similar to FIG. 4), for a different example embodiment containing beamforming and Rake combining, using a time sequence of resource allocation diagrams.

FIG. 8 is a functional block diagram of one embodiment of a processing architecture for the integrated beamforming/Rake multi-channel demodulator, illustrating: the manner in which sequential data from the PN matched filter is processed to form PN, carrier, AGC, and symbol tracking loops for each channel and Rake Finger; the integration of the carrier tracking rotation and beamforming functions; and the presentation of all channels and Rake Fingers to a single integrated demodulator, which can host a variety of algorithms capable of optimizing and combining same-channel multipath (Rake Fingers) and joint detection of multiple, potentially interfering, co-channel users.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

The first aspect of the preferred embodiment relates to the implementation of multiple channel, multiple frequency band receivers. At any given point in time, the state of the art in analog-to-digital conversion (A/D) chips, and subsequent digital signal processing (DSP) technology for performing data demodulation, will allow

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only a certain amount of frequency spectrum (band) to be digitized into a single data stream. Within that band, multiple user channels can coexist using various well known multiple-access techniques such as FDMA, TDMA, CDMA, etc.

When additional channels of interest lie outside of the frequency bandwidth that can be digitized into a single digital band, and simultaneous reception is required from each band, then multiple RF downconverters and A/Ds must be used to digitize multiple bands. The present invention allows an arbitrary number of such bands to be processed together in a unified computational engine. In this embodiment, a pool of arithmetic processing resources, or receiver channels, can be applied on demand to various user signals, regardless of which band they originated in. In this way, an almost arbitrary variety and amount of frequency spectrum can be utilized, and an almost arbitrary number of user channels of varying modulation type can be digitally extracted from it.

There are several advantages of using this technique to present multiple bands to a single receiver structure. Firstly, it is well known that as wider bandwidths containing multiple and various signals are received together, increasing analog fidelity requirements are imposed. This is a significant limitation, in that analog circuitry suffers from such problems as intermodulation distortion (IMD), where multiple frequency sources interact

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to produce distortion components. The present invention optimizes the analog signal fidelity by digitizing downconverting and digitizing each band, while preserving the advantages of a digital "software" radio—namely, integrated, flexible, multi-channel demodulation using DSP techniques.

Secondly, given an arbitrary RF and A/D dynamic range, it is desirable to use automatic gain control (AGC) to capture the signal of interest within the available amplitude range of both analog circuitry and A/D converter. As wider bandwidths containing multiple and various signals are digitized together, they must also be subject to a common AGC process, which will be dominated by the largest signals across all bands; this potentially decreases the SNR of the smaller signals, due to A/D quantization noise. The present invention optimizes the AGC process by allowing each band to be treated separately.

Thirdly, other schemes to digitize a composite mix of various frequency bands might use a technique of summing together the signals after translation to non-overlapping adjacent intermediate frequencies, allowing the use of a single A/D converter. In this type of scheme, the limitations of the analog circuitry will dictate that additive noise from each of the various RF bands will somewhat degrade the signal-to-noise ratio (SNR) of the resultant composite signal. The present invention

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optimizes the SNR of each band by maintaining separate RF, IF, and digital signal paths.

Fourthly, this aspect of the present invention directly supports digital beamforming by utilizing this multi-band receiver technique. Since digital beamforming involves the use of a multi-element antenna, resulting in dedicated RF downconversion paths for each element, the present invention allows beamforming to be accommodated in a flexible, scalable fashion, by treating each element in the same manner as if it were another signal band. Naturally, the RF implementation can in fact be simplified in comparison with the generic multi-band case, because a dedicated Beamformer implementation could optimize the frequency synthesis circuitry by using the same LO for each antenna element downconverter. If the beamformer combiner is implemented after the matched filter (despreader), the digital implementation is now able to treat each element as though it were just another datapath for another signal band.

The second aspect of implementing the preferred embodiment relates to the architecture of the flexible computation core of the digital matched filter. The architecture has been designed to satisfy two different driving requirements: accelerated acquisition of a single user channel, and simultaneous tracking of multiple user channels. Referring to FIG. 1, front end circuitry FE

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provides complex baseband samples for a plurality of frequency bands and multiple channels in the radio spectrum to an (N*M) stage data delay line (shown as being embodied by N distinct Slices), composed of B distinct bands, each band composed of E distinct elements of 2*W bits each (W bits I, W bits Q complex data), contains a sequence of samples of the bands of interest. It is well known that the sampling rate must be chosen to satisfy the Nyquist criterion to preserve the appropriate signal bandwidth of interest, and to allow sufficient time resolution for acquisition and tracking; generally two or more times the chipping rate for a spread spectrum signal. The data is then shifted through the data delay lines at the sampling rate.

For the purposes of acquisition, a single numerically controlled oscillator (PN-NCO) is needed, to serve as a finely controllable digital frequency source matched to the expected chipping rate of the incoming signal. In conjunction with this, during acquisition a single PN chip Generator is needed, to reproduce the PN sequence of the incoming signal, at the rate dictated by the PN-NCO. This PN Sequence is then presented to the leftmost end of the data delay line (to the leftmost Slice), where it is also shifted from left to right down a PN sequence delay line (shown in more detail in FIG. 2). At appropriate time intervals, the state of the PN sequence delay line is

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latched into a reference correlation register. The computational logic within the Slices then performs a correlation of the latched reference PN sequence against the signal samples contained in the data delay line. Note that in the example embodiment in FIG. 2, the Slice architecture is illustrated with a RAM-based implementation, which is efficient for low sampling rates with respect to the available processing rate. Other embodiments of the present invention might utilize a register-based architecture variant, which would allow for much higher sampling rates (less than or equal to the processing rate); registers are in that case used for all data shift-registers.

For each sample time, up to (N*M) multiplications (or N*M*E, if elements are acquired in parallel) are performed of each data sample with its corresponding reference PN chip (in some applications, the stages are decimated prior to performing the correlation, so that not all are tapped for computation); all of these products are then summed into a single partial correlation value by the Acquisition Summation Network shown in FIGS. 1-2, which is then passed on to the demodulator circuitry for further integration, beamforming and Rake Finger selection (depending on the acquisition scheme chosen), thresholding and detection. Because the data samples are shifted by one position at each sample time, and the latched reference PN sequence is

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held in the same position over a period of time (update period), each sequential partial correlation within a given update period represents a different potential alignment (code offset) between the reference PN sequence and the received signal. In this way, over time a correlation is performed for all possible code offsets, to within the nearest fraction of a chip defined by the chosen sampling rate; the timing of the latch update period, and the NCO/PN-Generator code phase, are carefully controlled to determine the specific offset search sequence. The post-processing circuit can perform additional integrations for each code offset to achieve sufficient SNR to enable detection at the correct offset.

At this point, the receiver can be said to have completed PN acquisition, and the matched filter is able to go into PN tracking mode. During tracking, the problem is substantially easier. If there were no phase or frequency drift present, only the single correctly aligned correlation sequence must be computed; that would be a single multiply and sum per input sample. Since there are phase and frequency drifts (i.e., the reference PN-NCO frequency setting becomes incorrect over time) in typical applications, two additional correlations must be computed as well, corresponding to the code offsets that are slightly early and slightly late, with respect to the currently tracked (on-time) code offset. These

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correlations allow the PN phase and frequency drift to be observed and tracked with the PN-NCO, using well known PN tracking loop techniques. The early, on-time, and late correlations (or partial correlations) are output via a separate signal path to the demodulator tracking circuitry. So, where (N*M or N*M*E) multiplies and sums must be computed for each input sample during acquisition, only (3*E) multiply/sums must be computed for each sample during tracking. Since there is motivation to choose (N*M) to be as large as possible for rapid acquisition, this leaves a substantial surplus of computational horsepower idle during tracking.

Thus, the primary nature of the second aspect of implementing the present invention lies in the agility of the computational structure in transitioning, one Slice at a time, from being part of an acquisition correlation process as described above, to being part of a tracking correlation process as described above. For the multi-channel case, this involves adding additional NCO/PN-Generator pairs corresponding to the desired number of channels and Rake Fingers (shown as G in FIG. 1) to be simultaneously tracked. Each of these creates a unique PN sequence, at unique chipping rates, and presents them to unique Slices, from left to right, as shown in FIG. 1.

Each combination of NCO/PN-Generator and Slice (matched up from left-to-right) form the required

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computational capability for tracking a single user signal, or single Rake Finger for a single user signal. The rightmost unused NCO/PN-Generator pair, and all rightmost unused Slices, form the available computational capability for acquiring a new user signal, and for searching for and acquiring the strongest Rake multipath components. The amount of time required to acquire the new signal depends on the number of correlation stages available, because that determines the number of correlation samples that are integrated at each sample time. All of this computation, for acquisition and tracking of multiple channels, happens concurrently using the flexible computation resources, and occurs transparently with respect to the multiple bands and elements of sampled data that constantly stream through the data delay lines. This entire process is illustrated in FIGS. 4, 6 and 7.

The third aspect of implementing the preferred embodiment relates to the partial acquisition integration method. For the problem of PN Acquisition, it would be ideal to integrate an arbitrary number of correlation samples until the appropriate SNR level is reached. However, this cannot be done in the presence of residual carrier components due to unknown doppler and other frequency offsets, which would cause integrations across complete carrier cycles to cancel out. In a similar manner, integrations across multiple data symbol

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transitions also causes cancellation. These effects limit the useful size of the acquisition matched filter, and would normally force much of the computational capabilities to go unused (through masking-out of that portion of the filter which exceeds the appropriate integration length). This problem is mitigated in the present invention by allowing the individual Slice partial integrations to be output to the post-processing circuitry. Various methods can be used to combine the partial integrations non-coherently into a complete integration while mitigating the cancellation effects.

An alternative embodiment of the present invention accomplishes this same goal by modifying the Slice architecture slightly to incorporate the magnitude detection circuitry, or other means of switching to non-coherent integration, directly into each Slice. This would allow each Slice to be configurable to integrate the appropriate amount of signal coherently, perform detection, and allow the summer tree to perform non-coherent summation of each Slice's output, passing that sum to the acquisition circuitry to complete the integration/detection process.

In a fourth aspect of the present invention, the preferred embodiment employs a defragmentation algorithm to ensure that the maximum acquisition capability is maintained over time. This is particularly important with the use of the Rake combiner functionality, as multipath

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components can change rather dynamically, depending on the channel environments; acquisition resources will continually need to be available to monitor and acquire them. The manner of sequential acquisition and, from left to right in FIG. 1, allocation of Slices for tracking has been described. In that initial context, the rightmost Slices are always optimally utilized for acquisition; none are wasted. However, as signals are dropped in a multiple channel tracking environment, holes will develop where middle Slices are no longer tracking, but cannot participate in acquisition in the normal fashion due to isolation from the rightmost Slices.

This problem is mitigated in the present invention by swapping out tracking Slices from right to left in order to maintain contiguous unused rightmost Slices for acquisition. This is done by initiallizing the NCO/PN-Generator of the unused (left) Slice to run in offset-synchronism with the currently tracking (right) Slice that is to be moved; offset, in the sense that chipping frequency is identical, but code phase is advanced by an appropriate amount to correspond with the relative difference in received signal phase at the two Slices. In units of time, this is basically the number of delay stages of offset between the two Slices, divided by the sampling rate. At the known chipping rate, this is easily converted to a code offset. After the handoff is complete, the

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process is repeated until all tracking Slices are packed to the left.

The fifth aspect of implementing the preferred embodiment involves a method of using a single clocking system, synchronous to the data sampling clock, to generate G independent NCO/PN-Generators that produce PN chipping sequences whose average rates can very precisely track the various received signal chipping rates. Also, if the NCO processing clock is in excess of the required NCO sampling rate, efficient RAM state storage and code phase computational hardware can be time-shared for reduced hardware size (if this is not the case, a more traditional register-based embodiment of the NCO would be required). A block diagram of this concept is shown in FIG. 3.

Because each NCO is operating at the NCO sampling rate (perhaps equal to the data sampling rate), it can only make a decision to advance to the next chip at those coarse sampling intervals. Thus, even though the NCO phase accumulator knows when to advance to the next chip to within fractions of a sampling interval, it must incorrectly wait until the end of the sampling interval to do so. However, this chip-jitter averages out in the long term (as long as the NCO sampling rate is asynchronous to the chipping rate); furthermore, because the NCO clocks are all synchronous to the data sampling clocks, the jitter exactly reflects the effective jitter that will be

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contained in the received chip transitions. In other words, both the incoming signal code phase, and the internal accumulated code phase will track very precisely; since they are both asynchronously sampled by data/NCO sampling clock, a common phase jitter will be superimposed onto both, such that the jitter itself causes no additional processing loss.

FIG. 3 shows an example 6-channel implementation of the RAM-based PN-code Generator. In this example, it is assumed that the processing clock is at least 6 times the desired NCO sampling rate. So, within the time of each NCO sampling interval, the computational resources may be cycled 6 times to produce new code phases and PN chips for each of 6 channels or Rake Fingers. This allows, for example, a single adder to compute for 6 phase accumulators. The six fractional and integer code phases are stored in RAM storage cells, and can be retrieved sequentially for processing. The new code phases are then sequentially updated back into the RAMs. Also, in this example, RAM is utilized to store the entire PN sequence for each channel. Thus, arbitrary sequences can be generated, and the phase accumulator circuitry merely plays back the chips at the correct rate. Alternatively, specific PN sequence generators could be constructed, with a slight modification of the indicated block diagram. A specific implementation requires a combination NCO/PN-

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Generator for each simultaneously tracked channel or Rake Finger, plus an additional one for acquisition.

In the sixth aspect of the present invention, it can be seen that the core matched filter architecture readily supports beamforming through the despreading of multiple antenna elements for each signal band independently for each user channel and Rake Finger, and presenting the narrowband data to the demodulator for weighting and combining. This is facilitated by first treating each antenna element as if it were just another supported band, and passing the digitized element samples into the multi-band matched filter. Second, the Slice architecture could then be configured to assign each channel-element to a unique Slice for despreading. Such an embodiment would directly extend the previously disclosed architecture (U.S. Patent Application No. 09/707,909, filed November 8, 2000) with essentially no change to the matched filter itself, but would likely require a large number of Slices to implement (#channels * #elements * #Rake-Fingers). This could also have the side-effect of increasing the relative length of the data delay lines (i.e., N*M, by increasing N).

An alternative embodiment, described here and illustrated in FIG. 2, evolves the Slice architecture by despreading all elements/channel or elements/Rake-Finger within a single Slice. This has several advantages: in

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the first advantage, the single PN-stream needed by each element is already available in the Slice; in the second advantage, the time-aligned samples for each element are all available (either from registers, or having been read from RAM) in the same processing clock cycle for multiplication; and third, the overall Slice count and delay line length may be reduced to (#channels * #Rake-Fingers). So, in this embodiment, each Slice requires E multipliers, and E early/on-time/late integrators. After a configurable amount of integration within the Slice, the stream of early/on-time/late partial integrations for each element are multiplexed into a sequential stream and presented to the multi-channel demodulator for further processing.

What is significant about this aspect of the present invention is its ability to reduce the beamforming computational burden proportionally to the matched filter decimation ratio, and utilize that advantage by sequentially processing the despread element samples in the demodulator. This allows the demodulator hardware to be multiplexed to accomplish combined carrier tracking, AGC, and beamformer weighting and combining, using minimal additional hardware resources compared to a non-beamforming demodulator. This advantage in beamforming, combined with the similar ease with which Rake combiner capability is also added, along with the possibility of joint processing

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of these functions for improved receiver performance, represents a significant improvement over implementations in the prior art.

The seventh aspect of the present invention is the sharing of existing computational resources in the demodulator to perform the actual beamforming weighting and combining functions. To form a beam on a given channel/Rake Finger, each complex sample must be multiplied by the appropriate complex weight (to cause the desired rotation of the vector). After the weighting/rotations are performed, the complex element samples can then be added together—the summation will constructively combine energy for signals arriving at the antenna array from the desired direction (and sidelobes), and destructively cancel elsewhere.

A schematic dataflow diagram showing elements and corresponding weights is shown in FIG. 5, along with mathematical operations necessary to perform beamforming. In the prior art, the physical implementation of this could take the form of anything from literally implementing the diagram as shown (for sampling rates equal to the processing rate), to a single complex multiplier and two accumulators (for sampling rates much less than the available processing rate). The innovation of the present invention is illustrated from a high level in FIG. 1, where the entire beamforming operation can be seen to be absorbed

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into computation already taking place in the demodulator for carrier tracking rotation, AGC scaling, and symbol integration. The only added complexity is the additional scalar adder that rotates the carrier NCO accumulated phase by the desired beamformer phase shift, prior to using the phase to determining corresponding SIN/COS amplitude, as well as additional multiply operations per sample due to the elements (E times as many multiplies).

FIG. 6 illustrates this in more detail, along with an example enumeration of the actual data operands that would flow through this process (element data samples, carrier NCO samples, and beamformer weights). Whereas in the conventional implementation (FIG. 5) only complex multiplies and summation are required, this technique is split into the beamformer rotation and the beamformer scaling as separate operations. This is due to the manner in which this technique works. Normally, multiplication of the complex weight and the complex element sample simultaneously rotates and scales the element I/Q vector. However, in the manner of this invention (FIGS. 1 and 6), the existing carrier rotation circuitry is exploited to serve the additional purpose of beamforming rotation. This is done by computing the desired carrier rotation for carrier tracking (which would be constant for each element for a given channel/Rake Finger), but adding to that the additional rotation desired (different for each element)

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for beamforming. While this achieves the desired element rotation, the gain coming out of the carrier NCO look-up table is fixed.

Thus, the scaling portion of the beamforming weighting operation is not yet done, and must be performed in a subsequent scalar multiply on each I and Q. Conveniently, just such a function is already next in the demodulator dataflow—the AGC function. Since software typically performs both the beamformer weight calculation and the AGC scale factor, at a relatively slow rate, the multiply is absorbed into a software operation to modify the AGC weight to also include the beamformer weight, and the single pair of existing scalar multipliers is used to serve both purposes.

In the eighth aspect of the present invention, snapshots of element data may need to be captured for various processing to aid the beamformer adaptive algorithms. By performing the beamforming on despread, narrowband data, the snapshot memory functionality benefits from the decimated sampling rate and potentially becomes reduced in complexity. This may be a benefit manifested in reduced implementation cost.

In the ninth aspect, the present invention enables advanced adaptive beamforming algorithms to be implemented, through the full integration and tight coupling of the beamformer with the demodulation process. Typically, in

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the case of a beamformer that is more standalone and distinct from demodulation, the beamformer would be able to point to a known signal location (DOA), and adaptively form nulls to mitigate powerful, readily measurable sources of interference. This invention, however, makes much more information available to the beamforming algorithm. By providing demodulator metrics to the beamformer algorithm, a closed loop is formed between demodulator performance (PN/carrier/symbol SNR/phase), and the weight adaptation process. This facilitates the use of algorithms that start with known information, such as signal DOA and interference DOA, and iteratively find the best weights that minimize the demodulator's prioritized, observable errors. Even after the symbol demodulator, error-control decoding performance metrics can also be fed back to the optimization process.

In the tenth aspect, the present invention combines the advantages of beamforming and Rake combining, yielding a result that improves SNR (actually, SINR—Signal-to-Interference-plus-Noise-Ratio, but the term SNR will continue to be used for convenience) with respect to either technique applied in isolation. By itself, beamforming is advantageous because it simultaneously increases the effective antenna aperture in the direction of the desired signal (as well as sidelobes), while also decreasing the effective antenna aperture in other directions, perhaps

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containing interferers. With an adaptive algorithm, the beam can actually be formed to perfectly null out detected interferers; typically, a compromise is actually made between these extremes, balancing desired signal gain and interfering signal attenuation.

The preferred embodiments of the present invention have the advantage of being able to form a completely independent set of beams on each signal channel, or on each Rake Finger of each signal channel. This allows each user channel the luxury of all degrees of freedom afforded by the available antenna elements to optimize its SNR. Furthermore, this allows each multipath component to be optimized independently as well. In many environments where multipath is prevalent, each multipath component (reflection) is likely to come from a different direction (DOA). Likewise, in those same environments the interference signals are likely to be subject to the same multipath conditions, causing interference power to be distributed among different DOAs as well. Thus, each desired signal multipath component really requires a completely different beam pattern, in order to optimize its particular signal gain and interference rejection situation.

It may be the case that a large multipath component—desirable for combining—arrives from the same direction as a strong interference signal. This may result

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in the situation where a beam pattern cannot be generated that both passes the desired signal, and excludes the interferer. This is an example of the strength of the joint beamformer/Rake optimization capability afforded by the present invention: an intelligent algorithm in the demodulator can make use of the broad information presented to it to select (or iteratively determine based on demodulator feedback) the best combination of multipath elements and beam patterns to optimize demodulator SNR. In this example, it may be necessary to reject the multipath component from combining, and choose one with better spatial isolation from interference.

In the eleventh aspect of the present invention, complex, integrated, beamformed symbol data is maintained coherently for each channel, and for each Rake Finger, and presented to a single-point detection process within the demodulator as shown in FIG. 8. Also available to this process is the integrated PN and carrier phase error, as well as information about the beamformer processing. Using this wealth of information, a single, unified, combiner-detection algorithm can now be used to optimize the SNR of each signal channel. Having already applied the benefits of beamforming to spatially isolate each desired incident signal component, and integrated/decimated each sampled stream to (or near) the symbol rate, it is necessary at

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this point in the demodulation process to form soft symbol decisions.

Although there are many ways in which this process could be carried out, a few example methods will be outlined for clarity. In the simplest method, samples for each Rake Finger are integrated to the symbol level, and then delayed, weighted, and combined according to various combining schemes well known in the literature. Then, a soft decision is formed on the combined result and output to the next process (e.g., error control decoding).

In a more complicated method, the process just described is used to independently form soft decisions for each of multiple signals sharing the same frequency channel (for example, co-channel signals in a CDMA system). These independent soft decisions are each corrupted by the combined co-channel interference of all of the other channels, due to imperfect orthogonality of the spreading codes. However, the character of the co-channel interference is now somewhat understood, having just formed soft decision estimates of each of the interferers. Thus, a process can now be followed to subtract the effects of the estimated interference from each signal, resulting in an improved estimated soft decision of each channel. Naturally, since the procedure just followed results in improved estimates of each interferer, it can be repeated, and in fact applied iteratively until each soft decision is

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somewhat cleansed of the effects of the co-channel interference. This process, joint detection, is a form of multi-user detection (MUD), and is one of many such techniques that is well described in the technical literature.

In even more complicated methods, the MUD iterative process can be combined with the Rake process, and perhaps even the beamforming process, to afford an almost arbitrary level of optimization to be achieved. What is novel in the present invention is the scalable architecture which efficiently processes all the available information, and makes it available to the demodulator to enable such algorithms to be implemented. The present invention allows spatial diversity (antenna elements), time diversity (Rake Fingers), and intelligent processing of interference (beam patterns, co-channel joint detection) information to be jointly optimized in a common demodulation and detection process.

In the twelfth aspect, the present invention facilitates a highly flexible, adaptable software radio architecture that allows a fixed hardware structure of computational dataflow elements to be tasked on a dynamic basis as needed. This allows the controlling software to choose how the hardware resources are allocated between the number of user channels, the number of channels supporting Rake, the number of Rake Fingers per channel (could be

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methods could be chosen to implement a specific embodiment under this invention, there are advantages to the former method, as illustrated in FIG. 2. Specifically, by incorporating the despreading of all elements for a given channel or Rake Finger into the same Slice, the integrations remain exactly time-aligned, which is required for coherent beamforming (while this could certainly still be satisfied in other embodiments, such as one element per Slice, the timing and control problem is more complicated). The dataflow control within the Slice is also simplified, because each element sample is automatically available in parallel for multiplication by the PN sequence. Furthermore, each element shares the same PN-Generator in a direct and convenient fashion, because the PN code phase misalignment on each element due to the angle of arrival at the element array should in most cases be negligible compared with the length of each chip.

In addition, another benefit to this aspect of the present invention lies in the ability to obtain the benefit of beamforming gain on the early and late error integrations. By rotating and combining the early/late outputs from each element, a single, coherent PN code phase error is generated, which is used to correct a single PN-tracking loop for each channel or Rake Finger.

In the fourteenth aspect of the present invention, the architecture of the preferred embodiment allows a single

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carrier tracking loop and a single symbol tracking loop to track all of the elements for a channel or Rake Finger. This is similar to the single PN tracking loop just described. The reduction in the number of tracking loops is useful in minimizing the demodulator complexity.

In the fifteenth aspect, the present invention represents a substantial improvement over implementations described in the prior art, particularly with respect to the calibration problem. In the ideal case, the geometry of the antenna array would be precisely known, each antenna element would exhibit identical performance characteristics, and the entire RF downconversion path through the A/D converters would have identically matched delay and other attributes. Furthermore, this perfection of array and element pathways must be maintained over time, temperature, and other variations. It is well known that this can only be achieved with limited precision, and that the resulting mismatch errors will severely degrade the ability to form a coherently phased beam. As a result, element calibration is required.

To calibrate the array and element pathways, a commonly used technique is to generate a reference signal at the center frequency of the array, and couple this reference signal into the receiver antenna elements such that a known and fixed angle of incidence (DOA) is achieved. Resources are then allocated within the

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beamformer hardware to measure the phase of the reference signal after propagating through the entire RF pathway for each element. In this way, the relative phase error for each element path can be measured over time. Once the phase mismatches are known, a calibration vector is formed which is embedded in the beamformer weight calculations in such a way as to remove most of the effects of the mismatch from the beamforming process. This calibration vector must be updated periodically to keep up with changes in the mismatch between elements. In some cases, this calibration method is sub-optimal, because it ignores any dispersive effects of the atmosphere that may slightly skew the signal arriving at each element.

In the present invention, the calibration process is greatly simplified and improved. In fact, due to the integration of the beamformers with the demodulators for each channel and Rake Finger, calibration can be done for each antenna element signal path in the absence of any additional calibration signal, and without consuming any additional matched filter or demodulator processing resources. Furthermore, calibration can be performed independently on each signal channel or Rake Finger, taking into account any atmospheric distortions that may distinguish their different propagation pathways. Finally, this process of calibration actually closes a loop between the beamforming process, and the integrated carrier error

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terms on a per element basis—the residual carrier phase error resulting from imperfections in pointing the beamformer are systematically forced to zero as a result. Thus, the complexity of calibration is reduced, no additional hardware is required, and the quality of calibration becomes nearly perfect, on a per-signal basis.

The way that this calibration is implemented, at essentially zero increase in cost, is once again due to the way the present invention embeds all despread element information with the demodulator, where the actual beamforming weighting and combining occurs. In the normal operation of the present invention, the element rotation complex multiplication occurs sequentially on an element by element basis, followed by the scalar magnitude multiplication, after which the products are combined by integrating and dumping in an accumulator (see FIGS. 1 and 6). In normal operation, only the combined weighted elements are subsequently used for symbol demodulation, and only a single PN, symbol, and carrier tracking loop is formed. As a result, the individual rotated element samples are not needed. However, those individual rotations are actually calculated, and can be saved and integrated for an arbitrary amount of time to achieve an extremely accurate accumulation of residual carrier phase error per element. If the pointing were perfect, the integrated error would approach zero. Any non-zero residue

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represents calibration error for that element, which can now be corrected and fed back to the weights. The only additional cost associated with this calibration process is additional memory or registers to store the per-element integrations, and an additional adder to perform the sequential integration.

The previous description of the preferred embodiments is provided to enable any person skilled in the art to make or use the present invention. The various modifications to these embodiments will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other embodiments without the use of the inventive facility. Thus, the present invention is not intended to be limited to the embodiments shown herein but is to be accorded the widest scope consistent with the principles and novel features disclosed herein.

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WHAT IS CLAIMED IS:

1. A multiple frequency band, multiple channel radio receiver comprising a front end circuitry for providing complex base band samples for a plurality of frequency bands and multiple channels in digital format, a parallel digital matched filter in which common digital arithmetic elements are used for both acquisition and tracking purposes connected to said front end circuitry, said matched filter being arranged to perform a plurality of simultaneous correlations of received spread spectrum signals against selected replica offsets of a spreading sequence, said parallel digital matched filter providing N slices with M stages per slice and W bit data quantization, each slice being adapted to perform 1/N of the acquisition computation and then is handed off to become a dedicated tracking module for one channel, respectively, and an integrated multi-element adaptive digital beamformer combiner connected to said parallel digital matched filter.

2. The multiple frequency band, multiple channel radio receiver defined in Claim 1 wherein said matched filter includes an N*M stage data delay line composed of B distinct bands, each band being composed of E distinct elements of 2*W bits each and a single numerically controlled oscillator to serve as a control digital

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frequency source matched to the expected chipping rate of the incoming signal.

3. The multiple frequency band, multiple channel radio receiver defined in Claim 1 including a Rake Combiner for mitigating the effects of multipath interference dominated communication channels connected to said parallel digital matched filter.

4. A multiple frequency band, multiple channel radio receiver comprising a front end circuitry for providing complex base band samples for a plurality of frequency bands and multiple channels in digital format, a matched filter in which common digital arithmetic elements are used for both acquisition and tracking purposes connected to said front end circuitry, said matched filter being arranged to perform a plurality of simultaneous correlations of received spread spectrum signals against selected replica offsets of a spreading sequence, said parallel digital matched filter providing N slices with M stages per slice and W bit data quantization, each slice being adapted to perform 1/N of the acquisition computation and then is handed off to become a dedicated tracking module for one channel, respectively, and integrated multi-element adaptive digital beamformer and Rake Combiners connected to said matched filter.

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5. The multiple frequency band multiple channel radio receiver defined in Claim 4 including a multi-channel demodulator connected to said matched filter for simultaneously processing all bands, elements and channels and Rake Fingers.

6. A multiple frequency band, multiple channel radio receiver comprising a front end circuitry for providing complex base band samples for a plurality of frequency bands and multiple channels in digital format, a matched filter in which common digital arithmetic elements are used for both acquisition and tracking purposes connected to said front end circuitry, said matched filter being arranged to perform a plurality of simultaneous correlations of received spread spectrum signals against selected replica offsets of a spreading sequence, said parallel digital matched filter providing N slices with M stages per slice and W bit data quantization, each slice being adapted to perform 1/N of the acquisition computation and then is handed off to become a dedicated tracking module for one channel, respectively, including a multi-channel demodulator processor connected to said matched filter for simultaneously processing all bands, elements and channels, and to function as an integrated multi-element adaptive digital beamformer combiner.

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7. The multiple frequency band, multiple channel radio receiver defined in Claim 6 wherein said multi-channel demodulator processor includes a defragmentation module to insure the maximum acquisition capability of said receiver is maintained over time.

8. The multiple frequency band, multiple channel radio receiver defined in Claim 6 including a single clocking system synchronous to a data sampling clock for generating G independent NCO/PN-generators that produce PN chipping sequences whose average rates can precisely track the various received signal chipping rates, respectively.

9. The multiple frequency band, multiple channel radio receiver defined in Claim 6 wherein said multichannel demodulator processor is adapted to form a completely independent set of beams on each single channel on each Rake Finger of each signal channel.

10. The multiple frequency band, multiple channel radio receiver defined in Claim 6 wherein as each channel is sequentially acquired by said matched filter, and said demodulator processor assures that common digital arithmetic elements are used both for acquisition and tracking purposes, respectively.

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11. The multiple frequency band, multiple channel radio receiver defined in Claim 6 wherein multiple data inputs and delay lines are present and are available for processing at each arithmetic element so that the matched filter/despreader processing is virtually independent of channel origin (e.g. CDMA users, beamform element, or Rake Fingers).

12. The multiple frequency band, multiple channel radio receiver defined in Claim 6 wherein there is a common NCO/PN-generator within a common beamformer element set.

13. A multiple frequency band, multiple channel radio receiver comprising a front end circuitry for providing complex base band samples for a plurality of frequency bands and multiple channels in digital format, a parallel digital matched filter in which common digital arithmetic elements are used for both acquisition and tracking purposes connected to said front end circuitry, said matched filter being arranged to perform a plurality of simultaneous correlations of received spread spectrum signals against selected replica offsets of a spreading sequence, said parallel digital matched filter providing N slices with M stages per slice and W bit data quantization, each slice being adapted to perform 1/N of the acquisition computation and then is handed off to become a dedicated

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tracking module for one channel, respectively, including a multi-channel demodulator processor connected to said matched filter for simultaneously processing all bands, elements and channels, and to function as an integrated multi-element multi-user detector.

14. The multiple frequency band, multiple channel radio receiver defined in Claim 13 wherein said matched filter includes an N*M stage data delay line composed of B distinct bands, each band being composed of E distinct elements of 2*W bits each and a single numerically controlled oscillator to serve as a control digital frequency source matched to the expected chipping rate of the incoming signal.

15. The multiple frequency band, multiple channel radio receiver defined in Claim 13 including a Rake Combiner for mitigating the effects of multipath interference dominated communication channels connected to said parallel digital matched filter.

16. The multiple frequency band multiple channel radio receiver defined in Claim 15 including a multi-channel demodulator connected to said matched filter for

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simultaneously processing all bands, elements and channels and Rake Fingers.

17. The multiple frequency band, multiple channel radio receiver defined in Claim 16 wherein said multi-channel demodulator processor includes a defragmentation module to insure the maximum acquisition capability of said receiver is maintained over time.

18. The multiple frequency band, multiple channel radio receiver defined in Claim 13 including a single clocking system synchronous to a data sampling clock for generating G independent NCO/PN-generators that produce PN chipping sequences whose average rates can precisely track the various received signal chipping rates, respectively.

19. The multiple frequency band, multiple channel radio receiver defined in Claim 13 wherein said multichannel demodulator processor is adapted to form a completely independent set of beams on each single channel on each Rake Finger of each signal channel.

20. The multiple frequency band, multiple channel radio receiver defined in Claim 13 wherein as each channel is sequentially acquired by said matched filter, and said

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demodulator processor assures that common digital arithmetic elements are used both for acquisition and tracking purposes, respectively.

21. The multiple frequency band, multiple channel radio receiver defined in Claim 13 wherein multiple data inputs and delay lines are present and are available for processing at each arithmetic element so that the matched filter/despreader processing is virtually independent of channel origin (e.g. CDMA users, beamform element, or Rake Fingers).

22. The multiple frequency band, multiple channel radio receiver defined in Claim 13 wherein there is a common NCO/PN-generator within a common beamformer element set.

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Figure 1: Integrated Multi-Channel Beamformer/Rake Receiver

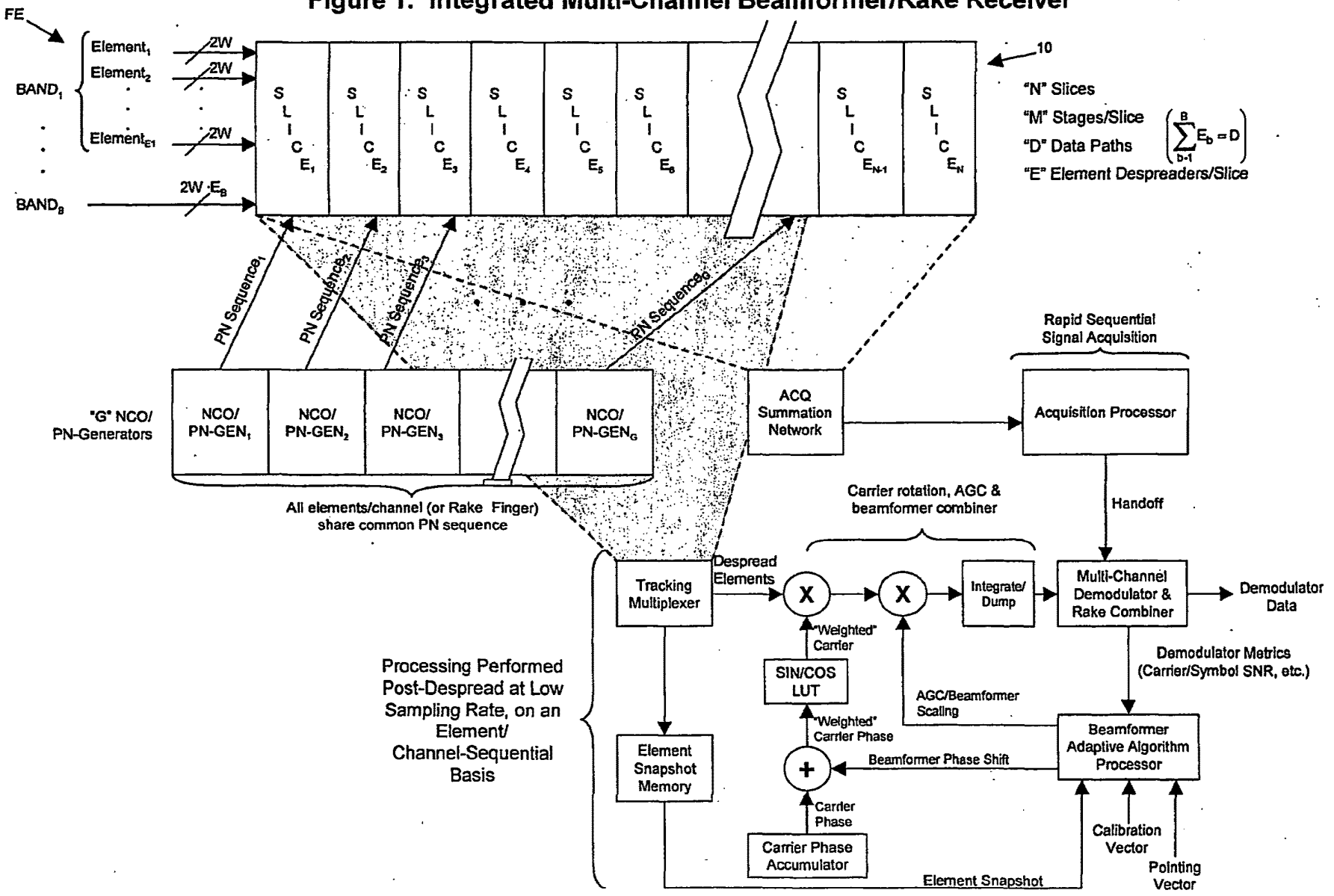


Figure 2: Integrated Beamformer/Despreader Slice Structure

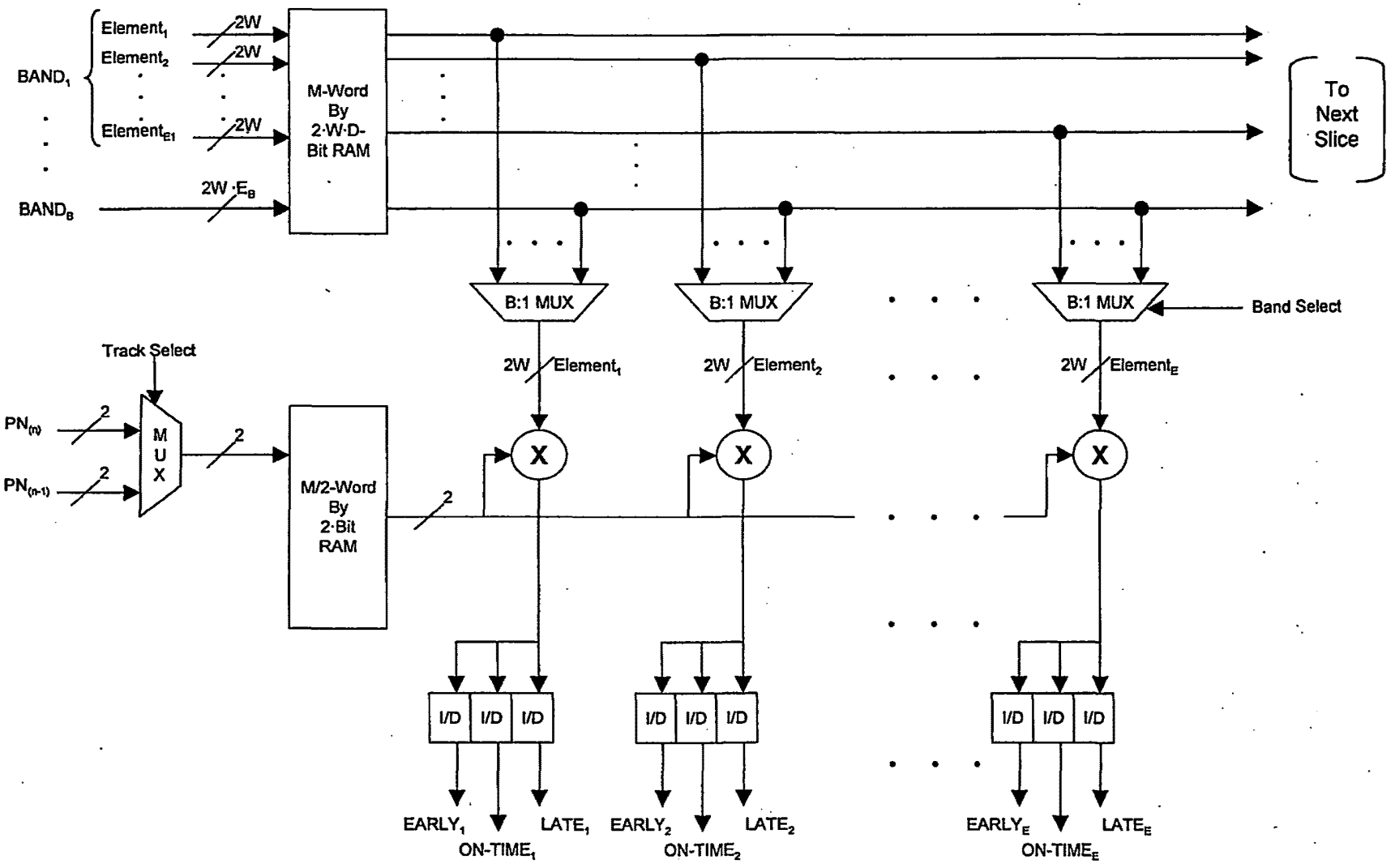
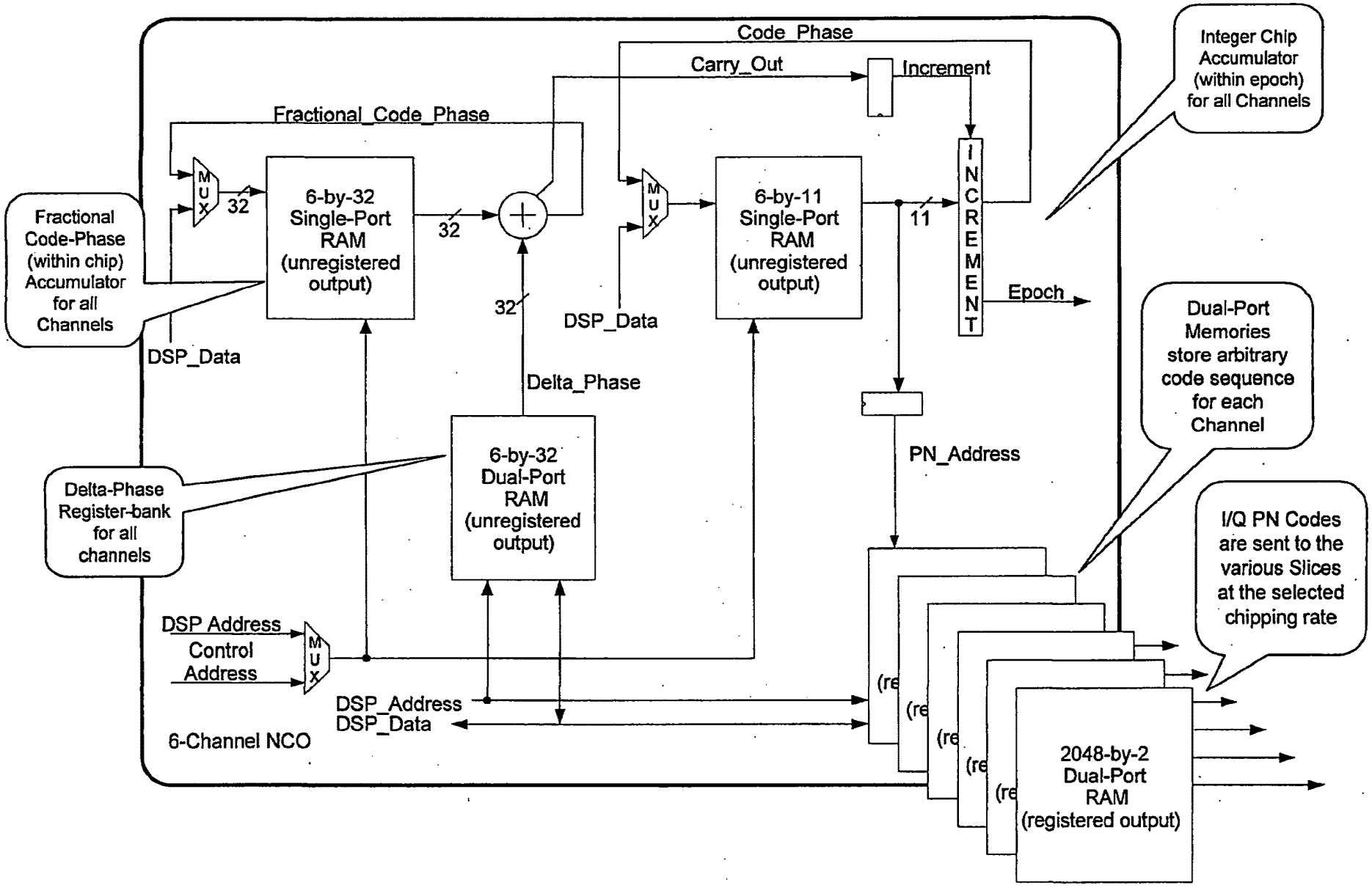
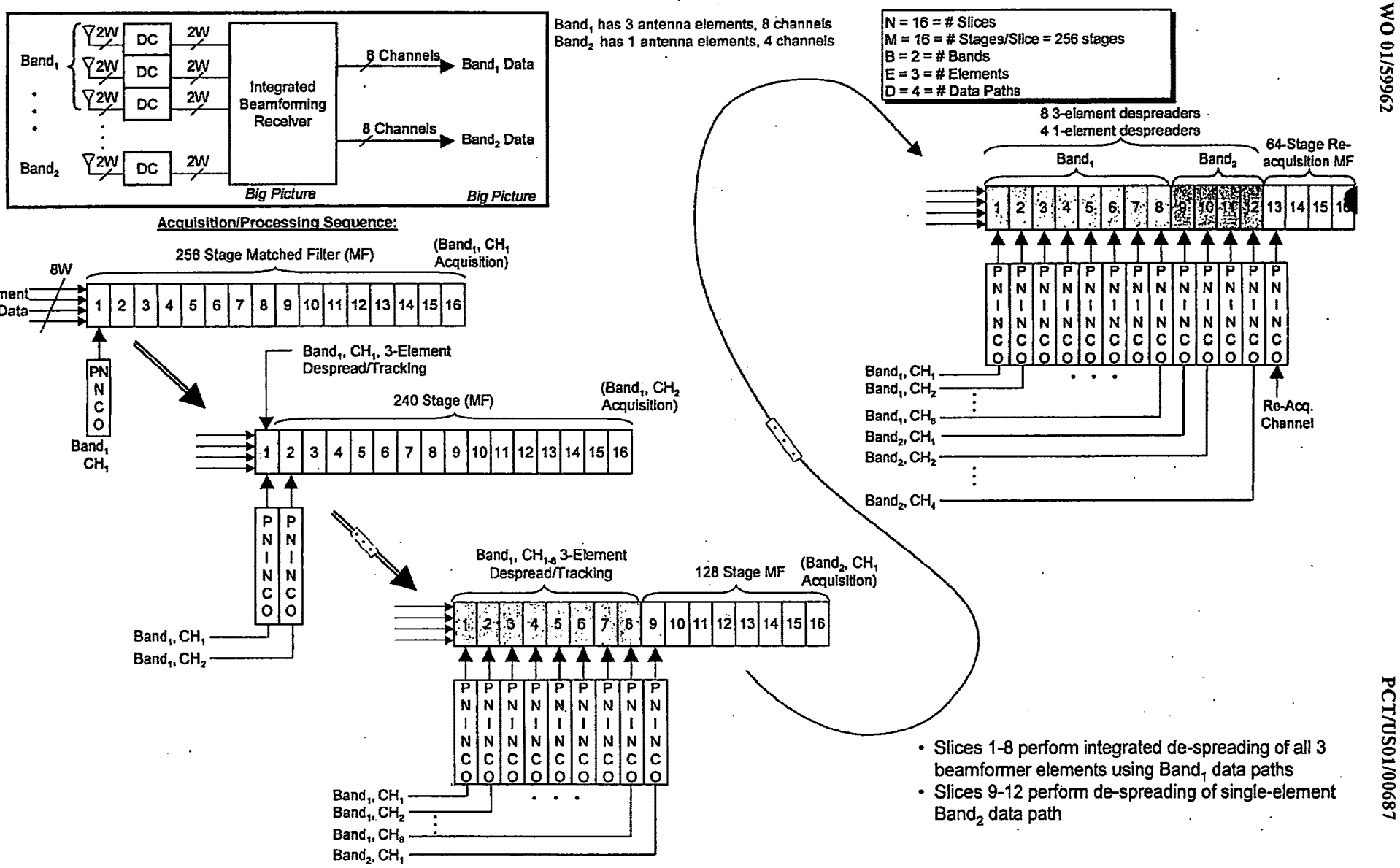


Figure 3: Example 6-Channel, 32-Bit, up to 2048 length, I/Q, RAM-based PN-Code Generator



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Figure 4: Example #1, 3-Element Beamformer, 12-Channels, 2-Bands (no Rake)



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Figure 5: Computation Required for an E-Element Beamformer (Per Sample)

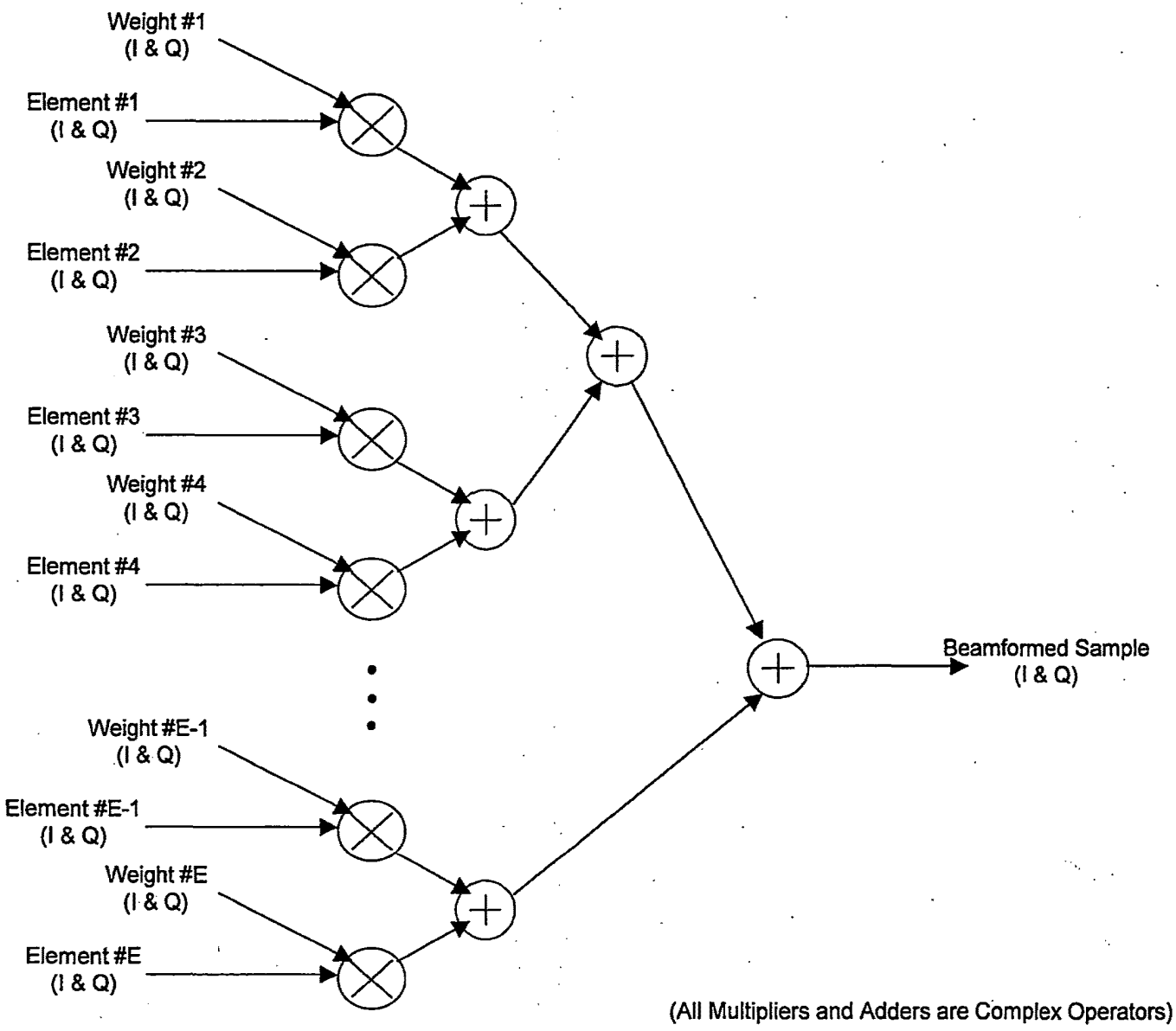


Figure 6: Example #1, 3-Element Beamformer (No Rake)

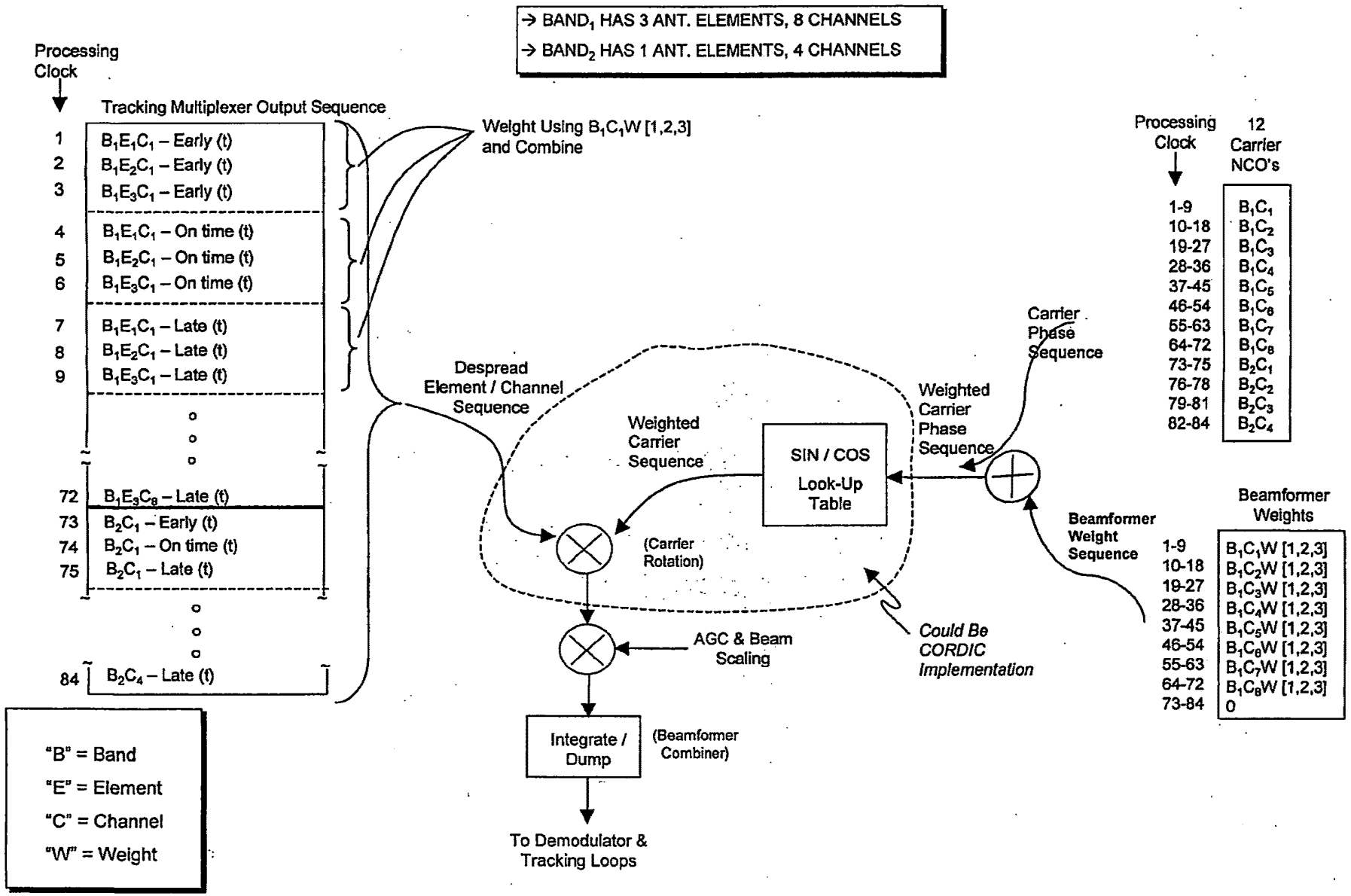
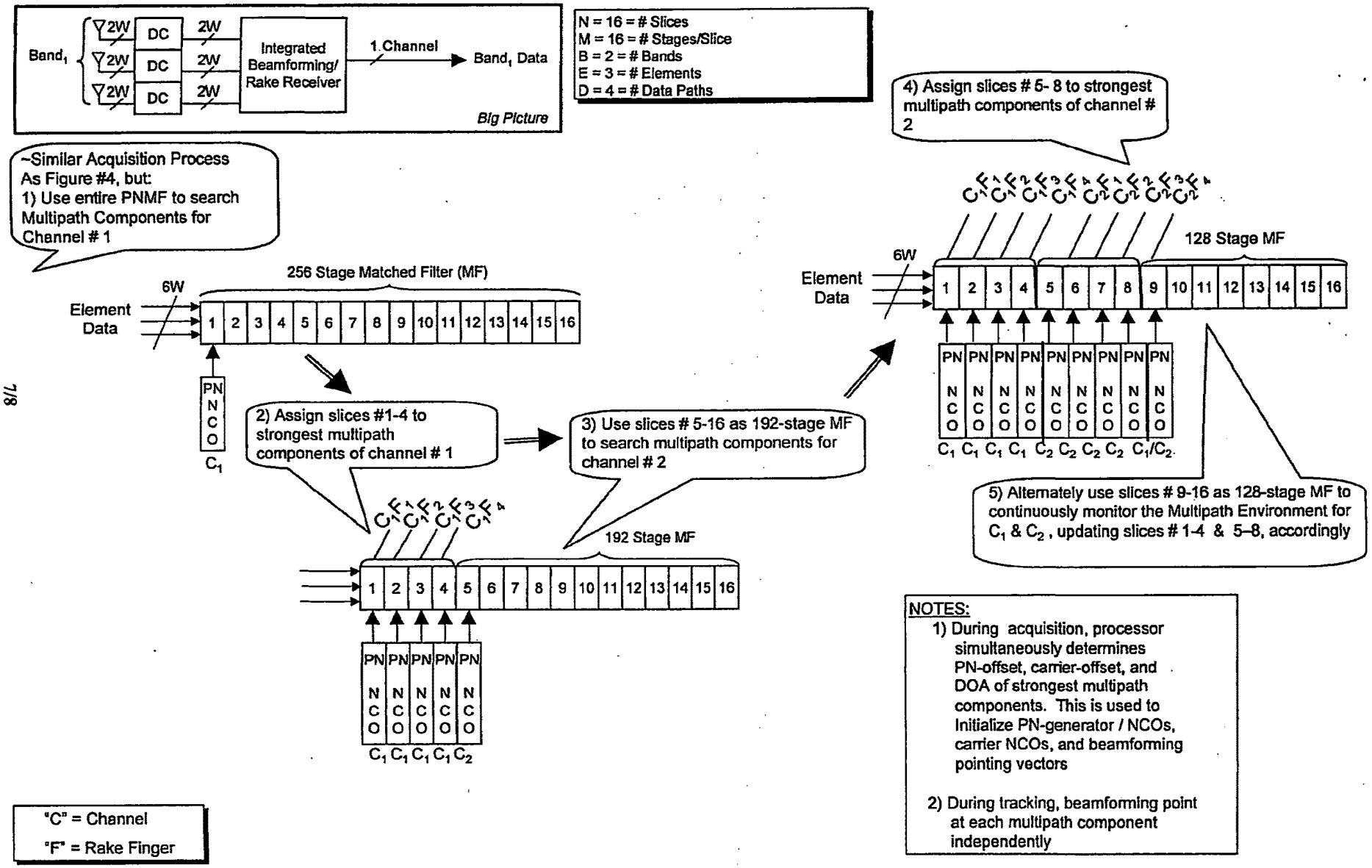
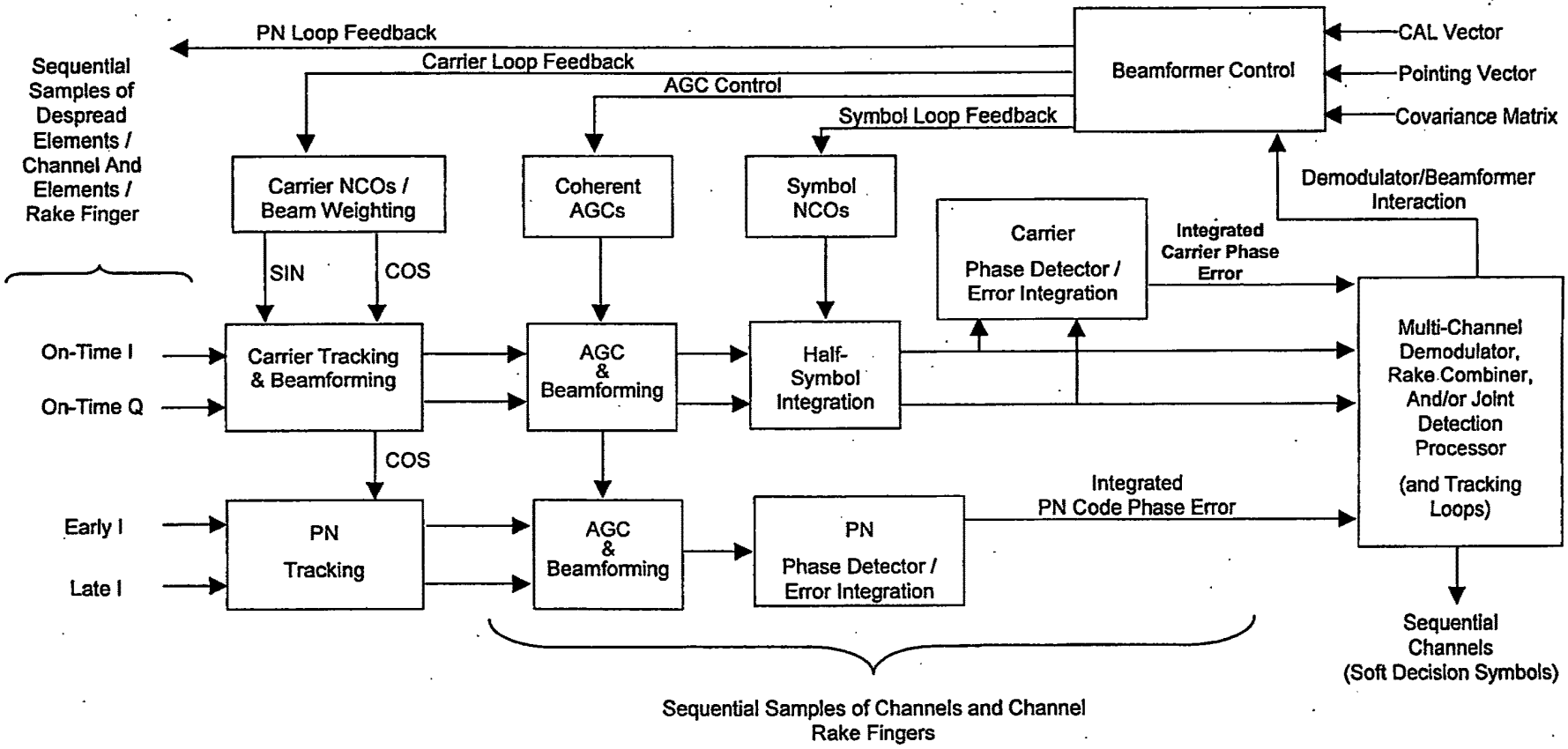


Figure 7: Example #2, 3-Element Beamformer (4 Rake Fingers, 2 Channels, 1 Band)



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Figure 8: Combined Multi-Channel Demodulator/Beamformer/Rake/Joint-Detection Architecture



INTERNATIONAL SEARCH REPORT

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A. CLASSIFICATION OF SUBJECT MATTER
IPC(7) : H04B 15/00
US CL : 375/130, 140, 142-144, 147, 150, 152, 343, 347, 349; 370/335, 336, 342, 343, 441, 442, 319-321
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 375/130, 140, 142-144, 147, 150, 152, 343, 347, 349; 370/335, 336, 342, 343, 441, 442, 319-321

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
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C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,654,980 A (LATVA-AHO et al.) 05 August 1997, column 1, line 35 to column 6, line 3.	1-22
Y	US 5,910,948 A (SHOU et al.) 08 June 1999, Abstract; column 2, line 65 to column 4, line 56.	1-22
Y,P	US 6,128,330 A (SCHILLING) 03 October 2000, Figures 6, 7; column 1, line 38 to column 3, line 48.	1-22
Y	US 5,202,903 A (OKANOUE) 13 April 1993; Abstract; column 1, line 12 to column 7, line 25	1-22
A	US 5,844,951 A (PROAKIS et al.) 01 December 1998, ALL	1-22
A,P	US 6,160,803 A (YUEN et al.) 12 December 2000, ALL	1-22

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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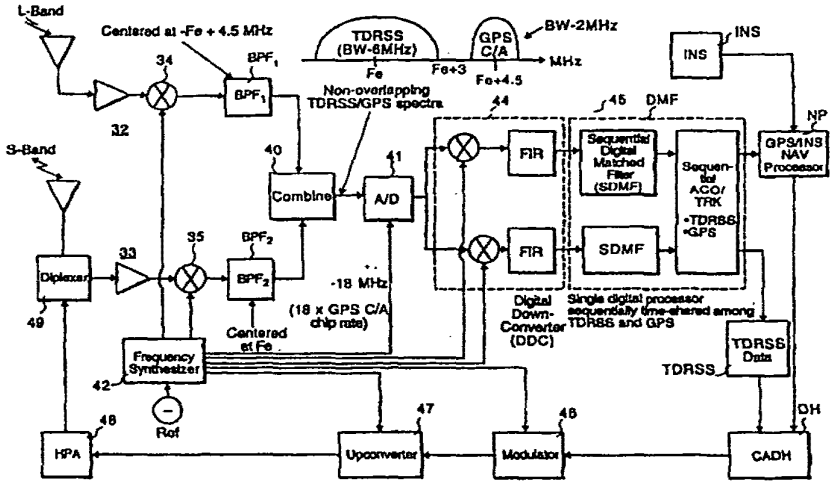
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(54) Title: MULTI-BAND, MULTI-FUNCTION INTEGRATED TRANSCEIVER



(57) Abstract

A communications system operating in one or more frequency bands (L and S) of various number of channels per band. The system comprises an antenna and RF front end (32 or 33) for each band, a separate RF to IF down converter for each band, an analog–to–digital converter (41) converts analog signals to digital signals from a combiner (40), a digital down converter (44) converts the digital signals to baseband signals and a single digital processor (45) sequentially time shared among all the bands and channels. The IF for each band is centered at a succession of frequencies f_0 such that the spectra for each band are non–overlapping, with the center frequency. An analog–to–digital converter sampling rate is chosen such that one band is centered at baseband, and one or more other bands are centered at a specific relationship with the sampling rate such that each band is individually down converted to baseband by appropriate selection of tap weight multiplying sequences.

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MULTI-BAND, MULTI-FUNCTION INTEGRATED TRANSCEIVER

REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part of application Serial No. 08/736,110 filed October 24, 1996 entitled A SYSTEM FOR INCREASING THE UTILITY OF SATELLITE COMMUNICATION SYSTEMS which, in turn, is a continuation-in-part of application Serial No. 159,410 filed November 19, 1993 entitled SYSTEM FOR INCREASING THE UTILITY OF SATELLITE COMMUNICATION SYSTEMS, now U.S. Patent No. 5,572,216, both of which are incorporated herein by reference. This application is also the subject of provisional application Serial No. 60/087,689 filed August 24, 1998.

BACKGROUND AND BRIEF DESCRIPTION OF THE INVENTION

In Figure 1 of the above-referenced application and patent, a low power transceiver is disclosed (the Figure shows only the receiver portion) in which a transmitter and receiver operate non-coherently, that is, without the requirement that transmitted and received signals bear a fixed electrical frequency and phase relationship so that as a result, the transceiver can be simple and robust and

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of lower power consumption. One such embodiment integrates a GPS receiver into an existing primary two-way communications system, which accomplishes position location for its user. Moreover, the resulting position location could be caused to be transmitted automatically or on signal from any other transceiver or ground location using the primary link.

The present invention provides wireless communications capability, for either terrestrial or space based operations, involving the simultaneous processing of multiple communications signals and types, received from various and multiple bands, such as an integrated TDRSS/GPS satellite receiver, as well as numerous other waveform and frequency band combinations. The key features of the transceiver are that it is multi-channel/multi-band, leverages ongoing transceiver technology, is low power, is applicable to both spread and non-spread signals (i.e. applicable to a much broader range of users) and provides high performance, rapid acquisition/reacquisition and tracking in a single digital processing path.

Applications of the invention include integrating GPS into a receiver primarily using another communications link, thus providing receiver position and time across that link; among others, tracking and telemetry for launch vehicles (i.e., range safety) using TDRSS/GPS is a prime example of this. Other applications include integrated

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GPS/GLONASS, multi-mode analog/digital cellular, integrated NASA/Government communications links (i.e., TDRSS, GN, SGLS, etc.).

The invention is directed to communications system operating in one or more frequency bands comprising a various number of channels per band (for a total of N channels), and transceiver means for receiving these multiple bands of signals characterized in that the transceiver comprises a system of antenna and RF front end for each said band, a separate RF to IF downconverter for each said band, said IF for each band centered at a succession of frequencies F_c such that the spectra for each band are non-overlapping, with said center frequencies and analog-to-digital converter sampling rate chosen such that one band is centered at baseband, and one or more other bands are centered at a specific relationship with the sampling rate such that each band is individually downconverted to baseband by appropriate selection of tap weight multiplying sequences (such as alternating +/- sequence for the case of F_c equal to one-fourth the sampling rate), combining means for combining said RF signals, analog-to-digital converter means for converting analog signals to digital signals from said combining means, digital downconverter means for converting said digital signals to baseband signals and a single digital processor sequentially time shared among all said Bands and channels,

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a signal processor connected to said single digital processor responsible for any final signal and/or data processing or formatting, and a signal transmitter of unspecified design details, coupled into the said transceiver antenna path by means of a diplexer device.

Further, the invention also features a tracking and data relay satellite system operating in the S-band (TDRSS) and in conjunction with a GPS satellite system operating in the L-band, and transceiver means for receiving L-band and S-band characterized in that the transceiver comprises a system antenna and RF front end for each said S-band and L-band signal, a separate RF to IF downconverter for each said S-band and L-band signal, said IF for said S-band signal operating at a frequency F_o and said IF signals for said L-band operating and centered at a frequency F_o plus a predetermined separation frequency so that the spectra for said S-band and the spectra for said L-band are non-overlapping, combining means for combining said IF signals analog-to-digital converter means for converting analog signals to digital signals from said combining means, digital downconverter means for converting said digital signals to baseband signals and a single digital processor sequentially time shared among said S-band and L-band signals, respectively, a GPS navigation processor and a TDRSS data processor connected to said single digital processor, a TDRSS (S-band) signal transmitter of

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unspecified design details, coupled into the said TDRSS (S-band) transceiver antenna path by means of a diplexer device.

Furthermore, invention also features a multi-Band, multi-channel digital matched filter (DMF) implementation comprising multiple sets (N) of PN-Generators and storage means for maintaining N sets of tap weights within the DMF, N-stage data delay line which shifts the digital data samples down the line at the baseband sampling rate, arithmetic circuitry for multiplying alternate taps of said delay line by one of the stored sets of tap weights, pre-multiplied by the +/- or other appropriate downconversion sequence, and summing each of said products, to form a correlation output sample that is a member of the sequence corresponding to a the channel represented by the selected tap weights; sufficient consecutive such sum-of-products samples are thus formed to form the complete correlation epoch function corresponding to the selected channel, whereby during acquisition, the tap weights for a single channel are manipulated appropriately such that consecutive DMF output samples represent correlation epochs associated with a particular PN alignment (offset), and thus an acquisition detection circuit can observe which of the correlation alignments is of sufficient magnitude to indicate the correct PN alignment, and thus transition that channel into tracking, and during tracking, the tap weights

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are alternated between various channels and manipulated appropriately such that the output sequence from the DMF thus consists of a sequence of sum-of-products samples that are in fact also a sequence of correlation epochs corresponding to each of the channels being tracked, and during ongoing operations in fact both acquisition and tracking operations among multiple channels may be simultaneously taking place using the said techniques.

DESCRIPTION OF THE DRAWINGS

The above and other objects, advantages and features of the invention will be more apparent when considered with the following specification and accompanying drawings wherein:

Figure 1 illustrates the primary novel receiver concept disclosed in this invention, which is the incorporation of multiple signal channels originating from multiple signal bands into a common integrated digital processing path (each band could also function as a transceiver, by adding commonly understood transmitter logic and coupling into the appropriate receiver antenna using a diplexer),

Figure 2 is a TDRSS transceiver incorporating a GPS receiver which can accomplish position location -- essentially an expanded version of Figure 4 of Patent No. 5,572,216,

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Figure 3 is a block diagram of one preferred embodiment of the transceiver illustrating an integrated TDRSS/GPS transceiver according to the invention,

Figure 4 discloses a digital matched filter (DMF) for the I or Inphase channel (identical Q or Quadrature channel not shown),

Figure 5 is a block diagram of a sequential digital matched filter (SDMF) for the Inphase (I) channel shown, illustrating the time sequential correlation epochs that appear at the DMF output for the multiple tracked signals,

Figure 6 is a chart showing the spectra separation of the GPS/TDRSS embodiment after the analog signals have been combined,

Figure 7 is a schematic illustration of a digital matched filter computational cycle for the example GPS/TDRSS embodiment,

Figure 8 is an illustrative allocation of a cycle of N clock ticks according to the invention for the example GPS/TDRSS embodiment, and

Figure 9 is a functional illustration of a feed forward sequential tracking algorithm incorporated in the invention.

DETAILED DESCRIPTION OF THE INVENTION

In the receiver shown in Figure 1, a B-band, N-channel receiver is disclosed having functional antennae A-1....A-B

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coupled via amplifiers to corresponding RF/IF converters 10-1....10-B which are supplied from corresponding frequency synthesizers 11-1...11-B which in turn are supplied, preferably, from a common frequency source 12. The IF signals are bandpass filtered in 13-A....13-B and then combined 14, analog to digital converted 15, downconverted 16, and passed to N-channel digital matched filter 17. The output of N-=channel sequential digital matched filter 17 is demodulated in demodulator means 18 and the demodulated signals for the various channels are processed in data handler or processor 19 and supplied to various utilization devices 20-1...20-B.

Referring to Figure 2, the upper portion 22 of the block diagram is an illustration of an example embodiment of the invention, an L-band (GPS) receiver having a separate frequency synthesizer 23 and RF front end 24 with a navigation processor 25 outputting GPS location signals and a separate S-band (TDRSS) processing channel 25 including an RF front end 26 and a separate receiver channel with a separate frequency synthesizer 27 and a separate transmitter channel having its own modulator 28, upconverter 29 and high-powered amplifier 30 feeding a diplexer 31 for transmissions on the S-band.

According to the present invention, the integrated TDRSS/GPS transceiver maintains separate RF front ends 32, 33 and RF/IF downconverters 34, 35 for both the TDRSS

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signals, channels and the GPS signal channels (S-band and L-band, respectively). However, according to the present invention, the transceiver has common frequency synthesis 36 and clock reference signals with carefully allocated frequency plans to minimize distinct frequencies and clocks. In addition, the present invention combines the TDRSS and GPS signals from bandpass filters BPF in combining 37 at intermediate frequency (IF) and shares all remaining circuitry to the maximum extent possible. In this way, the TDRSS and GPS IF signals do not spectrally overlap (which thereby avoids signal-to-noise degradation); the TDRSS and GPS IF spectral spacing is carefully selected for efficient digital signal processing. Moreover, the digital baseband processing shares common circuitry so as to enable programmable digital matched filter (DMF) usage, clear or spread modes, and rapid acquisition and reacquisition capability. There is also common sharing of feed-forward tracking and detection for carrier, PN, and symbol timing loops. Finally, it enables a dedicated GPS/inertial navigation processor NP to be incorporated in a small hand-held transceiver unit.

Figure 3 illustrates one preferred embodiment of the invention, for the case of the integrated TDRSS/GPS transceiver. In this embodiment, note that the receiver channel for the S-band is centered at F_o and that the IF for the L-band is centered at F_o + 4.5 MHz so that there is non-

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overlapping TDRSS and GPS spectra. The output of the combiner 40 is supplied to the analog-to-digital converter 41. A common frequency synthesizer 42 is used to provide frequency synthesis and clock references for the transceiver. Note also that the output of the Analog-to-Digital (A/D) converter 41 is fed to a digital downconverter (DDC) 44 which outputs signals to the sequential digital matched filter (SDMF) 45 in a single digital processor sequentially time shared among all TDRSS and GPS channels. An inertial navigation system INS may also be incorporated in the transceiver for purposes of providing the navigation processor NP with inertial navigation signals. The TDRSS signals to be transmitted, which may include GPS positioning information derived from the receiver, are supplied by data handler DH to a modulator 46, upconverted 47 and supplied to the high-power amplifier (HPA) 48 which feeds the diplexer 49 and transmits the signals on the S-band to the satellite *S*. The circuitry illustrated in Figure 3 is predicated on the following assumptions:

- GPS C/A signal @ L1:

  1575.42 MHz
  1.023 MHz PN chip rate

- TDRSS SSA

  Flexible S-band forward link frequency, F_1.

  Corresponding PN chip rate = $\frac{(31)F_1}{(221)(96)}$.

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User forward/return link signals may be spread or non-spread.

Return Link Frequency -- (240/221) F_1.

Noncoherent operation (since GPS is available).

- Users, such as ELV, dynamics warrants rapid acq/reacq receiver (for both TDRSS and GPS).

In regards to the referenced digital matched filter (DMF) shown in Figure 4, note:

- During PN acquisition, DMF essentially provides N-fold parallel processing:

  Yields ~ 2 orders of magnitude reduction in PN code acquisition time (spread cases).

  All DMF output samples used for acquisition.

- During tracking DMF provides on-time, early, late samples:

  All other DMF output samples (i.e., most of N-clock cycle), are unused during tracking.

  This unused time, during tracking, is the basis for the sequential digital matched filter (SDMF).

Sequential digital matched filter (SDMF) illustrated for the I-channel is shown in Figure 5. Note:

- During tracking, distinct PN correlation functions are uniformly spaced (as driven by the PN tracking loops) in time at the DMF output, as shown.

  The full cycle time is used in the DMF, in contrast to the reference DMF (where almost the entire cycle time goes unused during tracking),

- On-time, early, late samples sequentially used by single set of acquisition/tracking hardware/software to track <u>all</u> signals.

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- Cycle time can be flexibly allocated to:

  Signal acquisition, or

  Signal acquisition of 1 signal while tracking multiple other signals.

The key features of digital baseband processing include the following (refer to Figure 6):

- Low-pass spectrum after Digital Downconversion (DDC).

- A/D sampling rate is determined by the total bandwidth required for all Bands, plus any desired guard spacing; for the GPS/TDRSS embodiment, the sampling rate = (18)(1.023) MHz (greater than or equal to twice the low-pass composite bandwidth).

  The Nyquist Criterion is satisfied

  The SDMF sequentially processes TDRSS, GPS signals by suitable DMF tap weight settings.

- SDMF processes primary Band (for example, TDRSS) as baseband PN-coded (or clear mode) signal. For the TDRSS example:

  PN: DMF tap weights matched to PN code -- 18 x 1.023 MHz ~ 6 x TDRSS PN chip rate (note; exactly equals 6 x TDRSS PN chip rate, for 3.069 Mcps and F_1 = 2100.384 MHz).

  Clear mode: DMF tap weights set to all 1's.

  When tap weights set for TDRSS, the other signals (i.e., GPS signals) are filtered out.

- SDMF processes a secondary Band (for example, GPS) as IF PN-coded (or clear-mode) signal. For the GPS example:

  IF @ 4.5 x 1.023 MHz.

  Sampling rate = 4 x IF

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DMF tap weights set to GPS C/A code modulated by alternating {+,-} sequence (this effectively downconverts the signals to baseband).

When tap weights set for GPS, the other signals (i.e., TDRSS signals) are filtered out.

- For the case of further secondary Bands, other schemes for weight adjustment (i.e., to effect other than Fs/4 downconversion) may be used; alternatively, actual digital NCO/modulators may be incorporated into the tap multipliers to perform arbitrary downconversion for each Band.

Figures 7 and 8 are illustrative of the DMF computational cycle. For the GPS/TDRSS example embodiment, note:

In regards to Figure 7:

- 18 clock ticks of each DMF cycle spans:

  1 GPS C/A chip

  3 TDRSS PN chips (i.e., 6 clock ticks per TDRSS PN chip)

- Illustrative allocation of cycle of N clock ticks.

In regards to Figure 8:

- N = 354 DMF stages, which supports sequential tracking of 1 TDRSS signal + GPS signals.
- DMF I/O delay ~ 20 μs; accommodates ~ 10kHz uncertainty.

Referring now to Figure 9, a functional diagram of the sequential tracking process is illustrated. In this process, the I/Q early/on-time/late tracking samples coming out of the SDMF are phase rotated (for carrier tracking),

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and then formed into discriminators that are used as feedback to the various tracking loops. Additionally, the on-time samples are further integrated and formed into soft-decision data samples. For the case of GPS, various observables contained within both the SDMF and the tracking circuitry are made available to the Navigation Processor for use in computing time and position. Note that the single set of digital processing functionality is sequentially shared; i.e., although only a single actual hardware/firmware carrier/PN/symbol discriminator capability actually exists physically, N virtual instances of that capability are emulated through time sequencing.

While both a generalized description, as well as an example embodiment, of the present invention has been illustrated and described, it will be appreciated that various other embodiments, adaptations and modifications of the invention will be greatly apparent to those skilled in the art.

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WHAT IS CLAIMED IS:

1. In a communications system operating in one or more frequency bands, consisting of various number of channels per band (for a total of N channels), and means for receiving these multiple bands of signals, the improvement in said transceiver comprising:

a system of antenna and RF front end for each said band, a separate RF to IF downconverter for each said band, said IF for each band centered at a succession of frequencies F_c such that the spectra for each band are non-overlapping, with said center frequencies and analog-to-digital converter sampling rate chosen such that one band is centered at baseband, and one or more other bands are centered at a specific relationship with the sampling rate such that each band is individually downconverted to baseband by appropriate selection of tap weight multiplying sequences (such as alternating +/- sequence for the case of F_c equal to one-fourth the sampling rate),

analog-to-digital converter means for converting analog signals to digital signals from said combining means,

digital downconverter means for converting said digital signals to baseband signals and a single digital processor sequentially time shared among all said Bands and channels,

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a signal processor connected to said single digital processor responsible for any final signal and/or data processing or formatting,

a signal transmitter of unspecified design details, coupled into the said transceiver antenna path by means of a diplexer device.

2. In a tracking and data relay satellite system operating in the S-band (TDRSS) and in conjunction with a GPS satellite system operating in the L-band, and transceiver means for receiving L-band and S-band signals, the improvement in said transceiver comprising:

a system antenna and RF front end for each said S-band and L-band signal, a separate RF to IF downconverter for each said S-band and L-band signal, said IF for said S-band signal operating at a frequency F_o and said IF signals for said L-band operating and centered at a frequency F_o plus a predetermined separation frequency so that the spectra for said S-band and the spectra for said L-band are non-overlapping,

analog-to-digital converter means for converting analog signals to digital signals from said combining means,

digital downconverter means for converting said digital signals to baseband signals and a single digital

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processor sequentially time shared among said S-band and L-band signals, respectively,

a GPS navigation processor and a TDRSS data processor connected to said single digital processor,

a TDRSS (S-band) signal transmitter of unspecified design details, coupled into the said TDRSS (S-band) transceiver antenna path by means of a diplexer device.

3. Multi-Band, Multi-Channel Digital Matched Filter (DMF) implementation comprising:

multiple sets (N) of PN-Generators and storage means for maintaining N sets of tap weights within the DMF,

N-stage data delay line which shifts the digital data samples down the line at the baseband sampling rate,

arithmetic circuitry for multiplying alternate taps of said delay line by one of the stored sets of tap weights, pre-multiplied by the +/- or other appropriate downconversion sequence, and summing each of said products, to form a correlation output sample that is a member of the sequence corresponding to a the channel represented by the selected tap weights; sufficient consecutive such sum-of-products samples are thus formed to form the complete correlation epoch function corresponding to the selected channel,

whereby, during acquisition, the tap weights for a single channel are manipulated appropriately such that

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consecutive DMF output samples represent correlation epochs associated with a particular PN alignment (offset), and thus an acquisition detection circuit can observe which of the correlation alignments is of sufficient magnitude to indicate the correct PN alignment, and thus transition that channel into tracking,

during tracking, the tap weights are alternated between various channels and manipulated appropriately such that the output sequence from the DMF thus consists of a sequence of sum-of-products samples that are in fact also a sequence of correlation epochs corresponding to each of the channels being tracked,

during ongoing operations in fact both acquisition and tracking operations among multiple channels may be simultaneously taking place using the said techniques.

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FIGURE 1

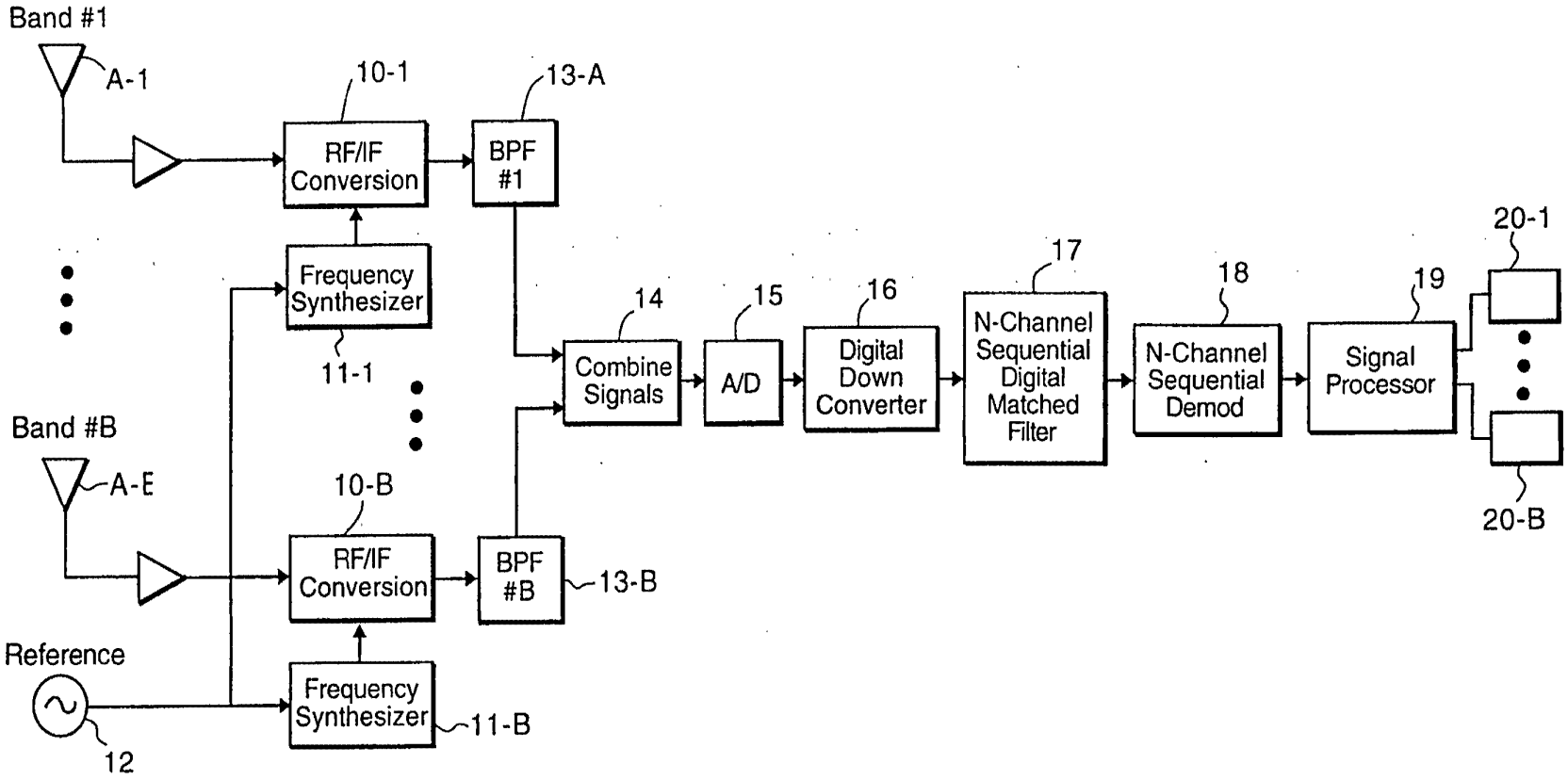

Band #1
A-1
10-1
13-A
RF/IF Conversion
BPF #1
Frequency Synthesizer
11-1
14
15
16
17
18
19
20-1
Combine Signals
A/D
Digital Down Converter
N-Channel Sequential Digital Matched Filter
N-Channel Sequential Demod
Signal Processor
20-B
Band #B
A-E
10-B
RF/IF Conversion
BPF #B
13-B
Reference
Frequency Synthesizer
11-B
12

FIGURE 2

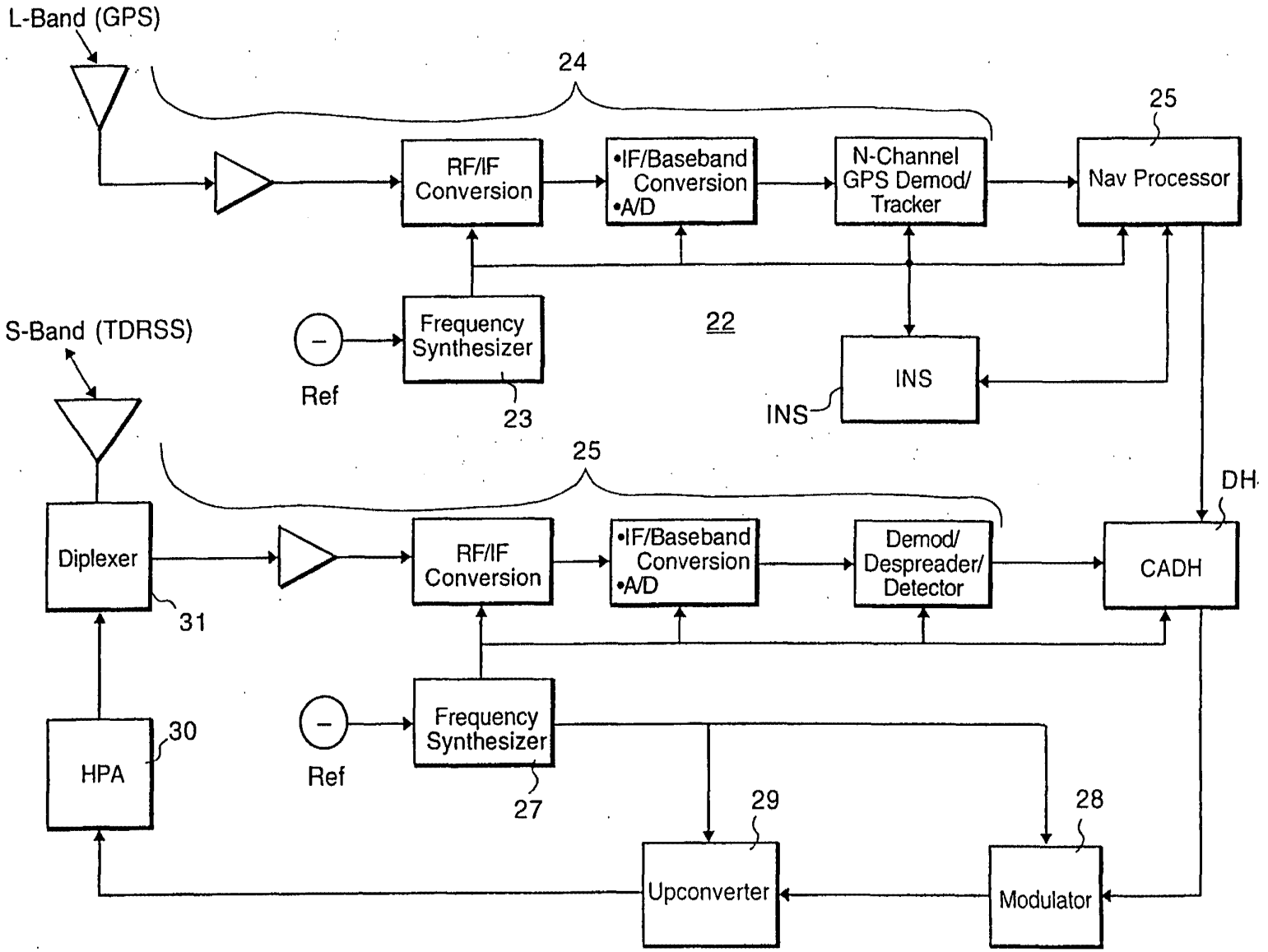
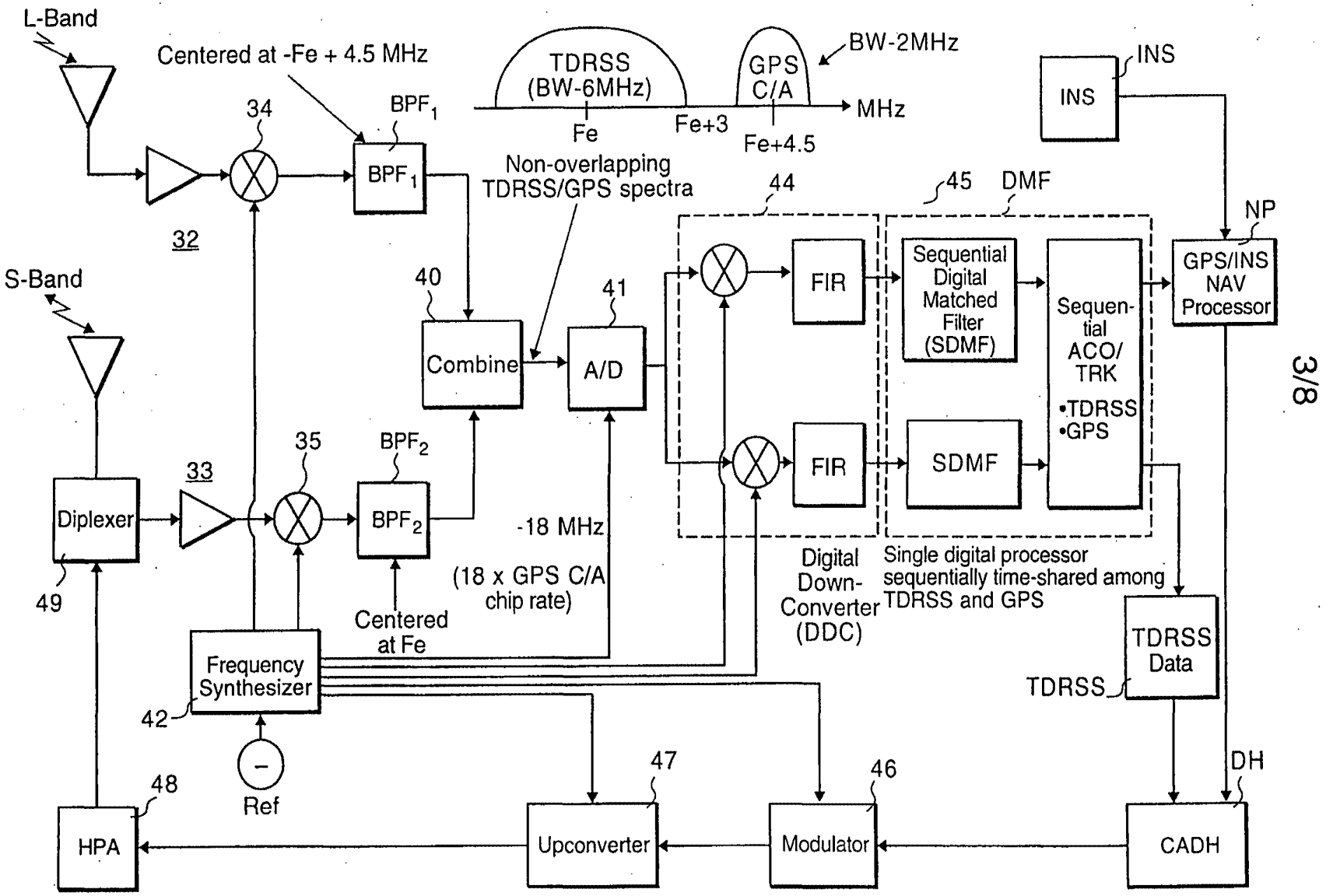
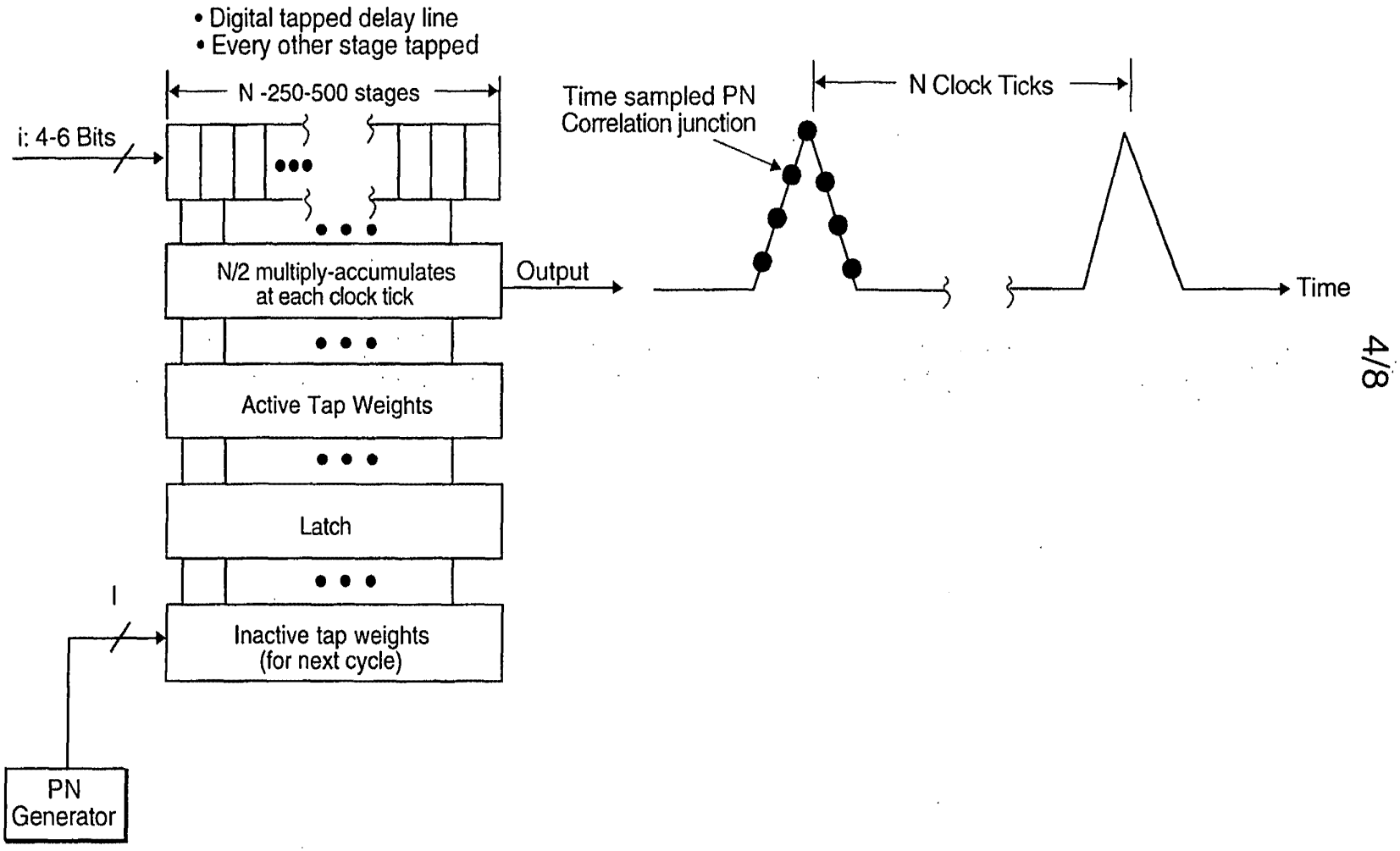

L-Band (GPS)
24
25
RF/IF Conversion
•IF/Baseband Conversion •A/D
N-Channel GPS Demod/ Tracker
Nav Processor
S-Band (TDRSS)
Frequency Synthesizer
Ref
23
22
INS
INS
25
DH
Diplexer
31
RF/IF Conversion
•IF/Baseband Conversion •A/D
Demod/ Despreader/ Detector
CADH
HPA
30
Frequency Synthesizer
Ref
27
29
28
Upconverter
Modulator

FIGURE 3



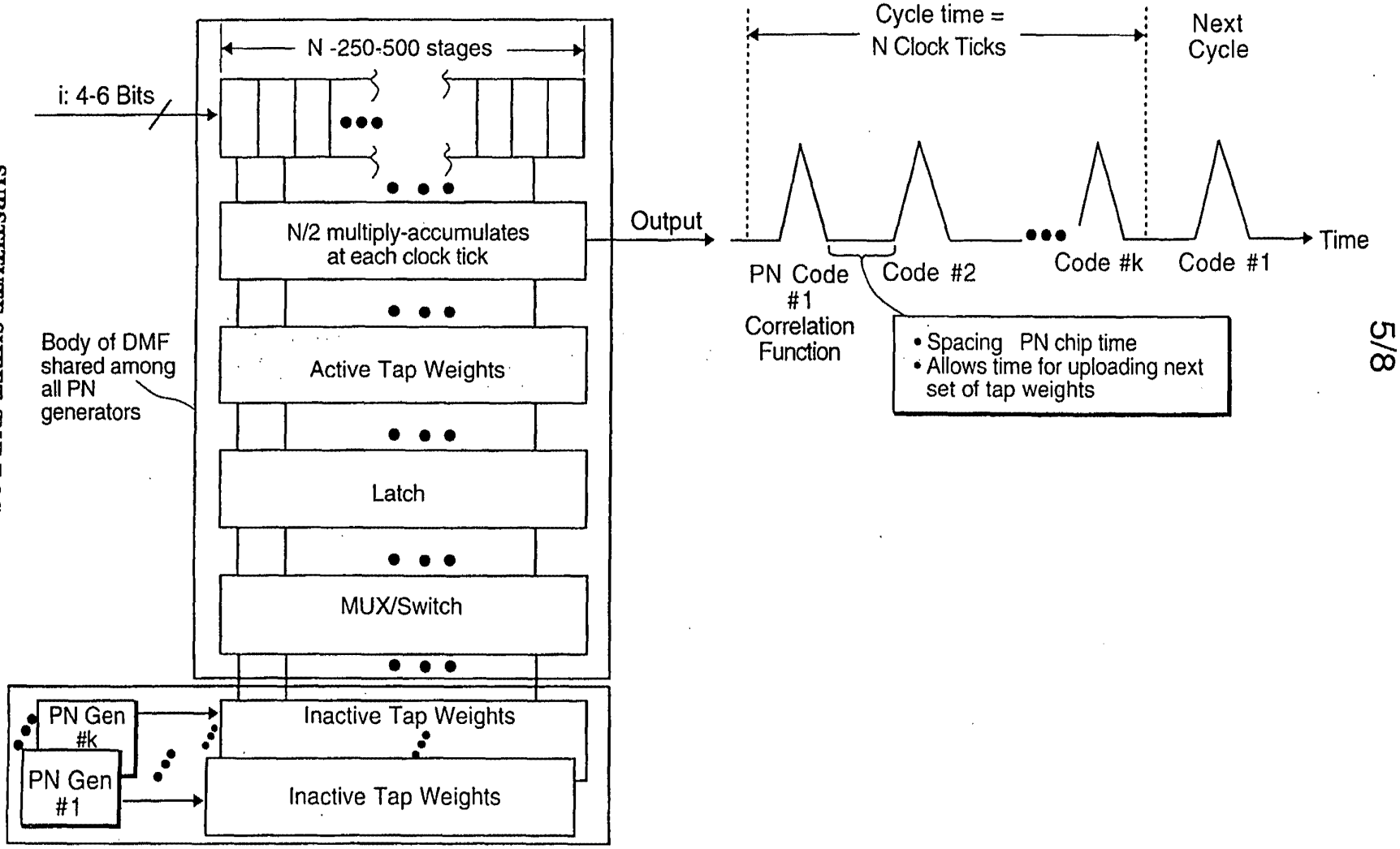
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FIGURE 4



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FIGURE 5


N -250-500 stages
i: 4-6 Bits
N/2 multiply-accumulates at each clock tick
Output
Active Tap Weights
Body of DMF shared among all PN generators
Latch
MUX/Switch
PN Gen #k
PN Gen #1
Inactive Tap Weights
Inactive Tap Weights
Cycle time = N Clock Ticks
Next Cycle
Time
PN Code #1 Correlation Function
Code #2
Code #k
Code #1
• Spacing PN chip time
• Allows time for uploading next set of tap weights

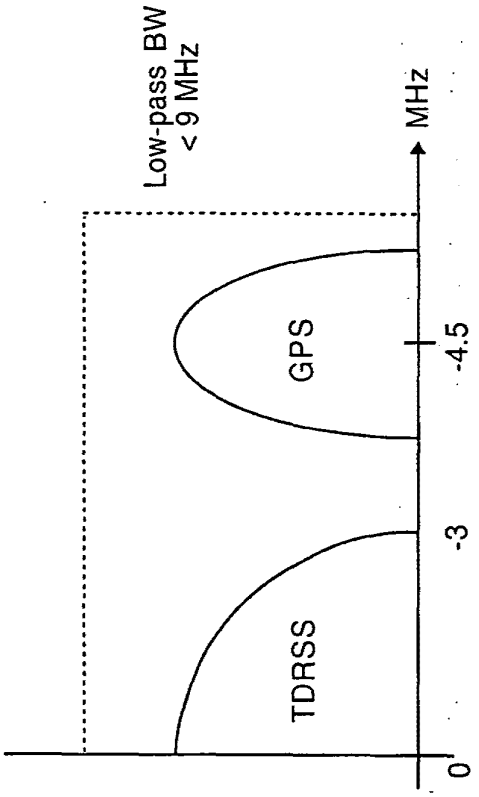


FIGURE 6

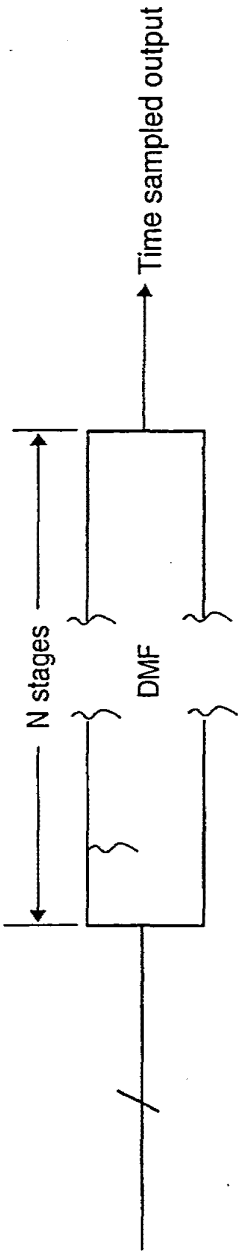


FIGURE 7

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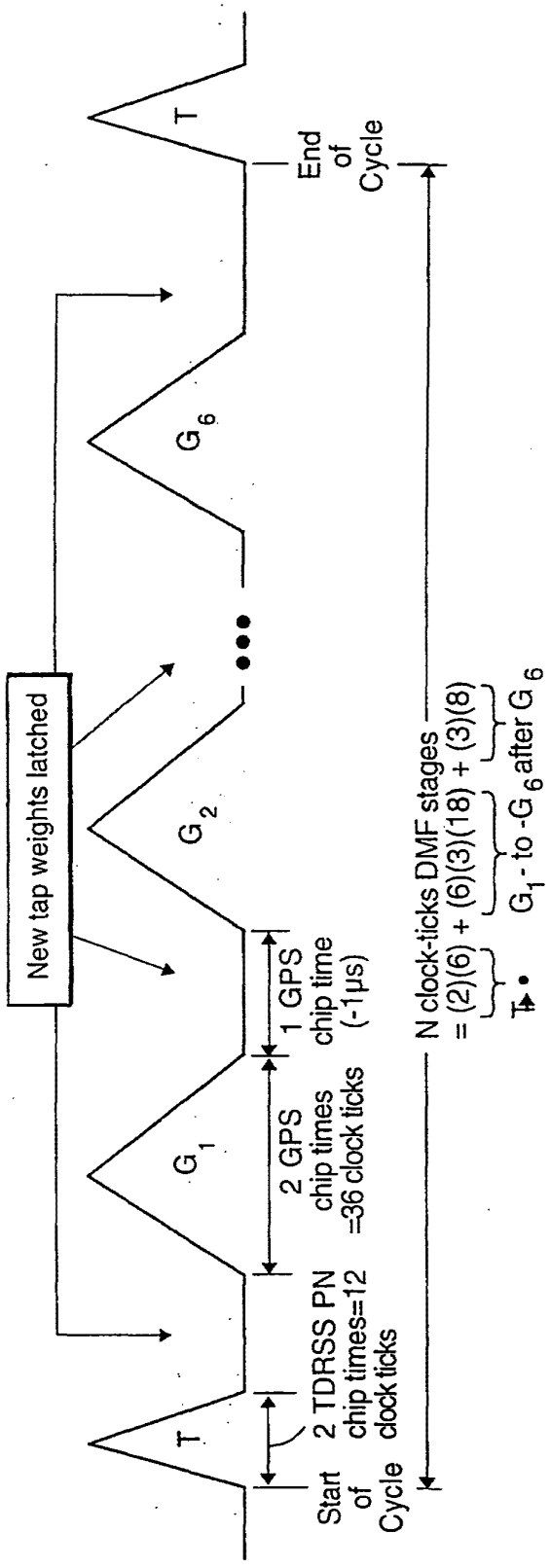
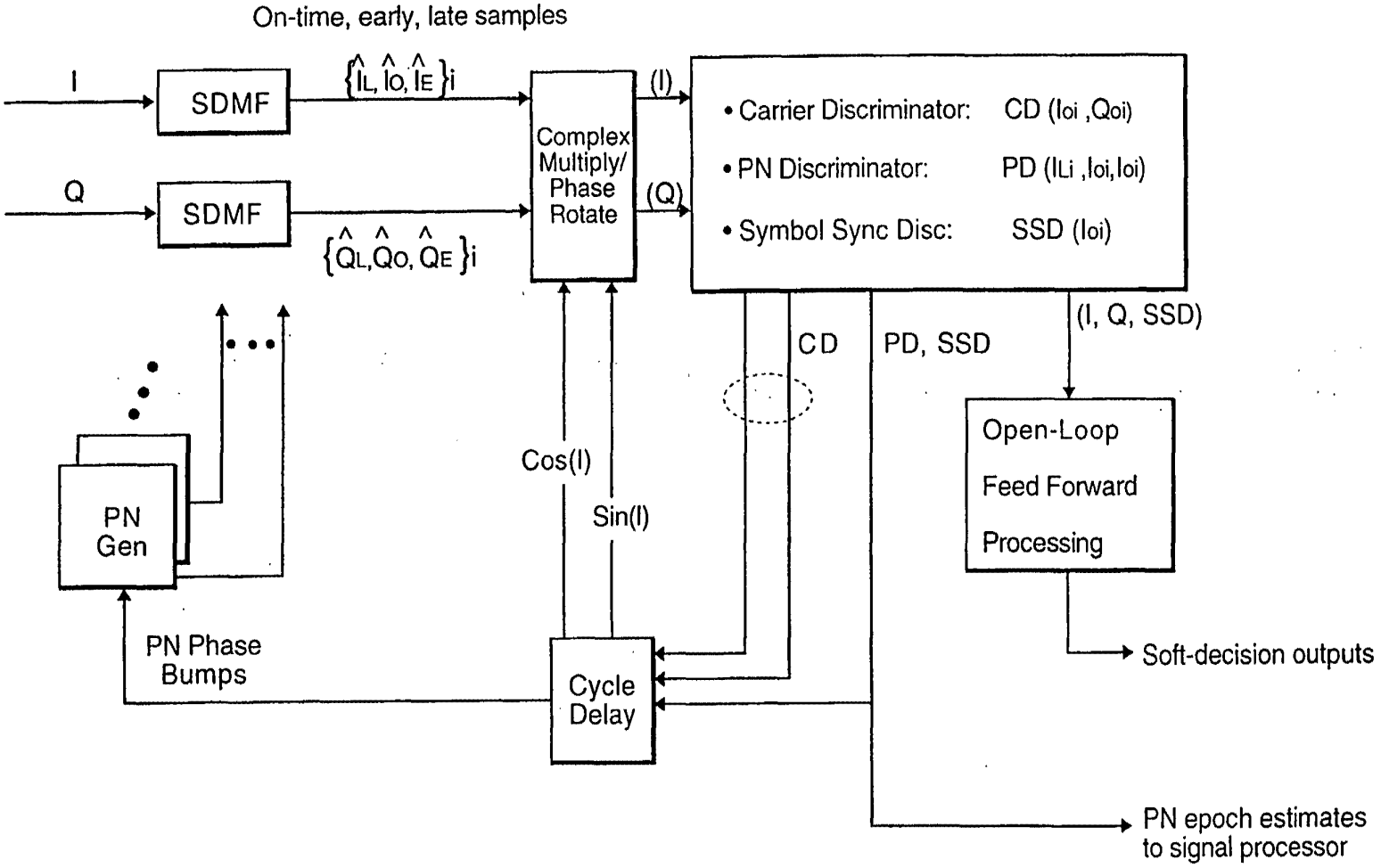


FIGURE 8

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FIGURE 9



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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/16730

A. CLASSIFICATION OF SUBJECT MATTER
IPC(6) :H04B 1/707
US CL :375/206, 207, 343
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 375/200, 206, 207, 208, 343

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EAST (center frequency, sampling rate, baseband, and match filter)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4,550,414 A (GUINON et al.) 29 October 1985, col. 9, lines 3-33.	3
A	US 4,785,463 A (JANC et al.) 15 November 1988, col. 5, lines 32-67.	1-2
A	US 5,375,146 A (CHALMERS) 20 December 1994, col. 5, line 41 to col. 6, line 43.	1-2
A	US 5,414,699 A (LEE) 09 May 1995, col. 6, lines 1-68.	3
A	US 5,606,575 A (WILLIAMS) 25 February 1997, col. 5, line 5 to col. 6, line 10.	1-2
A	US 5,638,362 A (DOHI et al.) 10 June 1997, col. 1, lines 34-47.	3

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be of particular relevance	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E"	earlier document published on or after the international filing date	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&"	document member of the same patent family
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"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search	Date of mailing of the international search report
28 OCTOBER 1999	07 DEC 1999
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer YOUNG TSE Telephone No. (703) 305-4736

Form PCT/ISA/210 (second sheet)(July 1992)*

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/16730

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5,640,416 A (CHALMERS) 17 June 1997, col. 6, line 66 to col. 8, line 6.	1-2
A	US 5,696,762 A (NATALI et al.) 09 December 1997, col. 5, lines 7-14.	3

Form PCT/ISA/210 (continuation of second sheet)(July 1992)*

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/16730

BOX II. OBSERVATIONS WHERE UNITY OF INVENTION WAS LACKING
This ISA found multiple inventions as follows:

Group I, claim(s)1-2, drawn to a communications system or a tracking and data relay satellite system operating in one or more freqyency bands.
Group II, claim(s) 3, drawn to a digital matched filter.
The inventions listed as Groups I and II do not relate to a single inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons:

The communications system or the tracking and data relay satellite system in Group I does not require the digital matched filter in Group II. For example, in Group I, an antenna and RF front end, an analog-to-digital converter, a digital down converter, a signal processor or a GPS nevigation processor, and a signal transmitter are provided in the system, however, in Group II, N-stage data delay line and arithmetic circuitry are provided in the digital matched filter which are not required in the system of Group I.

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2634
8-14-02

Atty. Docket No.: 0918.0153C

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the PATENT application of:

Scott BIERLY, et al.

Serial No.: 10/084,614

Filed: February 28, 2002

For: **Integrated Beamformer/Modem Architecture**

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Technology Center 2600

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AUG 13 2002

SUPPLEMENTAL INFORMATION DISCLOSURE STATEMENT

Assistant Commissioner for Patents
Washington, D.C. 20231

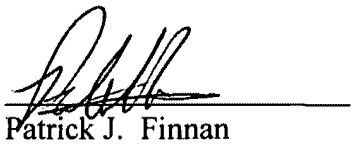
Sir:

Pursuant to the duty imposed by 37 C.F.R. §1.56 to disclose information which may be material to patentability of the above-identified patent application, the Examiner's attention is directed to the documents listed on the enclosed Supplemental Information Disclosure Citation Form. Copies of the documents listed thereon are enclosed herewith.

Since this Supplemental Information Disclosure Statement is being filed in compliance with 37 C.F.R. §1.97(b), within three (3) months of the filing date of the above-identified application and/or prior to the mailing date of a first Office Action on the merits, no fee is required in connection with its filing. However, the Commissioner is hereby authorized to charge payment of any fees required for the above-identified application or credit any overpayment to Deposit Account No. 05-0460.

The submission of the listed documents is not intended as an admission that any such document constitutes prior art against the claims of the present application. Applicant does not waive any right to take any action that would be appropriate to antedate or otherwise remove any listed document as a competent reference against the claims of the present application.

Respectfully submitted,



Patrick J. Finnan
Registration No. 39,189

EPSTEIN, EDELL, SHAPIRO, FINNAN & LYTLE, LLC
1901 Research Boulevard, Suite 400
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(301) 424-3640

Hand-delivered: 8/7/02

Sheet 1 of 1

FORM PTO 1449 (modified)

U.S. DEPARTMENT OF COMMERCE
PATENT AND TRADEMARK OFFICE

LIST OF REFERENCES CITED BY APPLICANT(S)
(Use several sheets if necessary)

Date Submitted to PTO:

ATTY DOCKET NO. 0918.0153C	SERIAL NO. 10/084,614
APPLICANT: Scott Bierly, et al.	
FILING DATE : February 28, 2002	GROUP

U.S. PATENT DOCUMENTS

*EXAMINER INITIAL		DOCUMENT NUMBER	DATE	NAME	CLASS	SUBCLASS	FILING DATE IF APPROPRIATE
		6,167,099	12/26/00	Rader et al			

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FOREIGN PATENT DOCUMENTS

		DOCUMENT NUMBER	DATE	COUNTRY	CLASS	SUBCLASS	TRANSLATION YES/NO/ OR ABSTRACT
	✓	WO 96/22662	12/01/95				

OTHER DOCUMENT(S) (Including Author, Title, Date, Pertinent Pages, Etc.)

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*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609; Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 :
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A1

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(21) International Application Number: PCT/US95/15641

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(30) Priority Data:
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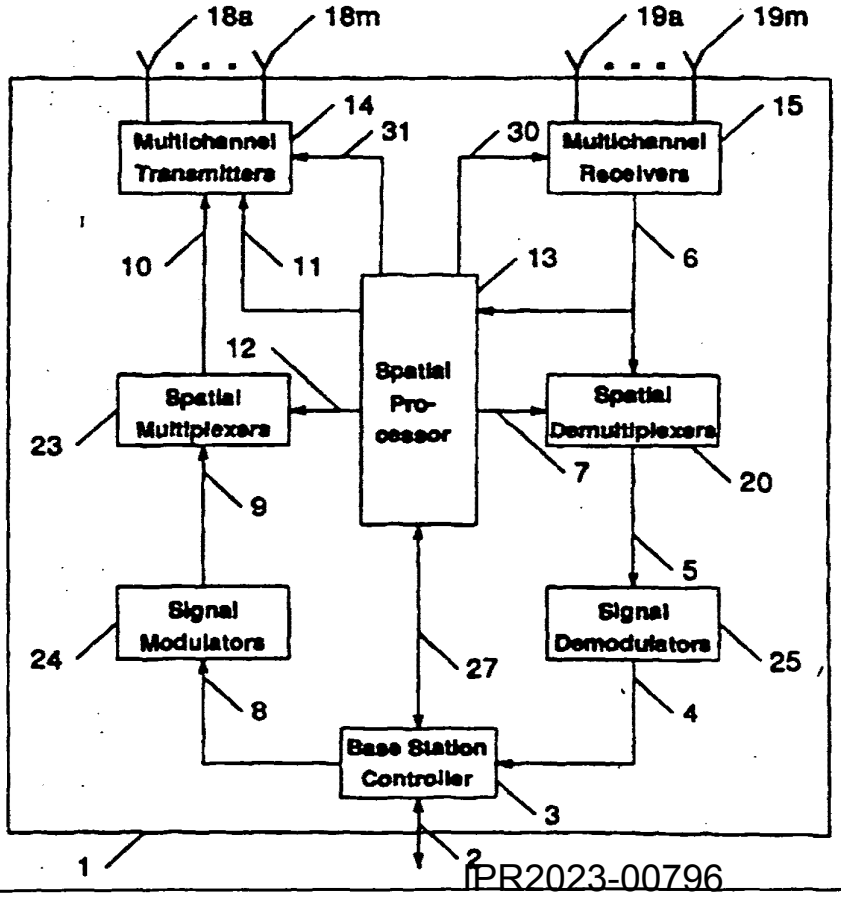
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(57) Abstract

A wireless system includes a network of base stations (1) for receiving uplink signals transmitted from a plurality of remote terminals (69) and for transmitting downlink signals to the remote terminals. Each base station (1) includes a plurality of transmitting antenna elements (18) for transmitting downlink signals and receiving antenna elements (19) for receiving uplink signals, a signal processor (13) connected to the antenna elements for determining spatial signatures and multiplexing and demultiplexing functions. A multiple base station controller (66) is used for optimizing network performance.



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SPECTRALLY EFFICIENT HIGH CAPACITY WIRELESS COMMUNICATION SYSTEMS

Background of the Invention

This invention relates to wireless communication systems and, more particularly, to using antenna arrays and signal processing to dramatically increase the capacity and performance of wireless communication systems.

Wireless communication systems can be used to complement and in some instances replace conventional wired communication systems in areas where conventional wire-line systems are unavailable, unreliable, or excessively expensive. Examples of such areas are: rural areas with a small number of widespread users, underdeveloped areas with little or no current infrastructure, reliability sensitive applications in areas where wired infrastructure is unreliable, and political environments where monopolistic wired service providers maintain artificially high prices. Even in metropolitan areas and highly developed countries, wireless communication systems may be used for low-cost ubiquitous communication, new flexible data services, and emergency communication systems. In general, wireless communication systems may be used for voice communications just like conventional telephone systems, and for data communications in a radio-based wide area or local area network as well.

Wireless users access wireless communication systems using remote terminals such as cellular telephones and data modems equipped with radio transceivers. Such systems (and in particular the remote terminals) have protocols for initiating calls, receiving calls, and general transfer of information. The information transfer can be performed in real-time such as is the case for circuit-switched voice conversations and faxes, or in a store-and-forward manner such as is often the case for electronic mail, paging and other similar message transfer systems.

Wireless communication systems are generally allocated a portion of the radio frequency spectrum for their operation. The allocated portion of the spectrum is divided up into communication channels. These channels may be distinguished by frequency, by time, by code, or by some combination of the above. Each of these communication channels will be referred to herein as *conventional channels*. Depending on the available frequency allocations, the wireless system might have from one to several hundred communication channels. To provide full-duplex communication links, typically some of the communication channels are used for communication from base stations to users' remote terminals (the downlink), and others are used for communication from users' remote terminals to base stations (the uplink).

Wireless communication systems generally have one or more radio base stations, each of which provide coverage to a geographic area known as a cell and often serve as a point-of-presence (PoP) providing connection to a wide area network such as a Public Switched Telephone Network (PSTN). Often a predetermined subset of the available communication channels is assigned to each radio base station in an attempt to minimize the amount of interference experienced by users of the system. Within its cell, a radio base station can communicate simultaneously with many remote terminals by using different conventional communication channels for each remote terminal.

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As aforementioned, base stations can act as PoPs, providing connection to one or more wired communication systems. Such systems include local data networks, wide area data networks, and PSTNs. Thus, remote users are provided access to local and/or wide area data services and the local public telephone system. Base stations can also be used to provide local connectivity without direct access to a wired network such as in local area emergency and mobile battlefield communication systems. Base stations can provide connectivity of various kinds as well. In the aforementioned examples, point-to-point communications where roughly equal amounts of information flow in both directions between two users were assumed. In other applications such as interactive television, information is broadcast to all users simultaneously, and responses from many of the remote units are to be processed at the base stations.

However, conventional wireless communication systems are comparatively spectrally inefficient. In conventional wireless communication systems, only one remote terminal can use any one conventional channel within a cell at any one time. If more than one remote terminal in a cell attempts to use the same channel at the same time, the downlink and uplink signals associated with the remote terminals interfere with each other. Since conventional receiver technology can not eliminate the interference in these combined uplink and downlink signals, remote terminals are unable to communicate effectively with the base station when interference is present. Thus, the total capacity of the system is limited by the number of conventional channels the base station has available, and in the overall system, by the way in which these channels are re-used among multiple cells. Consequently, conventional wireless systems are unable to provide capacity anywhere near that of wired communication systems.

Summary of the Invention

Accordingly, an object of the present invention is to use antenna arrays and signal processing to separate combinations of received (uplink) signals. Another object of the present invention is to transmit spatially multiplexed downlink signals. The result is a dramatic increase in spectral efficiency, capacity, signal quality, and coverage of wireless communication systems. Capacity is increased by allowing multiple users to simultaneously share the same conventional communication channel within a cell without interfering with one another, and further by allowing more frequent reuse of the same conventional channel within a geographic area covering many cells. Signal quality and coverage area are improved through intelligent processing of signals received from and transmitted by multiple antenna elements. Moreover, a further object of the present invention is to provide capacity gains by dynamically allocating conventional channels among base stations and remote terminals.

Briefly, the invention comprises antenna arrays and signal processing means for measuring, calculating, storing, and using *spatial signatures* of receivers and transmitters in wireless communication systems to increase system capacity, signal quality, and coverage, and to reduce overall system cost. The antenna array and signal processing means can be employed at base stations (PoPs) and remote terminals. Generally there can be different processing requirements at base stations where many signals are being concentrated than at remote terminals where in general only a limited number of communication links are being managed.

As an example, in a wireless local loop application, a particular base station might serve as a PoP for many remote terminals and employ the antenna array and signal processing described herein. Additionally, remote terminals could employ antenna arrays and signal processing to further improve their capacity and signal quality over simpler remote terminals that handle fewer communication links. Herein, the distinction between base stations and remote terminals is that base stations generally act as concentrators connecting

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to multiple remote units simultaneously, possibly providing a high capacity connection to a wide area network. While for the sake of clarity much of the ensuing discussion is couched in terms of simple remote terminals that do not employ antenna arrays, nothing herein should be interpreted as preventing such an application. Thus, while hereafter spatial signatures will be associated primarily with remote terminals, when antenna arrays are employed at remote terminals, base stations will have associated spatial signatures as well.

Briefly, there are two spatial signatures associated with each remote terminal/base station pair on a particular frequency channel, where for the purpose of this discussion it is assumed that only base stations have antenna arrays. Base stations associate with each remote terminal in their cell a spatial signature related to how that remote terminal receives signals transmitted to it by the base station's antenna array, and a second spatial signature related to how the base station's receive antenna array receives signals transmitted by the remote terminal. In a system with many conventional channels, each remote terminal/base station pair has transmit and receive spatial signatures for each conventional channel.

The receive spatial signature characterizes how the base station antenna array receives signals from the particular remote unit in a particular conventional channel. In one embodiment, it is a complex vector containing responses (amplitude and phase with respect to a reference) of each the antenna element receivers, *i.e.*, for an m-element array,

$$\mathbf{a}_{br} = [a_{br}(1), a_{br}(2), \ldots, a_{br}(m)]^T, \tag{1}$$

where $\mathbf{a}_{br}(i)$ is the response of the ith receiver to a unit power transmitted signal from the remote terminal. Assuming that a narrowband signal $s_r(t)$ is transmitted from the remote terminal, the base station receiver outputs at time t are then given by

$$\mathbf{z}_b(t) = \mathbf{a}_{br} s_r(t - \tau) + \mathbf{n}_b(t), \tag{2}$$

where τ accounts for the mean propagation delay between the remote terminal and the base station antenna array, and $\mathbf{n}_b(t)$ represents noise present in the environment and the receivers.

The transmit spatial signature characterizes how the remote terminal receives signals from each of the antenna array elements at the base station in a particular conventional channel. In one embodiment, it is a complex vector containing relative amounts (amplitude and phase with respect to a reference) of each the antenna element transmitter outputs that are contained in the remote terminal receiver output, *i.e.*, for an m-element array,

$$\mathbf{a}_{rb} = [a_{rb}(1), a_{rb}(2), \ldots, a_{rb}(m)], \tag{3}$$

where $\mathbf{a}_{rb}(i)$ is the amplitude and phase (with respect to some fixed reference) of the remote terminal receiver output for a unit power signal transmitted from the ith element in the base station array. Assuming that a vector of complex signals $\mathbf{s}_b = [s_b(1), \ldots, s_b(m)]^T$ were transmitted from the antenna array, the output of the remote terminal receiver would be given by

$$z_r(t) = \mathbf{a}_{rb} \mathbf{s}_b(t - \tau) + n_r(t), \tag{4}$$

where $n_r(t)$ represents noise present in the environment and the receiver. These spatial signatures are calculated (estimated) and stored at each base station for each remote terminal in its cell and for each conventional channel. For fixed remote terminals and base stations in stationary environments, the spatial

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signatures can be updated infrequently. In general, however, changes in the RF propagation environment between the base station and the remote terminal can alter the signatures and require that they be updated. Note that henceforth, the time argument in parentheses will be suppressed; integers inside parentheses will be used solely for indexing into vectors and matrices.

In the previous discussion, temporally matched receivers and transmitters were assumed. If there are differences in the temporal responses, these can be equalized using temporal filtering techniques as is well-known. Furthermore, the channel bandwidths were assumed to be small compared to the center frequency of operation. Large bandwidth channels may require more than one complex vector to accurately describe the outputs as is well known.

When more than one remote terminal wants to communicate at the same time, the signal processing means at the base station uses the spatial signatures of the remote terminals to determine if subsets of them can communicate with the base station simultaneously by sharing a conventional channel. In a system with m receive and m transmit antenna elements, up to m remote terminals can share the same conventional channel at the same time.

When multiple remote terminals are sharing a single conventional uplink channel, the multiple antenna elements at the base station each measure a combination of the arriving uplink signals and noise. These combinations result from the relative locations of the antenna elements, the locations of the remote terminals, and the RF propagation environment. The signal processing means calculates spatial demultiplexing weights to allow the uplink signals to be separated from the combinations of uplink signals measured by the multiple antenna elements.

In applications where different downlink signals are to be sent from the base station to the remote terminals, the signal processing means computes spatial multiplexing weights that are used to produce multiplexed downlink signals, which when transmitted from the antenna elements at the base station result in the correct downlink signal being received at each remote terminal with appropriate signal quality.

In applications where the same signal is to be transmitted from the base station to a large number (more than the number of antenna elements) of remote terminals, the signal processing means computes weights appropriate for broadcasting the signal, covering the area necessary to reach all the remote terminals.

Therefore, the signal processing means facilitates simultaneous communication between a base station and multiple remote terminals on the same conventional channel. The conventional channel may be a frequency channel, a time slot in a time division multiplexed system, a code in a code division multiplexed system, or any combination of the above.

In one embodiment, all elements of a single antenna array transmit and receive radio frequency signals, while in another embodiment the antenna array includes separate transmit antenna elements and receive antenna elements. The number of transmit and receive elements need not be the same. If they are not the same, the maximum number of point-to-point links that can simultaneously be established in one conventional channel is given by the smaller of the two numbers.

The invention and objects and features thereof will be more readily apparent from the following detailed description together with the figures and appended claims.

Brief Description of The Drawings

Figure 1 is a functional block diagram of a base station in accordance with the invention.

Figure 2 is a functional block diagram of multichannel receivers in the base station.

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Figure 3 is a functional block diagram of a spatial demultiplexer in the base station.

Figure 5 is a functional block diagram of a multichannel transmitter in the base station.

Figure 6 is a functional block diagram of a spatial processor in the base station.

Figure 7 is a functional block diagram of a remote terminal with a transponder switch.

Figure 8 is a functional block diagram of a remote terminal.

Figure 9 is a schematic diagram of a network system comprised of three base stations and a multiple base station controller.

List of Reference Numerals

1. base station
2. base station communication link
3. base station controller
4. demodulated received signal
5. spatially separated uplink signals
6. received signal measurements
7. demultiplexing weights
8. data to be transmitted directionally
9. modulated signal to be multiplexed for transmission
10. modulated, spatially multiplexed signals to be transmitted
11. calibration signals to be transmitted
12. multiplexing weights
13. spatial processor
14. multichannel transmitters
15. multichannel receivers

16a. multichannel receiver
16m. multichannel receiver
17a. multichannel transmitter
17m. multichannel transmitter
18a. transmit antenna
18m. transmit antenna
19a. receive antenna
19m. receive antenna

20. spatial demultiplexer
21. adder

22a. multipliers
22m. multipliers

23. spatial multiplexer
24. signal modulator
25. signal demodulator

26a. multipliers
26m. multipliers

27. spatial control data
28. spatial parameter data
29. common receiver oscillator
30. receiver control data
31. transmitter control data
32. common transmitter oscillator

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33. spatial processor controller
34. active remote terminal list
35. channel selector
36. remote terminal database
37. spatial weight processor
38. spatial signature processor
39. remote terminal antenna
40. remote terminal duplexer
41. remote terminal duplexer output
42. remote terminal receiver
43. remote terminal received signal
44. remote terminal received calibration signal
45. remote terminal demodulator
46. remote terminal demodulated data
47. remote terminal keyboard and keyboard controller
48. remote terminal keyboard data
49. remote terminal display data
50. remote terminal display and display controller
51. remote terminal modulator
52. remote terminal data to be transmitted
53. remote terminal modulated data to be transmitted
54. remote terminal transmitter
55. remote terminal transmitter output
56. remote terminal transmitter control data
57. remote terminal receiver control data
58. remote terminal microphone
59. remote terminal microphone signal
60. remote terminal speaker
61. remote terminal speaker signal
62. remote terminal central processing unit
63. remote terminal transponder switch
64. remote terminal transponder switch control
65. wide area network
66. multiple base station controller
67a. cell boundary
67b. cell boundary
67c. cell boundary
68. high speed message link
69. remote terminal

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Description of Invention

Figure 1 depicts the preferred embodiment of a base station 1. A base station controller 3 acts as an interface between base station 1 and any external connection via a base station communication link 2, and serves to coordinate the overall operation of base station 1. In the preferred embodiment, base station controller 3 is implemented with a conventional central processing unit and associated memory and programming.

Incoming or uplink radio transmissions impinge on an antenna array composed of a number, m, of receive antenna elements 19(a,...,m) each of whose outputs is connected to one of m multichannel receivers in a bank of phase-coherent multichannel receivers 15. Multichannel receivers 15 have well-matched amplitude and phase responses across the frequency bands of interest, or, as is well known, correction filters are implemented to account for any differences.

The illustrative embodiment describes a conventional frequency division multiple access system. Each multichannel receiver is capable of handling multiple frequency channels. The symbol N_{cc} will be used to reference the maximum number of conventional frequency channels that can be handled by the receivers. Depending on the frequencies allocated for the operation of the wireless communication system and the bandwidths chosen for particular communication links, N_{cc} could be as small as one (a single frequency channel) or as large as thousands. In alternate embodiments, multichannel receivers 15 might instead handle multiple time slots, multiple codes, or some combination of these well known multiple access techniques.

In each conventional channel, receive antenna elements 19(a,...,m) each measure a combination of the arriving uplink signals from the remote terminals sharing this conventional channel. These combinations result from the relative locations of the antenna elements, the locations of the remote terminals, and the RF propagation environment, and for narrowband signals are given by equation (2).

Figure 2 depicts individual multichannel receivers 16(a, ...,m) with antenna element connections, common local receiver oscillators 29, one for each conventional frequency channel to be used at that base station, and received signal measurements 6. Common local receiver oscillators 29 ensure that the signals from receive antenna elements 19(a,...,m) are coherently down-converted to baseband; its N_{cc} frequencies are set so that multichannel receivers 16(a,...,m) extract all N_{cc} frequency channels of interest. The frequencies of common local receiver oscillators 29 are controlled by a spatial processor 13 (figure 1) via receiver control data 30. In an alternate embodiment, where multiple frequency channels are all contained in a contiguous frequency band, a common local oscillator is used to downconvert the entire band which is then digitized, and digital filters and decimators extract the desired subset of channels using well known techniques.

The illustrative embodiment describes a frequency division multiple access system. In a time division multiple access or code division multiple access system, common oscillators 29 would be augmented to relay common time slot or common code signals respectively from spatial processor 13, via receiver control data 30, to multichannel receivers 16(a,...,m). In these embodiments, multichannel receivers 16(a,...,m) perform selection of conventional time division channels or conventional code division channels in addition to down conversion to baseband.

Referring again to Figure 1, multichannel receivers 15 produce received signal measurements 6 which are supplied to spatial processor 13 and to a set of spatial demultiplexers 20. In this embodiment, received signal measurements 6 contain m complex baseband signals for each of N_{cc} frequency channels.

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Figure 6 shows a more detailed block diagram of spatial processor 13. Spatial processor 13 produces and maintains spatial signatures for each remote terminal for each conventional frequency channel, and calculates spatial multiplexing and demultiplexing weights for use by spatial demultiplexers 20 and spatial multiplexers 23. In the preferred embodiment, spatial processor 13 is implemented using a conventional central processing unit. Received signal measurements 6 go into a spatial signature processor 38 which estimates and updates spatial signatures. Spatial signatures are stored in a spatial signature list in a remote terminal database 36 and are used by channel selector 35 and spatial weight processor 37, which also produces demultiplexing weights 7 and multiplexing weights 12. A spatial processor controller 33 connects to spatial weight processor 37 and also produces receiver control data 30 transmitter control data 31 and spatial control data 27.

Referring again to Figure 1, spatial demultiplexers 20 combine received signal measurements 6 according to spatial demultiplexing weights 7. Figure 3 shows a spatial demultiplexer 20 for a single conventional channel. In this embodiment, arithmetic operations in spatial demultiplexer 20 are carried out using general purpose arithmetic chips. In figure 3, $z_b(i)$ denotes the ith component of received signal measurement vector 6 for a single conventional channel, and $\mathbf{w}_{rx}^*(i)$ denotes the complex conjugate of the ith component of the spatial demultiplexing weight vector 7 for a remote terminal using this conventional channel.

For each remote terminal on each conventional channel, the spatial demultiplexer 20 computes the inner-product of the spatial demultiplexing weights 7 for the conventional channel with the received signal measurements 6:

$$\mathbf{w}_{rx}^* z_b = \mathbf{w}_{rx}^*(1)z_b(1) + \ \ldots \ + \mathbf{w}_{rx}^*(m)z_b(m), \tag{5}$$

where $(\cdot)^*$ indicates complex conjugation, numbers inside parentheses indicate element number (*e.g.*, $\mathbf{w}_{rx}(i)$ is the ith component of the vector $\mathbf{w}_{rx}$), the multiplication is performed by multipliers 22(a, ...m), and the addition is performed by adder 21. For each remote terminal on each conventional channel, the output of adder 21 given by equation (5) comprises the spatially separated uplink signals 5.

Referring again to Figure 1, the outputs of spatial demultiplexers 20 are spatially separated uplink signals 5 for each remote terminal communicating with the base station. Spatially separated uplink signals 5 are demodulated by signal demodulators 25, producing demodulated received signals 4 for each remote terminal communicating with the base station. Demodulated received signals 4 and corresponding spatial control data 27 are available to base station controller 3.

In embodiments where channel coding of the signals sent by remote terminals is performed, base station controller 3 sends the demodulated received signals 4 to spatial processor 13 which, using well known decoding techniques, estimates Bit-Error-Rates (BERs) and compares them against acceptable thresholds stored in the remote terminal database 36. If the BERs are unacceptable, spatial processor 13 reallocates resources so as to alleviate the problem. In one embodiment, links with unacceptable BERs are assigned to new channels using the same strategy as adding a new user with the exception that the current channel is not acceptable unless the current set of users of that particular channel changes. Additionally, recalibration of the receive signature for that remote terminal/base station pair is performed when that conventional channel is available.

For transmission, signal modulators 24 produce modulated signals 9 for each remote terminal the base station is transmitting to, and a set of spatial multiplexing weights 12 for each remote terminal are applied

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to the respective modulated signals in spatial multiplexers 23 to produce spatially multiplexed signals to be transmitted 10 for each of the m transmit antennas 18(a,...,m) and each of the N_{cc} conventional channels.

In the illustrative embodiment the number N_{cc} of downlink conventional channels is the same as the number N_{cc} of uplink conventional channels. In other embodiments, there may be different numbers of uplink and downlink conventional channels. Furthermore, the channels may be of different types and bandwidths as is the case for an interactive television application where the downlink is comprised of wideband video channels and the uplink employs narrowband audio/data channels.

Additionally, the illustrative embodiment shows the same number of antenna elements, m, for transmit and receive. In other embodiments, the number of transmit antenna elements and the number of receive antenna elements may be different, up to and including the case where transmit employs only one transmit antenna element in an omnidirectional sense such as in an interactive television application.

Figure 4 shows the spatial multiplexer for one remote terminal on a particular conventional channel. Arithmetic operations in spatial multiplexer 23 are carried out using general purpose arithmetic chips. The component of modulated signals 9 destined for this remote terminal on this conventional channel is denoted by s_b, and $\mathbf{w}_{tx}(i)$ denotes the ith component of spatial multiplexing weight vector 12 for this remote terminal on this conventional channel.

For each remote terminal on each conventional channel, the spatial multiplexer 23 computes the product of its spatial multiplexing weight vector (from the spatial multiplexing weights 12) with its modulated signal s_b (from the modulated signals 9):

$$\mathbf{w}_{tx}^{*} s_b = \begin{bmatrix} \mathbf{w}_{tx}^{*}(1) s_b \\ \vdots \\ \mathbf{w}_{tx}^{*}(m) s_b \end{bmatrix}, \tag{6}$$

where $(\cdot)^{*}$ indicates complex conjugate (transpose) and the multiplication is performed by multipliers 26(a, ...m). For each conventional channel, equation (6) is evaluated by the spatial multiplexer 23 for each remote terminal that is being transmitted to on this conventional channel. Corresponding to each remote terminal is a different multiplexing weight vector and modulated signal. For each conventional channel, spatial multiplexer 23 adds the spatially multiplexed signals for each remote terminal being transmitted to on this conventional channel, producing modulated and spatially multiplexed signals 10 that are the signals to be transmitted for each conventional downlink channel from each antenna.

Modulated and spatially multiplexed signals 10 are inputs to a bank of m phase coherent multichannel transmitters 14. Multichannel transmitters 14 either have well-matched amplitude and phase responses across the frequency bands of interest, or, as is well known, correction filters are implemented to account for any differences. Figure 5 depicts multichannel transmitters 17(a, ...m) with antenna connections, common local transmitter oscillators 32, and digital inputs 10. Common local transmitter oscillators 32 ensure that the relative phases of spatially multiplexed signals 10 are preserved during transmission by transmit antennas 18(a, ...m). The frequencies of common local transmitter oscillators 32 are controlled by spatial processor 13 (see figure 1) via transmitter control data 31.

In an alternate embodiment, spatial multiplexer 23 uses well known baseband multiplexing techniques to multiplex all the calculated conventional channel signals to be transmitted into a single wideband signal to be upconverted and transmitted by each of the multichannel transmitters 17(a, ...m). The multiplexing can be performed either digitally or in analog as appropriate.

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The illustrative embodiment shows a system with multiple frequency channels. In a time division multiple access or code division multiple access system, common oscillators 32 would be augmented to relay common time slot or common code signals respectively from spatial processor 13, via transmitter control data 31, to multichannel transmitters 17(a, . . . ,m).

Referring again to figure 1, in applications where transmit spatial signatures are required, spatial processor 13 is also able to transmit predetermined calibration signals 11 for each antenna on a particular conventional downlink channel. Spatial processor 13 instructs multichannel transmitters 17(a, ...m), via transmitter control data 31, to transmit predetermined calibration signals 11 in place of spatially multiplexed signals 10 for a particular conventional downlink channel. This is one mechanism used for determining the transmit spatial signatures of the remote terminals on this conventional downlink channel.

In alternate embodiments where well known channel coding techniques are used to encode the signals to be transmitted to remote terminals, remote terminals employ well known decoding techniques to estimate BERs which are then reported back to the base station on their uplink channel. If these BERs exceed acceptable limits, corrective action is taken. In one embodiment, the corrective active involves reallocating resources by using the same strategy as adding a new user with the exception that the current channel is not acceptable unless the current set of users of that particular channel changes. Additionally, recalibration of the transmit signature for that remote terminal/base station pair is performed when that conventional channel is available.

Figure 7 depicts the component arrangement in a remote terminal that provides voice communication. The remote terminal's antenna 39 is connected to a duplexer 40 to permit antenna 39 to be used for both transmission and reception. In an alternate embodiment, separate receive and transmit antennas are used eliminating the need for duplexer 40. In another alternate embodiment where reception and transmission occur on the same frequency channel but at different times, a transmit/receive (TR) switch is used instead of a duplexer as is well known. Duplexer output 41 serves as input to a receiver 42. Receiver 42 produces a down-converted signal 43 which is the input to a demodulator 45. A demodulated received voice signal 61 is input to a speaker 60.

Demodulated received control data 46 is supplied to a remote terminal central processing unit 62 (CPU). Demodulated received control data 46 is used for receiving data from base station 1 during call setup and termination, and in an alternate embodiment, for determining the quality (BER) of the signals being received by the remote terminal for transmission back to the base station as described above.

Remote terminal CPU 62 is implemented with a standard microprocessor. Remote terminal CPU 62 also produces receiver control data 57 for selecting the remote terminal's reception channel, transmitter control data 56 for setting the remote terminal's transmission channel and power level, control data to be transmitted 52, and display data 49 for remote terminal display 50. Remote terminal CPU 62 also receives keyboard data 48 from remote terminal keyboard 47.

The remote terminal's voice signal to be transmitted 59 from microphone 58 is input to a modulator 51. Control data to be transmitted 52 is supplied by remote terminal CPU 62. Control data to be transmitted 52 is used for transmitting data to base station 1 during call setup and termination as well as for transmitting information during the call such as measures of call quality (*e.g.*, bit error rates (BERs)). The modulated signal to be transmitted 53, output by modulator 51, is up-converted and amplified by a transmitter 54, producing a transmitter output signal 55. Transmitter output 55 is then input to duplexer 40 for transmission by antenna 39.

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In an alternate embodiment, the remote terminal provides digital data communication. Demodulated received voice signal 61, speaker 60, microphone 58, and voice signal to be transmitted 59 are replaced by digital interfaces well-known in the art that allow data to be transmitted to and from an external data processing device (for example, a computer).

Referring again to figure 7, the remote terminal allows received data 43 to be transmitted back to base station 1 via switch 63 controlled by remote terminal CPU 62 through switch control signal 64. In normal operation, switch 63 drives transmitter 54 with modulated signal 53 of modulator 51. When the remote terminal is instructed by base station 1 to enter calibration mode, remote terminal CPU 62 toggles switch control signal 64, which instructs switch 63 to drive transmitter 54 with received data 43.

Figure 8 shows an alternate embodiment of the remote terminal calibration function. Switch 63 of figure 7 is no longer used. Instead, the output of receiver 42 is supplied to remote terminal CPU 62 by data connection 44. In normal operation remote terminal CPU 62 ignores data connection 44. In calibration mode, remote terminal CPU 62 uses data connection 44 to compute the remote terminal's transmit spatial signature, which is transmitted back to base station 1 through modulator 51 and transmitter 54 as control data to be transmitted 52.

In an alternate embodiment, special calibration procedures in the remote terminal are not required. In many conventional wireless protocol standards, remote terminals regularly report received signal strength or receive signal quality back the base station. In this embodiment, the received signal strength reports are sufficient to compute the remote terminal's transmit spatial signature, as described below.

Operation of Invention

General Principles — Base Station

In many respects, the spectrally efficient base station shown in figure 1 behaves much like a standard wireless communication system base station. The primary distinction is that the spectrally efficient base station supports many more simultaneous conversations than it has conventional communication channels. The conventional communication channels may be frequency channels, time channels, code channels, or any combination of these. The spatial multiplexer/demultiplexer increases the system capacity by allowing multiple spatial channels on each of these conventional channels. Moreover, by combining signals from multiple receive antennas, the spatial demultiplexer 20 produces spatially separated uplink signals 5 that have substantially improved signal-to-noise, reduced interference, and improved quality in multipath environments compared to a standard base station.

In the illustrative embodiment, a wireless communication system comprised of multiple remote terminals and base stations incorporating antenna arrays and spatial signal processing is described. Such systems have application, for example, in providing wireless access to the local PSTN. Information transfers (or calls) are initiated by either a remote terminal or by communication link 2 through base station controller 3. Call initialization takes place on a downlink and uplink control channel as is well known in the art. In the present embodiment, the downlink control channel is transmitted using transmission antennas 18(a,....m). In an alternate embodiment, the downlink control channel is broadcast from a single, omnidirectional antenna. Base station controller 3 passes the identification of the remote terminal to be involved in the call to spatial processor 13 which uses the stored spatial signatures of that remote terminal to determine which conventional communication channel the remote terminal should use. The selected channel may already be occupied by several remote terminals, however spatial processor 13 uses the spatial signatures of all of

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the remote terminals on that channel to determine that they can share the channel without interference. In a system with m receive and m transmit antenna elements, up to m remote terminals can share the same conventional channel. More generally, the number of point-to-point full-duplex communication links that can occupy the same conventional channel at the same time is given by the smaller of the number of receive and transmit elements.

Spatial processor 13 uses calculated spatial multiplexing and demultiplexing weights for the selected channel and the remote terminal in question to configure spatial multiplexer 23 and spatial demultiplexer 20. Spatial processor 13 then informs controller 3 of the selected channel. As in a conventional base station, controller 3 then commands the remote terminal (via the downlink control channel) to switch to the selected channel for continued communications. In the event that the remote terminal has power control capabilities, as is well known in the art, controller 3 also commands the remote terminal to adjust its power to an appropriate level based on parameters such as the power levels of the other remote terminals sharing the same conventional channel and the required signal quality for each link as discussed below. At the termination of communications, the remote terminal returns to its idle state where it monitors the downlink control channel awaiting its next call. This frees up that "spatial channel" for another remote terminal.

Spatial Processing — Base Station

Figure 6 shows a block diagram of spatial processor 13. It is controlled by spatial processor controller 33, which interfaces to base station controller 3 via link 27. Spatial processor controller 33 controls the gain and frequency settings of multichannel transmitters 14 and multichannel receivers 15 by control lines 31 and 30.

Spatial processor 13 maintains an active remote terminal list 34 that catalogs which remote terminals are currently using each conventional communication channel as well as their current transmit power levels. Other parameters of the remote terminals such as modulation formats currently used, receiver noise levels in current frequency channels, and current signal quality requirements are stored as well. Spatial processor 13 also maintains a spatial signature list in the remote terminal database 36, which in alternate embodiments includes remote terminals' power control levels, allowed conventional frequency channels for receive and transmit, and list of modulation formats understood.

The spatial signature list in the remote terminal database 36 contains a transmit spatial signature, $\mathbf{a}_{rb}$, and a receive spatial signature, $\mathbf{a}_{br}$, for every frequency of operation for each remote terminal. In another embodiment, estimates of the quality (*e.g.*, estimate error covariances) of the spatial signatures are stored as well. As aforementioned, the transmit spatial signature, $\mathbf{a}_{rb}$, for a particular remote terminal and a particular frequency channel is defined as the vector of relative complex signal amplitudes that would be seen arriving at that particular remote terminal as a result of identical (equal amplitude and phase) unit power narrow band signals, at that particular frequency, being transmitted through multichannel transmitters 14 and transmission antennas 18(a, ...m). The transmit spatial signature includes the effects of the propagation environment between the base station and the remote terminal, as well as any amplitude and phase differences in multichannel transmitters 14, antenna cables, and transmission antennas 18(a, ...m). The receive spatial signature, $\mathbf{a}_{br}$, for a particular remote terminal and a particular frequency channel, is defined as the vector of complex signal amplitudes that would be measured at the outputs of

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multichannel receiver 16 given a single unit power narrow band signal being transmitted by that particular remote terminal, at that particular frequency.

When the base station controller 1 forwards a call initialization request for a particular remote terminal via link 27, a channel selector 35 searches active remote terminal list 34 to find a conventional communication channel that can accommodate the remote terminal. In the preferred embodiment, there is a receive active remote terminal list and a transmit active remote terminal list which are used by channel selector 35 in forming both a multiplexing and a demultiplexing spatial signature matrix for each conventional channel. For each conventional channel, the columns of the demultiplexing and rows of the multiplexing spatial signature matrices are the stored receive and transmit spatial signatures of each of the remote terminals currently active on (using) that channel plus one more column containing the appropriate spatial signature of the remote terminal requesting a communication channel.

The multiplexing spatial signature matrix for each channel, $A_{rb,p}$ (where p denotes the conventional channel number), is formed using transmit spatial signatures as shown in equation (7):

$$A_{rb,p} = \begin{bmatrix} \mathbf{a}_{rb,p}^{1} \\ \vdots \\ \mathbf{a}_{rb,p}^{n_p} \end{bmatrix}, \tag{7}$$

where $\mathbf{a}_{rb,p}^{i}$ is the transmit spatial signature for i^{th} remote terminal assigned to channel p and n_p is the total number of remotes on conventional channel p.

The demultiplexing spatial signature matrix, $A_{br,p}$, is formed using receive spatial signatures as shown in equation (8):

$$A_{br,p} = [\mathbf{a}_{br,p}^{1}, \mathbf{a}_{br,p}^{2}, \cdots, \mathbf{a}_{br,p}^{n_p}], \tag{8}$$

where $\mathbf{a}_{br,p}^{i}$ is the receive spatial signature for i^{th} remote terminal assigned to channel p.

Channel selector 35 calculates functions of these signature matrices to assess whether or not communication between the base station and the new remote terminal can be successfully carried out on the selected conventional channel. In the preferred embodiment, channel selector 35 first calculates spatial multiplexing and demultiplexing weights for that remote terminal and then uses these weights to estimate link performance.

In the illustrative embodiment, spatial multiplexing weights are the rows of a matrix W_{tx} given in equation (9):

$$W_{tx} = S_b(A_{rb}A_{rb}^{*})^{-1}A_{rb}, \tag{9}$$

where $(\cdot)^{-1}$ is the inverse of a matrix, $(\cdot)^{*}$ is the complex conjugate transpose of a matrix, A_{rb} is the multiplexing spatial signature matrix $A_{rb,p}$ associated with the relevant conventional channel, and S_b is a (diagonal) matrix containing the amplitudes of the signals to be transmitted. The amplitudes to be transmitted, S_b, are calculated in the preferred embodiment using the (diagonal) matrix of remote terminal receiver mean-square noise voltages (N) and the diagonal matrix of minimum desired signal qualities (SNR_{des}) as given in equation (10):

$$S_b = (SNR_{des} \times N)^{1/2} \tag{10}$$

Now channel selector 35 calculates the average mean-square voltage (power) $\overline{P_b}$ to be transmitted from each element as the sum of squares of the elements in each row of W_{tx}, i.e.,

$$\overline{P_b} = \mathrm{diag}\{W_{tx}W_{tx}^{*}\}. \tag{11}$$

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and the peak square voltage (power) P_b^{peak} to be transmitted from each element as the square of sum of the magnitude of the elements in each row of W_{tx}, *i.e.*,

$$P_b^{peak} = \text{diag}\{abs(W_{tx})\,\mathbf{I}\,abs(W_{tx}^*)\}, \tag{12}$$

where $\mathbf{I}$ is a matrix of all ones of the appropriate size and $abs(\cdot)$ is elementwise absolute value. Channel selector 35 compares these values against the limits for each of the transmitters for each of the elements. If any of the average or peak values exceed the acceptable limits, the remote terminal in question is not assigned to the candidate channel. Otherwise, the ability to successfully receive from the remote terminal is checked. In an alternate embodiment, the transmitter limits are used as inequality constraints in an optimization algorithm for calculating transmit weights that meet the specifications given and that also result in the minimum amount of transmitted power possible. If transmit weights satisfying the constraints can not be found, the remote terminal in question is not assigned to the candidate channel. Such optimization algorithms are well known.

To test the uplink, channel selector 35 calculates spatial demultiplexing weights W_{rx} using A_{br}, the demultiplexing spatial signature matrix A_{br}, associated with the relevant conventional channel, as given for the preferred embodiment in equation (13):

$$W_{rx} = (A_{br}P_rA_{br}^* + R_{nn})^{-1}A_{br}P_r, \tag{13}$$

where P_r is a (diagonal) matrix of mean-square amplitudes (powers) transmitted by the remote terminals and R_{nn} is the base station receiver noise covariance. Then, the expected value of the normalized mean-squared error covariance is calculated in one embodiment as follows:

$$\overline{MSE} = P_r^{-1/2}((I - W_{rx}^*A_{br})P_r(I - W_{rx}^*A_{br})^* + W_{rx}^*R_{nn}W_{rx})P_r^{-*/2} \tag{14}$$

The notation $(\cdot)^{-*/2}$ indicates complex conjugate transpose of the square root of the matrix. The inverse of MSE is an estimate of the expected Signal-to-Interference-plus-Noise Ratio ($SINR$) at the output of the spatial demultiplexer:

$$\overline{SINR} = \overline{MSE}^{-1}. \tag{15}$$

If all of the diagonal elements of $\overline{SINR}$ are above the desired thresholds based on the signal quality required to be received from each remote terminal, the remote terminal is allowed access to the channel. If the candidate remote terminal is below its threshold and has the ability to increase its output power, the same computations are again performed for increasing remote terminal power output until either the maximum output power for that remote terminal is reached and the $\overline{SINR}$ is still insufficient, another remote terminal $\overline{SINR}$ falls below its threshold in which case its power is increased if possible, or all thresholds are exceeded. If acceptable remote terminal transmit powers can be found, the remote terminal is granted access to this particular conventional channel, otherwise it is denied access and another conventional channel is checked.

In an alternate embodiment, the calculation of demultiplexing weights is performed using well known optimization procedures with the objective of minimizing remote terminal transmit powers subject to estimated signals at the base station meeting or exceeding their minimum desired $SINR$'s.

Also, in an alternate embodiment, in the case that no conventional channel can be found to accommodate the remote terminal, channel selector 35 calculates whether some rearrangement of the existing remote terminals among the conventional channels would allow the remote terminal to be supported on

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some conventional channel. In this case, the remote terminal will only be denied communication at this time if no rearrangement of existing users allows the remote terminal to be accommodated.

In an alternate embodiment employing frequency division duplexing (FDD), remote terminals are not restricted to being assigned a fixed conventional channel pair for transmit and receive. A sufficiently flexible system architecture is employed where channel selector 35 may choose to assign a particular remote to transmit and receive conventional channels separated by different frequency duplex offsets in order to minimize overall system interference levels.

Spatial multiplexing and demultiplexing weights for remote terminals already using a conventional channel must be recalculated because adding a new remote terminal to that conventional channel may change them significantly. In the preferred embodiment, channel selector 35, having already done the necessary calculations, sends the new spatial multiplexing and demultiplexing weights to the spatial weight processor 37 for use in setting up the spatial multiplexer 23 and demultiplexer 20. In an alternate embodiment, spatial weight processor 37 uses the spatial signature matrices sent to it by channel selector 35 to calculate different sets of spatial multiplexing and demultiplexing weights for all of the remote terminals on that conventional channel.

Spatial weight processor 37 then sends the new spatial demultiplexing weights to spatial demultiplexers 20 and the new spatial multiplexing weights to the spatial multiplexers 23 for this conventional channel, updates the active remote terminal list 34, and informs spatial processor controller 33 which in turn informs base station controller 3 of the selected channel. Base station controller 3 then transmits a message to the remote terminal using the downlink control channel that instructs the remote terminal to switch to the desired conventional channel.

It can be shown from equation (9) that the multiplexing weight matrices W_{tx} have the property:

$$A_{rb} W_{tx}^{*} = S_b. \tag{16}$$

This means that at the ith remote terminal, the signal intended to be sent to that terminal is received with a sufficient (positive real) amplitude $S_b(i,i)$. The fact that S_b has zero off-diagonal elements means that at the ith remote terminal, none of the other signals being transmitted are received by that remote terminal. In this manner, each remote terminal receives only the signals intended for it at the necessary power levels to ensure proper communications. In alternate embodiments, uncertainties in the estimates of A_{rb} are incorporated in setting base station transmit power levels and calculating weights so as to minimize the effect of errors and/or changes in A_{rb}.

Similarly, at the base station the particular demultiplexing weight matrices given in (13) have the property that conditioned on the knowledge of the receive spatial signatures and the transmitted voltages (powers) from the remote terminals, the estimated signals $\hat{S}$ given by:

$$\hat{S} = W_{rx}^{*} z_b, \tag{17}$$

are the most accurate in the sense of least mean-squared error. In particular, they most closely match the signals transmitted by the remote terminals given the measurements made at the base station by the multiple antenna elements.

Equations (9) and (13) represent only one way to calculate spatial multiplexing and demultiplexing weights. There are other similar strategies that demonstrate properties similar to those shown in equation (16) and described in the previous paragraph. Other well known techniques for calculating weight matrices

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W_{tx} and W_{rx} account for uncertainty in spatial signature matrices A_{rb} and A_{br}, for wide bandwidth conventional channels, and can incorporate more complex power and dynamic range constraints.

Determining Spatial Signatures

As shown in figure 6, spatial processor 13 also contains a spatial signature processor 38 for finding the spatial signatures of the remote terminals. In the illustrative embodiment, spatial signature processor 38 uses the calibration techniques described in copending U.S. patent application 08/234,747.

In the illustrative embodiment, each remote terminal is capable of entering a calibration mode in which the signal received by the remote terminal 43 is transmitted back to base station 1. Referring to figure 7, this function is provided by switch 63 controlled by remote terminal CPU 62 through switch control signal 64.

To determine the transmit and receive spatial signatures of a remote terminal, spatial signature processor 38 commands the remote terminal to enter calibration mode by transmitting a command to it on the downlink channel. This command is generated by base station controller 3, based on a request from spatial processor controller 33, and modulated by signal modulators 24. Spatial signature processor 38 then transmits predetermined calibration signals 11, on the conventional channel occupied by the remote terminal, by instructing multichannel transmitters 17(a, . . . ,m) via transmitter control data 31 and spatial processor controller 33. In the present embodiment, the m signals (for each antenna) among the predetermined calibration signals 11 are different frequency complex sinusoids. In another embodiment, the predetermined calibration signals 11 are any known, distinct, signals.

The remote terminal shown in figure 7 transmits back the signal received at the remote terminal. This transponded signal is received by multichannel receivers 15 in base station 1 shown in figure 1 and supplied to spatial signature processor 38 shown in figure 6. In one embodiment described in patent application 08/234,747, spatial signature processor 38 computes the receive and transmit spatial signatures of the remote terminal from the received signal measurements 6 and predetermined calibration signals 11 as follows. Time samples of the received data are stored in an m by n data matrix $\mathbf{Z}$ which in the absence of noise and parameter offsets is given by

$$\mathbf{Z} = k\mathbf{a}_{br}\mathbf{a}_{rb}\mathbf{S}, \tag{18}$$

where $\mathbf{S}$ is the m by n matrix of predetermined calibration signals and k is a known amount by which the signal is amplified in the remote terminal before transmission back to the base station. The receive spatial signature is proportional to the singular vector ($\mathbf{u}_1$) corresponding to the largest singular value (σ_{max} of the data matrix $\mathbf{Z}$. Transmission of a unit power signal from the remote terminal and received by the base station at antenna element 1 provides the necessary scaling g_{br} for the receive spatial signature

$$\mathbf{a}_{br} = g_{br}\mathbf{u}_1/\mathbf{u}_1(1), \tag{19}$$

where $\mathbf{u}_1(1)$ is the first element of $\mathbf{u}_1$. Once $\mathbf{a}_{br}$ is known, $\mathbf{a}_{rb}$ is calculated by

$$\mathbf{a}_{rb} = k^{-1}(g_{br}\mathbf{u}_1/\mathbf{u}_1(1))^{\dagger}\mathbf{Z}\mathbf{S}^{\dagger}. \tag{20}$$

where $B^{\dagger}$ is the well known Moore-Penrose pseudo-inverse of the matrix B satisfying $BB^{\dagger} = I$ (the identity matrix) for full-rank matrices B having more columns than rows. $B^{\dagger}B = I$ for full-rank matrices B having more rows than columns. In alternate embodiments also described in copending application 08/234,747,

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well known techniques are used to account for noise present in the system and parameter variations such as oscillator frequency offsets.

Spatial signature processor 38 stores the new spatial signatures in remote terminal database 36. Upon completion, spatial signature processor 38 commands the remote terminal to exit calibration mode by transmitting a command to it on the downlink channel.

In one alternate embodiment, computation of remote terminal transmit spatial signatures can be performed directly by the remote terminals. This embodiment of the remote terminal is shown in figure 8. In calibration mode, spatial signature processor 38 transmits predetermined calibration signals 11, on the conventional channel to be calibrated by the remote terminals, as before. Remote terminal CPU 62 uses received calibration signals 44 and the known transmitted waveforms to compute the remote terminal's transmit spatial signature using the same techniques used by spatial signature processor 38 in the previous embodiment. The computed transmit spatial signature is transmitted back to base station 1 through modulator 51 and transmitter 54 as control data to be transmitted 52. When received by base station 1, spatial signature processor 38 stores the new transmit spatial signature in remote terminal database 36. Since each remote terminal performs the transmit spatial signature calculation independently, this arrangement allows multiple remote terminals to compute their own transmit spatial signature simultaneously on the same conventional channel. In this embodiment, remote terminal receive spatial signatures are computed by spatial signature processor 38 in the same manner as in the previous embodiment.

Using these techniques, spatial signature processor 38 can measure a remote terminal transmit and receive spatial signatures for a particular channel any time that channel is idle. The efficiency of these calibration techniques allow spatial signature processor 38 to update the spatial signatures of numerous remote terminals for a particular channel while occupying that channel for only a short time.

Many other techniques for obtaining spatial signatures of remote terminals are also available. In some RF environments, spatial signatures for remote terminals can be determined using well-known techniques that depend upon knowledge of the geometric arrangement of the m reception antennas 19(a.....m) and their individual directivity patterns (element gain and phase, with respect to a reference, as a function of angle-of-arrival), and the direction from the base station to the remote terminal. Furthermore, techniques such as ESPRIT (U.S. patents 4,750,147 and 4,965,732) can be used to estimate directions in applications where they are not known a priori.

Similarly, as is well known, knowledge of any predetermined modulation format parameters of the underlying signals being transmitted by the remote terminals (for example, knowledge of certain training or preamble sequences, or knowledge that the signals are constant modulus) can also be used to determine the receive spatial signatures for remote terminals. A further example is decision-directed feedback techniques, also well known in the art, where receive data is demodulated and then remodulated to produce an estimate of the original modulated signal. These techniques allow receive spatial signatures to be estimated even when multiple remote terminals are occupying a single conventional channel.

In some RF environments, transmit spatial signatures for remote terminals can be calculated explicitly, as is well known, using knowledge of the remote terminal locations and the locations and directivity patterns of the base station transmit antennas. This requires no special capability on the part of the remote terminal.

If the remote terminal has the ability to measure and report the strength of the signal it is receiving, the system can use this information to derive transmit spatial signatures, albeit in a less efficient manner than the embodiment shown in figure 7 where the remote terminal has full transponder capabilities, or the

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embodiment shown in figure 8 where the remote terminal directly computes its transmit spatial signature. The transmit spatial signature is determined based solely on received signal power reports from the remote terminal as follows. First, spatial signature processor 38 transmits identical unit power signals from two of the m antenna elements at a time. Spatial signature processor 38 then changes the amplitude and phase of one of the two signals until the remote terminal reports that it is receiving no signal. The set of complex weights for antenna elements 2 through m required to null a unit power signal from element 1 are changed in sign and inverted to produce the transmit spatial signature for the remote terminal.

In yet another embodiment, the system can be designed to continuously update the spatial signatures of the remote terminals in a "closed loop" manner. This is done to account for the time variation of spatial signatures due to, for example, motion of the remote terminal or changes in the RF propagation conditions. To do this, both the base station and the remote terminal periodically transmit predetermined training sequences. Each remote terminal currently active on a particular channel is assigned a different predetermined training sequence and is given the training sequences for all other remotes currently active on that particular channel. In one embodiment, the different training sequences are orthogonal in the sense that the inner product of any two of the training sequence waveforms is zero. Each time the training sequences are transmitted, each remote terminal calculates how much of each training sequence it has received using well known techniques, and transmits this information to the base station.

In the illustrative embodiment, the base station uses the receiver outputs and knowledge of the transmitted waveforms to calculate the remote terminal receive spatial signatures. In another embodiment, the base station calculates how much of each remotely transmitted training sequence has come through on each output of the spatial demultiplexer, expressed as a complex vector of coupling coefficients. Knowledge of these coupling coefficients allows the currently active receive and transmit spatial signatures to be corrected so as to reduce mutual interference using well know techniques.

Finally, in systems that use time division duplexing (TDD) for full-duplex communications, as is well known in the art, the transmit and receive frequencies are the same. In this case, using the well known principle of reciprocity, the transmit and receive spatial signatures are directly related. Thus, this embodiment determines only one of the signatures, for example the receive spatial signature, and the other, in this case the transmit spatial signature, is calculated from the first (receive) spatial signature and knowledge of the relative phase and amplitude characteristics of multichannel receivers 15 and multichannel transmitters 14.

Network Level Spatial Processing

In the embodiment illustrated herein, the spatial processor for each base station in the cellular-like wireless communication system operates independently to maximize the number of communication channels in the immediate cell. However, significant system capacity improvements can be realized if the spatial processor from each base station communicates with and coordinates its efforts with the spatial processors from other nearby cells. A specific embodiment is shown in figure 9.

A multiple base station controller 66 acts as the interface between the wide area network 65 through link 68 and base stations 1 (a,b,c) via base station communication links 2 (a,b,c). Each base station is responsible for providing coverage to a number of remote terminals. In one embodiment, each remote terminal is assigned to only one base station thus defining cell boundaries 67 (a,b,c) within which all

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remotes attached to a particular base station are located. Users equipped with remote terminals 69 are identified by a boxed "R" in the figure.

Each spatial processor contained in base stations 1 (a,b,c) measures and stores the spatial signatures of the remote terminals in its cell and also of the remote terminals in adjacent cells. The determination of spatial signatures of the remote terminals in adjacent cells is coordinated by multiple base station controller 66 through base station communication links 2 (a,b,c). Through base station communication links 2 (a,b,c) and multiple base station controller 66, spatial processors in base stations 1 (a,b,c) from adjacent cells inform each other of which remote terminals they are communicating with on which conventional channels. Each spatial processor includes the spatial signatures of remote terminals that are currently active in adjacent cells to form extended transmit and receive spatial signature matrices A_{rb} and A_{br} which are sent to all the adjacent base stations. The channel selectors in each base station, using these extended spatial signature matrices, jointly assign remote terminals to each conventional channel in each of base stations 1 (a,b,c).

The resultant weight matrices W_{tr} and W_{rr} for each base station are then calculated using extended spatial signature matrices A_{rb} and A_{br}. In calculating the weights, the objective is to minimize the signal transmitted to and received from the adjacent cell's active remote terminals, thereby allowing many more remote terminals to simultaneously communicate.

In an alternate embodiment, multiple base station controller 66 assigns remote terminals requesting access to base stations dynamically using a list of active remote terminal/base station/conventional channel links, the associated remote terminal databases, and the particular requirements for the link to be assigned. Additionally, remote terminals can employ multiple (directional) transmit and receive antennas, to facilitate directive links to multiple nearby base stations as instructed by multiple base station controller 66 to further increase system capacity.

Advantages

The apparatus and method in accordance with the invention provides a significant advantage over the prior art in that it allows many remote terminals to simultaneously share the same conventional communication channel. In particular, for a system with m receive and m transmit antenna elements, up to m remote terminals can share a single conventional communication channel. Moreover, signals received from and transmitted to the remote terminals have substantially improved signal-to-noise, reduced interference, and improved quality in multipath environments compared to a standard base station.

Thus, a wireless communication system can support many times more conversations, or have a much greater data throughput, with the same amount of spectrum. Alternatively, a wireless communication system can support the same number of conversations or data throughput with much less spectrum.

Alternate Embodiments

In one alternate embodiment, transmission antennas 18(a,...,m) and reception antennas 19(a,...,m) at base station 1 are replaced by a single array of m antennas. Each element in this array is attached to both its respective component of multichannel transmitters 14 and its respective component of multichannel receivers 15 by means of a duplexer.

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In another alternate embodiment, signals on the uplink control channel may be processed in real time using the spatial processing described in copending patent application 07/806,695. This would allow multiple remote terminals to request a communication channel at the same time.

In yet another embodiment for applications involving data transfer of short bursts or packets of data, no separate uplink control channel is required and the system may service requests for communication and other control functions during control time intervals that are interspersed with communications intervals.

As stated above, many techniques are known for measuring the spatial signatures of the remote terminal radios and using these spatial signatures to calculate multiplexing and demultiplexing weights that will allow multiple simultaneous conversations and/or data transfers on the same conventional communication channel.

While the above description contains many specificities, these should not be construed as limitations on the scope of the invention, but rather as an exemplification of one preferred embodiment thereof. Many other variations are possible. Accordingly, the scope of the invention should be determined not by the illustrated embodiments, but by the appended claims and their legal equivalents.

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What is claimed is:

1. A wireless system at a base station for receiving uplink signals transmitted from a plurality of remote terminals using a common conventional uplink channel comprising:

   receiving means including a plurality of antenna elements and receivers for producing measurements of combinations of said uplink signals,

   receive spatial processing means for determining and storing receive spatial signatures for said plurality of remote terminals using said measurements, and

   spatial demultiplexing means using said receive spatial signatures and said measurements to produce separated uplink signals,

   whereby said uplink signals from said plurality of remote terminals can be received independently while simultaneously communicating on said common conventional uplink channel.

2. The wireless system as defined by claim 1 wherein said receive spatial processing means comprises:

   a receive spatial signature list comprising a receive spatial signature for each of said remote terminals and said common conventional uplink channel,

   receive spatial signature determining means for determining said receive spatial signatures,

   a receive channel selector utilizing said receive spatial signatures to determine whether said common conventional uplink channel can be further shared by an additional remote terminal, and

   a receive spatial weight processor for calculating spatial demultiplexing weights for said plurality of remote terminals, said spatial demultiplexing weights being utilized by said spatial demultiplexing means to produce said separated uplink signals.

3. The wireless system as defined by claim 2 wherein said receive spatial weight processor determines said spatial demultiplexing weights as the columns of matrix W_{rx} as follows:

$$W_{rx} = (A_{br} P_r A_{br}^* + R_{nn})^{-1} A_{br} P_r,$$

   where $()^*$ denotes the complex conjugate transpose of a matrix, R_{nn} is a base station receiver noise covariance matrix, P_r is a diagonal matrix of remote terminal transmit powers, and A_{br} is a demultiplexing spatial signature matrix whose columns are said receive spatial signatures for said plurality of remote terminals and said common conventional uplink channel.

4. The wireless system as defined by claim 1 wherein said common conventional uplink channel is one of a plurality of conventional uplink channels and wherein said receive spatial processing means comprises:

   a receive active remote terminal list of remote terminals assigned to each of said conventional uplink channels,

   a receive spatial signature list comprising a receive spatial signature for each of said remote terminals and each of said conventional uplink channels,

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receive spatial signature determining means for determining said receive spatial signatures,

a receive channel selector using said receive active remote terminal list and said receive spatial signature list to determine assignments of said remote terminals to said conventional uplink channels, and

a receive spatial weight processor for calculating spatial demultiplexing weights for each of said remote terminals assigned to each of said conventional uplink channels said spatial demultiplexing weights being utilized by said spatial demultiplexing means to produce said separated uplink signals.

5. The wireless system as defined by claim 4 wherein said base station is one of a plurality of base stations and said channel selector at each of said base stations further comprises:

communication means for communicating with said channel selector at each of said base stations, and

joint channel selector means for jointly determining assignments of said remote terminals to said conventional uplink channels and said base stations.

whereby said uplink signals from a maximum number of said remote terminals can be received independently by at least one of said base stations while simultaneously communicating on said common conventional uplink channels.

6. The wireless system as defined by claim 1 and including transmission means comprising a transmitter and an omnidirectional antenna for sending downlink signals from said base station to said plurality of remote terminals.

7. The wireless system as defined by claim 1 wherein said spatial demultiplexing means calculates spatial demultiplexing weights for said common conventional uplink channel as the columns of a matrix W_{rx} as follows:

$$W_{rx} = (A_{br} P_r A_{br}^* + R_{nn})^{-1} A_{br} P_r,$$

where $(\cdot)^*$ denotes the complex conjugate transpose of a matrix, $(\cdot)^{-1}$ denotes the inverse of a matrix, R_{nn} is a base station receiver noise covariance matrix, P_r is a diagonal matrix of remote terminal transmit powers, and A_{br} is a demultiplexing spatial signature matrix whose columns are said receive spatial signatures for said plurality of remote terminals and said common conventional uplink channel, said spatial demultiplexing means using said spatial demultiplexing weights to produce said separated uplink signals.

8. The wireless system as defined by claim 1 wherein said receive spatial processing means determines said receive spatial signatures using signals transponded from transponders co-located with each of said plurality of remote terminals.

9. The wireless system as defined by claim 1 wherein said receive spatial processing means determines said receive spatial signatures using location and directivity knowledge of said antenna elements, and the directions of arrival of said uplink signals from said plurality of remote terminals.

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10. The wireless system as defined by claim 1 wherein said receive spatial processing means determines said receive spatial signatures using location and directivity knowledge of said antenna elements and location knowledge of said plurality of remote terminals.

11. The wireless system as defined by claim 1 wherein said receive spatial processing means determines said receive spatial signatures using predetermined modulation format parameters of said uplink signals from said plurality of remote terminals.

12. The wireless system as defined by claim 1 further comprising:

transmission means including a plurality of transmit antenna elements and transmitters for transmitting multiplexed downlink signals to said plurality of remote terminals using a common conventional downlink channel,

transmit spatial processing means for determining and storing transmit spatial signatures for said plurality of remote terminals, and

spatial multiplexing means using said transmit spatial signatures and downlink signals to produce said multiplexed downlink signals,

whereby said base station can transmit said downlink signals to said plurality of remote terminals independently and simultaneously on said common conventional downlink channel.

13. The wireless system as defined by claim 12 wherein said receiving means and said transmission means share common antenna elements using duplexers.

14. The wireless system as defined by claim 12 wherein said receiving means and said transmission means share common antenna elements using transmit/receive switches.

15. The wireless system as defined by claim 12 wherein said common conventional uplink channel is one of a plurality of conventional uplink channels, said common conventional downlink channel is one of a plurality of conventional downlink channels, and wherein said receive spatial processing means and said transmit spatial processing means comprises:

an active remote terminal list of remote terminals assigned to each of said conventional uplink channels and each of said conventional downlink channels,

a spatial signature list comprising a receive spatial signature for each of said remote terminals and each of said conventional uplink channels, and a transmit spatial signature for each of said remote terminals and each of said conventional downlink channels,

receive spatial signature determining means for determining said receive spatial signatures,

transmit spatial signature determining means for determining said transmit spatial signatures,

a channel selector using said active remote terminal list and said receive spatial signature list and said transmit spatial signature list to determine assignments of said remote terminals to said conventional uplink channels and said conventional downlink channels,

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a receive spatial weight processor for calculating spatial demultiplexing weights for each of said remote terminals assigned to each of said conventional uplink channels, said spatial demultiplexing weights being utilized by said spatial demultiplexing means to produce said separated uplink signals, and

a transmit spatial weight processor for calculating spatial multiplexing weights for each of said remote terminals assigned to each of said conventional downlink channels, said spatial multiplexing weights being utilized by said spatial multiplexing means to produce said multiplexed downlink signals.

16. The wireless system as defined by claim 15 wherein said base station is one of a plurality of base stations and said channel selector at each of said base stations further comprises:

communication means for communicating with said channel selector at each of said base stations, and

joint channel selector means for jointly determining assignments for said remote terminals to said conventional uplink channels and said conventional downlink channels and said base stations,

whereby said uplink signals from a maximum number of said remote terminals can be received independently by at least one of said base stations and said downlink signals can be transmitted independently to a maximum number of said remote terminals by at least one of said base stations, while simultaneously communicating on said common conventional uplink channels and said common conventional downlink channels.

17. The wireless system as defined by claim 12 wherein said spatial multiplexing means determines spatial multiplexing weights for said common conventional downlink channel as the rows of a matrix W_{tr} as follows:

$$W_{tr} = S_b(A_{rb}A_{rb}^*)^{-1}A_{rb},$$

where $(\cdot)^*$ denotes the complex conjugate transpose of a matrix, $(\cdot)^{-1}$ denotes the inverse of a matrix, S_b is a diagonal matrix of amplitudes of said downlink signals, and A_{rb} is a multiplexing spatial signature matrix whose rows are said transmit spatial signatures for said plurality of remote terminals and said common conventional downlink channel and said spatial multiplexing means utilizes said spatial multiplexing weights to produce said multiplexed downlink signals.

18. The wireless system as defined by claim 12 wherein said transmit spatial processing means determines said transmit spatial signatures using signals transponded from transponders co-located with said plurality of remote terminals.

19. The wireless system as defined by claim 12 wherein said transmit spatial processing means determines said transmit spatial signatures using signals transponded by said plurality of remote terminals.

20. The wireless system as defined by claim 12 wherein said transmit spatial signatures are determined by said plurality of remote terminals using predetermined modulation format parameters of said downlink signals.

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21. The wireless system as defined by claim 12 wherein said transmit spatial processing means determines said transmit spatial signatures using knowledge of locations and directivity of said transmit antenna elements and estimates of directions of arrival of said uplink signals from said plurality of remote terminals.

22. The wireless system as defined by claim 12 wherein said downlink signals and said uplink signals are transmitted on the same radio frequency and said transmit spatial processing means determines said transmit spatial signatures by calculating them directly from said receive spatial signatures.

23. The wireless system as defined by claim 12 wherein said transmit spatial processing means determines said transmit spatial signatures using location and directivity knowledge of said antenna elements and location knowledge of said plurality of remote terminals.

24. A wireless system at a base station for transmitting to a plurality of remote terminals using a common conventional downlink channel comprising:

transmission means including a plurality of transmit antenna elements and transmitters for transmitting multiplexed downlink signals to said plurality of remote terminals,

transmit spatial processing means for determining and storing transmit spatial signatures for said plurality of remote terminals, and

spatial multiplexing means using said transmit spatial signatures and downlink signals to produce said multiplexed downlink signals,

whereby said base station can transmit said downlink signals to said plurality of remote terminals independently and simultaneously on a common conventional downlink channel.

25. The wireless system as defined by claim 24 wherein said common conventional downlink channel is one of a plurality of conventional downlink channels and wherein said transmit spatial processing means comprises:

a transmit active remote terminal list of remote terminals assigned to each of said conventional downlink channels,

a transmit spatial signature list comprising a transmit spatial signature for each of said remote terminals and each of said conventional downlink channels,

transmit spatial signature determining means for determining said transmit spatial signatures,

a transmit channel selector using said transmit active remote terminal list and said transmit spatial signature list to determine assignments of said remote terminals to said conventional downlink channels, and

a transmit spatial weight processor for calculating spatial multiplexing weights for each of said remote terminals assigned to each of said conventional downlink channels said spatial multiplexing weights being utilized by said spatial multiplexing means to produce said multiplexed downlink signals.

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26. The wireless system as defined by claim 25 wherein said base station is one of a plurality of base stations and said transmit channel selector at each of said base stations further comprises:

communication means for communicating with said transmit channel selector at each of said base stations, and

joint channel selector means for jointly determining assignments of said remote terminals to said conventional downlink channels and said base stations,

whereby said downlink signals can be transmitted independently to a maximum number of said remote terminals by at least one of said base stations, while simultaneously communicating on said common conventional downlink channels.

27. The wireless system as defined by claim 24 wherein said spatial multiplexing means determines spatial multiplexing weights for said common conventional downlink channel as the rows of a matrix W_{tr} as follows:

$$W_{tr} = S_b(A_{rb}A_{rb}^*)^{-1}A_{rb},$$

where $(\cdot)^*$ denotes the complex conjugate transpose of a matrix, $(\cdot)^{-1}$ denotes the inverse of a matrix, S_b is a diagonal matrix of amplitudes of said downlink signals, and A_{rb} is a multiplexing spatial signature matrix whose rows are said transmit spatial signatures for said plurality of remote terminals and said common conventional downlink channel and said spatial multiplexing means utilizes said spatial multiplexing weights to produce said multiplexed downlink signals.

28. The wireless system as defined by claim 24 wherein said transmit spatial processing means determines said transmit spatial signatures using signals transponded from transponders co-located with said plurality of remote terminals.

29. The wireless system as defined by claim 24 wherein said transmit spatial processing means determines said transmit spatial signatures using signals transponded by said plurality of remote terminals.

30. The wireless system as defined by claim 24 wherein said transmit spatial signatures are determined by said plurality of remote terminals using predetermined modulation format parameters of said downlink signals.

31. The wireless system as defined by claim 24 wherein said transmit spatial processing means determines said transmit spatial signatures using location and directivity knowledge of said antenna elements and location knowledge of said plurality of remote terminals.

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AMENDED CLAIMS

[received by the International Bureau on 23 April 1996 (23.04.96); original claims 1-31 replaced by amended claims 1-35 (12 pages)]

1. A wireless system for calculating uplink signals transmitted from a plurality of remote terminals using a common uplink channel, said system including at least one base station, said system comprising:

receiving means at said at least one base station including a plurality of antenna elements and receivers for producing measurements of combinations of said uplink signals from said plurality of remote terminals using said common uplink channel,

receive spatial processing means for determining and storing receive spatial signatures for said plurality of remote terminals using said measurements, and

spatial demultiplexing means using said receive spatial signatures and said measurements to calculate said uplink signals.

2. The wireless system as defined by claim 1 wherein said receive spatial processing means comprises:

a spatial signature list comprising a receive spatial signature for each remote terminal in said plurality of remote terminals and said common uplink channel,

receive spatial signature determining means for determining said receive spatial signatures, and

a receive channel selector utilizing said receive spatial signatures to determine whether said common uplink channel can be further shared by an additional remote terminal.

3. The wireless system as defined by claim 2 wherein said receive spatial processing means further comprises:

a receive spatial weight processor for calculating spatial demultiplexing weights for said plurality of remote terminals, said spatial demultiplexing weights being utilized by said spatial demultiplexing means to calculate said uplink signals.

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4. The wireless system as defined by claim 3 wherein said receive spatial weight processor determines said spatial demultiplexing weights as the columns of matrix W_{rx} as follows:

$$W_{rx} = (A_{br}P_rA^*_{br} + R_{nn})^{-1} A_{br}P_r$$

where ()* denotes the complex conjugate transpose of a matrix, R_{nn} is the noise covariance matrix of said receiving means, P_r is the diagonal matrix of transmit powers of the remote terminals in said plurality of remote terminals, and A_{br} is a demultiplexing spatial signature matrix whose columns are said receive spatial signatures for said plurality of remote terminals and said common uplink channel.

5. The wireless system as defined by claim 1 wherein said common uplink channel is one of a plurality of uplink channels and wherein said receive spatial processing means comprises:

an active remote terminal list comprising a list of remote terminals assigned to at least one channel of said plurality of uplink channels,

a spatial signature list comprising a receive spatial signature for each remote terminal of said plurality of remote terminals and each channel of said plurality of uplink channels,

receive spatial signature determining means for determining said receive spatial signatures in said spatial signature list,

a receive channel selector using said active remote terminal list and said spatial signature list to determine assignments of each remote terminal in said active remote terminal list to at least one of the channels of said plurality of uplink channels, and

a receive spatial weight processor for calculating spatial demultiplexing weights for each of the terminals in said active remote terminal list and each channel of said plurality of uplink channels assigned to at least one of the terminals in said active remote terminal list, said spatial demultiplexing weights being utilized by said spatial demultiplexing means to calculate said uplink signals.

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6. The wireless system as defined by claim 1 wherein said common uplink channel is one of a plurality of uplink channels, said at least one base station is one of a plurality of base stations, said receive spatial processing means is one of a plurality of receive spatial processing means, each base station in said plurality of base stations having a corresponding receive spatial processing means in said plurality of receive spatial processing means, each receive spatial processing means in said plurality of receive spatial processing means comprising:

an active remote terminal list comprising a list of remote terminals assigned to at least one channel of said plurality of uplink channels,

a spatial signature list comprising a receive spatial signature for each remote terminal of said plurality of remote terminals and each channel of said plurality of uplink channels,

receive spatial signature determining means for determining said receive spatial signatures in said spatial signature list, and

a receive spatial weight processor for calculating spatial demultiplexing weights for each of the terminals in said active remote terminal list and each channel of said plurality of uplink channels assigned to at least one of the terminals in said active remote terminal list, said spatial demultiplexing weights being utilized by said spatial demultiplexing means to calculate said uplink signals,

said system further comprising:

joint channel selector means for jointly determining assignments of each remote terminal in each said active remote terminal list to at least one of the channels of said plurality of uplink channels and to at least one of base stations of said plurality of base stations, and

communication means for communicating the status of said assignments between each base station in said plurality of base stations and said joint channel selector means.

7. The wireless system as defined by claim 1 and including transmission means comprising a transmitter and an antenna for sending downlink signals from said at least one

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base station to the terminals in said plurality of remote terminals.

8. The wireless system as defined by claim 1 wherein said spatial demultiplexing means calculates spatial demultiplexing weights for said common uplink channel as the columns of a matrix W_{rx} as follows:

$$W_{rx} = (A_{br}P_rA^*_{br} + R_{nn})^{-1} A_{br}P_r$$

where ()* denotes the complex conjugate transpose of a matrix, R_{nn} is the noise covariance matrix of said receiver means, P_r is the diagonal matrix of transmit powers of the remote terminals in said plurality of remote terminals, and A_{br} is a demultiplexing spatial signature matrix whose columns are said receive spatial signatures for said plurality of remote terminals and said common uplink channel, said spatial demultiplexing means using said spatial demultiplexing weights to calculate said uplink signals.

9. The wireless system as defined by claim 1 wherein said system includes a transponder co-located with each remote terminal of said plurality of remote terminals and wherein receive spatial processing means determines said receive spatial signatures using signals transponded from at least one of the transponders.

10. The wireless system as defined by claim 1 wherein each remote terminal of said plurality of remote terminals includes a transponder and said receive spatial processing means determines said receive spatial signatures using signals transponded from at least one of the transponders.

11. The wireless system as defined by claim 1 wherein said receive spatial processing means determines said receive spatial signatures using the known location and directivity of said antenna elements, and estimates of the directions of arrival of said uplink signals from said plurality of remote terminals.

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12. The wireless system as defined by claim 1 wherein said receive spatial processing means determines said receive spatial signatures using the known location and directivity of said antenna elements and the known location of said plurality of remote terminals.

13. The wireless system as defined by claim 1 wherein said uplink signals have predetermined modulation format parameters, and said receive spatial processing means determines said receive spatial signatures using said predetermined modulation format parameters of said uplink signals from said plurality of remote terminals.

14. The wireless system as defined by claim 1 further comprising:

transmission means including a plurality of transmit antenna elements and transmitters for transmitting multiplexed downlink signals to said plurality of remote terminals using a common downlink channel,

transmit spatial processing means for determining and storing transmit spatial signatures for said plurality of remote terminals, and

spatial multiplexing means using said transmit spatial signatures and downlink signals to produce said multiplexed downlink signals.

15. The wireless system as defined by claim 14 wherein said receiving means and said transmission means share common antenna elements using duplexers.

16. The wireless system as defined by claim 14 wherein said receiving means and said transmission means share common antenna elements using transmit/receive switches.

17. The wireless system as defined by claim 14 wherein said common uplink channel is one of a plurality of uplink channels, said common downlink channel is one of a plurality of downlink channels, and wherein said receive spatial processing means and said transmit spatial processing means comprise:

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an active remote terminal list comprising a list of remote terminals assigned to at least one of the channels of said plurality of uplink channels and remote terminals assigned to at least one of the channels of said plurality of downlink channels, a spatial signature list comprising a receive spatial signature for each remote terminal of said plurality of remote terminals and each channel of said plurality of uplink channels, and a transmit spatial signature for each remote terminal of said plurality of remote terminals and each channel of said plurality of downlink channels,

receive spatial signature determining means for determining said receive spatial signatures,

transmit spatial signature determining means for determining said transmit spatial signatures, and

a channel selector using said active remote terminal list and said spatial signature list to determine assignments of each remote terminal in said active remote terminal list to at least one of the channels of said plurality of uplink channels and at least one of the channels of said plurality of downlink channels.

18. The wireless system as defined by claim 17 wherein said receive spatial processing means and said transmit spatial processing means further comprise:

a receive spatial weight processor for calculating spatial demultiplexing weights for each of the terminals in said active remote terminals list to which a uplink channel is assigned and for each channel of said plurality of uplink channels assigned to at least one of the terminals in said active remote terminal list, said spatial demultiplexing weights being utilized by said spatial demultiplexing means to calculate said uplink signals, and

a transmit spatial weight processor for calculating spatial multiplexing weights for each of the terminals in said active remote terminal list to which a downlink channel is assigned and each channel of said plurality of downlink channels assigned to at least one of the terminals in said active remote terminal list, said spatial multiplexing weights being utilized by said spatial multiplexing means to produce said multiplexed downlink signals.

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19. The wireless system as defined by claim 14 wherein said at least one base station is one of a plurality of base stations, said common uplink channel is one of a plurality of uplink channels, said common downlink channel is one of a plurality of downlink channels, said receive spatial processing means is one of a plurality of receive spatial processing means, said transmit spatial processing means is one of a plurality of transmit spatial processing means, each base station in said plurality of base stations having a corresponding receive spatial processing means in said plurality of receive spatial processing means and a corresponding transmit spatial processing means in said plurality of transmit spatial processing means, each receive spatial processing means in said plurality of receive spatial processing means and each transmit spatial processing means in said plurality of transmit spatial processing means comprising:

an active remote terminal list comprising a list of remote terminals assigned to at least one of the channels of said plurality of uplink channels and remote terminals assigned to at least one of the channels of said plurality of downlink channels, a spatial signature list comprising a receive spatial signature for each remote terminal of said plurality of remote terminals and each channel of said plurality of uplink channels, and a transmit spatial signature for each remote terminal of said plurality of remote terminals and each channel of said plurality of downlink channels,

receive spatial signature determining means for determining said receive spatial signatures,

transmit spatial signature determining means for determining said transmit spatial signatures,

a receive spatial weight processor for calculating spatial demultiplexing weights for each of the terminals in said active remote terminal list to which a uplink channel is assigned and each channel of said plurality of uplink channels assigned to at least one of the terminals in said active remote terminal list, said spatial demultiplexing weights being utilized by said spatial demultiplexing means to calculate said uplink signals, and

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a transmit spatial weight processor for calculating spatial multiplexing weights for each of the terminals in said active remote terminal list to which a downlink channel is assigned and each channel of said plurality of downlink channels assigned to at least one of the terminals in said active remote terminal list, said spatial multiplexing weights being utilized by said spatial multiplexing means to produce said multiplexed downlink signals,

said system further comprising:

joint channel selector means for jointly determining assignments of each remote terminal in each said active remote terminal list to at least one of the channels of said plurality of uplink channels, to at least one of the channels of said plurality of downlink channels and to at least one of the base stations of said plurality of base stations, and

communication means for communicating said assignments between each base station in said plurality of base stations and said joint channel selector means.

20. The wireless system as defined by claim 14 wherein said spatial multiplexing means determines spatial multiplexing weights for said common downlink channel as the rows of a matrix W_{tx} as follows:

$$W_{tx} = S_b \ (A_{rb}A^*_{rb})^{-1} \ A_{rb},$$

where $()^*$ denotes the complex conjugate transpose of a matrix, S_b is the diagonal matrix of amplitudes of said downlink signals, and A_{rb} is a multiplexing spatial signature matrix whose rows are said transmit spatial signatures for said plurality of remote terminals and said common downlink channel, and wherein said spatial multiplexing means utilizes said spatial multiplexing weights to produce said multiplexed downlink signals.

21. The wireless system as defined by claim 14 wherein said system includes a transponder co-located with each remote terminal of said plurality of remote terminals and wherein transmit spatial processing means determines said transmit spatial signatures using signals transponded from at least one of the transponders.

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22. The wireless system as defined by claim 14 wherein each remote terminal in said plurality of remote terminals includes a transponder, and wherein said transmit spatial processing means determines said transmit spatial signatures using signals transponded from at least one of the transponders.

23. The wireless system as defined by claim 14 wherein said downlink signals have predetermined modulation format parameters, and said transmit spatial signatures are determined by the corresponding terminals in said plurality of remote terminals using the predetermined modulation format parameters of said downlink signals.

24. The wireless system as defined by claim 14 wherein said transmit spatial processing means determines said transmit spatial signatures using the known location and directivity of said transmit antenna elements and estimates of directions of arrival of said uplink signals from said plurality of remote terminals.

25. The wireless system as defined by claim 14 wherein said downlink signals and said uplink signals are transmitted on the same radio frequency and said transmit spatial processing means determines said transmit spatial signatures by calculating them directly from said receive spatial signatures.

26. The wireless system as defined by claim 14 wherein said transmit spatial processing means determines said transmit spatial signatures using the known location and directivity of said antenna elements and the known location of said plurality of remote terminals.

27. A wireless system including at least one base station for transmitting to a plurality of remote terminals using a common downlink channel, said system comprising:

transmission means at said at least one base station including a plurality of transmit antenna elements and

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transmitters for transmitting multiplexed downlink signals to said plurality of remote terminals,

transmit spatial processing means for determining transmit spatial signatures for said plurality of remote terminals, and

spatial multiplexing means using said transmit spatial signatures and downlink signals to produce said multiplexed downlink signals,

whereby said at least one base station can transmit said downlink signals to said plurality of remote terminals simultaneously on a common downlink channel.

28. The wireless system as defined by claim 27 wherein said common downlink channel is one of a plurality of downlink channels and wherein said transmit spatial processing means comprises:

an active remote terminal list comprising a list of remote terminals assigned to at least one the channels of said plurality of downlink channels,

a spatial signature list comprising a transmit spatial signature for each remote terminal of said plurality of remote terminals and each channel of said plurality of downlink channels,

transmit spatial signature determining means for determining said transmit spatial signatures, and

a transmit channel selector using said active remote terminal list and said spatial signature list to determine assignments of each remote terminal in said active remote terminal list to at least one of the channels of said plurality of downlink channels.

29. The wireless system as defined by claim 28 wherein said transmit spatial processing means further comprises:

a transmit spatial weight processor for calculating spatial multiplexing weights for each of the terminals in said active remote terminal list to which a downlink channel is assigned and each channel of said plurality of downlink channels assigned to at least one of the terminals in said active remote terminal list, said spatial multiplexing weights

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being utilized by said spatial multiplexing means to produce said multiplexed downlink signals.

30. The wireless system as defined by claim 27 wherein said at least one base station is one of a plurality of base stations, said common downlink channel is one of a plurality of downlink channels, said transmit spatial processing means is one of a plurality of transmit spatial processing means, each base station in said plurality of base stations having a corresponding transmit spatial processing means in said plurality of transmit spatial processing means, each transmit spatial processing means in said plurality of transmit spatial processing means comprising:

an active remote terminal list comprising a list of remote terminals assigned to at least one the channels of said plurality of downlink channels,

a spatial signature list comprising a transmit spatial signature for each remote terminal of said plurality of remote terminals and each channel of said plurality of downlink channels,

transmit spatial signature determining means for determining said transmit spatial signatures, and

a transmit spatial weight processor for calculating spatial multiplexing weights for each of the terminals in said active remote terminal list to which a downlink channel is assigned and each channel of said plurality of downlink channels assigned to at least one of the terminals in said active remote terminal list, said spatial multiplexing weights being utilized by said spatial multiplexing means to produce said multiplexed downlink signals,

said system further comprising:

joint channel selector means for jointly determining assignments of each remote terminal in each said active remote terminal list to at least one of the channels of said plurality of down channels and to at least one of the base stations of said plurality of base stations, and

communication means for communicating said assignments between each base station in said plurality of base stations and said joint channel selector means.

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31. The wireless system as defined by claim 27 wherein said spatial multiplexing means determines spatial multiplexing weights for said common downlink channel as the rows of a matrix W_{tx} as follows:

$$W_{tx} = S_b \ (A_{rb}A^*_{rb})^{-1}A_{rb}$$

where $()^*$ denotes the complex conjugate transpose of a matrix, S_b is the diagonal matrix of amplitudes of said downlink signals, and A_{rb} is a multiplexing spatial signature matrix whose rows are said transmit spatial signatures for said plurality of remote terminals and said common downlink channel, and said spatial multiplexing means utilizes said spatial multiplexing weights to produce said multiplexed downlink signals.

32. The wireless system as defined by claim 27 wherein said system includes a transponder co-located with each remote terminal of said plurality of remote terminals and wherein said transmit spatial processing means determines said transmit spatial signatures using signals transponded from at least one of the transponders.

33. The wireless system as defined by claim 27 wherein each remote terminal in said plurality of remote terminals includes a transponder, and wherein said transmit spatial processing means determines said transmit spatial signatures using signals transponded from at least one of the transponders.

34. The wireless system as defined by claim 27 wherein said downlink signals have predetermined modulation format parameters, and said transmit spatial signatures are determined by the corresponding terminals in said plurality of remote terminals using the predetermined modulation format parameters of said downlink signals.

35. The wireless system as defined by claim 27 wherein said transmit spatial processing means determines said transmit spatial signatures using the known location and directivity of said antenna elements and the known location of said plurality of remote terminals.

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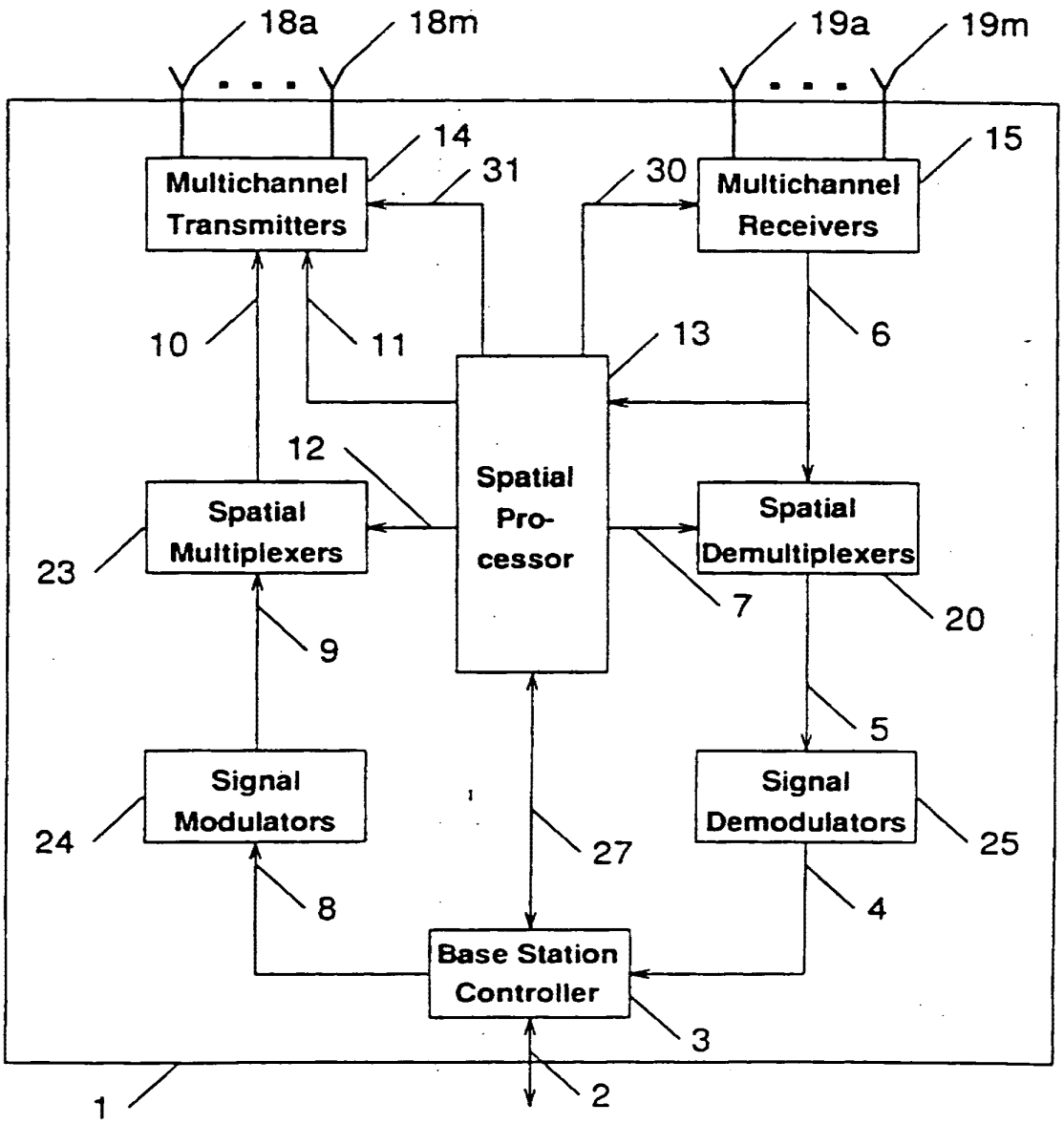

18a
18m
19a
19m
14
31
30
15
Multichannel Transmitters
Multichannel Receivers
10
11
13
6
12
Spatial Multiplexers
Spatial Pro-cessor
Spatial Demultiplexers
23
7
20
9
5
Signal Modulators
Signal Demodulators
24
27
25
8
4
Base Station Controller
3
1
2

FIG. 1

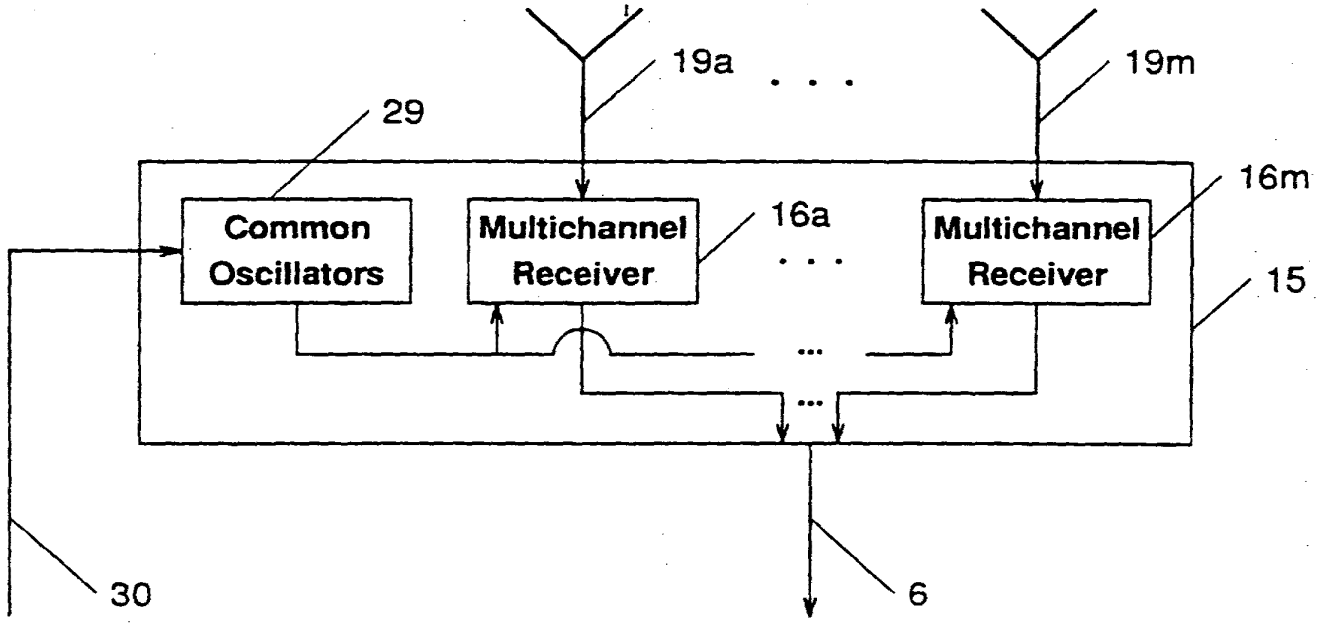

19a
19m
29
16m
Common Oscillators
Multichannel Receiver
16a
Multichannel Receiver
15
30
6

FIG. 2

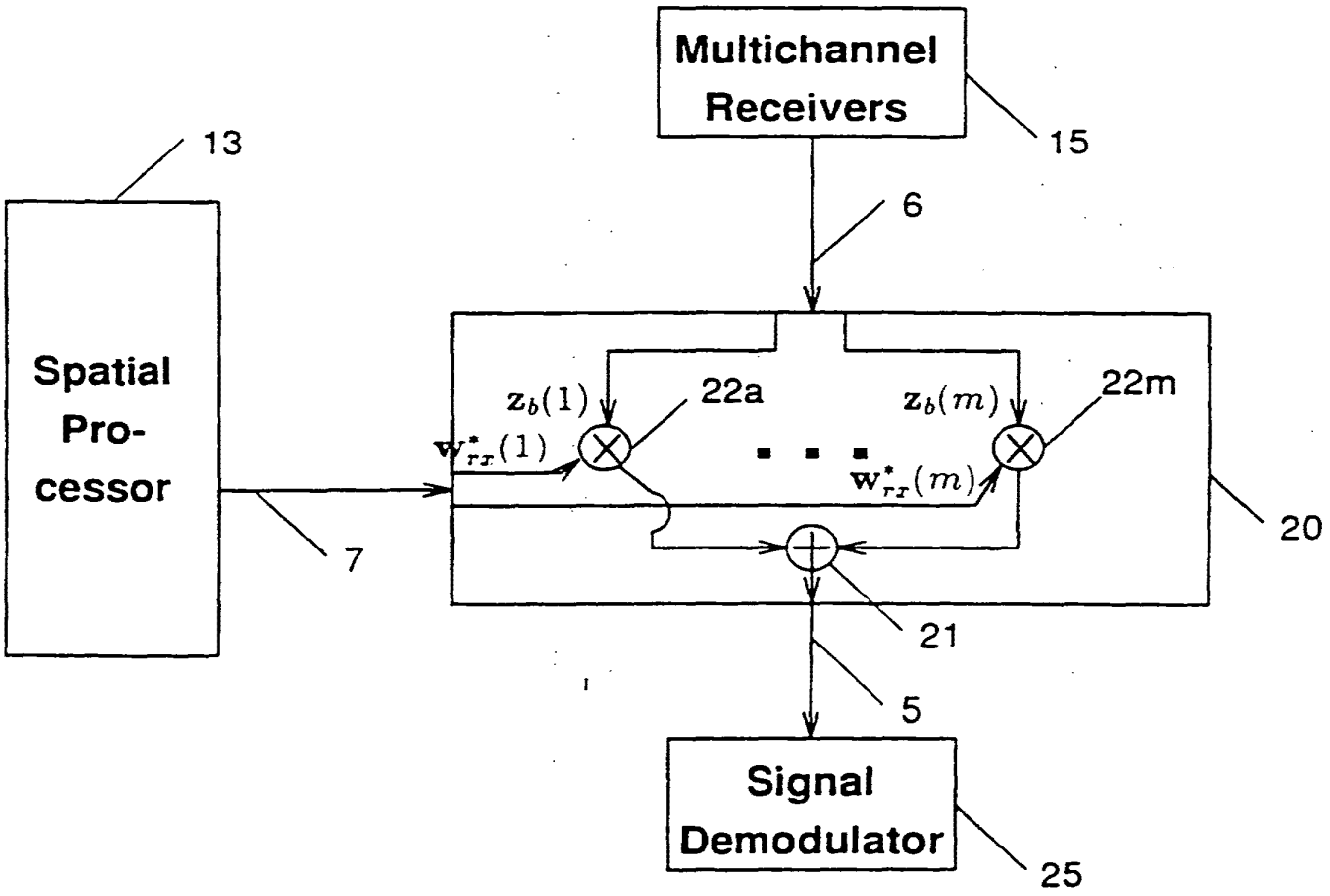

Multichannel Receivers
15
13
6
Spatial Pro-cessor
$z_b(1)$
22a
$z_b(m)$
22m
$w^*_{rx}(1)$
$w^*_{rx}(m)$
20
7
21
5
Signal Demodulator
25

FIG. 3

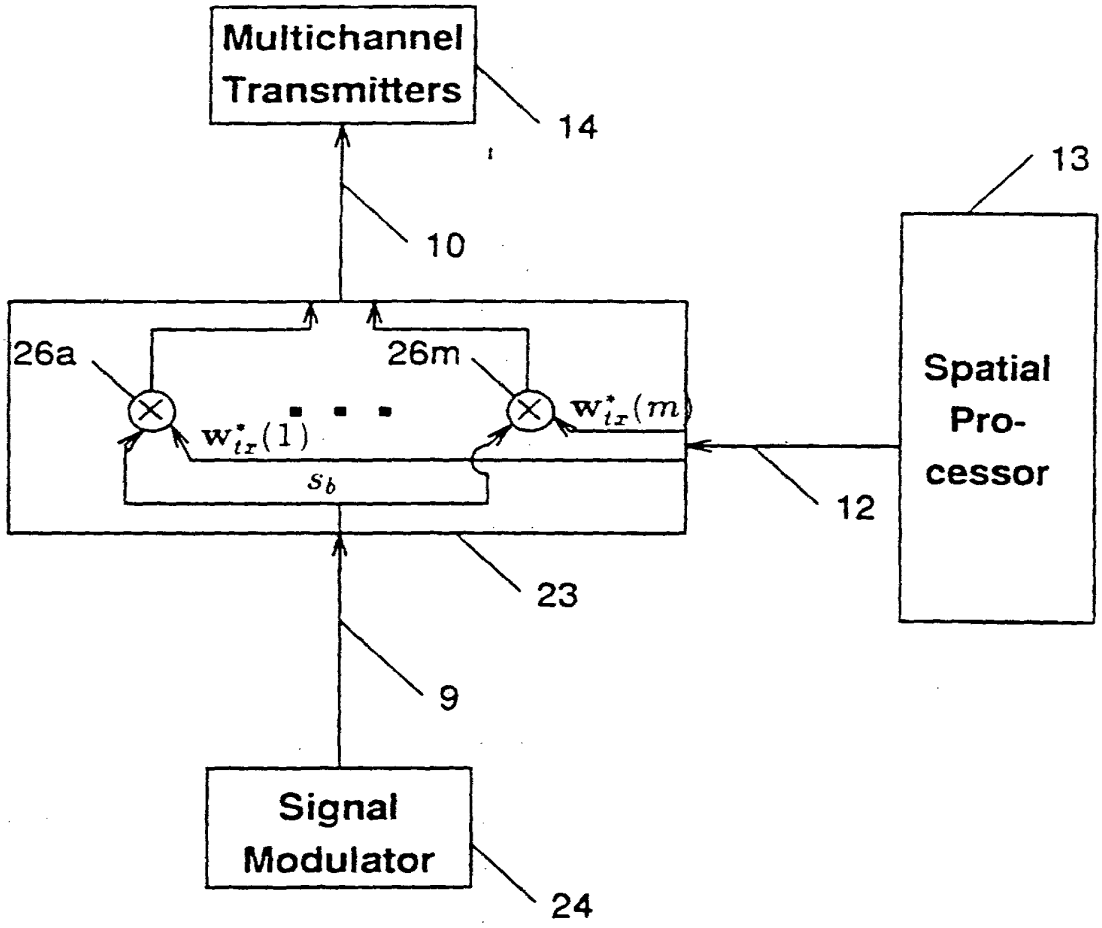

Multichannel Transmitters
14
13
10
26a
26m
$w^*_{tx}(m)$
$w^*_{tx}(1)$
s_b
Spatial Pro-cessor
12
23
9
Signal Modulator
24

FIG. 4

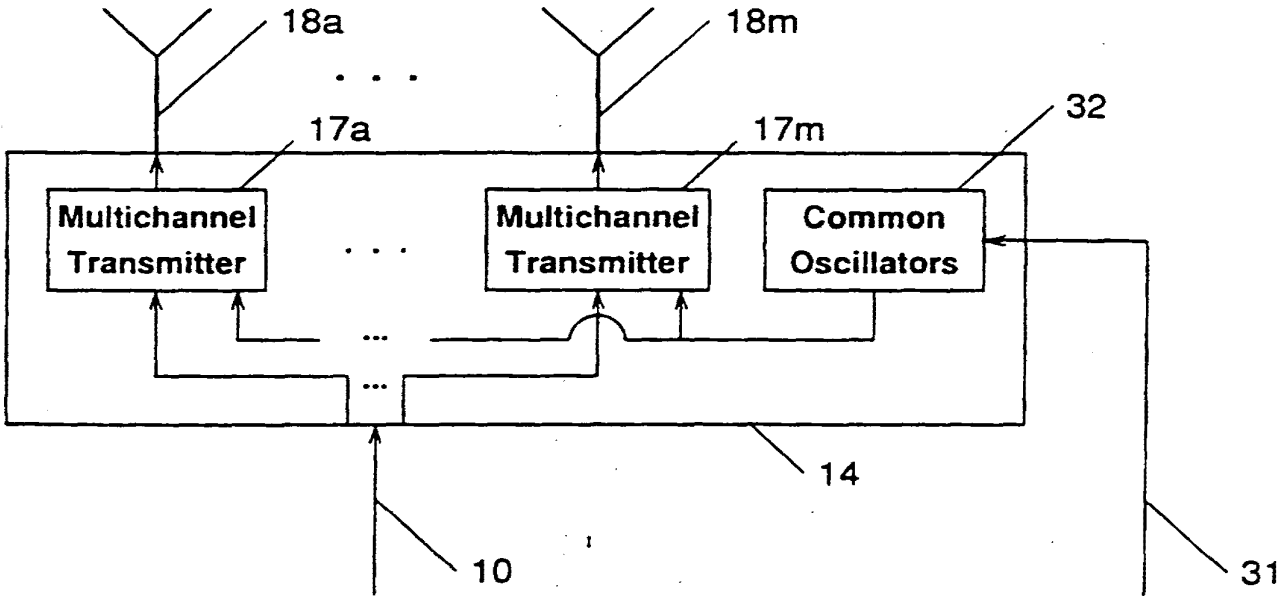

18a
18m
17a
17m
32
Multichannel Transmitter
Multichannel Transmitter
Common Oscillators
14
10
31

FIG. 5

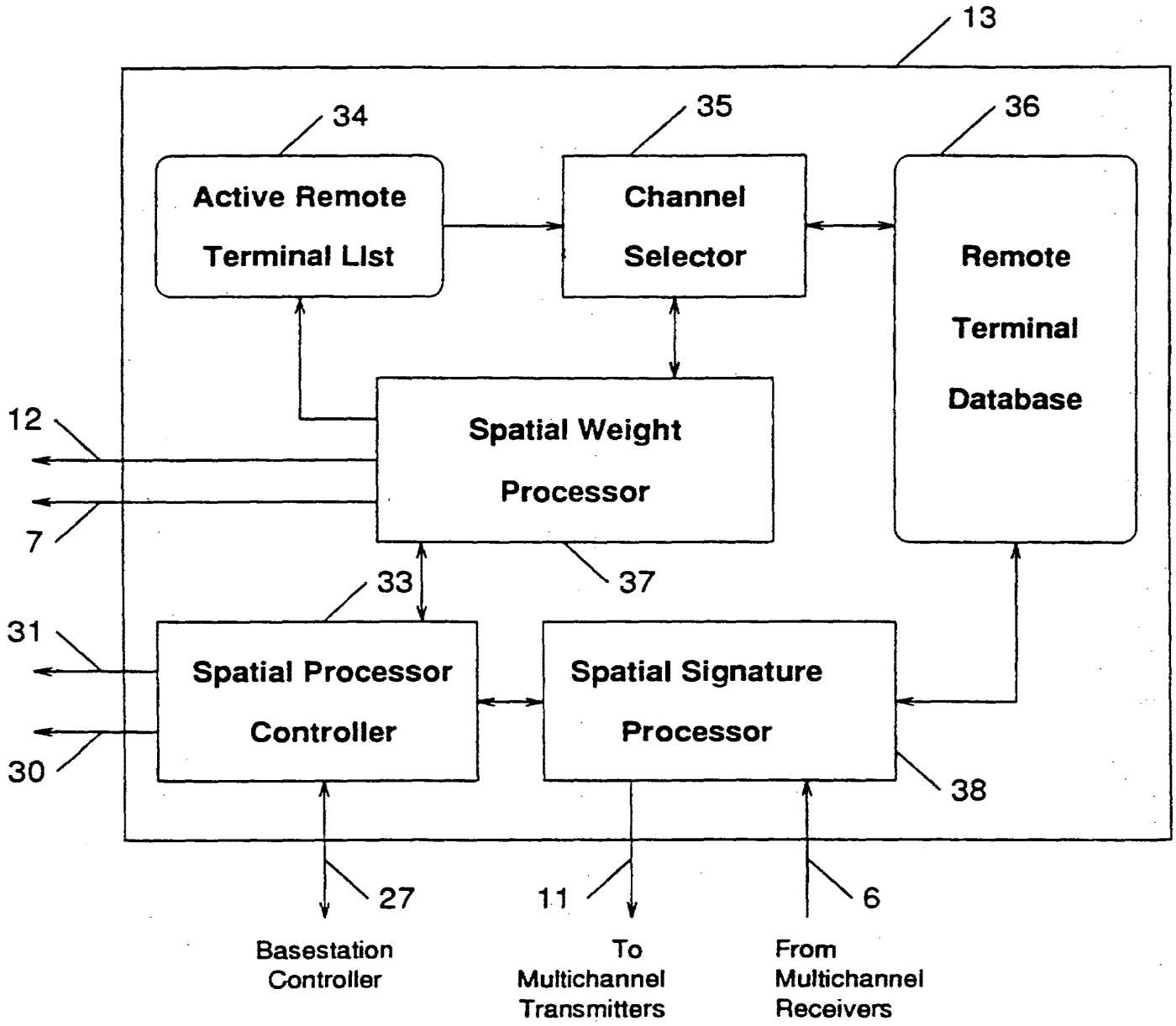

13
34
35
36
Active Remote Terminal List
Channel Selector
Remote Terminal Database
12
7
Spatial Weight Processor
37
33
31
30
Spatial Processor Controller
Spatial Signature Processor
38
27
11
6
Basestation Controller
To Multichannel Transmitters
From Multichannel Receivers

FIG. 6

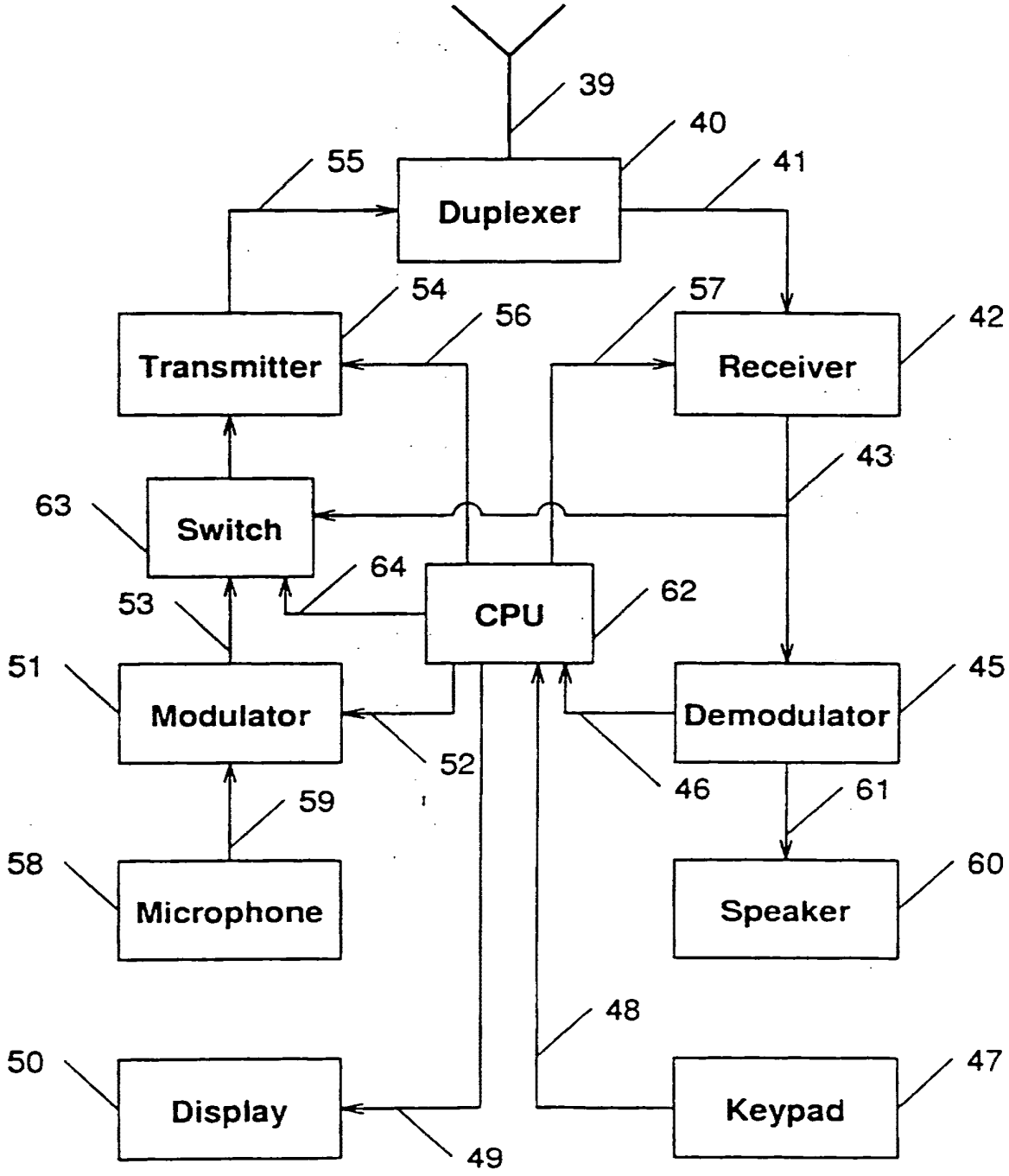

39
40
55
41
Duplexer
54
57
56
42
Transmitter
Receiver
43
63
Switch
64
53
CPU
62
51
45
Modulator
Demodulator
52
46
61
59
58
60
Microphone
Speaker
48
50
47
Display
Keypad
49

FIG. 7

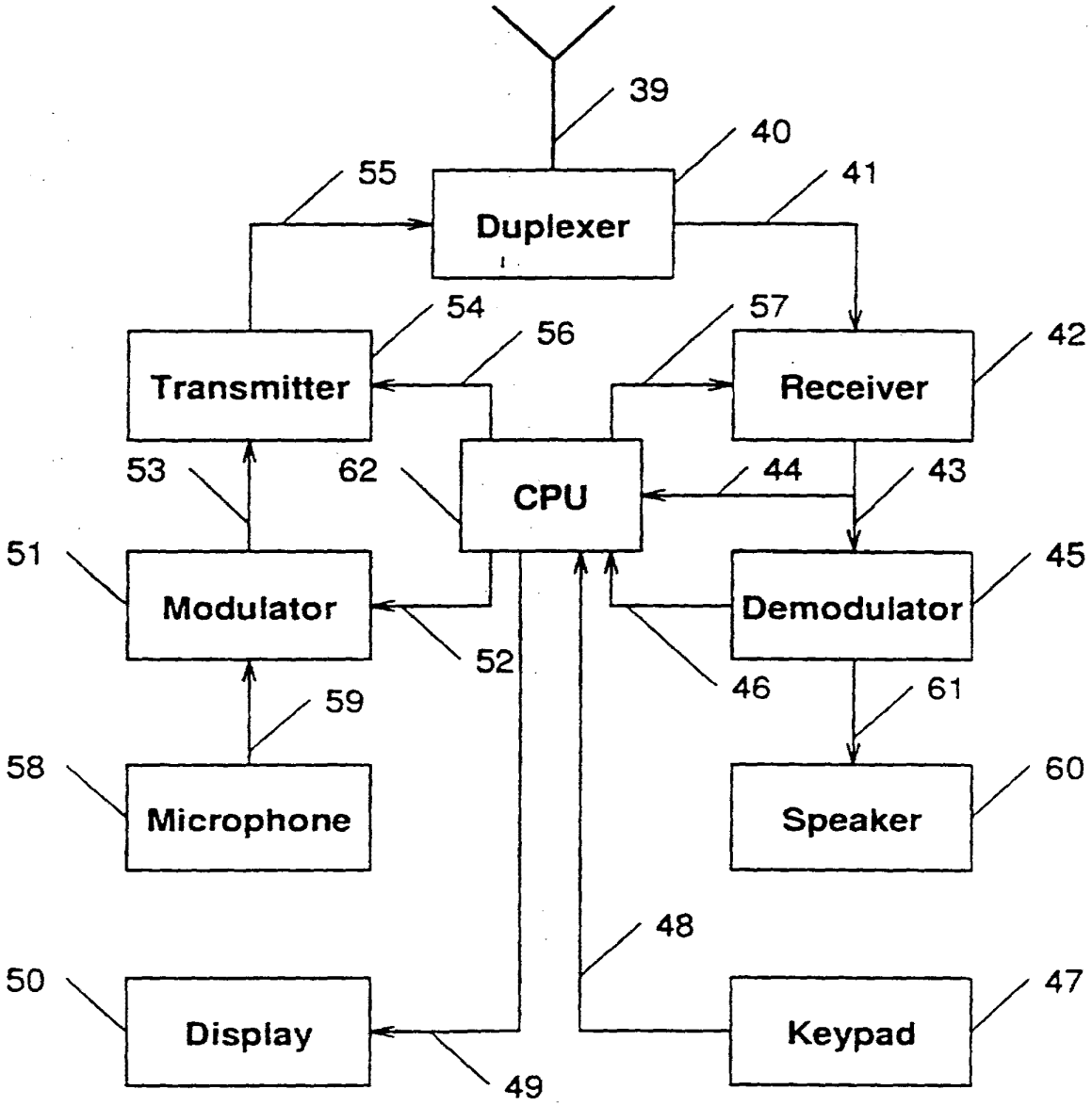

39
40
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54
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Transmitter
Receiver
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43
51
Modulator
Demodulator
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59
61
58
Microphone
Speaker
60
48
50
Display
Keypad
47
49

FIG. 8

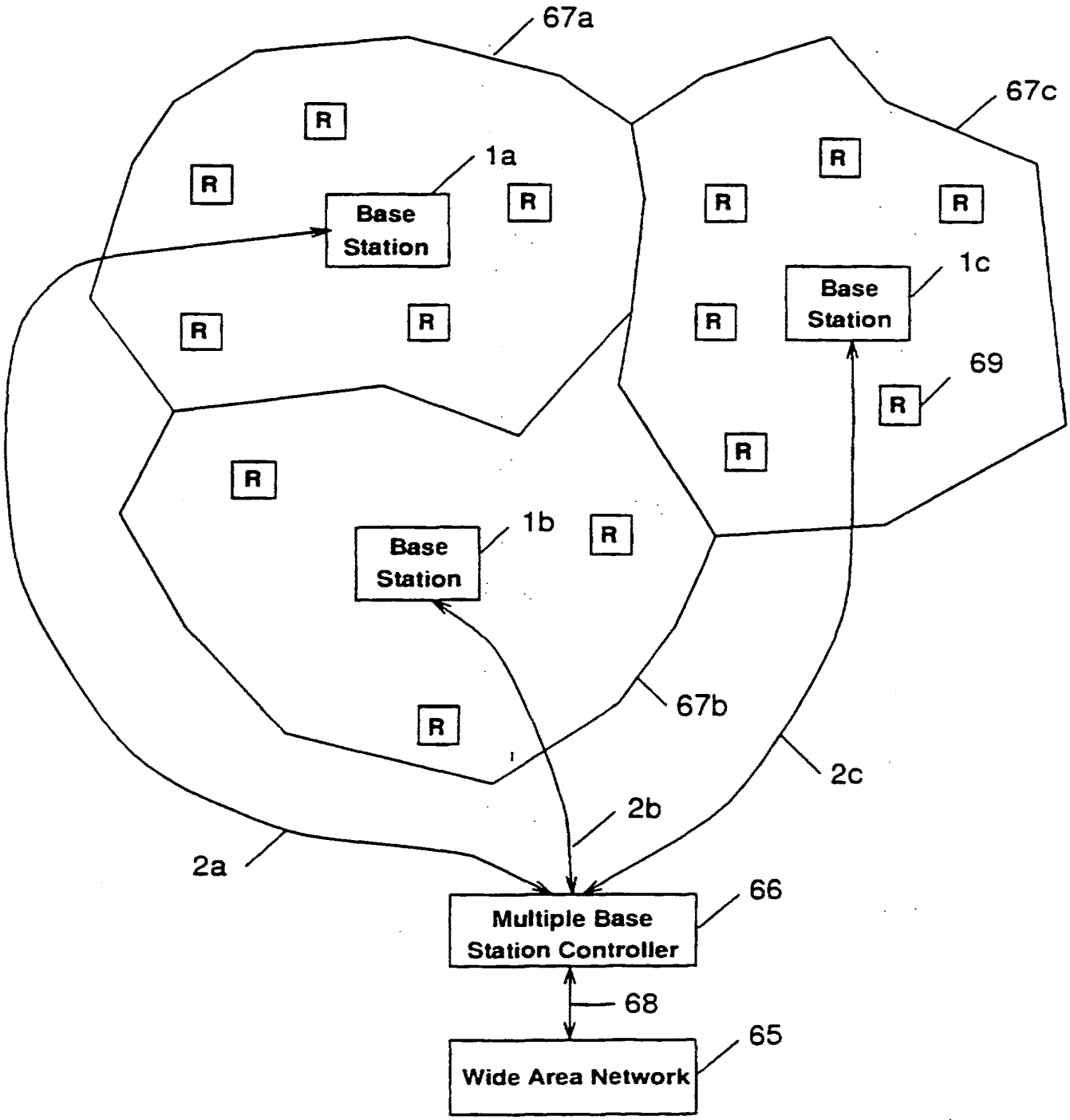

67a
67c
R
1a
Base Station
1c
69
1b
67b
2c
2b
2a
66
Multiple Base Station Controller
68
65
Wide Area Network

FIG. 9

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US95/15641

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :H04Q 7/20
US CL :370/95.1, 95.3, 119; 342/368, 442, 378, 383, 384; 364/572, 574, 578, 581; 375/200, 205
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 370/95.1, 95.3, 119; 342/368, 442, 378, 383, 384; 364/572, 574, 578, 581; 375/200, 205

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US, A, 5,260,968 (GARDNER ET AL.) 09 November 1993, Fig. 7, 8, and col. 14, line 25, to col. 15, line 41.	1, 6, 9, 10-12, 14, 24, and 31
Y		13
Y	US, A, 5,103,459 (GILHOUSEN ET AL.) 07 April 1992, Fig. 9. and col. 9.	13

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be part of particular relevance	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E"	earlier document published on or after the international filing date	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&"	document member of the same patent family
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search 07 MARCH 1996	Date of mailing of the international search report 19 MAR 1996
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer CHAU T. NGUYEN Telephone No. (703) 308-5340

Form PCT/ISA/210 (second sheet)(July 1992)*

OIPE JC54
MAY 23 2003
PATENT & TRADEMARK OFFICE

PCT

PATENT
Attorney Docket No. 401548

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

#6

In re Application of:

MASAKI et al.

Application No. 10/084,614

Art Unit: Unassigned

Examiner: Unassigned

Filed: February 4, 2002

For: BIDDING MECHANISM FOR DETERMINING PRIORITY NEWORK CONNECTIONS

RESPONSE TO NOTIFICATION OF MISSING REQUIREMENTS

Mail Stop Missing Parts
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir:

In response to the Notification of Missing Requirements mailed May 12, 2003, Applicants request that the Notice be withdrawn because it has been sent in error.

According to the Notice, although a Declaration was received, the Declaration is defective because it does not identify the application to which it is directed. The Notification states that the Declaration must identify the application by the international application number and international filing date.

The patent application was filed with two Declarations, one Declaration signed by each of the two inventors. Although there is no statement that no Declaration was received, to prove the filing of the Declarations, a copy of the postcard received from the U.S. Patent and Trademark Office and indicating the presence of the Declarations is attached.

Also attached are copies of the two Declarations filed with the patent application. Attention is directed to the first page of each of the two Declarations where the international application to which the Declarations pertain is identified along with the international filing date. These Declarations are entirely consistent with the requirements of the U.S. Patent and Trademark Office and the statement in the Notification to the contrary is erroneous. No surcharge is due and there is no deadline to be met for the completion of this application.

The Notification states that an additional claim fee of $1,638.00 is required because of the presence of ninety-one (91) claims over twenty (20).

Presumably a copy of the correct application, which was published as WO 01/97500 is present in the file. If a copy is not present, then an additional copy is supplied herewith. The application includes eighteen (18) pages and a total of twenty-two (22) claims with two (2) independent claims. The correct filing fee of $820.00 was paid at the time the patent application was filed. It is difficult to imagine where the idea arose that there are ninety-one (91) excess claims pending in this patent application or that there is any additional filing fee due.

In view of the errors in the Notification as proven by the attached documents, a formal notice that the Notification has been withdrawn is respectfully requested.

Respectfully submitted,

Jeffrey A. Wyand, Reg. No. 29,458
LEYDIG, VOIT & MAYER
700 Thirteenth Street, N.W., Suite 300
Washington, DC 20005-3960
(202) 737-6770 (telephone)
(202) 737-6776 (facsimile)

Date: May 23, 2003

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Leydig Voit & Mayer, Ltd.
700 13th St. N.W., Suite 300, Washington, D.C. 20005
Phone: 202 737-6770

JAW/etp

The Patent Office acknowledges, and has stamped hereon, the date of the receipt of the items checked below:

Docket No.: 401548/SOGA
Inventor(s): MASAKI ET AL
Title: BIDDING MECHANISM FOR DETERMINING PRIORITY NETWORK CONNECTIONS

10/048614

☒ Transmittal Letter for a (2 pages; w/duplicate copy)
☐ Rule 53(b) appln ☐ Rule 53(c) provisional appln
☒ §371 national phase appln of PCT/US00/16443

No. Pages of Spec.: ____ + Abstract No. Pages of Claims: ____ No. Sheets of Drawings: ____

☒ Application Data Sheet
Fee $820.00
☒ Declarations
☒ Assignments & Fee
☐ Priority Document
☐ Small Entity Statement(s) ( )
☒ Return Receipt Postcard
☒ Check ☐ Charged to Deposit Account
☐ Associate Power of Attorney
☐ Preliminary Amendment
☐ Information Disclosure Statement
☐ PTO-1449 (pages) ☐ & documents

JC07 Rec'd PCT/PTO 04 FEB 2002

Best Available Copy

Declaration and Power of Attorney For Patent Application

特許出願宣言書及び委任状

Japanese Language Declaration

日本語宣言書

下記の氏名の発明者として、私は以下の通り宣言します。

私の住所、私書箱、国籍は下記の私の氏名の後に記載された通りです。

下記の名称の発明に関して請求範囲に記載され、特許出願している発明内容について、私が最初かつ唯一の発明者（下記の氏名が一つの場合）もしくは最初かつ共同発明者（下記の名称が複数の場合）であると信じています。

上記発明の明細書は、

☐ 本書に添付されています。

☐ ___月___日に提出され、米国出願番号または特許協定条約国際出願番号を_____とし、
（該当する場合）_____に訂正されました。

私は、特許請求範囲を含む上記訂正後の明細書を検討し、内容を理解していることをここに表明します。

私は、連邦規則法典第37編第1条56項に定義されるとおり、特許資格の有無について重要な情報を開示する義務があることを認めます。

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled.

BIDDING MECHANISM FOR DETERMINING PRIORITY NETWORK CONNECTIONS

the specification of which

☐ is attached hereto.

☒ was filed on June 15, 2000
as United States Application Number or
PCT International Application Number
PCT/US 00/16443 and was amended on
_____ (if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56.

Japanese Language Declaration
(日本語宣言書)

私は、米国法典第35編119条 (a) - (d) 項又は365条 (b) 項に基づき下記の、米国以外の国の少なくとも一ヵ国を指定している特許協力条約365 (a) 項に基づく国際出願、又は外国での特許出願もしくは発明者証の出願についての外国優先権をここに主張するとともに、優先権を主張している、本出願の前に出願された特許または発明者証の外国出願を以下に、枠内をマークすることで、示しています。

I hereby claim foreign priority under Title 35, United States Code Section 119 (a)-(d) or 365(b) of any foreign application(s) for patent or inventor's certificate, or Section 365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or PCT International application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application(s)
外国での先行出願

(Number) (番号)	(Country) (国名)	(Day/Month/Year Filed) (出願年月日)	Priority Claimed 優先権主張 Yes はい	No いいえ
			☐	☐
			☐	☐

私は、第35編米国法典119条 (e) 項に基づいて下記の米国特許出願規定に記載された権利をここに主張いたします。

I hereby claim the benefit under Title 35, United States Code, Section 119(e) of any United States provisional application(s) listed below.

(Application No.) (出願番号)	(Filing Date) (出願日)

私は、下記の米国法典第35編120条に基づいて下記の米国特許出願に記載された権利、又は米国を指定している特許協力条約365条 (c) に基づく権利をここに主張します。また、本出願の各請求範囲の内容が米国法典第35編112条第1項又は特許協力条約で規定された方法で先行する米国特許出願に開示されていない限り、その先行米国出願書提出日以降で本出願書の日本国内または特許協力条約国際提出日までの期間中に入手された、連邦規則法典第37編1条56項で定義された特許資格の有無に関する重要な情報について開示義務があることを認識しています。

I hereby claim the benefit under Title 35, United States Code, Section 120 of any United States application(s), or Section 365(c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of Title 35, United States Code Section 112, I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56 which became available between the filing date of the prior application and the national or PCT International filing date of application.

(Application No.) (出願番号)	(Filing Date) (出願日)	(Status: Patented, Pending, Abandoned) (現況・特許許可済、係属中、放棄済)

私は、私自信の知識に基づいて本宣言書中で私が行なう表明が真実であり、かつ私の入手した情報と私の信じるところに基づく表明が全て真実であると信じていること、さらに故意になされた虚偽の表明及びそれと同等の行為は米国法典第18編第1001条に基づき、罰金または拘禁、もしくはその両方により処罰されること、そしてそのような故意による虚偽の声明を行なえば、出願した、又は既に許可された特許の有効性が失われることを認識し、よってここに上記のごとく宣誓を致します。

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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Apple EX1002 Page 194

Japanese Language Declaration
（日本語宣言書）

委任状： 私は本出願を審査する手続を行い、且つ米国特許商標庁との全ての業務を遂行するために、記名された発明者として、下記の弁理士及び／または弁理士を任命する。（氏名及び登録番号を記載すること）

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith (list name and registration number).

書類送付先



23548

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Send Correspondence to:

直通電話連絡先：（氏名及び電話番号）



23548

PATENT TRADEMARK OFFICE

Direct Telephone Calls to: (name and telephone number)

唯一または第一発明者氏名		Full name of sole or first inventor Ichiro MASAKI
発明者の署名	日付	Inventor's signature Date 1/28/02
住所		Residence MA, U.S.A.
国籍		Citizenship Japan
郵便の宛先		Post Office Address 73 Guggins Lane Boxborough, MA 01719 U.S.A.
第二共同発明者がいる場合、その氏名		Full name of second joint inventor, if any Ichiro MIZUNUMA
第二共同発明者の署名	日付	Second inventor's signature Date
住所		Residence MA, U.S.A.
国籍		Citizenship Japan
郵便の宛先		Post Office Address 159 Faneuil Street Brighton, MA 02135 U.S.A.

（第三以下の共同発明者についても同様に記載し、署名をすること）

(Supply similar information and signature for third and subsequent joint inventors.)

IPR2023-00796
Apple EX1002 Page 195

Declaration and Power of Attorney For Patent Application

特許出願宣言書及び委任状

Japanese Language Declaration

日本語宣言書

下記の氏名の発明者として、私は以下の通り宣言します。

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BIDDING MECHANISM FOR DETERMINING PRIORITY NETWORK CONNECTIONS

上記発明の明細書は、

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(Number) (番号)	(Country) (国名)	(Day/Month/Year Filed) (出願年月日)	Priority Claimed 優先権主張 Yes はい	No いいえ
			☐	☐
			☐	☐

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IPR2023-00796
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書類送付先



23548

PATENT TRADEMARK OFFICE

Send Correspondence to:

直通電話連絡先：（氏名及び電話番号）



23548

PATENT TRADEMARK OFFICE

Direct Telephone Calls to: (name and telephone number)

唯一または第一発明者氏名	Full name of sole or first inventor Ichiro MASAKI
発明者の署名　日付	Inventor's signature　Date
住所	Residence MA, U.S.A.
国籍	Citizenship Japan
郵便の宛先	Post Office Address 73 Guggins Lane Boxborough, MA 01719 U.S.A.
第二共同発明者がいる場合、その氏名	Full name of second joint inventor, if any Ichiro MIZUNUMA
第二共同発明者の署名　日付	Second inventor's signature　Date Ichiro Mizunuma　Dec 25, 2001
住所	Residence MA, U.S.A.
国籍	Citizenship Japan
郵便の宛先	Post Office Address 159 Faneuil Street Brighton, MA 02135 U.S.A.

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(Supply similar information and signature for third and subsequent joint inventors.)

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Apple EX1002 Page 198

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L1	164	multiplex$3 same modulator same antenna same element$2	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 12:51
L2	101	l1 and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 12:52
L3	40	multiplex$3 with modulator with antenna same element$2	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 12:52
L8	13	multiplex$3 with modulator with antenna same antenna near2 array	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 13:32
L9	7	l8 and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 15:12
L10	8	process$3 same (plurality parallel numberous) near2 (input data symbols user) same multipl$5 same complex same baseband	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 15:13
L12	5	l10 and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 15:14
L13	0	l12 and antenna near array	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 15:13
L14	11	process$3 same (plurality parallel numberous) near2 (input data symbols user) same multipl$5 same complex and antenna near array	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 15:27

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L15	4	l14 and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 15:31
L17	2	l15 and multiplex$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 15:14
L27	54	(multiple plurality parallel numberous two second) near2 (input$1 data symbol$1 user$1 stream$1) same (multiplication multiplied multiply$3) same (complex or in$1phase sin$1 cos$3) and multiplex$3 and antenna near array and (modulat$3 demodulat$3)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 16:00
L28	32	l27 and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 16:01
L29	15	(multiple plurality parallel numberous two second) near2 (input$1 data symbol$1 user$1 stream$1) same (multiplication multiplied multiply$3) same (complex or in$1phase sin$1 cos$3) same (amplitude phase beam) and multiplex$3 and antenna near array and (modulat$3 demodulat$3)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 16:00
L30	9	l29 and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 17:38
L33	152	antenna same (down near convert$3 baseband) same (parallel plurality) same multiplex$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 17:39
L34	74	antenna with (down near convert$3 baseband) same (parallel plurality) same multiplex$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 17:38

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L35	46	l34 and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 17:39
L36	6	antenna near2 array same (down near convert$3 baseband) same (parallel plurality) same multiplex$3 and decimat$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 17:39
L37	0	l36 and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 17:40
L38	7	antenna near2 array and antenna same (down near convert$3 baseband) same (parallel plurality) same multiplex$3 and decimat$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 18:00
L39	1	l38 and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 17:40
L40	6	antenna near2 array and antenna same (up near convert$3 radio) same (parallel plurality) same demultiplex$3 and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 18:14
L41	2	l40 and interpolation	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 18:04
L42	1	l40 and interpolation and (IF intermediate near frequency)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 18:05
L43	3	antenna near2 array and antenna same (up near convert$3 radio) same (parallel plurality) same demultiplex$3 and (IF intermediate near frequency) and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 18:14
L48	7	(transmit$4 uplink) and (intermediate near frequency IF) and demultiplexer and interpolat$3 and antenna near2 array and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 18:26

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L50	8339	(transmit$4 uplink) and antenna near2 array and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 18:27
L52	22	l50 and (intermediate near frequency IF) and demultiplex$3 and interpolat$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 18:55
L53	2	("20020154687").PN.	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2005/06/22 18:47
L54	260	beamform$3 with baseband	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 19:02
L55	29	beamform$3 with baseband same modulat$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 19:02
L56	15	l55 and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 19:10
L57	44	l50 and intermediate near frequency same (uplink up$1convert$3 transmit$4) and demultiplex$3 same (uplink transmit$4)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 19:11
L58	9	l57 and interpolat$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 19:11
L59	1864	(transceiver modem) and duplex near3 time and switch$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 20:01
L62	264	(transceiver modem) and duplex near3 time and switch and modulator and demodulator and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 19:38

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L63	51	(transceiver modem) and duplex near3 time and switch same modulator same demodulator and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 19:50
L66	8	(transceiver modem) and duplex near3 time same switch and switch same modulator same demodulator and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 19:50
L68	2	("5583562").PN.	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2005/06/22 20:06
L69	2	("6763062").PN.	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2005/06/22 20:06
L70	3	("6831943").PN.	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2005/06/22 20:06
L71	2	("5937348").PN.	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2005/06/22 20:07
L72	363	(transceiver modem) and FDMA and FPGA and (vlsi or ASIC)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 20:09
L73	74	l72 and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 20:08
L74	28	(transceiver modem).ab. and FDMA and FPGA and (vlsi or ASIC)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 20:09
L75	13	(transceiver modem).ab. and FDMA and FPGA and (vlsi or ASIC) and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 20:11

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L76	2	("5809422").PN.	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2005/06/22 20:11
S1	2	("6370182").PN.	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2005/06/15 14:19
S2	2	("20020154687").PN.	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2005/06/15 15:17
S3	98	baseband same modulat$3 same demodulat$3 and phase$1 near2 array$1 near2 antenna	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/15 15:42
S4	50	S3 and phase and amplitude	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/15 16:06
S5	25	S4 and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/15 17:08
S6	7	S5 and time near multiplex$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/15 15:20
S7	29	S3 and (phase and amplitude) same process$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/15 16:08
S8	5	baseband same modulat$3 same demodulat$3 and steer$5 near array$1 near2 antenna	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/15 15:43
S9	23	S5 and power	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/15 16:06

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S10	12	S3 and (phase and amplitude) same process$3 same modulat$3 same demodulat$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/15 16:42
S11	2520	(375/222).CCLS.	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2005/06/15 16:21
S12	1	S11 and S3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/15 16:22
S13	15146	(antenna receiver) same (beam near form$3 or phase$1 near3 (array rotat$3))	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/15 16:44
S14	622	S13 and baseband and modulat$3 and demodulat$3 and processor and phase and amplitude	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/15 17:08
S15	72	S13 and baseband and (modulat$3 same demodulat$3 same process$3 same phase same amplitude)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/15 17:08
S16	11	S13 and baseband and modulat$3 same demodulat$3 same (shared joint$2 one single) near3 processor and phase and amplitude	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/15 17:10
S17	4229	375/219-223.ccls.	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/15 17:22
S18	459	S17 and modulator and demodulator and phase and amplitude	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/15 17:23
S19	217	S18 and baseband	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/15 17:23

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S20	70	S17 and modulator same demodulator same processor and phase and amplitude	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/15 17:23
S21	38	S20 and baseband	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/15 17:23
S22	33	S21 and @ad<="20020228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/15 17:56
S23	4229	375/219-223.ccls.	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/15 17:56
S24	70	S23 and modulator same demodulator same processor and phase and amplitude	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/15 17:56
S25	38	S24 and baseband	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/15 17:56
S26	33	S25 and @ad<="20020228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/15 17:56
S27	6	S26 and array with antenna	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/15 17:56
S28	147	((beam near forming same antenna) or (array near2 antenna)) and modulat$3 and demodulat$3 and baseband with process$3 same phase and amplitude	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 11:04
S29	170	((beam$2forming same antenna) or (array near2 antenna)) and modulat$3 and demodulat$3 and baseband with process$3 same phase and amplitude	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 11:07

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S30	79	S29 and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 11:07
S31	6	S30 and 375/219-223.ccls.	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 11:08
S32	90	((beam$2forming same antenna) or (array near2 antenna)) and modulat$3 and demodulat$3 and baseband with process$3 same phase same amplitude	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 11:37
S33	41	S32 and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 15:20
S34	3	S33 and 375/219-223.ccls.	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 11:14
S35	2	("5937005").PN.	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2005/06/17 11:14
S36	12	S33 and (transceiver or modem)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 11:24
S37	5	((beam$2forming same antenna) or (array near2 antenna)) and modulat$3 and demodulat$3 and baseband same (sin and cos) same phase same amplitude	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 11:36
S38	2	S37 and (transceiver or modem)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 11:37
S39	4	modulat$3 and demodulat$3 and baseband same (sin$5cos or sin near2 cos) same phase same amplitude and (transceiver or modem)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 12:07

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S40	2	("5764187").PN.	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2005/06/17 11:51
S41	3	"SEQUENTIAL-ACQUISITION, MULTI-BAND, MULTI-CHANNEL"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 11:52
S42	8	(("5764187") or ("5943010") or ("6052085") or ("6167099")).PN.	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2005/06/17 12:03
S43	23	modulat$3 and baseband with process$3 same (sin$3cos or sin near2 cos)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 12:04
S44	16	S43 and @ad<="20020228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 12:04
S45	1103	modulat$3 and demodulat$3 and baseband and process$3 same phase same amplitude and (transceiver or modem)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 14:10
S46	473	(shared common) near2 process$3 same ((transmit$4 and receiv$3) or (uplink and downlink)) and modulat$3 and demodulat$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 14:12
S47	1	(shared common) near2 (process$3) same front$2end same ((transmit$4 and receiv$3) or (uplink and downlink)) and modulat$3 and demodulat$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 14:13
S48	199	S46 and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 14:12
S49	6	(shared common) near2 (process$3) same phase same amplitude same ((transmit$4 and receiv$3) or (uplink and downlink)) and modulat$3 and demodulat$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 14:13

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S50	25	(shared common) with (process$3) same phase same amplitude same ((transmit$4 and receiv$3) or (uplink and downlink)) and modulat$3 and demodulat$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 15:18
S51	18	S50 and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 14:21
S52	111631	modulat$3 and demodulat$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 14:20
S53	25	(shared common) with (process$3) same phase same amplitude same ((transmit$4 and receiv$3) or (uplink and downlink)) and S52	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 14:21
S54	15	S43 and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 14:22
S55	18	S53 and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 14:22
S56	115	(shared common) near3 (process$3) same ((transmit$4 and receiv$3) or (uplink and downlink)) and process$3 same phase same amplitude and modulat$3 and demodulat$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 15:22
S57	76	S56 and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 15:23
S58	28	(shared common) near3 (process$3) same ((transmit$4 and receiv$3) or (uplink and downlink)) and process$3 same ((adjust$3 rotat$3 chang$3 calibrat$3) near3 phase and (adjust$3 rotat$3 chang$3 calibrat$3) near3 amplitude) and modulat$3 and demodulat$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 15:26

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S59	24	S58 and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 15:27
S60	28	(shared common) near3 (process$3) same ((transmit$4 and receiv$3) or (uplink and downlink)) and process$3 same ((adjust$3 rotat$3 chang$3 calibrat$3 modif$7) near3 phase and (adjust$3 rotat$3 chang$3 calibrat$3 modif$7) near3 amplitude) and modulat$3 and demodulat$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 15:25
S61	20	(shared common) near3 (process$3) same ((transmit$4 and receiv$3) or (uplink and downlink)) and process$3 same ((adjust$3 rotat$3 chang$3 calibrat$3) near3 phase and (adjust$3 rotat$3 chang$3 calibrat$3) near3 amplitude) and modulator and demodulator	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 13:49
S62	19	S61 and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 15:27
S63	16	("3986123").URPN.	USPAT	OR	ON	2005/06/17 17:13
S67	0	"19750808".ad. and "D'oro"	USPAT	OR	ON	2005/06/17 17:25
S68	0	"19750808".ad. and "enzo"	USPAT	OR	ON	2005/06/17 17:14
S69	227	(beam$2forming antenna near2 array) and baseband and amplitude same phase same power	USPAT	OR	ON	2005/06/17 18:14
S70	137	S69 and multiplex$3	USPAT	OR	ON	2005/06/17 18:13
S71	104	S70 and oscillator	USPAT	OR	ON	2005/06/17 17:26
S72	113	S70 and @ad<="20010228"	USPAT	OR	ON	2005/06/17 18:13
S73	0	(beam$2forming with antenna or antenna near2 array) and baseband same amplitude same phase same power same scal$3	USPAT	OR	ON	2005/06/17 18:16
S74	28	(beam$2forming with antenna or antenna near2 array) and baseband same amplitude same phase same power	USPAT	OR	ON	2005/06/17 18:17

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S75	68	(beam$2forming with antenna or antenna near2 array) and baseband same amplitude same phase same power	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 18:17
S76	28	S75 and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 18:28
S77	1	polarization adj distortion with power near (control reduc$4 usage sav$3)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 18:29
S78	4	(amplitude and phase) near2 distortion with power near (control reduc$4 usage sav$3)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/20 12:17
S79	1174	steer$4 near3 array near2 antenna	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/20 12:17
S80	120	S79 and (adjust$3 chang$3 modif$7 var$5) near3 (phase and amplitude)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/20 12:19
S81	17	S79 and (adjust$3 chang$3 modif$7 var$5) near3 (phase and amplitude) and modulator and demodulator	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/20 12:39
S82	13	S81 and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/20 12:39
S83	2	time near multiplex$3 same antenna near2 array same amplitude same phase and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/20 13:00
S84	10	benefit$3 with time near multiplex$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/20 15:12

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S85	8	modulator with plurality near2 (signal$1 data input user$2) same time near multiplex$2 and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/20 15:21
S86	1	modulator with plurality near2 (signal$1 data input user$2) same time near multiplex$2 same process$3 and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/20 15:16
S87	7	modulator with plurality near2 (signal$1 data input user$2) same time near3 multiplex$2 and antenna and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/20 15:52
S88	347	modulator same time near3 multiplex$2 and antenna and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/20 15:52
S89	457	modulator with multiplex$2 and multiplex$2 near2 time and antenna and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/20 15:53
S90	65	modulator near4 multiplex$2 same multiplex$2 near2 time and antenna and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/20 15:53
S91	12	S90 and "375"/$.ccls.	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/20 17:02
S92	0	S91 and antenna near2 array	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/20 16:53
S93	346	baseband near modulator	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/20 17:02
S94	34	baseband near4 modulator with (purpose benefit advantag$5)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/20 17:03

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S95	22	S94 and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/20 17:03

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/084,614	02/28/2002	Scott Bierly	0918.0153C	1621

27896 7590 06/28/2005

EDELL, SHAPIRO & FINNAN, LLC
1901 RESEARCH BOULEVARD
SUITE 400
ROCKVILLE, MD 20850

EXAMINER	
LU, JIA	

ART UNIT	PAPER NUMBER
2634	

DATE MAILED: 06/28/2005

Please find below and/or attached an Office communication concerning this application or proceeding.

Office Action Summary	Application No.	Applicant(s)	
	10/084,614	BIERLY ET AL.	
	Examiner	Art Unit	
	Jia W. Lu	2634	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If the period for reply specified above is less than thirty (30) days, a reply within the statutory minimum of thirty (30) days will be considered timely.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☒ Responsive to communication(s) filed on *28 February 2002*.

2a)☐ This action is **FINAL**. 2b)☒ This action is non-final.

3)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

4)☒ Claim(s) *1-24* is/are pending in the application.

4a) Of the above claim(s) _____ is/are withdrawn from consideration.

5)☐ Claim(s) _____ is/are allowed.

6)☒ Claim(s) *1-4 and 7-24* is/are rejected.

7)☒ Claim(s) *5 and 6* is/are objected to.

8)☐ Claim(s) _____ are subject to restriction and/or election requirement.

Application Papers

9)☐ The specification is objected to by the Examiner.

10)☒ The drawing(s) filed on *28 February 2002* is/are: a)☒ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

11)☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

Priority under 35 U.S.C. § 119

12)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a)☐ All b)☐ Some * c)☐ None of:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☒ Notice of References Cited (PTO-892)
2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)
3) ☒ Information Disclosure Statement(s) (PTO-1449 or PTO/SB/08) Paper No(s)/Mail Date _____.
4) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____.
5) ☐ Notice of Informal Patent Application (PTO-152)
6) ☐ Other: _____.

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DETAILED ACTION

Claim Rejections - 35 USC § 103

1. The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

> (a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.

The factual inquiries set forth in *Graham* **v.** *John Deere Co.*, 383 U.S. 1, 148 USPQ 459 (1966), that are applied for establishing a background for determining obviousness under 35 U.S.C. 103(a) are summarized as follows:

1. Determining the scope and contents of the prior art.
2. Ascertaining the differences between the prior art and the claims at issue.
3. Resolving the level of ordinary skill in the pertinent art.
4. Considering objective evidence present in the application indicating obviousness or nonobviousness.

2. Claims 1, 22-24 are rejected under 35 U.S.C. 103(a) as being unpatentable over US patent 3,986,123, in view of Japanese Patent 8222934, further in view of US patent 6,763,062.

   a. Regarding claim 1, patent '123 discloses a modulator (fig 3, "DIS") in a transmitter (fig 2, "CLT"), a demodulator (fig 5, "DIS") in a receiver (fig 2, "CLR"), and a shared processor (fig 2, "ELT", described on column 4, lines 40-44 to be in an application that is incorporated in its entity) configured to receive signals from the modulator and signals going to the demodulator (fig 2) and adjusts the amplitudes and phases of the incoming and outgoing signals in order to reduce processing distortion (column 1, lines

56-61). While patent '123 does not teach power control, amplitude and phase adjustments are well known in the art to be directly related to power control (for example, see title abstract of JP 08222934). The modulating and processing of signals in the baseband is also well known in the art to be the most common and basic form used in transmission. While patent '123 does not teach the transmitting and receiving via phased array antenna, the art of steerable phased array antenna is well known in the art, as shown in patent '062 (figure 2, element 41). It would have been obvious for one ordinarily skilled in the art to use a processor described in patent '123 to adjust phase and amplitude elements in order to control composite antenna pattern in both uplink and downlink, to ensure low gain in the direction of interference and higher gain in the direction of transmission/reception (patent '062, fig 2).

b. Regarding claims 22 and 23, since a modem by definition is a system which modulates and demodulates, and a transceiver is a system that transmits and receives, patent '123 is both a modem and a transceiver.

3. Claims 2 and 3 are rejected under 35 U.S.C. 103(a) as being unpatentable over US patent 3,986,123 in view of Japanese Patent 8222934 and US patent 6,763,062 as applied to claim 1 above, and further in view of US patent 5,583,562.

a. Regarding claim 2, although patent '123 does not show time-multiplexing of received data, the use of time-multiplexing in transceiver systems is

well known for their ability to increase the throughput of a communications resource (for example, patent '562, fig 1). It would have been obvious for one ordinarily skilled in the art to use time-multiplexing in a system described in 2 above in order to allow more users to use a single channel in a duplex system.

b. Regarding claim 3, while patent '123 does not show the modulator to provide a time-multiplexed data stream from an input of multiple data streams, patent '562 shows a modulator (fig 1, element 130) receiving data symbols from a plurality of user channels (fig 1, element 110) and provide a single time-multiplexed data stream (column 5, lines 30-40). The reason to combine time-multiplexing with a modulator is stated in part a above.

4. Claim 4 is rejected under 35 U.S.C. 103(a) as being unpatentable over US patent 3,986,123 in view of Japanese Patent 8222934 and US patent 6,763,062, further in view of US patent 5,583,562 as applied to claim 3 above, and further in view of US patent 6,768,458. While patent '123 does not show a modulator generating a plurality of modulated data in the time-multiplexed stream corresponding to a plurality of antenna elements, patent '458 shows a modulator (figure 5, elements 216 and 218) generating a plurality of modulated data symbols in the time-multiplexed stream, corresponding to a plurality of antenna elements (figure 5, element 250). It would have been obvious for one ordinarily skilled in the art for a modulating system described in patent '123 to time-multiplex a plurality of

modulated data symbols corresponding to antenna elements in order to increase directional gain in transmission.

5. Claims 7-10 are rejected under 35 U.S.C. 103(a) as being unpatentable over US patent 3,986,123 in view of Japanese Patent 8222934 and US patent 6,763,062 as applied to claim 1 above, and further in view of US patent 6,831,943.

   a. Regarding claims 7-9, patent '123 does not describe the complex multiplication of signals in the processor relating to a plurality of user channels in a time-multiplexed manner. However, patent '943 teaches a transmission system where a processor unit (figure 10, elements 18 and 20) performs complex multiplication on signals on incoming signals that have been time-multiplexed (column 29, line 43), associated with a plurality of antennas (figure 1, elements A12). While the plurality of user channels is not shown, it is well known that a system using time-multiplexing takes signals from different users in order to multiplex them. It would have been obvious for one ordinarily skilled in the art to use complex multiplication in a system described in patent '123 for beamforming (column 7, lines 18-47) and power adjustments (column 15, lines 47-54) in order to improve power usage and reduce interference.

   b. Regarding claim 10, patent '123 does not disclose a beamformer configured to receive time-multiplexed baseband signals from shared baseband processor. Patent '943, however, shows a beamformer (figure 2, element 52) capable of receiving time-multiplexed (column 29, line 43)

signals from a front-end processor. It would have been obvious for one ordinarily skilled in the art to use a beamformer in a transceiver system described in patent '123 when incoming signals require directional and rotational adjustments in order to acquire precise directional transmission to increase gain while using lower power.

6. Claims 11-13 are rejected under 35 U.S.C. 103(a) as being unpatentable over US patent 3,986,123 in view of Japanese Patent 8222934 and US patent 6,763,062 as applied to claim 1 above, further in view of US patent 6,549,527. While patent '123 does not show the front-end specifics of its receiving circuitry, patent '527 shows a plurality of down-converters (column 2, lines 29-33) separately down-converting signals for each antenna element (figure 14, element 142). It also teaches the down-converting circuitry to include decimation means (figure 1, element 11) followed by multiplexing means (figure 1, element 12). It would have been obvious for one ordinarily skilled in the art to use decimation and multiplexing in the receiver end in order enable signal processing in an antenna array system without lowering system performance or increasing price, dimension or complexity of the hardware (column 3, line 48-line 59).
7. Claims 14-16, 18 are rejected under 35 U.S.C. 103(a) as being unpatentable over US patent 3,986,123 in view of Japanese Patent 8222934 and US patent 6,763,062 as applied to claim 1 above, further in view of US patent 5,809,422.
    a. Regarding claims 14-16, while patent '123 does not show a demultiplexer and up-converters in transmission, patent '422 teaches the use of

demultiplexers (figure 4, element 134) and IF up-converters (column 7, lines 33-40) in separate transmitting antenna elements (column 11, lines 56-60). Patent '422 also teaches interpolation in order to increase the sampling rate of the transmission signals (column 13, lines 39-40). It would have been obvious for one ordinarily skilled in the art to employ demultiplexing in an transmission end as described in patent '123 in order to separate time-multiplexed symbols for transmission and up convert baseband signals into a higher, intermediate frequency in order to enable signal transmission in a wireless medium.

b. Regarding claim 18, while patent '123 does not teach the use of TDMA, patent '422 teaches the use of TDMA (column 8, line 41) in its transceiver system. Because TDMA is a very common technique used in transmission, and it would have been obvious to one ordinarily skilled in the art to use TDMA to allow multiple users to share time slots within a single channel.

8. Claim 17 is rejected under 35 U.S.C. 103(a) as being unpatentable over US patent 3,986,123 in view of Japanese Patent 8222934 and US patent 6,763,062 as applied to claim 1 above, further in view of US patent 5,937,348. While patent '123 teaches the use of a duplexer between the transmitter and receiver portion of its transceiver, it does not specify the duplex to be time-division or the use of a switch. Patent '348 shows a duplex switch capable of using time division duplex (column 5, line 20). It would have been obvious to one ordinarily skilled in the art

to use a switch in a time division duplex transceiver system described in patent '123 in order to provide better control over the system while allowing it to transmit and receive using a single front-end processor.

9. Claims 19-21 are rejected under 35 U.S.C. 103(a) as being unpatentable over US patent 3,986,123 in view of Japanese Patent 8222934 and US patent 6,763,062 as applied to claim 1 above, further in view of US patent application 20020141478. While patent '123 does not show the use FDMA, FPGA or VLSI in its transceiver system, application '478 teaches all these elements (FDMA on paragraph 2, line 6, FPGA on paragraph 621, line 4, and ASIC on paragraph 621, line 5). It would have been obvious to one ordinarily skilled in the art to use FDMA to allow multiple users to share time slots, FPGA to increase flexibility in designs and programming, or ASIC to reduce power usage, save space and lower cost of production.

Allowable Subject Matter

10. Claims 5 and 6 are objected to as being dependent upon a rejected base claim, but would be allowable if rewritten in independent form including all of the limitations of the base claim and any intervening claims.

Conclusion

Any inquiry concerning this communication or earlier communications from the examiner should be directed to Jia W. Lu whose telephone number is 571-272-6042. The examiner can normally be reached on Mon- Fri, 10:30AM-6:30PM.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Stephen Chin can be reached on (571)272-3056. The fax phone number for the organization where this application or proceeding is assigned is 703-872-9306.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free).

Jia Lu
Examiner

STEPHEN CHIN
SUPERVISORY PATENT EXAMINER
TECHNOLOGY CENTER 2600

Sheet 1 of 1

FORM PTO-1449 (modified)

U.S. DEPARTMENT OF COMMERCE
PATENT AND TRADEMARK OFFICE

LIST OF REFERENCES CITED BY APPLICANT(S)
(Use several sheets if necessary)

Date Submitted to PTO:

OIPE JC139 JUN 18 2002 PATENT & TRADEMARK OFFICE

ATTY DOCKET NO. 0918.0153C	SERIAL NO. 10/084,614
APPLICANT: Scott Bierly, et al.	
FILING DATE : February 28, 2002	GROUP

U.S. PATENT DOCUMENTS

*EXAMINER INITIAL		DOCUMENT NUMBER	DATE	NAME	CLASS	SUBCLASS	FILING DATE IF APPROPRIATE
JL		5,764,187	06/09/98	Rudish et al.			
JL		5,943,010	08/24/99	Rudish et al.			
JL		6,052,085	04/18/00	Hanson et al.			

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JUN 19 2002
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FOREIGN PATENT DOCUMENTS

		DOCUMENT NUMBER	DATE	COUNTRY	CLASS	SUBCLASS	TRANSLATION YES/NO/ OR ABSTRACT
JL	✓	WO 01/59962	08/16/01				
JL	✓	WO 00/11800	03/02/00				

OTHER DOCUMENT(S) (Including Author, Title, Date, Pertinent Pages, Etc.)

JL		✓	Bierly, et al.; Sequential-Acquisition, Multi-Band, Multi-Channel, Matched Filter; U.S. Patent Application Serial No. 09/707,909; filed November 8, 2000.

EXAMINER [signature] DATE CONSIDERED 6/22/05

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609; Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

IPT-212(a):4/90

Sheet 1 of 1

FORM PTO-1449 (modified)

U.S. DEPARTMENT OF COMMERCE
PATENT AND TRADEMARK OFFICE

LIST OF REFERENCES CITED BY APPLICANT(S)
(Use several sheets if necessary)

Date Submitted to PTO:

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AUG 07 2002
PATENT & TRADEMARK OFFICE

ATTY DOCKET NO. 0918.0153C	SERIAL NO. 10/084,614
APPLICANT: Scott Bierly, et al.	
FILING DATE : February 28, 2002	GROUP

U.S. PATENT DOCUMENTS

*EXAMINER INITIAL		DOCUMENT NUMBER	DATE	NAME	CLASS	SUBCLASS	FILING DATE IF APPROPRIATE
JL		6,167,099	12/26/00	Rader et al			

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FOREIGN PATENT DOCUMENTS

		DOCUMENT NUMBER	DATE	COUNTRY	CLASS	SUBCLASS	TRANSLATION YES/NO/ OR ABSTRACT
	✓	WO 96/22662	12/01/95				

OTHER DOCUMENT(S) (Including Author, Title, Date, Pertinent Pages, Etc.)

EXAMINER [signature] DATE CONSIDERED 6/22/05

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609; Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

IPT-212(a):4/90

Notice of References Cited	Application/Control No. 10/084,614	Applicant(s)/Patent Under Reexamination BIERLY ET AL.	
	Examiner Jia W. Lu	Art Unit 2634	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	Classification
	A	US-3,986,123	10-1976	Tirro et al.	455/60
	B	US-2002/0141478	10-2002	Ozluturk et al.	375/130
	C	US-5,937,348	08-1999	Cina et al.	455/421
	D	US-6,768,458	07-2004	Green et al.	342/375
	E	US-6,831,943	12-2004	Dabak et al.	375/147
	F	US-6,763,062	07-2004	Kohno et al.	375/220
	G	US-5,583,562	12-1996	Birch et al.	725/151
	H	US-5,809,422	09-1998	Raleigh et al.	455/449
	I	US-			
	J	US-			
	K	US-			
	L	US-			
	M	US-			

FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	Classification
	N					
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	S					
	T					

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	
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	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

Index of Claims

Application/Control No.	Applicant(s)/Patent under Reexamination
10/084,614	BIERLY ET AL.
Examiner	**Art Unit**
Jia W. Lu	2634

√	Rejected	–	(Through numeral) Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

Claim		Date
Final	Original	6/24/05
	1	√
	2	√
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Search Notes

Application/Control No.	Applicant(s)/Patent under Reexamination
10/084,614	BIERLY ET AL.
Examiner	**Art Unit**
Jia W. Lu	2634

SEARCHED			
Class	Subclass	Date	Examiner
375	219	6/15/2005	JL
375	220	6/15/2005	JL
375	221	6/15/2005	JL
375	222	6/15/2005	JL
375	223	6/15/2005	JL

INTERFERENCE SEARCHED			
Class	Subclass	Date	Examiner
375	**222**	6/15/2005	**JL**

SEARCH NOTES (INCLUDING SEARCH STRATEGY)		
	DATE	EXMR
US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	6/15/2005	JL
INVENTORSHIP	6/14/2005	JL

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Alexandria, Virginia 22313-1450
www.uspto.gov

Bib Data Sheet

CONFIRMATION NO. 1621

SERIAL NUMBER	FILING DATE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.
10/084,614	02/28/2002 RULE	375	2634	0918.0153C

APPLICANTS

Scott Bierly, Oak Hill, VA;

Marc Harlacher, Herndon, VA;
Robert Smarrelli, Oak Hill, VA;Aaron Weinberg, Potomac, MD;

** CONTINUING DATA **********
This appln claims benefit of 60/271,961 02/28/2001

Yes

** FOREIGN APPLICATIONS **********

NO

IF REQUIRED, FOREIGN FILING LICENSE GRANTED
** 03/18/2002

Foreign Priority claimed	STATE OR	SHEETS	TOTAL	INDEPENDENT
35 USC 119 (a-d) conditions met	COUNTRY	DRAWING	CLAIMS	CLAIMS
Verified and Acknowledged	VA	3	24	1

☐ yes ☑ no
☐ yes ☒ no ☐ Met after Allowance
Examiner's Signature _____ Initials

ADDRESS
27896
EDELL, SHAPIRO & FINNAN, LLC
1901 RESEARCH BOULEVARD
SUITE 400
ROCKVILLE , MD
20850

TITLE
Integrated beamformer/modem architecture

FILING FEE	FEES: Authority has been given in Paper	☐ All Fees
RECEIVED 942	No. _____ to charge/credit DEPOSIT ACCOUNT No. _____ for following:	☐ 1.16 Fees (Filing) ☐ 1.17 Fees (Processing Ext. of time) ☐ 1.18 Fees (Issue)

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OIPE IAP23
OCT 06 2005
PATENT & TRADEMARK OFFICE

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Appl. No.	:	10/084,614
Applicant	:	Scott BIERLY et al.
Filed	:	February 28, 2002
TC/A.U.	:	2634
Examiner	:	LU, J.
Confirmation No.	:	1621
Docket No.	:	0918.0153C
Customer No.	:	27896
Title	:	Integrated Beamformer/Modem Architecture

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

AMENDMENT

Sir:

In response to the Office Action mailed June 28, 2005, please amend the above-identified application as follows:

Amendments to the Claims are reflected in the listing of claims, which begins on page 2 of this paper.

Remarks begin on page 9 of this paper.

10/07/2005 SZEWDIE1 00000026 10084614
01 FC:1202 300.00 OP

Amendments to the Claims:

This listing of claims will replace all prior versions, and listings, of claims in the application.

Listing of Claims:

1. (Currently Amended) An apparatus for modulating and demodulating signals transmitted and received via an electronically steerable phased array antenna comprising a plurality of antenna elements, the apparatus comprising:

a baseband modulator configured to modulate outbound digital baseband signals to be transmitted via the phased array antenna;

a baseband demodulator configured to demodulate incoming digital baseband signals generated from signals received via the phased array antenna; and

a shared baseband processor configured to receive digital baseband signals including the modulated outbound digital baseband signals ~~from said baseband modulator~~ and the incoming digital baseband signals ~~received via the phased array antenna which are destined for said baseband demodulator~~, said shared baseband processor ~~adjusting phases of~~ applying phases to the digital baseband signals to ~~jointly~~ account for both beamforming phase rotation of individual antenna elements and carrier phase rotation~~, and adjusting amplitudes of the baseband signals to jointly perform power control and antenna element beam scaling~~.

2. (Currently Amended) The apparatus of claim 1, wherein said digital baseband signals received by said shared baseband processor are time multiplexed, and said shared baseband processor operates on said digital baseband signals on a time-slot-by-time-slot basis.

3. (Currently Amended) The apparatus of claim 1, wherein said baseband modulator receives data symbols from a plurality of user channels and supplies to said shared baseband processor a time-multiplexed stream of modulated digital data symbols from said plurality of user channels.

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4. (Currently Amended) The apparatus of claim 3, wherein, for each input digital data symbol, said baseband modulator generates a plurality of modulated digital data symbols in the time-multiplexed stream respectively corresponding to the plurality of antenna elements.

5. (Currently Amended) The apparatus of claim 1, wherein said shared baseband processor comprises:

a numerically controlled oscillator configured to generate a stream of carrier phases for digital baseband signals of each of a plurality of user channels in a time-multiplexed manner;

a beamforming phase rotator configured to generate a stream of beam rotation phases corresponding to individual antenna elements for each of the plurality of user channels in a time-multiplexed manner;

a phase adder configured to sum the beam rotation phases and the carrier phases to produce a time-multiplexed stream of combined phase adjustments; and

a complex multiplier configured to adjust phases of a time-multiplexed stream of digital baseband signals corresponding to the plurality of user channels in accordance with the combined phase adjustments.

6. (Original) The apparatus of claim 5, wherein said combined phase adjustments index a sine/cosine lookup table which supplies multiplicands to said complex multiplier.

7. (Currently Amended) The apparatus of claim 1, wherein said shared baseband processor comprises a multiplier which performs complex multiplication on digital baseband signals relating to a plurality of user channels in a time-multiplexed manner.

8. (Currently Amended) The apparatus of claim 1, wherein said shared baseband processor comprises a multiplier which performs complex multiplication on digital baseband signals associated with a plurality of individual antenna elements in a time-multiplexed manner.

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9. (Currently Amended) The apparatus of claim 1, wherein said shared baseband processor comprises a beam scaling and power control processor configured to generate a time-multiplexed stream of gain control signals for digital baseband signals corresponding to individual antenna elements for each of a plurality of user channels, the gain control signals jointly accounting for power control and antenna element beam scaling; and

a multiplier configured to adjust amplitudes of a time-multiplexed stream of digital baseband signals corresponding to the plurality of user channels in accordance with the gain control signals.

10. (Currently Amended) The apparatus of claim 1, further comprising:

a baseband beamformer configured to receive time-multiplexed digital baseband signals from said shared baseband processor corresponding to individual antenna elements, said baseband processor forming a combined signal from said time-multiplex digital baseband signals.

11. (Currently Amended) The apparatus of claim 1, further comprising:

a plurality of digital down-converters respectively down-converting digitized signals received from the plurality of antenna elements to produce parallel streams of sampled digital baseband signals; and

a multiplexer receiving the parallel streams of sampled digital baseband signals and supplying a time-multiplexed stream of the sampled digital baseband signals to said shared baseband processor.

12. (Currently Amended) The apparatus of claim 11, wherein said plurality of digital down-converters perform decimation to reduce a sampling rate of the ~~digitized~~ sampled digital baseband signals.

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13. (Original) The apparatus of claim 11, wherein said plurality of digital down-converters separately down-convert digitized signals for each antenna element for each of a plurality of frequency channels.

14. (Currently Amended) The apparatus of claim 1, further comprising:

a demultiplexer receiving a time-multiplexed stream of digital baseband signals from said shared baseband processor and generating parallel streams of digital baseband signals corresponding to the plurality of antenna elements; and

a plurality of digital up-converters respectively up-converting the parallel streams of digital baseband signals to produce a plurality of digitized intermediate frequency signals corresponding to the plurality of antenna elements.

15. (Original) The apparatus of claim 14, wherein said plurality of digital up-converters perform interpolation to increase a sampling rate of the digitized intermediate frequency signals.

16. (Currently Amended) The apparatus of claim 14, wherein said plurality of digital up-converters separately up-convert digital baseband signals for each antenna element for each of a plurality of frequency channels.

17. (Original) The apparatus of claim 1, wherein signals are transmitted and received using time division duplex, said apparatus further comprising switching elements to selectively connect said shared baseband processor to said baseband modulator and front-end transmit circuitry for signal transmission and to said baseband demodulator and front-end receive circuitry for signal reception.

18. (Original) The apparatus of claim 1, wherein said apparatus employs time division multiple access (TDMA) to transmit and receive signals.

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19. (Original) The apparatus of claim 1, wherein said apparatus employs frequency division multiple access (FDMA) to transmit and receive signals.

20. (Original) The apparatus of claim 1, wherein said apparatus is a field programmable gate array (FPGA).

21. (Original) The apparatus of claim 1, wherein the apparatus is implemented via a very large scale integration (VLSI) circuit or an application specific integrated circuit (ASIC).

22. (Original) The apparatus of claim 1, wherein said apparatus is a modem.

23. (Original) The apparatus of claim 1, wherein said apparatus is a transceiver.

24. (Original) The apparatus of claim 1, wherein said apparatus is a basestation transceiver.

25. (New) The apparatus of claim 1, wherein the shared baseband processor adjusts amplitudes of the digital baseband signals to perform power control and antenna element beam scaling.

26. (New) A method of processing an RF signal received via an electronically steerable phased array antenna comprising a plurality of antenna elements, the method comprising:

(a) separately down-converting the RF signal from each antenna element to an intermediate frequency (IF) signal;

(b) separately analog-to-digital converting the IF signal from each antenna element;

(c) separately digitally down-converting the digital IF signal from each antenna element to a digital baseband signal to form a set of parallel baseband signals from the plurality of antenna elements;

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(d) time multiplexing the set of parallel baseband signals to form a serial stream of digital baseband signals;

(e) applying phases to the digital baseband signals in the serial stream to account for both carrier phase tracking and antenna element beamforming; and

(f) performing beamforming by combining digital baseband signals respectively associated with the plurality of antenna elements.

27. (New) The method of claim 26, wherein (c) includes decimating the digital IF signal from each antenna element to reduce a number of samples in the serial stream of digital baseband signal.

28. (New) The method of claim 26, wherein (c) includes generating baseband signals for a plurality of frequency channels from the digital IF signal of each antenna element, such that digital samples in the serial stream of digital baseband signals are associated with a particular antenna element and frequency channel.

29. (New) A method of processing signals to be transmitted via an electronically steerable phased array antenna comprising a plurality of antenna elements, the method comprising:

(a) generating a stream of digital baseband signals representing data symbols to be transmitted via the phased array antenna, wherein digital baseband signals in the stream are associated with individual antenna elements;

(b) applying phases to each of the digital baseband signals to account for both carrier phase rotation and antenna element beamforming;

(c) demultiplexing the stream of digital baseband signals into a plurality of parallel signals respectively associated with individual antenna elements;

(d) digitally up-converting the parallel signals to produce a plurality of digital intermediate frequency (IF) signals respectively associated with individual antenna elements;

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(e) digital-to-analog converting the digital IF signals to produce a plurality of IF signals respectively associated with individual antenna elements; and

(f) up-converting the IF signals to RF signals for transmission via the phased array antenna.

30. (New) The method of claim 29, wherein the phased array antenna simultaneously transmits signals on a plurality of frequency channels, and the stream of digital baseband signals includes signals associated with individual ones of the frequency channels.

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REMARKS

Claims 1 – 30 are pending in the subject application: claims 1 – 24 have been examined: claims 1 – 4 and 7 – 24 stand rejected, and claims 5 and 6 are indicated as containing allowable subject matter. By the above amendments, claims 1 – 5, 7 – 12, 14, and 16 have been amended, and new claims 25-30 have been added. Favorable reconsideration of the application and allowance of all of the pending claims are respectfully requested in view of the above amendments and the following remarks.

Applicant respectfully requests the Examiner to issue another PTO-892 form with the next communication listing U.S. Patent No. 6,549,527 (Tsutsui), since this document is relied upon by the Examiner but was apparently inadvertently omitted from the PTO-892 form supplied with the subject Office Action.

Claims 1 and 22 – 24 stand rejected under 35 U.S.C. §103(a) as being unpatentable over U.S. Patent No. 3,986,123 to Tirro in view of Japanese Patent No. 8222934 (JP '934) and U.S. Patent No. 6,763,062 to Kohno. Further, claims 2 and 3 stand rejected as being unpatentable over Tirro, JP '934, Kohno, and U.S. Patent No. 5,583,562 to Birch et al.; claim 4 stands rejected over Tirro, JP '934, Kohno, Birch, and U.S. Patent No. 6,768,458 to Green et al.; claims 7 – 10 stand rejected over Tirro, JP '934, Kohno, and U.S. Patent No. 6,831,943 to Dabak et al.; claims 11 – 13 stand rejected over Tirro, JP '934, Kohno, and U.S. Patent No. 6,549,527 to Tsutsui et al.; claims 14 – 16 and 18 stand rejected over Tirro, JP '934, Kohno, and U.S. Patent No. 5,809,422 to Raleigh et al.; claim 17 stands rejected over Tirro, JP '934, Kohno, and U.S. Patent No. 5,937,348 to Cina et al.; and claims 19 – 21 stand rejected over Tirro, JP '934, Kohno, and U.S. Patent Application Publication No. 2002/0141478 to Ozluturk et al. Applicant respectfully traverses these rejections insofar as they apply to amended claim 1 and its dependent claims.

Independent claim 1 sets forth an apparatus for modulating and demodulating signals transmitted and received via an electronically steerable phased array antenna comprising a plurality of antenna elements. The claimed apparatus includes:

a baseband modulator configured to modulate outbound digital baseband signals to be transmitted via the phased array antenna;

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a baseband demodulator configured to demodulate incoming digital baseband signals generated from signals received via the phased array antenna; and

a shared baseband processor configured to receive digital baseband signals including the modulated outbound digital baseband signals and the incoming digital baseband signals, wherein the shared baseband processor applies phases to the digital baseband signals to account for both beamforming phase rotation of individual antenna elements and carrier phase rotation.

Notably, the apparatus of claim 1 requires a shared baseband processor that receives digital baseband signals including both modulated outbound digital baseband signals (destined to be transmitted via the phased array antenna) and incoming digital baseband signals (arriving from the phased array antenna). Further, the processor performs substantially the same operation on both the outbound and incoming digital baseband signals, namely, applying phases to the signals to account for both beamsteering and the carrier phase (i.e., the baseband carrier phase is applied to the digital signal). Moreover, claim 1 requires the baseband signals to be digital signals. Finally, claim 1 requires the beamforming phase rotation to be for individual antenna elements, which necessarily means that the processor processes digital baseband signals associated with individual antenna elements. In short, the claimed invention relates to system that performs digital beamforming at baseband in conjunction with application of carrier phases to digital baseband signals for both transmitted and received signals.

No combination of Tirro, JP '394, and Kohno would have rendered obvious the subject matter of claim 1, since none of these references discloses or suggests the above requirements of claim 1, whether considered singly or jointly. Tirro discloses a system for correcting polarization distortion in a satellite communication station that employs conjugate signal polarizations to support multiple communication channels. Tirro's processor ELT (cited by the Examiner) receives polarization distortion feedback information from received signals and uses the distortion information to control a predistorter (PRE) in the transmitting waveguide branch and a regenerative distortion corrector (CRT) in the receiving waveguide branch (see Fig. 3).

As a preliminary matter, Tirro's system is entirely analog; consequently, Tirro's processor ELT does not receive or process any digital baseband signals, as require by claim 1.

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Moreover, as clearly seen in Figs. 2 – 4, Tirro's processor ELT is not a baseband processor at all and does not receive or process baseband signals (incoming, outgoing, digital or otherwise), as required by claim 1. More specifically, the distortion feedback sent to processor ELT from the distortion monitor is an intermediate frequency (IF) signal, not a baseband signal. This is clearly explained in Tirro's Abstract as well as at column 4, lines 56 – 62. The received signals are not down-converted to baseband in Tirro's system until further downstream (in unit CCA), such that the baseband signal is present at the inputs (e and g) to the receiver (CLR) (see col. 4, lines 62 – 67). Furthermore, the predistorter and distortion corrector controlled by Tirro's processor ELT adjust the signal at the radio frequency (RF), not at baseband (see col. 4, lines 49 – 52 and col. 5, lines 11 – 13, which clarify that the signals are at microwave frequencies at the point of the predistorter and distortion corrector). In short, neither the input nor the outputs of Tirro's processor ELT are at baseband. Thus, not only does Tirro's processor ELT not receive or process baseband signals as required by claim 1; Tirro's processor does not interact with baseband signals in any way.

JP '394 and Kohno do not compensate for the deficiencies of Tirro. JP '394 is relied upon for a general teaching of power, amplitude, and phase control, and Kohno is relied upon for a general teaching of steerable phased array antennas. However, like Tirro, neither of these documents discloses or suggests a shared baseband processor that receives outbound and incoming digital baseband signals and that applies phases to the digital baseband signals to account for both beamforming phase rotation of individual antenna elements and carrier phase rotation, as required by claim 1. In particular, Fig. 2 of Kohno clearly shows the various antenna element signals being combined at combiner 46 prior to being sent to the receiver for baseband processing. Likewise, Fig. 2 of Kohno shows the beamforming phases being applied to outgoing signals at RF, not baseband. Thus, no combination of Tirro, JP '394, and Kohno could have rendered obvious the shared baseband processor of claim 1. Moreover, claim 1 requires "beamforming phase rotation of individual antenna elements," and none of these references, including Kohno, suggests digital baseband beamforming; thus, the subject matter of claim 1 would not have been (and could not have been) obvious from any combination of these

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documents for this additional reason. Accordingly, the Examiner is respectfully requested to reconsider and withdraw the rejection of claim 1.

The remaining documents are relied upon by the Examiner for teachings of subject matter recited in various dependent claims. Aside from whether these documents teach what the Examiner alleges or whether it would have been obvious to combine these documents in the manner proposed, none of these documents discloses or suggests the shared baseband processor as recited in claim 1 or the claimed subject matter discussed above in relation to Tirro, JP '394, and Kohno. Consequently, the subject matter of claim 1 and its dependent claims could not have been obvious from any combination of the cited documents. Accordingly, the Examiner is respectfully requested to reconsider and withdraw the rejections relating to the dependent claims.

New claim 25 (25/1) requires the shared baseband processor to adjust amplitudes of the digital baseband signals to perform power control and antenna element beam scaling. Similar limitations were originally recited in independent claim 1.

Claim 26 sets forth a method of processing an RF signal received via an electronically steerable phased array antenna comprising a plurality of antenna elements. The method includes: (a) separately down-converting the RF signal from each antenna element to an intermediate frequency (IF) signal; (b) separately analog-to-digital converting the IF signal from each antenna element; (c) separately digitally down-converting the digital IF signal from each antenna element to a digital baseband signal to form a set of parallel baseband signals from the plurality of antenna elements; (d) time multiplexing the set of parallel baseband signals to form a serial stream of digital baseband signals; (e) applying phases to the digital baseband signals in the serial stream to account for both carrier phase tracking and antenna element beamforming; and (f) performing beamforming by combining digital baseband signals respectively associated with the plurality of antenna elements. Dependent claim 27 (27/26) further requires decimating the digital IF signal from each antenna element to reduce the number of samples in the digital baseband signal. Dependent claim 28 (28/26) further requires generating baseband signals for a plurality of frequency channels from the digital IF signal of each antenna element, such that

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digital samples in the serial stream of digital baseband signals are associated with a particular antenna element and frequency channel.

New independent claim 29 sets forth a method of processing signals to be transmitted via an electronically steerable phased array antenna comprising a plurality of antenna elements. The method includes: (a) generating a stream of digital baseband signals representing data symbols to be transmitted via the phased array antenna, wherein digital baseband signals in the stream are associated with individual antenna elements; (b) applying phases to each of the digital baseband signals to account for both carrier phase rotation and antenna element beamforming; (c) demultiplexing the stream of digital baseband signals into a plurality of parallel signals respectively associated with individual antenna elements; (d) digitally up-converting the parallel signals to produce a plurality of digital intermediate frequency (IF) signals respectively associated with individual antenna elements; (e) digital-to-analog converting the digital IF signals to produce a plurality of IF signals respectively associated with individual antenna elements; and (f) up-converting the IF signals to RF signals for transmission via the phased array antenna. Dependent claim 30 (30/29) further requires that the phased array antenna simultaneously transmit signals on a plurality of frequency channels, and that the stream of digital baseband signals include signals associated with individual ones of the frequency channels. Support for new claims 25-30 is found throughout Applicant's specification (e.g., see Figs. 2 and 3). These claims are distinguishable from the cited prior art, since the prior art does not suggest the recited aspects of the methods, as is evident from the foregoing remarks.

The Examiner indicates that claims 5 and 6 would be allowable if rewritten in independent form to include all of the limitations of their parent claims and any intervening claims. The Examiner is requested to hold in abeyance the requirement of rewriting of claims 5 and 6 in independent form, until the Examiner has had an opportunity to reconsider (and withdraw) the rejection of parent claim 1 under 35 U.S.C. §103(a).

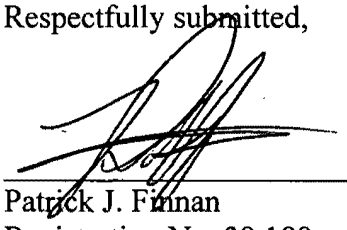
In view of the foregoing, Applicant respectfully requests the Examiner to find the application to be in condition for allowance with claims 1 – 30. However, if for any reason the Examiner feels that the application is not now in condition for allowance, the Examiner is

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respectfully requested to call the undersigned attorney to discuss any unresolved issues and to expedite the disposition of the application.

Filed concurrently herewith is a Petition (with payment) for an Extension of Time of One Month. Also filed concurrently herewith is payment of an excess claim fee in the amount of $300 for six (6) new claims in excess of the twenty-four (24) previously paid for. Applicant hereby petitions for any extension of time which may be required to maintain the pendency of this case, and any required fee for such extension is to be charged to Deposit Account No. 05-0460.

Respectfully submitted,



Patrick J. Finnan
Registration No. 39,189

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Hand Delivered on: October 6, 2005

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OIPE IAP53
OCT 06 2005
PATENT & TRADEMARK OFFICE

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Appl. No.	:	10/084,614
Applicant	:	Scott BIERLY et al.
Filed	:	February 28, 2002
TC/A.U.	:	2634
Examiner	:	LU, J.
Confirmation No.	:	1621
Docket No.	:	0918.0153C
Customer No.	:	27896
Title	:	Integrated Beamformer/Modem Architecture

Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450

PETITION FOR EXTENSION OF TIME

Sir:

Pursuant to 37 C.F.R. § 1.136(a), Applicants hereby petition for an extension of time of one month, extending the time period for responding to the Office Action of June 28, 2005, from September 28, 2005, to October 28, 2005. Applicants further petition that any and all extensions of the term necessary to render timely the filing of the accompanying or any future responses be granted.

The extension fee is: ☐ $60.00 ☒ $120.00

☒ An extension fee in the amount of $120.00 is enclosed.

☐ The shortened statutory period has been reset by an Advisory Action dated

10/07/2005 SZEWDIE1 00000025 10084614
01 FC:1251 120.00 OP

☒ The Commissioner is hereby authorized to charge any additional appropriate fees under 37 C.F.R. §§ 1.16, 1.17 and 1.21 that may be required by this paper, and to credit any overpayment, to Deposit Account No. 05-0460.

Respectfully submitted,

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Hand-Delivered: October 6, 2005

OIPE IAP53 OCT 06 2005 PATENT & TRADEMARK OFFICE

1621

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Appl. No.	:	10/084,614
Applicant	:	Scott BIERLY et al.
Filed	:	February 28, 2002
TC/A.U.	:	2634
Examiner	:	LU, J.
Confirmation No.	:	1621
Docket No.	:	0918.0153C
Customer No.	:	27896
Title	:	Integrated Beamformer/Modem Architecture

Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450

TRANSMITTAL OF AMENDMENT

Enclosed are the following documents in response to the Office Action mailed June 28, 2005, for the above-identified application:

- ☒ Amendment (14 Pages)
- ☒ Petition for Extension of Time (2 pages)
- ☐ Request for Approval of Drawing Changes
- ☐ Notice of Appeal
- ☐ Associate Power
- ☐ Revocation and New Power
- ☐ Change of Address
- ☐ Return receipt postcard
- ☒ Check No. 9150 in the amount of $300.00 for the total fee as calculated below
- ☒ Check No. 9151 in the amount of $120.00 for payment of the one-month extension of time fee

The fee has been calculated as follows:

	NO OF CLAIMS REMAINING	NO. OF CLAIMS PREVIOUSLY PAID FOR	NO OF EXCESS CLAIMS	RATE	FEE
Total Claims	30	- 24 =	6	$50.00	$300.00
Independent Claims	3	- 3 =	0	$200.00	0.00
If multiple dependent claims are presented, add $360.00					0.00
Total Amendment Fee					$300.00
☐ Applicant claims Small Entity Status (subtract 50% of Total Application Fee)					0.00
Other fees: (specify)					0.00
TOTAL FEE DUE					$300.00

☒ A check for the total fee is attached.

☐ Please charge $ to Deposit Account No. 05-0460 for the total fee. This paper is being submitted in duplicate.

☒ The Commissioner is hereby authorized to charge any additional appropriate fees under 37 C.F.R. §§1.16, 1.17, and 1.21 that may be required by this paper, and to credit any overpayment, to Deposit Account No. 05-0460.

Dated: 10/6/05

Respectfully submitted by
EDELL, SHAPIRO & FINNAN, LLC

By: _____
Patrick J. Finnan
Reg. No. 39,189

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(301) 424-3640

PATENT APPLICATION FEE DETERMINATION RECORD
Effective October 1, 2001

Application or Docket Number: 10081614

CLAIMS AS FILED - PART I

	(Column 1)	(Column 2)
TOTAL CLAIMS	24	
FOR	NUMBER FILED	NUMBER EXTRA
TOTAL CHARGEABLE CLAIMS	24 minus 20=	* 4
INDEPENDENT CLAIMS	1 minus 3 =	*
MULTIPLE DEPENDENT CLAIM PRESENT		☐

* If the difference in column 1 is less than zero, enter "0" in column 2

SMALL ENTITY TYPE ☐			OTHER THAN SMALL ENTITY	
RATE	FEE	OR	RATE	FEE
BASIC FEE	370.00	OR	BASIC FEE	740.00
X$ 9=		OR	X$18=	72
X42=		OR	X84=	156.00
+140=		OR	+280=	
TOTAL		OR	TOTAL	968.00

CLAIMS AS AMENDED - PART II

10/6/05

AMENDMENT A	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA
Total	* 30	Minus	** 24	= 6
Independent	* 3	Minus	*** 3	=
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM				☐

SMALL ENTITY			OTHER THAN SMALL ENTITY	
RATE	ADDITIONAL FEE	OR	RATE	ADDITIONAL FEE
X$ 9=		OR	X$18= 50	300
X42=		OR	X84=	
+140=		OR	+280=	
TOTAL ADDIT. FEE		OR	TOTAL ADDIT. FEE	

AMENDMENT B	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA
Total	*	Minus	**	=
Independent	*	Minus	***	=
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM				☐

RATE	ADDITIONAL FEE	OR	RATE	ADDITIONAL FEE
X$ 9=		OR	X$18=	
X42=		OR	X84=	
+140=		OR	+280=	
TOTAL ADDIT. FEE		OR	TOTAL ADDIT. FEE	

AMENDMENT C	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA
Total	*	Minus	**	=
Independent	*	Minus	***	=
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM				☐

RATE	ADDITIONAL FEE	OR	RATE	ADDITIONAL FEE
X$ 9=		OR	X$18=	
X42=		OR	X84=	
+140=		OR	+280=	
TOTAL ADDIT. FEE		OR	TOTAL ADDIT. FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20."
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3."
The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

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Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
S1	2	("6370182").PN.	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2005/06/15 14:19
S2	2	("20020154687").PN.	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2005/06/15 15:17
S6	7	S5 and time near multiplex$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/15 15:20
S3	98	baseband same modulat$3 same demodulat$3 and phase$1 near2 array$1 near2 antenna	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/15 15:42
S8	5	baseband same modulat$3 same demodulat$3 and steer$5 near array$1 near2 antenna	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/15 15:43
S9	23	S5 and power	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/15 16:06
S4	50	S3 and phase and amplitude	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/15 16:06
S7	29	S3 and (phase and amplitude) same process$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/15 16:08
S11	2520	(375/222).CCLS.	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2005/06/15 16:21

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S12	1	S11 and S3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/15 16:22
S10	12	S3 and (phase and amplitude) same process$3 same modulat$3 same demodulat$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/15 16:42
S13	15146	(antenna receiver) same (beam near form$3 or phase$1 near3 (array rotat$3))	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/15 16:44
S15	72	S13 and baseband and (modulat$3 same demodulat$3 same process$3 same phase same amplitude)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/15 17:08
S14	622	S13 and baseband and modulat$3 and demodulat$3 and processor and phase and amplitude	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/15 17:08
S5	25	S4 and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/15 17:08
S16	11	S13 and baseband and modulat$3 same demodulat$3 same (shared joint$2 one single) near3 processor and phase and amplitude	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/15 17:10
S17	4229	375/219-223.ccls.	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/15 17:22
S21	38	S20 and baseband	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/15 17:23
S20	70	S17 and modulator same demodulator same processor and phase and amplitude	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/15 17:23

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S19	217	S18 and baseband	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/15 17:23
S18	459	S17 and modulator and demodulator and phase and amplitude	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/15 17:23
S27	6	S26 and array with antenna	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/15 17:56
S26	33	S25 and @ad<="20020228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/15 17:56
S25	38	S24 and baseband	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/15 17:56
S24	70	S23 and modulator same demodulator same processor and phase and amplitude	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/15 17:56
S23	4229	375/219-223.ccls.	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/15 17:56
S22	33	S21 and @ad<="20020228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/15 17:56
S28	147	((beam near forming same antenna) or (array near2 antenna)) and modulat$3 and demodulat$3 and baseband with process$3 same phase and amplitude	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 11:04
S30	79	S29 and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 11:07

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S29	170	((beam$2forming same antenna) or (array near2 antenna)) and modulat$3 and demodulat$3 and baseband with process$3 same phase and amplitude	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 11:07
S31	6	S30 and 375/219-223.ccls.	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 11:08
S35	2	("5937005").PN.	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2005/06/17 11:14
S34	3	S33 and 375/219-223.ccls.	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 11:14
S36	12	S33 and (transceiver or modem)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 11:24
S37	5	((beam$2forming same antenna) or (array near2 antenna)) and modulat$3 and demodulat$3 and baseband same (sin and cos) same phase same amplitude	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 11:36
S38	2	S37 and (transceiver or modem)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 11:37
S32	90	((beam$2forming same antenna) or (array near2 antenna)) and modulat$3 and demodulat$3 and baseband with process$3 same phase same amplitude	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 11:37
S40	2	("5764187").PN.	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2005/06/17 11:51
S41	3	"SEQUENTIAL-ACQUISITION, MULTI-BAND, MULTI-CHANNEL"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 11:52

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S42	8	(("5764187") or ("5943010") or ("6052085") or ("6167099")).PN.	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2005/06/17 12:03
S44	16	S43 and @ad<="20020228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 12:04
S43	23	modulat$3 and baseband with process$3 same (sin$3cos or sin near2 cos)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 12:04
S39	4	modulat$3 and demodulat$3 and baseband same (sin$5cos or sin near2 cos) same phase same amplitude and (transceiver or modem)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 12:07
S45	1103	modulat$3 and demodulat$3 and baseband and process$3 same phase same amplitude and (transceiver or modem)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 14:10
S48	199	S46 and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 14:12
S46	473	(shared common) near2 process$3 same ((transmit$4 and receiv$3) or (uplink and downlink)) and modulat$3 and demodulat$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 14:12
S49	6	(shared common) near2 (process$3) same phase same amplitude same ((transmit$4 and receiv$3) or (uplink and downlink)) and modulat$3 and demodulat$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 14:13
S47	1	(shared common) near2 (process$3) same front$2end same ((transmit$4 and receiv$3) or (uplink and downlink)) and modulat$3 and demodulat$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 14:13
S52	111631	modulat$3 and demodulat$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 14:20

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S53	25	(shared common) with (process$3) same phase same amplitude same ((transmit$4 and receiv$3) or (uplink and downlink)) and S52	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 14:21
S51	18	S50 and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 14:21
S55	18	S53 and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 14:22
S54	15	S43 and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 14:22
S50	25	(shared common) with (process$3) same phase same amplitude same ((transmit$4 and receiv$3) or (uplink and downlink)) and modulat$3 and demodulat$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 15:18
S33	41	S32 and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 15:20
S56	115	(shared common) near3 (process$3) same ((transmit$4 and receiv$3) or (uplink and downlink)) and process$3 same phase same amplitude and modulat$3 and demodulat$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 15:22
S57	76	S56 and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 15:23
S60	28	(shared common) near3 (process$3) same ((transmit$4 and receiv$3) or (uplink and downlink)) and process$3 same ((adjust$3 rotat$3 chang$3 calibrat$3 modif$7) near3 phase and (adjust$3 rotat$3 chang$3 calibrat$3 modif$7) near3 amplitude) and modulat$3 and demodulat$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 15:25

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S58	28	(shared common) near3 (process$3) same ((transmit$4 and receiv$3) or (uplink and downlink)) and process$3 same ((adjust$3 rotat$3 chang$3 calibrat$3) near3 phase and (adjust$3 rotat$3 chang$3 calibrat$3) near3 amplitude) and modulat$3 and demodulat$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 15:26
S62	19	S61 and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 15:27
S59	24	S58 and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 15:27
S63	16	("3986123").URPN.	USPAT	OR	ON	2005/06/17 17:13
S68	0	"19750808".ad. and "enzo"	USPAT	OR	ON	2005/06/17 17:14
S67	0	"19750808".ad. and "D'oro"	USPAT	OR	ON	2005/06/17 17:25
S71	104	S70 and oscillator	USPAT	OR	ON	2005/06/17 17:26
S72	113	S70 and @ad<="20010228"	USPAT	OR	ON	2005/06/17 18:13
S70	137	S69 and multiplex$3	USPAT	OR	ON	2005/06/17 18:13
S69	227	(beam$2forming antenna near2 array) and baseband and amplitude same phase same power	USPAT	OR	ON	2005/06/17 18:14
S73	0	(beam$2forming with antenna or antenna near2 array) and baseband same amplitude same phase same power same scal$3	USPAT	OR	ON	2005/06/17 18:16
S75	68	(beam$2forming with antenna or antenna near2 array) and baseband same amplitude same phase same power	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 18:17
S74	28	(beam$2forming with antenna or antenna near2 array) and baseband same amplitude same phase same power	USPAT	OR	ON	2005/06/17 18:17
S76	28	S75 and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 18:28

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S77	1	polarization adj distortion with power near (control reduc$4 usage sav$3)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/17 18:29
S79	1174	steer$4 near3 array near2 antenna	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/20 12:17
S78	4	(amplitude and phase) near2 distortion with power near (control reduc$4 usage sav$3)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/20 12:17
S80	120	S79 and (adjust$3 chang$3 modif$7 var$5) near3 (phase and amplitude)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/20 12:19
S82	13	S81 and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/20 12:39
S81	17	S79 and (adjust$3 chang$3 modif$7 var$5) near3 (phase and amplitude) and modulator and demodulator	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/20 12:39
S83	2	time near multiplex$3 same antenna near2 array same amplitude same phase and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/20 13:00
S84	10	benefit$3 with time near multiplex$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/20 15:12
S86	1	modulator with plurality near2 (signal$1 data input user$2) same time near multiplex$2 same process$3 and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/20 15:16
S85	8	modulator with plurality near2 (signal$1 data input user$2) same time near multiplex$2 and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/20 15:21

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S88	347	modulator same time near3 multiplex$2 and antenna and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/20 15:52
S87	7	modulator with plurality near2 (signal$1 data input user$2) same time near3 multiplex$2 and antenna and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/20 15:52
S90	65	modulator near4 multiplex$2 same multiplex$2 near2 time and antenna and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/20 15:53
S89	457	modulator with multiplex$2 and multiplex$2 near2 time and antenna and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/20 15:53
S92	0	S91 and antenna near2 array	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/20 16:53
S93	346	baseband near modulator	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/20 17:02
S91	12	S90 and "375"/$.ccls.	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/20 17:02
S95	22	S94 and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/20 17:03
S94	34	baseband near4 modulator with (purpose benefit advantag$5)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/20 17:03
S96	164	multiplex$3 same modulator same antenna same element$2	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 12:51

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S98	40	multiplex$3 with modulator with antenna same element$2	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 12:52
S97	101	S96 and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 12:52
S103	13	multiplex$3 with modulator with antenna same antenna near2 array	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 13:32
S61	20	(shared common) near3 (process$3) same ((transmit$4 and receiv$3) or (uplink and downlink)) and process$3 same ((adjust$3 rotat$3 chang$3 calibrat$3) near3 phase and (adjust$3 rotat$3 chang$3 calibrat$3) near3 amplitude) and modulator and demodulator	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 13:49
S104	7	S103 and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 15:12
S108	0	S107 and antenna near array	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 15:13
S105	8	process$3 same (plurality parallel numberous) near2 (input data symbols user) same multipl$5 same complex same baseband	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 15:13
S112	2	S110 and multiplex$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 15:14
S107	5	S105 and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 15:14

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S109	11	process$3 same (plurality parallel numberous) near2 (input data symbols user) same multipl$5 same complex and antenna near array	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 15:27
S110	4	S109 and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 15:31
S124	15	(multiple plurality parallel numberous two second) near2 (input$1 data symbol$1 user$1 stream$1) same (multiplication multiplied multiply$3) same (complex or in$1phase sin$1 cos$3) same (amplitude phase beam) and multiplex$3 and antenna near array and (modulat$3 demodulat$3)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 16:00
S122	54	(multiple plurality parallel numberous two second) near2 (input$1 data symbol$1 user$1 stream$1) same (multiplication multiplied multiply$3) same (complex or in$1phase sin$1 cos$3) and multiplex$3 and antenna near array and (modulat$3 demodulat$3)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 16:00
S123	32	S122 and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 16:01
S127	74	antenna with (down near convert$3 baseband) same (parallel plurality) same multiplex$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 17:38
S125	9	S124 and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 17:38
S129	6	antenna near2 array same (down near convert$3 baseband) same (parallel plurality) same multiplex$3 and decimat$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 17:39

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S128	46	S127 and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 17:39
S126	152	antenna same (down near convert$3 baseband) same (parallel plurality) same multiplex$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 17:39
S132	1	S131 and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 17:40
S130	0	S129 and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 17:40
S131	7	antenna near2 array and antenna same (down near convert$3 baseband) same (parallel plurality) same multiplex$3 and decimat$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 18:00
S134	2	S133 and interpolation	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 18:04
S135	1	S133 and interpolation and (IF intermediate near frequency)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 18:05
S136	3	antenna near2 array and antenna same (up near convert$3 radio) same (parallel plurality) same demultiplex$3 and (IF intermediate near frequency) and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 18:14
S133	6	antenna near2 array and antenna same (up near convert$3 radio) same (parallel plurality) same demultiplex$3 and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 18:14
S137	7	(transmit$4 uplink) and (intermediate near frequency IF) and demultiplexer and interpolat$3 and antenna near2 array and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 18:26

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S139	8339	(transmit$4 uplink) and antenna near2 array and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 18:27
S142	2	("20020154687").PN.	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2005/06/22 18:47
S141	22	S139 and (intermediate near frequency IF) and demultiplex$3 and interpolat$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 18:55
S144	29	beamform$3 with baseband same modulat$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 19:02
S143	260	beamform$3 with baseband	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 19:02
S145	15	S144 and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 19:10
S147	9	S146 and interpolat$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 19:11
S146	44	S139 and intermediate near frequency same (uplink up$1convert$3 transmit$4) and demultiplex$3 same (uplink transmit$4)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 19:11
S151	264	(transceiver modem) and duplex near3 time and switch and modulator and demodulator and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 19:38
S155	8	(transceiver modem) and duplex near3 time same switch and switch same modulator same demodulator and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 19:50

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S152	51	(transceiver modem) and duplex near3 time and switch same modulator same demodulator and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 19:50
S148	1864	(transceiver modem) and duplex near3 time and switch$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 20:01
S159	3	("6831943").PN.	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2005/06/22 20:06
S158	2	("6763062").PN.	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2005/06/22 20:06
S157	2	("5583562").PN.	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2005/06/22 20:06
S160	2	("5937348").PN.	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2005/06/22 20:07
S162	74	S161 and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 20:08
S163	28	(transceiver modem).ab. and FDMA and FPGA and (vlsi or ASIC)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 20:09
S161	363	(transceiver modem) and FDMA and FPGA and (vlsi or ASIC)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 20:09
S164	13	(transceiver modem).ab. and FDMA and FPGA and (vlsi or ASIC) and @ad<="20010228"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/06/22 20:11

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S165	2	("5809422").PN.	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2005/06/23 11:17
S167	2	("20030214976").PN.	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2005/06/23 11:19
S166	2	("20040013191").PN.	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2005/06/23 11:19
S169	14186	digital with signal same baseband	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/11/29 16:29
S173	41	S172 and antenna	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/11/29 16:33
S172	83	S169 and (shared sharing joint collective composite combined conjoint common communal) with (phase near rotat$3)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/11/29 16:33
S171	3	S169 and (shared sharing joint collective composite combined conjoint common communal) with (phase near rotat$3 with antenna)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/11/29 16:33
S175	4419	(duplex transceiver) and S169	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/11/29 17:12
S174	11	S169 and (shared sharing joint collective composite combined conjoint common communal) with processor same (phase near rotat$3)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/11/29 17:12
S170	1	S169 and (shared sharing joint collective composite combined conjoint common communal) with processor same (phase near rotat$3 with antenna)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/11/29 17:12

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S178	97	S177 and antenna and phase near3 (rotat$3 adjust$4)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/11/29 17:13
S177	550	(single shared sharing joint collective composite combined conjoint common communal) near5 processor and S175	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/11/29 17:13
S176	69845	(single shared sharing joint collective composite combined conjoint common communal) near5 processor	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/11/29 17:13
S180	88	S179 and antenna and phase near3 (rotat$3 adjust$4)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/11/29 17:14
S182	62	S180 and (@ad<="20010228" or @prad<="20010228" or @rlad<="20010228")	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/11/29 17:15
S179	493	(single shared sharing joint collective composite combined conjoint common communal) near4 processor and S175	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/11/29 17:15
S184	493	(single shared sharing joint composite combined conjoint common) near4 processor and S175	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/11/29 17:16
S188	88	S187 and antenna and phase near3 (rotat$3 adjust$4)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/11/30 11:01
S186	4419	(duplex transceiver) and S185	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/11/30 11:01
S185	14186	digital with signal same baseband	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/11/30 11:01

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S183	41	S180 and (@ad<="20010228" or @prad<="20010228")	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/11/30 11:01
S190	14	S189 and antenna with array	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/11/30 11:05
S187	493	(single shared sharing joint collective composite combined conjoint common communal) near4 processor and S186	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/11/30 11:09
S191	12	S190 and modulat$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/11/30 11:30
S193	46	S192 and modulat$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/11/30 11:33
S189	41	S188 and (@ad<="20010228" or @prad<="20010228")	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/11/30 11:33
S192	47	(single shared sharing joint collective composite combined conjoint common communal) near4 antenna with weights and S186	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/11/30 12:28
S195	81	(single shared sharing joint collective composite combined conjoint common communal) near4 (beamform$3 beam$1form$3) and S186	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/11/30 12:39
S194	19	S193 and (@ad<="20010228" or @prad<="20010228")	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/11/30 12:40
S196	29	S195 and (@ad<="20010228" or @prad<="20010228") and modulat$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/11/30 13:06

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S197	0	(@ad<="20010228" or @prad<="20010228") and digital near3 processor same (beamform$3 beam$1form$3) same (phase near3 rotat$3 or AFC)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/11/30 13:07
S199	148	(beamform$3 or beam$1form$3) same (phase near3 rotat$3 or AFC)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/11/30 13:10
S198	2	(@ad<="20010228" or @prad<="20010228") and digital near3 process$3 same (beamform$3 or beam$1form$3) same (phase near3 rotat$3 or AFC)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/11/30 13:10
S201	5	(beamform$3 or beam$1form$3) same (phase near3 rotat$3 or AFC) same digital near3 process$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/11/30 13:11
S200	143	(beamform$3 or beam$1form$3) same (phase near3 rotat$3 or AFC) and process$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/11/30 13:11
S202	37	(beamform$3 or beam$1form$3 or beam adj form$3) same (phase near3 rotat$3 or AFC) and (duplex transceiver)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/11/30 13:12
S203	2	("6615024").PN.	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2005/12/13 15:43
S204	2	("5764187").PN.	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2005/12/13 18:01
S205	160	(downconvert$3 down-convert$3 down adj convert$3) and (A/D analog adj2 digital analog-to-digital) and (IF intermediate near frequency) and (baseband) and (mux multiplex$3) and phase and (beamform$3 beam adj form$3 beam-form$3)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/12/13 18:03

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S208	71	S207 and (@ad<="20010228" or @prad<="20010228")	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/12/13 18:08
S209	20	S208 and (downconvert$3 down-convert$3 down adj convert$3) near4 (IF intermediate near frequency) and (downconvert$3 down-convert$3 down adj convert$3) near4 (baseband)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/12/13 19:14
S211	169	(downconvert$3 down-convert$3 down adj convert$3) near2 (baseband) with (A/D analog adj2 digital analog-to-digital)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/12/13 19:15
S210	517	(downconvert$3 down-convert$3 down adj convert$3) near2 (baseband) same (A/D analog adj2 digital analog-to-digital)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/12/13 19:15
S212	6	S211 and S209	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/12/13 19:29
S213	3	(A/D analog adj2 digital analog-to-digital) with IF with (benefit purpose for advantage)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/12/13 19:30
S207	128	S205 and antenna near2 array	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/12/13 19:38
S215	2641	(375/222).CCLS.	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2005/12/13 19:54
S214	22	S207 and decimat$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/12/13 19:54
L2	2	("5631898").PN.	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2005/12/14 09:54

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L1	2	("6894643").PN.	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2005/12/14 09:54

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EXAMINER	
LU, JIA	

ART UNIT	PAPER NUMBER
2634	

DATE MAILED: 12/29/2005

Please find below and/or attached an Office communication concerning this application or proceeding.

Office Action Summary	Application No.	Applicant(s)	
	10/084,614	BIERLY ET AL.	
	Examiner	Art Unit	
	Jia W. Lu	2634	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) OR THIRTY (30) DAYS, WHICHEVER IS LONGER, FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☒ Responsive to communication(s) filed on *06 October 2005*.

2a)☐ This action is **FINAL**. 2b)☒ This action is non-final.

3)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

4)☒ Claim(s) *1-30* is/are pending in the application.

4a) Of the above claim(s) _____ is/are withdrawn from consideration.

5)☐ Claim(s) _____ is/are allowed.

6)☒ Claim(s) *1-4 and 7-30* is/are rejected.

7)☒ Claim(s) *5 and 6* is/are objected to.

8)☐ Claim(s) _____ are subject to restriction and/or election requirement.

Application Papers

9)☐ The specification is objected to by the Examiner.

10)☒ The drawing(s) filed on *28 February 2002* is/are: a)☒ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

11)☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

Priority under 35 U.S.C. § 119

12)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a)☐ All b)☐ Some * c)☐ None of:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☒ Notice of References Cited (PTO-892)
2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)
3) ☐ Information Disclosure Statement(s) (PTO-1449 or PTO/SB/08) Paper No(s)/Mail Date _____.
4) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____.
5) ☐ Notice of Informal Patent Application (PTO-152)
6) ☐ Other: _____.

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DETAILED ACTION

Response to Arguments

Applicant's arguments with respect to claims have been considered but are moot in view of the new ground(s) of rejection.

Claim Rejections - 35 USC § 103

The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

> (a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.

The text of those sections of Title 35, U.S. Code not included in this action can be found in a prior Office action.

1. Claims 1, 22-25 are rejected under 35 U.S.C. 103(a) as being unpatentable over US patent 6,615,024.
    a. Regarding claims 1, 22-24, '024 shows a baseband modulator (column 13, lines 20-25), a baseband demodulator (figure 4, element 411), and a shared baseband processor (figure 1, elements 111, 117 and 123) which receives outbound and incoming signals, said processor applying phases to the signals to account for both beamforming and carrier phase rotations (column 13, lines 30-45). While the shared baseband processor used in this rejection is based on a grouping of receive and transmit processors,

the system that '024 describes performs the same functions of adjusting the antenna array. It would have been obvious to one ordinarily skilled in the art to group the weight generators (figure 4, element 409, figure 1, elements 131 and 117) into a single circuit to call it a "shared" processor to reduce the size and complexity of the circuit.

b. Regarding claim 25, '024 describes the processor to adjust amplitude of the signals (column 12, lines 65-68).

2. Claims 2 and 3 are rejected under 35 U.S.C. 103(a) as being unpatentable over US patent 6,615,024 as applied to claim 1 above, and further in view of US patent 5,583,562.

a. Regarding claim 2, although patent '024 does not show time-multiplexing of received data, the use of time-multiplexing in transceiver systems is well known for their ability to increase the throughput of a communications resource (for example, patent '562, fig 1). It would have been obvious for one ordinarily skilled in the art to use time-multiplexing in a system described in '024 in order to allow more users to use a single channel in a duplex system.

b. Regarding claim 3, while patent '024 does not show the modulator to provide a time-multiplexed data stream from an input of multiple data streams, patent '562 shows a modulator (fig 1, element 130) receiving data symbols from a plurality of user channels (fig 1, element 110) and provide a single time-multiplexed data stream (column 5, lines 30-40). The

reason to combine time-multiplexing with a modulator is stated in part a above.

3. Claim 4 is rejected under 35 U.S.C. 103(a) as being unpatentable over US patent 6,615,024 and US patent 5,583,562 as applied to claim 3 above, and further in view of US patent 6,768,458. While patent '024 does not show a modulator generating a plurality of modulated data in the time-multiplexed stream corresponding to a plurality of antenna elements, patent '458 shows a modulator (figure 5, elements 216 and 218) generating a plurality of modulated data symbols in the time-multiplexed stream, corresponding to a plurality of antenna elements (figure 5, element 250). It would have been obvious for one ordinarily skilled in the art for a modulating system described in patent '024 to time-multiplex a plurality of modulated data symbols corresponding to antenna elements in order to increase directional gain in transmission.
4. Claims 7-10 are rejected under 35 U.S.C. 103(a) as being unpatentable over US patent 6,615,024 as applied to claim 1 above, and further in view of US patent 6,831,943.
    a. Regarding claims 7-9, patent '024 does not describe the complex multiplication of signals in the processor relating to a plurality of user channels in a time-multiplexed manner. However, patent '943 teaches a transmission system where a processor unit (figure 10, elements 18 and 20) performs complex multiplication on signals on incoming signals that have been time-multiplexed (column 29, line 43), associated with a

plurality of antennas (figure 1, elements A12). While the plurality of user channels is not shown, it is well known that a system using time-multiplexing takes signals from different users in order to multiplex them. It would have been obvious for one ordinarily skilled in the art to use complex multiplication in a system described in patent '024 for beamforming (column 7, lines 18-47) and power adjustments (column 15, lines 47-54) in order to improve power usage and reduce interference.

b. Regarding claim 10, patent '024 does not disclose a beamformer configured to receive time-multiplexed baseband signals from shared baseband processor. Patent '943, however, shows a beamformer (figure 2, element 52) capable of receiving time-multiplexed (column 29, line 43) signals from a front-end processor. It would have been obvious for one ordinarily skilled in the art to use a beamformer in a transceiver system described in patent '024 when incoming signals require directional and rotational adjustments in order to acquire precise directional transmission to increase gain while using lower power.

5. Claims 11-13 are rejected under 35 U.S.C. 103(a) as being unpatentable over US patent 6,615,024 as applied to claim 1 above, and further in view of US patent 6,549,527. While patent '024 does not show the front-end specifics of its receiving circuitry, patent '527 shows a plurality of down-converters (column 2, lines 29-33) separately down-converting signals for each antenna element (figure 14, element 142). It also teaches the down-converting circuitry to include

decimation means (figure 1, element 11) followed by multiplexing means (figure 1, element 12). It would have been obvious for one ordinarily skilled in the art to use decimation and multiplexing in the receiver end in order enable signal processing in an antenna array system without lowering system performance or increasing price, dimension or complexity of the hardware (column 3, line 48-line 59).

6. Claims 14-16, 18 are rejected under 35 U.S.C. 103(a) as being unpatentable over US patent 6,615,024 as applied to claim 1 above, and further in view of US patent 5,809,422.

   a. Regarding claims 14-16, while patent '024 does not show a demultiplexer and up-converters in transmission, patent '422 teaches the use of demultiplexers (figure 4, element 134) and IF up-converters (column 7, lines 33-40) in separate transmitting antenna elements (column 11, lines 56-60). Patent '422 also teaches interpolation in order to increase the sampling rate of the transmission signals (column 13, lines 39-40). It would have been obvious for one ordinarily skilled in the art to employ demultiplexing in an transmission end as described in patent '024 in order to separate time-multiplexed symbols for transmission and up convert baseband signals into a higher, intermediate frequency in order to enable signal transmission in a wireless medium.

   b. Regarding claim 18, while patent '024 does not teach the use of TDMA, patent '422 teaches the use of TDMA (column 8, line 41) in its transceiver

system. Because TDMA is a very common technique used in transmission, and it would have been obvious to one ordinarily skilled in the art to use TDMA to allow multiple users to share time slots within a single channel.

7. Claim 17 is rejected under 35 U.S.C. 103(a) as being unpatentable over US patent 6,615,024 as applied to claim 1 above, further in view of US patent 5,937,348. While patent '024 teaches the use of a duplexer between the transmitter and receiver portion of its transceiver, it does not specify the duplex to be time-division or the use of a switch. Patent '348 shows a duplex switch capable of using time division duplex (column 5, line 20). It would have been obvious to one ordinarily skilled in the art to use a switch in a time division duplex transceiver system described in patent '024 in order to provide better control over the system while allowing it to transmit and receive using a single front-end processor.
8. Claims 19-21 are rejected under 35 U.S.C. 103(a) as being unpatentable over US patent 6,615,024 as applied to claim 1 above, further in view of US patent application 20020141478. While patent '024 does not show the use FDMA, FPGA or VLSI in its transceiver system, application '478 teaches all these elements (FDMA on paragraph 2, line 6, FPGA on paragraph 621, line 4, and ASIC on paragraph 621, line 5). It would have been obvious to one ordinarily skilled in the art to use FDMA to allow multiple users to share time slots, FPGA to

increase flexibility in designs and programming, or ASIC to reduce power usage, save space and lower cost of production.

9. Claims 26-30 are rejected under 35 U.S.C. 103(a) as being unpatentable over US patent 6,101,399, in view of US patent 5,631,898, further in view of US patent 6,072,994.

    a. Regarding claims 26 and 28, while '399 shows a method of processing signals received via antenna arrays comprising downconverter producing parallel signals (figure 3, element 54), and applying phases to the signals and performing beamforming (element 60), it does not show individual down-converting and A/D units, patents '898 and 643 show these features. Patent '898 shows separate IF down-converters (figure 12, element 1203), baseband down-converters (element 1207), A/D (element 1212), and a digital multiplexer (element 1213). It does not show the A/D to be down at IF, however, patent '994 shows this (column 31, lines 30-35). It would have been obvious to one ordinarily skilled in the art to perform A/D at IF in the circuit in '898 to allow many benefits such as easier digital programming, replacement of bulky circuitry, and better tuning; It would also have been obvious to one ordinarily skilled in the art to use the individual antenna processing elements of '898 in the system described in '399 to have more maneuverable controls of individual antenna elements.

b. Regarding claim 27, '399 describes the decimation of signals after digitizing and downconverting to baseband and prior to beamforming.

c. Claims 29 and 30 describe the limitations in claim 26 at its transmitting end. It would have been obvious to one ordinarily skilled in the art to reverse, step-by-step, the limitations of claim 26 in a receiver end to achieve transmission.

Allowable Subject Matter

10. Claims 5 and 6 are objected to as being dependent upon a rejected base claim, but would be allowable if rewritten in independent form including all of the limitations of the base claim and any intervening claims.

Conclusion

Any inquiry concerning this communication or earlier communications from the examiner should be directed to Jia W. Lu whose telephone number is 571-272-6042. The examiner can normally be reached on Mon- Fri, 10:30AM-6:30PM.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Stephen Chin can be reached on (571)272-3056. The fax phone number for the organization where this application or proceeding is assigned is 703-872-9306.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free).

Jia Lu
Examiner

STEPHEN CHIN
SUPERVISORY PATENT EXAMINER
TECHNOLOGY CENTER 2600

Notice of References Cited	Application/Control No. 10/084,614	Applicant(s)/Patent Under Reexamination BIERLY ET AL.	
	Examiner Jia W. Lu	Art Unit 2634	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	Classification
*	A	US-6,101,399	08-2000	Raleigh et al.	455/561
*	B	US-5,631,898	05-1997	Dent, Paul W.	370/203
*	C	US-6,072,994	06-2000	Phillips et al.	455/84
	D	US-			
	E	US-			
	F	US-			
	G	US-			
	H	US-			
	I	US-			
	J	US-			
	K	US-			
	L	US-			
	M	US-			

FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	Classification
	N					
	O					
	P					
	Q					
	R					
	S					
	T					

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	
	V	
	W	
	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

Index of Claims

Application/Control No.	Applicant(s)/Patent under Reexamination
10/084,614	BIERLY ET AL.
Examiner	**Art Unit**
Jia W. Lu	2634

√	Rejected	–	(Through numeral) Cancelled	N	Non-Elected	A	Appeal
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Claim		Date								
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	2	√								
	3	√								
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Search Notes

Application/Control No.	Applicant(s)/Patent under Reexamination	
10/084,614	BIERLY ET AL.	
Examiner	**Art Unit**	
Jia W. Lu	2634	

SEARCHED			
Class	Subclass	Date	Examiner
375	222	12/12/2005	JL

INTERFERENCE SEARCHED			
Class	Subclass	Date	Examiner
375	**222**	12/12/2005	**JL**

SEARCH NOTES (INCLUDING SEARCH STRATEGY)		
	DATE	EXMR
ALL EAST DATABASES	12/12/2005	JL

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PATENT & TRADEMARK OFFICE

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Appl. No.	:	10/084,614
Applicant	:	Scott BIERLY et al.
Filed	:	February 28, 2002
TC/A.U.	:	2634
Examiner	:	LU, J.
Confirmation No.	:	1621
Docket No.	:	0918.0153C
Customer No.	:	27896
Title	:	Integrated Beamformer/Modem Architecture

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

AMENDMENT

Sir:

In response to the Office Action mailed December 29, 2005, please amend the above-identified application as follows:

Amendments to the Claims are reflected in the listing of claims, which begins on page 2 of this paper.

Remarks begin on page 9 of this paper.

05/02/2006 JADD01 00000072 10084614
02 FC:1202 300.00 OP

Amendments to the Claims:

This listing of claims will replace all prior versions, and listings, of claims in the application.

Listing of Claims:

1. (Currently Amended) An apparatus for modulating and demodulating signals transmitted and received via an electronically steerable phased array antenna comprising a plurality of antenna elements, the apparatus comprising:

a baseband modulator configured to modulate outbound digital baseband signals to be transmitted via the phased array antenna;

a baseband demodulator configured to demodulate incoming digital baseband signals generated from signals received via the phased array antenna; and

a shared baseband processor configured to receive digital baseband signals including the modulated outbound digital baseband signals and the incoming digital baseband signals, said shared baseband processor applying phases to the digital baseband signals to account for both beamforming phase rotation ~~of individual antenna elements~~ and carrier phase rotation of individual antenna elements.

2. (Previously Presented) The apparatus of claim 1, wherein said digital baseband signals received by said shared baseband processor are time multiplexed, and said shared baseband processor operates on said digital baseband signals on a time-slot-by-time-slot basis.

3. (Previously Presented) The apparatus of claim 1, wherein said baseband modulator receives data symbols from a plurality of user channels and supplies to said shared baseband processor a time-multiplexed stream of modulated digital data symbols from said plurality of user channels.

4. (Previously Presented) The apparatus of claim 3, wherein, for each input digital data

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symbol, said baseband modulator generates a plurality of modulated digital data symbols in the time-multiplexed stream respectively corresponding to the plurality of antenna elements.

5. (Previously Presented) The apparatus of claim 1, wherein said shared baseband processor comprises:

a numerically controlled oscillator configured to generate a stream of carrier phases for digital baseband signals of each of a plurality of user channels in a time-multiplexed manner;

a beamforming phase rotator configured to generate a stream of beam rotation phases corresponding to individual antenna elements for each of the plurality of user channels in a time-multiplexed manner;

a phase adder configured to sum the beam rotation phases and the carrier phases to produce a time-multiplexed stream of combined phase adjustments; and

a complex multiplier configured to adjust phases of a time-multiplexed stream of digital baseband signals corresponding to the plurality of user channels in accordance with the combined phase adjustments.

6. (Original) The apparatus of claim 5, wherein said combined phase adjustments index a sine/cosine lookup table which supplies multiplicands to said complex multiplier.

7. (Previously Presented) The apparatus of claim 1, wherein said shared baseband processor comprises a multiplier which performs complex multiplication on digital baseband signals relating to a plurality of user channels in a time-multiplexed manner.

8. (Previously Presented) The apparatus of claim 1, wherein said shared baseband processor comprises a multiplier which performs complex multiplication on digital baseband signals associated with a plurality of individual antenna elements in a time-multiplexed manner.

9. (Previously Presented) The apparatus of claim 1, wherein said shared baseband

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processor comprises a beam scaling and power control processor configured to generate a time-multiplexed stream of gain control signals for digital baseband signals corresponding to individual antenna elements for each of a plurality of user channels, the gain control signals jointly accounting for power control and antenna element beam scaling; and

a multiplier configured to adjust amplitudes of a time-multiplexed stream of digital baseband signals corresponding to the plurality of user channels in accordance with the gain control signals.

10. (Previously Presented) The apparatus of claim 1, further comprising:

a baseband beamformer configured to receive time-multiplexed digital baseband signals from said shared baseband processor corresponding to individual antenna elements, said baseband processor forming a combined signal from said time-multiplex digital baseband signals.

11. (Previously Presented) The apparatus of claim 1, further comprising:

a plurality of digital down-converters respectively down-converting digitized signals received from the plurality of antenna elements to produce parallel streams of sampled digital baseband signals; and

a multiplexer receiving the parallel streams of sampled digital baseband signals and supplying a time-multiplexed stream of the sampled digital baseband signals to said shared baseband processor.

12. (Previously Presented) The apparatus of claim 11, wherein said plurality of digital down-converters perform decimation to reduce a sampling rate of the sampled digital baseband signals.

13. (Original) The apparatus of claim 11, wherein said plurality of digital down-converters separately down-convert digitized signals for each antenna element for each of a

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plurality of frequency channels.

14. (Previously Presented) The apparatus of claim 1, further comprising:

a demultiplexer receiving a time-multiplexed stream of digital baseband signals from said shared baseband processor and generating parallel streams of digital baseband signals corresponding to the plurality of antenna elements; and

a plurality of digital up-converters respectively up-converting the parallel streams of digital baseband signals to produce a plurality of digitized intermediate frequency signals corresponding to the plurality of antenna elements.

15. (Original) The apparatus of claim 14, wherein said plurality of digital up-converters perform interpolation to increase a sampling rate of the digitized intermediate frequency signals.

16. (Previously Presented) The apparatus of claim 14, wherein said plurality of digital up-converters separately up-convert digital baseband signals for each antenna element for each of a plurality of frequency channels.

17. (Original) The apparatus of claim 1, wherein signals are transmitted and received using time division duplex, said apparatus further comprising switching elements to selectively connect said shared baseband processor to said baseband modulator and front-end transmit circuitry for signal transmission and to said baseband demodulator and front-end receive circuitry for signal reception.

18. (Original) The apparatus of claim 1, wherein said apparatus employs time division multiple access (TDMA) to transmit and receive signals.

19. (Original) The apparatus of claim 1, wherein said apparatus employs frequency division multiple access (FDMA) to transmit and receive signals.

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20. (Original) The apparatus of claim 1, wherein said apparatus is a field programmable gate array (FPGA).

21. (Original) The apparatus of claim 1, wherein the apparatus is implemented via a very large scale integration (VLSI) circuit or an application specific integrated circuit (ASIC).

22. (Original) The apparatus of claim 1, wherein said apparatus is a modem.

23. (Original) The apparatus of claim 1, wherein said apparatus is a transceiver.

24. (Original) The apparatus of claim 1, wherein said apparatus is a basestation transceiver.

25. (Previously Presented) The apparatus of claim 1, wherein the shared baseband processor adjusts amplitudes of the digital baseband signals to perform power control and antenna element beam scaling.

26. (Previously Presented) A method of processing an RF signal received via an electronically steerable phased array antenna comprising a plurality of antenna elements, the method comprising:

(a) separately down-converting the RF signal from each antenna element to an intermediate frequency (IF) signal;

(b) separately analog-to-digital converting the IF signal from each antenna element;

(c) separately digitally down-converting the digital IF signal from each antenna element to a digital baseband signal to form a set of parallel baseband signals from the plurality of antenna elements;

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(d) time multiplexing the set of parallel baseband signals to form a serial stream of digital baseband signals;

(e) applying phases to the digital baseband signals in the serial stream to account for both carrier phase tracking and antenna element beamforming; and

(f) performing beamforming by combining digital baseband signals respectively associated with the plurality of antenna elements.

27. (Previously Presented) The method of claim 26, wherein (c) includes decimating the digital IF signal from each antenna element to reduce a number of samples in the serial stream of digital baseband signal.

28. (Previously Presented) The method of claim 26, wherein (c) includes generating baseband signals for a plurality of frequency channels from the digital IF signal of each antenna element, such that digital samples in the serial stream of digital baseband signals are associated with a particular antenna element and frequency channel.

29. (Previously Presented) A method of processing signals to be transmitted via an electronically steerable phased array antenna comprising a plurality of antenna elements, the method comprising:

(a) generating a stream of digital baseband signals representing data symbols to be transmitted via the phased array antenna, wherein digital baseband signals in the stream are associated with individual antenna elements;

(b) applying phases to each of the digital baseband signals to account for both carrier phase rotation and antenna element beamforming;

(c) demultiplexing the stream of digital baseband signals into a plurality of parallel signals respectively associated with individual antenna elements;

(d) digitally up-converting the parallel signals to produce a plurality of digital intermediate frequency (IF) signals respectively associated with individual antenna elements;

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(e) digital-to-analog converting the digital IF signals to produce a plurality of IF signals respectively associated with individual antenna elements; and

(f) up-converting the IF signals to RF signals for transmission via the phased array antenna.

30. (Previously Presented) The method of claim 29, wherein the phased array antenna simultaneously transmits signals on a plurality of frequency channels, and the stream of digital baseband signals includes signals associated with individual ones of the frequency channels.

31. (New) The apparatus of claim 1, wherein the shared baseband processor applies a single phase adjustment to each of the digital baseband signals, wherein the single phase adjustment jointly accounts for both beamsteering phase rotation and carrier phase rotation.

32. (New) The apparatus of claim 1, wherein the shared baseband processor generates a stream of combined phase adjustments by summing a stream of carrier phases for the digital baseband signals with a stream of beam rotation phases for the digital baseband signals, and adjusts phases of the digital baseband signals in accordance with the combined phase adjustments.

33. (New) The method of claim 26, wherein (e) includes applying a single phase adjustment to each of the digital baseband signals in the serial stream, wherein the single phase adjustment jointly accounts for both beamsteering phase rotation and carrier phase rotation.

34. (New) The method of claim 26, wherein (e) includes:

generating a stream of carrier phases for the digital baseband signals;

generating a stream of beam rotation phases for the digital baseband signals;

summing the beam rotation phases and the carrier phases to produce a stream of combined phase adjustments; and

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applying the stream of combined phase adjustments to the digital signals in the serial stream to account for both carrier phase tracking and antenna element beamforming.

35. (New) The method of claim 29, wherein (b) includes applying a single phase adjustment to each of the digital baseband signals, wherein the single phase adjustment jointly accounts for both beamsteering phase rotation and carrier phase rotation.

36. (New) The method of claim 29, wherein (b) includes:

generating a stream of carrier phases for the digital baseband signals;

generating a stream of beam rotation phases for the digital baseband signals;

summing the beam rotation phases and the carrier phases to produce a stream of combined phase adjustments; and

applying the stream of combined phase adjustments to the stream of digital baseband signals to account for both carrier phase rotation and antenna element beamforming.

REMARKS

Claims 1 – 36 are pending in the subject application: claims 1 – 30 have been examined: claims 1 – 4 and 7 – 30 stand rejected, and claims 5 and 6 are indicated as containing allowable subject matter. By the above amendments, claim 1 has been amended, and new claims 31 – 36 have been added. Favorable reconsideration of the application and allowance of all of the pending claims are respectfully requested in view of the above amendments and the following remarks.

As a preliminary matter, the primary reference relied upon by the Examiner, U.S. Patent No. 6,615,024 to Boros et al., is not listed on either of the PTO-892 forms issued by the Examiner. Further, as noted in the previously filed Amendment, U.S. Patent No. 6,549,527 to Tsutsui also has not been listed on a PTO-892 form. Accordingly, Applicant respectfully requests the Examiner to issue another PTO-892 form with the next communication listing both of these documents.

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Claims 1 and 22 – 25 stand rejected under 35 U.S.C. §103(a) as being unpatentable over U.S. Patent No. 6,615,024 to Boros et al. Further, claims 2 and 3 stand rejected as being unpatentable over Boros in view of U.S. Patent No. 5,583,562 to Birch et al.; claim 4 stands rejected over Boros, Birch, and U.S. Patent No. 6,768,458 to Green et al.; claims 7 – 10 stand rejected over Boros and U.S. Patent No. 6,831,943 to Dabak et al.; claims 11 – 13 stand rejected over Boros and U.S. Patent No. 6,549,527 to Tsutsui et al.; claims 14 – 16 and 18 stand rejected over Boros and U.S. Patent No. 5,809,422 to Raleigh et al.; claim 17 stands rejected over Boros and U.S. Patent No. 5,937,348 to Cina et al.; claims 19 – 21 stand rejected over Boros and U.S. Patent Application Publication No. 2002/0141478 to Ozluturk et al; and claims 26 – 30 stand rejected over U.S. Patent No. 6,101,399 to Rayleigh in view of U.S. Patent No. 5,631,898 to Dent and U.S. Patent No. 6,072,994 to Phillips et al. Applicant respectfully traverses these rejections for the following reasons.

Independent claim 1 sets forth an apparatus for modulating and demodulating signals transmitted and received via an electronically steerable phased array antenna comprising a plurality of antenna elements. The claimed apparatus includes:

a baseband modulator configured to modulate outbound digital baseband signals to be transmitted via the phased array antenna;

a baseband demodulator configured to demodulate incoming digital baseband signals generated from signals received via the phased array antenna; and

a shared baseband processor configured to receive digital baseband signals including the modulated outbound digital baseband signals and the incoming digital baseband signals, wherein the shared baseband processor applies phases to the digital baseband signals to account for both beamforming phase rotation and carrier phase rotation of individual antenna elements.

Notably, the apparatus of claim 1 requires the shared baseband processor to apply phases to the digital baseband signals to account for both beamsteering and the carrier phase of individual antenna elements (i.e., the baseband carrier phase is applied to the digital signal). As explained on page 9, lines 1-13, digital baseband processors do not generally process carrier phase on an antenna-element-by-antenna-element basis, since the carrier phase is the same for all

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antenna elements. In the claimed architecture, the phases applied to the digital baseband signal account for beamforming phase rotation and carrier phase rotation of individual antenna elements. This approach makes it possible to apply a single phase adjustment to each digital baseband signal that jointly accounts for both beamsteering and carrier phase.

Boros does not disclose or suggest applying phases to the digital baseband signals to account for both beamsteering and the carrier phase of individual antenna elements. In particular, the transmit weights referred to by Boros at column 13 (and cited by the Examiner) relate exclusive to beamforming. Boros is completely silent as to how carrier phase modulation is accomplished. In particular, Boros does not appear to include even a general teaching of applying carrier phase rotations to digital baseband signals, much less the more specific claim requirement that the phases applied to the digital baseband signals account for both beamsteering and carrier phase of individual antenna elements. In short, while Boros appears to teach applying beamsteering weights for individual antenna elements, Boros does not disclose or suggest applying carrier phase rotation to digital baseband signals that correspond to individual antenna elements as claimed. Accordingly, the subject matter of claim 1 would not have been obvious from Boros.

The remaining documents cited in combination with Boros are relied upon by the Examiner for teachings of subject matter recited in various dependent claims. Aside from whether these documents teach what the Examiner alleges or whether it would have been obvious to combine these documents in the manner proposed, none of these documents discloses or suggests apply phases to the digital baseband signals to account for both beamsteering and the carrier phase of individual antenna elements, as recited in claim 1. Consequently, the subject matter of claim 1 and its dependent claims would not have been obvious from any combination of the cited documents. Accordingly, the Examiner is respectfully requested to reconsider and withdraw the rejections of claim 1 and its dependent claims.

Turning to the rejection of claims 26-30 over Rayleigh, Dent, and Phillips, each of independent method claims 26 and 29 includes essentially the same requirement of claim 1 discussed above. In particular, these claims require applying phases to the digital baseband

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signals in a serial stream to account for both carrier phase tracking and antenna element beamforming, where the digital baseband signals in the serial stream are associated with individual antenna elements. In other words, both the carrier phase rotation and beamforming phase are applied to signals associated with individual antenna elements. This claim requirement is simply not disclosed or suggested anywhere in Rayleigh, Dent, and Phillips, and the Examiner's arguments do not address this point. Accordingly, the subject matter of claims 26-30 would not have been obvious from any combination of these documents, and the Examiner is respectfully requested to reconsider and withdraw this rejection.

Applicant has added new dependent claims 31 (31/1), 33 (32/26), and 35 (35/29), which require applying a single phase adjustment to each of the digital baseband signals, wherein the single phase adjustment jointly accounts for both beamsteering phase rotation and carrier phase rotation. Further, new dependent claims 32 (32/1), 34 (34/26), and 36 (36/29) require generating a stream of combined phase adjustments by summing a stream of carrier phases for the digital baseband signals with a stream of beam rotation phases for the digital baseband signals, and adjusting phases of the digital baseband signals in accordance with the combined phase adjustments. Note that the limitations in these new dependent claims are somewhat similar to certain limitations found in allowable claim 5 in that the beamsteering and carrier phase are combined and jointly applied to the digital baseband signals.

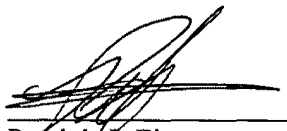
The Examiner indicates that claims 5 and 6 would be allowable if rewritten in independent form to include all of the limitations of their parent claims and any intervening claims. The Examiner is requested to hold in abeyance the requirement of rewriting of claims 5 and 6 in independent form, until the Examiner has had an opportunity to reconsider (and withdraw) the rejection of parent claim 1 under 35 U.S.C. §103(a).

In view of the foregoing, Applicant respectfully requests the Examiner to find the application to be in condition for allowance with claims 1 – 36. However, if for any reason the Examiner feels that the application is not now in condition for allowance, the Examiner is respectfully requested to call the undersigned attorney to discuss any unresolved issues and to expedite the disposition of the application.

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Filed concurrently herewith is a Petition (with payment) for an Extension of Time of One Month. Also filed concurrently herewith is payment of an excess claim fee in the amount of $300 for six (6) new claims in excess of the thirty (30) previously paid for. Applicant hereby petitions for any extension of time which may be required to maintain the pendency of this case, and any required fee for such extension is to be charged to Deposit Account No. 05-0460.

Respectfully submitted,



Patrick J. Finnan
Registration No. 39,189

EDELL, SHAPIRO & FINNAN, LLC
1901 Research Boulevard, Suite 400
Rockville, Maryland 20850-3164
(301) 424-3640

Hand Delivered on: May 1, 2006

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PATENT & TRADEMARK OFFICE

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Appl. No.	:	10/084,614
Applicant	:	Scott BIERLY et al.
Filed	:	February 28, 2002
TC/A.U.	:	2634
Examiner	:	LU, J.
Confirmation No.	:	1621
Docket No.	:	0918.0153C
Customer No.	:	27896
Title	:	Integrated Beamformer/Modem Architecture

Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450

PETITION FOR EXTENSION OF TIME

Sir:

Pursuant to 37 C.F.R. § 1.136(a), Applicants hereby petition for an extension of time of one month, extending the time period for responding to the Office Action of December 29, 2005, from March 29, 2006, to April 29, 2006. Applicants further petition that any and all extensions of the term necessary to render timely the filing of the accompanying or any future responses be granted.

The extension fee is: ☐ $60.00 ☒ $120.00

☒ An extension fee in the amount of $120.00 is enclosed.

☐ The shortened statutory period has been reset by an Advisory Action dated

05/02/2006 JADD01 00000072 10084614
01 FC:1251 120.00 OP

☒ The Commissioner is hereby authorized to charge any additional appropriate fees under 37 C.F.R. §§ 1.16, 1.17 and 1.21 that may be required by this paper, and to credit any overpayment, to Deposit Account No. 05-0460.

Respectfully submitted,

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(301) 424-3640

Hand-Delivered: May 1, 2006

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Appl. No.	:	10/084,614
Applicant	:	Scott BIERLY et al.
Filed	:	February 28, 2002
TC/A.U.	:	2634
Examiner	:	LU, J.
Confirmation No.	:	1621
Docket No.	:	0918.0153C
Customer No.	:	27896
Title	:	Integrated Beamformer/Modem Architecture

Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450

TRANSMITTAL OF AMENDMENT

Enclosed are the following documents in response to the Office Action mailed December 29, 2005, for the above-identified application:

- ☒ Amendment (13 Pages)
- ☒ Petition for Extension of Time (2 pages)
- ☐ Request for Approval of Drawing Changes
- ☐ Notice of Appeal
- ☐ Associate Power
- ☐ Revocation and New Power
- ☐ Change of Address
- ☐ Return receipt postcard
- ☒ Check No. 9630 in the amount of $300.00 for the total fee as calculated below
- ☒ Check No. 9629 in the amount of $120.00 for payment of the one-month extension of time fee

The fee has been calculated as follows:

	NO OF CLAIMS REMAINING	NO. OF CLAIMS PREVIOUSLY PAID FOR	NO OF EXCESS CLAIMS	RATE	FEE
Total Claims	36	- 30 =	6	$50.00	$300.00
Independent Claims	3	- 3 =	0	$200.00	0.00
If multiple dependent claims are presented, add $360.00					0.00
Total Amendment Fee					$300.00
☐ Applicant claims Small Entity Status (subtract 50% of Total Application Fee)					0.00
Other fees: (specify)					0.00
TOTAL FEE DUE					$300.00

☒ A check for the total fee is attached.

☐ Please charge $ to Deposit Account No. 05-0460 for the total fee. This paper is being submitted in duplicate.

☒ The Commissioner is hereby authorized to charge any additional appropriate fees under 37 C.F.R. §§1.16, 1.17, and 1.21 that may be required by this paper, and to credit any overpayment, to Deposit Account No. 05-0460.

Dated: 5/1/06

Respectfully submitted by
EDELL, SHAPIRO & FINNAN, LLC

By: _____
Patrick J. Finnan
Reg. No. 39,189

EDELL, SHAPIRO & FINNAN, LLC
CUSTOMER NO. 27896
1901 Research Boulevard, Suite 400
Rockville, MD 20850
(301) 424-3640

PATENT APPLICATION FEE DETERMINATION RECORD
Effective October 1, 2001

Application or Docket Number: 10081614

CLAIMS AS FILED - PART I

	(Column 1)		(Column 2)
TOTAL CLAIMS	24		
FOR	NUMBER FILED		NUMBER EXTRA
TOTAL CHARGEABLE CLAIMS	24	minus 20=	* 4
INDEPENDENT CLAIMS	1	minus 3 =	*
MULTIPLE DEPENDENT CLAIM PRESENT			☐

* If the difference in column 1 is less than zero, enter "0" in column 2

SMALL ENTITY TYPE ☐	RATE	FEE	OR	OTHER THAN SMALL ENTITY	RATE	FEE
	BASIC FEE	370.00	OR		BASIC FEE	740.00
	X$ 9=		OR		X$18=	72
	X42=		OR		X84=	156.00
	+140=		OR		+280=	
	TOTAL		OR		TOTAL	968.00

CLAIMS AS AMENDED - PART II

10/6/05

AMENDMENT A

	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA
Total	* 30	Minus	** 24	= 6
Independent	* 3	Minus	*** 3	=
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM				☐

SMALL ENTITY	RATE	ADDITIONAL FEE	OR	OTHER THAN SMALL ENTITY	RATE	ADDITIONAL FEE
	X$ 9=		OR		X$18= 50	300
	X42=		OR		X84=	
	+140=		OR		+280=	
	TOTAL ADDIT. FEE		OR		TOTAL ADDIT. FEE	

5/10/06

AMENDMENT B

	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA
Total	* 36	Minus	** 30	= 6
Independent	* 3	Minus	*** 3	=
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM				☐

SMALL ENTITY	RATE	ADDITIONAL FEE	OR	OTHER THAN SMALL ENTITY	RATE	ADDITIONAL FEE
	X$ 9=		OR		X$18= 50	300
	X42=		OR		X84=	
	+140=		OR		+280=	
	TOTAL ADDIT. FEE		OR		TOTAL ADDIT. FEE	300

AMENDMENT C

	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA
Total	*	Minus	**	=
Independent	*	Minus	***	=
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM				☐

SMALL ENTITY	RATE	ADDITIONAL FEE	OR	OTHER THAN SMALL ENTITY	RATE	ADDITIONAL FEE
	X$ 9=		OR		X$18=	
	X42=		OR		X84=	
	+140=		OR		+280=	
	TOTAL ADDIT. FEE		OR		TOTAL ADDIT. FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20."
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3."
The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

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UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
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Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/084,614	02/28/2002	Scott Bierly	0918.0153C	1621

27896 7590 06/22/2006

EDELL, SHAPIRO & FINNAN, LLC
1901 RESEARCH BOULEVARD
SUITE 400
ROCKVILLE, MD 20850

EXAMINER	
LU, JIA	

ART UNIT	PAPER NUMBER
2611	

DATE MAILED: 06/22/2006

Please find below and/or attached an Office communication concerning this application or proceeding.

Office Action Summary	Application No.	Applicant(s)	
	10/084,614	BIERLY ET AL.	
	Examiner	Art Unit	
	Jia W. Lu	2611	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) OR THIRTY (30) DAYS, WHICHEVER IS LONGER, FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☒ Responsive to communication(s) filed on *01 May 2006*.

2a)☒ This action is **FINAL**. 2b)☐ This action is non-final.

3)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

4)☒ Claim(s) *1-30* is/are pending in the application.

4a) Of the above claim(s) _____ is/are withdrawn from consideration.

5)☐ Claim(s) _____ is/are allowed.

6)☒ Claim(s) *1-4 and 7-30* is/are rejected.

7)☒ Claim(s) *5 and 6* is/are objected to.

8)☐ Claim(s) _____ are subject to restriction and/or election requirement.

Application Papers

9)☐ The specification is objected to by the Examiner.

10)☒ The drawing(s) filed on *28 February 2002* is/are: a)☒ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

11)☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

Priority under 35 U.S.C. § 119

12)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a)☐ All b)☐ Some * c)☐ None of:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☒ Notice of References Cited (PTO-892)
2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)
3) ☐ Information Disclosure Statement(s) (PTO-1449 or PTO/SB/08) Paper No(s)/Mail Date _____.
4) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____.
5) ☐ Notice of Informal Patent Application (PTO-152)
6) ☐ Other: _____.

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Response to Arguments

Regarding independent claim 1, applicant argues that "Boros does not disclose or suggest applying phases to the digital baseband signals to account for both beamsteering and the carrier phase of individual antenna elements". In dealing with antenna arrays, "beam forming" inherently includes the adjustments of carrier phases of antenna elements, therefore, Boros discloses both beamsteering and carrier phase rotation in his description of beam forming. While Boros does not specify performing carrier phase rotation for each individual antenna element, the language of the claim does not limit the carrier phases to being different for each individual antenna element. In the case that they are all identical to each other, Boros' invention reads on the claim.

Regarding independent claims 26 and 29, applicant argues that these claims require applying phases to the digital baseband signals in a serial stream to account for both carrier phase tracking and antenna element beamforming, where the digital baseband signals in the serial stream are associated with individual antenna elements. In addition to the response presented above, claims 26 and 29 do not clearly indicate that carrier phase tracking and antenna element beamforming are performed on individually on each received or transmitted signal.

Claim Rejections - 35 USC § 103

The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

> (a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.

The text of those sections of Title 35, U.S. Code not included in this action can be found in a prior Office action.

1. Claims 1, 22-25 are rejected under 35 U.S.C. 103(a) as being unpatentable over US patent 6,615,024.

    a. Regarding claims 1, 22-24, '024 shows a baseband modulator (column 13, lines 20-25), a baseband demodulator (figure 4, element 411), and a shared baseband processor (figure 1, elements 111, 117 and 123) which receives outbound and incoming signals, said processor applying phases to the signals to account for both beamforming and carrier phase rotations (column 13, lines 30-45). While the shared baseband processor used in this rejection is based on a grouping of receive and transmit processors, the system that '024 describes performs the same functions of adjusting the antenna array. It would have been obvious to one ordinarily skilled in the art to group the weight generators (figure 4, element 409, figure 1, elements 131 and 117) into a single circuit to call it a "shared" processor to reduce the size and complexity of the circuit.

    b. Regarding claim 25, '024 describes the processor to adjust amplitude of the signals (column 12, lines 65-68).

2. Claims 2 and 3 are rejected under 35 U.S.C. 103(a) as being unpatentable over US patent 6,615,024 as applied to claim 1 above, and further in view of US patent 5,583,562.

    a. Regarding claim 2, although patent '024 does not show time-multiplexing of received data, the use of time-multiplexing in transceiver systems is well known for their ability to increase the throughput of a communications resource (for example, patent '562, fig 1). It would have been obvious for one ordinarily skilled in the art to use time-multiplexing in a system described in '024 in order to allow more users to use a single channel in a duplex system.

    b. Regarding claim 3, while patent '024 does not show the modulator to provide a time-multiplexed data stream from an input of multiple data streams, patent '562 shows a modulator (fig 1, element 130) receiving data symbols from a plurality of user channels (fig 1, element 110) and provide a single time-multiplexed data stream (column 5, lines 30-40). The reason to combine time-multiplexing with a modulator is stated in part a above.

3. Claim 4 is rejected under 35 U.S.C. 103(a) as being unpatentable over US patent 6,615,024 and US patent 5,583,562 as applied to claim 3 above, and further in view of US patent 6,768,458. While patent '024 does not show a modulator generating a plurality of modulated data in the time-multiplexed stream corresponding to a plurality of antenna elements, patent '458 shows a modulator

(figure 5, elements 216 and 218) generating a plurality of modulated data symbols in the time-multiplexed stream, corresponding to a plurality of antenna elements (figure 5, element 250). It would have been obvious for one ordinarily skilled in the art for a modulating system described in patent '024 to time-multiplex a plurality of modulated data symbols corresponding to antenna elements in order to increase directional gain in transmission.

4. Claims 7-10 are rejected under 35 U.S.C. 103(a) as being unpatentable over US patent 6,615,024 as applied to claim 1 above, and further in view of US patent 6,831,943.

    a. Regarding claims 7-9, patent '024 does not describe the complex multiplication of signals in the processor relating to a plurality of user channels in a time-multiplexed manner. However, patent '943 teaches a transmission system where a processor unit (figure 10, elements 18 and 20) performs complex multiplication on signals on incoming signals that have been time-multiplexed (column 29, line 43), associated with a plurality of antennas (figure 1, elements A12). While the plurality of user channels is not shown, it is well known that a system using time-multiplexing takes signals from different users in order to multiplex them. It would have been obvious for one ordinarily skilled in the art to use complex multiplication in a system described in patent '024 for beamforming (column 7, lines 18-47) and power adjustments (column 15, lines 47-54) in order to improve power usage and reduce interference.

b. Regarding claim 10, patent '024 does not disclose a beamformer configured to receive time-multiplexed baseband signals from shared baseband processor. Patent '943, however, shows a beamformer (figure 2, element 52) capable of receiving time-multiplexed (column 29, line 43) signals from a front-end processor. It would have been obvious for one ordinarily skilled in the art to use a beamformer in a transceiver system described in patent '024 when incoming signals require directional and rotational adjustments in order to acquire precise directional transmission to increase gain while using lower power.

5. Claims 11-13 are rejected under 35 U.S.C. 103(a) as being unpatentable over US patent 6,615,024 as applied to claim 1 above, and further in view of US patent 6,549,527. While patent '024 does not show the front-end specifics of its receiving circuitry, patent '527 shows a plurality of down-converters (column 2, lines 29-33) separately down-converting signals for each antenna element (figure 14, element 142). It also teaches the down-converting circuitry to include decimation means (figure 1, element 11) followed by multiplexing means (figure 1, element 12). It would have been obvious for one ordinarily skilled in the art to use decimation and multiplexing in the receiver end in order enable signal processing in an antenna array system without lowering system performance or increasing price, dimension or complexity of the hardware (column 3, line 48-line 59).

6. Claims 14-16, 18 are rejected under 35 U.S.C. 103(a) as being unpatentable over US patent 6,615,024 as applied to claim 1 above, and further in view of US patent 5,809,422.

    a. Regarding claims 14-16, while patent '024 does not show a demultiplexer and up-converters in transmission, patent '422 teaches the use of demultiplexers (figure 4, element 134) and IF up-converters (column 7, lines 33-40) in separate transmitting antenna elements (column 11, lines 56-60). Patent '422 also teaches interpolation in order to increase the sampling rate of the transmission signals (column 13, lines 39-40). It would have been obvious for one ordinarily skilled in the art to employ demultiplexing in an transmission end as described in patent '024 in order to separate time-multiplexed symbols for transmission and up convert baseband signals into a higher, intermediate frequency in order to enable signal transmission in a wireless medium.

    b. Regarding claim 18, while patent '024 does not teach the use of TDMA, patent '422 teaches the use of TDMA (column 8, line 41) in its transceiver system. Because TDMA is a very common technique used in transmission, and it would have been obvious to one ordinarily skilled in the art to use TDMA to allow multiple users to share time slots within a single channel.

7. Claim 17 is rejected under 35 U.S.C. 103(a) as being unpatentable over US patent 6,615,024 as applied to claim 1 above, further in view of US patent

5,937,348. While patent '024 teaches the use of a duplexer between the transmitter and receiver portion of its transceiver, it does not specify the duplex to be time-division or the use of a switch. Patent '348 shows a duplex switch capable of using time division duplex (column 5, line 20). It would have been obvious to one ordinarily skilled in the art to use a switch in a time division duplex transceiver system described in patent '024 in order to provide better control over the system while allowing it to transmit and receive using a single front-end processor.

8. Claims 19-21 are rejected under 35 U.S.C. 103(a) as being unpatentable over US patent 6,615,024 as applied to claim 1 above, further in view of US patent application 20020141478. While patent '024 does not show the use FDMA, FPGA or VLSI in its transceiver system, application '478 teaches all these elements (FDMA on paragraph 2, line 6, FPGA on paragraph 621, line 4, and ASIC on paragraph 621, line 5). It would have been obvious to one ordinarily skilled in the art to use FDMA to allow multiple users to share time slots, FPGA to increase flexibility in designs and programming, or ASIC to reduce power usage, save space and lower cost of production.
9. Claims 26-30 are rejected under 35 U.S.C. 103(a) as being unpatentable over US patent 6,101,399, in view of US patent 5,631,898, further in view of US patent 6,072,994.
    a. Regarding claims 26 and 28, while '399 shows a method of processing signals received via antenna arrays comprising downconverter producing

parallel signals (figure 3, element 54), and applying phases to the signals and performing beamforming (element 60), it does not show individual down-converting and A/D units, patents '898 and 643 show these features. Patent '898 shows separate IF down-converters (figure 12, element 1203), baseband down-converters (element 1207), A/D (element 1212), and a digital multiplexer (element 1213). It does not show the A/D to be down at IF, however, patent '994 shows this (column 31, lines 30-35). It would have been obvious to one ordinarily skilled in the art to perform A/D at IF in the circuit in '898 to allow many benefits such as easier digital programming, replacement of bulky circuitry, and better tuning; It would also have been obvious to one ordinarily skilled in the art to use the individual antenna processing elements of '898 in the system described in '399 to have more maneuverable controls of individual antenna elements.

b. Regarding claim 27, '399 describes the decimation of signals after digitizing and downconverting to baseband and prior to beamforming.

c. Claims 29 and 30 describe the limitations in claim 26 at its transmitting end. It would have been obvious to one ordinarily skilled in the art to reverse, step-by-step, the limitations of claim 26 in a receiver end to achieve transmission.

Allowable Subject Matter

10. Claims 5 and 6 are objected to as being dependent upon a rejected base claim, but would be allowable if rewritten in independent form including all of the limitations of the base claim and any intervening claims.

Conclusion

Applicant's amendment necessitated the new ground(s) of rejection presented in this Office action. Accordingly, **THIS ACTION IS MADE FINAL**. See MPEP § 706.07(a). Applicant is reminded of the extension of time policy as set forth in 37 CFR 1.136(a).

A shortened statutory period for reply to this final action is set to expire THREE MONTHS from the mailing date of this action. In the event a first reply is filed within TWO MONTHS of the mailing date of this final action and the advisory action is not mailed until after the end of the THREE-MONTH shortened statutory period, then the shortened statutory period will expire on the date the advisory action is mailed, and any extension fee pursuant to 37 CFR 1.136(a) will be calculated from the mailing date of the advisory action. In no event, however, will the statutory period for reply expire later than SIX MONTHS from the date of this final action.

Any inquiry concerning this communication or earlier communications from the examiner should be directed to Jia W. Lu whose telephone number is 571-272-6042. The examiner can normally be reached on Mon- Fri, 10:30AM-6:30PM.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Stephen Chin can be reached on (571)272-3056. The fax phone number for the organization where this application or proceeding is assigned is 703-872-9306.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free).

Jia Lu
Examiner

CHIEH M. FAN
SUPERVISORY PATENT EXAMINER

Notice of References Cited	Application/Control No. 10/084,614	Applicant(s)/Patent Under Reexamination BIERLY ET AL.	
	Examiner Jia W. Lu	Art Unit 2611	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	Classification
*	A	US-6,615,024	09-2003	Boros et al.	455/67.14
*	B	US-6,549,527	04-2003	Tsutsui et al.	370/342
*	C	US-6,307,506	10-2001	Despain, Alvin M.	342/368
	D	US-			
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FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	Classification
	N					
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NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
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	V	
	W	
	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

Index of Claims

Application/Control No.	Applicant(s)/Patent under Reexamination
10/084,614	BIERLY ET AL.
Examiner	**Art Unit**
Jia W. Lu	2611

√	Rejected	–	(Through numeral) Cancelled	N	Non-Elected	A	Appeal
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Claim		Date
Final	Original	12/14/05
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Search Notes

Application/Control No.	Applicant(s)/Patent under Reexamination	
10/084,614	BIERLY ET AL.	
Examiner	**Art Unit**	
Jia W. Lu	2611	

SEARCHED			
Class	Subclass	Date	Examiner
375	222	6/13/2006	JL

INTERFERENCE SEARCHED			
Class	Subclass	Date	Examiner
375	**222**	6/13/2006	**JL**

SEARCH NOTES (INCLUDING SEARCH STRATEGY)		
	DATE	EXMR
ALL EAST DATABASES	6/13/2006	JL

OIPE
NOV 22 2006
PATENT & TRADEMARK OFFICE

PTO/SB/31 (08-03)
Approved for use through 07/31/2006. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

NOTICE OF APPEAL FROM THE EXAMINER TO THE BOARD OF PATENT APPEALS AND INTEFERENCES

Docket Number (Optional): 0918.0153C

I hereby certify that this correspondence is being deposited with the United States Postal Service with sufficient postage as first class mail in an envelope addressed to "Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450" on _____

Signature _____

Typed or printed name _____

In re Application of: Bierly et al.

Application Number: 10/084,614 | Filed: February 28, 2002

For: Integrated Beamformer/Modem Architecture

Art Unit: 2634 | Examiner: LU, J.

Applicant hereby **appeals** to the Board of Patent Appeals and Interferences from the last decision of the examiner.

The fee for this Notice of Appeal is (37 CFR 1.17(b)) $ 500.00

☐ Applicant claims small entity status. See 37 CFR 1.27. Therefore, the fee shown above is reduced by half, and the resulting fee is: $ _____

☑ A check in the amount of the fee is enclosed.

☐ Payment by credit card. Form PTO-2038 is attached.

☐ The Director has already been authorized to charge fees in this application to a Deposit Account. I have enclosed a duplicate copy of this sheet.

☐ The Director is hereby authorized to charge any fees which may be required, or credit any overpayment to Deposit Account No. 05-0460 . I have enclosed a duplicate copy of this sheet.

☑ A petition for an extension of time under 37 CFR 1.136(a) (PTO/SB/22) is enclosed.

WARNING: Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038.

I am the

☐ applicant/inventor.

☐ assignee of record of the entire interest. See 37 CFR 3.71. Statement under 37 CFR 3.73(b) is enclosed. (Form PTO/SB/96)

☑ attorney or agent of record. Registration number 39,189

☐ attorney or agent acting under 37 CFR 1.34(a). Registration number if acting under 37 CFR 1.34(a). _____

Signature

Patrick J. Finnan
Typed or printed name

301/424-3640
Telephone number

November 22, 2006
Date

NOTE: Signatures of all the inventors or assignees of record of the entire interest or their representative(s) are required. Submit multiple forms if more than one signature is required, see below*.

11/24/2006 IRESHUN1 00000015 10084614

☑ *Total of 1 forms are submitted.

01 FC:1401 500.00 OP

This collection of information is required by 37 CFR 1.191. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

NOV 22 2006
PATENT & TRADEMARK OFFICE

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Appl. No.	:	10/084,614
Applicant	:	Scott Bierly et al.
Filed	:	February 28, 2002
TC/A.U.	:	2634
Examiner	:	Lu, J.
Confirmation No.	:	1621
Docket No.	:	0918.0153C
Customer No.	:	27896
Title	:	Integrated Beamformer/Modem Architecture

PETITION FOR EXTENSION OF TIME

COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

Pursuant to 37 C.F.R. § 1.136(a), Applicant hereby petitions for an extension of time of two months, extending the time period for responding to the Office Action of June 22, 2006 from September 22, 2006 to November 22, 2006. Applicant further petitions that any and all extensions of the term necessary to render timely the filing of the accompanying or any future responses be granted.

The extension fee is:

☐ $225.00 ☒ $450.00

☒ Check No. 10062 in the amount of $950.00 is enclosed ($450.00 for the extension fee, and $500.00 for the Notice of Appeal fee).

☐ The shortened statutory period has been reset by an Advisory Action dated .

☐ Charge $ to Deposit Account No. 05-0460.

☒ The Commissioner is hereby authorized to charge any additional appropriate fees that may be required for the subject application, and to credit any overpayment, to Deposit Account No. 05-0460.

Respectfully submitted,

11/22/2006 TDESHAN1 00000015 10084614
02 FC:1252 450.00 OP

Dated: 11/22/06

Patrick J. Finnan
Registration No. 39,189

EDELL, SHAPIRO & FINNAN, LLC
1901 Research Boulevard, Suite 400
Rockville, Maryland 20850-3164
(301) 424-3640

OIPE
NOV 22 2006
PATENT & TRADEMARK OFFICE

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Appl. No.	:	10/084,614
Applicant	:	Scott BIERLY et al.
Filed	:	February 28, 2002
TC/A.U.	:	2634
Examiner	:	LU, J.
Confirmation No.	:	1621
Docket No.	:	0918.0153C
Customer No.	:	27896
Title	:	Integrated Beamformer/Modem Architecture

ATTN: Mail Stop AF
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

REQUEST FOR RECONSIDERATION

Sir:

In response to the Office Action mailed June 22, 2006, please amend the above-identified application as follows:

A Listing of the Claims begins on page 2 of this paper.

Remarks begin on page 9 of this paper.

NOV 22 2006
PATENT & TRADEMARK OFFICE

Listing of Claims:

This listing of the claims is provided for the Examiner's convenience. No amendments are being made at this time.

1. (Previously Presented) An apparatus for modulating and demodulating signals transmitted and received via an electronically steerable phased array antenna comprising a plurality of antenna elements, the apparatus comprising:

a baseband modulator configured to modulate outbound digital baseband signals to be transmitted via the phased array antenna;

a baseband demodulator configured to demodulate incoming digital baseband signals generated from signals received via the phased array antenna; and

a shared baseband processor configured to receive digital baseband signals including the modulated outbound digital baseband signals and the incoming digital baseband signals, said shared baseband processor applying phases to the digital baseband signals to account for both beamforming phase rotation and carrier phase rotation of individual antenna elements.

2. (Previously Presented) The apparatus of claim 1, wherein said digital baseband signals received by said shared baseband processor are time multiplexed, and said shared baseband processor operates on said digital baseband signals on a time-slot-by-time-slot basis.

3. (Previously Presented) The apparatus of claim 1, wherein said baseband modulator receives data symbols from a plurality of user channels and supplies to said shared baseband processor a time-multiplexed stream of modulated digital data symbols from said plurality of user channels.

4. (Previously Presented) The apparatus of claim 3, wherein, for each input digital data symbol, said baseband modulator generates a plurality of modulated digital data symbols in the time-multiplexed stream respectively corresponding to the plurality of antenna elements.

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5. (Previously Presented) The apparatus of claim 1, wherein said shared baseband processor comprises:

a numerically controlled oscillator configured to generate a stream of carrier phases for digital baseband signals of each of a plurality of user channels in a time-multiplexed manner;

a beamforming phase rotator configured to generate a stream of beam rotation phases corresponding to individual antenna elements for each of the plurality of user channels in a time-multiplexed manner;

a phase adder configured to sum the beam rotation phases and the carrier phases to produce a time-multiplexed stream of combined phase adjustments; and

a complex multiplier configured to adjust phases of a time-multiplexed stream of digital baseband signals corresponding to the plurality of user channels in accordance with the combined phase adjustments.

6. (Original) The apparatus of claim 5, wherein said combined phase adjustments index a sine/cosine lookup table which supplies multiplicands to said complex multiplier.

7. (Previously Presented) The apparatus of claim 1, wherein said shared baseband processor comprises a multiplier which performs complex multiplication on digital baseband signals relating to a plurality of user channels in a time-multiplexed manner.

8. (Previously Presented) The apparatus of claim 1, wherein said shared baseband processor comprises a multiplier which performs complex multiplication on digital baseband signals associated with a plurality of individual antenna elements in a time-multiplexed manner.

9. (Previously Presented) The apparatus of claim 1, wherein said shared baseband processor comprises a beam scaling and power control processor configured to generate a time-multiplexed stream of gain control signals for digital baseband signals corresponding to

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individual antenna elements for each of a plurality of user channels, the gain control signals jointly accounting for power control and antenna element beam scaling; and

a multiplier configured to adjust amplitudes of a time-multiplexed stream of digital baseband signals corresponding to the plurality of user channels in accordance with the gain control signals.

10. (Previously Presented) The apparatus of claim 1, further comprising:

a baseband beamformer configured to receive time-multiplexed digital baseband signals from said shared baseband processor corresponding to individual antenna elements, said baseband processor forming a combined signal from said time-multiplex digital baseband signals.

11. (Previously Presented) The apparatus of claim 1, further comprising:

a plurality of digital down-converters respectively down-converting digitized signals received from the plurality of antenna elements to produce parallel streams of sampled digital baseband signals; and

a multiplexer receiving the parallel streams of sampled digital baseband signals and supplying a time-multiplexed stream of the sampled digital baseband signals to said shared baseband processor.

12. (Previously Presented) The apparatus of claim 11, wherein said plurality of digital down-converters perform decimation to reduce a sampling rate of the sampled digital baseband signals.

13. (Original) The apparatus of claim 11, wherein said plurality of digital down-converters separately down-convert digitized signals for each antenna element for each of a plurality of frequency channels.

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14. (Previously Presented) The apparatus of claim 1, further comprising:

a demultiplexer receiving a time-multiplexed stream of digital baseband signals from said shared baseband processor and generating parallel streams of digital baseband signals corresponding to the plurality of antenna elements; and

a plurality of digital up-converters respectively up-converting the parallel streams of digital baseband signals to produce a plurality of digitized intermediate frequency signals corresponding to the plurality of antenna elements.

15. (Original) The apparatus of claim 14, wherein said plurality of digital up-converters perform interpolation to increase a sampling rate of the digitized intermediate frequency signals.

16. (Previously Presented) The apparatus of claim 14, wherein said plurality of digital up-converters separately up-convert digital baseband signals for each antenna element for each of a plurality of frequency channels.

17. (Original) The apparatus of claim 1, wherein signals are transmitted and received using time division duplex, said apparatus further comprising switching elements to selectively connect said shared baseband processor to said baseband modulator and front-end transmit circuitry for signal transmission and to said baseband demodulator and front-end receive circuitry for signal reception.

18. (Original) The apparatus of claim 1, wherein said apparatus employs time division multiple access (TDMA) to transmit and receive signals.

19. (Original) The apparatus of claim 1, wherein said apparatus employs frequency division multiple access (FDMA) to transmit and receive signals.

20. (Original) The apparatus of claim 1, wherein said apparatus is a field programmable

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gate array (FPGA).

21. (Original) The apparatus of claim 1, wherein the apparatus is implemented via a very large scale integration (VLSI) circuit or an application specific integrated circuit (ASIC).

22. (Original) The apparatus of claim 1, wherein said apparatus is a modem.

23. (Original) The apparatus of claim 1, wherein said apparatus is a transceiver.

24. (Original) The apparatus of claim 1, wherein said apparatus is a basestation transceiver.

25. (Previously Presented) The apparatus of claim 1, wherein the shared baseband processor adjusts amplitudes of the digital baseband signals to perform power control and antenna element beam scaling.

26. (Previously Presented) A method of processing an RF signal received via an electronically steerable phased array antenna comprising a plurality of antenna elements, the method comprising:

(a) separately down-converting the RF signal from each antenna element to an intermediate frequency (IF) signal;

(b) separately analog-to-digital converting the IF signal from each antenna element;

(c) separately digitally down-converting the digital IF signal from each antenna element to a digital baseband signal to form a set of parallel baseband signals from the plurality of antenna elements;

(d) time multiplexing the set of parallel baseband signals to form a serial stream of digital baseband signals;

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(e) applying phases to the digital baseband signals in the serial stream to account for both carrier phase tracking and antenna element beamforming; and

(f) performing beamforming by combining digital baseband signals respectively associated with the plurality of antenna elements.

27. (Previously Presented) The method of claim 26, wherein (c) includes decimating the digital IF signal from each antenna element to reduce a number of samples in the serial stream of digital baseband signal.

28. (Previously Presented) The method of claim 26, wherein (c) includes generating baseband signals for a plurality of frequency channels from the digital IF signal of each antenna element, such that digital samples in the serial stream of digital baseband signals are associated with a particular antenna element and frequency channel.

29. (Previously Presented) A method of processing signals to be transmitted via an electronically steerable phased array antenna comprising a plurality of antenna elements, the method comprising:

(a) generating a stream of digital baseband signals representing data symbols to be transmitted via the phased array antenna, wherein digital baseband signals in the stream are associated with individual antenna elements;

(b) applying phases to each of the digital baseband signals to account for both carrier phase rotation and antenna element beamforming;

(c) demultiplexing the stream of digital baseband signals into a plurality of parallel signals respectively associated with individual antenna elements;

(d) digitally up-converting the parallel signals to produce a plurality of digital intermediate frequency (IF) signals respectively associated with individual antenna elements;

(e) digital-to-analog converting the digital IF signals to produce a plurality of IF signals respectively associated with individual antenna elements; and

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(f) up-converting the IF signals to RF signals for transmission via the phased array antenna.

30. (Previously Presented) The method of claim 29, wherein the phased array antenna simultaneously transmits signals on a plurality of frequency channels, and the stream of digital baseband signals includes signals associated with individual ones of the frequency channels.

31. (Previously Presented) The apparatus of claim 1, wherein the shared baseband processor applies a single phase adjustment to each of the digital baseband signals, wherein the single phase adjustment jointly accounts for both beamsteering phase rotation and carrier phase rotation.

32. (Previously Presented) The apparatus of claim 1, wherein the shared baseband processor generates a stream of combined phase adjustments by summing a stream of carrier phases for the digital baseband signals with a stream of beam rotation phases for the digital baseband signals, and adjusts phases of the digital baseband signals in accordance with the combined phase adjustments.

33. (Previously Presented) The method of claim 26, wherein (e) includes applying a single phase adjustment to each of the digital baseband signals in the serial stream, wherein the single phase adjustment jointly accounts for both beamsteering phase rotation and carrier phase rotation.

34. (Previously Presented) The method of claim 26, wherein (e) includes:

generating a stream of carrier phases for the digital baseband signals;

generating a stream of beam rotation phases for the digital baseband signals;

summing the beam rotation phases and the carrier phases to produce a stream of combined phase adjustments; and

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applying the stream of combined phase adjustments to the digital signals in the serial stream to account for both carrier phase tracking and antenna element beamforming.

35. (Previously Presented) The method of claim 29, wherein (b) includes applying a single phase adjustment to each of the digital baseband signals, wherein the single phase adjustment jointly accounts for both beamsteering phase rotation and carrier phase rotation.

36. (Previously Presented) The method of claim 29, wherein (b) includes:

generating a stream of carrier phases for the digital baseband signals;

generating a stream of beam rotation phases for the digital baseband signals;

summing the beam rotation phases and the carrier phases to produce a stream of combined phase adjustments; and

applying the stream of combined phase adjustments to the stream of digital baseband signals to account for both carrier phase rotation and antenna element beamforming.

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REMARKS

Claims 1 – 36 are pending in the subject application. Claims 1 – 4 and 7 – 30 stand rejected, claims 5 and 6 are indicated as containing allowable subject matter, and the status of claims 31-36 is unknown, since the Examiner erroneously did not address these claims in the Office Action. Favorable reconsideration of the application and allowance of all of the pending claims are respectfully requested in view of the following remarks.

Dependent Claims 31-36 Were Not Address In the Office Action

In the Amendment filed May 1, 2006, Applicant introduce six new dependent claims, which contain certain limitations similar to those found in the allowable claims. In the subject Office Action, the Examiner failed to examiner or even acknowledge these claims.

Specifically, Applicant added dependent claims 31 (31/1), 33 (32/26), and 35 (35/29), which require applying a single phase adjustment to each of the digital baseband signals, wherein the single phase adjustment jointly accounts for both beamsteering phase rotation and carrier phase rotation. Further, Applicant added dependent claims 32 (32/1), 34 (34/26), and 36 (36/29) which require generating a stream of combined phase adjustments by summing a stream of carrier phases for the digital baseband signals with a stream of beam rotation phases for the digital baseband signals, and adjusting phases of the digital baseband signals in accordance with the combined phase adjustments. Note that the limitations in these new dependent claims are somewhat similar to certain limitations found in allowable claim 5 in that the beamsteering and carrier phase are combined and jointly applied to the digital baseband signals.

Note that these claims were added in response to a non-final Office Action and therefore should have been entered and considered; thus, the Office Action is incomplete. Accordingly, the Examiner is respectfully requested to provide Applicant with a corrected Office Action in which these claims are considered.

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Prior Art Rejections

The prior art rejections in the present Office Action are identical to those in the previous Office Action. Specifically, claims 1 and 22 – 25 stand rejected under 35 U.S.C. §103(a) as being unpatentable over U.S. Patent No. 6,615,024 to Boros et al. Further, claims 2 and 3 stand rejected as being unpatentable over Boros in view of U.S. Patent No. 5,583,562 to Birch et al.; claim 4 stands rejected over Boros, Birch, and U.S. Patent No. 6,768,458 to Green et al.; claims 7 – 10 stand rejected over Boros and U.S. Patent No. 6,831,943 to Dabak et al.; claims 11 – 13 stand rejected over Boros and U.S. Patent No. 6,549,527 to Tsutsui et al.; claims 14 – 16 and 18 stand rejected over Boros and U.S. Patent No. 5,809,422 to Raleigh et al.; claim 17 stands rejected over Boros and U.S. Patent No. 5,937,348 to Cina et al.; claims 19 – 21 stand rejected over Boros and U.S. Patent Application Publication No. 2002/0141478 to Ozluturk et al; and claims 26 – 30 stand rejected over U.S. Patent No. 6,101,399 to Rayleigh in view of U.S. Patent No. 5,631,898 to Dent and U.S. Patent No. 6,072,994 to Phillips et al. Applicant again respectfully traverses these rejections for the reasons set forth in the Amendment of May 1, 2006, which are incorporated herein by reference.

In response to the Examiner's rebuttal arguments presented on page 2 of the Office Action, Applicant offers these additional remarks. In essence, the Examiner's position is that the process of beamforming inherently includes adjustments of carrier phases of signals being transmitted/received by antenna elements; thus, Boros' mere teaching of digital beamforming encompasses both beamforming phase rotation and carrier phase rotation as claimed.

Applicant respectfully disagrees. A digital baseband signal cannot be transmitted by an RF transmitter unless an RF carrier signal is applied to the digital signal via phase rotation. Since the RF carrier signal is generally the same for all antenna elements, the RF carrier signal is generally applied to a common baseband signal (separately from the beamforming phase adjustments). This common RF-modulated digital signal can then split into a plurality of signals corresponding to individual antenna elements, and the various different phase shifts associated with the different antenna elements can then respectively be applied to the plurality of signals. Likewise, upon reception of a signal via an array of antenna elements, the beamforming phase

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rotations are generally removed from the individual signals, and the signals are then combined into one composite signal before downconverting to baseband (i.e., removing the carrier phase from the composite digital signal). There is nothing in Boros' disclosure that suggest anything different from this conventional approach.

As explained in Applicant's specification, it is unknown in digital beamforming to apply a carrier signal to a digital baseband signal on an element-by-element basis, primarily because in typical architectures this approach would result in unnecessary processing (i.e., the carrier phase is the same for all antenna elements). For reasons explained in Applicant's specification, this is not the case with Applicant's architecture. Likewise, it is unknown to remove the carrier phase from digitized received signals on an element-by-element basis, since typical architectures involve combining the signals from the various antenna elements once the beamforming phases have been removed.

The relevant portion of Boros' disclosure is found in column 13. There is simply nothing in Boros' disclosure that suggests that a shared baseband processor receives both modulated outbound digital baseband signals and incoming digital baseband signals, and applies phases to these digital baseband signals to account for both beamforming phase rotation and carrier phase rotation of individual antenna elements. Simply applying or removing the beamforming phase rotation will not also cause the underlying carrier phase to be applied or removed, and there is certainly no suggestion that Boros handles the carrier phase in any manner different from the conventional approach.

Moreover, the claimed shared baseband processor handles both output digital baseband signals and incoming digital baseband signals, as is evident from Fig. 1. More specifically, the same processor jointly applies carrier phase rotation weights and beam rotation weights to both outbound transmission signals and incoming received signals. There is simply no device or structure within Boros' system that operates in this manner. As is clear from Figs. 1, 4, and 6 and column 13 of Boros, received signals are downconverted and processed in a receiver chain including functional blocks 109 and 11, and the transmit signals are processed and upconverted in a transmitter chain including blocks 123 and 125. Boros' transmit weight generator does not

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Apple EX1002 Page 329

apply phases to anything – it merely assesses incoming signals and provided feedback for beamsteering to the transmitter. There is simply no shared processor in Boros' system that operates in the manner claimed.

The Examiner notes that the language of the claim does not limit the carrier phases to being different for each individual antenna element. This is because the carrier phase rotation (absent the additional beamforming rotation) is *not* necessarily different for the various antenna elements! That is the reason why conventional architectures such as that in Boros do not apply the carrier phase rotation on an element-by-element basis – it would result in considerable additional unnecessary processing. However, as explained on page 9, lines 14-20, while Applicant's approach results in increased baseband computational complexity by a factor of the number of antenna elements, this approach affords significant performance advantages to each user channel.

Finally, Applicant notes that Boros contains no description of anything analogous to the limitations found in claims 31-36, which have not been considered by the Examiner.

With regard to claims 26-29, Applicant again notes that these claims include requirements comparable to those found in claim 1. In particular, these claims require applying phases to the digital baseband signals in a serial stream to account for both carrier phase tracking and antenna element beamforming, where the digital baseband signals in the serial stream are associated with individual antenna elements. In other words, both the carrier phase rotation and beamforming phase are applied to signals associated with individual antenna elements. This claim requirement is simply not disclosed or suggested anywhere in Rayleigh, Dent, and Phillips, and the Examiner's arguments do not address this point. Thus, for the foregoing additional reasons and for the reasons previously of record, Applicant respectfully requests the Examiner to reconsider and withdraw the rejections of claims 1-30.

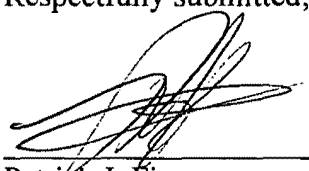
In view of the foregoing, Applicant respectfully requests the Examiner to find the application to be in condition for allowance with claims 1 – 36. However, if for any reason the Examiner feels that the application is not now in condition for allowance, the Examiner is

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Apple EX1002 Page 330

respectfully requested to call the undersigned attorney to discuss any unresolved issues and to expedite the disposition of the application.

Filed concurrently herewith is a Petition (with payment) for an Extension of Time of Two Months, together with a Notice of Appeal. Applicant hereby petitions for any extension of time which may be required to maintain the pendency of this case, and any required fee for such extension is to be charged to Deposit Account No. 05-0460.

Respectfully submitted,



Patrick J. Finnan
Registration No. 39,189

EDELL, SHAPIRO & FINNAN, LLC
1901 Research Boulevard, Suite 400
Rockville, Maryland 20850-3164
(301) 424-3640

Hand Delivered on: November 22, 2006

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Apple EX1002 Page 331

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AF/2634

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Appl. No.	:	10/084,614
Applicant	:	Scott Bierly et al.
Filed	:	February 28, 2002
TC/A.U.	:	2634
Examiner	:	Lu, J.
Confirmation No.	:	1621
Docket No.	:	0918.0153C
Customer No.	:	27896
Title	:	Integrated Beamformer/Modem Architecture

Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450

TRANSMITTAL OF REQUEST FOR RECONSIDERATION

Enclosed are the following documents in response to the Office Action mailed June 22, 2006 for the above-identified application:

- ☒ Request for Reconsideration (14 Pages)
- ☒ Petition for Extension of Time (1 Page(s))
- ☐ Request for Approval of Drawing Changes
- ☒ Notice of Appeal
- ☐ Associate Power
- ☐ Revocation and New Power
- ☐ Change of Address
- ☐ Return receipt postcard
- ☒ Check No. 10062 in the amount of $950.00 ($500.00 for the Notice of Appeal and $450.00 for the extension fee)
- ☐ Other:

The fee has been calculated as follows:

	NO OF CLAIMS REMAINING	NO. OF CLAIMS PREVIOUSLY PAID FOR	NO OF EXCESS CLAIMS	RATE	FEE
Total Claims	36	- 36 =	0	$50.00	0.00
Independent Claims	3	- 3 =	0	$200.00	0.00
If multiple dependent claims are presented, add $360.00					0.00
Total Amendment Fee					0.00
☐ Applicant claims Small Entity Status (subtract 50% of Total Application Fee)					0.00
Other fees: (specify)					0.00
TOTAL FEE DUE					0.00

☐ A check for the total fee is attached.

☐ Please charge $ to Deposit Account No. 05-0460 for the total fee. This paper is being submitted in duplicate.

☒ The Commissioner is hereby authorized to charge any additional appropriate fees under 37 C.F.R. §§1.16, 1.17, and 1.21 that may be required by this paper, and to credit any overpayment, to Deposit Account No. 05-0460.

Dated: November 22, 2006

Respectfully submitted by
EDELL, SHAPIRO & FINNAN, LLC

By: _____
Patrick J. Finnan
Reg. No. 39,189

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/084,614	02/28/2002	Scott Bierly	0918.0153C	1621

27896 7590 01/09/2007
EDELL, SHAPIRO & FINNAN, LLC
1901 RESEARCH BOULEVARD
SUITE 400
ROCKVILLE, MD 20850

EXAMINER	
LU, JIA	
ART UNIT	PAPER NUMBER
2611	

SHORTENED STATUTORY PERIOD OF RESPONSE	MAIL DATE	DELIVERY MODE
3 MONTHS	01/09/2007	PAPER

Please find below and/or attached an Office communication concerning this application or proceeding.

If NO period for reply is specified above, the maximum statutory period will apply and will expire 6 MONTHS from the mailing date of this communication.

Office Action Summary	Application No.	Applicant(s)	
	10/084,614	BIERLY ET AL.	
	Examiner	Art Unit	
	Jia W. Lu	2611	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) OR THIRTY (30) DAYS, WHICHEVER IS LONGER, FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☒ Responsive to communication(s) filed on *22 November 2006*.

2a)☐ This action is **FINAL**. 2b)☒ This action is non-final.

3)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

4)☒ Claim(s) *1-36* is/are pending in the application.

4a) Of the above claim(s) _____ is/are withdrawn from consideration.

5)☒ Claim(s) _____ is/are allowed.

6)☒ Claim(s) *1-4 and 7-30* is/are rejected.

7)☒ Claim(s) *5,6 and 31-36* is/are objected to.

8)☐ Claim(s) _____ are subject to restriction and/or election requirement.

Application Papers

9)☐ The specification is objected to by the Examiner.

10)☒ The drawing(s) filed on *28 February 2002* is/are: a)☒ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

11)☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

Priority under 35 U.S.C. § 119

12)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a)☐ All b)☐ Some * c)☐ None of:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☐ Notice of References Cited (PTO-892)
2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)
3) ☐ Information Disclosure Statement(s) (PTO-1449 or PTO/SB/08) Paper No(s)/Mail Date _____.
4) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____.
5) ☐ Notice of Informal Patent Application (PTO-152)
6) ☐ Other: _____.

Response to Arguments

Applicant's arguments filed 11/22/06 have been fully considered but they are not persuasive. While applicant's position and arguments do distinguish application from prior art, they are *not adequately reflected in the claim language*.

"Beamforming" itself is process of steering an array. In order to steer all elements of an array to communicate in a given direction only, all array elements must be calibrated, as shown in US 6,615,024. Calibration is needed because the arrays are located differently in space and are manufactured differently. Calibration enables all elements to add up in phase in the given direction by using a correction term, and one term is calculated per array element, per frequency, or per "carrier phase." Therefore, the calibration of antenna elements prior to beamforming implicitly includes carrier phase rotation adjustments. Beamforming phase rotation is then performed to adjust the phase of the elements relative to the calibration. Hence, "beamforming" is almost always a two-step process that includes both calibration for individual carrier phase at each of the elements and adding beamforming phase rotations to properly steer the beam.

See also Response to Arguments in action sent on 6/22/2006.

Examiner hereby apologizes for missing claims 31-36 in the previous action. Prosecution is re-opened.

DETAILED ACTION

Claim Rejections - 35 USC § 103

The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

> (a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.

The text of those sections of Title 35, U.S. Code not included in this action can be found in a prior Office action.

1. Claims 1, 22-25 are rejected under 35 U.S.C. 103(a) as being unpatentable over US patent 6,615,024.

    a. Regarding claims 1, 22-24, '024 shows a baseband modulator (column 13, lines 20-25), a baseband demodulator (figure 4, element 411), and a shared baseband processor (figure 1, elements 111, 117 and 123) which receives outbound and incoming signals, said processor applying phases to the signals to account for both beamforming and carrier phase rotations (column 13, lines 30-45). While the shared baseband processor used in this rejection is based on a grouping of receive and transmit processors, the system that '024 describes performs the same functions of adjusting the antenna array. It would have been obvious to one ordinarily skilled in the art to group the weight generators (figure 4, element 409, figure 1, elements 131 and 117) into a single circuit to call it a "shared" processor to reduce the size and complexity of the circuit.

b. Regarding claim 25, '024 describes the processor to adjust amplitude of the signals (column 12, lines 65-68).

c. Regarding claim 31, '024

2. Claims 2 and 3 are rejected under 35 U.S.C. 103(a) as being unpatentable over US patent 6,615,024 as applied to claim 1 above, and further in view of US patent 5,583,562.

a. Regarding claim 2, although patent '024 does not show time-multiplexing of received data, the use of time-multiplexing in transceiver systems is well known for their ability to increase the throughput of a communications resource (for example, patent '562, fig 1). It would have been obvious for one ordinarily skilled in the art to use time-multiplexing in a system described in '024 in order to allow more users to use a single channel in a duplex system.

b. Regarding claim 3, while patent '024 does not show the modulator to provide a time-multiplexed data stream from an input of multiple data streams, patent '562 shows a modulator (fig 1, element 130) receiving data symbols from a plurality of user channels (fig 1, element 110) and provide a single time-multiplexed data stream (column 5, lines 30-40). The reason to combine time-multiplexing with a modulator is stated in part a above.

3. Claim 4 is rejected under 35 U.S.C. 103(a) as being unpatentable over US patent 6,615,024 and US patent 5,583,562 as applied to claim 3 above, and further in view of US patent 6,768,458. While patent '024 does not show a modulator generating a plurality of modulated data in the time-multiplexed stream corresponding to a plurality of antenna elements, patent '458 shows a modulator (figure 5, elements 216 and 218) generating a plurality of modulated data symbols in the time-multiplexed stream, corresponding to a plurality of antenna elements (figure 5, element 250). It would have been obvious for one ordinarily skilled in the art for a modulating system described in patent '024 to time-multiplex a plurality of modulated data symbols corresponding to antenna elements in order to increase directional gain in transmission.

4. Claims 7-10 are rejected under 35 U.S.C. 103(a) as being unpatentable over US patent 6,615,024 as applied to claim 1 above, and further in view of US patent 6,831,943.

    a. Regarding claims 7-9, patent '024 does not describe the complex multiplication of signals in the processor relating to a plurality of user channels in a time-multiplexed manner. However, patent '943 teaches a transmission system where a processor unit (figure 10, elements 18 and 20) performs complex multiplication on signals on incoming signals that have been time-multiplexed (column 29, line 43), associated with a plurality of antennas (figure 1, elements A12). While the plurality of user

channels is not shown, it is well known that a system using time-multiplexing takes signals from different users in order to multiplex them. It would have been obvious for one ordinarily skilled in the art to use complex multiplication in a system described in patent '024 for beamforming (column 7, lines 18-47) and power adjustments (column 15, lines 47-54) in order to improve power usage and reduce interference.

b. Regarding claim 10, patent '024 does not disclose a beamformer configured to receive time-multiplexed baseband signals from shared baseband processor. Patent '943, however, shows a beamformer (figure 2, element 52) capable of receiving time-multiplexed (column 29, line 43) signals from a front-end processor. It would have been obvious for one ordinarily skilled in the art to use a beamformer in a transceiver system described in patent '024 when incoming signals require directional and rotational adjustments in order to acquire precise directional transmission to increase gain while using lower power.

5. Claims 11-13 are rejected under 35 U.S.C. 103(a) as being unpatentable over US patent 6,615,024 as applied to claim 1 above, and further in view of US patent 6,549,527. While patent '024 does not show the front-end specifics of its receiving circuitry, patent '527 shows a plurality of down-converters (column 2, lines 29-33) separately down-converting signals for each antenna element (figure 14, element 142). It also teaches the down-converting circuitry to include

decimation means (figure 1, element 11) followed by multiplexing means (figure 1, element 12). It would have been obvious for one ordinarily skilled in the art to use decimation and multiplexing in the receiver end in order enable signal processing in an antenna array system without lowering system performance or increasing price, dimension or complexity of the hardware (column 3, line 48-line 59).

6. Claims 14-16, 18 are rejected under 35 U.S.C. 103(a) as being unpatentable over US patent 6,615,024 as applied to claim 1 above, and further in view of US patent 5,809,422.

   a. Regarding claims 14-16, while patent '024 does not show a demultiplexer and up-converters in transmission, patent '422 teaches the use of demultiplexers (figure 4, element 134) and IF up-converters (column 7, lines 33-40) in separate transmitting antenna elements (column 11, lines 56-60). Patent '422 also teaches interpolation in order to increase the sampling rate of the transmission signals (column 13, lines 39-40). It would have been obvious for one ordinarily skilled in the art to employ demultiplexing in an transmission end as described in patent '024 in order to separate time-multiplexed symbols for transmission and up convert baseband signals into a higher, intermediate frequency in order to enable signal transmission in a wireless medium.

b. Regarding claim 18, while patent '024 does not teach the use of TDMA, patent '422 teaches the use of TDMA (column 8, line 41) in its transceiver system. Because TDMA is a very common technique used in transmission, and it would have been obvious to one ordinarily skilled in the art to use TDMA to allow multiple users to share time slots within a single channel.

7. Claim 17 is rejected under 35 U.S.C. 103(a) as being unpatentable over US patent 6,615,024 as applied to claim 1 above, further in view of US patent 5,937,348. While patent '024 teaches the use of a duplexer between the transmitter and receiver portion of its transceiver, it does not specify the duplex to be time-division or the use of a switch. Patent '348 shows a duplex switch capable of using time division duplex (column 5, line 20). It would have been obvious to one ordinarily skilled in the art to use a switch in a time division duplex transceiver system described in patent '024 in order to provide better control over the system while allowing it to transmit and receive using a single front-end processor.

8. Claims 19-21 are rejected under 35 U.S.C. 103(a) as being unpatentable over US patent 6,615,024 as applied to claim 1 above, further in view of US patent application 20020141478. While patent '024 does not show the use FDMA, FPGA or VLSI in its transceiver system, application '478 teaches all these

elements (FDMA on paragraph 2, line 6, FPGA on paragraph 621, line 4, and ASIC on paragraph 621, line 5). It would have been obvious to one ordinarily skilled in the art to use FDMA to allow multiple users to share time slots, FPGA to increase flexibility in designs and programming, or ASIC to reduce power usage, save space and lower cost of production.

9. Claims 26-30 are rejected under 35 U.S.C. 103(a) as being unpatentable over US patent 6,101,399, in view of US patent 5,631,898, further in view of US patent 6,072,994.

    a. Regarding claims 26 and 28, while '399 shows a method of processing signals received via antenna arrays comprising downconverter producing parallel signals (figure 3, element 54), and applying phases to the signals and performing beamforming (element 60), it does not show individual down-converting and A/D units, patents '898 and 643 show these features. Patent '898 shows separate IF down-converters (figure 12, element 1203), baseband down-converters (element 1207), A/D (element 1212), and a digital multiplexer (element 1213). It does not show the A/D to be down at IF, however, patent '994 shows this (column 31, lines 30-35). It would have been obvious to one ordinarily skilled in the art to perform A/D at IF in the circuit in '898 to allow many benefits such as easier digital programming, replacement of bulky circuitry, and better tuning; It would also have been obvious to one ordinarily skilled in the art

to use the individual antenna processing elements of '898 in the system described in '399 to have more maneuverable controls of individual antenna elements.

b. Regarding claim 27, '399 describes the decimation of signals after digitizing and downconverting to baseband and prior to beamforming.

c. Claims 29 and 30 describe the limitations in claim 26 at its transmitting end. It would have been obvious to one ordinarily skilled in the art to reverse, step-by-step, the limitations of claim 26 in a receiver end to achieve transmission.

Allowable Subject Matter

10. Claims 5, 6, 31-36 are objected to as being dependent upon a rejected base claim, but would be allowable if rewritten in independent form including all of the limitations of the base claim and any intervening claims.

Conclusion

Any inquiry concerning this communication or earlier communications from the examiner should be directed to Jia W. Lu whose telephone number is 571-272-6042. The examiner can normally be reached on Mon- Fri, 8:30AM-4:30PM.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Chieh M. Fan can be reached on (571)272-3042. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

Jia Lu
Examiner

CHIEH M. FAN
SUPERVISORY PATENT EXAMINER

Search Notes

Application/Control No.	Applicant(s)/Patent under Reexamination	
10/084,614	BIERLY ET AL.	
Examiner	**Art Unit**	
Jia W. Lu	2611	

SEARCHED			
Class	Subclass	Date	Examiner
375	222	12/20/2006	JL

INTERFERENCE SEARCHED			
Class	Subclass	Date	Examiner
375	**222**	12/20/2006	**JL**

SEARCH NOTES (INCLUDING SEARCH STRATEGY)		
	DATE	EXMR
ALL EAST DATABASES	12/20/2006	JL

Index of Claims

Application/Control No.	Applicant(s)/Patent under Reexamination
10/084,614	BIERLY ET AL.
Examiner	**Art Unit**
Jia W. Lu	2611

√	Rejected	–	(Through numeral) Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Appl. No.	:	10/084,614
Applicant	:	Scott Bierly et al.
Filed	:	February 28, 2002
TC/A.U.	:	2634
Examiner	:	Lu, J.
Confirmation No.	:	1621
Docket No.	:	0918.0153C
Customer No.	:	27896
Title	:	Integrated Beamformer/Modem Architecture

Mail Stop Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450

TRANSMITTAL OF RESPONSE

Enclosed are the following documents in response to the Office Action mailed January 9, 2007 for the above-identified application:

☒	Amendment/Response (12 pages)	☐	Associate Power
☐	Petition for Extension of Time	☐	Revocation and New Power
☐	Amended Drawings	☐	Change of Address
☐	Information Disclosure Statement	☐	Other:
☐	Notice of Appeal		

Fees—the fees have been calculated as follows:

	CLAIMS REMAINING AFTER AMENDMENT	CLAIMS PREVIOUSLY PAID FOR	EXTRA CLAIMS	RATE	FEE
Total Claims	33	- 36=	0	x $50.00 $25.00	0.00
Independent Claims	6	- 3=	3	x $200.00 $100.00	600.00
Subtotal Total Amendment Fee					600.00
Other fees:					
TOTAL FEE DUE					600.00

☐ Applicant claims **small entity** status.

☐ No fees are believed to be due at this time.

☒ Credit card payment has been submitted concurrently with the filing of this transmittal (fees have been calculated by EFS Web System).

☒ Applicant hereby petitions for any extension of time required to maintain the pendency of the application.

☒ The Commissioner is hereby authorized to charge any additional appropriate fees under 37 C.F.R. §§1.16, 1.17, and 1.21 that may be required during the pendency of the application, and to credit any overpayment, to Deposit Account No. 05-0460.

Dated: January 16, 2007

Respectfully submitted by:

/Patrick J. Finnan/

Patrick J. Finnan
Reg. No. 39189

EDELL, SHAPIRO & FINNAN, LLC
CUSTOMER NO. 27896
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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Appl. No.	:	10/084,614
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Title	:	Integrated Beamformer/Modem Architecture

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

AMENDMENT

Sir:

In response to the Office Action mailed January 9, 2007, please amend the above-identified application as follows:

Amendments to the Claims are reflected in the listing of claims, which begins on page 2 of this paper.

Remarks begin on page 11 of this paper.

Amendments to the Claims:

This listing of claims will replace all prior versions, and listings, of claims in the application.

Listing of Claims:

1. (Currently Amended) An apparatus for modulating and demodulating signals transmitted and received via an electronically steerable phased array antenna comprising a plurality of antenna elements, the apparatus comprising:

a baseband modulator configured to modulate outbound digital baseband signals to be transmitted via the phased array antenna;

a baseband demodulator configured to demodulate incoming digital baseband signals generated from signals received via the phased array antenna; and

a shared baseband processor configured to receive digital baseband signals including the modulated outbound digital baseband signals and the incoming digital baseband signals, said shared baseband processor applying a single phase~~s~~ adjustment to each of the digital baseband signals to jointly account for both beamforming phase rotation and carrier phase rotation of individual antenna elements.

2. (Previously Presented) The apparatus of claim 1, wherein said digital baseband signals received by said shared baseband processor are time multiplexed, and said shared baseband processor operates on said digital baseband signals on a time-slot-by-time-slot basis.

3. (Previously Presented) The apparatus of claim 1, wherein said baseband modulator receives data symbols from a plurality of user channels and supplies to said shared baseband processor a time-multiplexed stream of modulated digital data symbols from said plurality of user channels.

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4. (Previously Presented) The apparatus of claim 3, wherein, for each input digital data symbol, said baseband modulator generates a plurality of modulated digital data symbols in the time-multiplexed stream respectively corresponding to the plurality of antenna elements.

5. (Previously Presented) The apparatus of claim 1, wherein said shared baseband processor comprises:

a numerically controlled oscillator configured to generate a stream of carrier phases for digital baseband signals of each of a plurality of user channels in a time-multiplexed manner;

a beamforming phase rotator configured to generate a stream of beam rotation phases corresponding to individual antenna elements for each of the plurality of user channels in a time-multiplexed manner;

a phase adder configured to sum the beam rotation phases and the carrier phases to produce a time-multiplexed stream of combined phase adjustments; and

a complex multiplier configured to adjust phases of a time-multiplexed stream of digital baseband signals corresponding to the plurality of user channels in accordance with the combined phase adjustments.

6. (Original) The apparatus of claim 5, wherein said combined phase adjustments index a sine/cosine lookup table which supplies multiplicands to said complex multiplier.

7. (Previously Presented) The apparatus of claim 1, wherein said shared baseband processor comprises a multiplier which performs complex multiplication on digital baseband signals relating to a plurality of user channels in a time-multiplexed manner.

8. (Previously Presented) The apparatus of claim 1, wherein said shared baseband processor comprises a multiplier which performs complex multiplication on digital baseband signals associated with a plurality of individual antenna elements in a time-multiplexed manner.

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9. (Previously Presented) The apparatus of claim 1, wherein said shared baseband processor comprises a beam scaling and power control processor configured to generate a time-multiplexed stream of gain control signals for digital baseband signals corresponding to individual antenna elements for each of a plurality of user channels, the gain control signals jointly accounting for power control and antenna element beam scaling; and

a multiplier configured to adjust amplitudes of a time-multiplexed stream of digital baseband signals corresponding to the plurality of user channels in accordance with the gain control signals.

10. (Previously Presented) The apparatus of claim 1, further comprising:

a baseband beamformer configured to receive time-multiplexed digital baseband signals from said shared baseband processor corresponding to individual antenna elements, said baseband processor forming a combined signal from said time-multiplex digital baseband signals.

11. (Previously Presented) The apparatus of claim 1, further comprising:

a plurality of digital down-converters respectively down-converting digitized signals received from the plurality of antenna elements to produce parallel streams of sampled digital baseband signals; and

a multiplexer receiving the parallel streams of sampled digital baseband signals and supplying a time-multiplexed stream of the sampled digital baseband signals to said shared baseband processor.

12. (Previously Presented) The apparatus of claim 11, wherein said plurality of digital down-converters perform decimation to reduce a sampling rate of the sampled digital baseband signals.

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13. (Original) The apparatus of claim 11, wherein said plurality of digital down-converters separately down-convert digitized signals for each antenna element for each of a plurality of frequency channels.

14. (Previously Presented) The apparatus of claim 1, further comprising:

a demultiplexer receiving a time-multiplexed stream of digital baseband signals from said shared baseband processor and generating parallel streams of digital baseband signals corresponding to the plurality of antenna elements; and

a plurality of digital up-converters respectively up-converting the parallel streams of digital baseband signals to produce a plurality of digitized intermediate frequency signals corresponding to the plurality of antenna elements.

15. (Original) The apparatus of claim 14, wherein said plurality of digital up-converters perform interpolation to increase a sampling rate of the digitized intermediate frequency signals.

16. (Previously Presented) The apparatus of claim 14, wherein said plurality of digital up-converters separately up-convert digital baseband signals for each antenna element for each of a plurality of frequency channels.

17. (Original) The apparatus of claim 1, wherein signals are transmitted and received using time division duplex, said apparatus further comprising switching elements to selectively connect said shared baseband processor to said baseband modulator and front-end transmit circuitry for signal transmission and to said baseband demodulator and front-end receive circuitry for signal reception.

18. (Original) The apparatus of claim 1, wherein said apparatus employs time division multiple access (TDMA) to transmit and receive signals.

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19. (Original) The apparatus of claim 1, wherein said apparatus employs frequency division multiple access (FDMA) to transmit and receive signals.

20. (Original) The apparatus of claim 1, wherein said apparatus is a field programmable gate array (FPGA).

21. (Original) The apparatus of claim 1, wherein the apparatus is implemented via a very large scale integration (VLSI) circuit or an application specific integrated circuit (ASIC).

22. (Original) The apparatus of claim 1, wherein said apparatus is a modem.

23. (Original) The apparatus of claim 1, wherein said apparatus is a transceiver.

24. (Original) The apparatus of claim 1, wherein said apparatus is a basestation transceiver.

25. (Previously Presented) The apparatus of claim 1, wherein the shared baseband processor adjusts amplitudes of the digital baseband signals to perform power control and antenna element beam scaling.

26. (Currently Amended) A method of processing an RF signal received via an electronically steerable phased array antenna comprising a plurality of antenna elements, the method comprising:

(a) separately down-converting the RF signal from each antenna element to an intermediate frequency (IF) signal;

(b) separately analog-to-digital converting the IF signal from each antenna element;

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(c) separately digitally down-converting the digital IF signal from each antenna element to a digital baseband signal to form a set of parallel baseband signals from the plurality of antenna elements;

(d) time multiplexing the set of parallel baseband signals to form a serial stream of digital baseband signals;

(e) applying a single phase~~s~~ adjustment to each of the digital baseband signals in the serial stream to jointly account for both carrier phase tracking and antenna element beamforming; and

(f) performing beamforming by combining digital baseband signals respectively associated with the plurality of antenna elements.

27. (Previously Presented) The method of claim 26, wherein (c) includes decimating the digital IF signal from each antenna element to reduce a number of samples in the serial stream of digital baseband signal.

28. (Previously Presented) The method of claim 26, wherein (c) includes generating baseband signals for a plurality of frequency channels from the digital IF signal of each antenna element, such that digital samples in the serial stream of digital baseband signals are associated with a particular antenna element and frequency channel.

29. (Currently Amended) A method of processing signals to be transmitted via an electronically steerable phased array antenna comprising a plurality of antenna elements, the method comprising:

(a) generating a stream of digital baseband signals representing data symbols to be transmitted via the phased array antenna, wherein digital baseband signals in the stream are associated with individual antenna elements;

(b) applying a single phase~~s~~ adjustment to each of the digital baseband signals to jointly account for both carrier phase rotation and antenna element beamforming;

(c) demultiplexing the stream of digital baseband signals into a plurality of parallel signals respectively associated with individual antenna elements;

(d) digitally up-converting the parallel signals to produce a plurality of digital intermediate frequency (IF) signals respectively associated with individual antenna elements;

(e) digital-to-analog converting the digital IF signals to produce a plurality of IF signals respectively associated with individual antenna elements; and

(f) up-converting the IF signals to RF signals for transmission via the phased array antenna.

30. (Previously Presented) The method of claim 29, wherein the phased array antenna simultaneously transmits signals on a plurality of frequency channels, and the stream of digital baseband signals includes signals associated with individual ones of the frequency channels.

31. (Canceled)

32. (Currently Amended) ~~The~~ An apparatus ~~of claim 1~~ for modulating and demodulating signals transmitted and received via an electronically steerable phased array antenna comprising a plurality of antenna elements, the apparatus comprising:

a baseband modulator configured to modulate outbound digital baseband signals to be transmitted via the phased array antenna;

a baseband demodulator configured to demodulate incoming digital baseband signals generated from signals received via the phased array antenna; and

a shared baseband processor configured to receive digital baseband signals including the modulated outbound digital baseband signals and the incoming digital baseband signals, said shared baseband processor applying phases to the digital baseband signals to account for both beamforming phase rotation and carrier phase rotation of individual antenna elements, wherein the shared baseband processor generates a stream of combined phase adjustments by summing a stream of carrier phases for the digital baseband signals with a stream of beam rotation phases

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for the digital baseband signals, and adjusts phases of the digital baseband signals in accordance with the combined phase adjustments.

33. (Canceled)

34. (Currently Amended) ~~The~~ A method of ~~claim 26, wherein~~ processing an RF signal received via an electronically steerable phased array antenna comprising a plurality of antenna elements, the method comprising:

(a) separately down-converting the RF signal from each antenna element to an intermediate frequency (IF) signal;

(b) separately analog-to-digital converting the IF signal from each antenna element;

(c) separately digitally down-converting the digital IF signal from each antenna element to a digital baseband signal to form a set of parallel baseband signals from the plurality of antenna elements;

(d) time multiplexing the set of parallel baseband signals to form a serial stream of digital baseband signals;

(e) ~~includes:~~ generating a stream of carrier phases for the digital baseband signals;

(f) generating a stream of beam rotation phases for the digital baseband signals;

(g) summing the beam rotation phases and the carrier phases to produce a stream of combined phase adjustments; ~~and~~

(h) applying the stream of combined phase adjustments to the digital signals in the serial stream to account for both carrier phase tracking and antenna element beamforming; and

(i) performing beamforming by combining digital baseband signals respectively associated with the plurality of antenna elements.

35. (Canceled)

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36. (Currently Amended) ~~The~~ A method of ~~claim 29, wherein~~ processing signals to be transmitted via an electronically steerable phased array antenna comprising a plurality of antenna elements, the method comprising:

(a) generating a stream of digital baseband signals representing data symbols to be transmitted via the phased array antenna, wherein digital baseband signals in the stream are associated with individual antenna elements;

(b) ~~includes:~~ generating a stream of carrier phases for the digital baseband signals;

(c) generating a stream of beam rotation phases for the digital baseband signals;

(d) summing the beam rotation phases and the carrier phases to produce a stream of combined phase adjustments; ~~and~~

(e) applying the stream of combined phase adjustments to the stream of digital baseband signals to account for both carrier phase rotation and antenna element beamforming;

(f) demultiplexing the stream of digital baseband signals into a plurality of parallel signals respectively associated with individual antenna elements;

(g) digitally up-converting the parallel signals to produce a plurality of digital intermediate frequency (IF) signals respectively associated with individual antenna elements;

(h) digital-to-analog converting the digital IF signals to produce a plurality of IF signals respectively associated with individual antenna elements; and

(i) up-converting the IF signals to RF signals for transmission via the phased array antenna.

REMARKS

Claims 1-36 have been examined: claims 1-4 and 7-30 stand rejected, and claims 5, 6, and 31-36 are indicated as containing allowable subject matter. By the above amendments, claims 1, 26, and 29, 32, 34, and 36 have been amended, and claims 31, 33, and 35 have been canceled. Accordingly, claims 1-30, 32, 34, and 36 are currently pending. Favorable reconsideration of the application and allowance of all of the pending claims are respectfully requested in view of the following remarks.

Claims 1 and 22 – 25 stand rejected under 35 U.S.C. §103(a) as being unpatentable over U.S. Patent No. 6,615,024 to Boros et al. Further, claims 2 and 3 stand rejected as being unpatentable over Boros in view of U.S. Patent No. 5,583,562 to Birch et al.; claim 4 stands rejected over Boros, Birch, and U.S. Patent No. 6,768,458 to Green et al.; claims 7 – 10 stand rejected over Boros and U.S. Patent No. 6,831,943 to Dabak et al.; claims 11 – 13 stand rejected over Boros and U.S. Patent No. 6,549,527 to Tsutsui et al.; claims 14 – 16 and 18 stand rejected over Boros and U.S. Patent No. 5,809,422 to Raleigh et al.; claim 17 stands rejected over Boros and U.S. Patent No. 5,937,348 to Cina et al.; claims 19 – 21 stand rejected over Boros and U.S. Patent Application Publication No. 2002/0141478 to Ozluturk et al; and claims 26 – 30 stand rejected over U.S. Patent No. 6,101,399 to Rayleigh in view of U.S. Patent No. 5,631,898 to Dent and U.S. Patent No. 6,072,994 to Phillips et al.

However, the Examiner indicates that claims 31-36 contain allowable subject matter. Independent claims 1, 26, and 29 have been amended to included the limitations of allowable claims 31, 33, and 35, respectively, and claims 32, 34, and 36 have been rewritten in independent form. Accordingly, the claims should now be in condition for allowance, and the Examiner is respectfully requested to reconsider and withdraw these rejections.

In view of the foregoing, Applicant respectfully requests the Examiner to find the application to be in condition for allowance with claims 1-30, 32, 34, and 36. However, if for any reason the Examiner feels that the application is not now in condition for allowance, the Examiner is respectfully requested to call the undersigned attorney to discuss any unresolved issues and to expedite the disposition of the application.

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Filed concurrently herewith is an excess claim fee in the amount of $600 for payment of 3 independent claims in excess of the 3 previously paid for. Applicant hereby petitions for any extension of time that may be necessary to maintain the pendency of this application. The Commissioner is hereby authorized to charge payment of any additional fees required for the above-identified application or credit any overpayment to Deposit Account No. 05-0460.

Dated: January 16, 2007

Respectfully submitted by:

/Patrick J. Finnan/

Patrick J. Finnan
Reg. No. 39189

EDELL, SHAPIRO & FINNAN, LLC
CUSTOMER NO. 27896
1901 Research Boulevard, Suite 400
Rockville, MD 20850
(301) 424-3640

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Electronic Patent Application Fee Transmittal

Application Number:	10084614
Filing Date:	28-Feb-2002
Title of Invention:	Integrated beamformer/modem architecture
First Named Inventor/Applicant Name:	Scott Bierly
Filer:	Patrick J. Finnan/Paula Verkuilen
Attorney Docket Number:	0918.0153C

Filed as Large Entity

Utility Filing Fees

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Independent claims in excess of 3	1201	3	200	600
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Miscellaneous:				
			Total in USD ($)	**600**

Electronic Acknowledgement Receipt

EFS ID:	1440426
Application Number:	10084614
International Application Number:	
Confirmation Number:	1621
Title of Invention:	Integrated beamformer/modem architecture
First Named Inventor/Applicant Name:	Scott Bierly
Customer Number:	27896
Filer:	Patrick J. Finnan/Paula Verkuilen
Filer Authorized By:	Patrick J. Finnan
Attorney Docket Number:	0918.0153C
Receipt Date:	16-JAN-2007
Filing Date:	28-FEB-2002
Time Stamp:	13:43:40
Application Type:	Utility

Payment information:

Submitted with Payment	yes
Payment was successfully received in RAM	$600
RAM confirmation Number	2421
Deposit Account	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)	Multi Part /.zip	Pages (if appl.)

1	Amendment - After Non-Final Rejection	EFSAmdTransmittal.pdf	122510	no	2
Warnings:					
Information:					
2		EFSAmendment3.pdf	139424	yes	12

Multipart Description/PDF files in .zip description

Document Description	Start	End
Amendment - After Non-Final Rejection	1	1
Claims	2	10
Applicant Arguments/Remarks Made in an Amendment	11	12

Warnings:					
Information:					
3	Fee Worksheet (PTO-06)	fee-info.pdf	8156	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	270090		

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

PATENT APPLICATION FEE DETERMINATION RECORD
Effective October 1, 2001

Application or Docket Number: 10/8-1614

CLAIMS AS FILED - PART I

	(Column 1)	(Column 2)
TOTAL CLAIMS	24	
FOR	NUMBER FILED	NUMBER EXTRA
TOTAL CHARGEABLE CLAIMS	24 minus 20=	* 4
INDEPENDENT CLAIMS	1 minus 3 =	*
MULTIPLE DEPENDENT CLAIM PRESENT		☐

* If the difference in column 1 is less than zero, enter "0" in column 2

SMALL ENTITY TYPE ☐		OR	OTHER THAN SMALL ENTITY	
RATE	FEE		RATE	FEE
BASIC FEE	370.00	OR	BASIC FEE	740.00
X$ 9=		OR	X$18=	72
X42=		OR	X84=	168
+140=		OR	+280=	
TOTAL		OR	TOTAL	980.00

CLAIMS AS AMENDED - PART II

10/6/05

AMENDMENT A	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA
Total	* 30	Minus	** 24	= 6
Independent	* 3	Minus	*** 3	=
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM				☐

SMALL ENTITY		OR	OTHER THAN SMALL ENTITY	
RATE	ADDITIONAL FEE		RATE	ADDITIONAL FEE
X$ 9=		OR	X$18= 50	300
X42=		OR	X84=	
+140=		OR	+280=	
TOTAL ADDIT. FEE		OR	TOTAL ADDIT. FEE	

5/10/00

AMENDMENT B	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA
Total	* 36	Minus	** 30	= 6
Independent	* 3	Minus	*** 3	=
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM				☐

RATE	ADDITIONAL FEE		RATE	ADDITIONAL FEE
X$ 9=		OR	X$18= 50	300
X42=		OR	X84=	
+140=		OR	+280=	
TOTAL ADDIT. FEE		OR	TOTAL ADDIT. FEE	300

1/16/07

AMENDMENT C	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA
Total	* 33	Minus	** 36	=
Independent	* 6	Minus	*** 3	= 3
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM				☐

RATE	ADDITIONAL FEE		RATE	ADDITIONAL FEE
X$ 9=		OR	X$18=	
X42=		OR	X84= 60	
+140=		OR	+280=	
TOTAL ADDIT. FEE		OR	TOTAL ADDIT. FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20."
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3."
The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

FORM PTO-875 (Rev. 8/01) — Patent and Trademark Office, U.S. DEPARTMENT OF COMMERCE

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PLUS Search Results for S/N 10084614, Searched Mon May 07 11:32:57 EDT 2007

The Patent Linguistics Utility System (PLUS) is a USPTO automated search system for U.S. Patents from 1971 to the present PLUS is a query-by-example search system which produces a list of patents that are most closely related linguistically to the application searched. This search was prepared by the staff of the Scientific and Technical Information Center, SIRA.

20020154687 99
6370182 82
5956620 75
20050113035 70
20060239366 70
20060239372 70
20060239373 70
20060239374 70
20060239375 70
20060291544 70
20070015543 70
6016124 69
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6483478 69
6624783 69
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6249251 68
5864548 68
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4780721 63
5247310 63
5274381 63
5274386 63
6240072 63

EAST Search History

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L1	2	"6615024".pn.	US-PGPUB; USPAT; EPO; JPO; DERWENT	OR	ON	2007/05/07 13:40
L2	89	("20020154687" "6370182" "5956620" "20050113035" "20060239366" "20060239372" "20060239373" "20060239374" "20060239375" "20060291544" "20070015543" "6016124" "6359923" "6483478" "6624783" "20020135517" "6249251" "5864548" "7103383" RE39275 "20040127168" "6873608" "20050083890" "5565873" "5570098" "5576717" "5602555" "5666123" "5714957" "5771017" "6480153" "7088964" "7142830" "20020146029" "20040235512" "20040266360" "20050105485" "6141567" "6259910" "7139592" "20020013164" "20050195103" "20070015545" "20010016504" "4780721" "5247310" "5274381" "5274386" "6240072" "4277787").pn.	US-PGPUB; USPAT; EPO; JPO; DERWENT	OR	ON	2007/05/07 13:42
L3	58	phase and 2	US-PGPUB; USPAT; EPO; JPO; DERWENT	OR	ON	2007/05/07 13:42
L4	3	("2002/0154687").URPN.	USPAT	OR	ON	2007/05/07 13:46

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EAST Search History

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L1	7990	375/340.ccls. 375/259.ccls. 375/260. ccls. 375/295.ccls. 375/299.ccls. 375/347.ccls. 375/349.ccls.	US-PGPUB; USPAT; EPO; JPO; DERWENT	OR	ON	2007/05/07 15:59
L2	100597	(adjust$4 correct$4) near3 phase	US-PGPUB; USPAT; EPO; JPO; DERWENT	OR	ON	2007/05/07 15:59
L3	1168	1 and 2	US-PGPUB; USPAT; EPO; JPO; DERWENT	OR	ON	2007/05/07 16:00
L4	412	beamform$4 same carrier	US-PGPUB; USPAT; EPO; JPO; DERWENT	OR	ON	2007/05/07 16:00
L5	48	beamform$4 and 3	US-PGPUB; USPAT; EPO; JPO; DERWENT	OR	ON	2007/05/07 16:00

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UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

NOTICE OF ALLOWANCE AND FEE(S) DUE

27896 7590 05/16/2007

EDELL, SHAPIRO & FINNAN, LLC
1901 RESEARCH BOULEVARD
SUITE 400
ROCKVILLE, MD 20850

EXAMINER	
CORRIELUS, JEAN B	
ART UNIT	PAPER NUMBER
2611	

DATE MAILED: 05/16/2007

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/084,614	02/28/2002	Scott Bierly	0918.0153C	1621

TITLE OF INVENTION: INTEGRATED BEAMFORMER/MODEM ARCHITECTURE

APPLN. TYPE	SMALL ENTITY	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	NO	$1400	$300	$0	$1700	08/16/2007

THE APPLICATION IDENTIFIED ABOVE HAS BEEN EXAMINED AND IS ALLOWED FOR ISSUANCE AS A PATENT. PROSECUTION ON THE MERITS IS CLOSED. THIS NOTICE OF ALLOWANCE IS NOT A GRANT OF PATENT RIGHTS. THIS APPLICATION IS SUBJECT TO WITHDRAWAL FROM ISSUE AT THE INITIATIVE OF THE OFFICE OR UPON PETITION BY THE APPLICANT. SEE 37 CFR 1.313 AND MPEP 1308.

THE ISSUE FEE AND PUBLICATION FEE (IF REQUIRED) MUST BE PAID WITHIN THREE MONTHS FROM THE MAILING DATE OF THIS NOTICE OR THIS APPLICATION SHALL BE REGARDED AS ABANDONED. THIS STATUTORY PERIOD CANNOT BE EXTENDED. SEE 35 U.S.C. 151. THE ISSUE FEE DUE INDICATED ABOVE DOES NOT REFLECT A CREDIT FOR ANY PREVIOUSLY PAID ISSUE FEE IN THIS APPLICATION. IF AN ISSUE FEE HAS PREVIOUSLY BEEN PAID IN THIS APPLICATION (AS SHOWN ABOVE), THE RETURN OF PART B OF THIS FORM WILL BE CONSIDERED A REQUEST TO REAPPLY THE PREVIOUSLY PAID ISSUE FEE TOWARD THE ISSUE FEE NOW DUE.

HOW TO REPLY TO THIS NOTICE:

I. Review the SMALL ENTITY status shown above.

If the SMALL ENTITY is shown as YES, verify your current SMALL ENTITY status:

A. If the status is the same, pay the TOTAL FEE(S) DUE shown above.

B. If the status above is to be removed, check box 5b on Part B - Fee(s) Transmittal and pay the PUBLICATION FEE (if required) and twice the amount of the ISSUE FEE shown above, or

If the SMALL ENTITY is shown as NO:

A. Pay TOTAL FEE(S) DUE shown above, or

B. If applicant claimed SMALL ENTITY status before, or is now claiming SMALL ENTITY status, check box 5a on Part B - Fee(s) Transmittal and pay the PUBLICATION FEE (if required) and 1/2 the ISSUE FEE shown above.

II. PART B - FEE(S) TRANSMITTAL, or its equivalent, must be completed and returned to the United States Patent and Trademark Office (USPTO) with your ISSUE FEE and PUBLICATION FEE (if required). If you are charging the fee(s) to your deposit account, section "4b" of Part B - Fee(s) Transmittal should be completed and an extra copy of the form should be submitted. If an equivalent of Part B is filed, a request to reapply a previously paid issue fee must be clearly made, and delays in processing may occur due to the difficulty in recognizing the paper as an equivalent of Part B.

III. All communications regarding this application must give the application number. Please direct all communications prior to issuance to Mail Stop ISSUE FEE unless advised to the contrary.

IMPORTANT REMINDER: Utility patents issuing on applications filed on or after Dec. 12, 1980 may require payment of maintenance fees. It is patentee's responsibility to ensure timely payment of maintenance fees when due.

PTOL-85 (Rev. 07/06) Approved for use through 04/30/2007.

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PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), to: Mail **Mail Stop ISSUE FEE**
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450
or Fax (571)-273-2885

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

27896 7590 05/16/2007

EDELL, SHAPIRO & FINNAN, LLC
1901 RESEARCH BOULEVARD
SUITE 400
ROCKVILLE, MD 20850

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission

I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being facsimile transmitted to the USPTO (571) 273-2885, on the date indicated below.

(Depositor's name)
(Signature)
(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/084,614	02/28/2002	Scott Bierly	0918.0153C	1621

TITLE OF INVENTION: INTEGRATED BEAMFORMER/MODEM ARCHITECTURE

APPLN. TYPE	SMALL ENTITY	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	NO	$1400	$300	$0	$1700	08/16/2007

EXAMINER	ART UNIT	CLASS-SUBCLASS
CORRIELUS, JEAN B	2611	375-222000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

☐ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.

☐ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list

(1) the names of up to 3 registered patent attorneys or agents OR, alternatively,

(2) the name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

1 _____

2 _____

3 _____

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document has been filed for recordation as set forth in 37 CFR 3.11. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE (B) RESIDENCE: (CITY and STATE OR COUNTRY)

Please check the appropriate assignee category or categories (will not be printed on the patent) : ☐ Individual ☐ Corporation or other private group entity ☐ Government

4a. The following fee(s) are submitted:

☐ Issue Fee

☐ Publication Fee (No small entity discount permitted)

☐ Advance Order - # of Copies _____

4b. Payment of Fee(s): **(Please first reapply any previously paid issue fee shown above)**

☐ A check is enclosed.

☐ Payment by credit card. Form PTO-2038 is attached.

☐ The Director is hereby authorized to charge the required fee(s), any deficiency, or credit any overpayment, to Deposit Account Number _____ (enclose an extra copy of this form).

5. **Change in Entity Status** (from status indicated above)

☐ a. Applicant claims SMALL ENTITY status. See 37 CFR 1.27.

☐ b. Applicant is no longer claiming SMALL ENTITY status. See 37 CFR 1.27(g)(2).

NOTE: The Issue Fee and Publication Fee (if required) will not be accepted from anyone other than the applicant; a registered attorney or agent; or the assignee or other party in interest as shown by the records of the United States Patent and Trademark Office.

Authorized Signature _____ Date _____

Typed or printed name _____ Registration No. _____

This collection of information is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, Virginia 22313-1450.

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/084,614	02/28/2002	Scott Bierly	0918.0153C	1621

27896 7590 05/16/2007

EDELL, SHAPIRO & FINNAN, LLC
1901 RESEARCH BOULEVARD
SUITE 400
ROCKVILLE, MD 20850

EXAMINER	
CORRIELUS, JEAN B	
ART UNIT	PAPER NUMBER
2611	

DATE MAILED: 05/16/2007

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)
(application filed on or after May 29, 2000)

The Patent Term Adjustment to date is 690 day(s). If the issue fee is paid on the date that is three months after the mailing date of this notice and the patent issues on the Tuesday before the date that is 28 weeks (six and a half months) after the mailing date of this notice, the Patent Term Adjustment will be 690 day(s).

If a Continued Prosecution Application (CPA) was filed in the above-identified application, the filing date that determines Patent Term Adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) WEB site (http://pair.uspto.gov).

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Customer Service Center of the Office of Patent Publication at 1-(888)-786-0101 or (571)-272-4200.

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Apple EX1002 Page 372

Notice of Allowability	Application No.	Applicant(s)	
	10/084,614	BIERLY ET AL.	
	Examiner	Art Unit	
	Jean B. Corrielus	2611	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. ☒ This communication is responsive to *1/16/07*.

2. ☒ The allowed claim(s) is/are *1-30, 32, 34, and 36, renumbered as 1-33, respectively*.

3. ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).
   a) ☐ All b) ☐ Some* c) ☐ None of the:
      1. ☐ Certified copies of the priority documents have been received.
      2. ☐ Certified copies of the priority documents have been received in Application No. _____ .
      3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

   * Certified copies not received: _____.

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file a reply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.
THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.

4. ☐ A SUBSTITUTE OATH OR DECLARATION must be submitted. Note the attached EXAMINER'S AMENDMENT or NOTICE OF INFORMAL PATENT APPLICATION (PTO-152) which gives reason(s) why the oath or declaration is deficient.

5. ☐ CORRECTED DRAWINGS (as "replacement sheets") must be submitted.
   (a) ☐ including changes required by the Notice of Draftsperson's Patent Drawing Review (PTO-948) attached
      1) ☐ hereto or 2) ☐ to Paper No./Mail Date _____.
   (b) ☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date _____.

   Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).

6. ☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

Attachment(s)

1. ☐ Notice of References Cited (PTO-892)
2. ☐ Notice of Draftperson's Patent Drawing Review (PTO-948)
3. ☐ Information Disclosure Statements (PTO/SB/08), Paper No./Mail Date _____
4. ☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material
5. ☐ Notice of Informal Patent Application
6. ☒ Interview Summary (PTO-413), Paper No./Mail Date _____ .
7. ☒ Examiner's Amendment/Comment
8. ☐ Examiner's Statement of Reasons for Allowance
9. ☐ Other _____.

JEAN B. CORRIELUS
PRIMARY EXAMINER
5-10-07

EXAMINER'S AMENDMENT

1. An examiner's amendment to the record appears below. Should the changes and/or additions be unacceptable to applicant, an amendment may be filed as provided by 37 CFR 1.312. To ensure consideration of such an amendment, it MUST be submitted no later than the payment of the issue fee.

Authorization for this examiner's amendment was given in a telephone interview with Stuart Shapiro on 5/7/07.

The application has been amended as follows:

IN THE CLAIMS:

Claim 10, line 4, "processor" has been replaced by --beamformer--.

Claim 29, line 13, after "of", --analog--has been inserted; line 15, before "IF", --analog--has been inserted.

Claim 36, line 17, after "of", --analog--has been inserted; line 19, before "IF", --analog--has been inserted.

Any inquiry concerning this communication or earlier communications from the examiner should be directed to Jean B. Corrielus whose telephone number is 571-272-3020.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Jay Patel can be reached on 571-272-2988. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

Jean B Corrélus
Primary Examiner
Art Unit 2611
5-10-07

Examiner-Initiated Interview Summary	Application No.	Applicant(s)	
	10/084,614	BIERLY ET AL.	
	Examiner	Art Unit	
	Jean B. Corrielus	2611	

All Participants:

(1) *Jean B. Corrielus*.

(2) *Stuart Shapiro*.

Status of Application: _____

(3) _____.

(4) _____.

Date of Interview: *7 May 2007*

Time: _____

Type of Interview:

☒ Telephonic

☐ Video Conference

☐ Personal (Copy given to: ☐ Applicant ☐ Applicant's representative)

Exhibit Shown or Demonstrated: ☐ Yes ☐ No

If Yes, provide a brief description:

Part I.

Rejection(s) discussed:

Claims discussed:

10, 29 and 36

Prior art documents discussed:

Part II.

SUBSTANCE OF INTERVIEW DESCRIBING THE GENERAL NATURE OF WHAT WAS DISCUSSED:

Applicant's rep. agrees to amend claims 10, 29 and 36 as indicated in the attached examiner's amendment. Such amendment is necessary to correct for some informalities so as to place the application in better form for allowance

Part III.

☒ It is not necessary for applicant to provide a separate record of the substance of the interview, since the interview directly resulted in the allowance of the application. The examiner will provide a written summary of the substance of the interview in the Notice of Allowability.

☐ It is not necessary for applicant to provide a separate record of the substance of the interview, since the interview did not result in resolution of all issues. A brief summary by the examiner appears in Part II above.

(Examiner/SPE Signature)

(Applicant/Applicant's Representative Signature – if appropriate)

IPR2023-00796
Apple EX1002 Page 376

Issue Classification	Application/Control No.	Applicant(s)/Patent under Reexamination	
	10/084,614	BIERLY ET AL.	
	Examiner	Art Unit	
	Jean B. Corrielus	2611	

ISSUE CLASSIFICATION

ORIGINAL			CROSS REFERENCE(S)						
CLASS	SUBCLASS	CLASS	SUBCLASS (ONE SUBCLASS PER BLOCK)						
375	222	375	260	340	295	347			
INTERNATIONAL CLASSIFICATION									
H 04 B	1/38								
H 04 L	5/16								
	/								
	/								
	/								

XXXXXXXXXXXXXXXXXXXXXXX
(Assistant Examiner) (Date)

(Legal Instruments Examiner) (Date)

Jean B. Corrielus
(Primary Examiner) 5-10-07 (Date)

Total Claims Allowed: 33

O.G. Print Claim(s)	O.G. Print Fig.
1	1

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original
1	1		31		61		91		121		151		181
2	2	31	32		62		92		122		152		182
3	3		33		63		93		123		153		183
4	4	32	34		64		94		124		154		184
5	5		35		65		95		125		155		185
6	6	33	36		66		96		126		156		186
7	7		37		67		97		127		157		187
8	8		38		68		98		128		158		188
9	9		39		69		99		129		159		189
10	10		40		70		100		130		160		190
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24	24		54		84		114		144		174		204
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26	26		56		86		116		146		176		206
27	27		57		87		117		147		177		207
28	28		58		88		118		148		178		208
29	29		59		89		119		149		179		209
30	30		60		90		120		150		180		210

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Apple EX1002 Page 377

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

Bib Data Sheet

CONFIRMATION NO. 1621

SERIAL NUMBER	FILING OR 371(c) DATE / RULE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.
10/084,614	02/28/2002	375	2611	0918.0153C

APPLICANTS

Scott Bierly, Oak Hill, VA;
Marc Harlacher, Herndon, VA;
Robert Smarrelli, Oak Hill, VA;
Aaron Weinberg, Potomac, MD;

YES/M

**** CONTINUING DATA ***********************

This appln claims benefit of 60/271,961 02/28/2001

**** FOREIGN APPLICATIONS ***********************

NONE/M

IF REQUIRED, FOREIGN FILING LICENSE GRANTED **
03/18/2002

		STATE OR COUNTRY	SHEETS DRAWING	TOTAL CLAIMS	INDEPENDENT CLAIMS
Foreign Priority claimed	☐ yes ☑ no	VA	3	33	1
35 USC 119 (a-d) conditions met	☐ yes ☐ no ☐ Met after Allowance				
Verified and Acknowledged	Examiner's Signature / Initials				

ADDRESS
27896

TITLE
Integrated beamformer/modem architecture

FILING FEE RECEIVED	FEES: Authority has been given in Paper	
2142	No. _____ to charge/credit DEPOSIT ACCOUNT No. _____ for following:	☐ All Fees ☐ 1.16 Fees (Filing) ☐ 1.17 Fees (Processing Ext. of time) ☐ 1.18 Fees (Issue) ☐ Other _____ ☐ Credit

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Apple EX1002 Page 378

Search Notes

Application/Control No.	Applicant(s)/Patent under Reexamination
10/084,614	BIERLY ET AL.
Examiner	**Art Unit**
Jean B. Corrielus	2611

SEARCHED			
Class	Subclass	Date	Examiner
375	259-260 340	5/7/2007	JBC
375	299;295	5/7/2007	JBC
375	316	5/7/2007	JBC

INTERFERENCE SEARCHED			
Class	Subclass	Date	Examiner
375	**222;259**	5/7/2007	**JBC**
375	340;299	5/7/2007	JBC
375	347;349	5/7/2007	JBC

SEARCH NOTES (INCLUDING SEARCH STRATEGY)		
	DATE	EXMR
East	5/7/2007	JBC
Plus Search	5/7/2007	JBC

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), to: Mail **Mail Stop ISSUE FEE**
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450
or Fax (571)-273-2885

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

27896 7590 05/16/2007

EDELL, SHAPIRO & FINNAN, LLC
1901 RESEARCH BOULEVARD
SUITE 400
ROCKVILLE, MD 20850

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission
I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being facsimile transmitted to the USPTO (571) 273-2885, on the date indicated below.

(Depositor's name)
(Signature)
(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/084,614	02/28/2002	Scott Bierly	0918.0153C	1621

TITLE OF INVENTION: INTEGRATED BEAMFORMER/MODEM ARCHITECTURE

APPLN. TYPE	SMALL ENTITY	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	NO	$1400	$300	$0	$1700	08/16/2007

EXAMINER	ART UNIT	CLASS-SUBCLASS
CORRIELUS, JEAN B	2611	375-222000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).
☐ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.
☐ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list
(1) the names of up to 3 registered patent attorneys or agents OR, alternatively, 1 Edell, Shapiro & Finnan, LLC
(2) the name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed. 2 3

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document has been filed for recordation as set forth in 37 CFR 3.11. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE: ITT Manufacturing Enterprises, Inc.
(B) RESIDENCE: (CITY and STATE OR COUNTRY): Wilmington, Delaware

Please check the appropriate assignee category or categories (will not be printed on the patent) : ☐ Individual ☒ Corporation or other private group entity ☐ Government

4a. The following fee(s) are submitted:
☒ Issue Fee
☒ Publication Fee (No small entity discount permitted)
☒ Advance Order - # of Copies 6

4b. Payment of Fee(s): **(Please first reapply any previously paid issue fee shown above)**
☐ A check is enclosed.
☐ Payment by credit card. Form PTO-2038 is attached.
☐ The Director is hereby authorized to charge the required fee(s), any deficiency, or credit any overpayment, to Deposit Account Number 05-0460 (enclose an extra copy of this form).

5. **Change in Entity Status** (from status indicated above)
☐ a. Applicant claims SMALL ENTITY status. See 37 CFR 1.27.
☐ b. Applicant is no longer claiming SMALL ENTITY status. See 37 CFR 1.27(g)(2).

NOTE: The Issue Fee and Publication Fee (if required) will not be accepted from anyone other than the applicant; a registered attorney or agent; or the assignee or other party in interest as shown by the records of the United States Patent and Trademark Office.

Authorized Signature /Patrick J. Finnan/ Date June 18, 2007

Typed or printed name Patrick J. Finnan Registration No. 39,189

This collection of information is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, Virginia 22313-1450.

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

Electronic Patent Application Fee Transmittal

Application Number:	10084614
Filing Date:	28-Feb-2002
Title of Invention:	INTEGRATED BEAMFORMER/MODEM ARCHITECTURE
First Named Inventor/Applicant Name:	Scott Bierly
Filer:	Patrick J. Finnan/Joanna Sanchez
Attorney Docket Number:	0918.0153C

Filed as Large Entity

Utility Filing Fees

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Utility Appl issue fee	1501	1	1400	1400
Publ. Fee- early, voluntary, or normal	1504	1	300	300

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Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Extension-of-Time:				
Miscellaneous:				
Printed copy of patent - no color	8001	6	3	18
		Total in USD ($)		**1718**

Electronic Acknowledgement Receipt

EFS ID:	1970204
Application Number:	10084614
International Application Number:	
Confirmation Number:	1621
Title of Invention:	INTEGRATED BEAMFORMER/MODEM ARCHITECTURE
First Named Inventor/Applicant Name:	Scott Bierly
Customer Number:	27896
Filer:	Patrick J. Finnan/Joanna Sanchez
Filer Authorized By:	Patrick J. Finnan
Attorney Docket Number:	0918.0153C
Receipt Date:	13-JUL-2007
Filing Date:	28-FEB-2002
Time Stamp:	14:40:18
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment was successfully received in RAM	$1718
RAM confirmation Number	6386
Deposit Account	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes) /Message Digest	Multi Part /.zip	Pages (if appl.)

1	Miscellaneous Incoming Letter	IssueFeeXML.pdf	22184 e39c5067b74e2697aa7f2fd699258ee0fa9f585e	no	1
Warnings:					
Information:					
2	Issue Fee Payment (PTO-85B)	IFpayment.pdf	109214 59859a755169245b7c2617b5e7c606594234ef11	no	1
Warnings:					
Information:					
3	Fee Worksheet (PTO-06)	fee-info.pdf	8446 918f9dc0db2346112b68d061a2da462150a21a87	no	2
Warnings:					
Information:					
			Total Files Size (in bytes):	139844	

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Application No.	:	10/084,614
Applicant	:	Scott Bierly et al.
Confirmation No.	:	1621
Filed	:	February 28, 2002
TC/A.U.	:	2611
Examiner	:	Jean B. Corrielus
Customer No.	:	27896
Docket No.	:	0918.0153C
Title	:	Integrated Beamformer/Modem Architecture

ISSUE FEE TRANSMITTAL

IN RESPONSE TO THE NOTICE OF ALLOWANCE MAILED MAY 16, 2007, ENCLOSED ARE

☒ Issue Fee Transmittal (Form PTOL 85b)

☐ Other: _____

THE **FEES** HAVE BEEN CALCULATED AS FOLLOWS:

☒ Issue Fee: $1400.00

☒ Publication Fee ($300): $300.00

☒ Other Fees: $18.00

Total Fee Due: $1718.00

☒ Credit card payment has been submitted concurrently with the filing of this transmittal. The Director is hereby authorized to charge any additional appropriate fees that may be required during the pendency of the above-identified application (e.g., in the concurrent or in any future reply), as well as to credit any overpayment, to Deposit Account No. **05-0460**.

Dated: July 13, 2007

Respectfully submitted by:

EDELL, SHAPIRO & FINNAN, LLC
CUSTOMER NO. 27896
1901 Research Boulevard, Suite 400
Rockville, MD 20850
(301) 424-3640

/Patrick J. Finnan/

Patrick J. Finnan
Reg. No. 39189

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	ISSUE DATE	PATENT NO.	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/084,614	08/21/2007	7260141	0918.0153C	1621

27896 7590 08/01/2007

EDELL, SHAPIRO & FINNAN, LLC
1901 RESEARCH BOULEVARD
SUITE 400
ROCKVILLE, MD 20850

ISSUE NOTIFICATION

The projected patent number and issue date are specified above.

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)
(application filed on or after May 29, 2000)

The Patent Term Adjustment is 802 day(s). Any patent to issue from the above-identified application will include an indication of the adjustment on the front page.

If a Continued Prosecution Application (CPA) was filed in the above-identified application, the filing date that determines Patent Term Adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) WEB site (http://pair.uspto.gov).

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Customer Service Center of the Office of Patent Publication at (571)-272-4200.

APPLICANT(s) (Please see PAIR WEB site http://pair.uspto.gov for additional applicants):

Scott Bierly, Oak Hill, VA;
Marc Harlacher, Herndon, VA;
Robert Smarrelli, Oak Hill, VA;
Aaron Weinberg, Potomac, MD;

PTO/SB/44 (09-07)
Approved for use through 08/31/2010. OMB 0651-0033
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.
(Also Form PTO-1050)

UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 7,260,141

APPLICATION NO.: 10/084,614

ISSUE DATE : Aug. 21, 2007

INVENTOR(S) : Scott Bierly et al.

It is certified that an error appears or errors appear in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Front Page, Foreign Patent Documents:

Add "WO 96/22662 12/1995"

Col. 16, ll. 57, 60, 62: "convening" should read "converting"

MAILING ADDRESS OF SENDER (Please do not use customer number below):

Edell, Shapiro & Finnan, LLC
1901 Research Boulevard, Suite 400
Rockville, Maryland 20850

This collection of information is required by 37 CFR 1.322, 1.323, and 1.324. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 1.0 hour to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Attention Certificate of Corrections Branch, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

Electronic Acknowledgement Receipt

EFS ID:	2724864
Application Number:	10084614
International Application Number:	
Confirmation Number:	1621
Title of Invention:	INTEGRATED BEAMFORMER/MODEM ARCHITECTURE
First Named Inventor/Applicant Name:	Scott Bierly
Customer Number:	27896
Filer:	Patrick J. Finnan/Joan Donavan
Filer Authorized By:	Patrick J. Finnan
Attorney Docket Number:	0918.0153C
Receipt Date:	16-JAN-2008
Filing Date:	28-FEB-2002
Time Stamp:	15:03:18
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes) /Message Digest	Multi Part /.zip	Pages (if appl.)
1	Miscellaneous Incoming Letter	CertificateofCorrectionTransmittal.pdf	17107 ed5cce79871507e8b09bd3229faded0d58f2e508	no	1

Warnings:	
Information:	

IPR2023-00796
Apple EX1002 Page 388

2	Request for Certificate of Correction	CertificateofCorrection.pdf	40136 68cbd0eaf5f04860cd8c5fbdf136930ae7cf933e	no	1

Warnings:	
Information:	
Total Files Size (in bytes):	57243

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111
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National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Patent No.	: 7,260,141
Application No.	: 10/084,614
Applicant	: Scott Bierly et al.
Confirmation No.	: 1621
Issued	: Aug. 21, 2007
Customer No.	: 27896
Docket No.	: 0918.0153C
Title	: INTEGRATED BEAMFORMER/MODEM ARCHITECTURE

ATTN: Certificate of Correction Branch
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

TRANSMITTAL LETTER

Sir:

Transmitted herewith is a Certificate of Correction (1 page).

It is believed that no fees are required at this time, as the errors in the Official Letters Patent were on the part of the U.S. Patent and Trademark Office. However, the Commissioner is hereby authorized to charge payment of any additional fees required for the above-identified application or credit any overpayment to Deposit Account No. 05-0460.

Respectfully submitted,

/Patrick J. Finnan/
Patrick J. Finnan
Reg. No. 39,189

EDELL, SHAPIRO & FINNAN, LLC
1901 Research Boulevard, Suite 400
Rockville, Maryland 20850-3164
(301) 424-3640

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 7,260,141 B2
APPLICATION NO. : 10/084614
DATED : August 21, 2007
INVENTOR(S) : Scott Bierly et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Front Page, Foreign Patent Documents:

Add --WO 96/22662 12/1995--

Col. 16, ll. 57, 60, 62: "convening" should read --converting--

Signed and Sealed this

Twenty-ninth Day of April, 2008

JON W. DUDAS
Director of the United States Patent and Trademark Office

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
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www.uspto.gov

APPLICATION NUMBER	PATENT NUMBER	GROUP ART UNIT	REQUEST ID
10/084,614	7260141	2611	17394

PAIR Correspondence Address/Fee Address Change

The following fields have been changed to Customer Number 140878 on 05/10/2016 via Private PAIR in view of the certification copied below that authorized the change.

- Correspondence Address

The address for Customer Number 140878 is:
140878
EDELL, SHAPIRO & FINNAN, LLC
9801 Washingtonian Blvd.
Suite 750
Gaithersburg, MD 20878

I certify, in accordance with 37 CFR 1.4(d)(4) that I am:

An attorney or Agent of Record registered to practice before the Patent and Trademark Office who has been given power of attorney in this application

Signature:	/Patrick J. Finnan/
Name:	Patrick J. Finnan
Registration Number:	39189

AO 120 (Rev. 08/10)

TO:	REPORT ON THE FILING OR DETERMINATION OF AN ACTION REGARDING A PATENT OR TRADEMARK
Mail Stop 8 Director of the U.S. Patent and Trademark Office P.O. Box 1450 Alexandria, VA 22313-1450	

In Compliance with 35 U.S.C. § 290 and/or 15 U.S.C. § 1116 you are hereby advised that a court action has been filed in the U.S. District Court Eastern District of Texas on the following

☐ Trademarks or ☑ Patents. (☐ the patent action involves 35 U.S.C. § 292.):

DOCKET NO.	DATE FILED	U.S. DISTRICT COURT
	4/1/2022	Eastern District of Texas

PLAINTIFF	DEFENDANT
LIONRA TECHNOLOGIES LIMITED	SAMSUNG ELECTRONICS CO., LTD., SAMSUNG ELECTRONICS AMERICA, INC.

	PATENT OR TRADEMARK NO.	DATE OF PATENT OR TRADEMARK	HOLDER OF PATENT OR TRADEMARK
1	7,260,141	8/21/2007	Lionra Technologies Limited
2			
3			
4			
5			

In the above—entitled case, the following patent(s)/ trademark(s) have been included:

DATE INCLUDED	INCLUDED BY ☐ Amendment ☐ Answer ☐ Cross Bill ☐ Other Pleading	
PATENT OR TRADEMARK NO.	DATE OF PATENT OR TRADEMARK	HOLDER OF PATENT OR TRADEMARK
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In the above—entitled case, the following decision has been rendered or judgement issued:

DECISION/JUDGEMENT

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AO 120 (Rev. 08/10)

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DOCKET NO.	DATE FILED	U.S. DISTRICT COURT
6:22-cv-00351	4/1/2022	Western District of Texas

PLAINTIFF	DEFENDANT
LIONRA TECHNOLOGIES LIMITED	APPLE INC.

	PATENT OR TRADEMARK NO.	DATE OF PATENT OR TRADEMARK	HOLDER OF PATENT OR TRADEMARK
1	7,260,141	8/21/2007	Lionra Technologies Limited
2			
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5			

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DATE INCLUDED	INCLUDED BY ☐ Amendment ☐ Answer ☐ Cross Bill ☐ Other Pleading	
PATENT OR TRADEMARK NO.	DATE OF PATENT OR TRADEMARK	HOLDER OF PATENT OR TRADEMARK
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☐ Trademarks or ☑ Patents. (☐ the patent action involves 35 U.S.C. § 292.):

DOCKET NO.	DATE FILED	U.S. DISTRICT COURT
6:22-cv-467	5/9/2022	WESTERN DISTRICT OF TEXAS

PLAINTIFF	DEFENDANT
LIONRA TECHNOLOGIES LTD.	GOOGLE LLC

	PATENT OR TRADEMARK NO.	DATE OF PATENT OR TRADEMARK	HOLDER OF PATENT OR TRADEMARK
1	7,260,141	8/21/2007	LIONRA TECHNOLOGIES LTD.
2			
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DATE INCLUDED	INCLUDED BY ☐ Amendment ☐ Answer ☐ Cross Bill ☐ Other Pleading	
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TO:	Mail Stop 8 Director of the U.S. Patent and Trademark Office P.O. Box 1450 Alexandria, VA 22313-1450	REPORT ON THE FILING OR DETERMINATION OF AN ACTION REGARDING A PATENT OR TRADEMARK

In Compliance with 35 U.S.C. § 290 and/or 15 U.S.C. § 1116 you are hereby advised that a court action has been filed in the U.S. District Court Eastern District of Texas on the following

☐ Trademarks or ☑ Patents. (☐ the patent action involves 35 U.S.C. § 292.):

DOCKET NO.	DATE FILED	U.S. DISTRICT COURT
	4/1/2022	Eastern District of Texas

PLAINTIFF	DEFENDANT
LIONRA TECHNOLOGIES LIMITED	SAMSUNG ELECTRONICS CO., LTD., SAMSUNG ELECTRONICS AMERICA, INC.

	PATENT OR TRADEMARK NO.	DATE OF PATENT OR TRADEMARK	HOLDER OF PATENT OR TRADEMARK
1	7,260,141	8/21/2007	Lionra Technologies Limited
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In the above—entitled case, the following patent(s)/ trademark(s) have been included:

DATE INCLUDED	INCLUDED BY ☐ Amendment ☐ Answer ☐ Cross Bill ☐ Other Pleading		
	PATENT OR TRADEMARK NO.	DATE OF PATENT OR TRADEMARK	HOLDER OF PATENT OR TRADEMARK
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In the above—entitled case, the following decision has been rendered or judgement issued:

DECISION/JUDGEMENT
Accordingly, all pending claims and causes of action in this action by and between Lionra and Samsung are DISMISSED WITH PREJUDICE

CLERK	(BY) DEPUTY CLERK	DATE
David A. O'Toole	NKL	8/15/22

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AO 120 (Rev. 08/10)

TO:	**Mail Stop 8** **Director of the U.S. Patent and Trademark Office** **P.O. Box 1450** **Alexandria, VA 22313-1450**	**REPORT ON THE FILING OR DETERMINATION OF AN ACTION REGARDING A PATENT OR TRADEMARK**

In Compliance with 35 U.S.C. § 290 and/or 15 U.S.C. § 1116 you are hereby advised that a court action has been filed in the U.S. District Court Northern District of IL on the following

☐ Trademarks or ☑ Patents. (☐ the patent action involves 35 U.S.C. § 292.):

DOCKET NO.	DATE FILED	U.S. DISTRICT COURT
1:22-cv-02231	4/28/2022	Northern District of IL

PLAINTIFF	DEFENDANT
Lionra Technologies Limited	Motorola Mobility LLC

PATENT OR TRADEMARK NO.	DATE OF PATENT OR TRADEMARK	HOLDER OF PATENT OR TRADEMARK
1 see attached		
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PATENT OR TRADEMARK NO.	DATE OF PATENT OR TRADEMARK	HOLDER OF PATENT OR TRADEMARK
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DECISION/JUDGEMENT

CLERK	(BY) DEPUTY CLERK	DATE
Thomas Bruton	Carolina Roman	8/19/2022

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bandwidth required by the communication system in which the transceiver is used. In the specific implementation shown in FIG. **1**, the transceiver employs time-division duplexing (TDD) in which the transceiver is alternately in a transmit and receive mode, relying on the phased array antenna for both signal transmission and reception. Accordingly, each antenna element $\mathbf{10}_i$ has a corresponding RF switching element $\mathbf{12}_i$ selectively connecting the antenna element to the transmitter system and the receiver system. RF switching elements $\mathbf{12}_i$ can be a RF transmit/receive switches, circulators, diplexers, hybrid splitters or any other device suitable for selective connecting the antenna elements to the transmit and receive circuitry. It should be understood, however, that the invention is not limited to a TDD architecture, and the present invention can be employed with both simultaneous and non-simultaneous transmit/receive schemes.

On the receiver side, each of the antenna elements $\mathbf{10}_1$, $\mathbf{10}_2$, . . . , $\mathbf{10}_E$ is coupled to a respective bandpass filter $\mathbf{14}_1$, $\mathbf{14}_2$, . . . , $\mathbf{14}_E$ which attenuates signal frequencies outside the filter's pass band. Each antenna element $\mathbf{10}_i$ can simultaneously receive signals on a plurality of different frequency channels F within the receiver pass band (frequency division multiplexing FDM). Each frequency channel is in turn time-division multiplexed (TDM), such that the system employs both time division multiple access (TDMA) and frequency division multiple access (FDMA) channelizing. The filtered RF signal from each element $\mathbf{10}_1$, $\mathbf{10}_2$, . . . , $\mathbf{10}_E$ is amplified by a corresponding low-noise amplifier (LNA) $\mathbf{16}_1$, $\mathbf{16}_2$, . . . , $\mathbf{16}_E$ and then processed by an analog RF down-converter (DC) $\mathbf{18}_1$, $\mathbf{18}_2$, . . . , $\mathbf{18}_E$ which down-converts the RF signal to an intermediate frequency (IF). For each of the E IF signals, a corresponding analog-to-digital (A/D) converter $\mathbf{19}_1$, $\mathbf{19}_2$, . . . , $\mathbf{19}_E$ digitally samples the IF signal at a wideband input sampling rate Fs_1, and the digital IF signal is received by a bank of digital down-converters (DDC) **20** to perform frequency division multiplexing (FDM) de-channelization.

The DDC bank **20** includes a digital down-converter for each of the F frequency channels of each of the E antenna elements for a total of F×E digital down-converters. In practice, it may be possible under certain circumstances to perform digital down-conversion with fewer than F×E actual DDC devices, as will be explained herein in greater detail. DDC bank **20** down-converts the digital IF signal to a baseband frequency by decimating the digital IF signal and FIR filtering to bring the signal in each frequency channel of each antenna element down to baseband. Specifically, each DDC selects every R^{th} sample for inclusion in the baseband signal while discarding the intervening R-1 samples, such that each DDC produces a decimated signal for a particular element and frequency channel at a sampling rate of

$$Fs_2 = \frac{Fs_1}{R} \tag{1}$$

The factor R represents the narrowband rate reduction which facilitates multiplexing the multiple elements and frequency channels in order to share baseband processing circuitry. A frequency division multiplexer (FDM) channel numerically controlled oscillator bank **22** comprises F NCOs which are respectively tuned to the center frequency of the F frequency channels. The FDM channel NCO bank **22** supplies the F different frequency signals used by DDC bank **20** to perform the complex multiplying required to bring each of the F frequency channel signals from each of the E antenna elements down to baseband, which are then filtered by FIR filters.

As shown in FIG. **1**, each of the digital baseband signals generated in parallel by the F×E DDCs is time multiplexed by multiplexer (MUX) **24** into a serial signal having a rate of

$$Fs_3 = \frac{Fs_1 \cdot E \cdot F}{R} \tag{2}$$

The time-multiplexed serial baseband output signal of multiplexer **24** is processed at baseband as described below to detect data symbols for each of C user channels. It should be understood that the various data rates described herein relate to upper limits constrained by the relationships between factors such as the wideband sample rate, the number and bandwidth of frequency and time channels, the decimation/interpolation factor, the number of antenna elements, the number of users channels and input/output symbol rates. Accordingly, a particular architecture can be designed to operate up to particular clock rates in accordance with these relationships. However, these rate relationships do not imply that the hardware must be operated at the maximum designed rate. Thus, for example, while Fs_3 is shown in equation (2) to as "equal to" a particular expression, it will be understood that this expression represents an upper limit on the permissible value of Fs_3; in operation, Fs_3 can be set at an appropriate rate up to the value of this expression.

On the transmitter side, baseband signals are generated at the rate Fs_3 and supplied to a demultiplexer (DEMUX) **26**. The serial baseband signal stream includes time-multiplexed signals for each antenna element on each user channel. Demultiplexer **26** converts the serial baseband signal to F×E parallel signals, each having a rate of Fs_2, which are respectively received by F×E digital up-converters (DUC) of a DUC bank **28** which performs FDM channelization of the baseband signals. Receiving the center frequencies of the F frequency channels from FDM channel NCO bank **22**, DUC bank **28** performs the complex multiplying required to up-convert E signals (one for each antenna element) on each of the F channel frequencies into E digital IF signals. Further, to bring the sampling rate up to the wideband sampling rate Fs_1, required by the digital-to-analog converters $\mathbf{29}_1$, $\mathbf{29}_2$, . . . , $\mathbf{29}_E$ corresponding to antenna elements $\mathbf{10}_1$, $\mathbf{10}_2$, . . . , $\mathbf{10}_E$, DUC bank **28** interpolates each of the E digital IF signals by the factor of R. After digital-to-analog conversion, the analog IF signal for each of E antenna elements is up-converted to RF by respective analog up-converters $\mathbf{30}_1$, $\mathbf{30}_2$, . . . , $\mathbf{30}_E$ and amplified by respective power amplifiers $\mathbf{32}_1$, $\mathbf{32}_2$, . . . , $\mathbf{32}_E$. With RF switching elements $\mathbf{12}_1$, $\mathbf{12}_2$, . . . , $\mathbf{12}_E$ positioned to connect the transmit circuitry to respective antenna elements $\mathbf{10}_1$, $\mathbf{10}_2$, . . . , $\mathbf{10}_E$, the amplified RF signals are transmitted via the antenna elements in accordance with the beamforming applied in the baseband processing.

Beamforming in a multi-user modem or base station applications in the prior art has principally taken a non-integrated or detached approach. In some cases, beamforming rotation and combining is done in analog in the front-end UC/DC circuitry of the modem. In other cases, beamforming is performed using either analog or digital approaches as a distinct external apparatus from the modem. The approach of the present invention is to incorporate beamforming directly into the modem architecture. To accomplish beam-

forming, the appropriate relative signal phase and amplitude must be applied to the individual antenna elements to form an antenna beam which has a desired shape and points in a particular direction. To support signal modulation and demodulation, baseband processors typically perform the functions of carrier phase tracking (involving carrier phase rotation) and automatic gain control (AGC) (i.e., adjusting the amplitude of the baseband signal to be within the operational range of downstream devices), although baseband processors do not generally process carrier phase and amplitude on an antenna-element-by-antenna-element basis. In accordance with the present invention, beamforming is integrated into baseband processing such that beamforming computations are performed in a manner requiring only additional adders, due to integration with the existing modulation/demodulation carrier phase rotation and the AGC/power-control scaling functions.

An important novel aspect of the present invention is the independent processing of each antenna element all the way from the antenna elements down to individual baseband channel-level processing. While increasing the baseband computational complexity by a factor of the number of antenna elements E, this approach affords significant performance advantages to each user channel, permitting completely independent antenna beam patterns to be achieved per channel when receiving, as well as individual contributions to the beam pattern when transmitting.

Baseband processing is described in connection with transmission and reception of data symbols associated with a plurality of users. A flow diagram summarizing the signal processing operations associated with modulating and transmitting data symbols is shown in FIG. **2**, while a flow diagram summarizing the signal processing operations associated with receiving and demodulating data symbols is shown in FIG. **3**. Referring to FIGS. **1** and **2**, C independent data streams of symbols are received in parallel on C user channels at a certain data rate. The input data symbols from the C user channels are time multiplexed by multiplexer **34** into a serial signal having a data rate C times the input symbol rate, with each user channel receiving the fraction 1/C of the time slots (operation **100** in FIG. **2**). The serial signal is processed by a baseband modulator bank **36** comprising C baseband modulators which respectively generate in a time-multiplexed series baseband signals from the input data symbols of the C user channels for processing by shared baseband processor **38**.

Since beamforming is to be performed at baseband, for each input data symbol on each user channel, baseband modulator bank **36** must generate E copies of each symbol (operation **102**). Consequently, the data rate of the time-multiplexed signal out of baseband modulator bank **36** is the input data symbol rate times the number of user channels C times the number of antenna elements E, and for each input data symbol time slot, baseband modulator bank **36** produces E identical baseband modulated signals in E corresponding time slots. The output of the baseband modulator bank **36**, which is supplied to shared baseband processor **38**, is serialized in this manner so that shared baseband processor **38** can be implemented with a single complex multiplier and a single automatic gain control element. Shared baseband processor **38** applies different phases and scaling to each of the E copies of each symbol.

Shared baseband processor **38** includes a carrier phase accumulator bank **40** comprising a single numerically controlled oscillator (NCO) controlled in a time-multiplex manner via a memory bank of phase values corresponding to each user channel C (for both modulation and demodulation). The NCO supplies a rolling phase for the respective data channels to a phase adder **42** in a time-multiplexed manner. A bank of beam rotation weights **44** contains beamforming weights in the form of phase rotations for each channel and each antenna element, which are supplied to phase adder **42** channel-by-channel and element-by-element in a time-multiplexed manner. With C independent user channels, E different antenna elements and both transmit and receive beam steering, beam rotation weight bank **44** includes C×E×2 beamforming phase rotations. Phase adder **42** receives the beamforming rotation weights and adjusts the phase supplied by the carrier phase accumulator bank NCO **40** in accordance with the beamforming phases of the particular antenna elements. A sin/cos lookup table **46** is indexed by the adjusted phase value generated by phase adder **42** and supplies the corresponding sine/cosine multiplicands to a complex multiplier **48** for adjusting the phases of the input time-multiplex baseband signals on a time-slot-by-time-slot basis (operation **104**).

The phase-adjusted baseband signal in each time slot is then adjusted in amplitude by a scalar multiplier **50** based on scaling information received from beam scaling and AGC/power control processor **52** (operation **106**). Like the bank of beam rotation weights **44**, scaling processor **52** applies different scaling on a time-slot basis in accordance with the beam scaling to be applied to a particular antenna element for each user channel and for both signal transmission and reception power control, resulting in C×E×2 different scaling functions. For example, for received signals being demodulated, the automatic gain control adjusts the signal level to be within the operational range of downstream processing, simultaneously taking into account the relative scaling of the different antenna elements for proper beamforming.

By incorporating the individual antenna element phase rotations required to form a beam pattern into baseband signal rotations already required for each channel for carrier tracking, only a modest hardware impact occurs (this impact is shown in FIG. **1** by the dotted box enclosing adder **42** and beam rotation weights **44**). This is because the process of carrier tracking already rotates each complex baseband sample by some amount on the unit circle between 0 and 2π radians. The complexity of this rotation is the same, regardless of the amount of rotation. Thus, by adding the desired beamforming rotation to the sample-by-sample desired carrier tracking rotation, a new sum rotation is formed. This sum rotation is then applied to the existing complex multiplier **48**, which simultaneously performs carrier tracking and beam phasing, at the incremental cost of the adder **42** used to compute the rotation sum. In the same manner, the magnitude scaling component of beam weighting is incorporated into the existing AGC or power-control scalar multiplication. If the multiplication of the slowly changing beam scaling weight with the slowly changing AGC or power-control factor can be performed in software (which already calculates those individual values), then this second aspect of the beamforming computation is essentially achieved without additional hardware cost.

The phase and gain adjusted serial baseband signal stream produced by shared baseband processor is received by demultiplexer **26** and processed as previously described. Specifically, demultiplexer **26** converts the serial baseband signal to F×E parallel signals (operation **108**) which are digitally up-converted by DUC bank **28** to produce E parallel digital IF signals corresponding to the E antenna elements (operation **110**), which are then up-converted to RF at the analog front end and transmitted (operation **112**).

Ultimately, the TDMA/FDMA transmission scheme must support transmission of the data symbols on each of the C user channels. The relationship between the input/output data symbol rate of the C user channels and the front end processing rates can be understood as follows. Recall that each of the F frequency-multiplexed channels is time division multiplexed (TDM) to support T users simultaneously. The instantaneous bandwidth of any one of the F frequency-multiplexed channel is equal to the number of TDM users on that channel times the maximum data rate of the users. Thus, for example, if 10 TDM users each having at 1 kbps maximum data rate are sharing one FDM channel, then that FDM channel itself is running at a 10 kbps rate. The overall number of user channels C is then related to the number of frequency channels F by the relationship C=F×T.

In the TDD example shown in FIG. **1**, shared baseband processor **38** can also be used in a time-multiplexed manner to process the baseband signal samples generated from received RF signals. Referring to FIG. **3**, wideband RF signals received at each of the E antenna elements are down-converted to IF and digitized (operation **200**), digitally down-converted to baseband to form F×E parallel baseband signals (operation **202**) and then time multiplexed to form a serial baseband signal stream at F×E the parallel data rate (operation **204**) in the manner previously described. Shared baseband processor **38** operates on the serial baseband signal stream on a time-slot-by-time-slot basis to adjust the phase and amplitude of the time-multiplexed baseband samples.

In the receive case, the NCO's of the carrier phase accumulator bank **40** respectively track the carrier phase of the signal in each of the C user channels based on feedback from a phase discriminator within the corresponding baseband demodulator **58**. The bank of beam rotation weights **44** supplies beamforming weights for each channel and each antenna element in a time-multiplexed manner to adjust the rolling phase from the carrier tracker via adder **42** in accordance with the receive antenna beam. The sin/cos lookup table **46** is indexed by the adjusted phase value generated by phase adder **42** and supplies the corresponding sine/cosine multiplicands to complex multiplier **48** for adjusting the phases of the received time-multiplexed baseband signals on a time-slot-by-time-slot basis (operation **206**). The phase adjusted baseband signal in each time slot is then adjusted in amplitude by multiplier **50** based on the required AGC and antenna element beam scaling (operation **208**). Thus, beamforming for both modulation and demodulation can be seen to be implemented using the primarily existing baseband carrier rotation/AGC/power-control computational hardware. The beamformer/demodulator function can be used to compute the direction of arrival (DOA) of each user signal as it is processed. This not only accomplishes tracking of the received beam pattern on the signal, but also provides a known bearing for use during transmit beamforming.

The phase and amplitude adjusted baseband samples are supplied to a beamformer combiner bank **54** which, for each user channel C, combines at baseband the E simultaneously-received antenna element signals. That is, the antenna element signals forming a particular receive antenna beam via their appropriate phase and amplitude adjustments are combined to realize the resultant signal received via the particular antenna beam. The serial output data stream from beamformer combiner bank **54** has a data rate of

$$Fs_4 = \frac{Fs_1 \cdot C}{R} \tag{3}$$

The output of beamformer/combiner bank **54** is supplied to a channel equalizer bank **56** comprising C channel equalizers which perform channel equalization on the C respective user channel signals. The output of channel equalizer bank **56** is supplied to a baseband demodulator **58** which demodulates the baseband signals for each of the C user channels. A demultiplexer **60** serial-to-parallel converts the output of baseband demodulator **58**, and the C parallel signals undergo joint detection **62** to produce C soft detect output symbols.

As illustrated in FIG. **1**, non-simultaneous transmit/receive cases, such as TDD, allow FDM Channel-NCO-Bank and Beamforming/Carrier-Rotation/AGC/Power-Control functions to be time-shared between modulation and demodulation computation. Identical mathematical functionality is required during both modulation and demodulation, but operating on different signal data and different state information such as FDM frequency channel, carrier frequency offset, NCO phase, beam weights, and AGC/Power-Control values. Thus, the computational hardware is reused in both modes, while appropriate signal data must be routed to the hardware, and appropriate state vectors retrieved from local storage (e.g., random access memory (RAM)) and routed to the hardware. In FIG. **1**, signal data is routed at the correct time by synchronizing the switching of the RF switching elements $\mathbf{12}_{1\text{-}E}$ as well as closing either switches **64** and **66** to connect the shared baseband processor **38** to the receiver/demodulator circuitry or switches **68** and **70** to connect the shared baseband processor to the modulation/transmitter circuitry; internal state vectors are represented by the boxes that have depth (e.g., carrier phase accumulator bank, which is implemented as a single hardware accumulator connected to a RAM containing C*2 accumulated phase words).

It is also possible in a TDD-type system to share much of the computational complexity of the DDC bank and DUC bank (for purposes of clarity, this potential sharing is not shown in FIG. **1**). In both cases, for instance, F*E wideband complex multiplies must be performed for TDM tuning. Furthermore, F*E FIR filters must be implemented at the wideband Fs_1, rate, using identical filter coefficients in both cases (for the DDC case, the filter is decimating by a factor of R, and for the DUC case the filter is interpolating by a factor of R), essentially the same hardware is required to perform the filtering operation, allowing a single efficient structure to perform both functions.

If non-beamforming prior-art modem architectures were merely extended to support multiple elements, wideband computational complexity would be increased by a factor of E. Another important aspect of the present invention is the manner in which this additional signal processing complexity due to beamforming is implemented. By exploiting several architectural innovations that perform this extended processing in a non-obvious manner, the additional capabilities are obtained at reduced implementation cost. Firstly, in the wideband DDC/DUC processing, the prior art (or extrapolation thereof) technique would simply repeat DDC/DUC modules on a per-element basis. According to the present invention, the DDC and DUC modules are broken down into constituent functions of NCO, complex multiplication, and interpolation/decimation FIR filtering. While the

state vectors of those functions are unique and must be maintained for each element and frequency, both up-converting and down-converting, the computation is almost identical. Therefore, the present invention shares that processing between elements, frequencies, up-conversion, and down-conversion as is appropriate given the processing required by the input sampling rate Fs_1, and the arithmetic processing rate Fp. For example, if Fp/Fs_1, is four, then a single physical DDC/DUC hardware resource can actually be shared across four elements or frequencies. Furthermore, in a time-multiplexed transmit/receive scenario, a single computational hardware implementation can serve as both DDC and DUC. As previously mentioned, in a TDD system, the DDC and DUC NCOs produce the same frequency waveform for a given frequency channel, and can thus be directly shared.

As has already been noted, significant complexity exists in the baseband portion of the beamforming base station modem. This is true for both arithmetic computation, as well as variety and multiple-rates of data operands for frequency bands, channel time slots, and antenna elements. Additional novel features of the present invention specifically address the organization of this complexity, to produce a dataflow architecture that can be effectively implemented on a VLSI, FPGA or ASIC type device. The typically large interpolation/decimation factor R is leveraged and used to multiplex/demultiplex the F×E streams of complex data from/to the DDC/DUC processing functions. This approach reduces the wiring interconnect complexity compared to other approaches. If R is greater than the product F×E, the sequential frequency/element data stream can likely be demodulated and beamformed by a single processing unit, as shown in FIG. **1**; otherwise, multiple units would service the excess computational demand. This also applies to the beamformer/combiner function. In a TDD system, where modulation and demodulation do not occur at the same time, this carrier-tracking/beamforming hardware is also shared for both modulation and demodulation. In an FDD system, twice the capacity would be required, either through R being at least 2×F×E, or through an additional computational block.

As illustrated in FIG. **1**, the additional functions of baseband modulation, channel equalizer, baseband demodulation, and detection are achieved through distinct hardware blocks. In the manner just described, a single instance of these processing blocks can handle all C user channels, in this case where R is greater than or equal to C. Since this modem jointly demodulates many (C) users simultaneously, advanced signal processing techniques such as joint detection are readily enabled by the present invention.

Although beamforming on each user channel C requires a relatively large amount of beamforming computation to be performed (E*C complex multiply-accumulates per sample), this computation is at baseband, thus leveraging the sampling rate reduction of 1/R due to filtering and decimation in the DDC. Consequently, the beamforming computation rate in the share baseband processor is given by

$$Fs_5 = \frac{2 \cdot Fs_1 \cdot E \cdot C}{R} \quad (4)$$

If 2×E×C can be set to be approximately equal to R, then it can be seen that the entire beamforming computation for all user channels, transmit and receive, can be accomplished with a single complex multiply-accumulator running at the input sample rate Fs_1. This example is for the case of transmit/receive multiplexing.

The present invention improves the state of the art by mitigating the growth in wideband hardware complexity due to beamforming through novel restructuring of fundamental transceiver building blocks. At the same time, baseband hardware complexity growth is also minimized. The complex weighting required for beamforming potentially represents the largest impact of all. However, by incorporating the element rotations required to form a beam pattern into baseband signal rotations already required for each channel for carrier tracking, only a modest hardware impact occurs.

One of the principal advantages of the present invention is the potential for dramatically increasing processing capability in applications where there is a limited hardware resource. For example, where the digital signal processing associated with up/down-converting and modulation/demodulation are to be implemented on field programmable gate arrays (FPGA), there is a fixed resource and a finite number of processing/memory elements that can be formed on the chip. Consider an example where the signals being processed are voice circuits in a cellular base station, where typical processing rates are 10 to 20 kHz. If modem processing is performed at clock rates on this order, a tremendous waste of expensive hardware resources results, since, regardless of the processing rates, the modem processing requires complex multipliers, random access memories, arithmetic logic, oscillators, and other signal processing hardware to be formed in the FPGA. According to the present invention, by employing time-multiplexing in the modem processing between user channels, antenna elements and modulation/demodulation, and by operating the FPGA at 10 MHz to accommodate the time-multiplex a thousand times more voice signal processing can be performed on a comparable FPGA with roughly the same amount of circuitry therein. Thus, in additional to cost savings, the invention is advantageous in any application where smaller size and weight would be beneficial, such as in handheld or airborne units.

The present invention advantageously permits an element snapshot memory to operate at narrowband sampling rates, allowing an eased implementation for any snapshot operations required. Furthermore, these snapshots occur after narrowband channel filtering, thus containing only received signals of interest for that frequency band.

Further, integration of the beamformer with the demodulator in the present invention allows advanced adaptive algorithms to be implemented that can be enhanced by the feedback of post-demodulation metrics such as carrier-SNR/phase, symbol-SNR/phase, and error control decoding metrics.

In accordance with another aspect of the present invention, the beamformer spatial processing for each user channel is integrated with demodulation functionality, such as adaptive equalization temporal processing, allowing more complex algorithms to be implemented that jointly perform spatial/temporal optimization.

While the present invention has been described in the context of multiple user channels and certain features of the present invention are most advantageously exploited in this context, it will be understood that the present invention is nevertheless useful in the context of a single user channel or only a few user channels, and can be employed in devices such as mobile communication devices serving only a single end-user at a time. Further, the baseband time-multiplexing and shared processing techniques described herein can be employed in systems using only one of TDMA and FDMA,

and has applicability in virtually any multi-user communication system employing multiplexing, including those employing code division multiple access (CDMA).

The present invention performs demodulation and detection of potentially all visible user channels in the antenna field of view. This capability facilitates the joint detection (rather than individual) of all channels simultaneously, which is known in the prior art to substantially increase cellular capacity. The present invention further enables the combined processing of beamforming, equalization, and joint detection in a single demodulation process.

Having described preferred embodiments of new and improved integrated beamformer/modem architecture, it is believed that other modifications, variations and changes will be suggested to those skilled in the art in view of the teachings set forth herein. It is therefore to be understood that all such variations, modifications and changes are believed to fall within the scope of the present invention as defined by the appended claims. Although specific terms are employed herein, they are used in a generic and descriptive sense only and not for purposes of limitation.

What is claimed is:

1. An apparatus for modulating and demodulating signals transmitted and received via an electronically steerable phased array antenna comprising a plurality of antenna elements, the apparatus comprising:

a baseband modulator configured to modulate outbound digital baseband signals to be transmitted via the phased array antenna;

a baseband demodulator configured to demodulate incoming digital baseband signals generated from signals received via the phased array antenna; and

a shared baseband processor configured to receive digital baseband signals including the modulated outbound digital baseband signals and the incoming digital baseband signals, said shared baseband processor applying a single phase adjustment to each of the digital baseband signals to jointly account for both beamforming phase rotation and carrier phase rotation of individual antenna elements.

2. The apparatus of claim **1**, wherein said digital baseband signals received by said shared baseband processor are time multiplexed, and said shared baseband processor operates on said digital baseband signals on a time-slot-by-time-slot basis.

3. The apparatus of claim **1**, wherein said baseband modulator receives data symbols from a plurality of user channels and supplies to said shared baseband processor a time-multiplexed stream of modulated digital data symbols from said plurality of user channels.

4. The apparatus of claim **3**, wherein, for each input digital data symbol, said baseband modulator generates a plurality of modulated digital data symbols in the time-multiplexed stream respectively corresponding to the plurality of antenna elements.

5. The apparatus of claim **1**, wherein said shared baseband processor comprises:

a numerically controlled oscillator configured to generate a stream of carrier phases for digital baseband signals of each of a plurality of user channels in a time-multiplexed manner;

a beamforming phase rotator configured to generate a stream of beam rotation phases corresponding to individual antenna elements for each of the plurality of user channels in a time-multiplexed manner;

a phase adder configured to sum the beam rotation phases and the carrier phases to produce a time-multiplexed stream of combined phase adjustments; and

a complex multiplier configured to adjust phases of a time-multiplexed stream of digital baseband signals corresponding to the plurality of user channels in accordance with the combined phase adjustments.

6. The apparatus of claim **5**, wherein said combined phase adjustments index a sine/cosine lookup table which supplies multiplicands to said complex multiplier.

7. The apparatus of claim **1**, wherein said shared baseband processor comprises a multiplier which performs complex multiplication on digital baseband signals relating to a plurality of user channels in a time-multiplexed manner.

8. The apparatus of claim **1**, wherein said shared baseband processor comprises a multiplier which performs complex multiplication on digital baseband signals associated with a plurality of individual antenna elements in a time-multiplexed manner.

9. The apparatus of claim **1**, wherein said shared baseband processor comprises a beam scaling and power control processor configured to generate a time-multiplexed stream of gain control signals for digital baseband signals corresponding to individual antenna elements for each of a plurality of user channels, the gain control signals jointly accounting for power control and antenna element beam scaling; and

a multiplier configured to adjust amplitudes of a time-multiplexed stream of digital baseband signals corresponding to the plurality of user channels in accordance with the gain control signals.

10. The apparatus of claim **1**, further comprising:

a baseband beamformer configured to receive time-multiplexed digital baseband signals from said shared baseband processor corresponding to individual antenna elements, said baseband beamformer forming a combined signal from said time-multiplex digital baseband signals.

11. The apparatus of claim **1**, further comprising:

a plurality of digital down-converters respectively down-converting digitized signals received from the plurality of antenna elements to produce parallel streams of sampled digital baseband signals; and

a multiplexer receiving the parallel streams of sampled digital baseband signals and supplying a time-multiplexed stream of the sampled digital baseband signals to said shared baseband processor.

12. The apparatus of claim **11**, wherein said plurality of digital down-converters perform decimation to reduce a sampling rate of the sampled digital baseband signals.

13. The apparatus of claim **11**, wherein said plurality of digital down-converters separately down-convert digitized signals for each antenna element for each of a plurality of frequency channels.

14. The apparatus of claim **1**, further comprising:

a demultiplexer receiving a time-multiplexed stream of digital baseband signals from said shared baseband processor and generating parallel streams of digital baseband signals corresponding to the plurality of antenna elements; and

a plurality of digital up-converters respectively up-converting the parallel streams of digital baseband signals to produce a plurality of digitized intermediate frequency signals corresponding to the plurality of antenna elements.

15. The apparatus of claim 14, wherein said plurality of digital up-converters perform interpolation to increase a sampling rate of the digitized intermediate frequency signals.

16. The apparatus of claim 14, wherein said plurality of digital up-converters separately up-convert digital baseband signals for each antenna element for each of a plurality of frequency channels.

17. The apparatus of claim 1, wherein signals are transmitted and received using time division duplex, said apparatus further comprising switching elements to selectively connect said shared baseband processor to said baseband modulator and front-end transmit circuitry for signal transmission and to said baseband demodulator and front-end receive circuitry for signal reception.

18. The apparatus of claim 1, wherein said apparatus employs time division multiple access (TDMA) to transmit and receive signals.

19. The apparatus of claim 1, wherein said apparatus employs frequency division multiple access (FDMA) to transmit and receive signals.

20. The apparatus of claim 1, wherein said apparatus is a field programmable gate array (FPGA).

21. The apparatus of claim 1, wherein the apparatus is implemented via a very large scale integration (VLSI) circuit or an application specific integrated circuit (ASIC).

22. The apparatus of claim 1, wherein said apparatus is a modem.

23. The apparatus of claim 1, wherein said apparatus is a transceiver.

24. The apparatus of claim 1, wherein said apparatus is a basestation transceiver.

25. The apparatus of claim 1, wherein the shared baseband processor adjusts amplitudes of the digital baseband signals to perform power control and antenna element beam scaling.

26. A method of processing an RF signal received via an electronically steerable phased array antenna comprising a plurality of antenna elements, the method comprising:

(a) separately down-converting the RF signal from each antenna element to an intermediate frequency (IF) signal;

(b) separately analog-to-digital converting the IF signal from each antenna element;

(c) separately digitally down-converting the digital IF signal from each antenna element to a digital baseband signal to form a set of parallel baseband signals from the plurality of antenna elements;

(d) time multiplexing the set of parallel baseband signals to form a serial stream of digital baseband signals;

(e) applying a single phase adjustment to each of the digital baseband signals in the serial stream to jointly account for both carrier phase tracking and antenna element beamforming; and

(f) performing beamforming by combining digital baseband signals respectively associated with the plurality of antenna elements.

27. The method of claim 26, wherein (c) includes decimating the digital IF signal from each antenna element to reduce a number of samples in the serial stream of digital baseband signal.

28. The method of claim 26, wherein (c) includes generating baseband signals for a plurality of frequency channels from the digital IF signal of each antenna element, such that digital samples in the serial stream of digital baseband signals are associated with a particular antenna element and frequency channel.

29. A method of processing signals to be transmitted via an electronically steerable phased array antenna comprising a plurality of antenna elements, the method comprising:

(a) generating a stream of digital baseband signals representing data symbols to be transmitted via the phased array antenna, wherein digital baseband signals in the stream are associated with individual antenna elements;

(b) applying a single phase adjustment to each of the digital baseband signals to jointly account for both carrier phase rotation and antenna element beamforming;

(c) demultiplexing the stream of digital baseband signals into a plurality of parallel signals respectively associated with individual antenna elements;

(d) digitally up-converting the parallel signals to produce a plurality of digital intermediate frequency (IF) signals respectively associated with individual antenna elements;

(e) digital-to-analog converting the digital IF signals to produce a plurality of analog IF signals respectively associated with individual antenna elements; and

(f) up-converting the analog IF signals to RF signals for transmission via the phased array antenna.

30. The method of claim 29, wherein the phased array antenna simultaneously transmits signals on a plurality of frequency channels, and the stream of digital baseband signals includes signals associated with individual ones of the frequency channels.

31. An apparatus for modulating and demodulating signals transmitted and received via an electronically steerable phased array antenna comprising a plurality of antenna elements, the apparatus comprising:

a baseband modulator configured to modulate outbound digital baseband signals to be transmitted via the phased array antenna;

a baseband demodulator configured to demodulate incoming digital baseband signals generated from signals received via the phased array antenna; and

a shared baseband processor configured to receive digital baseband signals including the modulated outbound digital baseband signals and the incoming digital baseband signals, said shared baseband processor applying phases to the digital baseband signals to account for both beamforming phase rotation and carrier phase rotation of individual antenna elements, wherein the shared baseband processor generates a stream of combined phase adjustments by summing a stream of carrier phases for the digital baseband signals with a stream of beam rotation phases for the digital baseband signals, and adjusts phases of the digital baseband signals in accordance with the combined phase adjustments.

32. A method of processing an RF signal received via an electronically steerable phased array antenna comprising a plurality of antenna elements, the method comprising:

(a) separately down-convening the RF signal from each antenna element to an intermediate frequency (IF) signal;

(b) separately analog-to-digital convening the IF signal from each antenna element;

(c) separately digitally down-convening the digital IF signal from each antenna element to a digital baseband signal to form a set of parallel baseband signals from the plurality of antenna elements;

(d) time multiplexing the set of parallel baseband signals to form a serial stream of digital baseband signals;

(e) generating a stream of carrier phases for the digital baseband signals;

(f) generating a stream of beam rotation phases for the digital baseband signals;

(g) summing the beam rotation phases and the carrier phases to produce a stream of combined phase adjustments;

(h) applying the stream of combined phase adjustments to the digital signals in the serial stream to account for both carrier phase tracking and antenna element beamforming; and

(i) performing beamforming by combining digital baseband signals respectively associated with the plurality of antenna elements.

33. A method of processing signals to be transmitted via an electronically steerable phased array antenna comprising a plurality of antenna elements, the method comprising:

(a) generating a stream of digital baseband signals representing data symbols to be transmitted via the phased array antenna, wherein digital baseband signals in the stream are associated with individual antenna elements;

(b) generating a stream of carrier phases for the digital baseband signals;

(c) generating a stream of beam rotation phases for the digital baseband signals;

(d) summing the beam rotation phases and the carrier phases to produce a stream of combined phase adjustments;

(e) applying the stream of combined phase adjustments to the stream of digital baseband signals to account for both carrier phase rotation and antenna element beamforming;

(f) demultiplexing the stream of digital baseband signals into a plurality of parallel signals respectively associated with individual antenna elements;

(g) digitally up-converting the parallel signals to produce a plurality of digital intermediate frequency (IF) signals respectively associated with individual antenna elements;

(h) digital-to-analog converting the digital IF signals to produce a plurality of analog IF signals respectively associated with individual antenna elements; and

(i) up-converting the analog IF signals to RF signals for transmission via the phased array antenna.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 7,260,141 B2
APPLICATION NO. : 10/084614
DATED : August 21, 2007
INVENTOR(S) : Scott Bierly et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

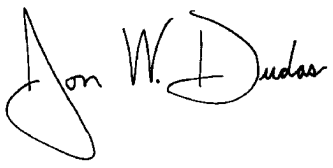
Front Page, Foreign Patent Documents:

Add --WO 96/22662 12/1995--

Col. 16, ll. 57, 60, 62: "convening" should read --converting--

Signed and Sealed this

Twenty-ninth Day of April, 2008



JON W. DUDAS
Director of the United States Patent and Trademark Office

UNITED STATES DISTRICT COURT
FOR THE Northern District of Illinois – CM/ECF NextGen 1.6.3
Eastern Division

Lionra Technologies Limited

Plaintiff,

v.

Case No.: 1:22–cv–02231
Honorable Andrea R. Wood

Motorola Mobility LLC

Defendant.

NOTIFICATION OF DOCKET ENTRY

This docket entry was made by the Clerk on Thursday, August 18, 2022:

MINUTE entry before the Honorable Andrea R. Wood: The parties' joint motion to dismiss [15] is granted. Plaintiff's claims against Defendant are dismissed with prejudice. Defendant's counterclaims against Plaintiff are dismissed without prejudice. Each party will bear its own attorneys' fees, costs, and expenses. All other motions and hearing dates are stricken. Civil case terminated. Mailed notice (lma,)

ATTENTION: This notice is being sent pursuant to Rule 77(d) of the Federal Rules of Civil Procedure or Rule 49(c) of the Federal Rules of Criminal Procedure. It was generated by CM/ECF, the automated docketing system used to maintain the civil and criminal dockets of this District. If a minute order or other document is enclosed, please refer to it for additional information.

For scheduled events, motion practices, recent opinions and other information, visit our web site at ***www.ilnd.uscourts.gov***.



Exhibit 1

US007260141B2

(12) **United States Patent**
Bierly et al.

(10) **Patent No.: US 7,260,141 B2**
(45) **Date of Patent: Aug. 21, 2007**

(54) **INTEGRATED BEAMFORMER/MODEM ARCHITECTURE**

(75) Inventors: **Scott Bierly**, Oak Hill, VA (US); **Marc Harlacher**, Herndon, VA (US); **Robert Smarrelli**, Oak Hill, VA (US); **Aaron Weinberg**, Potomac, MD (US)

(73) Assignee: **ITT Manufacturing Enterprises, Inc.**, Wilmington, DE (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 802 days.

(21) Appl. No.: **10/084,614**

(22) Filed: **Feb. 28, 2002**

(65) **Prior Publication Data**

US 2002/0154687 A1 Oct. 24, 2002

Related U.S. Application Data

(60) Provisional application No. 60/271,961, filed on Feb. 28, 2001.

(51) **Int. Cl.**
H04B 1/38 (2006.01)
H04L 5/16 (2006.01)

(52) **U.S. Cl.** **375/222**; 375/260; 375/340; 375/295; 375/347

(58) **Field of Classification Search** 375/219, 375/220, 221, 222, 223, 259–260, 340, 299, 375/295, 316
See application file for complete search history.

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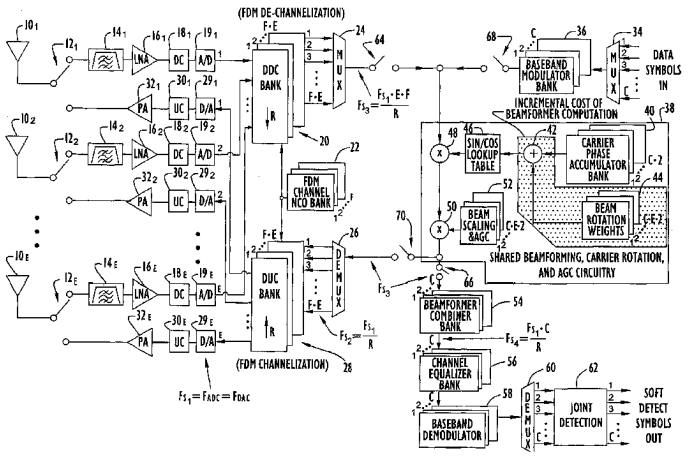
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Primary Examiner—Jean B. Corrielus
(74) *Attorney, Agent, or Firm*—Edell, Shapiro & Finnan, LLC

(57) **ABSTRACT**

A transceiver employing a steerable phased-array antenna includes a modem architecture in which signals from each antenna element in the array are independently processed down to the individual baseband channel level, and digital beamforming is performed at baseband. The data rate reduction from IF to baseband permits parallel signal data from multiple antenna elements to be time multiplexed and serially processed at acceptable data rates at baseband with minimal modem hardware requirements. Both for transmit signal modulation and received signal demodulation, the computation of carrier tracking, automatic gain control (AGC)/power-control, and beamforming are shared by the same processing circuitry for all channels when performed at baseband. The resulting baseband circuitry is only incrementally larger than that required for carrier tracking and AGC alone, yet accomplishes independent beamforming for each antenna element on each user channel.

33 Claims, 3 Drawing Sheets



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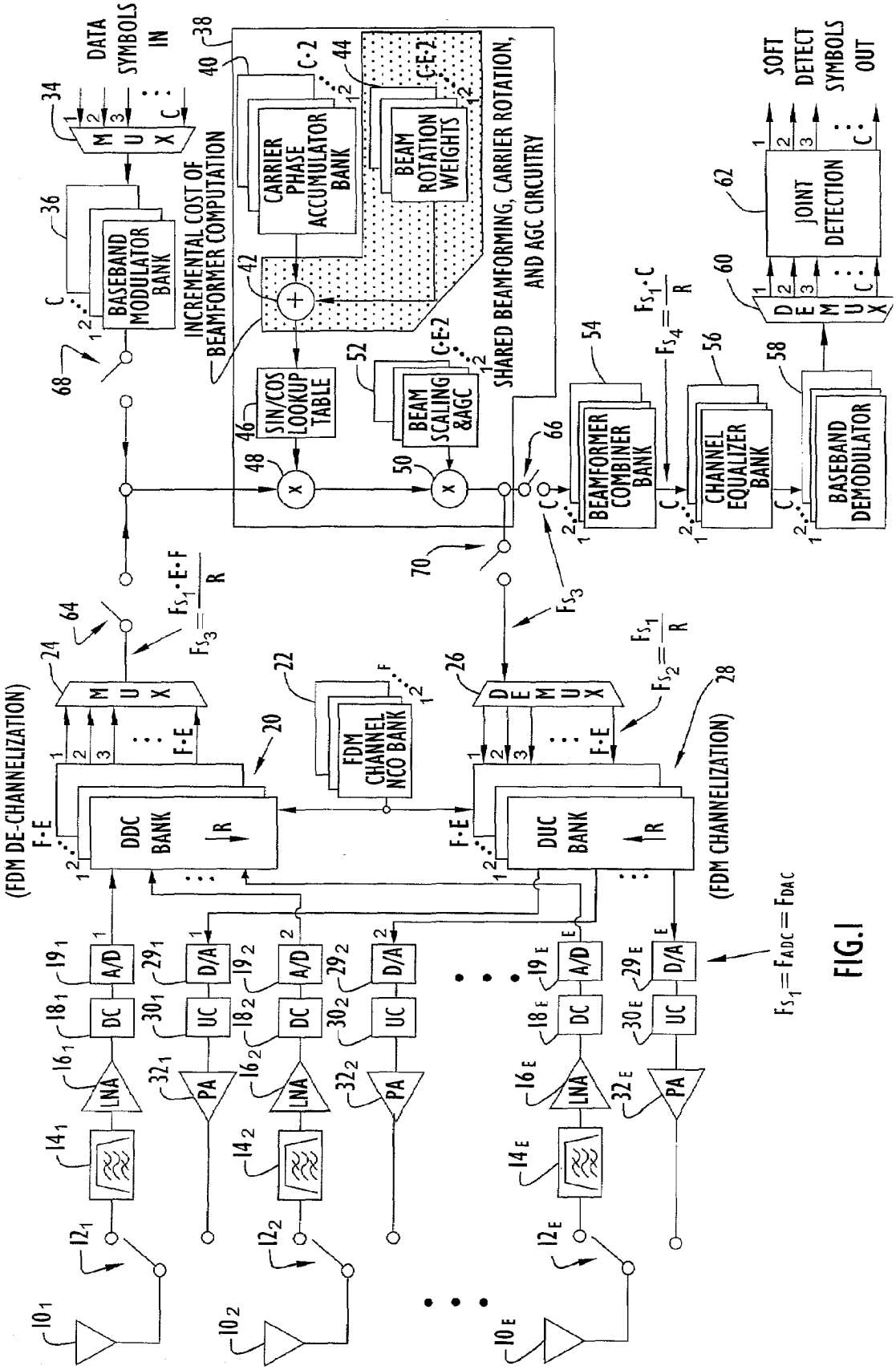


FIG. 1

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Apple EX1002 Page 410

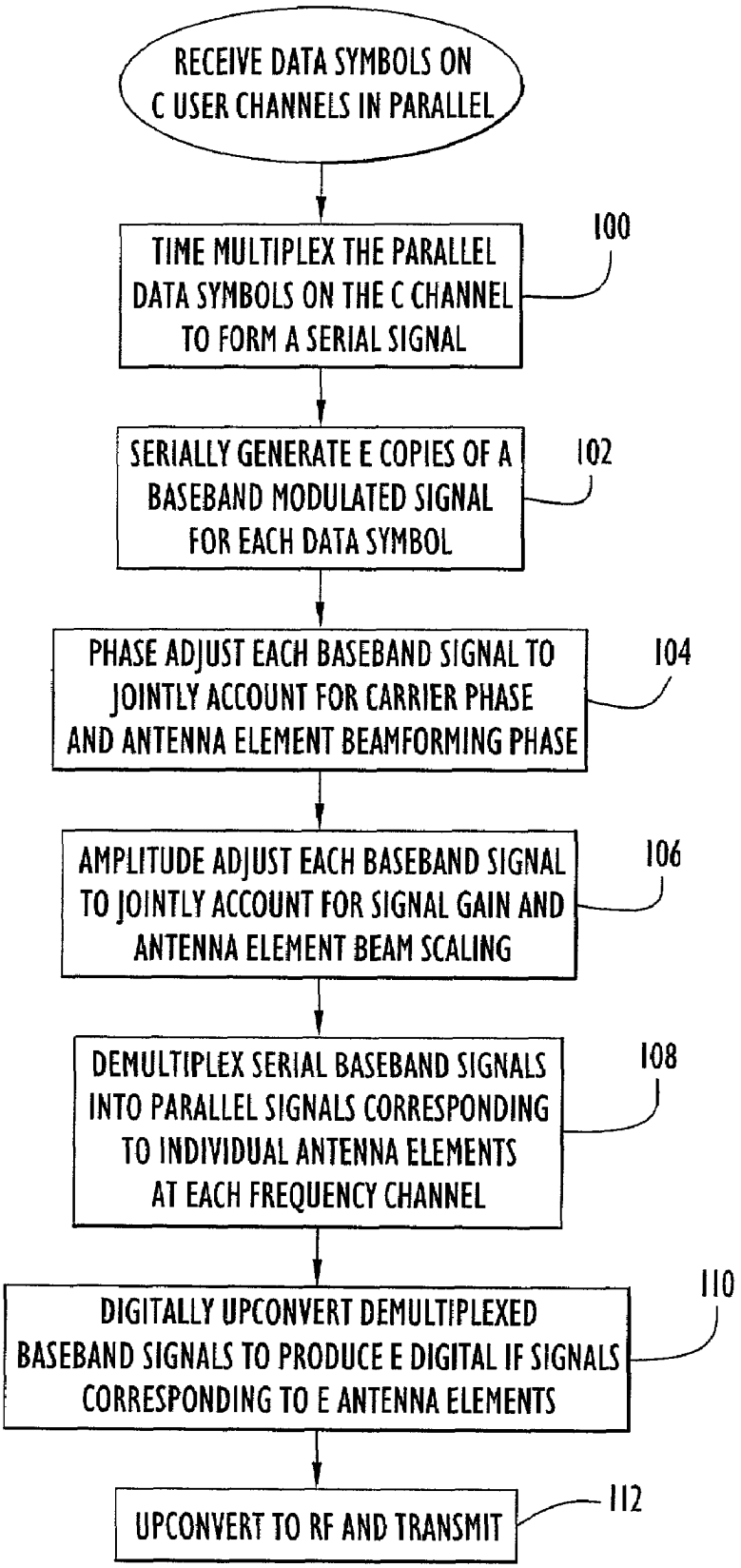

RECEIVE DATA SYMBOLS ON C USER CHANNELS IN PARALLEL
TIME MULTIPLEX THE PARALLEL DATA SYMBOLS ON THE C CHANNEL TO FORM A SERIAL SIGNAL
100
SERIALLY GENERATE E COPIES OF A BASEBAND MODULATED SIGNAL FOR EACH DATA SYMBOL
102
PHASE ADJUST EACH BASEBAND SIGNAL TO JOINTLY ACCOUNT FOR CARRIER PHASE AND ANTENNA ELEMENT BEAMFORMING PHASE
104
AMPLITUDE ADJUST EACH BASEBAND SIGNAL TO JOINTLY ACCOUNT FOR SIGNAL GAIN AND ANTENNA ELEMENT BEAM SCALING
106
DEMULTIPLEX SERIAL BASEBAND SIGNALS INTO PARALLEL SIGNALS CORRESPONDING TO INDIVIDUAL ANTENNA ELEMENTS AT EACH FREQUENCY CHANNEL
108
DIGITALLY UPCONVERT DEMULTIPLEXED BASEBAND SIGNALS TO PRODUCE E DIGITAL IF SIGNALS CORRESPONDING TO E ANTENNA ELEMENTS
110
UPCONVERT TO RF AND TRANSMIT
112

FIG.2

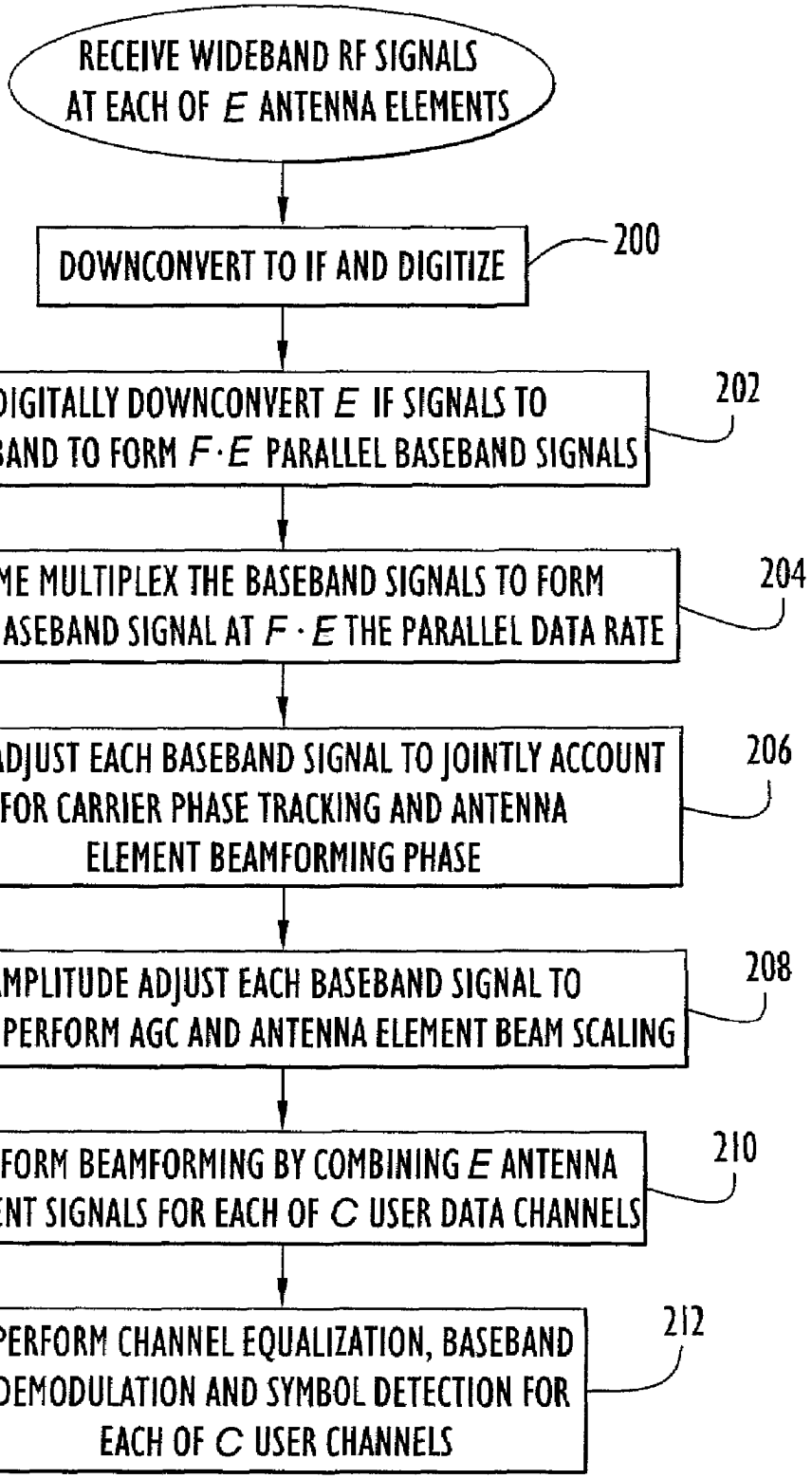

RECEIVE WIDEBAND RF SIGNALS AT EACH OF E ANTENNA ELEMENTS
DOWNCONVERT TO IF AND DIGITIZE
200
DIGITALLY DOWNCONVERT E IF SIGNALS TO BASEBAND TO FORM F·E PARALLEL BASEBAND SIGNALS
202
TIME MULTIPLEX THE BASEBAND SIGNALS TO FORM SERIAL BASEBAND SIGNAL AT F · E THE PARALLEL DATA RATE
204
PHASE ADJUST EACH BASEBAND SIGNAL TO JOINTLY ACCOUNT FOR CARRIER PHASE TRACKING AND ANTENNA ELEMENT BEAMFORMING PHASE
206
AMPLITUDE ADJUST EACH BASEBAND SIGNAL TO JOINTLY PERFORM AGC AND ANTENNA ELEMENT BEAM SCALING
208
PERFORM BEAMFORMING BY COMBINING E ANTENNA ELEMENT SIGNALS FOR EACH OF C USER DATA CHANNELS
210
PERFORM CHANNEL EQUALIZATION, BASEBAND DEMODULATION AND SYMBOL DETECTION FOR EACH OF C USER CHANNELS
212

FIG.3

INTEGRATED BEAMFORMER/MODEM ARCHITECTURE

CROSS REFERENCE TO RELATED APPLICATION

This application claims priority from U.S. Provisional Patent Application Ser. No. 60/271,961 entitled "Integrated TDMA Beamformer/Modem Architecture," filed Feb. 28, 2001. The disclosure of this provisional patent application is incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to wireless communication transceivers and modems and, more particularly, to the construction of a multi-frequency, multi-channel transceiver system such as might be used in a multi-user base station for terrestrial cellular or fixed-wireless applications.

2. Description of the Related Art

Directional antennas are widely used in a variety of communications systems to more efficiently transmit and receive radiated signals. Relative to an isotropic antenna, which transmits and receives signals equally in all directions, a directional antenna has an antenna gain pattern that is greater in certain directions than others, typically having a higher-gain main lobe several degrees wide (i.e., an antenna beam). Generally, a greater antenna gain reduces the amount of power required to transmit and receive signals between two communication devices. Thus, steering the main lobe of a transceiver's antenna gain pattern in the direction of another communication device facilitates communication between the two devices.

To be useful in certain applications, it may be necessary to rapidly point the antenna beam of a directional antenna in different directions. For example, base stations employed in cellular or wireless communication systems are required to communicate with several mobile communication devices at once. Often, the cell or region covered by the base station is divided into angular sectors (e.g., three 120° sectors), with certain antennas being responsible for communications with any mobile communication devices in a given sector. To permit virtually instantaneous redirecting of the antenna beam within the sector, an antenna formed of a phased array of independently controllable antenna elements may be used. The antenna beam is formed by applying appropriate phase and gain to the individual elements in the array.

More specifically, beamforming is a type of spatial filtering in which an array of sensor elements is controlled with appropriate signal processing to implement a phased array antenna for the purpose of shaping the antenna response over time in a space-varying manner (i.e., steering gain in some directions, while producing attenuation or nulls in other directions). In a radio communications system, a signal arriving at each element of an antenna array will arrive at slightly different times due to the direction of arrival with respect to the antenna array plane (unless the signal has normal incidence to the plane, in which case the signal will arrive at all elements simultaneously). A phased-array receive antenna achieves gain in a particular direction by phase shifting, or time shifting, the signal from each element, and then summing the phase-shifted element signals in a signal combiner. By choosing the relative phasing of each element appropriately, coherence can be achieved for a particular direction of arrival (DOA), across a particular signal bandwidth.

Digital beamforming is analogous to analog beamforming, except that the received signal on each antenna element is independently digitized, and the phasing/combining operation is performed mathematically on the digital samples. The present inventors describe digital beamforming techniques in U.S. patent application Ser. No. 09/778,854 entitled "Integrated Beam Forming/Rake/MUD CDMA Receiver Architecture", filed Feb. 8, 2001, the disclosure of which is incorporated herein by reference in its entirety. Conventionally, digital beamforming is done on a wideband signal, prior to despreading a CDMA waveform. This forces the computationally intense beamforming to take place at a much higher sampling rate, resulting in more mathematical operations per second, and corresponding increased hardware cost. To address this shortcoming, beamforming can be performed at baseband, as disclosed by Hanson et al. in U.S. Pat. No. 6,052,085, the disclosure of which is incorporated herein by reference in its entirety.

Furthermore, digital beamforming is conventionally performed as a separate process, independent of symbol modulation/demodulation, perhaps even as a separate product from the modem. In addition to the resulting inability to support advanced demodulation techniques with this architecture, the cost of the beamforming function is greater as a stand-alone function, compared to the incremental cost of adding the capability to a modem. The largest cost-component of beamforming is the complex multiplication of each sample for each element with the beamforming weights. Thus, whether stand-alone beamformers merely point in the direction of the signal of interest, or respond more adaptively to dynamic interference conditions by null-steering, such beamformers still lack the ability to be tightly coupled with potential advanced demodulation techniques.

When combined with the modem, there is potential to absorb the complex multiply required for beamforming into computation already taking place for extremely low incremental cost. In U.S. Pat. No. 5,764,187, the disclosure of which is incorporated herein by reference, Rudish et al. disclose an implementation of beamforming using digital direct synthesis (DDS) functions. However, Rudish does not suggest or recognize potential hardware and processing savings in both signal transmission and reception. Specifically, Rudish does not suggest combining demodulation with beamforming or using hardware in a time-shared manner for both transmit and receive. Rudish's architecture is highly parallel and does lend itself to time multiplexing techniques which could potentially reduce hardware requirements.

Accordingly, there remains a need for an efficient, integrated way of incorporating beamforming technology, for both transmit and receive, into base stations or transceiver terminals that process large number of users simultaneously using time division multiple access (TDMA) and/or frequency division multiple access (FDMA) technology. This problem can be extremely computationally burdensome, and architectures for cost-effectively performing this processing are not addressed sufficiently in the prior art.

SUMMARY OF THE INVENTION

Therefore, in light of the above, and for other reasons that become apparent when the invention is fully described, an object of the present invention is to integrate digital beamforming capabilities into baseband processing functions

such as modulation and demodulation carrier phase rotation and AGC/power-control scaling functions.

Another object of the present invention is to efficiently implement a digital signal processing architecture for a TDMA and/or FDMA base station transceiver performing digital adaptive beamforming with a multi-element antenna array.

A further object of the present invention is to reduce overall hardware and processing requirements in a multi-user transceiver system employing antenna beam steering.

Yet a further object of the present invention is to share common processing elements between modulation and demodulation functions in a modem.

A still further object of the present invention is to take advantage of intermediate frequency (IF) to baseband data rate reductions to process parallel signal data in a time-multiplexed manner at baseband to thereby reduce modem hardware requirements.

Another object of the present invention is to reduce the size and weight of transceiver/modem equipment.

Yet another object of the present invention is to maximize the amount of processing performed with a limited hardware resource.

Still another object of the present invention is to implement transceiver/modem processing of multiple signals in a cost-effective manner.

The aforesaid objects are achieved individually and in combination, and it is not intended that the present invention be construed as requiring two or more of the objects to be combined unless expressly required by the claims attached hereto.

In accordance with the present invention, a modulator/demodulator (modem) architecture is presented for TDMA and FDMA applications. In particular, a transceiver configured to simultaneously communicate with multiple users, such as a base station transceiver, employs a phased-array antenna capable of generating a steerable, directed antenna beam for communication with other devices. Rather than implementing the beamforming phase and amplitude control of the antenna elements in the front-end circuitry, the signals from each antenna element are independently processed all the way down to the individual baseband channel level, and digital beamforming is performed at baseband. While this approach would suggest significantly higher processing demands due to the separate processing for each antenna element, the transceiver of the present invention is implemented using a symmetrical processing structure, leveraging the relationship of increasing computational complexity with decreasing computational rate from IF to baseband processing. Specifically, the data rate reduction from IF to baseband permits parallel signal data from multiple antenna elements to be time multiplexed and serially processed at acceptable data rates at baseband with minimal modem hardware requirements.

Further, the approach of the present invention allows the computation of carrier tracking, automatic gain control (AGC)/power-control, and beamforming to be shared by the same processing circuitry for all channels when performed at baseband. The resulting baseband circuitry is only incrementally larger than that already required in the modem for performing carrier tracking and AGC, yet accomplishes independent beamforming for each antenna element on each user channel. For non-simultaneous transmit/receive systems, such as time division duplex (TDD), additional savings are realized by sharing wideband digital down-converter (DDC) and digital up-converter (DUC) hardware as well as the baseband beamforming circuitry in a time-multiplexed manner between the demodulator and modulator functions.

The above and still further objects, features and advantages of the present invention will become apparent upon consideration of the following definitions, descriptions and descriptive figures of specific embodiments thereof wherein like reference numerals in the various figures are utilized to designate like components. While these descriptions go into specific details of the invention, it should be understood that variations may and do exist and would be apparent to those skilled in the art based on the descriptions herein.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a functional block diagram of an integrated TDMA/FMDA beamformer/modem architecture in accordance with an exemplary embodiment of the present invention.

FIG. **2** is a functional flow diagram illustrating the signal processing operations associated with transmitting and modulating signals in accordance with the exemplary embodiment of the present invention.

FIG. **3** is a functional flow diagram illustrating the signal processing operations associated with receiving and demodulating signals in accordance with the exemplary embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The following detailed explanations of FIGS. **1-3** and of the preferred embodiments reveal the methods and apparatus of the present invention. FIG. **1** is a generalized functional block diagram of an integrated beamformer/modem architecture in accordance with an exemplary embodiment of the present invention. The beamformer/modem architecture of the present invention can be employed in any communication device that transmits or receives signals from other communication devices. As used herein and in the claims, a "communication device" includes any device, mobile or stationary, that is capable of transmitting and/or receiving communication signals, including but not limited to: a handheld or body-mounted radio; any type of mobile or wireless telephone (e.g., analog cellular, digital cellular, PCS or satellite-based); a pager, beeper or PDA device; a radio or transceiver carried on, built into or embedded in a ground-based or airborne vehicle; any portable electronic device equipped with wireless reception/transmission capabilities, including multimedia terminals capable of receiving/transmitting audio, video and/or data information; and any device mounted in a fixed location with transmission/reception capabilities. The architecture of the present invention is particularly useful in any transceiver communication device requiring the use of directed antenna beams to transmit signals to and receive signals from a plurality of other communication devices used in transmission of audio, video and/or data information including, but not limited to, base stations of wireless communication systems, mobile communication devices, airborne communication systems, and communications satellites.

Referring to FIG. **1**, the transceiver beamformer/modem architecture includes a plurality E of transmit/receive antenna elements $\mathbf{10}_1, \mathbf{10}_2, \ldots, \mathbf{10}_E$ forming a phased array antenna which is electronically steerable via digital beamforming. Antenna elements **10** may have any hardware configuration suitable for operating at the frequency and

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TO:	REPORT ON THE FILING OR DETERMINATION OF AN ACTION REGARDING A PATENT OR TRADEMARK
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In Compliance with 35 U.S.C. § 290 and/or 15 U.S.C. § 1116 you are hereby advised that a court action has been filed in the U.S. District Court WESTERN DISTRICT OF TEXAS on the following

☐ Trademarks or ☑ Patents. (☐ the patent action involves 35 U.S.C. § 292.):

DOCKET NO.	DATE FILED	U.S. DISTRICT COURT
6:22-cv-467	5/9/2022	WESTERN DISTRICT OF TEXAS

PLAINTIFF	DEFENDANT
LIONRA TECHNOLOGIES LTD.	GOOGLE LLC

	PATENT OR TRADEMARK NO.	DATE OF PATENT OR TRADEMARK	HOLDER OF PATENT OR TRADEMARK
1	7,260,141	8/21/2007	LIONRA TECHNOLOGIES LTD.
2			
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In the above—entitled case, the following patent(s)/ trademark(s) have been included:

DATE INCLUDED	INCLUDED BY ☐ Amendment ☐ Answer ☐ Cross Bill ☐ Other Pleading	
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DECISION/JUDGEMENT
10/17/2022 - Order Granting Joint Motion to Dismiss - Doc #11

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Phillip J. Devlin	Suzanne Miles	10/17/2022

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