DT16 Rec'd PCT/PTO 23 APR 2003

FORM PTO-1390 (Modified) (REV. 11-2000) U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

ATTORNEY'S DOCKET NUMBER: 14316NP

U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR): 10/399859

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/RU00/00426	October 27, 2000	

TITLE OF INVENTION

COMBINATION OF SPACE-TIME CODING AND SPATIAL MULTIPLEXING, AND THE USE OF ORTHOGONAL TRANSFORMATION IN SPACE-TIME CODING

APPLICANT(S) FOR DO/EO/US

WEN TONG, ET AL

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☐ This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include items (5), (6), (9) and (24) indicated below.
4. ☒ The US has been elected by the expiration of 19 months from the priority date (Article 31).
5. ☒ A copy of the International Application as filed (35 U.S.C. 371 (c) (2))
   a. ☐ is attached hereto (required only if not communicated by the International Bureau).
   b. ☒ has been communicated by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☐ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
   a. ☐ is attached hereto.
   b. ☐ has been previously submitted under 35 U.S.C. 154(d)(4).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371 (c)(3))
   a. ☐ are attached hereto (required only if not communicated by the International Bureau).
   b. ☐ have been communicated by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☒ have not been made and will not be made.
8. ☐ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371 (c)(4)). (UNEXECUTED)
10. ☐ An English language translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371 (c)(5)).
11. ☐ A copy of the International Preliminary Examination Report (PCT/IPEA/409).
12. ☒ A copy of the International Search Report (PCT/ISA/210).

Items 13 to 20 below concern document(s) or information included:

13. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
14. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
15. ☐ A **FIRST** preliminary amendment.
16. ☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
17. ☐ A substitute specification.
18. ☐ A change of power of attorney and/or address letter.
19. ☐ A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1.821 - 1.825.
20. ☐ A second copy of the published international application under 35 U.S.C. 154(d)(4).
21. ☐ A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).
22. ☐ Certificate of Mailing by Express Mail
23. ☐ Other items or information:

Nintendo Exhibit 1013
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U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR)	INTERNATIONAL APPLICATION NO.	ATTORNEY'S DOCKET NUMBER
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24. The following fees are submitted:.	CALCULATIONS PTO USE ONLY	
BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)) :		
☐ Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO **$1060.00**		
☒ International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO **$900.00**		
☐ International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO **$750.00**		
☐ International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4) **$720.00**		
☐ International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4) **$100.00**		
ENTER APPROPRIATE BASIC FEE AMOUNT =	**$900.00**	
Surcharge of **$130.00** for furnishing the oath or declaration later than ☐ 20 ☒ 30 months from the earliest claimed priority date (37 CFR 1.492 (e)).	**$130.00**	

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	23 - 20 =	3	x $18.00	**$54.00**	
Independent claims	3 - 3 =	0	x $84.00	**$0.00**	
Multiple Dependent Claims **(check if applicable)**.			☐	**$0.00**	

TOTAL OF ABOVE CALCULATIONS =	**$1,084.00**	
☐ Applicant claims small entity status. See 37 CFR 1.27. The fees indicated above are reduced by 1/2.	**$0.00**	
SUBTOTAL =	**$1,084.00**	
Processing fee of **$130.00** for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (f)). +	**$0.00**	
TOTAL NATIONAL FEE =	**$1,084.00**	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31) **(check if applicable).** ☐	**$0.00**	
TOTAL FEES ENCLOSED =	**$1,084.00**	
	Amount to be: refunded	$
	charged	$

a. ☒ A check in the amount of **$1,084.00** to cover the above fees is enclosed.

b. ☐ Please charge my Deposit Account No. _____ in the amount of _____ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 04-1577 A duplicate copy of this sheet is enclosed.

d. ☐ Fees are to be charged to a credit card. **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.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

DOWELL & DOWELL, P.C.
1215 Jefferson Davis Highway
Suite 309
Arlington, Virginia 22202-3124
U.S.A.

SIGNATURE

Ralph A. Dowell
NAME

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REGISTRATION NUMBER

April 23, 2003
DATE

COMBINATION OF SPACE-TIME CODING AND SPATIAL MULTIPLEXING, AND THE USE OF ORTHOGONAL TRANSFORMATION IN SPACE-TIME CODING

Field of the Invention

The invention relates to systems and methods for performing layered space-time coding for wireless channels.

Background of the Invention

With the explosion in the demand for wireless Internet services, a number of competing solutions have been developed. UMTS (Universal Mobile Terrestrial Service) standardization has lead to the 3Gpp standard which offers a 2 Mbps data rate per sector. Work is underway on HSPDA (high speed data access), a higher speed packet data access variation. IS-2000, an evolution of IS-95 provides HDR (High Speed Data Rate) and 1XEV (1X Evolution) which allow wireless Internet browsing at a rate of 7.2 Mbps per sector. Notwithstanding these solutions, there is still the demand to push rates higher.

Recently, it has been proposed to use BLAST (Bell Labs Layered Space Time) which is a layered space-time coding approach, as a wireless data solution. Referring to Figure 1, the basic concept behind this layered space-time coding approach involves, at the transmit side, a demultiplexer 10 which demultiplexes a primary data stream 11 into M data substreams of equal rate. Each of the M data streams is then encoded and modulated separately in respective coding/modulating blocks 12 (12A, 12B,…, 12M) to produce respective encoded and modulated streams 13 (13A,13B,…,13M). There are M transmit antennas 14 (14A, 14B,…,14M). A switch 16 periodically cycles the association between the modulated streams 13A,13B,…,13M and the antennas 14A,14B,…,14M. At the receive side, there are

M antennas 18 (18A,18B,…,18M) which feed into a beamforming/spatial separation/substruction block 20 which performs a spatial beamforming/nulling (zero forcing) process to separate the individual coded streams and feeds these to respective individual decoders 22 (22A,22B,…,22M). The outputs of the decoders 22A,22B,…,22M are fed to a multiplexer 24 which multiplexes the signals to produce an output 25 which is an estimate of the primary data stream 11.

There are a number of variations on this architecture. One is to modify the receiver antenna pre-processing to carry out MMSE (minimum mean square error) beamforming rather than nulling in order to improve the wanted signal SNR (signal-to-noise ratio) at the expense of slightly increased ISI (inter-symbol interference). Both the MMSE and nulling approaches normally have the disadvantage that some sort of diversity of the receiver antenna array is necessarily sacrificed in the beamforming process. In order to overcome this problem, layering of the receiver processing can be employed such that after the strongest signal has been decoded (typically using the Viterbi MLSE (maximum likelihood sequence estimation) algorithm) it is subtracted from the received antenna signals in order to remove the strongest signal. This process is iterated down until detection of the weakest signal requires no nulling at all, and its diversity performance is therefore maximized. A disadvantage with this layered approach is the same as that with all subtractive multi-user detection schemes, that the wrong subtraction can cause error propagation.

There are several types of layered space-time coding structures, including horizontal BLAST (H-BLAST),

diagonal BLAST (D-BLAST) and vertical BLAST. They have identical performance for both optimal linear and non-linear receivers, assuming error control coding is not used in such systems. For optimal linear reception (linear maximum likelihood), these structures have the same SNR performances as those with only a single transmit antenna and a single receive antenna, but do offer the advantage of improved spectral efficiency.

In order to achieve this improved spectral efficiency, in such systems it would be advantageous to have a large number of transmit and receive antennas, for example four of each. However, while this may be practical for larger wireless devices such as laptop computers, it is impractical for smaller hand-held devices because it is not possible to get the antennas far enough apart to ensure their independence. Because of this, for hand-held devices, a practical limit might be two transmit and two receive antennas. Also, another factor limiting the practical number of antennas is cost. Typically about two thirds of the cost of a base station transceiver is in the power amplifier plus antennas, and this will increase if more antennas are added. These factors make only a two by two system commercially practical.

By way of example, consider a system with M transmit and N receive antennas in a frequency non-selective, slowly fading channel. The sampled baseband-equivalent channel model is given by

$$Y = HS + \eta$$

where $H \in C^{NxM}$ is the complex channel matrix with the (i,j)-th element being random fading between the i-th receive and j-th transmit antenna. $\eta \in C^N$ is the additive

noise source and is modelled as a zero mean circularly symmetric complex Gaussian random vector with statistically independent elements, that is $\eta \sim C\aleph(0, 2\sigma_\eta^2 I_N)$. The i-th element of $S \in C^M$ is the symbol transmitted at the i-th transmit antenna and that of $Y \in C^N$ is the symbol received at the i-th received antenna. The model is shown in Figure 2.

That such a system has no improvement in SNR performance can be explained by noting that the data symbol s_m is transmitted only by one antenna, and in case of full cancellation of other transmit antennas, the model of such a system is shown in Figure 3. In this case there is one transmit antenna and N receive antennas. Therefore, for symbol s_m there is no coding gain.

It would be advantageous to have a layered space-time coding structure which provides the improved spectral efficiency, but which also provides improved SNR performance.

Summary of the Invention

Embodiments of the invention provide coding gain systems and methods which feature combined space-time coding and spatial multiplexing, and transmitters adapted to include such functionality. The space-time coding introduces a coding gain, and makes symbols more immune to fading since each information component is represented somehow in each spatial output. In some embodiments, the space-time coding comprises a layered space-time architecture. Advantageously, these solutions are amenable to implementation with two transmit antennas and two

receive antennas, a configuration suitable for hand-held devices.

According to one broad aspect, the invention provides a coding gain system adapted to transmit a plurality M of symbol substreams. The coding gain system has a space-time coding function adapted to produce M space-time coded streams, with each symbol of the M symbol substreams being represented in all M space-time coded streams and at different times. In some embodiments, the coding gain system provided by the invention can be considered to include M transmit antennas each adapted to transmit a respective one of the M space-time coded streams, and/or demultiplexing and encoding functionality adapted to produce the M symbol substreams from a primary input stream.

In some embodiments, the space-time coding function has an orthogonal transform adapted to produce M orthogonal outputs each of which is a function of the M substreams, and has delay elements adapted to insert delays in the M orthogonal outputs to produced M delayed orthogonal outputs such that each of the M delayed orthogonal outputs is a function of a given element of each of the M substreams at a different time. For example, the delay elements can be adapted to introduce a delay of m-1 symbol periods in the mth orthogonal output, where m=1,…,M.

In another embodiment, the space-time coding function has delay elements adapted to insert a delay of M-1 symbol periods in each of the M substreams, and an orthogonal transform adapted to produce M orthogonal outputs, with the mth orthogonal output being a function of the M substreams delayed in the delay elements by m-1 symbol periods.

In some embodiments the M substreams are non-binary symbols. In other embodiments the M substreams are bit streams. In these embodiments, the orthogonal transform comprises orthogonal symbol mappings, for example M 2^M QAM or MPSK mapping functions, each adapted to produce a respective sequence of M-ary symbols with the M-ary symbol of the mth 2^M QAM mapping function being a function of the M substreams delayed in said delay elements by m-1 bit periods.

Brief Description of the Drawings

Preferred embodiments of the invention will now be described with reference to the attached drawings in which:

Figure 1 is a block diagram of a known space-time coding system;

Figure 2 is a channel model for the system of Figure 1;

Figure 3 is a channel model for a single antenna output of the system of Figure 1;

Figure 4 is a block diagram of a transmitter featuring a coding gain system provided by an embodiment of the invention;

Figure 5 is a block diagram of a transmitter featuring a coding gain system provided by another embodiment of the invention;

Figure 6 is a block diagram of a transmitter featuring a coding gain system provided by another embodiment of the invention;

Figure 7 is a block diagram of a transmitter featuring a coding gain system provided by another embodiment of the invention; and

Figure 8 is a constellation diagram for the 16 QAM Gray mappings of Figure 7.

Detailed Description of the Preferred Embodiments

Embodiments of the invention provide a layered space-time architecture with additional gain provided with

space-time coding. To achieve this each information symbol s_m is arranged to as to be represented on all M Transmit Antennas. An algorithm of space-time coding is developed for one transmitter, and aggregated with algorithms for M transmitters, so that the spectral efficiency expected for conventional BLAST architecture is retained.

A range of coding gain methods/systems and transmitters are provided which combine space time coding and spatial multiplexing. Referring firstly to figure 4, shown is a space-time coder/multiplexer coding gain system consisting of a 1:M demultiplexer 29 having a single primary input 27 and having M outputs which are each coded and modulated in respective encoder/modulator blocks 31A,…,31M to produce encoded substreams $s_1, s_2, \ldots, s_M$. There is an orthogonal transformation block 30 and a number of delay blocks 32 (only two shown, 32m-1, 32M-1) the outputs of which are connected to respective transmit antennas 34A,…,34M. The orthogonal transformation block 30 has as its inputs the M encoded and modulated substreams $s_1, s_2, \ldots, s_M$. The orthogonal transformation block 30 performs the following matrix transform on the input substreams at each symbol interval:

$$X = FS,$$

where S= $(s_1, s_2, \ldots s_M)$ at a given instant, $X = (x_1, x_2, \ldots, x_M) \in C^M$ is the output of the orthogonal transformation block 30; and $F \in C^{MxM}$ is a complex matrix defining the orthogonal transformation. In one embodiment, the (i,m)-th element of F is defined by:

$$f_{im} = (Had(i, m) \cdot e^{j(\pi(m\ 1))/(2M))/(\sqrt{M})} ,$$

where $Had(i,m) \in (1; -1)$ is the (i,m)-th element of the Hadamard matrix. For M=2 this matrix is

$$F = \frac{1}{\sqrt{2}} \begin{bmatrix} 1 & e^{j\pi/4} \\ 1 & -e^{j\pi/4} \end{bmatrix} .$$

However, this transformation matrix is not unique, this being only an example of a suitable orthogonal transformation. The optimization and/or search for the best of transformation matrix depends on the modulation for initial symbols s_m and on the number of antennas M. It is important that each output of the orthogonal transformation be a function of all the instantaneous inputs. In other words, $x_1 = f_1(s_1, s_2, \ldots, s_M), \ldots, x_m = f_m(s_1, s_2, \ldots, s_M), \ldots, x_M = f_M(s_1, s_2, \ldots, s_M)$.

Now, to achieve the separation in time, the mth orthogonal transformation output xm is delayed by a time period equal to (m-1)T, where T is the symbol duration, such that the first output x_1 experiences no delay, and the Mth output x_M experiences a delay of (M-1)T. The output of the delay blocks 32 consists of the symbols $z_1, \ldots, z_M$ to be transmitted on the antennas 34. The effect of the orthogonal transformation 30 plus the delay blocks 32 is that the mth input symbol s_m is represented in all m output streams, but at different times.

Referring now to Figure 5, another embodiment of the invention is provided in which the encoded and modulated symbols s_m are fed through respective delay banks 40 (40A,...,40M) each containing M-1 delay elements. Each symbol with equal delay is fed to a common scaling block 42. Thus, all undelayed symbols $s_1, \ldots, s_M$ are fed to a

first scaling block 42a, the symbols $s_1,\ldots,s_M$ delayed by (m-1)T are fed to an mth scaling block 42m and so on. Each scaling block 42m multiplies each of its inputs by a respective complex multiplier, and the results are summed in a respective summer 44m the output of which is the mth transmitted symbol z_m. This is really mathematically equivalent to the embodiment of Figure 4 in that each output symbol z_m is again a function of all of the input symbols at a given instant, but at different times. Effectively, the delay block and the orthogonal transformation functions have been done in reverse order.

Both the examples of Figure 4 and 5 perform symbol level space-time encoding in the sense that the input to the space-time encoding process consists of symbols output by the encoder/modulator blocks. Referring now to Figure 6, another embodiment of the invention is provided in which bit-level space-time encoding is performed. In this embodiment, a 1:M demultiplexer 59 produces from an input bit stream 58 M bit substreams $u_1,\ldots,u_M$ which are all fed into delay elements 60A,…,60M-1 each adding a further bit period T delay. The undelayed bits $u_1,\ldots,u_M$, and the bits output by each of the delay elements 60A,…,60M-1 are fed to respective symbol mapping functions 62a,…62M which in the illustrated embodiment are QAM functions. Each QAM mapping function 62A,…,62M maps its M input bits to a corresponding output symbol zm which is output by corresponding antennas 64A,…,64M. In one embodiment, the QAM mappings are designed such that they are orthogonal to each other.

Referring now to Figure 7 a specific example of the embodiment of Figure 6 is shown which is a very practical embodiment, and in which the same numbering

scheme as Figure 6 is used. In this case, it is assumed that the demultiplexer 59 is a 1:4 demultiplexer which produces four bit substreams u_1,u_2,u_3,u_4 which are all fed undelayed to a first 16 QAM mapping 62A, and are all fed to a delay element 60 which introduces a delay T into the substreams and outputs the delayed substreams into a second 16 QAM mapping 62B. The two QAM mappings 62A,62B have outputs z_1,z_2 fed to respective transmit antennas 64A,64B. Details of an example receiver are shown in which there is a 2^M state MLSE decoder 80 connected to two receive antennas 82A,82B. It is to be understood that many different receiver structures can be used, and this is not important to the invention. This implementation lends itself to efficient implementation in hand-held devices because there are only two transmit and two receive antennas.

A recommended mapping for the 16 QAM mapping functions 62A,62B is shown in Figure 8. A first mapping is shown for the first antenna 64A, generally indicated by 90. A second mapping is shown for the second antenna 64B, generally indicated by 92. Each mapping shows how the 16 16QAM constellation points, defined by their position on the horizontal (real) and vertical (imaginary) axes, map to corresponding decimal versions (0 to 15) of input bit combinations u_1,u_2,u_3,u_4 (0000 to 1111).

In one example above, the receiver is a 2^M state MLSE decoder. As indicated previously, the particular receiver design is not important. It may be a Viterbi decoder, an iterative decoder, or some other type of decoder.

In the above embodiments, for symbol level space-time coding, it is assumed that the input to the space-time functionality consists of encoded and modulated symbol streams. In another embodiment, the encoding and modulation is integrated with the space-time coding.

Numerous modifications and variations of the present invention are possible in light of the above teachings. It is therefore to be understood that within the scope of the appended claims, the invention may be practised otherwise than as specifically described herein.

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WE CLAIM:

1. A coding gain system comprising combined space-time coding and spatial multiplexing.

2. A system according to claim 1 wherein the space-time coding comprises a layered space-time architecture.

3. A transmitter comprising the coding gain system according to claim 1.

4. A system according to claim 1 wherein the space time coding comprises symbol level space-time encoding means.

5. A system according to claim 1 wherein the space time coding comprises bit-level space-time coding means.

6. A coding gain system adapted to transmit a plurality M of symbol substreams, the coding gain system comprising:

a space-time coding function adapted to produce M space-time coded streams, with each symbol of the M symbol substreams being represented in all M space-time coded streams and at different times.

7. A coding gain system according to claim 6 further comprising:

a plurality M of transmit antennas each adapted to transmit a respective one of the M space-time coded streams.

8. A coding gain system according to claim 6 further comprising demultiplexing and encoding functionality adapted to produce the M symbol substreams from a primary input stream.

9. A coding gain system according to claim 8 wherein the multiplexing and encoding functionality comprises a demultiplexer having M outputs, and M encoder/modulators each producing a respective one of the M symbol substreams, with each of the M encoder/modulators connected to receive a respective one of the multiplexer outputs.

10. A coding gain system according to claim 7 wherein the multiplexing and encoding functionality comprises an encoder/modulator which produces an encoded and modulated output, and a demultiplexer connected to receive the encoded and modulated output and having M outputs as said M symbol substreams.

11. A coding gain system according to claim 6 wherein the space-time coding function comprises:

an orthogonal transform adapted to produce M orthogonal outputs each of which is a function of the M substreams;

delay elements adapted to insert delays in the M orthogonal outputs to produced M delayed orthogonal outputs such that each of the M delayed orthogonal outputs is a function of a given element of each of the M substreams at a different time.

12. A coding gain system according to claim 11 wherein the delay elements are adapted to introduce a delay of m-1 symbol periods in the mth orthogonal output, where m=1,...,M.

13. A coding gain system according to claim 6 wherein the space-time coding function comprises:

delay elements adapted to insert a delay of M symbol periods in each of the M substreams;

an orthogonal transform adapted to produce M orthogonal outputs, with the mth orthogonal output being a function of the M substreams delayed in said delay elements by m-1 symbol periods.

14. A coding gain system according to claim 13 wherein the M substreams are bit streams, and wherein the orthogonal transform comprises M 2^M M-ary mapping functions, each adapted to produce a respective sequence of M-ary symbols with the M-ary symbol of the mth 2^M M-ary mapping function being a function of the M substreams delayed in said delay elements by m-1 bit periods.

15. A coding gain system according to claim 6 wherein the M symbol substreams are bit streams.

16. A coding gain system according to claim 6 further comprising encoder/modulator functionality integrated with the space-time coding function.

17. A coding method comprising

demultiplexing an input symbol stream into M symbol substreams;

performing a space-time coding function adapted to produce M space-time coded streams from the M symbol substreams, with each symbol of the M symbol substreams being represented in all M space-time coded streams and at different times;

transmitting the M space-time coded streams on respective antennas.

18. A method according to claim 17 further comprising performing coding and modulation on each of said M symbol substreams

19. A method according to claim 17 further comprising performing coding and modulation on a primary data stream to produce said input symbol stream prior to performing the demultiplexing stream.

20. A method according to claim 17 wherein performing the space-time coding function comprises:

executing an orthogonal transform to produce M orthogonal outputs each of which is a function of the M substreams;

delaying the M orthogonal outputs to produced M delayed orthogonal outputs such that each of the M delayed orthogonal outputs is a function of a given element of each of the M substreams at a different time.

21. A method according to claim 20 wherein the mth orthogonal output is delayed by m-1 symbol periods, where m=1,...,M.

22. A method according to claim 17 wherein performing the space-time coding function comprises:

delaying by M symbol periods each of the M substreams;

executing an orthogonal transform adapted to produce M orthogonal outputs, with the mth orthogonal output being a function of the M substreams delayed m-1 symbol periods.

23. A method according to claim 20 wherein the M substreams are bit streams, and wherein the orthogonal transform comprises M 2^M M-ary mapping functions, each adapted to produce a respective sequence of M-ary symbols with the M-ary symbol of the mth 2^M M-ary mapping function being a function of the M substreams delayed in said delay elements by m-1 bit periods.

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(71) Applicant *(for all designated States except US)*: **NORTEL NETWORKS LIMITED** [CA/CA]; 2351 Boulevard Alfred-Nobel, St. Laurent, Quebec H4S 2A9 (CA).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **TONG, Wen** [CA/CA]; 12 Whitestone Drive, Ottawa, Ontario K2C 4A7 (CA). **BAKULIN, Mikhail, G.** [RU/RU]; ul. Klrova, 35-31, Podolsk, Moskovskaya obl., 142110 (RU). **KREYNDELIN, Vitaly B.** [RU/RU]; ul. Graivoronovskaya, 8-87, Moscow, 109518 (RU). **SHLOMA, Alexander M.** [RU/RU]; ul. Gagarina, 63-27, Zhukovsky, Moskovskaya obl., 140160 (RU). **SHINAKOV, Yuriy, S.** [RU/RU]; Vilnjusskaya ul., 7-2-125, Moscow, 117574 (RU).

(74) Agent: **KLIUKIN, Viacheslav Alexandrovich**; Gowlings International Inc., Prechistensky pereulok 14-1, 4 floor, Moscow, 119034 (RU).

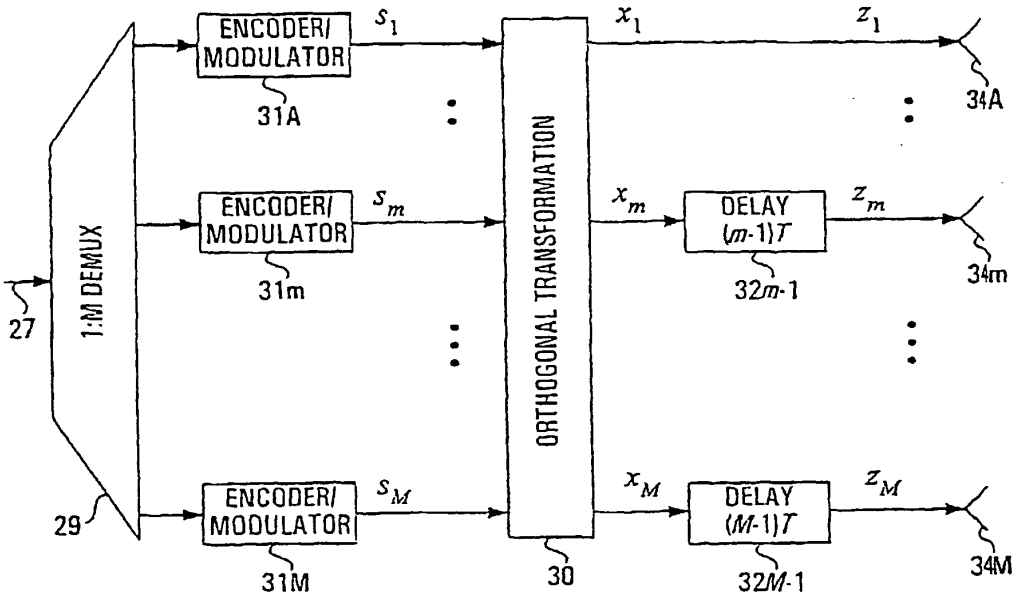
(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*

[Continued on next page]

(54) Title: COMBINATION OF SPACE-TIME CODING AND SPATIAL MULTIPLEXING, AND THE USE OF ORTHOGONAL TRANSFORMATION IN SPACE-TIME CODING



(57) Abstract: It is proposed to combine space-time coding and spatial multiplexing. Also, the use of orthogonal transformation matrices is proposed, which ensures that each bistream contributes to the signal on each antenna.

WO 02/35762 A1

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.

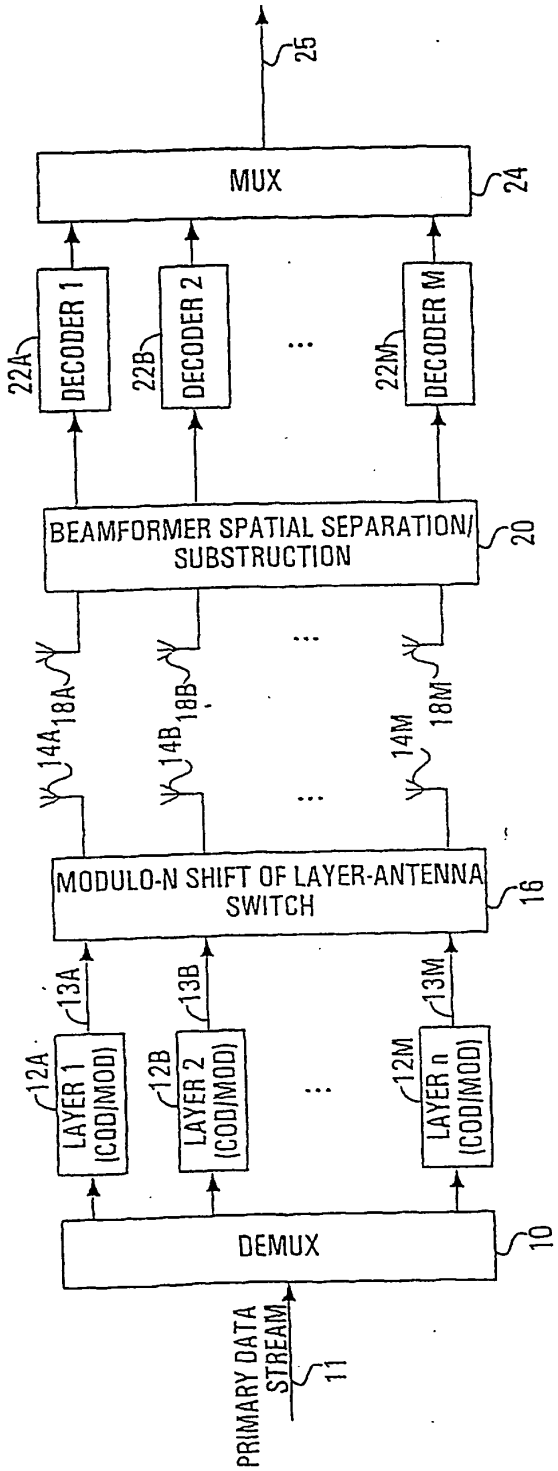


FIG. 1
PRIOR ART

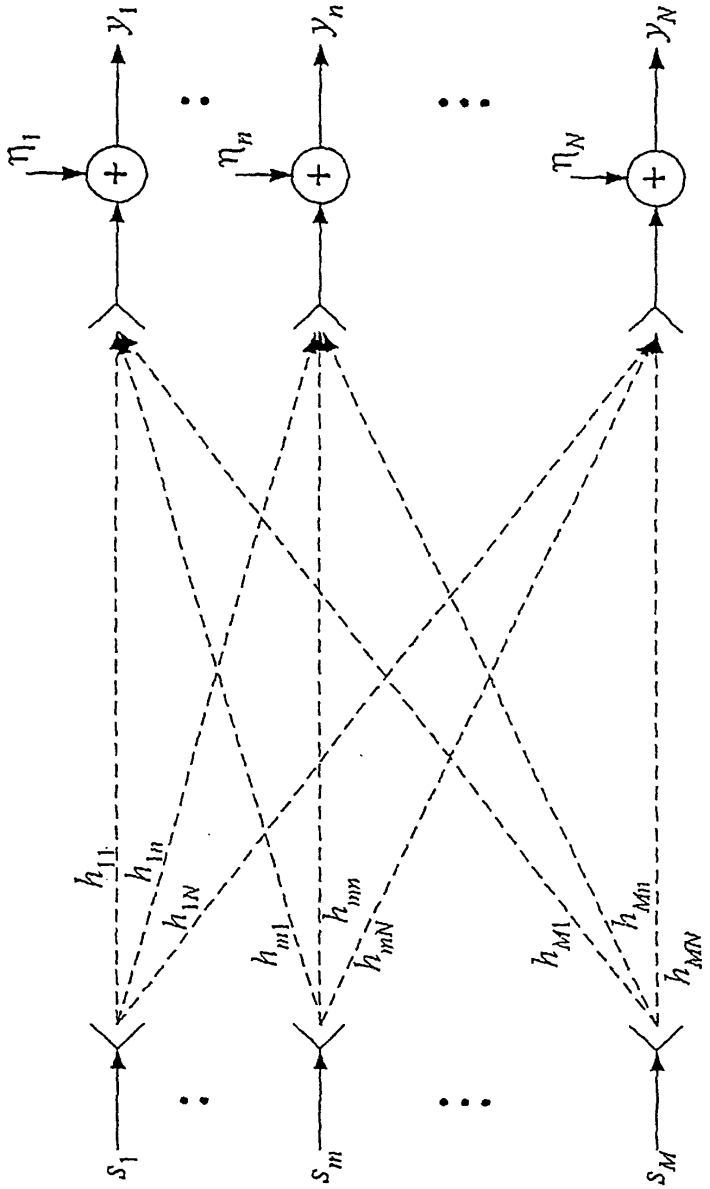

y_1
y_n
y_N
η_1
η_n
η_N
h_{11}
h_{1n}
h_{1N}
h_{m1}
h_{mn}
h_{mN}
h_{M1}
h_{Mn}
h_{MN}
s_1
s_m
s_M

FIG. 2

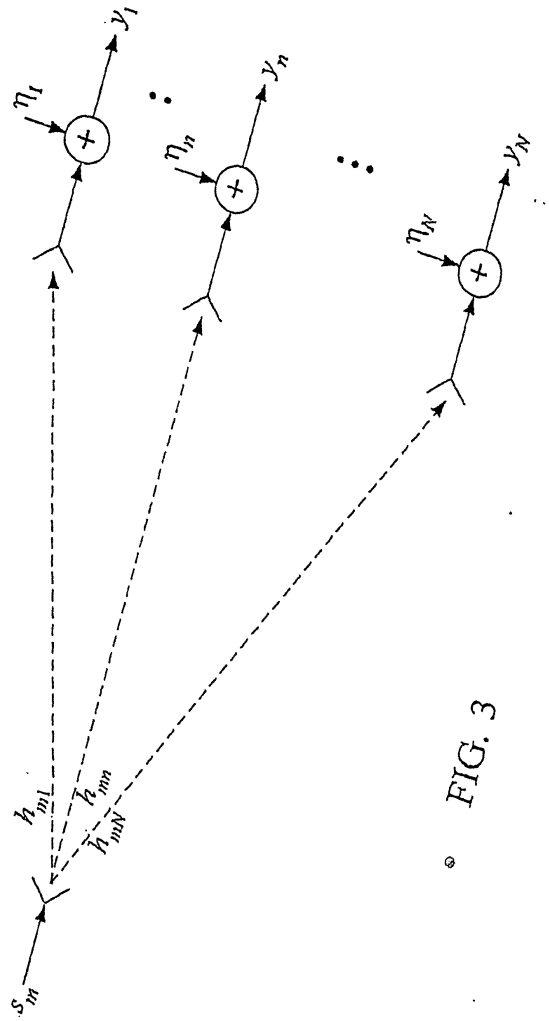


FIG. 3

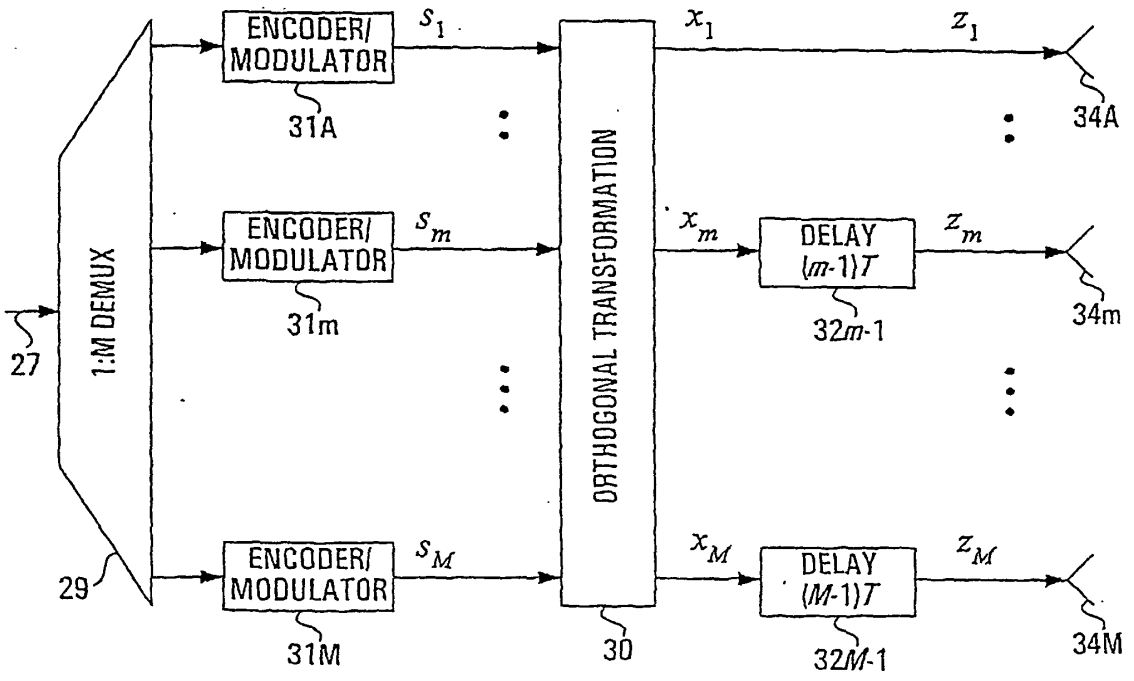

ENCODER/ MODULATOR
31A
ENCODER/ MODULATOR
31m
ENCODER/ MODULATOR
31M
1:M DEMUX
27
29
s_1
s_m
s_M
ORTHOGONAL TRANSFORMATION
30
x_1
x_m
x_M
DELAY (m-1)T
32m-1
DELAY (M-1)T
32M-1
z_1
z_m
z_M
34A
34m
34M

FIG. 4

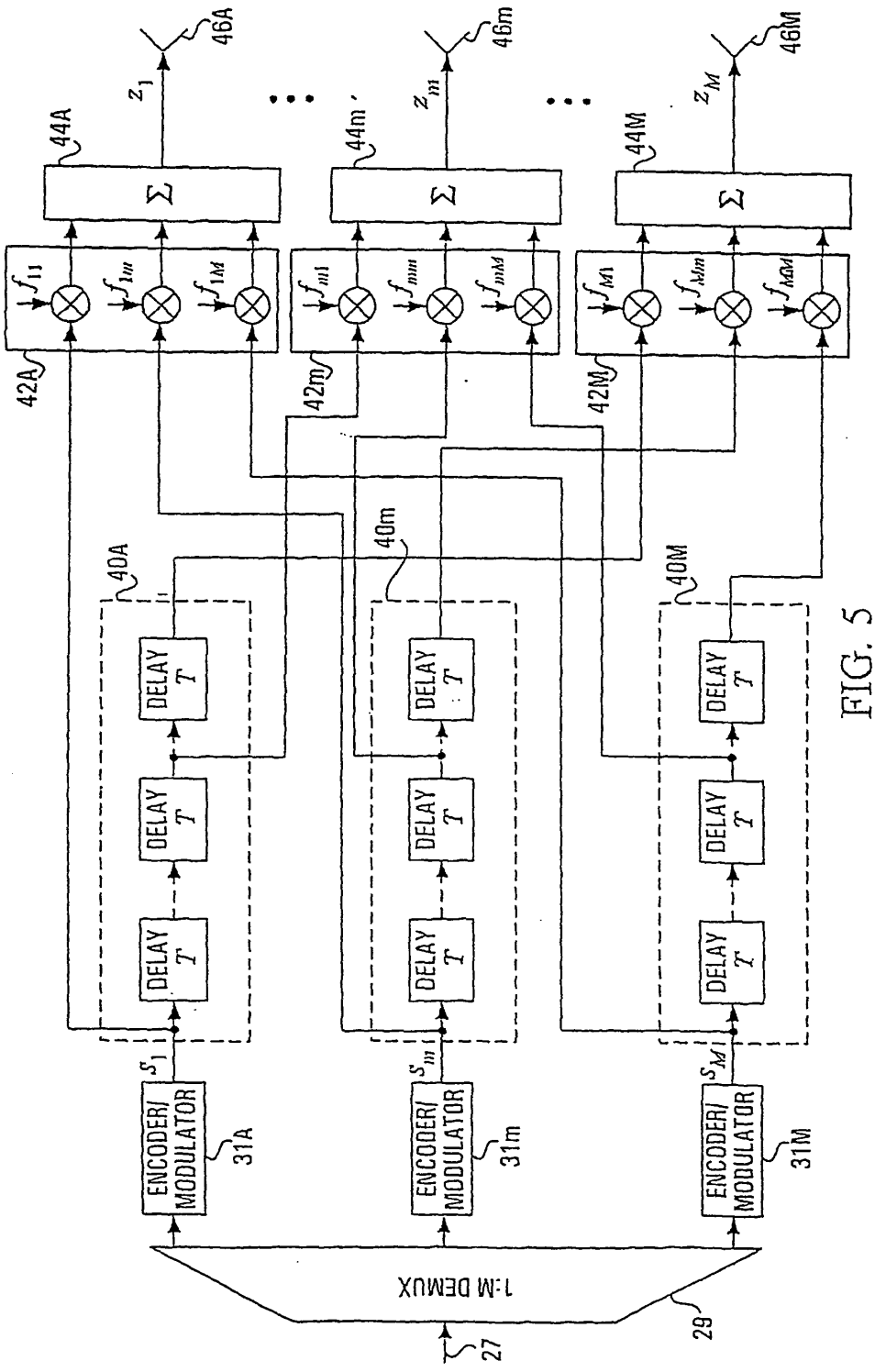

46A
46m
46M
z_1
z_m
z_M
44A
44m
44M
Σ
f_{11}
f_{1m}
f_{1M}
f_{m1}
f_{mm}
f_{mM}
f_{M1}
f_{Mm}
f_{MM}
42A
42m
42M
40A
40m
40M
DELAY T
s_1
s_m
s_M
ENCODER/ MODULATOR
31A
31m
31M
1:M DEMUX
27
29

FIG. 5

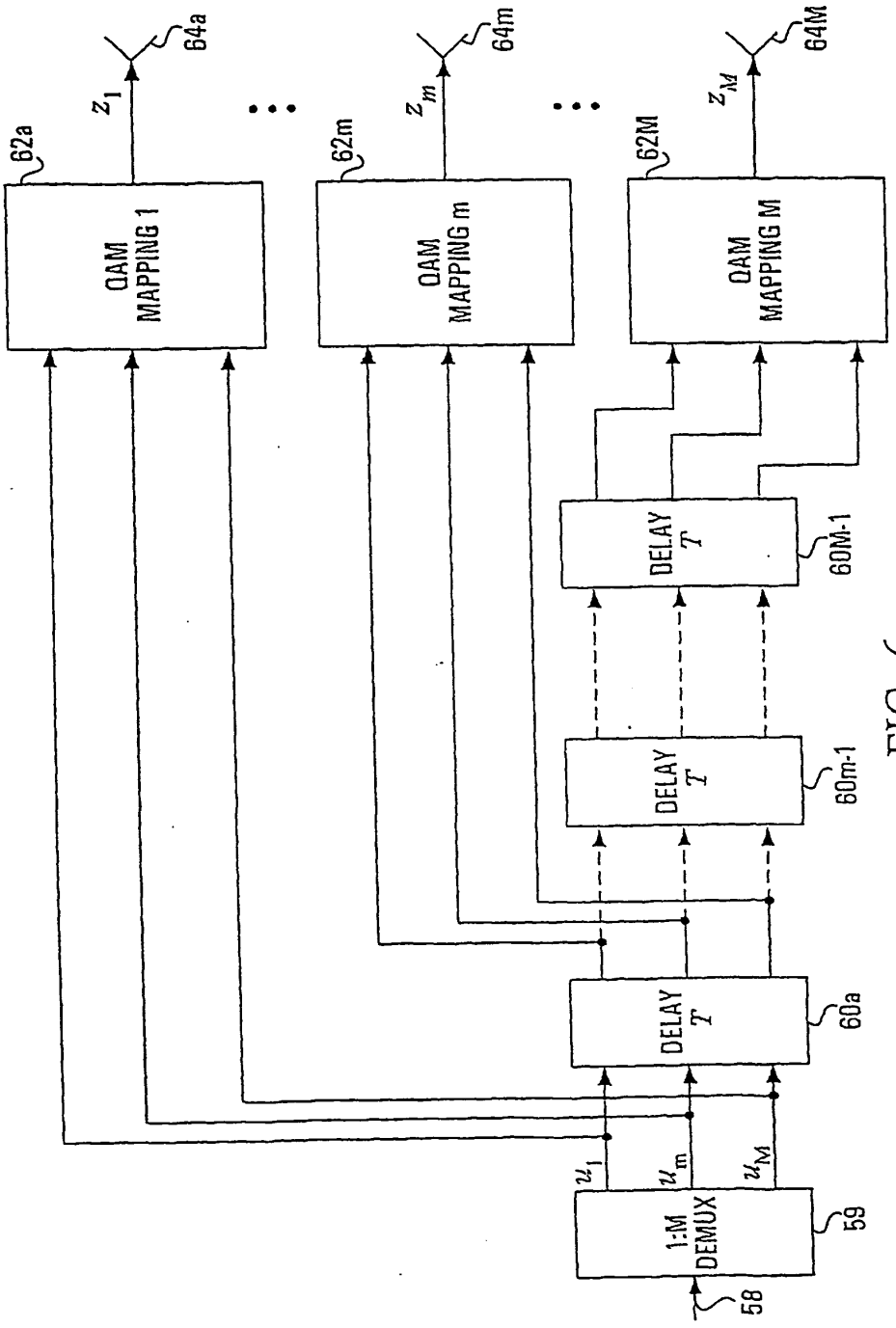

64a
64m
64M
z_1
z_m
z_M
62a
62m
62M
QAM MAPPING 1
QAM MAPPING m
QAM MAPPING M
DELAY T
60M-1
DELAY T
60m-1
DELAY T
60a
u_1
u_m
u_M
1:M DEMUX
59
58

FIG. 6

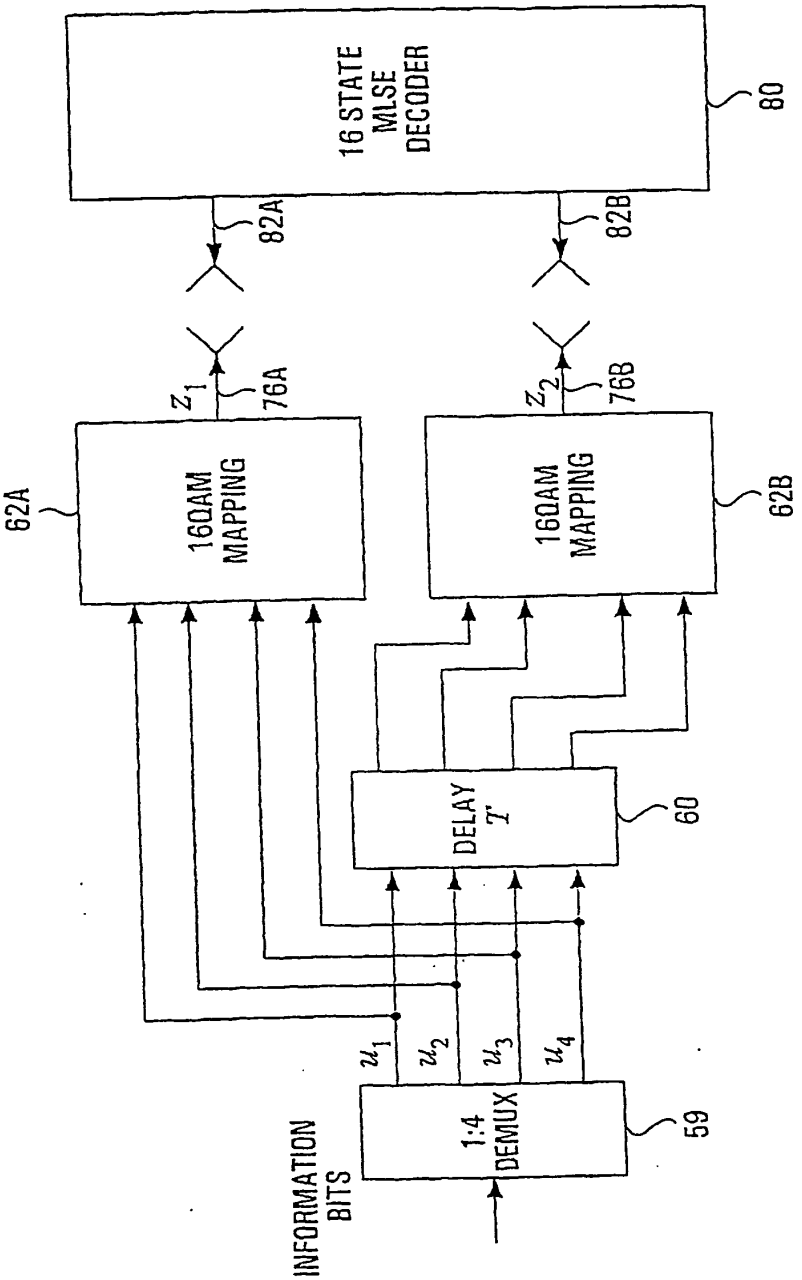

16 STATE MLSE DECODER
80
82A
82B
z_1
z_2
76A
76B
16QAM MAPPING
62A
16QAM MAPPING
62B
DELAY T
60
u_1
u_2
u_3
u_4
1:4 DEMUX
59
INFORMATION BITS

FIG. 7

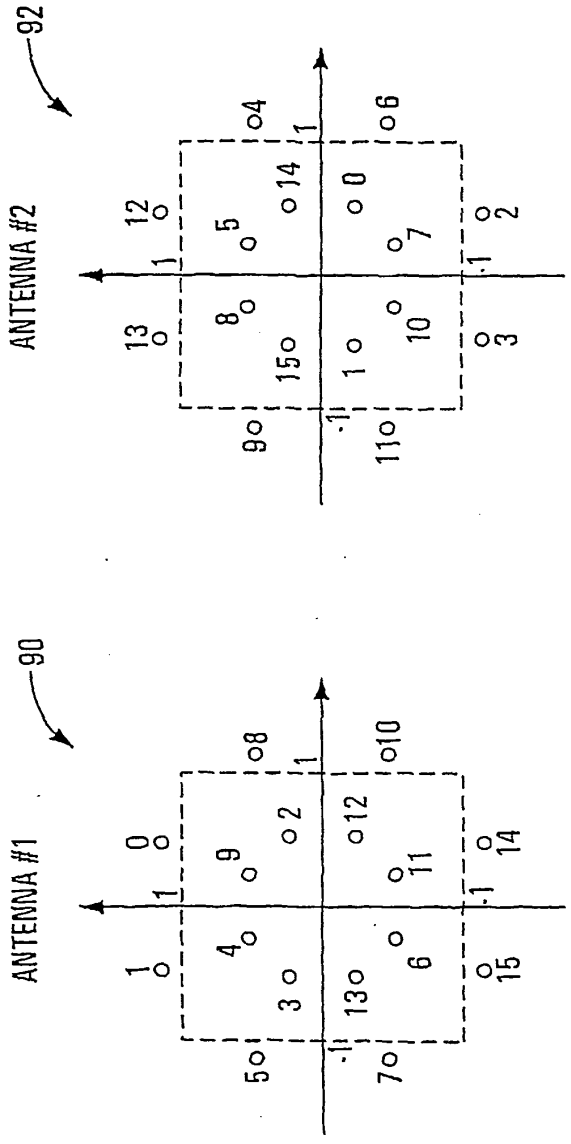

92
ANTENNA #2
4
6
12
5
14
0
2
7
13
8
10
3
15
1
9
11
90
ANTENNA #1
0
9
2
12
14
11
1
4
3
13
6
15
5
7
8
10

FIG. 8

Docket No.
71493-1178 /pw

D claration For Patent Application

English Language Declaration

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 listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

COMBINING OF SPACE-TIME CODING AND SPATIAL MULTIPLEXING, AND THE USE OF ORTHOGONAL TRANSFORMATION IN SPACE-TIME CODING

the specification of which

(check one)

☐ is attached hereto.

☒ was filed on **October 27, 2000** as United States Application No. or PCT International Application Number **PCT/RU00/00426**

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 to the United States Patent and Trademark Office all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, Section 119(a)-(d) or Section 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)			Priority Not Claimed
(Number)	(Country)	(Day/Month/Year Filed)	☐
(Number)	(Country)	(Day/Month/Year Filed)	☐
(Number)	(Country)	(Day/Month/Year Filed)	☐

I hereby claim the benefit under 35 U.S.C. Section 119(e) of any United States provisional application(s) listed below:

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

I hereby claim the benefit under 35 U. S. C. 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 35 U.S.C. Section 112, I acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me to be material to patentability as defined in Title 37, CFR Section 1.56 which became available 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) (patented, pending, abandoned)
(Application Serial No.)	(Filing Date)	(Status) (patented, pending, abandoned)
(Application Serial No.)	(Filing Date)	(Status) (patented, pending, abandoned)

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.

Full name of sole or first inventor **WEN TONG**
Sole or first inventor's signature Date
Residence **Ottawa, Ontario, Canada**
Citizenship **CANADIAN**
Post Office Address **312 Whitestone Drive, Ottawa, Ontario, Canada K2C 4A7**

Full name of second inventor, if any **MICHAIL G. BAKULIN**
Second inventor's signature Date
Residence **Kirova, Russia**
Citizenship **RUSSIAN**
Post Office Address **142110 Moskovskaja Oblast, gor. Podolsk, ul. Kirova, dom 35, kv. 31, Russia**

Full name of third inventor, if any **VITALY B. KREYNDELIN**
Third inventor's signature Date
Residence **Moskva, Russia**
Citizenship **RUSSIAN**
Post Office Address **109518, gor. Moskva, ul. Grayvoronovskaja, dom 8, kv. 87, Russia**

Full name of fourth inventor, if any **ALEXANDER M. SHLOMA**
Fourth inventor's signature Date
Residence **Zhukovsky, Gagarina, Russia**
Citizenship **RUSSIAN**
Post Office Address **140180 M skovskaja Oblast, g r. Zhukovsky, ul gagarina, d m 63, kv. 27, Russia**

Full name of fifth inventor, if any **YURIY S. SHINAKOV**
Fifth inventor's signature Date
Residence **Moscow, Russia**
Citizenship **RUSSIAN**
Post Office Address **117574 Moscow, Vilnusskaja ul. dom 7, kor. 2, kv. 125, Russia**

Full name of sixth inventor, if any
Sixth inventor's signature Date
Residence
Citizenship
Post Office Address

Full name of seventh inventor, if any
Seventh inventor's signature Date
Residence
Citizenship
Post Office Address

Full name of eighth inventor, if
Eighth inventor's signature Date
Residence
Citizenship
Post Office Address

Rec'd PCT/PTO 2 3 APR 2003

PATENT/DOCKET NO. **71493-1178 /pw**
CUSTOMER NO. **000293**

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In Re Application of:	§	Attorney Docket No. **71493-1178 /pw**
Serial No.: n/a	§	
Filed: Herewith	§	Group Art Unit: n/a
Title: **COMBINATION OF SPACE-TIME CODING AND SPATIAL MULTIPLEXING, AND THE USE OF ORTHOGONAL TRANSFORMATION IN SPACE-TIME CODING**	§	Examiner: n/a

Commissioner for Patents
Washington, D.C. 20231

POWER OF ATTORNEY FOR
PATENT APPLICATION

Nortel Networks Limited, a Canadian corporation having principal offices at:

Nortel Networks Limited
2351 Boulevard Alfred-Nobel
St. Laurent, Quebec H4S 2A9, Canada

the owner by assignment of the entire right, title and interest to the invention for **COMBINATION OF SPACE-TIME CODING AND SPATIAL MULTIPLEXING, AND THE USE OF ORTHOGONAL TRANSFORMATION IN SPACE-TIME CODING**, by **Wen TONG, Michail G. BAKULIN, Vitaly B. KREYNDELIN, Alexander M. SHLOMA and Yuriy S. SHINAKOV** and in and to the application for patent and any Letters Patent, whether domestic or foreign, that may issue thereon, by virtue of the assignment:

- ☒ Recorded Concurrently Herewith
- ☐ Recorded on
- ☐ Recorded at Reel Frame
- ☐ Copy Attached

hereby appoints the following attorneys and/or agents to prosecute this application and transact all business in the Patent and Trademark Office connected therewith:

A. DAVID MORROW (Reg. No. 28,816)
ROBERT D. GOULD (Reg. No. 27,523)
THOMAS R. KELLY (Reg. No. 29,244)
TOKUO HIRAMA (Reg. No. 32,551)
KOHJI SUZUKI (Reg. No. 44,467)
R. JOHN HALEY (Reg. No. 29,502)
THUY HUONG NGUYEN (Reg. No. 47,336)
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PHILIP D. LAPIN (Reg. No. 44,443)
CHRISTINE N. GENGE (Reg. No. 45,405)
KEVIN K. GRAHAM (Reg. No. 47,365)
ELLIOTT S. SIMCOE (Reg. No. 50,010)
SOHRAB SABET (Reg. No. 30,723)
COLIN B. INGRAM (Reg. No. 52,437)
RALPH A. DOWELL (Reg.. No. 26,868)

PLEASE SEND CORRESPONDENCE TO: **CUSTOMER No. 000293**

DOWELL & DOWELL, P.C.
1215 Jefferson Davis Highway
Suite 309
Arlington, Virginia 22202-3124
U.S.A.
Tel: (703) 415-2555
Fax: (703) 415-2559

its attorneys with full power of substitution and revocation, to prosecute all domestic and foreign patent applications, including PCT and EPO filings, relating to said invention and to transact all business connected therewith, including signing of all papers on its behalf and making alterations and amendments.

The undersigned is the representative for the Assignee of the entire right, title, and interest in the patent application identified above, and is authorized to act on behalf of the Assignee.

NORTEL NETWORKS LIMITED

_____ _____
Date Name:

_____
Title

PATENT APPLICATION FEE DETERMINATION RECORD
Effective January 1, 2003

Application or Docket Number: 143/6NP

CLAIMS AS FILED - PART I

	(Column 1)	(Column 2)
TOTAL CLAIMS		
FOR	NUMBER FILED	NUMBER EXTRA
TOTAL CHARGEABLE CLAIMS	23 minus 20=	* 3
INDEPENDENT CLAIMS	3 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	375.00	OR	BASIC FEE	750.00
X$ 9=		OR	X$18=	54
X42=		OR	X84=	
+140=		OR	+280=	
TOTAL		OR	TOTAL	954

CLAIMS AS AMENDED - PART II

AMENDMENT A

	(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		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) 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		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		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.

FORM PTO-875 (Rev. 12/02) *U.S. Government Printing Office: 2003 — 498-278/69151 Patent and Trademark Office, U.S. DEPARTMENT OF COMMERCE

PATENT APPLICATION SERIAL NO. _____

U.S. DEPARTMENT OF COMMERCE
PATENT AND TRADEMARK OFFICE
FEE RECORD SHEET

04/25/2003 GFREY1 00000031 10399859

01 FC:1613	900.00	OP
02 FC:1617	130.00	OP
03 FC:1615	54.00	OP

PTO-1556
(5/87)

*U.S. Government Printing Office: 2002 — 489-267/69033

PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

To:

Commissioner
US Department of Commerce
United States Patent and Trademark Office, PCT
2011 South Clark Place Room CP2/5C24
Arlington, VA 22202
ETATS-UNIS D'AMERIQUE

in its capacity as elected Office

Date of mailing (day/month/year) 05 August 2002 (05.08.02)	
International application No. PCT/RU00/00426	**Applicant's or agent's file reference** 71493-948
International filing date (day/month/year) 27 October 2000 (27.10.00)	**Priority date** (day/month/year)
Applicant TONG, Wen et al	

1. The designated Office is hereby notified of its election made:

   [X] in the demand filed with the International Preliminary Examining Authority on:

   24 May 2002 (24.05.02)

   [ ] in a notice effecting later election filed with the International Bureau on:

   _____

2. The election [X] was

   [ ] was not

   made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland**	Authorized officer Zakaria EL KHODARY
Facsimile No.: (41-22) 740.14.35	Telephone No.: (41-22) 338.83.38

Form PCT/IB/331 (July 1992)

RU0000426

PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

To:

Commissioner
US Department of Commerce
United States Patent and Trademark Office, PCT
2011 South Clark Place Room
CP2/5C24
Arlington, VA 22202
ETATS-UNIS D'AMERIQUE

in its capacity as elected Office

Date of mailing (day/month/year) 29 July 2002 (29.07.02)	
International application No. PCT/RU00/00426	**Applicant's or agent's file reference** 71493-948
International filing date (day/month/year) 27 October 2000 (27.10.00)	**Priority date** (day/month/year)
Applicant TONG, Wen et al	

1. The designated Office is hereby notified of its election made:

[X] in the demand filed with the International Preliminary Examining Authority on:

24 May 2002 (24.05.02)

[ ] in a notice effecting later election filed with the International Bureau on:

2. The election [X] was

[ ] was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO **34, chemin des Colombettes** **1211 G neva 20, Switzerland**	Authorized officer Zakaria EL KHODARY
Facsimile No.: (41-22) 740.14.35	Telephone No.: (41-22) 338.83.38

Form PCT/IB/331 (July 1992) RU0000426

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference	**FOR FURTHER ACTION** see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.	
71493-948		
International application No.	International filing date *(day/month/year)*	(Earliest) Priority Date *(day/month/year)*
PCT/RU 00/ 00426	27/10/2000	
Applicant		
NORTEL NETWORKS LIMITED et al.		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 6 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

   a. With regard to the **language,** the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

   [ ] the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

   b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :

   [ ] contained in the international application in written form.

   [ ] filed together with the international application in computer readable form.

   [ ] furnished subsequently to this Authority in written form.

   [ ] furnished subsequently to this Authority in computer readble form.

   [ ] the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

   [ ] the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. [ ] **Certain claims were found unsearchable** (See Box I).

3. [X] **Unity of invention is lacking** (see Box II).

4. With regard to the **title,**

   [ ] the text is approved as submitted by the applicant.

   [X] the text has been established by this Authority to read as follows:

   COMBINATION OF SPACE-TIME CODING AND SPATIAL MULTIPLEXING, AND THE USE OF ORTHOGONAL TRANSFORMATION IN SPACE-TIME CODING

5. With regard to the **abstract,**

   [ ] the text is approved as submitted by the applicant.

   [X] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is Figure No. 4

   [X] as suggested by the applicant.

   [ ] None of the figures.

   [ ] because the applicant failed to suggest a figure.

   [X] because this figure better characterizes the invention.

Form PCT/ISA/210 (first sheet) (July 1998)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/RU 00/00426

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☒ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☒ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. Claims: 1-5

   Combined space-time coding and spatial multiplexing

2. Claims: 6-23

   Space-time coding with mixing of substreams

Box III TEXT OF THE ABSTRACT (Continuation f item 5 of the first sheet)

It is proposed to combine space-time coding and spatial multiplexing. Also, the use of orthogonal transformation matrices is proposed, which ensures that each bitstream contributes to the signal on each antenna.

INTERNATIONAL SEARCH REPORT

International Application No
PCT/[redacted]00/00426

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04L1/06

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)
IPC 7 H04L

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 practical, search terms used)
PAJ, WPI Data, EPO-Internal, INSPEC, COMPENDEX

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	HOCHWALD, MARZETTA: "Space-time modulation for unknown fading" PROCEEDINGS OF THE SPIE, vol. 57, no. 8, April 1999 (1999-04), pages 10-19, XP000914262 Bellingham, US abstract ---	1-5
X	YUMIN ZHANG & R. BLUM: "Multistage multiuser detection for CDMA with space-time coding" IEEE WORKSHOP ON STATISTICAL SIGNAL AND ARRAY PROCESSING, 14 - 16 August 2000, pages 1-5, XP002174378 Piscataway, US ISBN: 0-7803-5988-7 page 1, left-hand column, paragraph 1 --- -/--	1-5

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"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)

"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

"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

"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

"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.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
2 January 2002	23. 01. 2002

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Scriven, P

3

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

Nintendo Exhibit 1013
Page 044

INTERNATIONAL SEARCH REPORT

International Application No
PCT/[redacted]00/00426

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
X	BEN LU &: "Iterative receivers for multiuser space-time coding systems" IEEE INTERNATIONAL CONFERENCE ON COMMUNICATIONS, 18 - 22 June 2000, pages 302-306, XP002174379 Piscataway, US page 302, left-hand column, paragraph 1 ---	1-5
X	EP 0 905 920 A (LUCENT) 31 March 1999 (1999-03-31) page 6, line 34 - line 36; figure 3 ---	6-23
X	EP 0 993 130 A (TEXAS INSTRUMENTS) 12 April 2000 (2000-04-12) figure 2 -----	6-23

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

Nintendo Exhibit 1013
Page 045

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/[redacted]00/00426

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
EP 0905920	A	31-03-1999	US	6058105 A	02-05-2000
			CA	2247618 A1	26-03-1999
			EP	0905920 A2	31-03-1999
			JP	11168453 A	22-06-1999
EP 0993130	A	12-04-2000	EP	0993130 A2	12-04-2000
			JP	2000138623 A	16-05-2000

Form PCT/ISA/210 (patent family annex) (July 1992)

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04L1/06

Rec'd PCT/PTO 23 APR 2003

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

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"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.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
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Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Scriven, P

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

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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X	EP 0 993 130 A (TEXAS INSTRUMENTS) 12 April 2000 (2000-04-12) figure 2 -----	6-23

Rec'd PCT/PTO 23 APR 2003

From the INTERNATIONAL SEARCHING AUTHORITY

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL SEARCH REPORT OR THE DECLARATION

(PCT Rule 44.1)

To:
GOWLINGS INTERNATIONAL INC.
Attn. Kliukin, Viacheslav A.
Prechistensky, Pereulok 14
Building 1, 4th Floor
MOSCOW, 119034
RUSSIAN FEDERATION

Date of mailing *(day/month/year)*	23/01/2002
Applicant's or agent's file reference: 71493-948	**FOR FURTHER ACTION** See paragraphs 1 and 4 below
International application No.: PCT/RU 00/00426	International filing date *(day/month/year)* 27/10/2000
Applicant: NORTEL NETWORKS LIMITED et al.	

1. [X] The applicant is hereby notified that the International Search Report has been established and is transmitted herewith.

Filing of amendments and statement under Article 19:
The applicant is entitled, if he so wishes, to amend the claims of the International Application (see Rule 46):

When? The time limit for filing such amendments is normally 2 months from the date of transmittal of the International Search Report; however, for more details, see the notes on the accompanying sheet.

Where? Directly to the International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland
Fascimile No.: (41-22) 740.14.35

For more detailed instructions, see the notes on the accompanying sheet.

2. [ ] The applicant is hereby notified that no International Search Report will be established and that the declaration under Article 17(2)(a) to that effect is transmitted herewith.

3. [ ] **With regard to the protest** against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:

[ ] the protest together with the decision thereon has been transmitted to the International Bureau together with the applicant's request to forward the texts of both the protest and the decision thereon to the designated Offices.

[ ] no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. **Further action(s):** The applicant is reminded of the following:

Shortly after **18 months** from the priority date, the international application will be published by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau as provided in Rules 90*bis*.1 and 90*bis*.3, respectively, before the completion of the technical preparations for international publication.

Within **19 months** from the priority date, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase until 30 months from the priority date (in some Offices even later).

Within **20 months** from the priority date, the applicant must perform the prescribed acts for entry into the national phase before all designated Offices which have not been elected in the demand or in a later election within 19 months from the priority date or could not be elected because they are not bound by Chapter II.

Name and mailing address of the International Searching Authority	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Carole Emery

Form PCT/ISA/220 (July 1998)

These Notes are intended to give the basic instructions concerning the filing of amendments under article 19. The Notes are based on the requirements of the Patent Cooperation Treaty, the Regulations and the Administrative Instructions under that Treaty. In case of discrepancy between these Notes and those requirements, the latter are applicable. For more detailed information, see also the PCT Applicant's Guide, a publication of WIPO.

In these Notes, "Article", "Rule", and "Section" refer to the provisions of the PCT, the PCT Regulations and the PCT Administrative Instructions, respectively.

INSTRUCTIONS CONCERNING AMENDMENTS UNDER ARTICLE 19

The applicant has, after having received the international search report, one opportunity to amend the claims of the international application. It should however be emphasized that, since all parts of the international application (claims, description and drawings) may be amended during the international preliminary examination procedure, there is usually no need to file amendments of the claims under Article 19 except where, e.g. the applicant wants the latter to be published for the purposes of provisional protection or has another reason for amending the claims before international publication. Furthermore, it should be emphasized that provisional protection is available in some States only.

ON DOCKET PSH Due MAR. 23/02.

What parts of the international application may be amended?

Under Article 19, only the claims may be amended.

During the international phase, the claims may also be amended (or further amended) under Article 34 before the International Preliminary Examining Authority. The description and drawings may only be amended under Article 34 before the International Examining Authority.

Upon entry into the national phase, all parts of the international application may be amended under Article 28 or, where applicable, Article 41.

When? Within 2 months from the date of transmittal of the international search report or 16 months from the priority date, whichever time limit expires later. It should be noted, however, that the amendments will be considered as having been received on time if they are received by the International Bureau after the expiration of the applicable time limit but before the completion of the technical preparations for international publication (Rule 46.1).

Where not to file the amendments?

The amendments may only be filed with the International Bureau and not with the receiving Office or the International Searching Authority (Rule 46.2).

Where a demand for international preliminary examination has been/is filed, see below.

How? Either by cancelling one or more entire claims, by adding one or more new claims or by amending the text of one or more of the claims as filed.

A replacement sheet must be submitted for each sheet of the claims which, on account of an amendment or amendments, differs from the sheet originally filed.

All the claims appearing on a replacement sheet must be numbered in Arabic numerals. Where a claim is cancelled, no renumbering of the other claims is required. In all cases where claims are renumbered, they must be renumbered consecutively (Administrative Instructions, Section 205(b)).

The amendments must be made in the language in which the international application is to be published.

What documents must/may accompany the amendments?

Letter (Section 205(b)):

The amendments must be submitted with a letter.

The letter will not be published with the international application and the amended claims. It should not be confused with the "Statement under Article 19(1)" (see below, under "Statement under Article 19(1)").

The letter must be in English or French, at the choice of the applicant. However, if the language of the international application is English, the letter must be in English; if the language of the international application is French, the letter must be in French.

The letter must indicate the differences between the claims as filed and the claims as amended. It must, in particular, indicate, in connection with each claim appearing in the international application (it being understood that identical indications concerning several claims may be grouped),whether

(i) the claim is unchanged;

(ii) the claim is cancelled;

(iii) the claim is new;

(iv) the claim replaces one or more claims as filed;

(v) the claim is the result of the division of a claim as filed.

The following examples illustrate the manner in which amendments must be explained in the accompanying letter:

1. [Where originally there were 48 claims and after amendment of some claims there are 51]:
"Claims 1 to 29, 31, 32, 34, 35, 37 to 48 replaced by amended claims bearing the same numbers; claims 30, 33 and 36 unchanged; new claims 49 to 51 added."

2. [Where originally there were 15 claims and after amendment of all claims there are 11]:
"Claims 1 to 15 replaced by amended claims 1 to 11."

3. [Where originally there were 14 claims and the amendments consist in cancelling some claims and in adding new claims]:
"Claims 1 to 6 and 14 unchanged; claims 7 to 13 cancelled; new claims 15, 16 and 17 added." or
"Claims 7 to 13 cancelled; new claims 15, 16 and 17 added; all other claims unchanged."

4. [Where various kinds of amendments are made]:
"Claims 1-10 unchanged; claims 11 to 13, 18 and 19 cancelled; claims 14, 15 and 16 replaced by amended claim 14; claim 17 subdivided into amended claims 15, 16 and 17; new claims 20 and 21 added."

"Statement under article 19(1)" (Rule 46.4)

The amendments may be accompanied by a statement explaining the amendments and indicating any impact that such amendments might have on the description and the drawings (which cannot be amended under Article 19(1)).

The statement will be published with the international application and the amended claims.

It must be in the language in which the international application is to be published.

It must be brief, not exceeding 500 words if in English or if translated into English.

It should not be confused with and does not replace the letter indicating the differences between the claims as filed and as amended. It must be filed on a separate sheet and must be identified as such by a heading, preferably by using the words "Statement under Article 19(1)."

It may not contain any disparaging comments on the international search report or the relevance of citations contained in that report. Reference to citations, relevant to a given claim, contained in the international search report may be made only in connection with an amendment of that claim.

Consequence if a demand for international preliminary examination has already been filed

If, at the time of filing any amendments and any accompanying statement, under Article 19, a demand for international preliminary examination has already been submitted, the applicant must preferably, at the time of filing the amendments (and any statement) with the International Bureau, also file with the International Preliminary Examining Authority a copy of such amendments (and of any statement) and, where required, a translation of such amendments for the procedure before that Authority (see Rules 55.3(a) and 62.2, first sentence). For further information, see the Notes to the demand form (PCT/IPEA/401).

Consequence with regard to translation of the international application for entry into the national phase

The applicant's attention is drawn to the fact that, upon entry into the national phase, a translation of the claims as amended under Article 19 may have to be furnished to the designated/elected Offices, instead of, or in addition to, the translation of the claims as filed.

For further details on the requirements of each designated/elected Office, see Volume II of the PCT Applicant's Guide.

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference	FOR FURTHER ACTION	see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.
71493-948		
International application No.	International filing date *(day/month/year)*	(Earliest) Priority Date *(day/month/year)*
PCT/RU 00/ 00426	27/10/2000	
Applicant		
NORTEL NETWORKS LIMITED et al.		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 6 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

   a. With regard to the **language**, the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

   [ ] the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

   b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :

   [ ] contained in the international application in written form.

   [ ] filed together with the international application in computer readable form.

   [ ] furnished subsequently to this Authority in written form.

   [ ] furnished subsequently to this Authority in computer readable form.

   [ ] the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

   [ ] the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. [ ] **Certain claims were found unsearchable** (See Box I).

3. [X] **Unity of invention is lacking** (see Box II).

4. With regard to the **title**,

   [ ] the text is approved as submitted by the applicant.

   [X] the text has been established by this Authority to read as follows:

   COMBINATION OF SPACE-TIME CODING AND SPATIAL MULTIPLEXING, AND THE USE OF ORTHOGONAL TRANSFORMATION IN SPACE-TIME CODING

5. With regard to the **abstract**,

   [ ] the text is approved as submitted by the applicant.

   [X] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is Figure No. 4

   [X] as suggested by the applicant.

   [ ] because the applicant failed to suggest a figure.

   [X] because this figure better characterizes the invention.

   [ ] None of the figures.

Form PCT/ISA/210 (first sheet) (July 1998)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/RU 00/00426

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☒ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☒ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. Claims: 1-5

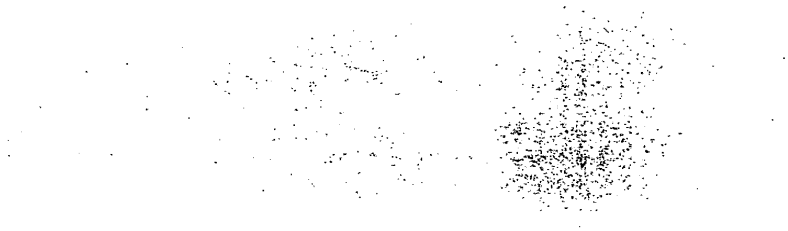
   Combined space-time coding and spatial multiplexing

2. Claims: 6-23

   Space-time coding with mixing of substreams

Box III TEXT OF THE ABSTRACT (Continuation of item 5 of the first sheet)

It is proposed to combine space-time coding and spatial multiplexing. Also, the use of orthogonal transformation matrices is proposed, which ensures that each bitstream contributes to the signal on each antenna.



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Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Scriven, P

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

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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			EP	0905920 A2	31-03-1999
			JP	11168453 A	22-06-1999
EP 0993130	A	12-04-2000	EP	0993130 A2	12-04-2000
			JP	2000138623 A	16-05-2000

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
2 May 2002 (02.05.2002)

PCT

(10) International Publication Number
WO 02/35762 A1

(51) International Patent Classification[7]: H04L 1/06

(21) International Application Number: PCT/RU00/00426

(22) International Filing Date: 27 October 2000 (27.10.2000)

(25) Filing Language: English

(26) Publication Language: English

(71) Applicant *(for all designated States except US)*: **NORTEL NETWORKS LIMITED** [CA/CA]; 2351 Boulevard Alfred-Nobel, St. Laurent, Quebec H4S 2A9 (CA).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **TONG, Wen** [CA/CA]; 12 Whitestone Drive, Ottawa, Ontario K2C 4A7 (CA). **BAKULIN, Mikhail, G.** [RU/RU]; ul. Klrova, 35-31, Podolsk, Moskovskaya obl., 142110 (RU). **KREYNDELIN, Vitaly B.** [RU/RU]; ul. Graivoronovskaya, 8-87, Moscow, 109518 (RU). **SHLOMA, Alexander M.** [RU/RU]; ul. Gagarina, 63-27, Zhukovsky, Moskovskaya obl., 140160 (RU). **SHINAKOV, Yuriy, S.** [RU/RU]; Vilnjusskaya ul., 7-2-125, Moscow, 117574 (RU).

(74) Agent: **KLIUKIN, Viacheslav Alexandrovich**; Gowlings International Inc., Prechistensky pereulok 14-1, 4 floor, Moscow, 119034 (RU).

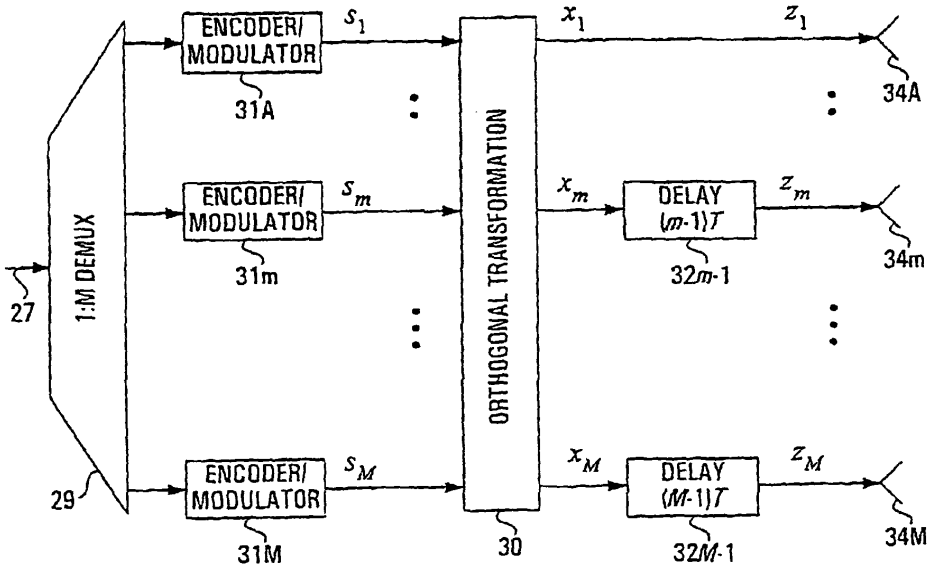
(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

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[Continued on next page]

(54) Title: COMBINATION OF SPACE-TIME CODING AND SPATIAL MULTIPLEXING, AND THE USE OF ORTHOGONAL TRANSFORMATION IN SPACE-TIME CODING



(57) Abstract: It is proposed to combine space-time coding and spatial multiplexing. Also, the use of orthogonal transformation matrices is proposed, which ensures that each bistream contributes to the signal on each antenna.

WO 02/35762 A1

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.

COMBINATION OF SPACE-TIME CODING AND SPATIAL MULTIPLEXING, AND THE USE OF ORTHOGONAL TRANSFORMATION IN SPACE-TIME CODING

Field of the Invention

The invention relates to systems and methods for performing layered space-time coding for wireless channels.

Background of the Invention

With the explosion in the demand for wireless Internet services, a number of competing solutions have been developed. UMTS (Universal Mobile Terrestrial Service) standardization has lead to the 3Gpp standard which offers a 2 Mbps data rate per sector. Work is underway on HSPDA (high speed data access), a higher speed packet data access variation. IS-2000, an evolution of IS-95 provides HDR (High Speed Data Rate) and 1XEV (1X Evolution) which allow wireless Internet browsing at a rate of 7.2 Mbps per sector. Notwithstanding these solutions, there is still the demand to push rates higher.

Recently, it has been proposed to use BLAST (Bell Labs Layered Space Time) which is a layered space-time coding approach, as a wireless data solution. Referring to Figure 1, the basic concept behind this layered space-time coding approach involves, at the transmit side, a demultiplexer 10 which demultiplexes a primary data stream 11 into M data substreams of equal rate. Each of the M data streams is then encoded and modulated separately in respective coding/modulating blocks 12 (12A, 12B,…, 12M) to produce respective encoded and modulated streams 13 (13A,13B,…,13M). There are M transmit antennas 14 (14A, 14B,…,14M). A switch 16 periodically cycles the association between the modulated streams 13A,13B,…,13M and the antennas 14A,14B,…,14M. At the receive side, there are

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M antennas 18 (18A,18B,…,18M) which feed into a beamforming/spatial separation/substruction block 20 which performs a spatial beamforming/nulling (zero forcing) process to separate the individual coded streams and feeds these to respective individual decoders 22 (22A,22B,…,22M). The outputs of the decoders 22A,22B,…,22M are fed to a multiplexer 24 which multiplexes the signals to produce an output 25 which is an estimate of the primary data stream 11.

There are a number of variations on this architecture. One is to modify the receiver antenna pre-processing to carry out MMSE (minimum mean square error) beamforming rather than nulling in order to improve the wanted signal SNR (signal-to-noise ratio) at the expense of slightly increased ISI (inter-symbol interference). Both the MMSE and nulling approaches normally have the disadvantage that some sort of diversity of the receiver antenna array is necessarily sacrificed in the beamforming process. In order to overcome this problem, layering of the receiver processing can be employed such that after the strongest signal has been decoded (typically using the Viterbi MLSE (maximum likelihood sequence estimation) algorithm) it is subtracted from the received antenna signals in order to remove the strongest signal. This process is iterated down until detection of the weakest signal requires no nulling at all, and its diversity performance is therefore maximized. A disadvantage with this layered approach is the same as that with all subtractive multi-user detection schemes, that the wrong subtraction can cause error propagation.

There are several types of layered space-time coding structures, including horizontal BLAST (H-BLAST),

diagonal BLAST (D-BLAST) and vertical BLAST. They have identical performance for both optimal linear and non-linear receivers, assuming error control coding is not used in such systems. For optimal linear reception (linear maximum likelihood), these structures have the same SNR performances as those with only a single transmit antenna and a single receive antenna, but do offer the advantage of improved spectral efficiency.

In order to achieve this improved spectral efficiency, in such systems it would be advantageous to have a large number of transmit and receive antennas, for example four of each. However, while this may be practical for larger wireless devices such as laptop computers, it is impractical for smaller hand-held devices because it is not possible to get the antennas far enough apart to ensure their independence. Because of this, for hand-held devices, a practical limit might be two transmit and two receive antennas. Also, another factor limiting the practical number of antennas is cost. Typically about two thirds of the cost of a base station transceiver is in the power amplifier plus antennas, and this will increase if more antennas are added. These factors make only a two by two system commercially practical.

By way of example, consider a system with M transmit and N receive antennas in a frequency non-selective, slowly fading channel. The sampled baseband-equivalent channel model is given by

$$Y = HS + \eta$$

where $H \in C^{NxM}$ is the complex channel matrix with the (i,j)-th element being random fading between the i-th receive and j-th transmit antenna. $\eta \in C^N$ is the additive

noise source and is modelled as a zero mean circularly symmetric complex Gaussian random vector with statistically independent elements, that is $\eta \sim C\aleph(0, 2\sigma_\eta^2 I_N)$. The i-th element of $S \in C^M$ is the symbol transmitted at the i-th transmit antenna and that of $Y \in C^N$ is the symbol received at the i-th received antenna. The model is shown in Figure 2.

That such a system has no improvement in SNR performance can be explained by noting that the data symbol s_m is transmitted only by one antenna, and in case of full cancellation of other transmit antennas, the model of such a system is shown in Figure 3. In this case there is one transmit antenna and N receive antennas. Therefore, for symbol s_m there is no coding gain.

It would be advantageous to have a layered space-time coding structure which provides the improved spectral efficiency, but which also provides improved SNR performance.

Summary of the Invention

Embodiments of the invention provide coding gain systems and methods which feature combined space-time coding and spatial multiplexing, and transmitters adapted to include such functionality. The space-time coding introduces a coding gain, and makes symbols more immune to fading since each information component is represented somehow in each spatial output. In some embodiments, the space-time coding comprises a layered space-time architecture. Advantageously, these solutions are amenable to implementation with two transmit antennas and two

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receive antennas, a configuration suitable for hand-held devices.

According to one broad aspect, the invention provides a coding gain system adapted to transmit a plurality M of symbol substreams. The coding gain system has a space-time coding function adapted to produce M space-time coded streams, with each symbol of the M symbol substreams being represented in all M space-time coded streams and at different times. In some embodiments, the coding gain system provided by the invention can be considered to include M transmit antennas each adapted to transmit a respective one of the M space-time coded streams, and/or demultiplexing and encoding functionality adapted to produce the M symbol substreams from a primary input stream.

In some embodiments, the space-time coding function has an orthogonal transform adapted to produce M orthogonal outputs each of which is a function of the M substreams, and has delay elements adapted to insert delays in the M orthogonal outputs to produced M delayed orthogonal outputs such that each of the M delayed orthogonal outputs is a function of a given element of each of the M substreams at a different time. For example, the delay elements can be adapted to introduce a delay of m-1 symbol periods in the mth orthogonal output, where m=1,…,M.

In another embodiment, the space-time coding function has delay elements adapted to insert a delay of M-1 symbol periods in each of the M substreams, and an orthogonal transform adapted to produce M orthogonal outputs, with the mth orthogonal output being a function of the M substreams delayed in the delay elements by m-1 symbol periods.

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In some embodiments the M substreams are non-binary symbols. In other embodiments the M substreams are bit streams. In these embodiments, the orthogonal transform comprises orthogonal symbol mappings, for example M 2^M QAM or MPSK mapping functions, each adapted to produce a respective sequence of M-ary symbols with the M-ary symbol of the mth 2^M QAM mapping function being a function of the M substreams delayed in said delay elements by m-1 bit periods.

Brief Description of the Drawings

Preferred embodiments of the invention will now be described with reference to the attached drawings in which:

Figure 1 is a block diagram of a known space-time coding system;

Figure 2 is a channel model for the system of Figure 1;

Figure 3 is a channel model for a single antenna output of the system of Figure 1;

Figure 4 is a block diagram of a transmitter featuring a coding gain system provided by an embodiment of the invention;

Figure 5 is a block diagram of a transmitter featuring a coding gain system provided by another embodiment of the invention;

Figure 6 is a block diagram of a transmitter featuring a coding gain system provided by another embodiment of the invention;

Figure 7 is a block diagram of a transmitter featuring a coding gain system provided by another embodiment of the invention; and

Figure 8 is a constellation diagram for the 16 QAM Gray mappings of Figure 7.

Detailed Description of the Preferred Embodiments

Embodiments of the invention provide a layered space-time architecture with additional gain provided with

space-time coding. To achieve this each information symbol s_m is arranged to as to be represented on all M Transmit Antennas. An algorithm of space-time coding is developed for one transmitter, and aggregated with algorithms for M transmitters, so that the spectral efficiency expected for conventional BLAST architecture is retained.

A range of coding gain methods/systems and transmitters are provided which combine space time coding and spatial multiplexing. Referring firstly to figure 4, shown is a space-time coder/multiplexer coding gain system consisting of a 1:M demultiplexer 29 having a single primary input 27 and having M outputs which are each coded and modulated in respective encoder/modulator blocks 31A,…,31M to produce encoded substreams $s_1, s_2, \ldots, s_M$. There is an orthogonal transformation block 30 and a number of delay blocks 32 (only two shown, 32m-1, 32M-1) the outputs of which are connected to respective transmit antennas 34A,…,34M. The orthogonal transformation block 30 has as its inputs the M encoded and modulated substreams $s_1, s_2, \ldots, s_M$. The orthogonal transformation block 30 performs the following matrix transform on the input substreams at each symbol interval:

$$X = FS,$$

where $S = (s_1, s_2, \ldots s_M)$ at a given instant, $X = (x_1, x_2, \ldots, x_M) \in C^M$ is the output of the orthogonal transformation block 30; and $F \in C^{MxM}$ is a complex matrix defining the orthogonal transformation. In one embodiment, the (i,m)-th element of F is defined by:

$$f_{im} = (Had(i, m) \cdot e^{j(\pi(m\ 1))/(2M)})/(\sqrt{M}) \quad ,$$

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where $Had(i,m) \in (1; -1)$ is the (i,m)-th element of the Hadamard matrix. For M=2 this matrix is

$$F = \frac{1}{\sqrt{2}} \begin{bmatrix} 1 & e^{j\pi/4} \\ 1 & -e^{j\pi/4} \end{bmatrix} .$$

However, this transformation matrix is not unique, this being only an example of a suitable orthogonal transformation. The optimization and/or search for the best of transformation matrix depends on the modulation for initial symbols s_m and on the number of antennas M. It is important that each output of the orthogonal transformation be a function of all the instantaneous inputs. In other words, $x_1 = f_1(s_1, s_2, \ldots, s_M), \ldots, x_m = f_m(s_1, s_2, \ldots, s_M), \ldots, x_M = f_M(s_1, s_2, \ldots, s_M)$.

Now, to achieve the separation in time, the mth orthogonal transformation output xm is delayed by a time period equal to (m-1)T, where T is the symbol duration, such that the first output x_1 experiences no delay, and the Mth output x_M experiences a delay of (M-1)T. The output of the delay blocks 32 consists of the symbols $z_1, \ldots, z_M$ to be transmitted on the antennas 34. The effect of the orthogonal transformation 30 plus the delay blocks 32 is that the mth input symbol s_m is represented in all m output streams, but at different times.

Referring now to Figure 5, another embodiment of the invention is provided in which the encoded and modulated symbols s_m are fed through respective delay banks 40 (40A,…,40M) each containing M-1 delay elements. Each symbol with equal delay is fed to a common scaling block 42. Thus, all undelayed symbols $s_1, \ldots, s_M$ are fed to a

first scaling block 42a, the symbols $s_1,\ldots,s_M$ delayed by (m-1)T are fed to an mth scaling block 42m and so on. Each scaling block 42m multiplies each of its inputs by a respective complex multiplier, and the results are summed in a respective summer 44m the output of which is the mth transmitted symbol z_m. This is really mathematically equivalent to the embodiment of Figure 4 in that each output symbol z_m is again a function of all of the input symbols at a given instant, but at different times. Effectively, the delay block and the orthogonal transformation functions have been done in reverse order.

Both the examples of Figure 4 and 5 perform symbol level space-time encoding in the sense that the input to the space-time encoding process consists of symbols output by the encoder/modulator blocks. Referring now to Figure 6, another embodiment of the invention is provided in which bit-level space-time encoding is performed. In this embodiment, a 1:M demultiplexer 59 produces from an input bit stream 58 M bit substreams $u_1,\ldots,u_M$ which are all fed into delay elements 60A,…,60M-1 each adding a further bit period T delay. The undelayed bits $u_1,\ldots,u_M$, and the bits output by each of the delay elements 60A,…,60M-1 are fed to respective symbol mapping functions 62a,…62M which in the illustrated embodiment are QAM functions. Each QAM mapping function 62A,…,62M maps its M input bits to a corresponding output symbol zm which is output by corresponding antennas 64A,…,64M. In one embodiment, the QAM mappings are designed such that they are orthogonal to each other.

Referring now to Figure 7 a specific example of the embodiment of Figure 6 is shown which is a very practical embodiment, and in which the same numbering

scheme as Figure 6 is used. In this case, it is assumed that the demultiplexer 59 is a 1:4 demultiplexer which produces four bit substreams u_1,u_2,u_3,u_4 which are all fed undelayed to a first 16 QAM mapping 62A, and are all fed to a delay element 60 which introduces a delay T into the substreams and outputs the delayed substreams into a second 16 QAM mapping 62B. The two QAM mappings 62A,62B have outputs z_1,z_2 fed to respective transmit antennas 64A,64B. Details of an example receiver are shown in which there is a 2^M state MLSE decoder 80 connected to two receive antennas 82A,82B. It is to be understood that many different receiver structures can be used, and this is not important to the invention. This implementation lends itself to efficient implementation in hand-held devices because there are only two transmit and two receive antennas.

A recommended mapping for the 16 QAM mapping functions 62A,62B is shown in Figure 8. A first mapping is shown for the first antenna 64A, generally indicated by 90. A second mapping is shown for the second antenna 64B, generally indicated by 92. Each mapping shows how the 16 16QAM constellation points, defined by their position on the horizontal (real) and vertical (imaginary) axes, map to corresponding decimal versions (0 to 15) of input bit combinations u_1,u_2,u_3,u_4 (0000 to 1111).

In one example above, the receiver is a 2^M state MLSE decoder. As indicated previously, the particular receiver design is not important. It may be a Viterbi decoder, an iterative decoder, or some other type of decoder.

In the above embodiments, for symbol level space-time coding, it is assumed that the input to the space-time functionality consists of encoded and modulated symbol streams. In another embodiment, the encoding and modulation is integrated with the space-time coding.

Numerous modifications and variations of the present invention are possible in light of the above teachings. It is therefore to be understood that within the scope of the appended claims, the invention may be practised otherwise than as specifically described herein.

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WE CLAIM:

1. A coding gain system comprising combined space-time coding and spatial multiplexing.

2. A system according to claim 1 wherein the space-time coding comprises a layered space-time architecture.

3. A transmitter comprising the coding gain system according to claim 1.

4. A system according to claim 1 wherein the space time coding comprises symbol level space-time encoding means.

5. A system according to claim 1 wherein the space time coding comprises bit-level space-time coding means.

6. A coding gain system adapted to transmit a plurality M of symbol substreams, the coding gain system comprising:

a space-time coding function adapted to produce M space-time coded streams, with each symbol of the M symbol substreams being represented in all M space-time coded streams and at different times.

7. A coding gain system according to claim 6 further comprising:

a plurality M of transmit antennas each adapted to transmit a respective one of the M space-time coded streams.

8. A coding gain system according to claim 6 further comprising demultiplexing and encoding functionality adapted to produce the M symbol substreams from a primary input stream.

9. A coding gain system according to claim 8 wherein the multiplexing and encoding functionality comprises a demultiplexer having M outputs, and M encoder/modulators each producing a respective one of the M symbol substreams, with each of the M encoder/modulators connected to receive a respective one of the multiplexer outputs.

10. A coding gain system according to claim 7 wherein the multiplexing and encoding functionality comprises an encoder/modulator which produces an encoded and modulated output, and a demultiplexer connected to receive the encoded and modulated output and having M outputs as said M symbol substreams.

11. A coding gain system according to claim 6 wherein the space-time coding function comprises:

an orthogonal transform adapted to produce M orthogonal outputs each of which is a function of the M substreams;

delay elements adapted to insert delays in the M orthogonal outputs to produced M delayed orthogonal outputs such that each of the M delayed orthogonal outputs is a function of a given element of each of the M substreams at a different time.

12. A coding gain system according to claim 11 wherein the delay elements are adapted to introduce a delay of m-1 symbol periods in the mth orthogonal output, where m=1,...,M.

13. A coding gain system according to claim 6 wherein the space-time coding function comprises:

18. A method according to claim 17 further comprising performing coding and modulation on each of said M symbol substreams

19. A method according to claim 17 further comprising performing coding and modulation on a primary data stream to produce said input symbol stream prior to performing the demultiplexing stream.

20. A method according to claim 17 wherein performing the space-time coding function comprises:

executing an orthogonal transform to produce M orthogonal outputs each of which is a function of the M substreams;

delaying the M orthogonal outputs to produced M delayed orthogonal outputs such that each of the M delayed orthogonal outputs is a function of a given element of each of the M substreams at a different time.

21. A method according to claim 20 wherein the mth orthogonal output is delayed by m-1 symbol periods, where m=1,...,M.

22. A method according to claim 17 wherein performing the space-time coding function comprises:

delaying by M symbol periods each of the M substreams;

executing an orthogonal transform adapted to produce M orthogonal outputs, with the mth orthogonal output being a function of the M substreams delayed m-1 symbol periods.

delay elements adapted to insert a delay of M symbol periods in each of the M substreams;

an orthogonal transform adapted to produce M orthogonal outputs, with the mth orthogonal output being a function of the M substreams delayed in said delay elements by m-1 symbol periods.

14. A coding gain system according to claim 13 wherein the M substreams are bit streams, and wherein the orthogonal transform comprises M 2^M M-ary mapping functions, each adapted to produce a respective sequence of M-ary symbols with the M-ary symbol of the mth 2^M M-ary mapping function being a function of the M substreams delayed in said delay elements by m-1 bit periods.

15. A coding gain system according to claim 6 wherein the M symbol substreams are bit streams.

16. A coding gain system according to claim 6 further comprising encoder/modulator functionality integrated with the space-time coding function.

17. A coding method comprising

demultiplexing an input symbol stream into M symbol substreams;

performing a space-time coding function adapted to produce M space-time coded streams from the M symbol substreams, with each symbol of the M symbol substreams being represented in all M space-time coded streams and at different times;

transmitting the M space-time coded streams on respective antennas.

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23. A method according to claim 20 wherein the M substreams are bit streams, and wherein the orthogonal transform comprises M 2^M M-ary mapping functions, each adapted to produce a respective sequence of M-ary symbols with the M-ary symbol of the mth 2^M M-ary mapping function being a function of the M substreams delayed in said delay elements by m-1 bit periods.

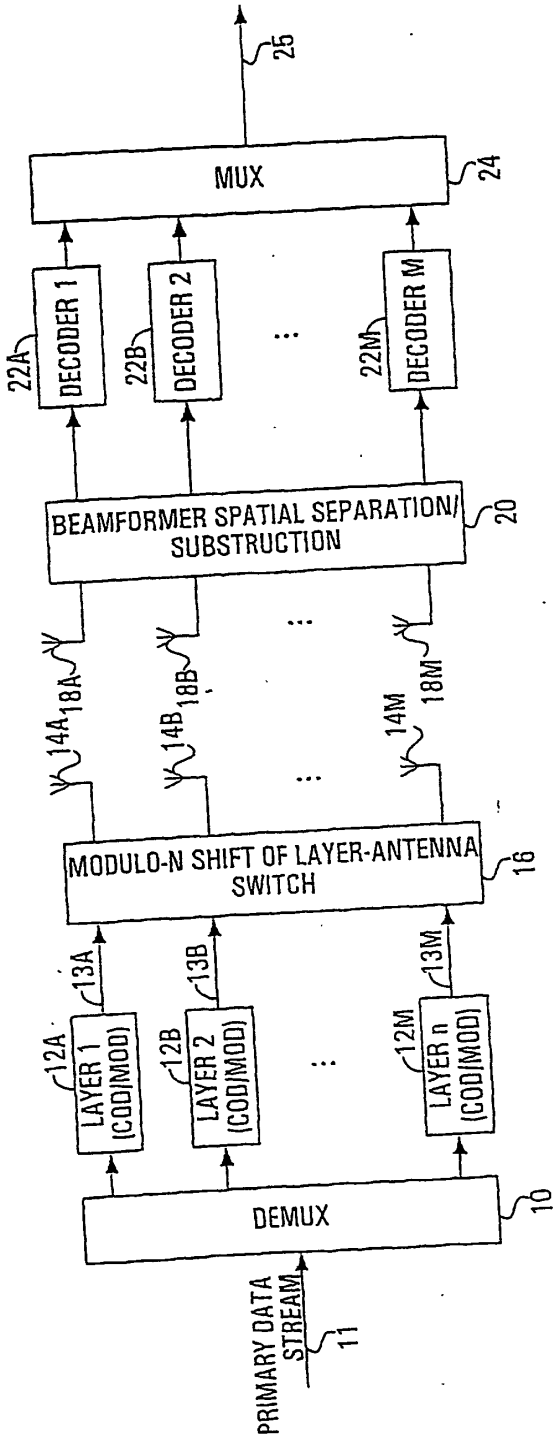


FIG. 1
PRIOR ART

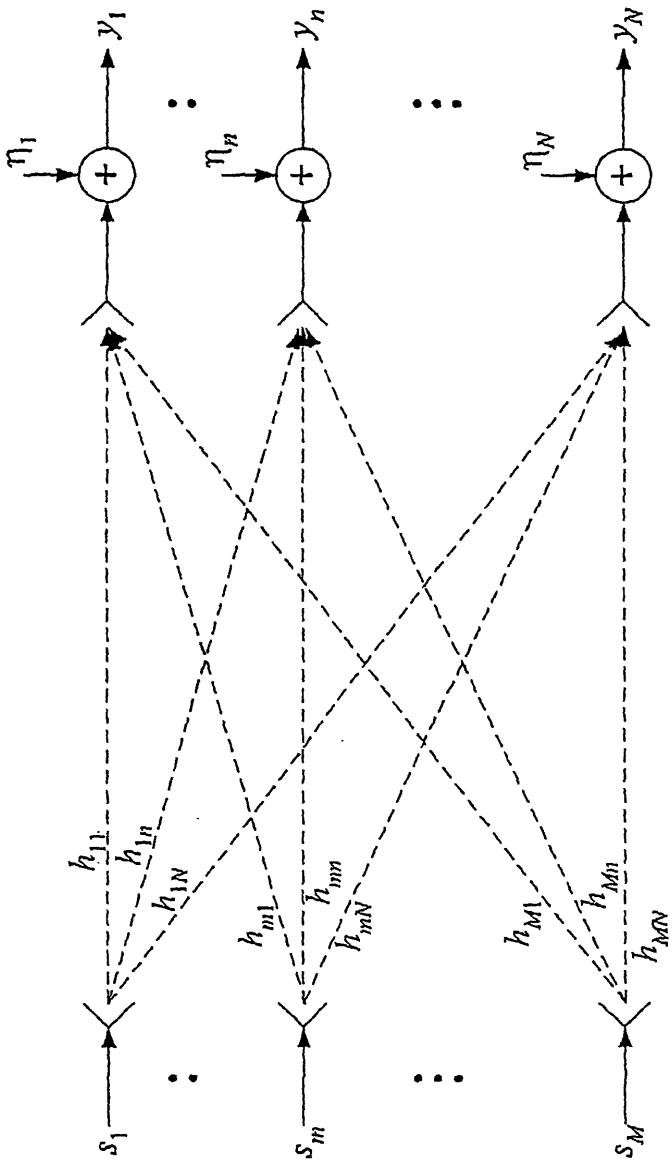

y_1
y_n
y_N
η_1
η_n
η_N
h_{11}
h_{1n}
h_{1N}
h_{m1}
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h_{M1}
h_{Mn}
h_{MN}
s_1
s_m
s_M

FIG. 2

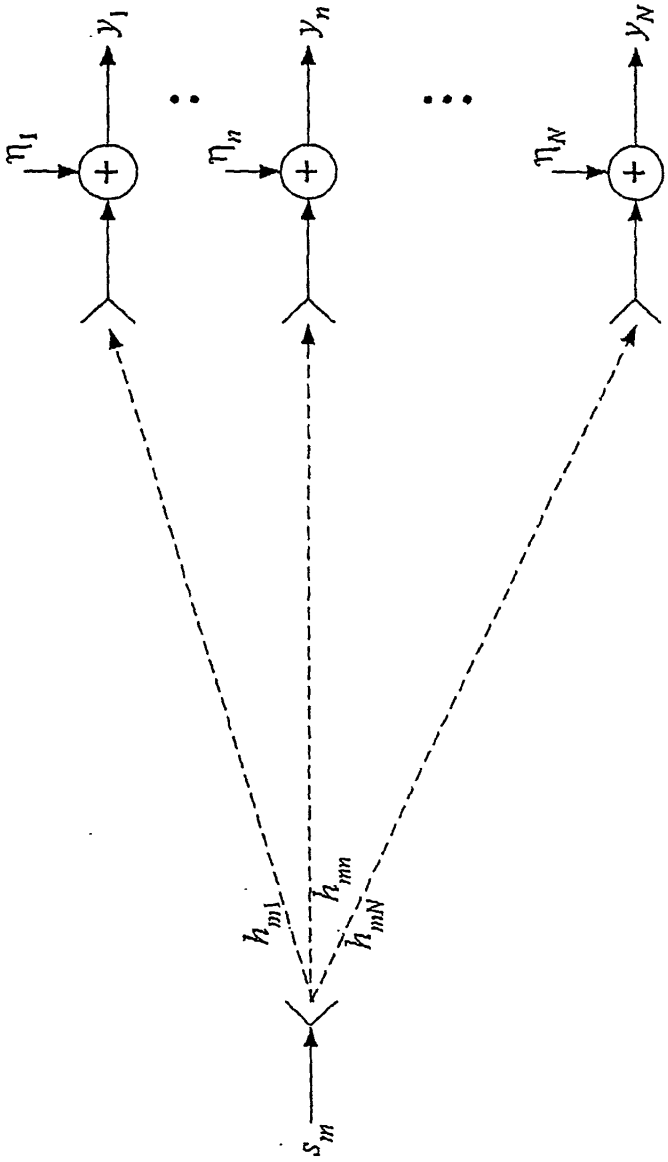


FIG. 3

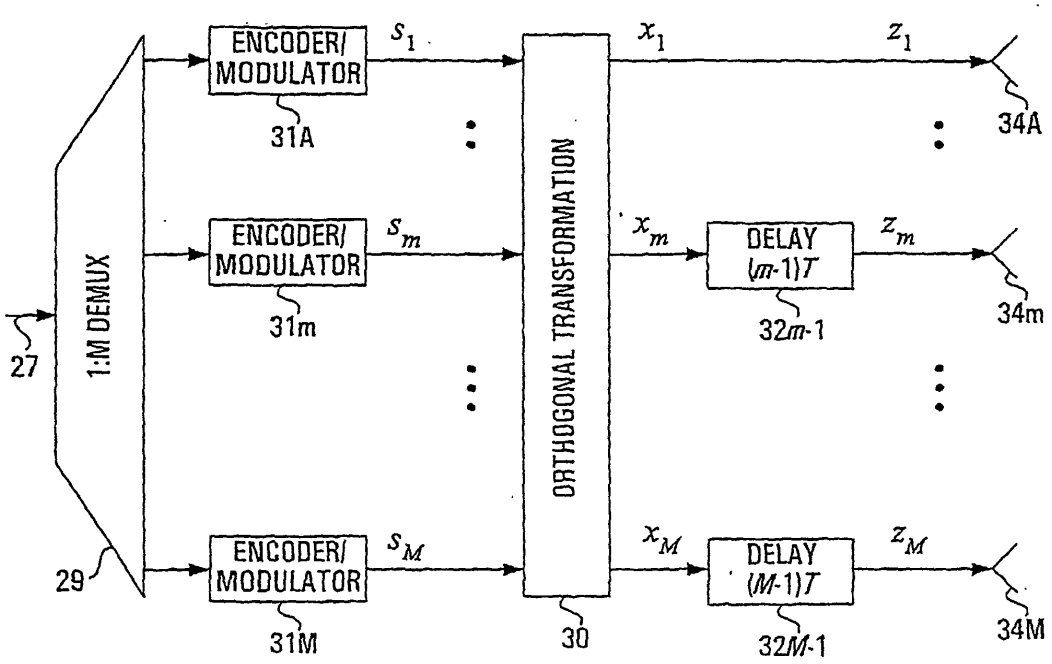

ENCODER/ MODULATOR
31A
ENCODER/ MODULATOR
31m
ENCODER/ MODULATOR
31M
1:M DEMUX
27
29
ORTHOGONAL TRANSFORMATION
30
DELAY (m-1)T
32m-1
DELAY (M-1)T
32M-1
34A
34m
34M

FIG. 4

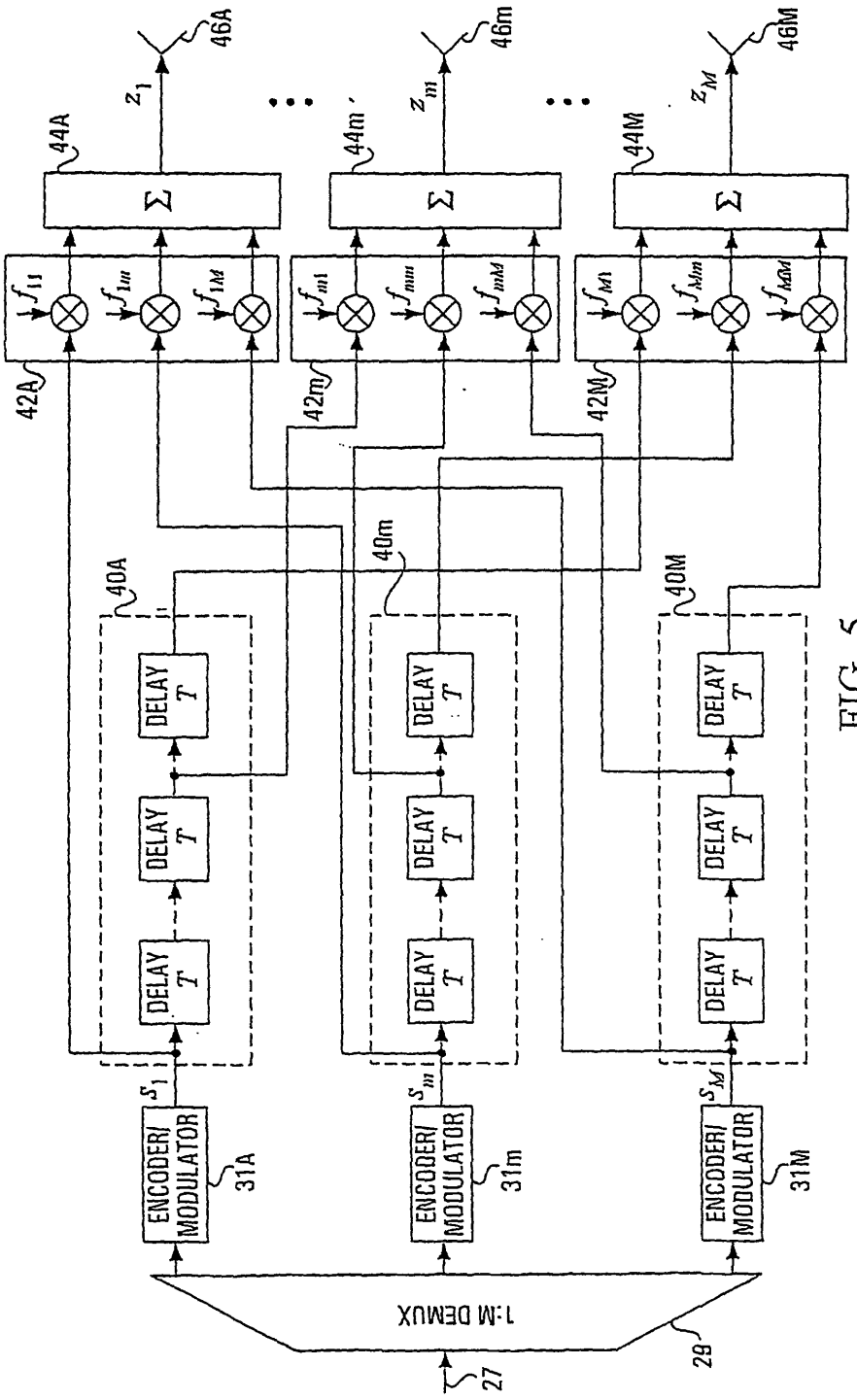

46A
46m
46M
z_1
z_m
z_M
44A
44m
44M
Σ
f_{11}
f_{1m}
f_{1M}
f_{m1}
f_{mm}
f_{mM}
f_{M1}
f_{Mm}
f_{MM}
42A
42m
42M
40A
40m
40M
DELAY T
S_1
S_m
S_M
ENCODER/ MODULATOR
31A
31m
31M
1:M DEMUX
27
29

FIG. 5

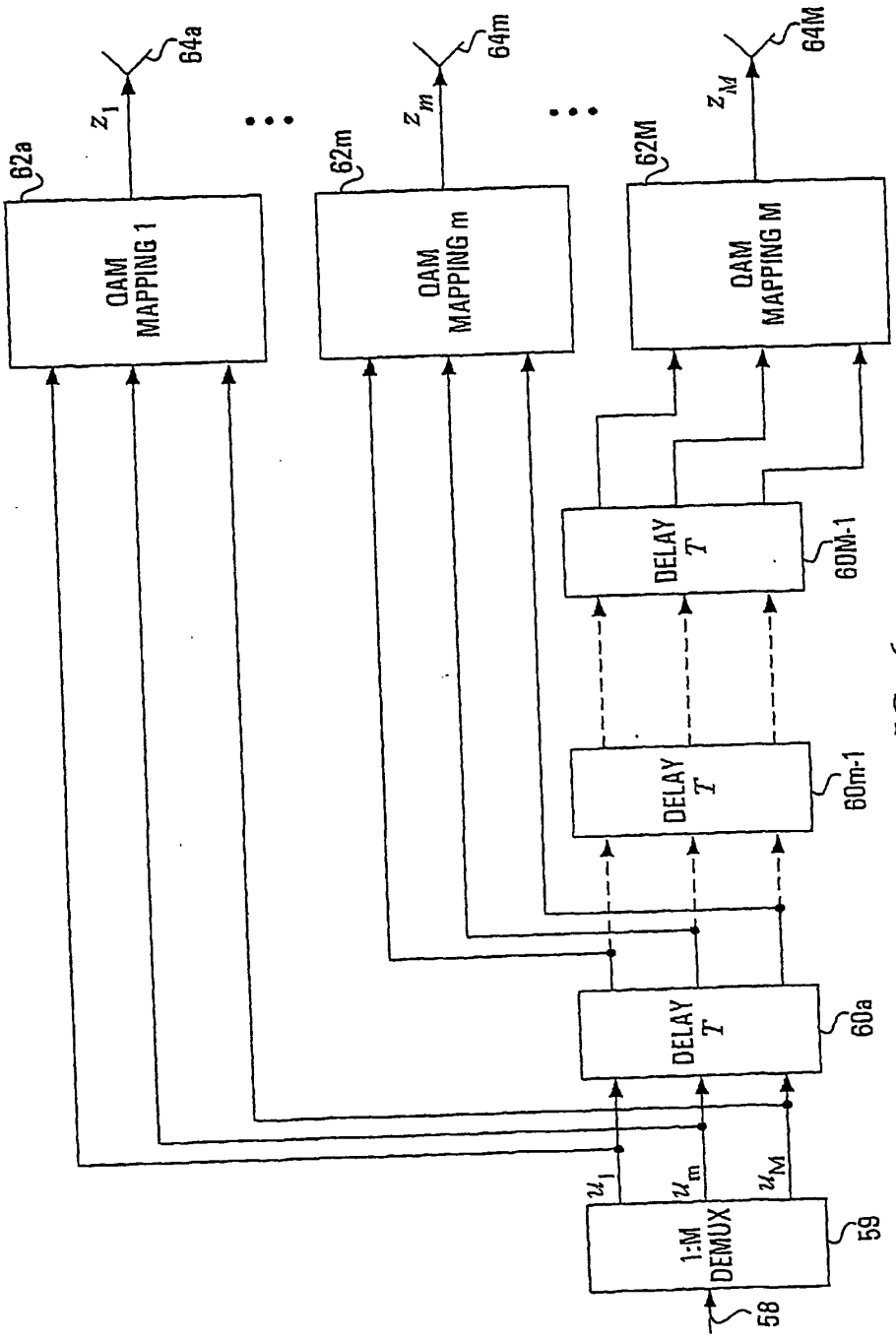

64a
64m
64M
z_1
z_m
z_M
62a
62m
62M
QAM MAPPING 1
QAM MAPPING m
QAM MAPPING M
DELAY T
60M-1
DELAY T
60m-1
DELAY T
60a
u_1
u_m
u_M
1:M DEMUX
59
58

FIG. 6

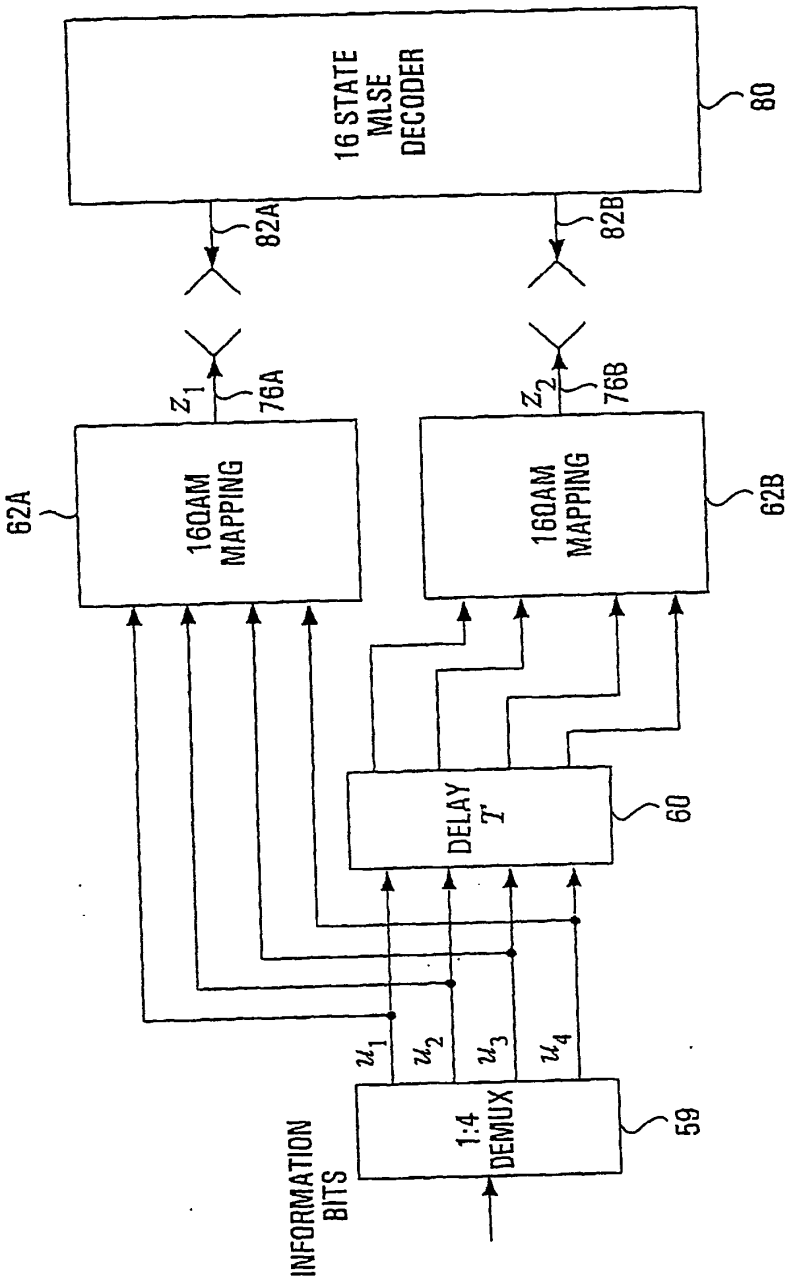

16 STATE MLSE DECODER
80
82A
82B
z_1
76A
z_2
76B
62A
16QAM MAPPING
16QAM MAPPING
62B
DELAY T
60
u_1
u_2
u_3
u_4
1:4 DEMUX
59
INFORMATION BITS

FIG. 7

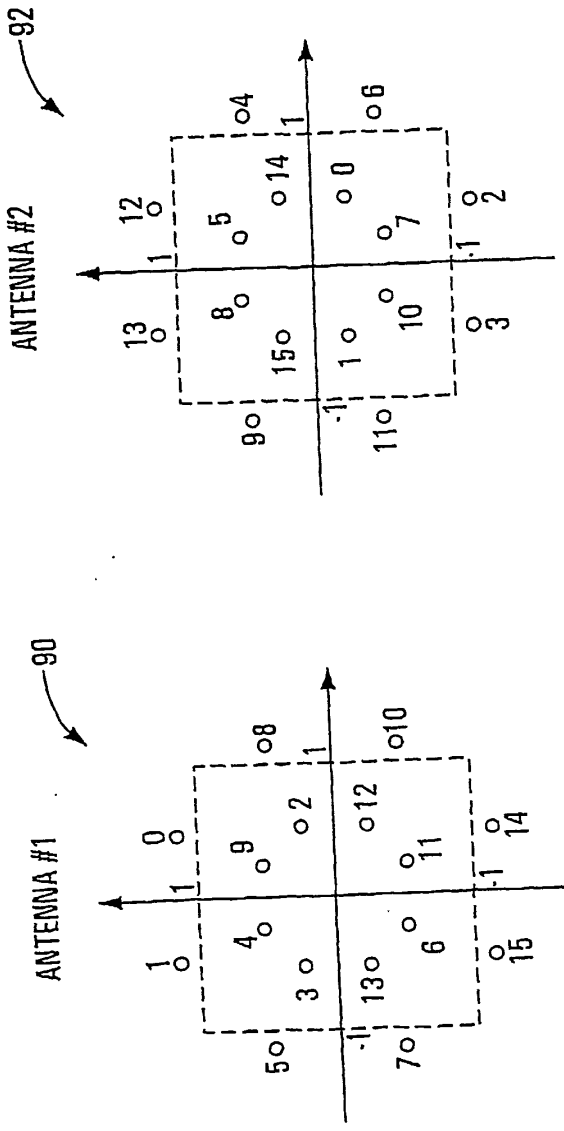


FIG. 8

INTERNATIONAL SEARCH REPORT

International Application No
PCT/RU [redacted]0426

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04L1/06

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)
IPC 7 H04L

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 practical, search terms used)
PAJ, WPI Data, EPO-Internal, INSPEC, COMPENDEX

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	HOCHWALD, MARZETTA: "Space-time modulation for unknown fading" PROCEEDINGS OF THE SPIE, vol. 57, no. 8, April 1999 (1999-04), pages 10-19, XP000914262 Bellingham, US abstract	1-5
X	YUMIN ZHANG & R. BLUM: "Multistage multiuser detection for CDMA with space-time coding" IEEE WORKSHOP ON STATISTICAL SIGNAL AND ARRAY PROCESSING, 14 - 16 August 2000, pages 1-5, XP002174378 Piscataway, US ISBN: 0-7803-5988-7 page 1, left-hand column, paragraph 1	1-5

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"P" document published prior to the international filing date but later than the priority date claimed

"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

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"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.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
2 January 2002	23. 01. 2002

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax (+31-70) 340-3016	Scriven, P

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/RU [redacted]00426

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	BEN LU &: "Iterative receivers for multiuser space-time coding systems" IEEE INTERNATIONAL CONFERENCE ON COMMUNICATIONS, 18 - 22 June 2000, pages 302-306, XP002174379 Piscataway, US page 302, left-hand column, paragraph 1	1-5
X	EP 0 905 920 A (LUCENT) 31 March 1999 (1999-03-31) page 6, line 34 - line 36; figure 3	6-23
X	EP 0 993 130 A (TEXAS INSTRUMENTS) 12 April 2000 (2000-04-12) figure 2	6-23

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

INTERNATIONAL SEARCH REPORT

national application No.
PCT/RU 00/00426

Box I Observations where certain claims were found unsearchable (Continuation f item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☒ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☒ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. Claims: 1-5

   Combined space-time coding and spatial multiplexing

2. Claims: 6-23

   Space-time coding with mixing of substreams

INTERNATIONAL SEARCH REPORT

Information [redacted]ent family members

International Application No
PCT/RU [redacted]0426

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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		CA 2247618 A1	26-03-1999
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		JP 11168453 A	22-06-1999
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		JP 2000138623 A	16-05-2000

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(71) Applicant: **LUCENT TECHNOLOGIES INC.**
Murray Hill, New Jersey 07974-0636 (US)

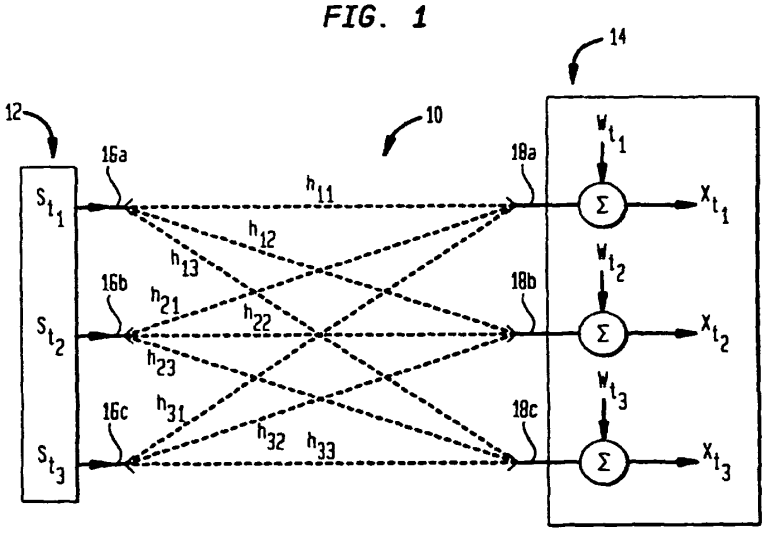
(72) Inventors:
- **Hochwald, Bertrand M.**
  Summit, New Jersey 07901 (US)
- **Marzetta, Thomas Louis**
  Summit, New Jersey 07901 (US)

(74) Representative:
Buckley, Christopher Simon Thirsk et al
Lucent Technologies (UK) Ltd,
5 Mornington Road
Woodford Green, Essex IG8 0TU (GB)

(54) Multiple antenna communication system and method thereof

(57) A communications system achieves high bit rates over an actual communications channel between M transmitter antennas (16a-16c) of a first unit (12) and N receiver antennas (18a-18c) of a second unit (14), where M or N>1, by creating virtual sub-channels from the actual communications channel. The multiple antenna system creates the virtual sub-channels from the actual communications channel by using propagation information characterizing the actual communications channel at the first and second units. For transmissions from the first unit (12) to the second unit (14), the first unit sends a virtual transmitted signal over at least a subset of the virtual sub-channels using at least a portion of the propagation information. The second unit retrieves a corresponding virtual received signal from the same set of virtual sub-channels using at least another portion of said propagation information.

FIG. 1



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BACKGROUND OF THE INVENTION

1. Field of Th Invention

[0001] This invention relates to wireless communication systems and, more particularly, to a multiple antenna communication system.

2. Description of Related Art

[0002] The ultimate bit rate at which a digital wireless communication system may communicate data may be derived using Shannon's approach to information theory (commonly referred to as the Shannon limit). The ultimate bit rate is based on a number of different parameters, including: the total radiated power at the transmitter; the number of antennas at the transmitter and receiver; bandwidth; noise power at the receiver; and the characteristics of the propagation environment. For wireless transmission using multiple antennas at the transmitter and/or receiver in a so-called Rayleigh fading environment, the ultimate bit rate could be enormous, for example, hundreds of bits per second per Hz for a system employing 30 antennas at both the transmitter and receiver and experiencing an average signal-to-noise ratio of 16dB.

[0003] A need exists for a wireless communications system which achieves high bit rates in a cost effective and relatively simple manner.

SUMMARY OF THE INVENTION

[0004] The present invention involves a communications system that achieves high bit rates over an actual communications channel between M transmitter antennas of a first unit and N receiver antennas of a second unit, where M or N >1, by creating virtual sub-channels from the actual communications channel. The multiple antenna system creates the virtual sub-channels from the actual communications channel by using at the first and second units propagation information characterizing the actual communications channel. For transmissions from the first unit to the second unit, the first unit sends a virtual transmitted signal over at least a subset of the virtual sub-channels using at least a portion of the propagation information. The second unit retrieves a corresponding virtual received signal from the same set of virtual sub-channels using at least another portion of said propagation information.

[0005] In general, a propagation matrix of propagation coefficients characterizes the propagation of communication signals between the transmitting antenna(s) of the first unit and the receiving antenna(s) of the second unit. By knowing the propagation characteristics of the actual communications channel (multiple-antenna channel), the multiple antenna system can decompose the actual communications channel into multiple virtual sub-channels. For transmissions from the first unit to the second unit, both the first unit and the second unit obtain propagation information which characterizes the transmissions from the first unit to the second unit. In certain embodiments, the first unit obtains at least a portion of the propagation information, and the second unit obtains at least another portion of the propagation information. Using the respective portions of the propagation information, the first and second units cooperatively render the actual communications channel into virtual sub-channels, thereby achieving high bit rate or throughput in a relatively simple manner.

[0006] In certain embodiments, the first and second units obtain the propagation matrix as the propagation information for transmissions from the first unit to the second unit. Initially, the first unit and second units obtain the propagation matrix by an exchange of signals. For example, the first unit transmits training signals to the second unit. From the training signals as transmitted and the training signals as received over the actual communications channel, the propagation matrix can be determined. Once the propagation matrix is determined, each unit can perform a singular value decomposition of the propagation matrix. The singular value decomposition of the propagation matrix yields the propagation matrix as the product of three factors D, Φ and $\psi^{\dagger}$, where D is a diagonal matrix and Φ and $\psi^{\dagger}$ are two unitary matrices with the superscript "†"denoting a conjugate transpose. The singular value decomposition serves to diagonalize the propagation matrix. The number of nonzero diagonal elements in the diagonal matrix D corresponds to the number of parallel independent virtual sub-channels for the actual communications channel. In some embodiments, for transmissions from the first unit to the second unit, the first unit obtains at least a portion of the propagation information which includes the diagonal matrix D and the unitary matrix Φ. The first unit provides the diagonal matrix D to a channel coder/modulator to encode and modulate an incoming bit or information stream onto the independent virtual sub-channels according to the values of the diagonal matrix D to produce a virtual transmitted signal. As such the diagonal matrix D can provide relative scaling of the bit rate. The first unit then performs a unitary transformation on the virtual transmitted signal by multiplying the virtual transmitted signal with the conjugate transpose of the unitary

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matrix Φ to produce the actual transmitted signal.

[0007] The second unit obtains at least another portion of the propagation information which includes the unitary matrix $\psi^{\dagger}$ and the diagonal matrix D in certain embodiments. The second unit performs a unitary transformation on the actual received signal by multiplying the actual received signal with the unitary matrix ψ to produce a virtual received signal. The multiplications at the first and second units by the unitary matrices establish a virtual channel from the actual communications channel between the virtual transmitted signal and the virtual received signal which can be treated as parallel independent virtual sub-channels. The second unit provides the diagonal matrix D to a channel decoder/demodulator to decode and demodulate the virtual received signal according to the matrix D to produce an information stream. Thus, the multiple antenna system provides high capacity by effectively providing parallel independent sub-channels within the same frequency band. The multiple antenna system also provides enhanced performance because the multiple antenna system transmits bits on the virtual sub-channels relative to the values of the diagonal matrix D, thereby the stronger virtual sub-channels are used to transmit more information.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] Other aspects and advantages of the present invention may become apparent upon reading the following detailed description and upon reference to the drawings in which:

FIG. 1 shows a baseband representation of a multiple antenna channel or the actual communications channel used according to the principles of the present invention;
FIG. 2 shows a baseband representation of the virtual sub-channels derived from the actual communications channel according to certain principles of the present invention;
FIG. 3 shows a block diagram of an embodiment of the multiple antenna system according to the principles of the present invention;
FIG. 4 shows a block diagram of an embodiment of a multiple antenna transmitter according to certain principles of the present invention; and
FIG. 5 shows a block diagram of a particular embodiment of the transmit circuitry for the transmitter of FIG. 4;
FIG. 6 shows a block diagram of an embodiment of a multiple antenna receiver according to certain principles of the present invention; and
FIG. 7 shows a block diagram of an embodiment of the receive circuitry of the receiver of FIG. 6.

DETAILED DESCRIPTION OF THE DRAWINGS

[0009] An illustrative embodiment of the multiple antenna communication system according to the principles of the present invention is described below as the multiple antenna communication system might be implemented to provide high bit rate and enhanced performance. The multiple antenna system accomplishes this by using multiple antenna arrays at the transmitter and/or receiver and taking advantage of the propagation characteristics obtained for the multiple-antenna channel between the antenna(s) of a first unit and the antenna(s) of a second unit. By knowing certain propagation characteristics of the actual communications channel (multiple-antenna channel) at the first unit and the second unit, the multiple antenna system can achieve high bit rates by having the first unit and second unit cooperatively decompose the actual communications channel into multiple virtual sub-channels. For transmissions from the first unit to the second unit, the first and second units obtain at least respective portions of the propagation information characterizing the transmissions from the first unit to the second unit. The first and second units use at least their respective portions of the propagation information to decompose the actual communications channel into multiple virtual sub-channels over which communication signals are transmitted. As such, the multiple antenna communication system achieves high bit rates in a relatively simple manner without increasing total power or bandwidth by using the virtual sub-channels within the same frequency band. Additionally, the multiple antenna system provides enhanced performance by transmitting more bits over the stronger sub-channels as determined by the propagation information.

[0010] FIG. 1 shows a baseband representation for an actual communications channel 10 over which a first unit 12 transmits the RF signals corresponding to the components s_{t1}, s_{t2} and s_{t3} of an actual transmitted signal on carriers of the same frequency over respective multiple antennas 16a-c to a second unit 14. In this particular embodiment, the first unit 12 has three antennas 16a-c, and the second unit 14 has three antennas 18a-c. The second unit 14 receives the RF signals at the respective receive antennas 18a-c corresponding to the components x_{t1}, x_{t2} and x_{t3} of the actual received signal. Each receive antenna 18a-c responds to each transmit antenna 16a-c through a complex-valued, scalar propagation coefficient h_{mn}, where m designates the respective transmit antenna 16a-c and n designates the respective receive antenna 18a-c. As such, the actual received signal x_{t1}, x_{t2} and x_{t3} can be characterized by the following:

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$$X_{t1} = h_{11} \times s_{t1} + h_{21} \times s_{t2} + h_{31} \times s_{t3} + w_{t1}$$

$$x_{t2} = h_{12} \times s_{t1} + h_{22} \times s_{t2} + h_{32} \times s_{t3} + w_{t2}$$

$$x_{t3} = h_{13} \times s_{t1} + h_{23} \times s_{t2} + h_{33} \times s_{t3} + w_{t3},$$

where $\{w_{t1}, w_{t2}, w_{t3}\}$ are receiver noise added at the second unit 14. In vector notation, $\underline{x}_t = \underline{s}_t \times H + \underline{w}_t$ where $\underline{x}_t = [x_{t1}, x_{t2}, x_{t3}]$, $\underline{s}_t = [s_{t1}, s_{t2}, s_{t3}]$, $\underline{w}_t = [w_{t1}, w_{t2}, w_{t3}]$, and the propagation matrix can be represented as:

H =	h11	h12	h13
	h21	h22	h23
	h31	h32	h33.

[0011] In this particular embodiment, the second unit 14 can transmit signals in the reverse direction to the first unit 12. The second unit 14 can use its receive antennas 18a-c to transmit the signals, and the first unit 12 can use its transmit antennas 16a-c to receive the signals. If the same frequency is used in both directions (using a time division duplex (TDD) scheme in certain bi-directional communications embodiments), the propagation coefficients for transmissions from the second unit 14 to the first unit 12 can be considered equal to the propagation coefficients for transmissions from the first unit 12 to the second unit 14 (according to the reciprocity principle), so $H_{2to1} = H^{T}_{1to2}$, where the superscript "T" denotes the transpose. If different frequencies are used in both directions (using a frequency division duplex scheme), the propagation coefficients for the signals propagating in both directions are determined. Using an appropriate training and set-up scheme, the first unit 12 and the second unit 14 can both learn the first unit 12 to second unit 14 propagation coefficients and the second unit 14 to first unit 12 propagation coefficients. For example, the units 12 and 14 could transmit known training signals over one antenna at a time and/or transmit training signals using orthogonal signals transmitted simultaneously over all respective antennas.

[0012] For ease of discussion, the multiple antenna scheme according to the principles of the present invention is discussed with particular reference to transmissions from the first unit 12 to the second unit 14. It should be understood that the multiple antenna scheme can be applied to both uni-directional or bi-directional communications. In this particular embodiment, both units 12 and 14 perform a singular value decomposition (SVD) of the 3 × 3 propagation matrix H obtained by both units 12 and 14. In this particular embodiment, the SVD of H yields $H = \Phi \times D \times \psi^{\dagger}$, where D is a 3 × 3 real-valued, nonnegative, diagonal matrix,

D=	d11	0	0
	0	d22	0
	0	0	d33,

and Φ and $\psi^{\dagger}$ are 3 × 3 complex unitary matrices with the superscript "†" denoting the "conjugate transpose." The columns of a unitary matrix have unit length and are mutually orthogonal. Multiplying a vector by a unitary matrix does not change the length of the vector but merely changes the direction of the vector. The inverse of a unitary matrix is equal to the conjugate transpose of the matrix, for example, $\Phi^{\dagger} \times \Phi = I$ or for 1= 1 to 3, $\Sigma\, \Phi_{li}^{*} \times \Phi_{lj}$ is equal to 1 if i=j and is equal to 0, if i≠j, where the superscript "*" denotes the "complex-conjugate."

[0013] The second unit 14 uses the matrix ψ to multiply the received signal $\underline{x}_t$ by the 3 × 3 unitary matrix ψ to obtain $\underline{r}_t = [r_{t1}, r_{t2}, r_{t3}] = \underline{x}_t \times \psi$. The first unit 12 uses the matrix Φ to transform the virtual transmitted signal $\underline{y}_t$ into the actual transmitted signal $\underline{s}_t$ by letting the actual transmitted signal $\underline{s}_t$ be equal to the conjugate transpose of the 3 × 3 unitary matrix Φ times the virtual transmitted signal $\underline{y}_t$, $\underline{s}_t = \underline{y}_t \times \Phi^{\dagger}$ where $\underline{y}_t = [y_{t1}, y_{t2}, y_{t3}]$. The multiplications by the unitary matrices are invertible operations, so there is no loss of information. In effect, a link is established between the virtual transmitted signal $\underline{y}_t$ and the virtual received signal $\underline{r}_t$, where

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$$\underline{r}_i = \underline{x}_i \times \psi \quad = (\underline{s}_i \times H + \underline{w}_i) \times \psi$$
$$= (\underline{y}_i \times \Phi^{\dagger} \times H + \underline{w}_i) \times \psi$$
$$= \underline{y}_i \times \Phi^{\dagger} \times H \times \psi + \underline{w}_i \times \psi.$$

Substituting $H = \Phi \times D \times \psi^{\dagger}$ in the above expression gives:

$$\underline{r}_i = \underline{y}_i \times \Phi^{\dagger} \times (\Phi \times D \times \psi^{\dagger})\, \psi + \underline{w}_i \times \psi$$
$$= \underline{y}_i \times D + \underline{v}_i, \text{ where } \underline{v}_i = \underline{w}_i \times \psi.$$

Thus, the original link 10 between $\underline{s}_i$ and $\underline{x}_i$ is equivalent to a much simpler virtual link 20 between $\underline{y}_i$ and $\underline{r}_i$ as shown in FIG. 2. In the actual communications channel, every one of the N receiver antennas responds to every one of the M transmitter antennas. The advantage of the virtual link or channel 10 is that it comprises virtual sub-channels, wherein each of a plurality of virtual receiver antennas responds to exactly one respective virtual transmitter antenna. In effect, the cross-coupled actual communications channel 10 of FIG. 1 can be treated as the three parallel, independent virtual sub-channels d_{11}, d_{22} and d_{33} shown in FIG. 2 according to the principles of the present invention.

[0014] The first and second units 12 and 14 can determine the respective propagation information needed to establish the virtual sub-channels between the first unit 12 and the second unit 14 in alternative ways. For example, since the matrix $HH^{\dagger} = \Phi \times D \times D^{\dagger} \times \Phi^{\dagger}$, the first unit 12 and/or the second unit 14 can determine the unitary matrix $\Phi^{\dagger}$ from the eigenvectors of the matrix $HH^{\dagger}$ and the diagonal matrix D from the eigenvalues of $HH^{\dagger}$. Additionally, since $H^{\dagger}H = \psi \times D^{\dagger} \times D \times \psi^{\dagger}$, the first unit 12 and/or the second unit 14 can determine the unitary matrix ψ from the eigenvectors of $H^{\dagger}H$ and the diagonal matrix D from the eigenvalues of $H^{\dagger}H$. The diagonal matrix can be determined by using the squareroots of the eigenvalues of $HH^{\dagger}$ or $H^{\dagger}H$.

[0015] FIG. 3 shows an embodiment of the multiple antenna communication system 10 according to certain principles of the present invention for transmissions between the first unit 12 and the second unit 14. In this particular embodiment, the first unit 12 is shown as transmitting, and the second unit 14 is shown as receiving. For transmissions in the reverse direction, the first unit 12 would typically include receiver components (not shown) as will be described below for the second unit 14, and the second unit 14 would typically include transmitter components (not shown) as described below for the first unit 12. In accordance with certain embodiments of the present invention, the first unit 12 uses the multiple antenna array 16 for transmitting and receiving communication signals, and the second unit 14 use the multiple antenna array 18 for transmitting and receiving communication signals.

[0016] In this particular embodiment for transmissions from the first unit 12 to the second unit 14, the propagation of the signals over the actual communications channel 10 has a baseband characterization that comprises a matrix of complex-valued (having real and imaginary parts) propagation coefficients between the transmitting antennas 16a-c and the receiving antennas 18a-c. In this particular embodiment, the first unit 12 and the second unit 14 learn the values of the propagation matrix and determine the appropriate propagation information to establish the virtual sub-channels between the first unit 12 and the second unit 14. Alternatively, the first unit 12 and/or the second unit 14 do not learn the propagation matrix. Instead, the units 12 and 14 obtain and/or determine some portion of the propagation information, such as the diagonal matrix D, and the first unit 12 obtains and/or determines other propagation information, such as the unitary matrix $\Phi^{\dagger}$ while the second unit 14 obtains and/or determines the unitary matrix ψ.

[0017] To learn the propagation matrix (or derive the appropriate propagation information for certain embodiments) for communications from the first unit 12 to the second unit 14, the first unit 12 can send training signals to the unit 14 from which the unit 14 determines or estimates the propagation matrix (or propagation information). The unit 14 can then send the propagation matrix (or propagation information) to the unit 12 by using a conventional communication scheme employing one or multiple antennas at the first and second units 12 and 14. Alternatively, the unit 14 can send the propagation matrix (or propagation information) to the unit 12 using other communication links, such as a phone line. Additionally, the unit 14 can simply send back to the unit 12 the training signals received from the unit 12, and the unit 12 determines the propagation matrix (or propagation information). The unit 12 then sends the propagation matrix (or propagation information) to the unit 14.

[0018] Likewise, to learn the propagation matrix (or propagation information) for signals propagating from the unit 14 to the unit 12, the unit 14 sends training signals to the unit 12 from which the unit 12 determines or estimates the propagation matrix (or propagation information). Once again, as discussed for determining the propagation matrix (or

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propagation information) for transmissions from the unit 12 to the unit 14, the unit 12 can provide and/or derive different forms or amounts of propagation information to the unit 14 depending on the particular embodiment and using different communication schemes.

[0019] Two-way transmissions between the unit 12 and the unit 14 can be accomplished using a variety of schemes, such as time division duplex (TDD) or frequency division duplex (FDD). TDD has the advantage that the channel characteristics for signals propagating from the first unit 12 to the second unit 14 are generally the same as the channel characteristics for signals propagating from the second unit 14 to the second station 12. In the case of TDD, both units 12 and 14 occupy the same frequency band. As such, the propagation matrix for transmissions from the first unit 12 to the second unit 14 are considered transposes of each other due to the principle of reciprocity as described in D.S. Jones, "Acoustic and Electromagnetic Waves," Oxford University Press, 1989, pp. 63-64 and no further exchange of training signals is required (although updates to the propagation matrix or to propagation information can be performed). In FDD for certain embodiments, the second unit 14 transmits to the first unit 12 the propagation matrix (or propagation information) for transmissions from the first unit 12 to the second unit 14. Additionally, after the appropriate set-up or training scheme is performed for transmissions from the second unit 14 to the first unit 12, the first unit 12 can transmit to the second unit 14 the propagation matrix (or propagation information) for transmissions from the second unit 14 to the first unit 12.

[0020] With particular reference to FIG. 3, since the first and second units 12 and 14 know the propagation matrix (or propagation information which can be derived from the propagation matrix or propagation information which can be used to derive the propagation matrix or other propagation information), the units 12 and 14 can effectively decompose the complicated multiple-antenna channel 10 into multiple independent virtual sub-channels using the propagation matrix (or respective propagation information). In this particular embodiment, the units 12 and 14 derive the multiple virtual sub-channels from the multiple-antenna channel 10 by using propagation information derived from a singular value decomposition of the propagation matrix. After learning the propagation matrix for transmissions from the first unit 12 to the second unit 14, the first unit 12 provides the propagation matrix H to a singular value decomposition block 22. The singular value decomposition 22 performs a singular value decomposition of the propagation matrix H which produces some propagation information, including the diagonal matrix D and two unitary matrices Φ and $\psi^{\dagger}$ where the superscript † denotes a conjugate transpose. The number of nonzero diagonal elements in the matrix D represents the number of parallel independent virtual sub-channels.

[0021] For transmissions from the first unit 12 to the second unit 14 in this particular embodiment, the first unit 12 provides the diagonal matrix D to a channel coder/modulator 24 to encode and modulate an incoming information stream from an information source 28. The channel coder/modulator 24 encodes and modulates the information stream to form a plurality of sub-information streams depending on the nonzero values of the diagonal matrix D to produce the virtual transmitted signal. The virtual transmitted signal can be represented as a vector, the respective components of which are transmitted onto respective virtual sub-channels. In this particular embodiment, a unitary transformation block 30 performs a unitary transformation on the virtual transmitted signal by multiplying the virtual transmitted signal with the conjugate transpose of the unitary matrix Φ. Finally, the first unit 12 uses the results of the unitary transformation 30 to produce the baseband version of the actual transmitted signal.

[0022] In this particular embodiment, the second unit 14 also provides the propagation matrix H to a singular value decomposition 32 and uses the results from the singular value decomposition 32 to perform a unitary transformation 34 on the actual received signal. In this particular embodiment, the unitary transformation block 34 multiplies the actual received signal with the unitary matrix ψ to produce a virtual received signal. In this particular embodiment, the multiplications by the unitary matrices at the unitary transformations 30 and 34 tend not to amplify noise and are invertible operations, so information should not be lost. The multiplications by the unitary matrices establishes a link, which can be treated as parallel independent virtual sub-channels, between the virtual transmitted signal at the first unit 12 and the virtual received signal at the second unit 14. The second unit 14 provides the diagonal matrix D to a channel demodulator/decoder 36 which uses the diagonal matrix D to decode and demodulate the virtual received signal vector to form a single information stream which corresponds to the information stream provided to the channel coder/modulator 24 at the first unit 12. Additionally, the first unit 12 can use the diagonal matrix D to provide enhanced performance by sending more bits on the stronger virtual sub-channels according to the nonzero values of the diagonal matrix. If the amplitude of a nonzero value of the matrix D is below a certain level, the multiple antenna system can advantageously not use the corresponding virtual sub-channel, thereby a subset of the stronger virtual sub-channels can be used. As such, the multiple antenna system achieves higher data rates in a narrow bandwidth by effectively providing parallel independent virtual sub-channels within the same frequency band and enhanced performance.

[0023] FIG. 4 shows a block diagram of a transmitter 40 having the multiple antenna array 16 with three antennas 16a-c for use in any unit 12 or 14 according to the principles of the present invention. For ease of discussion, the transmitter 40 will be described as being included in the unit 12 (FIG. 3) because the multiple-element antenna communication system according to the principles of the present invention has been described in the context of transmissions from the first unit 12 (FIG. 3) to the second unit 14 (FIG. 3). The units 12 and 14 (FIG. 3) in this particular

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embodiment, however, can both transmit and receive signals according to the principles of the present invention. In doing so, the units 12 and 14 exchange training signals to estimate th propagation matrices (or propagation information which can be the actual training signals in certain embodiments) for communications between them. After learning the propagation matrix H for signals propagating from the first unit 12 (FIG. 3) to the second unit 14 (FIG. 3), the transmitter 40 provides the propagation matrix H to the singular value decomposition block 22.

[0024] The singular value decomposition block 22 performs a singular value decomposition of the propagation matrix H (which can be done for any H) to yield $H = \Phi \times D \times \psi^{\dagger}$, where D is a real-valued, non-negative, diagonal matrix and Φ and $\psi^{\dagger}$ are unitary matrices. The number of nonzero diagonal elements is less than or equal to the smaller of the number of antennas 16 at the transmitter 40 and at the second unit 14 (FIG. 3) and represents the number of parallel independent virtual sub-channels that are available within the same frequency band. Additionally, the sizes of the nonzero diagonal elements indicate the relative signal-to-noise ratios of the virtual sub-channels. In accordance with an aspect of the present invention, the transmitter 40 allocates power to the virtual sub-channels depending on the relative signal-to-noise ratios of the sub-channels as determined by the values of the nonzero diagonal elements of the diagonal matrix D. Thus, the better sub-channels can get more transmitter power and carry more data. In accordance with particular embodiments of this aspect of the present invention, the transmitter 40 has a total power restriction and generally allocates power to the different sub-channels to provide a higher, reliable bit rate. In doing so, the transmitter 40 can allocate power to the different subchannels using a version of a Water Pouring algorithm as disclosed by Robert G. Gallager, "Information Theory and Reliable Communication," John Wiley & Sons, 1968, pp. 343-345.

[0025] The transmitter 40 receives information signals from the information source 28, and the information stream is input into a buffer 43. According to certain aspects of the present invention, if all of the non-zero diagonal elements of the diagonal matrix D are equal or relatively similar in this particular embodiment, the channel coder/modulator 24 can direct the first bit of a bit stream 42 from the buffer 43 to encoder/modulator 44a, the second bit of the bit stream 42 to encoder/modulator 44b, and the third bit of the bit stream 42 to encoder/modulator 44c. If the amplitude of the nonzero diagonal value of the matrix D corresponding to a first virtual sub-channel is twice as large as the nonzero diagonal values of the matrix D corresponding to the second and third virtual sub-channels in this particular example, the channel coder/modulator 24 could send the first two bits of the bit stream 42 to the encoder/modulator 44a and the next two bits of the bit stream 42 being split between the encoder/modulator 44b and the encoder/modulator 44c. To combat the effects of noise, the channel coder/modulator 24 can use ordinary error-correcting codes of the types typically used for conventional additive Gaussian noise channels as would be understood by one of ordinary skill in the art in combination with conventional modulation schemes, such as Quadrature Phase Shift Keying (QPSK) modulation.

[0026] In this particular embodiment, the channel coder/modulator 24 produces three signal vector components y_{t1}, y_{t2} and y_{t3} of the virtual transmitted signal. The components of the virtual transmitted signal are digital complex values which can be fixed point or floating point depending on the implementation. The three components y_{t1}, y_{t2} and y_{t3} of the virtual transmitted signal from the encoder/modulators 44a-c are provided to the unitary transformation block 30. The unitary transformation block performs a 3×3 matrix multiplication on the components y_{t1}, y_{t2} and y_{t3} using a unitary matrix $\Phi^{\dagger}$. The result of the unitary transformation 30 is an actual transmitted signal having components s_{t1}, s_{t2} and s_{t3} which are sent to respective transmit circuits 48a-c and converted as necessary to the radio frequency (RF) domain. In this particular embodiment, the transmit circuitry 48a-c modulates the components s_{t1}, s_{t2} and s_{t3} of the actual transmitted signal onto the same carrier and transmits each component s_{t1}, s_{t2} and s_{t3} of the actual transmitted signal over a respective antenna 16a-c.

[0027] FIG. 5 shows a general diagram for an embodiment of the transmit circuitry 48. In this particular embodiment, each components s_{t1}, s_{t2} and s_{t3} of the virtual transmitted signal vector is split into real and imaginary parts by block 50. The real and imaginary parts of each component s_{t1}, s_{t2} and s_{t3} are input to digital-to-analog converters 51. Multipliers 52 multiply the analog real part of each component s_{t1}, s_{t2} and s_{t3} by $\cos\omega_c t$ with ω_c being the carrier frequency (radians/second) and multiply the analog imaginary part of each component s_{t1}, s_{t2} and s_{t3} by $\sin\omega_c t$. Afterward, respective real and imaginary parts of each component s_{t1}, s_{t2} and s_{t3} are added together by summers 53 to produce an RF signal for each component s_{t1}, s_{t2} and s_{t3} on the same carrier frequency ω_c. Each RF signal is then amplified by respective RF power amplifiers 54 and transmitted over respective antennas 16a-c in this particular embodiment. Alternative embodiments for the transmit circuitry 48 are possible.

[0028] FIG. 6 shows a block diagram of a receiver 60 having the multiple antenna array 18 with three antennas 18a-c for use in any unit 12 or 14 (FIG. 3) according to the principles of the present invention. For ease of discussion, the receiver 60 will be described as being included in the second unit 14 (FIG. 3) because the multiple-element antenna communication system according to the principles of the present invention has been described in the context of transmissions from the first unit 12 (FIG. 3) to the second unit 14 (FIG. 3). As mentioned above, the units 12 and 14 (FIG. 3) in this particular embodiment can both transmit and receive signals according to the principles of the present invention.

[0029] As described above for this particular embodiment, the receiver 60 receives training signals from the trans-

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mitter 40 (FIG. 4) and estimates the propagation matrix H for communications from the transmitter 40 (FIG. 4) to the receiver 60. After learning the propagation matrix H for signals propagating from the transmitter 40 (FIG. 4) to the receiver 60, the receiver 60 provides the propagation matrix H to the singular value decomposition block 32. As in the transmitter 40 (FIG. 4), the singular value decomposition block 32 performs a singular value decomposition of the propagation matrix H to yield $H = \Phi \times D \times \psi^{\dagger}$, where D is a real-valued, non-negative, diagonal matrix and Φ and $\psi^{\dagger}$ are 3 × 3 complex unitary matrices with the superscript "†" denoting the "conjugate transpose."

[0030] The receiver 60 receives the signals propagating from the transmitter 40 (FIG. 4) through the multiple antenna array 18, and receiver circuits 62a-c process the signals received from the respective antennas 18a-c down to baseband. In this particular embodiment, the actual received signal vector $\underline{x}_t$ is digitized before being provided to the unitary transformation block 34. The unitary transformation block 34 uses its propagation information derived from the propagation matrix H to multiply the actual received signal $\underline{x}_t$ by the 3 × 3 unitary matrix ψ to obtain a virtual received signal $\underline{r}_t = [r_{t1}, r_{t2}, r_{t3}] = \underline{x}_t \times \psi$. The channel demodulator/decoder 36 receives the virtual received signal $\underline{r}_t$ from the unitary transformation block 34 with respective parallel components r_{t1}, r_{t2} and r_{t3}. The components r_{t1}, r_{t2} and r_{t3} are provided to respective parallel demodulators/decoders 68a-c. The parallel demodulators/decoders 68a-c demodulate and decode the virtual received signal $\underline{r}_t$ according to the modulation and coding scheme used by the transmitter 40 (FIG. 4).

[0031] Using the nonzero diagonal values of the diagonal matrix D from the SVD block 32 and reflecting the use of the matrix D in the transmitter 40 (FIG. 4), the channel demodulator/decoder 36 constructs a single stream 70 of information bits from the parallel components r_{t1}, r_{t2} and r_{t3} of the virtual received signal. As such, the diagonal matrix D used to construct the information stream 70 from the parallel streams 64a-c in the receiver 60 is the same matrix D used to separate the single stream 42 (FIG. 4) into parallel streams 46a-c (FIG. 4) in the transmitter 40 (FIG. 4). The information stream 70 is then output to its destination 38 before which the information stream 70 can pass through additional processing or circuitry 72 which can include a data buffer.

[0032] FIG. 7 shows a general diagram for an embodiment of the receive circuitry 62. In this particular embodiment, the transmitted RF signals from the transmit circuitry 48 (FIG. 5) are received at the antennas 18a-c. The RF signals received at each antenna 18a-c are amplified by respective pre-amplifiers 80. Multipliers 82 multiply the respective RF signals by $\cos\omega_c t$ and $\sin\omega_c t$ with ω_c being the carrier frequency to produce analog versions of the real and imaginary parts of the components of the actual received signal which were modulated onto carriers of the same frequency ω_c. The analog versions of the real and imaginary parts for each component of the actual received signal are low pass filtered by filters 83 and provided to analog-to-digital converters 84 to produce digital versions of the real and imaginary parts of each component. Combiner 86 combine the real and imaginary parts of each component to produce the components x_{t1}, x_{t2} and x_{t3} of the actual received signal as complex digital values. In this particular embodiment as described above, the components x_{t1}, x_{t2} and x_{t3} of the actual received signal are provided to the unitary transformation block 34 (FIG. 6). The receive circuitry 62 is shown as a homodyne receiver, but alternative embodiments for the receive circuitry 62 are possible.

[0033] In accordance with certain embodiments of the present invention, the multiple antenna system updates the propagation matrix or information periodically or continuously as operating conditions change. As such, if an antenna 16 (FIG. 4) or 18 becomes unavailable, the multiple antenna system can update the propagation matrix(ices) or information at the two units 12 and 14, thereby maintaining the communications between the units 12 and 14 and still providing a high bit rate. Additionally, depending on the conditions of the virtual sub-channels (which can be measured by the nonzero diagonal values of the diagonal matrix D), the bit rate between the two units 12 and 14 using the multiple antenna system is scaleable. Accordingly, if the signal-to-noise ratio, virtual sub-channel gain or other measurement value for a virtual sub-channel drops below a certain threshold level and/or a relative level compared to the other sub-channels, the multiple antenna system can either reduce the number of bits transmitted over the virtual sub-channel or drop the virtual sub-channel, thereby reducing the bit rate, until updates of the propagation matrix or information show that the virtual sub-channel has risen above the threshold level and/or the relative level. Furthermore, in similar fashion, the multiple antenna system according to certain principles of the present invention can allocate power to the different virtual sub-channels based on the conditions of the different virtual sub-channels as determined by the nonzero values of the diagonal matrix D or other measurement values corresponding to the virtual sub-channels.

[0034] The multiple antenna system enables an increase in bit rate without an increase in power or bandwidth as compared to single antenna systems. In certain embodiments, the propagation of the signals is modeled as flat fading (no frequency dependence to fading). Additionally, in the event of receiver noise and external interference, the multiple antenna system can use a covariance matrix or the like which characterizes the receiver noise and/or the external interference to effectively alter the propagation information or to include the covariance matrix or the like as part of the propagation information. If the elements of the propagation matrix H are statistically independent, identically distributed, with Rayleigh-distributed magnitude and uniformly distributed phase, the capacity of the channel grows linearly with the smaller of the number of transmitter and receiver antennas. Theoretically, there is no limit to the number of antennas that can be utilized in the multiple antenna system, thereby providing the potential for enormous capacities in a narrow bandwidth. For example, if 170 antennas are used at the transmitter and the receiver in a 30 kHz bandwidth with signal-

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to-noise ratios of 20dB, 20Mb/s of High Definition TV (HDTV) may be sent over the multiple antenna channel after being decomposed to 170 virtual sub-channels according to the principles of the present invention.

[0035] The multiple-element antenna system according to the principles of the present invention can achieve such high bit rates in the narrow bandwidth and in a simple manner by using multiple antennas at both the transmitter and receiver to decompose the multiple antenna channel into multiple independent virtual sub-channels. A pair of units using the multiple antenna system use a distinct band of frequencies for communicating with each other over the multiple-antenna channel. Thus, different pairs of units can be frequency division multiplexed. A pair of units can take a variety of forms, such as units which can handle voice and/or data in a wireless local area network. Additionally, th multiple antenna system can provide security in communications between a pair of units because the propagation information characterizing the actual communications channel between the pair of units is unique to that pair. As such, even if a third party obtained the propagation information for the pair, it would be difficult for the third party to intercept the communications between the pair because the propagation information for an actual communications channels between the third party and each of the pair of units would be different.

[0036] In addition to the embodiments described above, alternative configurations of the multiple antenna system according to the principles of the present invention are possible which omit and/or add components and/or use variations or portions of the described multiple antenna system. For example, the multiple antenna system has been described with three antennas at both the first unit and the second unit to provide three virtual sub-channels, but different numbers of antennas can be employed at the first unit and the second unit. Additionally, the multiple antenna system has been described as being employed in terms of communications over a multiple antenna channel from the first unit to the second unit. The multiple antenna system, however, includes units which transmit and/or receive according to the principles of the present invention. In certain embodiments, the units use the same multiple antennas for both transmission and reception. Alternative embodiments of units employing the multiple antenna system are possible, however, which use a subset of the multiple antennas for transmission and/or reception depending on the number of antennas at the unit on the other end of the multiple antenna channel or upon the values of the diagonal matrix in the reverse direction.

[0037] The above-described multiple antenna system has been described as comprising several components or blocks, but it should be understood that the multiple antenna system and portions thereof can be implemented in application specific integrated circuits, software-driven processing circuitry, or other arrangements of discrete components as would be understood by one of ordinary skill in the art with the benefit of this disclosure. What has been described is merely illustrative of the application of the principles of the present invention. Those skilled in the art will readily recognize that these and various other modifications. arrangements and methods can be made to the present invention without strictly following the exemplary applications illustrated and described herein and without departing from the spirit and scope of the present invention.

Claims

1. A method for transmitting communication signals, said method CHARACTERIZED BY the step of:

   creating virtual sub-channels from an actual communications channel between M transmitter antennas of a first unit and N receiver antennas of a second unit, where M or N >1, by using at said first unit and said second unit propagation information characterizing said actual communications channel; and
   sending by said first unit a virtual transmitted signal over at least a subset of said virtual sub-channels using at least a portion of said propagation information.

2. The method of claim 1 CHARACTERIZED IN THAT said step of sending including the steps of:

   transforming said virtual transmitted signal into an actual transmitted signal using said at least a portion of said propagation information; and
   transmitting said actual transmitted signal over said M transmitter antennas onto said actual communications channel.

3. The method of claim 2 CHARACTERIZED IN THAT said step of transmitting including the step of:
   transmitting each component of said actual transmitted signal using a respective one of said M transmitter antennas.

4. The method of claim 2 CHARACTERIZED BY including the step of:
   producing a unitary matrix from said at least a portion of said propagation information.

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5. The method of claim 4 CHARACTERIZED BY the steps of:

using said unitary matrix to perform a unitary transformation of said virtual transmitted signal into said actual transmitted signal; and
transmitting each component of said actual transmitted signal onto carriers having the same frequency.

6. The method of claim 1 CHARACTERIZED BY the step of:

receiving by the first unit an information stream from an information source; and
separating said information stream into a plurality of signal streams using at least a portion of said propagation information to form said virtual transmitted signal.

7. The method of claim 6 CHARACTERIZED BY the step of:
producing a diagonal matrix D from at least said portion of said propagation information with the nonzero diagonal values corresponding to said virtual sub-channels of said actual communications channel.

8. The method of claim 6 CHARACTERIZED IN THAT said step of separating including the step of:
using values of a diagonal matrix D from at least said portion of said propagation information to separate said information stream into a plurality of signal streams according to said values of said diagonal matrix D.

9. The method of claim 8 CHARACTERIZED BY the step of:
using said values of said diagonal matrix D to allocate power for transmitting each component of said virtual transmitted signal.

10. A method of receiving communication signals, said method CHARACTERIZED BY the steps of:

creating virtual sub-channels from an actual communications channel between M transmitter antennas of a first unit and N receiver antennas of a second unit, where M or N >1, by using at said first unit and said second unit propagation information characterizing said actual communications channel; and
retrieving by said second unit a virtual received signal from at least a subset of said virtual sub-channels using at least a portion of said propagation information.

11. The method of claim 10 CHARACTERIZED IN THAT said step of retrieving including the step of:

receiving an actual received signal from said actual communications channel on said N receiver antennas; and transforming said actual received signal into said virtual received signal using said at least a portion of said propagation information.

12. The method of claim 11 CHARACTERIZED IN THAT said step of retrieving including the step of:
receiving each component of said actual received signal using a respective one of said N receiver antennas.

13. A transmitter for transmitting information signals CHARACTERIZED BY:

a plurality of antennas;
processing circuitry configured to obtain propagation information for an actual communications channel between said plurality of antennas and a plurality of receiver antennas;
a channel coder configured to receive an information signal stream and at least a portion of said propagation information, said channel coder CHARACTERIZED BY configured to separate said information signal stream using said at least a portion of said propagation information to form a virtual transmitted signal of components corresponding to sub-channels of said communications channel;
said processing circuitry CHARACTERIZED BY configured to perform a unitary transformation on said virtual transmitted signal using at least another portion of said propagation information to form an actual transmitted signal; and
transmit circuitry coupled to said plurality of antennas and configured to transmit each component of said actual transmitted signal through a respective one of said plurality of antennas on carriers of the same frequency.

14. A receiver for receiving information signals CHARACTERIZED BY: a plurality of antennas;

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receive circuitry coupled to said plurality of antennas and configured to receive each component of an actual received signal through a respective one of said plurality of antennas;
processing circuitry configured to obtain propagation information for a communications channel between said plurality of antennas and a plurality of transmitter antennas, said processing circuitry CHARACTERIZED BY configured to perform a unitary transformation on said actual received signal using at least a portion of said propagation information to form a virtual received signal; and
a channel decoder configured to receive said virtual received signal and at least another portion of said propagation information, said channel decoder configured to combine said virtual received signal into an information stream using said at least another portion of said propagation information.

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FIG. 1

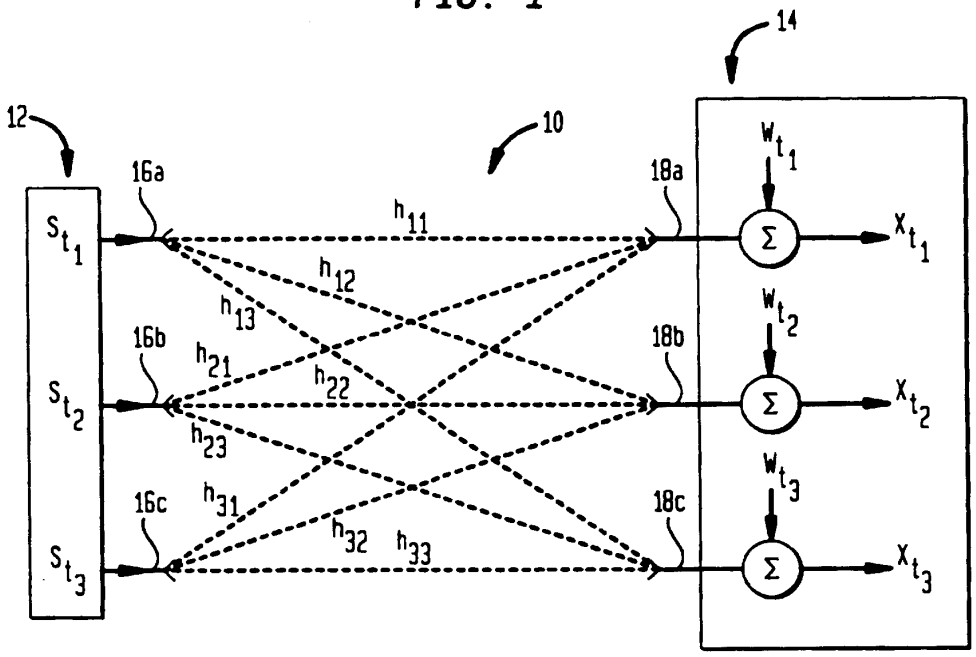
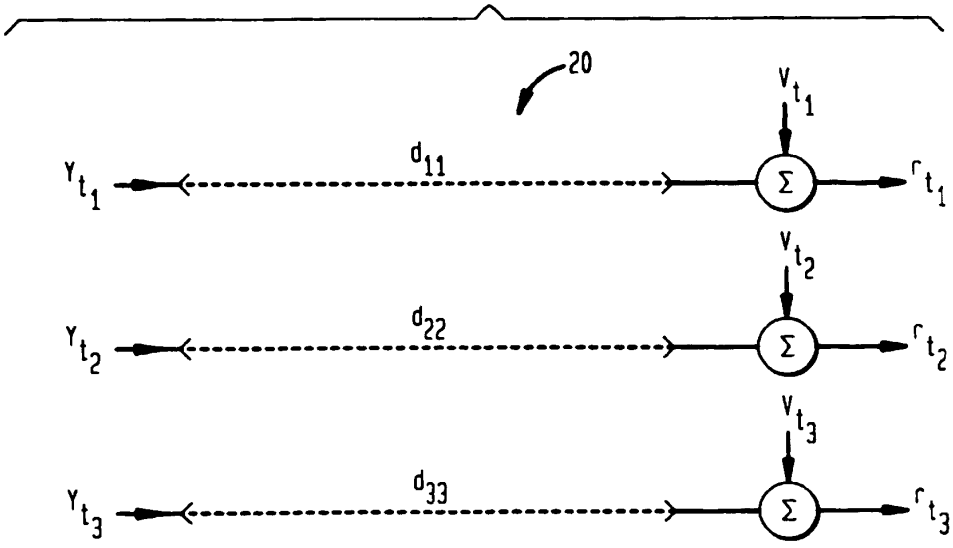


FIG. 2



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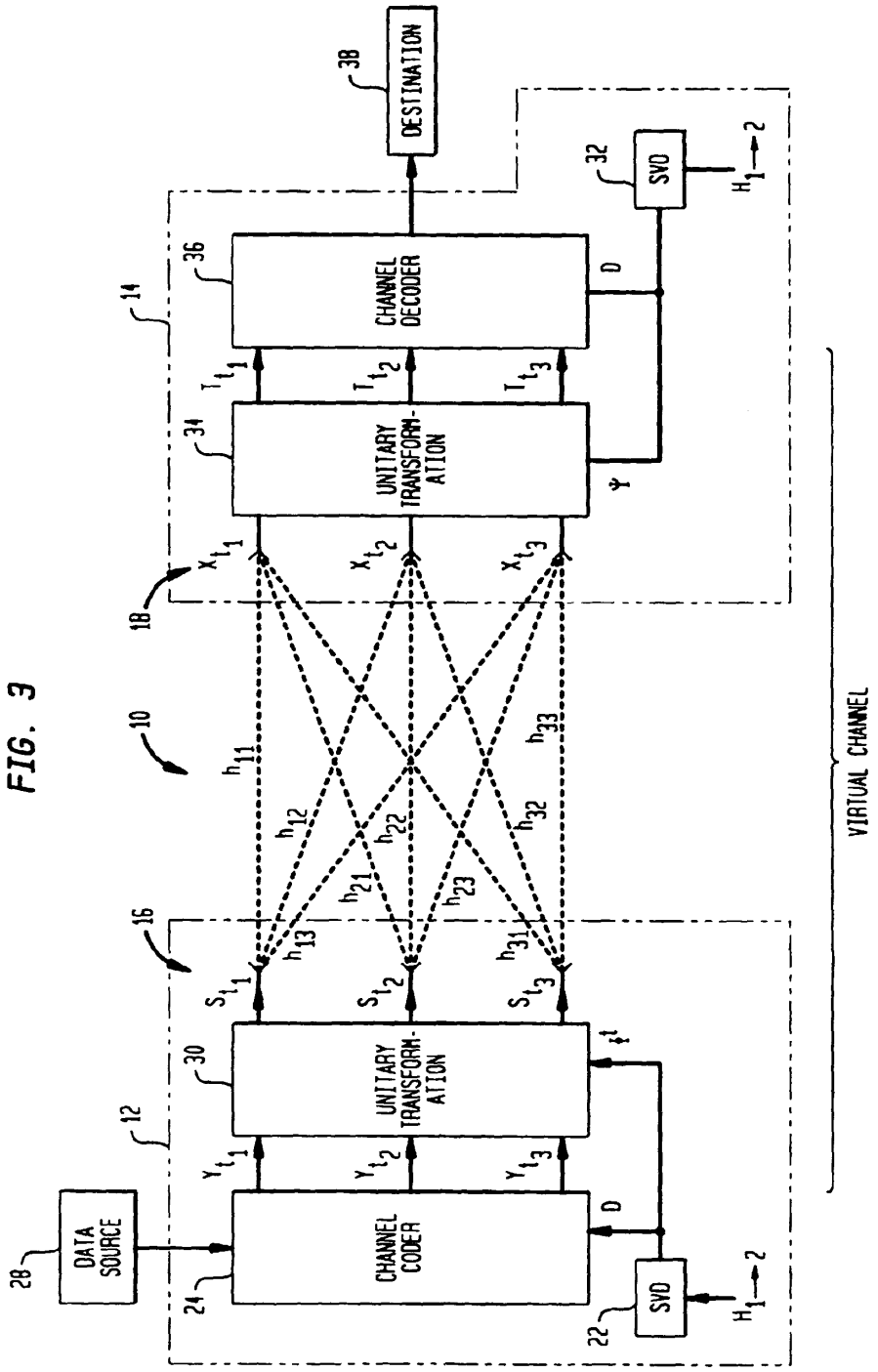


FIG. 3

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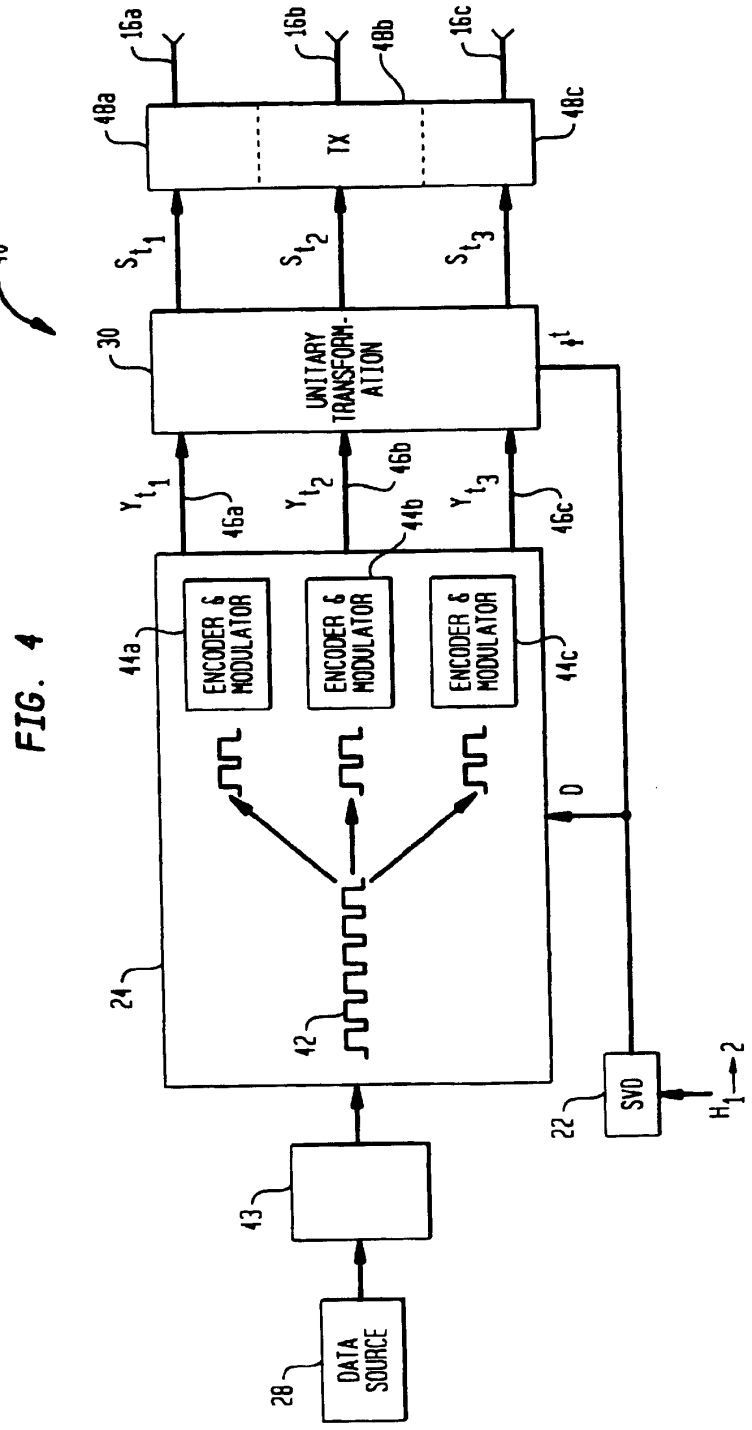


FIG. 4

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FIG. 5

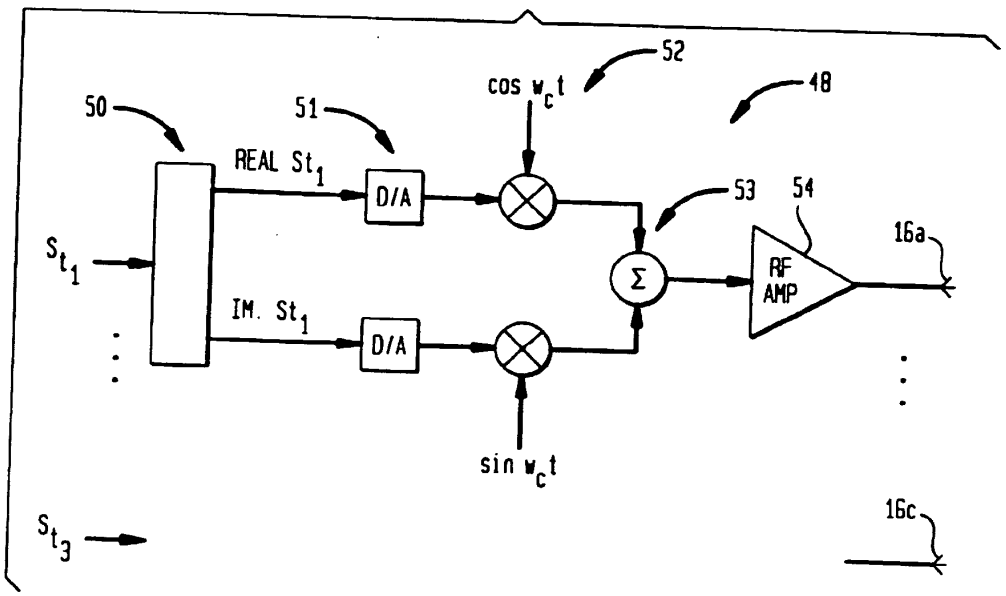
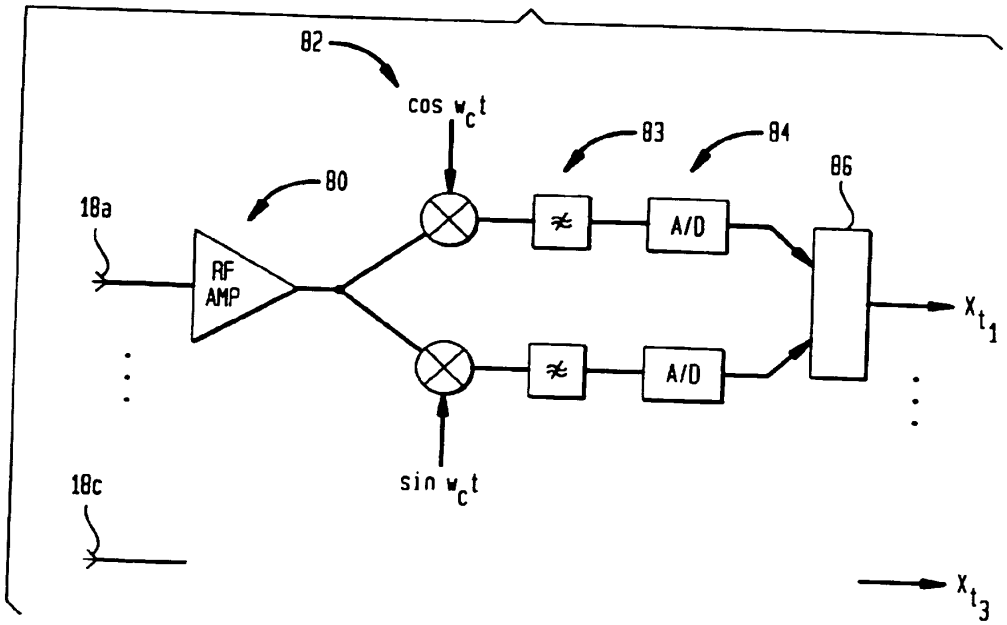


FIG. 7



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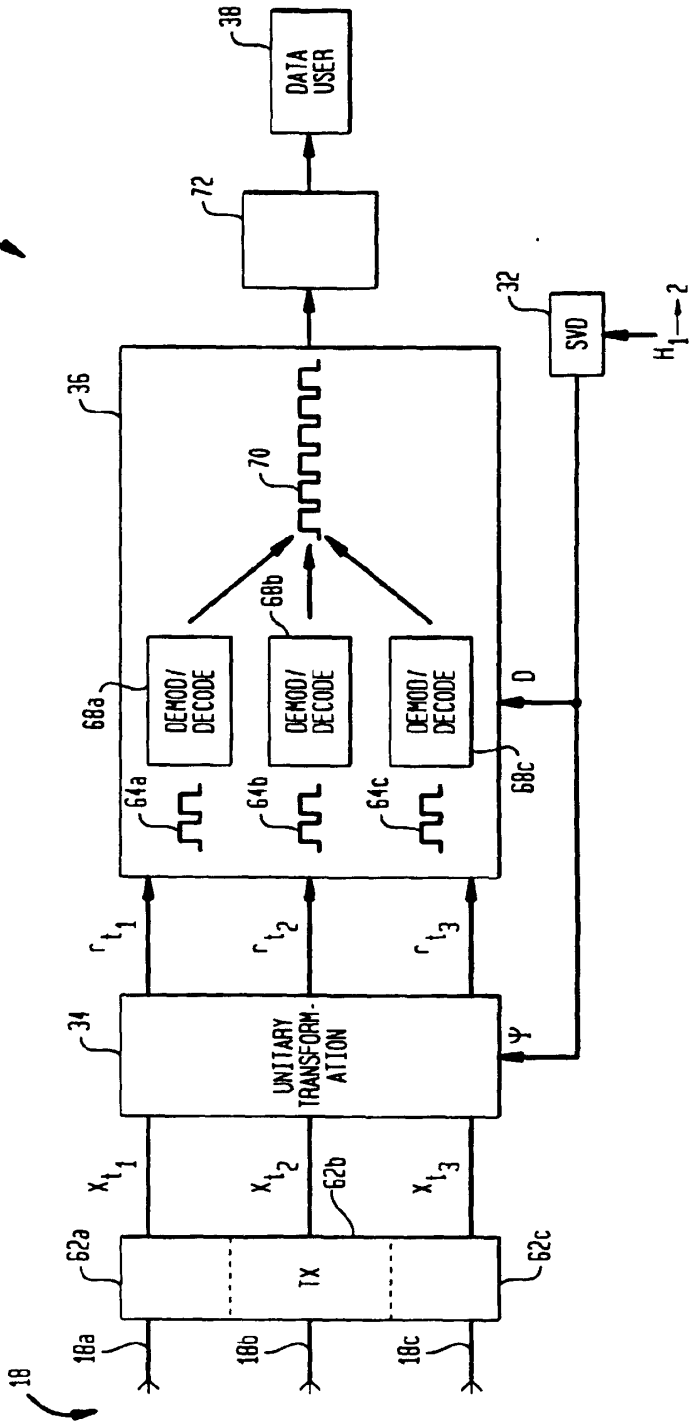


FIG. 6

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(71) Applicant: **LUCENT TECHNOLOGIES INC.**
Murray Hill, New Jersey 07974-0636 (US)

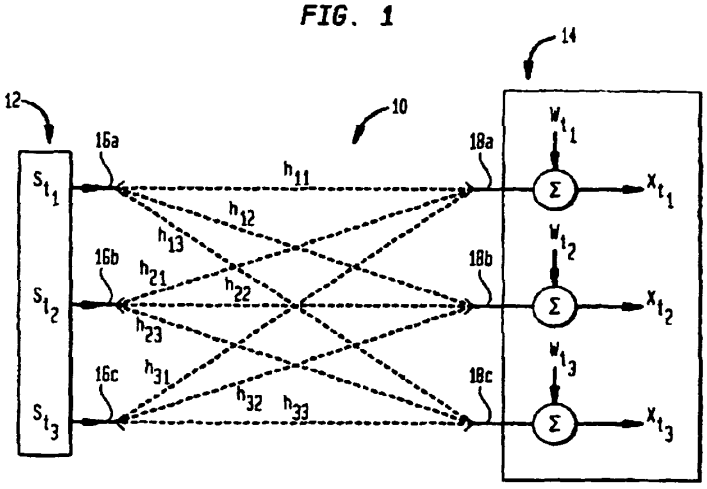
(72) Inventors:
- **Hochwald, Bertrand M.**
  Summit, Union New Jersey 07901 (US)
- **Marzetta, Thomas Louis**
  Summit, New Jersey 07901 (US)

(74) Representative:
Buckley, Christopher Simon Thirsk et al
Lucent Technologies (UK) Ltd,
5 Mornington Road
Woodford Green, Essex IG8 0TU (GB)

(54) Multiple antenna communication system and method thereof

(57) A communications system achieves high bit rates over an actual communications channel between M transmitter antennas (16a-16c) of a first unit (12) and N receiver antennas (18a-18c) of a second unit (14), where M or N>1, by creating virtual sub-channels from the actual communications channel. The multiple antenna system creates the virtual sub-channels from the actual communications channel by using propagation information characterizing the actual communications channel at the first and second units. For transmissions from the first unit (12) to the second unit (14), the first unit sends a virtual transmitted signal over at least a subset of the virtual sub-channels using at least a portion of the propagation information. The second unit retrieves a corresponding virtual received signal from the same set of virtual sub-channels using at least another portion of said propagation information.

FIG. 1



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European Patent Office

EUROPEAN SEARCH REPORT

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EP 98 30 7449

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	US 3 646 443 A (ROWLAND HOWARD J ET AL) 29 February 1972 * column 1, line 6 - line 35; figure 1 * * column 2, line 20 - line 73 *	1-14	H04B7/04 H04B17/00
A	EP 0 773 638 A (AT & T CORP) 14 May 1997 * abstract; figures 2,6 *	10-12,14	

TECHNICAL FIELDS SEARCHED (Int.Cl.6)

H04B
H04Q

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
MUNICH	9 June 1999	Felsen, J

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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EPO FORM 1503 03.82 (P04C01)

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 98 30 7449

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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09-06-1999

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

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(71) Applicant:
Texas Instruments Incorporated
Dallas, TX 75251 (US)

(72) Inventors:
- **Negi, Rohit,**
c/o Durand 112
Stanford, CA 94305 (US)
- **Dabak, Anand G.**
Richardson, TX 75082 (US)

(74) Representative: **Holt, Michael**
Texas Instruments Ltd.,
PO Box 5069
Northampton, Northamptonshire NN4 7ZE (GB)

(54) Space time block coded transmit antenna diversity for WCDMA

(57) A mobile communication system is designed with an input circuit coupled to receive a first plurality of signals ($r_j(i+\tau_j)$, i=0-N-1) during a first time (T0-T1) from an external source and coupled to receive a second plurality of signals ($r_j(i+\tau_j)$, i=N-2N-1) during a second time (T1-T2) from the external source. The input circuit receives each of the first and second plurality of signals along respective first and second paths (j). The input circuit produces a first input signal (610) (R_j^1) and a second input signal (614) (R_j^2) from the respective first and second plurality of signals. A correction circuit is coupled to receive a first estimate signal (302) (α_j^1), a second estimate signal (306) (α_j^2) and the first and second input signals. The correction circuit produces a first symbol estimate ($\tilde{S}_1$) in response to the first and second estimate signals and the first and second input signals. The correction circuit produces a second symbol estimate ($\tilde{S}_2$) in response to the first and second estimate signals and the first and second input signals.

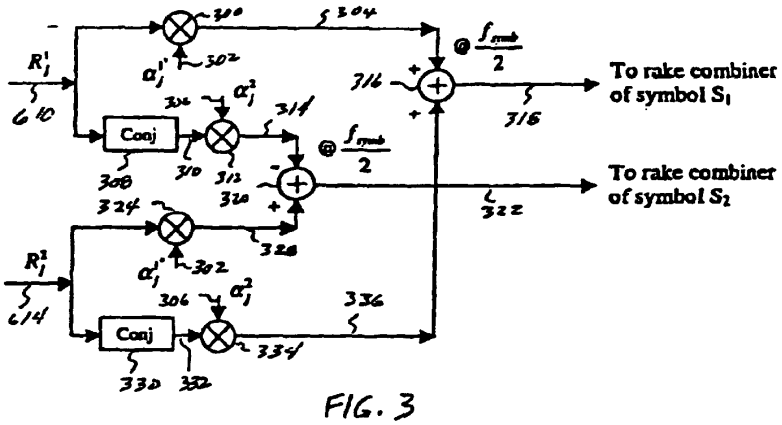


FIG. 3

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Description

FIELD OF THE INVENTION

[0001] This invention relates to wideband code division multiple access (WCDMA) for a communication system and more particularly to space time block coded transmit antenna diversity for WCDMA.

BACKGROUND OF THE INVENTION

[0002] Present code division multiple access (CDMA) systems are characterized by simultaneous transmission of different data signals over a common channel by assigning each signal a unique code. This unique code is matched with a code of a selected receiver to determine the proper recipient of a data signal. These different data signals arrive at the receiver via multiple paths due to ground clutter and unpredictable signal reflection. Additive effects of these multiple data signals at the receiver may result in significant fading or variation in received signal strength. In general, this fading due to multiple data paths may be diminished by spreading the transmitted energy over a wide bandwidth. This wide bandwidth results in greatly reduced fading compared to narrow band transmission modes such as frequency division multiple access (FDMA) or time division multiple access (TDMA).

[0003] New standards are continually emerging for next generation wideband code division multiple access (WCDMA) communication systems as described in European Patent Application No. EP 99201224.5 filed April 21, 1999, and incorporated herein by reference. These WCDMA systems are coherent communications systems with pilot symbol assisted channel estimation schemes. These pilot symbols are transmitted as quadrature phase shift keyed (QPSK) known data in predetermined time frames to any receivers within range. The frames may propagate in a discontinuous transmission (DTX) mode. For voice traffic, transmission of user data occurs when the user speaks, but no data symbol transmission occurs when the user is silent. Similarly for packet data, the user data may be transmitted only when packets are ready to be sent. The frames include pilot symbols as well as other control symbols such as transmit power control (TPC) symbols and rate information (RI) symbols. These control symbols include multiple bits otherwise known as chips to distinguish them from data bits. The chip transmission time (T_C), therefore, is equal to the symbol time rate (T) divided by the number of chips in the symbol (N).

[0004] Previous studies have shown that multiple transmit antennas may improve reception by increasing transmit diversity for narrow band communication systems. In their paper New Detection Schemes for Transmit Diversity with no Channel Estimation, Tarokh et al. describe such a transmit diversity scheme for a TDMA system. The same concept is described in A Simple Transmitter Diversity Technique for Wireless Communications by Alamouti. Tarokh et al. and Alamouti, however, fail to teach such a transmit diversity scheme for a WCDMA communication system.

[0005] Other studies have investigated open loop transmit diversity schemes such as orthogonal transmit diversity (OTD) and time switched time diversity (TSTD) for WCDMA systems. Both OTD and TSTD systems have similar performance. Both use multiple transmit antennas to provide some diversity against fading, particularly at low Doppler rates and when there are insufficient paths for the rake receiver. Both OTD and TSTD systems, however, fail to exploit the extra path diversity that is possible for open loop systems. For example, the OTD encoder circuit of FIG. 5 receives symbols S_1 and S_2 on lead 500 and produces output signals on leads 504 and 506 for transmission by first and second antennas, respectively. These transmitted signals are received by a despreader input circuit (FIG. 6). The input circuit receives the ith of N chip signals per symbol together with noise along the jth of L multiple signal paths at a time τ_j after transmission. Both here and in the following text, noise terms are omitted for simplicity. This received signal $r_j(i+\tau_j)$ at lead 600 is multiplied by a channel orthogonal code signal $C_m(i+\tau_j)$ that is unique to the receiver at lead 604. Each chip signal is summed over a respective symbol time by circuit 608 and produced as first and second output signals R_j^1 and R_j^2 on leads 612 and 614 as in equations [1-2], respectively. Delay circuit 610 provides a one-symbol delay T so that the output signals are produced simultaneously.

$$R_j^1=\sum_{i=0}^{N-1} r_j(i+\tau_j)=\alpha_j^1 S_1+\alpha_j^2 S_2 \qquad [1]$$

$$R_j^2=\sum_{i=N}^{2N-1} r_j(i+\tau_j)=\alpha_j^1 S_1-\alpha_j^2 S_2 \qquad [2]$$

[0006] The OTD phase correction circuit of FIG. 7 receives the signals R_j^1 and R_j^2 as input signals corresponding to the jth of L multiple signal paths. The phase correction circuit produces soft outputs or signal estimates $\tilde{S}_1$ and $\tilde{S}_2$ for symbols S_1 and S_2 at leads 716 and 718 as shown in equations [3-4], respectively.

$$\tilde{S}_1=\sum_{j=1}^{L}(R_j^1+R_j^2)\alpha_j^{1*}=\sum_{j=1}^{L}2|\alpha_j^1|^2 S_1 \qquad [3]$$

$$\tilde{S}_2=\sum_{j=1}^{L}(R_j^1-R_j^2)\alpha_j^{2*}=\sum_{j=1}^{L}2|\alpha_j^2|^2 S_2 \qquad [4]$$

Equations [3-4] show that the QTD method provides a

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single channel estimate α for each path j. A similar analysis for the TSTD system yields the same result. The OTD and TSTD methods, therefore, are limited to a path diversity of L. This path diversity limitation fails to exploit the extra path diversity that is possible for open loop systems as will be explained in detail.

SUMMARY OF THE INVENTION

[0007] These problems are resolved by a mobile communication system comprising an input circuit coupled to receive a first plurality of signals during a first time from an external source and coupled to receive a second plurality of signals during a second time from the external source. The input circuit receives each of the first and second plurality of signals along respective first and second paths. The input circuit produces a first input signal and a second input signal from the respective first and second plurality of signals. A correction circuit is coupled to receive a first estimate signal, a second estimate signal and the first and second input signals. The correction circuit produces a first symbol estimate in response to the first and second estimate signals and the first and second input signals. The correction circuit produces a second symbol estimate in response to the first and second estimate signals and the first and second input signals.

[0008] The present invention improves reception by providing at least $2L$ diversity over time and space. No additional transmit power or bandwidth is required. Power is balanced across multiple antennas.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] A more complete understanding of the invention may be gained by reading the subsequent detailed description with reference to the drawings wherein:

FIG. 1 is a simplified block diagram of a typical transmitter using Space Time Transit Diversity (STTD) of the present invention;
FIG. 2 is a block diagram showing signal flow in an STTD encoder of the present invention that may be used with the transmitter of FIG. 1;
FIG. 3 is a schematic diagram of a phase correction circuit of the present invention that may be used with a receiver;
FIG. 4A is a simulation showing STTD performance compared to Time Switched Time Diversity (TSTD) for a vehicular rate of 3 kmph;
FIG. 4B is a simulation showing STTD performance compared to TSTD for a vehicular rate of 120 kmph;
FIG. 5 is a block diagram showing signal flow in an OTD encoder of the prior art;
FIG. 6 is a block diagram of a despreader input circuit of the prior art; and
FIG. 7 is a schematic diagram of a phase correction circuit of the prior art.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0010] Referring to FIG. 1, there is a simplified block diagram of a typical transmitter using Space Time Transit Diversity (STTD) of the present invention. The transmitter circuit receives pilot symbols, TPC symbols, RI symbols and data symbols on leads 100, 102, 104 and 106, respectively. Each of the symbols is encoded by a respective STTD encoder as will be explained in detail. Each STTD encoder produces two output signals that are applied to multiplex circuit 120. The multiplex circuit 120 produces each encoded symbol in a respectiv symbol time of a frame. Thus, a serial sequence of symbols in each frame is simultaneously applied to each respective multiplier circuit 124 and 126. A channel orthogonal code C_m is multiplied by each symbol to provide a unique signal for a designated receiver. The STTD encoded frames are then applied to antennas 128 and 130 for transmission.

[0011] Turning now to FIG. 2, there is a block diagram showing signal flow in an STTD encoder of the present invention that may be used with the transmitter of FIG. 1. The STTD encoder receives symbol S_1 at symbol time T and symbol S_2 at symbol time $2T$ on lead 200. The STTD encoder produces symbol S_1 on lead 204 and symbol $-S_2^*$ on lead 206 at symbol time T, where the asterisk indicates a complex conjugate operation. Furthermore, the symbol time indicates a relative position within a transmit frame and not an absolute time. The STTD encoder then produces symbol S_1 on lead 204 and symbol S_1^* on lead 206 at symbol time $2T$. The bit or chip signals of these symbols are transmitted serially along respective paths 208 and 210. Rayleigh fading parameters are determined from channel estimates of pilot symbols transmitted from respective antennas at leads 204 and 208. For simplicity of analysis, a Rayleigh fading parameter α_j^1 is assumed for a signal transmitted from the first antenna 204 along the jth path. Likewise, a Rayleigh fading parameter α_j^2 is assumed for a signal transmitted from the second antenna 206 along the jth path. Each ith chip or bit signal $r_j(i+\tau_j)$ of a respective symbol is subsequently received at a remote mobile antenna 212 after a transmit time τ_j corresponding to the jth path. The signals propagate to a despreader input circuit (FIG. 6) where they are summed over each respective symbol time to produce output signals R_j^1 and R_j^2 corresponding to the jth of L multiple signal paths as previously described.

[0012] Referring now to FIG. 3, there is a schematic diagram of a phase correction circuit of the present invention that may be used with a remote mobile receiver. This phase correction circuit receives signals R_j^1 and R_j^2 as input signals on leads 610 and 614 as shown in equations [5-6], respectively.

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$$R_j^1 = \sum_{i=0}^{N-1} r_j(i+\tau_j) = \alpha_j^1 S_1 - \alpha_j^2 S_2^* \quad [5]$$

$$R_j^2 = \sum_{i=N}^{2N-1} r_j(i+\tau_j) = \alpha_j^1 S_1 + \alpha_j^2 S_1^* \quad [6]$$

The phase correction circuit receives a complex conjugate of a channel estimate of a Rayleigh fading parameter α_j^{1*} corresponding to the first antenna on lead 302 and a channel estimate of another Rayleigh fading parameter α_j^2 corresponding to the second antenna on lead 306. Complex conjugates of the input signals are produced by circuits 308 and 330 at leads 310 and 322, respectively. These input signals and their complex conjugates are multiplied by Rayleigh fading parameter estimate signals and summed as indicated to produce path-specific first and second symbol estimates at respective output leads 318 and 322 as in equations [7-8].

$$R_j^1 \alpha_j^{1*} + R_j^{2*} \alpha_j^2 = (|\alpha_j^1|^2 + |\alpha_j^2|^2) S_1 \quad [7]$$

$$-R_j^{1*} \alpha_j^2 + R_j^2 \alpha_j^{1*} = (|\alpha_j^1|^2 + |\alpha_j^2|^2) S_2 \quad [8]$$

These path-specific symbol estimates are then applied to a rake combiner circuit to sum individual path-specific symbol estimates, thereby providing net soft symbols as in equations [9-10].

$$\tilde{S}_1 = \sum_{j=1}^{L} R_j^1 \alpha_j^{1*} + R_j^{2*} \alpha_j^2 \quad [9]$$

$$\tilde{S}_2 = \sum_{j=1}^{L} -R_j^{1*} \alpha_j^2 + R_j^2 \alpha_j^{1*} \quad [10]$$

These soft symbols or estimates provide a path diversity L and a transmit diversity 2. Thus, the total diversity of the STTD system is $2L$. This increased diversity is highly advantageous in providing a reduced bit error rate. The simulation result of FIG. 4 compares a bit error rate (BER) of STTD with TSTD for various ratios of energy per bit (Eb) to noise (No) at a relative speed of 3 Kmph. The OTD and TSTD systems were found to be the same in other simulations. The simulation shows that a 7.5 dB ratio Eb/No corresponds to a BER of 2.0E-3 for TSTD. The same BER, however, is achieved with a 7.2 dB ratio Eb/No. Thus, STTD produces approximately 0.3 dB improvement over TSTD. The simulation of FIG. 5 compares the BER of STTD with TSTD for various values of Eb/No at a relative speed of 120 Kmph. This simulation shows a typical 0.25 dB improvement for STTD over TSTD even for high Doppler rates. By way of comparison, STTD demonstrates a 1.0 dB advantage over the simulated curve of FIG. 5 without diversity at a BER of 2.6E-3. This substantial advantage further demonstrates the effectiveness of the present invention.

[0013] Although the invention has been described in detail with reference to its preferred embodiment, it is to be understood that this description is by way of example only and is not to be construed in a limiting sense. For example, several variations in the order of symbol transmission would provide the same $2L$ diversity. Moreover, the exemplary diversity of the present invention may be increased with a greater number of transmit or receive antennas. Furthermore, novel concepts of the present invention are not limited to exemplary circuitry, but may also be realized by digital signal processing as will be appreciated by those of ordinary skill in the art with access to the instant specification.

[0014] It is to be further understood that numerous changes in the details of the embodiments of the invention will be apparent to persons of ordinary skill in the art having reference to this description. It is contemplated that such changes and additional embodiments are within the spirit and true scope of the invention.

Claims

1. Circuitry, comprising:

   a correction circuit for receiving first and second input signals from an external source along a signal path of a plurality of signal paths, the correction circuit arranged for producing a first symbol estimate in response to first and second estimate signals and the first and second input signals, and for producing a second symbol estimate in response to the first and second estimate signals and the first and second input signals; and

   a combining circuit coupled for receiving a plurality of first symbol estimates including the first symbol estimate and for receiving a plurality of second symbol estimates including the second symbol estimate, the combining circuit arranged for producing a first symbol signal in response to the plurality of first symbol estimates and for producing a second symbol signal in response to the plurality of second symbol estimates.

2. A circuitry as in claim 1 further comprising:

   an input circuit arranged for receiving a first plurality of signals during a first period from the external source and for receiving a second plurality of signals during a second period from the external source, the input circuit arranged for receiving each of the first and second plurality of signals along respective first and second

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paths, the input circuit arranged for producing the first input signal and the second input signal from the respective first and second plurality of signals.

3. A circuitry as in claim 1 further comprising:

an input circuit arranged for receiving a plurality of signals from an external source along a plurality of signal paths, for producing a plurality of input signals including the first input signal and the second input signal corresponding to a respective signal path of the plurality of signal paths.

4. A circuitry as in any preceding claim, wherein the correction circuit and the combining circuit are formed on a single integrated circuit.

5. A circuitry as in any preceding claim, wherein each of the first and second symbol signals includes at least one of a pilot symbol, a transmit power control symbol, a rate information symbol and a data symbol.

6. A circuit as in any preceding claim, wherein the first period corresponds to a transmission time of one of the first and second symbol signals and the second period corresponds to a transmission time of the other of the first and second symbol signals.

7. A circuit as in any preceding claim, wherein a total path diversity of each of the first and second symbol signals is at least twice a number of transmitting antennas.

8. A circuit as in any preceding claim, wherein the first input signal is transmitted by a first antenna and a second antenna and wherein the second input signal is transmitted by the first antenna and the second antenna.

9. A circuit as in claim 8, wherein the first and the second input signal are wideband code division multiple access signals.

10. A method of processing signals in a communication circuit, comprising:

receiving a plurality of first signals during a first period, each first signal corresponding to a respective signal path;
receiving a plurality of second signals during a second period;
estimating a first Rayleigh fading parameter;
estimating a second Rayleigh fading parameter;
producing a first symbol signal in response to said plurality of first signals, said plurality of second signals and said first and second Rayleigh fading parameters; and
producing a second symbol signal in response to said plurality of first signals, said plurality of second signals and said first and second Rayleigh fading parameters.

11. A method of processing signals as in claim 10, further comprising the steps of:

determining a conjugate of said each first signal;
determining a conjugate of each second signal of said plurality of second signals;
determining a conjugate of each said first Rayleigh fading parameter; and
determining a conjugate of each said second Rayleigh fading parameter.

12. A method of processing signals as in claim 11, further comprising the steps of:

determining an approximate said first symbol by adding a product of said each first signal and each respective said conjugate of each said first Rayleigh fading parameter to a product of said conjugate of said each second signal and each respective said second Rayleigh fading parameter; and
determining an approximate said second symbol by adding a product of a complement of said conjugate of said each first signal and each respective second Rayleigh fading parameter to a product of said each second signal and each respective said conjugate of each said second Rayleigh fading parameter.

13. A mobile communication system, comprising:

a mobile antenna arranged for receiving a plurality of signals from an external source along a plurality of signal paths;
an input circuit arranged for receiving the plurality of signals from the antenna, and for producing a plurality of input signals including a first input signal and a second input signal corresponding to respective signal paths of the plurality of signal paths; and
a correction circuit arranged for receiving a first estimate signal, a second estimate signal and the first and second input signals, for producing a first symbol estimate in response to the first and second estimate signals and the first and second input signals, the correction circuit arranged for producing a second symbol estimate in response to the first and second estimate signals and the first and second input

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signals.

14. A mobile communication system as in claim 13, further comprising a combining circuit arranged for receiving a plurality of first symbol estimates including the first symbol estimate, and for receiving a plurality of second symbol estimates including the second symbol estimate, the combining circuit arranged for producing a first symbol signal in response to the plurality of first symbol estimates and producing a second symbol signal in response to the plurality of second symbol estimates.

15. A mobile communication system as in claim 14, wherein the input circuit, the correction circuit and the combining circuit are formed on a single integrated circuit.

16. A mobile communication system as in claim 14, wherein each of the first and second symbol signals include at least one of a pilot symbol, a transmit power control symbol, a rate information symbol and a data symbol.

17. A mobile communication system as in any of claims 13 to 16, wherein each of the first and second estimate signals is a Rayleigh fading parameter estimate.

18. A mobile communication system as in any of claims 13 to 17, wherein a total path diversity of each of the first and second symbol signals is at least twice a number of transmitting antennas.

19. A mobile communication system as in any of claims 13 to 18, wherein each of the first and second input signals is transmitted by a first antenna and a second antenna.

20. A mobile communication system as in claim 19, wherein each of the first and second input signals is a wideband code division multiple access signal.

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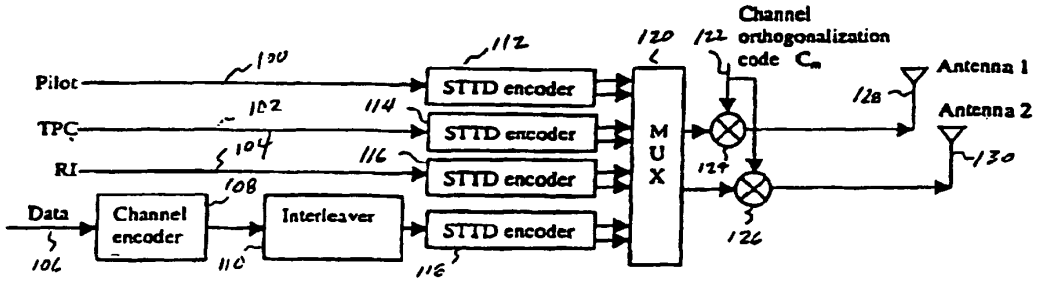


FIG. 1

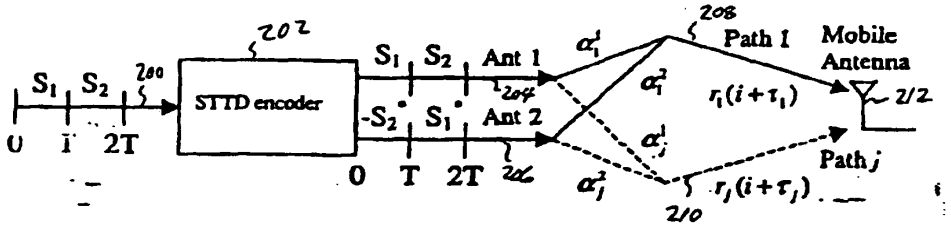


FIG. 2

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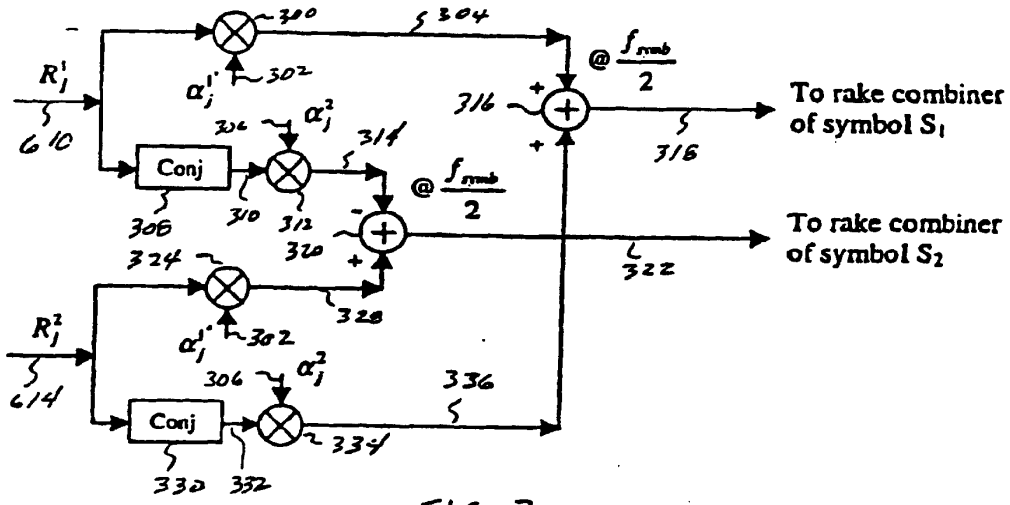


FIG. 3

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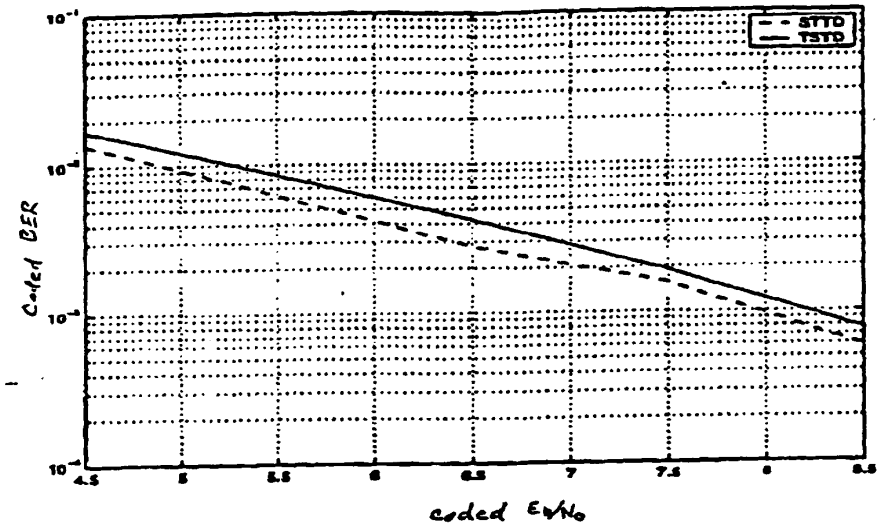


FIG. 4A

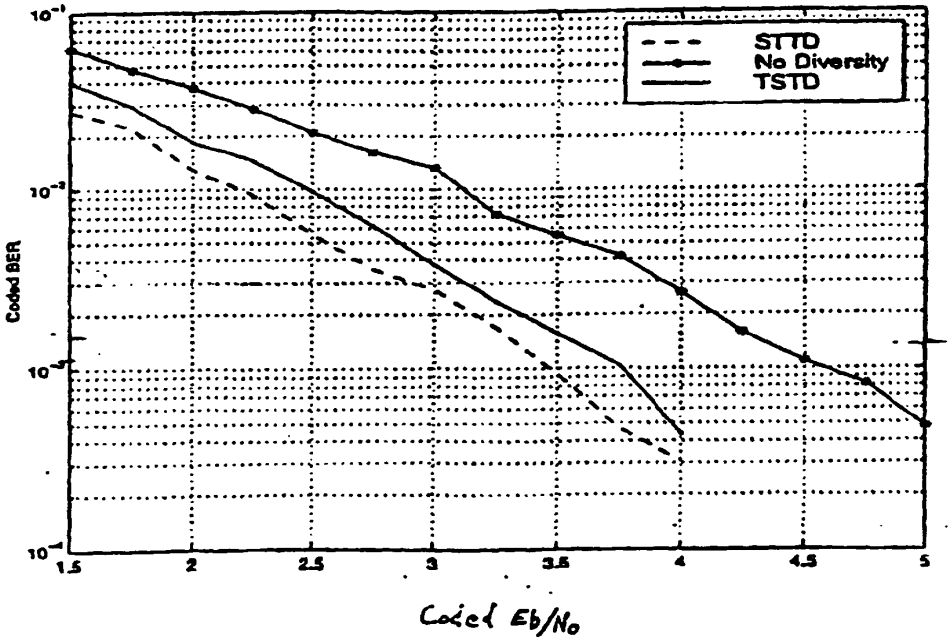


FIG. 4B

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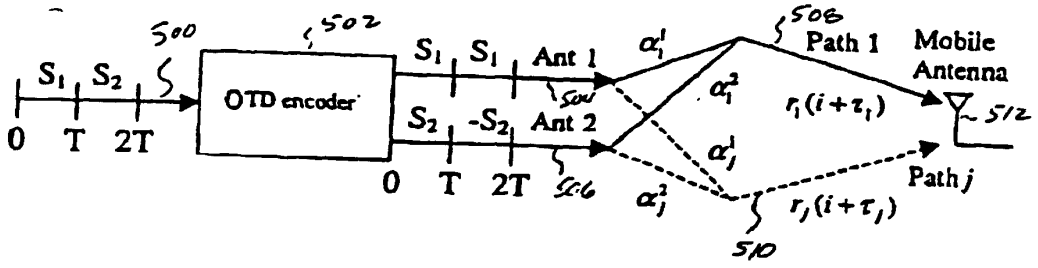


FIG. 5
(PRIOR ART)

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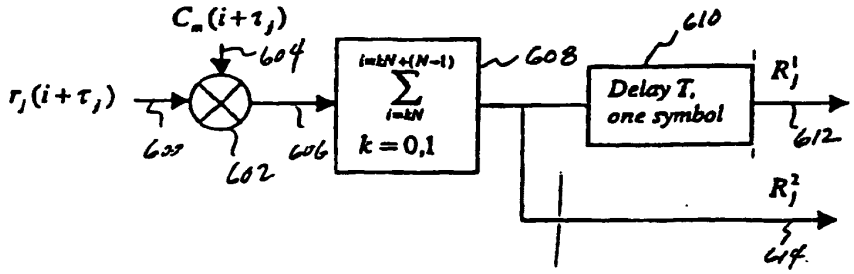


FIG. 6
(PRIOR ART)

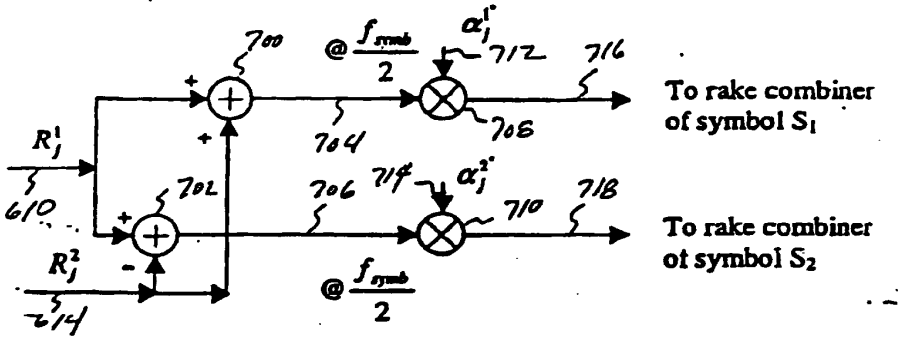


FIG. 7
(PRIOR ART)

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U.S. APPLICATION NUMBER NO.	FIRST NAMED APPLICANT	ATTY. DOCKET NO.
10/399,859	Wen Tong et al	14316NP

INTERNATIONAL APPLICATION NO.	
PCT/RU00/00426	
I.A. FILING DATE	PRIORITY DATE
10/27/2000	

Dowell & Dowell PC
1215 Jefferson Davis Highway
Suite 309
Arlington, VA 22202-3124

CONFIRMATION NO. 9275

371 FORMALITIES LETTER

OC000000010382705

Date Mailed: 07/01/2003

NOTIFICATION OF MISSING REQUIREMENTS UNDER 35 U.S.C. 371 IN THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US)

The following items have been submitted by the applicant or the IB to the United States Patent and Trademark Office as a Designated / Elected Office (37 CFR 1.495).

- Copy of the International Application filed on 04/23/2003
- Copy of the International Search Report filed on 04/23/2003
- Oath or Declaration filed on 04/23/2003
- Copy of references cited in ISR filed on 04/23/2003
- U.S. Basic National Fees filed on 04/23/2003

The following items **MUST** be furnished within the period set forth below in order to complete the requirements for acceptance under 35 U.S.C. 371:

- Oath or declaration of the inventors, in compliance with 37 CFR 1.497(a) and (b), identifying the application by the International application number and international filing date. The current oath or declaration does not comply with 37 CFR 1.497(a) and (b) in that it:
  - is not executed in accordance with either 37 CFR 1.66 or 37 CFR 1.68.

ALL OF THE ITEMS SET FORTH ABOVE MUST BE SUBMITTED WITHIN TWO (2) MONTHS FROM THE DATE OF THIS NOTICE OR BY 32 MONTHS FROM THE PRIORITY DATE FOR THE APPLICATION, WHICHEVER IS LATER. FAILURE TO PROPERLY RESPOND WILL RESULT IN ABANDONMENT.

The time period set above may be extended by filing a petition and fee for extension of time under the provisions of 37 CFR 1.136(a).

Applicant is reminded that any communications to the United States Patent and Trademark Office must be mailed to the address given in the heading and include the U.S. application no. shown above (37 CFR 1.5)

*A copy of this notice **MUST** be returned with the response.*

PAULETTE R KIDWELL

Telephone: (703) 305-3656

PART 2 - OFFICE COPY

U.S. APPLICATION NUMBER NO.	INTERNATIONAL APPLICATION NO.	ATTY. DOCKET NO.
10/399,859	PCT/RU00/00426	14316NP

FORM PCT/DO/EO/905 (371 Formalities Notice)

1T02 Rec'd PCT/PTO 29 AUG 2003

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant	:	TONG et al.
Appl. No.	:	10/399,859
Based on	:	PCT/RU00/00426
Filed	:	April 23, 2003
Title	:	COMBINATION OF SPACE-TIME CODING AND SPATIAL MULTIPLEXING, AND THE USE OF ORTHOGONAL TRANSFORMATION IN SPACE-TIME CODING
Grp./A.U.	:	
Examiner	:	
Attn.	:	PCT Branch
Docket No.	:	14316NP

Honorable Assistant Commissioner of Patents
Alexandria, VA 22313-1450

Sir:

RESPONSE TO NOTIFICATION OF MISSING REQUIREMENTS UNDER 35 U.S.C. 371 IN THE UNITED STATES DESIGNATED/ ELECTED OFFICE (DO/EO/US)

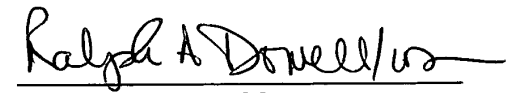
In response to the Notification of Missing Requirements under 35 U.S.C. 371 mailed July 1, 2003, applicant submits herewith a copy of the notice form together with a signed Declaration and Power of Attorney.

All fees with respect to the late submission of the Declaration and Power of Attorney have previously been submitted. Any deficiencies may be charged to Deposit Account 04-1577.

It is believed that all requirements to enter the National Phase have now been submitted. Should the Examiner have any questions concerning this matter, it is requested that the

Examiner contact the undersigned attorney at the telephone number shown below.

Respectfully submitted,



Ralph A. Dowell
Registration No. 26,868
Date: August 29, 2003

DOWELL & DOWELL, P.C.
Suite 309
1215 Jefferson Davis Highway
Arlington, Virginia 22202
Telephone (703) 415-2555

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CONFIRMATION NO. 9275

371 FORMALITIES LETTER

CC0000000010362705

Date Mailed: 07/01/2003

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  - is not executed in accordance with either 37 CFR 1.66 or 37 CFR 1.68.

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*A copy of this notice **MUST** be returned with the response.*

PAULETTE R KIDWELL

Telephone: (703) 305-3656

PART 1 - ATTORNEY/APPLICANT COPY

U.S APPLICATION NUMBER NO.	INTERNATIONAL APPLICATION NO.	ATTY. DOCKET NO.
10/399,859	PCT/RU00/00426	14316NP

FORM PCT/DO/EO/905 (371 Formalities Notice)

Express Mail Label No.

Docket No.
71493-117B /pw

Declaration For Patent Application

English Language Declaration

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 listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

COMBINATION OF SPACE-TIME CODING AND SPATIAL MULTIPLEXING, AND THE USE OF ORTHOGONAL TRANSFORMATION IN SPACE-TIME CODING

the specification of which

(check one)

☐ is attached hereto.

☒ was filed on October 27, 2000 / 04/23/2003 as United States Application No. or PCT International Application Number PCT/RU00/00426 --- US 10/399,859

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 to the United States Patent and Trademark Office all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, Section 119(a)-(d) or Section 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)			Priority Not Claimed
(Number)	(Country)	(Day/Month/Year Filed)	☐
(Number)	(Country)	(Day/Month/Year Filed)	☐
(Number)	(Country)	(Day/Month/Year Filed)	☐

I hereby claim the benefit under 35 U.S.C. Section 119(e) of any United States provisional application(s) listed below:

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

I hereby claim the benefit under 35 U. S. C. 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 35 U.S.C. Section 112, I acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me to be material to patentability as defined in Title 37, CFR Section 1.56 which became available 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) (patented, pending, abandoned)
(Application Serial No.)	(Filing Date)	(Status) (patented, pending, abandoned)
(Application Serial No.)	(Filing Date)	(Status) (patented, pending, abandoned)

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.

1 00

Full name of sole or first inventor
WEN TONG

Sole or first inventor's signature

Date
28 Aug. 2003

Residence
Ottawa, Ontario, Canada CAN

Citizenship
CANADIAN

Post Office Address
312 Whitestone Drive, Ottawa, Ontario, Canada K2C 4A7

2 00

Full name of second inventor, if any
MICHAIL G. BAKULIN

Second inventor's signature

Date
27 June '03

Residence
Kirova, Russia RUX

Citizenship
RUSSIAN

Post Office Address
142119 Moskovskaja Oblast, gor. Podolsk, ul. Kirova, dom 39, kv. 31, Russia

3 00

Full name of third inventor, if any
VITALY B. KREYNDELIN

Third inventor's signature

Date
27 June, 2003

Residence
Moskva, Russia RUX

Citizenship
RUSSIAN

Post Office Address
109518, gor. Moskva, ul. Grayvoronovskaja, dom 8, kv. 87, Russia

4 00

Full name of fourth inventor, if any
ALEXANDER M. SHLOMA

Fourth inventor's signature

Date
29 June, 2003

Residence
Zhukovsky, Gagarina, Russia RUX

Citizenship
RUSSIAN

Post Office Address
140180 Moskovskaja Oblast, gor. Zhukovsky, ul gagarina, dom 63, kv. 27, Russia

5.0

Full name of fifth inventor, if any
YURIY S. SHNAKOV

Fifth inventor's signature Date 27 June 2003.

Residence
Moscow, Russia RUX

Citizenship
RUSSIAN

Post Office Address
117574 Moscow, Vilnusskaja ul. dom 7, kor. 2, kv. 125, Russia

Full name of sixth inventor, if any

Sixth inventor's signature Date

Residence

Citizenship

Post Office Address

Full name of seventh inventor, if any

Seventh inventor's signature Date

Residence

Citizenship

Post Office Address

Full name of eighth inventor, if

Eighth inventor's signature Date

Residence

Citizenship

Post Office Address

TOTAL P.07

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER OF PATENTS AND TRADEMARKS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

U.S. APPLICATION NUMBER NO.	FIRST NAMED APPLICANT	ATTY. DOCKET NO.
10/399,859	Wen Tong	14316NP

INTERNATIONAL APPLICATION NO.	
PCT/RU00/00426	
I.A. FILING DATE	PRIORITY DATE
10/27/2000	

Dowell & Dowell
1215 Jefferson Davis Highway
Suite 309
Arlington, VA 22202-3124

CONFIRMATION NO. 9275

371 ACCEPTANCE LETTER

OC000000010864094

Date Mailed: 09/26/2003

NOTICE OF ACCEPTANCE OF APPLICATION UNDER 35 U.S.C 371 AND 37 CFR 1.495

The applicant is hereby advised that the United States Patent and Trademark Office in its capacity as a Designated / Elected Office (37 CFR 1.495), has determined that the above identified international application has met the requirements of 35 U.S.C. 371, and is ACCEPTED for national patentability examination in the United States Patent and Trademark Office.

The United States Application Number assigned to the application is shown above and the relevant dates are:

08/29/2003	08/29/2003
DATE OF RECEIPT OF 35 U.S.C. 371(c)(1), (c)(2) and (c)(4) REQUIREMENTS	DATE OF RECEIPT OF ALL 35 U.S.C. 371 REQUIREMENTS

A Filing Receipt (PTO-103X) will be issued for the present application in due course. **THE DATE APPEARING ON THE FILING RECEIPT AS THE " FILING DATE" IS THE DATE ON WHICH THE LAST OF THE 35 U.S.C. 371 REQUIREMENTS HAS BEEN RECEIVED IN THE OFFICE. THIS DATE IS SHOWN ABOVE.** *The filing date of the above identified application is the international filing date of the international application (Article 11(3) and 35 U.S.C. 363).* Once the Filing Receipt has been received, send all correspondence to the Group Art Unit designated thereon.

The following items have been received:

- Copy of the International Application filed on 04/23/2003
- Copy of the International Search Report filed on 04/23/2003
- Oath or Declaration filed on 08/29/2003
- Copy of references cited in ISR filed on 04/23/2003
- U.S. Basic National Fees filed on 04/23/2003

Applicant is reminded that any communications to the United States Patent and Trademark Office must be mailed to the address given in the heading and include the U.S. application no. shown above (37 CFR 1.5)

PAULETTE R KIDWELL
Telephone: (703) 305-3656

PART 3 - OFFICE COPY

FORM PCT/DO/EO/903 (371 Acceptance Notice)

2661

AMENDMENT TRANSMITTAL LETTER (Large Entity) Applicant(s): WEN TONG, ET AL	Docket No. 14316NP

Serial No.	Filing Date	Examiner	Group Art Unit
10/399,859	April 23, 2003		

Invention: **COMBINATION OF SPACE-TIME CODING AND SPATIAL MULTIPLEXING, AND THE USE OF ORTHOGONAL TRANSFORMATION IN SPACE-TIME CODING**

OIPE JC17
NOV 18 2003
PATENT & TRADEMARK OFFICE

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NOV 20 2003
Technology Center 2600

TO THE ASSISTANT COMMISSIONER FOR PATENTS:

Transmitted herewith is an amendment in the above-identified application.
The fee has been calculated and is transmitted as shown below.

CLAIMS AS AMENDED

	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST # PREV. PAID FOR		NUMBER EXTRA CLAIMS PRESENT	RATE	ADDITIONAL FEE
TOTAL CLAIMS	19	-	23	=	0	x $18.00	$0.00
INDEP. CLAIMS	3	-	3	=	0	x $84.00	$0.00
Multiple Dependent Claims (check if applicable) ☐							$0.00
TOTAL ADDITIONAL FEE FOR THIS AMENDMENT							$0.00

☒ No additional fee is required for amendment.
☐ Please charge Deposit Account No. in the amount of
A duplicate copy of this sheet is enclosed.
☐ A check in the amount of to cover the filing fee is enclosed.
☒ The Commissioner is hereby authorized to charge payment of the following fees associated with this communication or credit any overpayment to Deposit Account No. **04-1577**
A duplicate copy of this sheet is enclosed.
☒ Any additional filing fees required under 37 C.F.R. 1.16.
☒ Any patent application processing fees under 37 CFR 1.17.

Dated: **September 17, 2003**

Signature

R. Allan Brett (Reg. No. 40,476)

I certify that this document and fee is being deposited on with the U.S. Postal Service as first class mail under 37 C.F.R. 1.8 and is addressed to the Assistant Commissioner for Patents, Washington, D.C. 20231.

Signature of Person Mailing Correspondence

Typed or Printed Name of Person Mailing Correspondence

cc:

P11LARGE/REV06

OIPE JC17
NOV 18 2003
PATENT & TRADEMARK OFFICE

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Appl. No.	:	10/399,859
Applicant	:	WEN TONG, ET AL
Filed	:	April 23, 2003
TC/A.U.	:	
Examiner	:	
Docket No.	:	14316NP
Customer No.	:	000293

RECEIVED
NOV 20 2003
Technology Center 2600

Commissioner for Patents
Alexandria, VA 22313-1450
U.S.A.

Dear Sir:

By way of voluntary amendment, 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 6 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:

Claim 1 (original): A coding gain system comprising combined space-time coding and spatial multiplexing.

Claim 2 (original): A system according to claim 1 wherein the space-time coding comprises a layered space-time architecture.

Claim 3 (original): A transmitter comprising the coding gain system according to claim 1.

Claim 4 (original): A system according to claim 1 wherein the space time coding comprises symbol level space-time encoding means.

Claim 5 (original): A system according to claim 1 wherein the space time coding comprises bit-level space-time coding means.

Claim 6 (currently amended): A coding gain system adapted to transmit a plurality M of symbol substreams, the coding gain system comprising:

~~a space-time coding function adapted to produce M space-time coded streams, with each symbol of the M symbol substreams being represented in all M space-time coded streams and at different times;~~

a space-time coding function adapted to produce M space-time coded symbols per input set of M symbols, each input set of M symbols comprising one symbol per symbol substream, each of the M space-time coded symbols being included in a respective one of M space-time coded streams, but at a different time from the inclusion of each other of the M space-time coded symbols in their respective space-time coded stream;

a plurality M of transmit antennas each adapted to transmit a respective one of the

M space-time coded streams[[;]]

~~further comprising the demultiplexing and encoding functionality comprising a demultiplexer having M outputs, and M encoder/modulators each producing a respective one of the M symbol substreams, with each of the M encoder/modulators connected to receive a respective one of the demultiplexer outputs~~.

Claim 7 (currently amended): A coding gain system according to claim 19[[6]] wherein the demultiplexing and encoding functionality is adapted to produce the M symbol substreams from a primary input stream.

Claim 8 (currently amended): A coding gain system according to claim 7[[6]] wherein the space-time coding function comprises:

an orthogonal transform adapted to produce M orthogonal outputs each of which is a function of the M substreams;

~~delay elements adapted to insert delays in the M orthogonal outputs to produced M delayed orthogonal outputs such that each of the M delayed orthogonal outputs is a function of a given element of each of the M substreams at a different time~~delay elements adapted to insert a respective different delay in M-1 of the M orthogonal outputs to produce the M space-time coded streams.

Claim 9(original): A coding gain system according to claim 8 wherein the delay elements are adapted to introduce a delay of m-1 symbol periods in the mth orthogonal output, where m=1,…,M.

Claim 10 (original): A coding gain system according to claim 6 wherein the space-time coding function comprises:

delay elements adapted to insert a delay of M symbol periods in each of the M substreams;

an orthogonal transform adapted to produce M orthogonal outputs, with the mth

orthogonal output being a function of the M substreams delayed in said delay elements by m-1 symbol periods.

Claim 11 (original): A coding gain system according to claim 10 wherein the M substreams are bit streams, and wherein the orthogonal transform comprises M 2^M M-ary mapping functions, each adapted to produce a respective sequence of M-ary symbols with the M-ary symbol of the mth 2^M M-ary mapping function being a function of the M substreams delayed in said delay elements by m-1 bit periods.

Claim 12 (original): A coding gain system according to claim 6 wherein the M symbol substreams are bit streams.

Claim 13 (original): A coding gain system according to claim 6 further comprising encoder/modulator functionality integrated with the space-time coding function.

Claim 14 (currently amended): A coding method comprising:

demultiplexing an input symbol stream into M symbol substreams;

performing coding and modulation on each of said M symbol substreams;

~~performing a space-time coding function adapted to produce M space-time coded streams from the M symbol substreams, with each symbol of the M symbol substreams being represented in all M space-time coded streams and at different times;~~

performing a space-time coding function adapted to produce M space-time coded symbols per input set of M symbols, each input set of M symbols comprising one symbol per symbol substream, each of the M space-time coded symbols being included in a respective one of M space-time coded streams, but at a different time from the inclusion of each other of the M space-time coded symbols in their respective space-time coded stream;

transmitting the M space-time coded streams on respective antennas.

Claim 15 (currently amended): A method according to claim 14 wherein performing the space-

time coding function comprises:

executing an orthogonal transform to produce M orthogonal outputs each of which is a function of the M substreams;

delaying the M orthogonal outputs to produce[produced] M delayed orthogonal outputs such that each of the M delayed orthogonal outputs is a function of a given element of each of the M substreams at a different time.

Claim 16 (original): A method according to claim 15 wherein the mth orthogonal output is delayed by m-1 symbol periods, where m=1,...,M.

Claim 17 (original): A method according to claim 14 wherein performing the space-time coding function comprises:

delaying by M symbol periods each of the M substreams;

executing an orthogonal transform adapted to produce M orthogonal outputs, with the mth orthogonal output being a function of the M substreams delayed m-1 symbol periods.

Claim 18 (original): A method according to claim 15 wherein the M substreams are bit streams, and wherein the orthogonal transform comprises M 2^M M-ary mapping functions, each adapted to produce a respective sequence of M-ary symbols with the M-ary symbol of the mth 2^M M-ary mapping function being a function of the M substreams delayed in said delay elements by m-1 bit periods.

Claim 19 (new): A coding gain system according to claim 6 further comprising the demultiplexing and encoding functionality comprising a demultiplexer having M outputs, and M encoder/modulators each producing a respective one of the M symbol substreams, with each of the M encoder/modulators connected to receive a respective one of the demultiplexer outputs.

REMARKS/ARGUMENTS

Claims 6 to 8, 14, and 15 are being amended and new claim 19 is being added. Except for claim numbering, this amendment is consistent with an amendment of April 7, 2003 which was submitted at the international level but not entered. This effectively "undoes" the amendment filed March 10, 2003 at the international level which includes unnecessary narrowing amendments to the claims.

Regarding claim 6, some of the subject matter of this claim has been moved to new dependent claim 19 and other amendments regarding the space-time coding function have been made.

Claim 7 has been amended to depend on new claim 19.

Claim 8 has been amended to depend on claim 7 and amendments have been made regarding the delay elements.

Regarding claim 14, amendments have been made in respect of the step of performing a space-time coding function.

Claim 15 has been amended to correct for a grammatical error.

In view of the forgoing, early favorable consideration of this application is earnestly solicited.

Respectfully submitted,

SMART & BIGGAR

By _____
Allan Brett
Reg. No. 40,476

Date: September 17, 2003

RAB:MPP:acb

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.
10/399,859	08/29/2003	Wen Tong	14316NP	9275

7590 04/28/2004

Dowell & Dowell
1215 Jefferson Davis Highway
Suite 309
Arlington, VA 22202-3124

EXAMINER	
VU, HUY DUY	

ART UNIT	PAPER NUMBER
2665	

DATE MAILED: 04/28/2004

Please find below and/or attached an Office communication concerning this application or proceeding.

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UNITED STATES PATENT AND TRADEMARK OFFICE
UNDER SECRETARY OF COMMERCE FOR INTELLECTUAL PROPERTY AND DIRECTOR OF THE UNITED STATES PATENT AND TRADEMARK OFFICE
WASHINGTON, DC 20231
www.uspto.gov

Paper No.

Notice of Non-Compliant Amendment (37 CFR 1.121)

The amendment document filed on 11-18-03 is considered non-compliant because it has failed to meet the requirements of 37 CFR 1.121, as amended on June 30, 2003 (see *68 Fed. Reg. 38611*, Jun. 30, 2003). In order for the amendment document to be compliant, correction of the following omission(s) or provision is required. **Only the section (1.121(h)) of the amendment document containing the omission or non-compliant provision must be resubmitted (in its entirety), e.g., the entire "Amendments to the claims" section of applicant's amendment document must be re-submitted.**

THE FOLLOWING CHECKED (X) ELEMENTS(S) CAUSE THE AMENDMENT DOCUMENT TO BE NON-COMPLIANT:

☐ 1. Amendments to the specification:
- ☐ A. Amended paragraph(s) do not include markings.
- ☐ B. New paragraph(s) should not be underlined.
- ☐ C. Other _____

☐ 2. Abstract:
- ☐ A. Not presented on a separate sheet. 37 CFR 1.72.
- ☐ B. Other _____

☐ 3. Amendments to the drawings: _____

☒ 4. Amendments to the claims:
- ☒ A. A complete listing of all of the claims is not present.
- ☐ B. The listing of claims does not include the text of all claims (incl. withdrawn claims)
- ☐ C. Each claim has not been provided with the proper status identifier, and as such, the individual status of each claim cannot be identified.
- ☐ D. The claims of this amendment paper have not been presented in ascending numerical order.
- ☒ E. Other: Original claims are 1-23

For further explanation of the amendment format required by 37 CFR 1.121, see MPEP Sec. 714 and the USPTO website at http://www.uspto.gov/web/offices/pac/dapp/opla/preognotice/officeflyer.pdf.

If the non-compliant amendment is a **PRELIMINARY AMENDMENT,** applicant is given ONE MONTH from the mail date of this letter to supply the corrected section which complies with 37 CFR 1.121. Failure to comply with 37 CFR 1.121 will result in non-entry of the preliminary amendment and examination on the merits will commence without consideration of the proposed changes in the preliminary amendment(s). This notice is not an action under 35 U.S.C. 132, and **this ONE MONTH time limit is not extendable.**

If the non-compliant amendment is a reply to a **NON-FINAL OFFICE ACTION,** and since the amendment appears to be a *bona fide* attempt to be a reply (37 CFR 1.135(c)), applicant is given a TIME PERIOD of ONE MONTH from the mailing of this notice within which to re-submit the corrected section which complies with 37 CFR 1.121 in order to avoid abandonment. **EXTENSIONS OF THIS TIME PERIOD ARE AVAILABLE UNDER 37 CFR 1.136(a).**

If the amendment is a reply to a **FINAL REJECTION,** this form may be an attachment to an Advisory Action. **The period for response to a final rejection continues to run from the date set in the final rejection,** and is not affected by the non-compliant status of the amendment.

Marcia Gordon
Legal Instruments Examiner (LIE)

July 22, 2003 (rev.)

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AMENDMENT TRANSMITTAL LETTER (Large Entity) Applicant(s): WEN TONG, ET AL				Docket No. 14316NP	
Application No. 10,399,859	Filing Date 04/23/03	Examiner HUY DUY VU	Customer No. 000293	Group Art Unit 2665	Confirmation No. 9275

Invention: **COMBINATION OF SPACE-TIME CODING AND SPATIAL MULTIPLEXING, AND THE USE OF ORTHOGONAL TRANSFORMATION IN SPACE-TIME CODING**

OIPE JC17 JUN 04 2004 PATENT & TRADEMARK OFFICE

RECEIVED
JUN 0 8 2004
Technology Center 2600

COMMISSIONER FOR PATENTS:

Transmitted herewith is an amendment in the above-identified application.
The fee has been calculated and is transmitted as shown below.

CLAIMS AS AMENDED

	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST # PREV. PAID FOR		NUMBER EXTRA CLAIMS PRESENT	RATE	ADDITIONAL FEE
TOTAL CLAIMS	19	-	23	=	0	x $18.00	$0.00
INDEP. CLAIMS	3	-	3	=	0	x $86.00	$0.00
Multiple Dependent Claims (check if applicable) ☐							$0.00
TOTAL ADDITIONAL FEE FOR THIS AMENDMENT							$0.00

☒ No additional fee is required for amendment.
☐ Please charge Deposit Account No. in the amount of
☐ A check in the amount of to cover the filing fee is enclosed.
☒ The Director is hereby authorized to charge payment of the following fees associated with this communication or credit any overpayment to Deposit Account No. **19-2550**
  ☒ Any additional filing fees required under 37 C.F.R. 1.16.
  ☒ Any patent application processing fees under 37 CFR 1.17.

Signature

Kohji Suzuki
Reg. No. 44,467

Dated: **June 1, 2004**

I certify that this document and fee is being deposited on with the U.S. Postal Service as first class mail under 37 C.F.R. 1.8 and is addressed to the Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

Signature of Person Mailing Correspondence

Typed or Printed Name of Person Mailing Correspondence

cc:

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P11LARGE/REV07

OIPE JC177 JUN 04 2004 PATENT & TRADEMARK OFFICE

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Appl. No.	: 10/399,859	Confirmation No.	9275
Applicant	: WEN TONG, ET AL.		
Filed	: 04/23/2003		
TC/A.U.	: 2665		
Examiner	: VU, HUY DUY		
Docket No.	: 14316NP		
Customer No.	: 000293		

RECEIVED
JUN 0 8 2004
Technology Center 2600

Commissioner for Patents
Alexandria, VA 22313-1450
U.S.A.

Dear Sir:

By way of Voluntary Amendment, 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/Arguments begin on page 6 of this paper.

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Amendments to the Claims:

This listing of claims will replace all prior versions, and listings, of claims in the application:

Listing of Claims:

1. (Original) A coding gain system comprising combined space-time coding and spatial multiplexing.

2. (Original) A system according to claim 1 wherein the space-time coding comprises a layered space-time architecture.

3. (Original) A transmitter comprising the coding gain system according to claim 1.

4. (Original) A system according to claim 1 wherein the space-time coding comprises symbol level space-time encoding means.

5. (Original) A system according to claim 1 wherein the space-time coding comprises bit-level space-time coding means.

6. (Currently Amended) A coding gain system adapted to transmit a plurality M of symbol substreams, the coding gain system comprising:

a space-time coding function adapted to produce M space-time coded symbols per input set of M symbols, each input set of M symbols comprising one symbol per symbol substream, each of the M space-time coded symbols being included in a respective one of M space-time coded streams, but at a different time from the inclusion of each other of the M space-time coded symbols in their respective space-time coded stream;

a plurality M of transmit antennas each adapted to transmit a respective one of the M space-time coded streams~~a space-time coding function adapted to produce M space-time coded streams, with each symbol of the M symbol substreams being represented in all M space-time coded streams and at different times~~.

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7. (Currently Amended) A coding gain system according to claim 6 further comprising:

multiplexing and encoding functionality comprising a demultiplexer having M outputs, and M encoder/modulators each producing a respective one of the M symbol substreams, with each of the M encoder/modulators connected to receive a respective one of the multiplexer outputs.~~a plurality M of transmit antennas each adapted to transmit a respective one of the M space-time coded streams.~~

8. (Currently Amended) A coding gain system according to claim ~~6 further comprising~~ 7 wherein the demultiplexing and encoding functionality is adapted to produce the M symbol substreams from a primary input stream.

9. (Cancelled)

10. (Cancelled)

11. (Currently Amended) A coding gain system according to claim ~~6~~ 8 wherein the space-time coding function comprises:

an orthogonal transform adapted to produce M orthogonal outputs each of which is a function of the M substreams;

delay elements adapted to insert a respective different delays in M-1 of the M orthogonal outputs to produce~~d~~ the M space-time coded streams ~~delayed orthogonal outputs such that each of the M delayed orthogonal outputs is a function of a given element of each of the M substreams at a different time~~.

12. (Original) A coding gain system according to claim 11 wherein the delay elements are adapted to introduce a delay of m-1 symbol periods in the mth orthogonal output, where m=1,…,M.

13. (Original) A coding gain system according to claim 6 wherein the space-time coding function comprises:

delay elements adapted to insert a delay of M symbol periods in each of the M

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substreams;

an ortogonal transform adapted to produce M orthogonal outputs, with the mth orthogonal output being a function of the M substreams delayed in said delay elements by m-1 symbol periods.

14. (Original) A coding gain system according to claim 13 wherein the M substreams are bit streams, and wherein the orthogonal transform comprises M 2^M M-ary mapping functions, each adapted to produce a respective sequence of M-ary symbols with the M-ary symbol of the mth 2^M M-ary mapping function being a function of the M substreams delayed in said delay elements by m-1 bit periods.

15. (Original) A coding gain system according to claim 6 wherein the M symbol substreams are bit streams.

16. (Original) A coding gain system according to claim 6 further comprising encoder/modulator functionality integrated with the space-time coding function.

17. (Currently Amended) A coding method comprising

demultiplexing an input symbol stream into M symbol substreams;

performing coding and modulation on each of said M symbol substreams;

perfoming a space-time coding function adapted to produce M space-time coded symbols per input set of M symbols, each input set of M symbols comprising one symbol per symbol substream, each of the M space-time coded symbols being included in a respective one of M space-time coded streams, but at a different time from the inclusion of each other of the M space-time coded symbols in their respective space-time coded stream; ~~a space-time coding function adapted to produce M space-time coded streams from the M symbol substreams, with each symbol of the M symbol substreams being represented in all M space-time coded streams and at different times;~~

transmitting the M space-time coded streams on respective antennas.

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18. (Cancelled)

19. (Cancelled)

20. (Currently Amended) A method according to claim 17 wherein performing the space-time coding function comprises:

executing an orthogonal transform to produce M orthogonal outputs each of which is a function of the M substreams;

delaying the M orthogonal outputs to produced M delayed orthogonal outputs such that each of the M delayed orthogonal outputs is a function of a given element of each of the M substreams at a different time.

21. (Original) A method according to claim 20 wherein the mth orthogonal output is delayed by m-1 symbol periods, where m=1,…,M.

22. (Original) A method according to claim 17 wherein performing the space-time coding function comprises:

delaying by M symbol periods each of the M substreams;

executing an orthogonal transform adapted to produce M orthogonal outputs, with the mth orthogonal output being a function of the M substreams delayed m-1 symbol periods.

23. (Original) A method according to claim 20 wherein the M substreams are bit streams, and wherein the orthogonal transform comprises M 2^M M-ary mapping functions, each adapted to produce a respective sequence of M-ary symbols with the M-ary symbol of the mth 2^M M-ary mapping function being a function of the M substreams delayed in said delay elements by m-1 bit periods.

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REMARKS/ARGUMENTS

Claims 6-8, 11, 17, and 20 are amended. This amendment is consistent with amendments submitted during the International Phase of this National Phase application.

Regarding claims 6 and 17, amendments have been made to the recitation of the space-time coding function.

Claim 6 has been further amended to recite a feature of former claim 7.

Claim 7 has been amended to recite a feature from former claim 9, and claims 9 and 10 have been cancelled.

Claim 8 has been amended to depend from claim 7.

Claim 11 has been amended to depend from claim 8, and amendments have been made regarding the delay elements.

Claim 17 has been further amended to recite a feature of claim 18, and claims 18 and 19 have been cancelled.

Claim 20 has been amended to correct an apparent typographical error by replacing "produced" with "produce" in the expression "to produced M delayed orthogonal outputs".

In view of the forgoing, early favorable consideration of this application is earnestly solicited.

Respectfully submitted,

WEN TONG, ET AL.

By

Kohji Suzuki
Reg. No. 44,467
Tel.: (613) 232-2486 ext. 263

Date: June 1, 2004
KS:DMW:map

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AMENDMENT TRANSMITTAL LETTER (Large Entity)	Docket No.
Applicant(s): WEN TONG ET AL	14316NP/wfs

Application No.	Filing Date	Examiner	Customer No.	Group Art Unit	Confirmation No.
10/399,859	04/23/03	HUY DUY VU	000293	2665	9275

Invention: COMBINATION OF SPACE-TIME CODING AND SPATIAL MULTIPLEXING, AND THE USE OF ORTHOGONAL TRANSFORMATION IN SPACE-TIME CODING

OIPE SC174 MAY 0 3 2005 PATENT & TRADEMARK OFFICE

COMMISSIONER FOR PATENTS:

Transmitted herewith is an amendment in the above-identified application.

The fee has been calculated and is transmitted as shown below.

CLAIMS AS AMENDED

	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST # PREV. PAID FOR		NUMBER EXTRA CLAIMS PRESENT	RATE	ADDITIONAL FEE
TOTAL CLAIMS	13	-	23	=	0	x $50.00	$0.00
INDEP. CLAIMS	2	-	3	=	0	x $200.00	$0.00
Multiple Dependent Claims (check if applicable) ☐							$0.00
TOTAL ADDITIONAL FEE FOR THIS AMENDMENT							$0.00

☒ No additional fee is required for amendment.

☐ Please charge Deposit Account No. in the amount of

☐ A check in the amount of to cover the filing fee is enclosed.

☒ The Director is hereby authorized to charge payment of the following fees associated with this communication or credit any overpayment to Deposit Account 19-2550

- ☒ Any additional filing fees required under 37 C.F.R. 1.16.
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Signature

Dated: May 3, 2005

Allan Brett (Reg. No. 40,476)

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OIPE JC17 MAY 0 3 2005 PATENT & TRADEMARK OFFICE

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Appl. No.	:	10/399,859	Confirmation No. 9275
Applicant	:	Wen Tong et al.	
Filed	:	April 23, 2003	
TC/A.U.	:	2665	
Examiner	:	Huy Duy Vu	
Docket No.	:	14316NP	
Customer No.	:	000293	

Commissioner for Patents
Alexandria, VA 22313-1450
U.S.A.

Dear Sir:

By way of voluntary amendment, please amend this application as follows:

Amendments to the Claims are reflected in the listing of claims which begins on page 2 of this paper.

Remarks/Arguments begin on page 5 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:

Claims 1-23 (Cancelled)

24. (New) A transmitter adapted to process a plurality M of symbol substreams, the transmitter comprising:

a space-time coding function adapted to produce M space-time coded symbols per input set of M symbols, each input set of M symbols comprising one symbol per symbol substream, each of the M space-time coded symbols being included in a respective one of M space-time coded streams, wherein each symbol of the M symbol substreams is represented in all M space-time coded streams, and for each symbol a time of representation of the symbol in the M space-time coded streams is different for each of the M space-time coded streams;

a plurality M of transmit antennas each adapted to transmit a respective one of the M space-time coded streams.

25. (New) A transmitter according to claim 24 further comprising the demultiplexing and encoding functionality comprising a demultiplexer having M outputs, and M encoder/modulators each producing a respective one of the M symbol substreams, with each of the M encoder/modulators connected to receive a respective one of the demultiplexer outputs.

26. (New) A transmitter according to claim 25 wherein the demultiplexing and encoding functionality is adapted to produce the M symbol substreams from an input stream.

27. (New) A transmitter according to claim 26 wherein the space-time coding function comprises:

an orthogonal transform adapted to produce M orthogonal outputs each of which is a function of the M substreams;

delay elements adapted to insert a respective different delay in M-1 of the M orthogonal outputs to produce the M space-time coded streams.

28. (New) A transmitter according to claim 27 wherein the delay elements are adapted to introduce a delay of m-1 symbol periods in the mth orthogonal output, where m=1, ..., M.

29. (New) A transmitter according to claim 24 wherein the space-time coding function comprises:

delay elements adapted to insert a delay of M symbol periods in each of the M substreams;

an orthogonal transform adapted to produce M orthogonal outputs, with the mth orthogonal output being a function of the M substreams delayed in said delay elements by m-1 symbol periods.

30. (New) A transmitter according to claim 29 wherein the M substreams are bit streams, and wherein the orthogonal transform comprises M M-ary mapping functions, each adapted to produce a respective sequence of M-ary symbols with the M-ary symbol of the mth M-ary mapping function being a function of the M substreams delayed in said delay elements by m-1 bit periods.

31. (New) A transmitter according to claim 24 further comprising encoder/modulator functionality integrated with the space-time coding function.

32. (New) A method of combined spatial multiplexing and space-time coding, comprising:

demultiplexing an input symbol stream into M symbol substreams;

performing coding and modulation on each of said M symbol substreams;

performing a space-time coding function adapted to produce M space-time coded symbols per input set of M symbols, each input set of M symbols comprising one symbol per symbol substream, each of the M space-time coded symbols being included in a respective one of M space-time coded streams, wherein each symbol of the M symbol substreams is represented

in all M space-time coded streams, and for each symbol a time of representation of the symbol in the M space-time coded streams is different for each of the M space-time coded streams;

transmitting the M space-time coded streams on respective antennas.

33. (New) A method according to claim 32 wherein performing the space-time coding function comprises:

executing an orthogonal transform to produce M orthogonal outputs each of which is a function of the M substreams;

delaying the M orthogonal outputs to produce M delayed orthogonal outputs such that each of the M delayed orthogonal outputs is a function of a given element of each of the M substreams at a different time.

34. (New) A method according to claim 33 wherein the mth orthogonal output is delayed by m-1 symbol periods, where m=1, ..., M.

35. (New) A method according to claim 32 wherein performing the space-time coding function comprises:

delaying by M symbol periods each of the M substreams;

executing an orthogonal transform adapted to produce M orthogonal outputs, with the mth orthogonal output being a function of the M substreams delayed m-1 symbol periods.

36. (New) A method according to claim 33 wherein the M substreams are bit streams, and wherein the orthogonal transform comprises M M-ary mapping functions, each adapted to produce a respective sequence of M-ary symbols with the M-ary symbol of the mth M-ary mapping function being a function of the M substreams delayed in said delay elements by m-1 bit periods.

REMARKS/ARGUMENTS

In view of the foregoing, early favorable consideration of this application is earnestly solicited.

Respectfully submitted,

WEN TONG, ET AL.

By _____
Allan Brett
Reg. No. 40,476
Tel.: (703) 415-2555

Date: May 3, 2005

RAB:rld

10399859

PATENT APPLICATION FEE DETERMINATION RECORD
Effective January 1, 2003

Application or Docket Number: 14316NP

CLAIMS AS FILED - PART I

	(Column 1)	(Column 2)
TOTAL CLAIMS		
FOR	NUMBER FILED	NUMBER EXTRA
TOTAL CHARGEABLE CLAIMS	23 minus 20=	* 3
INDEPENDENT CLAIMS	3 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	375.00	OR	BASIC FEE	750.00
X$ 9=		OR	X$18=	34
X42=		OR	X84=	
+140=		OR	+280=	
TOTAL		OR	TOTAL	934

6/4/04

CLAIMS AS AMENDED - PART II

AMENDMENT A

	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA
Total	* 4	Minus	** 23	=
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=	
X42=		OR	X84=	
+140=		OR	+280=	
TOTAL ADDIT. FEE		OR	TOTAL ADDIT. FEE	

5/3/05

AMENDMENT B

	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA
Total	* 13	Minus	** 23	=
Independent	* 2	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=	
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				☐

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	

* 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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APPLICATION NUMBER	PATENT NUMBER	GROUP ART UNIT	FILE WRAPPER LOCATION
10/399,859		2665	0500

Correspondence Address / Fee Address Change

The following fields have been set to Customer Number 293 on 08/31/2005

- Correspondence Address

The address of record for Customer Number 293 is:
Ralph A. Dowell of DOWELL & DOWELL P.C.
2111 Eisenhower Ave.
Suite 406
Alexandria,VA 22314

OIPE IAP40 FEB 28 2006 PATENT & TRADEMARK OFFICE

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE
ATTY. DOCKET NO. 14316NP

In re Patent Application of Wen Tong, et al.

Serial No. 10/399,859 Group Art Unit: 2665

Filed: April 23, 2003 Examiner: Huy Duy Vu

For: COMBINATION OF SPACE-TIME CODING AND SPATIAL MULTIPLEXING, AND THE USE OF ORTHOGONAL TRANSFORMATION IN SPACE-TIME CODING

INFORMATION DISCLOSURE STATEMENT

This Information Disclosure Statement is being filed in the manner prescribed by 37 CFR 1.97(b) - (d) to satisfy the duty under 37 CFR 1.56 to disclose to the Office information, known to individuals associated with the filing and prosecution of the subject application, which is material to the examination of the application.

In accordance with 37 CFR 1.97(g) and (h), this statement is not to be construed as a representation that a search has been made or an admission that the information cited herein is, or is considered to be, material to patentability as defined in 37 CFR 1.56(b).

This Information Disclosure Statement is being filed within three months of the filing date of a national application; within three months of the date of entry of the national stage as set forth in 37 CFR 1.491 in an international application; or before the mailing date of a first official action on the merits and therefore applicant respectfully requests consideration under 37 CFR 1.97(b).

In compliance with 37 CFR 1.98(a)(2), also enclosed is a legible copy of:

i) each foreign patent;
ii) each publication or that portion which caused it to be listed; and
iii) all other information or that portion which caused it to be listed, excluding any copies of a United States patent application.

In compliance with 37 CFR 1.98(a)(1), a list of all patents, publications, applications or other information submitted for consideration by the Office is hereby provided by way of the attached Form PTO/SB/08.

It is respectfully requested that the information be expressly considered by the Examiner and that the references be made of record and appear among the "References Cited" on any patent to issue therefrom.

The Patent Office is hereby authorized to charge any deficiency, or credit any overpayment in fees to Deposit Account Number 19-2550.

Respectfully submitted,

WEN TONG, ET AL.

Dated: February 28, 2006

Ralph A. Dowell
Reg. No. 26,868
Telephone: (703) 415-2555
Fax: (703) 415-2559

Encls.: Form PTO/SB/08
All references listed on Form PTO/SB/08
EP Search Report
Acknowledgement Card

OIPE IAP40 FEB 28 2006 PATENT & TRADEMARK OFFICE

PTO/SB/08A (08-03)
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Substitute for form 1449/PTO

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Use as many sheets as necessary)

Sheet 1 of 2

Complete if Known	
Application Number	10/399,859
Filing Date	April 23, 2003
First Named Inventor	Wen Tong
Art Unit	2665
Examiner Name	Huy Duy Vu
Attorney Docket Number	14316NP

U.S. PATENT DOCUMENTS

Examiner Initials *	Cite No. [1]	Document Number Number-Kind code [2] *(if known)*	Publication Date MM-DD-YYY	Name of Patentee or Applicant of Cited Document	Page, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
		US-			
		US-			
		US-			
		US-			
		US-			
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FOREIGN PATENT DOCUMENTS

Examiner Initials *	Cite No. [1]	Foreign Patent Document Country Code[3]-Number[4]-Kind Code[5] *(if known)*	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages Or Relevant Figures	T[6]
	AA	EP 0 905 920 A2	31.03.1999	Lucent Technolgoies Inc.		☐
	AB	EP 0 993 130 A2	12.04.2000	Texas Instruments Incorporated		☐
						☐
						☐
						☐

Examiner Signature		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. [1] Applicant's unique citation designation number (optional). [2] See Kinds codes of USPTO patent Documents at www.upsto.gov or MPEP 901.04 [3] Enter Office that issued the document, by the two-letter code (WIPO Standard ST.3). [4] For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. [5] Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. [6] Applicant is to place a checkmark here if English language Translation is attached.

This collection of information is required by 37 CFR 1.97 and 1.98. 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 2 hours 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, 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.**

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OIPE IAP40 FEB 28 2006 PATENT & TRADEMARK OFFICE

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Use as many sheets as necessary)

Sheet 2 of 2

Complete if Known	
Application Number	10/399,859
Filing Date	April 23, 2003
First Named Inventor	Wen Tong
Art Unit	2665
Examiner Name	Huy Duy Vu
Attorney Docket Number	14316NP

NON PATENT LITERATURE DOCUMENTS

Examiner Initials *	Cite No. [1]	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, pages), volume-issue number(s), publisher, city and /or country where published.	T[2]
	AC	Hochwald, Marzetta; SPACE-TIME MODULATION FOR UNKNOWN FADING; Proceedings of the SPIE, Vol. 57, No. 8, April 1999, pgs 10-19, XP000914262	☐
	AD	Yumin Zhang & R. Blum; MULTISTAGE MULTIUSER DETECTION FOR CDMA WITH SPACE-TIME CODING; IEEE Workshop on Statistical Signal and Array Processing; 14-16 August 2000, pgs 1-5, XP002174378.	☐
	AE	Ben Lu; et al.; ITERATIVE RECEIVERS FOR MULTIUSER SPACE-TIME CODING SYSTEMS; IEEE International Conference on Communications, 18-22 June 2000, pgs 302-306, XP002174379.	☐
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[1] Applicant's unique citation designation number (optional). [2] Applicant is to place a checkmark here if English language Translation is attached.
This collection of information is required by 37 CFR 1.98. 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 2 hours 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, 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.**

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(19) Europäisches Patentamt
European Patent Office
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(11) EP 0 905 920 A2

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
31.03.1999 Bulletin 1999/13

(51) Int Cl.[6]: **H04B 7/04**, H04B 17/00

(21) Application number: **98307449.3**

(22) Date of filing: **15.09.1998**

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: **26.09.1997 US 938168**

(71) Applicant: **LUCENT TECHNOLOGIES INC.**
Murray Hill, New Jersey 07974-0636 (US)

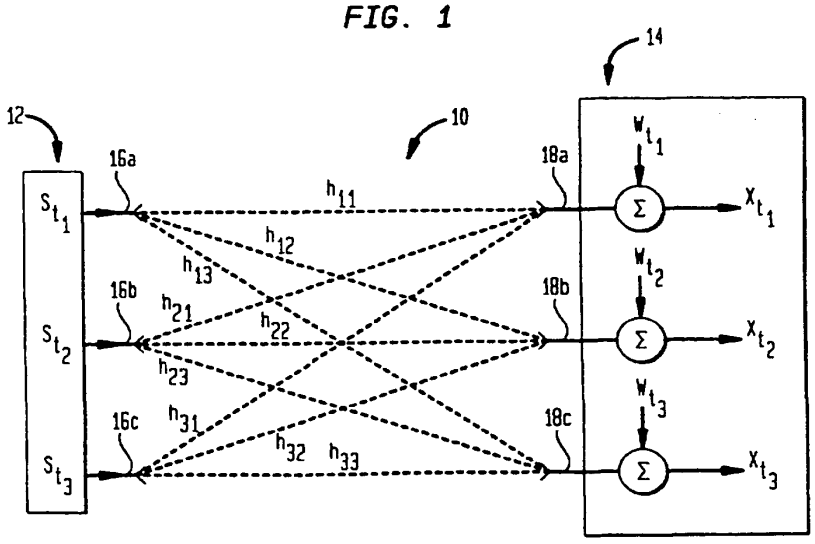
(72) Inventors:
- **Hochwald, Bertrand M.**
  Summit, New Jersey 07901 (US)
- **Marzetta, Thomas Louis**
  Summit, New Jersey 07901 (US)

(74) Representative:
Buckley, Christopher Simon Thirsk et al
Lucent Technologies (UK) Ltd,
5 Mornington Road
Woodford Green, Essex IG8 0TU (GB)

(54) Multiple antenna communication system and method thereof

(57) A communications system achieves high bit rates over an actual communications channel between M transmitter antennas (16a-16c) of a first unit (12) and N receiver antennas (18a-18c) of a second unit (14), where M or N>1, by creating virtual sub-channels from the actual communications channel. The multiple antenna system creates the virtual sub-channels from the actual communications channel by using propagation information characterizing the actual communications channel at the first and second units. For transmissions from the first unit (12) to the second unit (14), the first unit sends a virtual transmitted signal over at least a subset of the virtual sub-channels using at least a portion of the propagation information. The second unit retrieves a corresponding virtual received signal from the same set of virtual sub-channels using at least another portion of said propagation information.

FIG. 1



EP 0 905 920 A2

Printed by Jouve, 75001 PARIS (FR)

BNSDOCID: <EP___0905920A2_I_>

Description

BACKGROUND OF THE INVENTION

1. Field of The Invention

[0001] This invention relates to wireless communication systems and, more particularly, to a multiple antenna communication system.

2. Description of Related Art

[0002] The ultimate bit rate at which a digital wireless communication system may communicate data may be derived using Shannon's approach to information theory (commonly referred to as the Shannon limit). The ultimate bit rate is based on a number of different parameters, including: the total radiated power at the transmitter; the number of antennas at the transmitter and receiver; bandwidth; noise power at the receiver; and the characteristics of the propagation environment. For wireless transmission using multiple antennas at the transmitter and/or receiver in a so-called Rayleigh fading environment, the ultimate bit rate could be enormous, for example, hundreds of bits per second per Hz for a system employing 30 antennas at both the transmitter and receiver and experiencing an average signal-to-noise ratio of 16dB.

[0003] A need exists for a wireless communications system which achieves high bit rates in a cost effective and relatively simple manner.

SUMMARY OF THE INVENTION

[0004] The present invention involves a communications system that achieves high bit rates over an actual communications channel between M transmitter antennas of a first unit and N receiver antennas of a second unit, where M or N >1, by creating virtual sub-channels from the actual communications channel. The multiple antenna system creates the virtual sub-channels from the actual communications channel by using at the first and second units propagation information characterizing the actual communications channel. For transmissions from the first unit to the second unit, the first unit sends a virtual transmitted signal over at least a subset of the virtual sub-channels using at least a portion of the propagation information. The second unit retrieves a corresponding virtual received signal from the same set of virtual sub-channels using at least another portion of said propagation information.

[0005] In general, a propagation matrix of propagation coefficients characterizes the propagation of communication signals between the transmitting antenna(s) of the first unit and the receiving antenna(s) of the second unit. By knowing the propagation characteristics of the actual communications channel (multiple-antenna channel), the multiple antenna system can decompose the actual communications channel into multiple virtual sub-channels. For transmissions from the first unit to the second unit, both the first unit and the second unit obtain propagation information which characterizes the transmissions from the first unit to the second unit. In certain embodiments, the first unit obtains at least a portion of the propagation information, and the second unit obtains at least another portion of the propagation information. Using the respective portions of the propagation information, the first and second units cooperatively render the actual communications channel into virtual sub-channels, thereby achieving high bit rate or throughput in a relatively simple manner.

[0006] In certain embodiments, the first and second units obtain the propagation matrix as the propagation information for transmissions from the first unit to the second unit. Initially, the first unit and second units obtain the propagation matrix by an exchange of signals. For example, the first unit transmits training signals to the second unit. From the training signals as transmitted and the training signals as received over the actual communications channel, the propagation matrix can be determined. Once the propagation matrix is determined, each unit can perform a singular value decomposition of the propagation matrix. The singular value decomposition of the propagation matrix yields the propagation matrix as the product of three factors D, Φ and $\psi^{\dagger}$, where D is a diagonal matrix and Φ and $\psi^{\dagger}$ are two unitary matrices with the superscript "†"denoting a conjugate transpose. The singular value decomposition serves to diagonalize the propagation matrix. The number of nonzero diagonal elements in the diagonal matrix D corresponds to the number of parallel independent virtual sub-channels for the actual communications channel. In some embodiments, for transmissions from the first unit to the second unit, the first unit obtains at least a portion of the propagation information which includes the diagonal matrix D and the unitary matrix Φ. The first unit provides the diagonal matrix D to a channel coder/modulator to encode and modulate an incoming bit or information stream onto the independent virtual sub-channels according to the values of the diagonal matrix D to produce a virtual transmitted signal. As such the diagonal matrix D can provide relative scaling of the bit rate. The first unit then performs a unitary transformation on the virtual transmitted signal by multiplying the virtual transmitted signal with the conjugate transpose of the unitary

BNSDOCID: <EP__.0905920A2 I >

Nintendo Exhibit 1013
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matrix Φ to produce the actual transmitted signal.

[0007] The second unit obtains at least another portion of the propagation information which includes the unitary matrix $\psi^{\dagger}$ and the diagonal matrix D in certain embodiments. The second unit performs a unitary transformation on the actual received signal by multiplying the actual received signal with the unitary matrix ψ to produce a virtual received signal. The multiplications at the first and second units by the unitary matrices establish a virtual channel from the actual communications channel between the virtual transmitted signal and the virtual received signal which can be treated as parallel independent virtual sub-channels. The second unit provides the diagonal matrix D to a channel decoder/demodulator to decode and demodulate the virtual received signal according to the matrix D to produce an information stream. Thus, the multiple antenna system provides high capacity by effectively providing parallel independent sub-channels within the same frequency band. The multiple antenna system also provides enhanced performance because the multiple antenna system transmits bits on the virtual sub-channels relative to the values of the diagonal matrix D, thereby the stronger virtual sub-channels are used to transmit more information.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] Other aspects and advantages of the present invention may become apparent upon reading the following detailed description and upon reference to the drawings in which:

FIG. 1 shows a baseband representation of a multiple antenna channel or the actual communications channel used according to the principles of the present invention;
FIG. 2 shows a baseband representation of the virtual sub-channels derived from the actual communications channel according to certain principles of the present invention;
FIG. 3 shows a block diagram of an embodiment of the multiple antenna system according to the principles of the present invention;
FIG. 4 shows a block diagram of an embodiment of a multiple antenna transmitter according to certain principles of the present invention; and
FIG. 5 shows a block diagram of a particular embodiment of the transmit circuitry for the transmitter of FIG. 4;
FIG. 6 shows a block diagram of an embodiment of a multiple antenna receiver according to certain principles of the present invention; and
FIG. 7 shows a block diagram of an embodiment of the receive circuitry of the receiver of FIG. 6.

DETAILED DESCRIPTION OF THE DRAWINGS

[0009] An illustrative embodiment of the multiple antenna communication system according to the principles of the present invention is described below as the multiple antenna communication system might be implemented to provide high bit rate and enhanced performance. The multiple antenna system accomplishes this by using multiple antenna arrays at the transmitter and/or receiver and taking advantage of the propagation characteristics obtained for the multiple-antenna channel between the antenna(s) of a first unit and the antenna(s) of a second unit. By knowing certain propagation characteristics of the actual communications channel (multiple-antenna channel) at the first unit and the second unit, the multiple antenna system can achieve high bit rates by having the first unit and second unit cooperatively decompose the actual communications channel into multiple virtual sub-channels. For transmissions from the first unit to the second unit, the first and second units obtain at least respective portions of the propagation information characterizing the transmissions from the first unit to the second unit. The first and second units use at least their respective portions of the propagation information to decompose the actual communications channel into multiple virtual sub-channels over which communication signals are transmitted. As such, the multiple antenna communication system achieves high bit rates in a relatively simple manner without increasing total power or bandwidth by using the virtual sub-channels within the same frequency band. Additionally, the multiple antenna system provides enhanced performance by transmitting more bits over the stronger sub-channels as determined by the propagation information.

[0010] FIG. 1 shows a baseband representation for an actual communications channel 10 over which a first unit 12 transmits the RF signals corresponding to the components s_{t1}, s_{t2} and s_{t3} of an actual transmitted signal on carriers of the same frequency over respective multiple antennas 16a-c to a second unit 14. In this particular embodiment, the first unit 12 has three antennas 16a-c, and the second unit 14 has three antennas 18a-c. The second unit 14 receives the RF signals at the respective receive antennas 18a-c corresponding to the components x_{t1}, x_{t2} and x_{t3} of the actual received signal. Each receive antenna 18a-c responds to each transmit antenna 16a-c through a complex-valued, scalar propagation coefficient h_{mn}, where m designates the respective transmit antenna 16a-c and n designates the respective receive antenna 18a-c. As such, the actual received signal x_{t1}, x_{t2} and x_{t3} can be characterized by the following:

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$$x_{t1} = h_{11} \times s_{t1} + h_{21} \times s_{t2} + h_{31} \times s_{t3} + w_{t1}$$

$$x_{t2} = h_{12} \times s_{t1} + h_{22} \times s_{t2} + h_{32} \times s_{t3} + w_{t2}$$

$$x_{t3} = h_{13} \times s_{t1} + h_{23} \times s_{t2} + h_{33} \times s_{t3} + w_{t3},$$

where $\{w_{t1}, w_{t2}, w_{t3}\}$ are receiver noise added at the second unit 14. In vector notation, $\underline{x}_t = \underline{s}_t \times H + \underline{w}_t$ where $\underline{x}_t = [x_{t1}, x_{t2}, x_{t3}]$, $\underline{s}_t = [s_{t1}, s_{t2}, s_{t3}]$, $\underline{w}_t = [w_{t1}, w_{t2}, w_{t3}]$, and the propagation matrix can be represented as:

H =	h11	h12	h13
	h21	h22	h23
	h31	h32	h33.

[0011] In this particular embodiment, the second unit 14 can transmit signals in the reverse direction to the first unit 12. The second unit 14 can use its receive antennas 18a-c to transmit the signals, and the first unit 12 can use its transmit antennas 16a-c to receive the signals. If the same frequency is used in both directions (using a time division duplex (TDD) scheme in certain bi-directional communications embodiments), the propagation coefficients for transmissions from the second unit 14 to the first unit 12 can be considered equal to the propagation coefficients for transmissions from the first unit 12 to the second unit 14 (according to the reciprocity principle), so $H_{2to1} = H^{T}_{1to2}$, where the superscript "T" denotes the transpose. If different frequencies are used in both directions (using a frequency division duplex scheme), the propagation coefficients for the signals propagating in both directions are determined. Using an appropriate training and set-up scheme, the first unit 12 and the second unit 14 can both learn the first unit 12 to second unit 14 propagation coefficients and the second unit 14 to first unit 12 propagation coefficients. For example, the units 12 and 14 could transmit known training signals over one antenna at a time and/or transmit training signals using orthogonal signals transmitted simultaneously over all respective antennas.

[0012] For ease of discussion, the multiple antenna scheme according to the principles of the present invention is discussed with particular reference to transmissions from the first unit 12 to the second unit 14. It should be understood that the multiple antenna scheme can be applied to both uni-directional or bi-directional communications. In this particular embodiment, both units 12 and 14 perform a singular value decomposition (SVD) of the 3 × 3 propagation matrix H obtained by both units 12 and 14. In this particular embodiment, the SVD of H yields $H = \Phi \times D \times \psi^{\dagger}$, where D is a 3 × 3 real-valued, nonnegative, diagonal matrix,

D=	d11	0	0
	0	d22	0
	0	0	d33,

and Φ and $\psi^{\dagger}$ are 3 × 3 complex unitary matrices with the superscript "†" denoting the "conjugate transpose." The columns of a unitary matrix have unit length and are mutually orthogonal. Multiplying a vector by a unitary matrix does not change the length of the vector but merely changes the direction of the vector. The inverse of a unitary matrix is equal to the conjugate transpose of the matrix, for example, $\Phi^{\dagger} \times \Phi = I$ or for 1= 1 to 3, $\Sigma \Phi_{li}^{*} \times \Phi_{lj}$ is equal to 1 if i=j and is equal to 0, if i≠j, where the superscript "*" denotes the "complex-conjugate."

[0013] The second unit 14 uses the matrix ψ to multiply the received signal $\underline{x}_t$ by the 3 × 3 unitary matrix ψ to obtain $\underline{r}_t = [r_{t1}, r_{t2}, r_{t3}] = \underline{x}_t \times \psi$. The first unit 12 uses the matrix Φ to transform the virtual transmitted signal $\underline{y}_t$ into the actual transmitted signal $\underline{s}_t$ by letting the actual transmitted signal $\underline{s}_t$ be equal to the conjugate transpose of the 3 × 3 unitary matrix Φ times the virtual transmitted signal $\underline{y}_t$, $\underline{s}_t = \underline{y}_t \times \Phi^{\dagger}$ where $\underline{y}_t = [y_{t1}, y_{t2}, y_{t3}]$. The multiplications by the unitary matrices are invertible operations, so there is no loss of information. In effect, a link is established between the virtual transmitted signal $\underline{y}_t$ and the virtual received signal $\underline{r}_t$, where

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$$\underline{r}_t = \underline{x}_t \times \psi \quad = (\underline{s}_t \times H + \underline{w}_t) \times \psi$$
$$= (\underline{y}_t \times \Phi^{\dagger} \times H + \underline{w}_t) \times \psi$$
$$= \underline{y}_t \times \Phi^{\dagger} \times H \times \psi + \underline{w}_t \times \psi.$$

Substituting $H = \Phi \times D \times \psi^{\dagger}$ in the above expression gives:

$$\underline{r}_t = \underline{y}_t \times \Phi^{\dagger} \times (\Phi \times D \times \psi^{\dagger})\ \psi + \underline{w}_t \times \psi$$
$$= \underline{y}_t \times D + \underline{v}_t, \text{ where } \underline{v}_t = \underline{w}_t \times \psi.$$

Thus, the original link 10 between $\underline{s}_t$ and $\underline{x}_t$ is equivalent to a much simpler virtual link 20 between $\underline{y}_t$ and $\underline{r}_t$ as shown in FIG. 2. In the actual communications channel, every one of the N receiver antennas responds to every one of the M transmitter antennas. The advantage of the virtual link or channel 10 is that it comprises virtual sub-channels, wherein each of a plurality of virtual receiver antennas responds to exactly one respective virtual transmitter antenna. In effect, the cross-coupled actual communications channel 10 of FIG. 1 can be treated as the three parallel, independent virtual sub-channels d_{11}, d_{22} and d_{33} shown in FIG. 2 according to the principles of the present invention.

[0014] The first and second units 12 and 14 can determine the respective propagation information needed to establish the virtual sub-channels between the first unit 12 and the second unit 14 in alternative ways. For example, since the matrix $HH^{\dagger} = \Phi \times D \times D^{\dagger} \times \Phi^{\dagger}$, the first unit 12 and/or the second unit 14 can determine the unitary matrix $\Phi^{\dagger}$ from the eigenvectors of the matrix $HH^{\dagger}$ and the diagonal matrix D from the eigenvalues of $HH^{\dagger}$. Additionally, since $H^{\dagger}H = \psi \times D^{\dagger} \times D \times \psi^{\dagger}$, the first unit 12 and/or the second unit 14 can determine the unitary matrix ψ from the eigenvectors of $H^{\dagger}H$ and the diagonal matrix D from the eigenvalues of $H^{\dagger}H$. The diagonal matrix can be determined by using the squareroots of the eigenvalues of $HH^{\dagger}$ or $H^{\dagger}H$.

[0015] FIG. 3 shows an embodiment of the multiple antenna communication system 10 according to certain principles of the present invention for transmissions between the first unit 12 and the second unit 14. In this particular embodiment, the first unit 12 is shown as transmitting, and the second unit 14 is shown as receiving. For transmissions in the reverse direction, the first unit 12 would typically include receiver components (not shown) as will be described below for the second unit 14, and the second unit 14 would typically include transmitter components (not shown) as described below for the first unit 12. In accordance with certain embodiments of the present invention, the first unit 12 uses the multiple antenna array 16 for transmitting and receiving communication signals, and the second unit 14 use the multiple antenna array 18 for transmitting and receiving communication signals.

[0016] In this particular embodiment for transmissions from the first unit 12 to the second unit 14, the propagation of the signals over the actual communications channel 10 has a baseband characterization that comprises a matrix of complex-valued (having real and imaginary parts) propagation coefficients between the transmitting antennas 16a-c and the receiving antennas 18a-c. In this particular embodiment, the first unit 12 and the second unit 14 learn the values of the propagation matrix and determine the appropriate propagation information to establish the virtual sub-channels between the first unit 12 and the second unit 14. Alternatively, the first unit 12 and/or the second unit 14 do not learn the propagation matrix. Instead, the units 12 and 14 obtain and/or determine some portion of the propagation information, such as the diagonal matrix D, and the first unit 12 obtains and/or determines other propagation information, such as the unitary matrix $\Phi^{\dagger}$ while the second unit 14 obtains and/or determines the unitary matrix ψ.

[0017] To learn the propagation matrix (or derive the appropriate propagation information for certain embodiments) for communications from the first unit 12 to the second unit 14, the first unit 12 can send training signals to the unit 14 from which the unit 14 determines or estimates the propagation matrix (or propagation information). The unit 14 can then send the propagation matrix (or propagation information) to the unit 12 by using a conventional communication scheme employing one or multiple antennas at the first and second units 12 and 14. Alternatively, the unit 14 can send the propagation matrix (or propagation information) to the unit 12 using other communication links, such as a phone line. Additionally, the unit 14 can simply send back to the unit 12 the training signals received from the unit 12, and the unit 12 determines the propagation matrix (or propagation information). The unit 12 then sends the propagation matrix (or propagation information) to the unit 14.

[0018] Likewise, to learn the propagation matrix (or propagation information) for signals propagating from the unit 14 to the unit 12, the unit 14 sends training signals to the unit 12 from which the unit 12 determines or estimates the propagation matrix (or propagation information). Once again, as discussed for determining the propagation matrix (or

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propagation information) for transmissions from the unit 12 to the unit 14, the unit 12 can provide and/or derive different forms or amounts of propagation information to the unit 14 depending on the particular embodiment and using different communication schemes.

[0019] Two-way transmissions between the unit 12 and the unit 14 can be accomplished using a variety of schemes, such as time division duplex (TDD) or frequency division duplex (FDD). TDD has the advantage that the channel characteristics for signals propagating from the first unit 12 to the second unit 14 are generally the same as the channel characteristics for signals propagating from the second unit 14 to the second station 12. In the case of TDD, both units 12 and 14 occupy the same frequency band. As such, the propagation matrix for transmissions from the first unit 12 to the second unit 14 are considered transposes of each other due to the principle of reciprocity as described in D.S. Jones, "Acoustic and Electromagnetic Waves," Oxford University Press, 1989, pp. 63-64 and no further exchange of training signals is required (although updates to the propagation matrix or to propagation information can be performed). In FDD for certain embodiments, the second unit 14 transmits to the first unit 12 the propagation matrix (or propagation information) for transmissions from the first unit 12 to the second unit 14. Additionally, after the appropriate set-up or training scheme is performed for transmissions from the second unit 14 to the first unit 12, the first unit 12 can transmit to the second unit 14 the propagation matrix (or propagation information) for transmissions from the second unit 14 to the first unit 12.

[0020] With particular reference to FIG. 3, since the first and second units 12 and 14 know the propagation matrix (or propagation information which can be derived from the propagation matrix or propagation information which can be used to derive the propagation matrix or other propagation information), the units 12 and 14 can effectively decompose the complicated multiple-antenna channel 10 into multiple independent virtual sub-channels using the propagation matrix (or respective propagation information). In this particular embodiment, the units 12 and 14 derive the multiple virtual sub-channels from the multiple-antenna channel 10 by using propagation information derived from a singular value decomposition of the propagation matrix. After learning the propagation matrix for transmissions from the first unit 12 to the second unit 14, the first unit 12 provides the propagation matrix H to a singular value decomposition block 22. The singular value decomposition 22 performs a singular value decomposition of the propagation matrix H which produces some propagation information, including the diagonal matrix D and two unitary matrices Φ and $\psi^{\dagger}$ where the superscript † denotes a conjugate transpose. The number of nonzero diagonal elements in the matrix D represents the number of parallel independent virtual sub-channels.

[0021] For transmissions from the first unit 12 to the second unit 14 in this particular embodiment, the first unit 12 provides the diagonal matrix D to a channel coder/modulator 24 to encode and modulate an incoming information stream from an information source 28. The channel coder/modulator 24 encodes and modulates the information stream to form a plurality of sub-information streams depending on the nonzero values of the diagonal matrix D to produce the virtual transmitted signal. The virtual transmitted signal can be represented as a vector, the respective components of which are transmitted onto respective virtual sub-channels. In this particular embodiment, a unitary transformation block 30 performs a unitary transformation on the virtual transmitted signal by multiplying the virtual transmitted signal with the conjugate transpose of the unitary matrix Φ. Finally, the first unit 12 uses the results of the unitary transformation 30 to produce the baseband version of the actual transmitted signal.

[0022] In this particular embodiment, the second unit 14 also provides the propagation matrix H to a singular value decomposition 32 and uses the results from the singular value decomposition 32 to perform a unitary transformation 34 on the actual received signal. In this particular embodiment, the unitary transformation block 34 multiplies the actual received signal with the unitary matrix ψ to produce a virtual received signal. In this particular embodiment, the multiplications by the unitary matrices at the unitary transformations 30 and 34 tend not to amplify noise and are invertible operations, so information should not be lost. The multiplications by the unitary matrices establishes a link. which can be treated as parallel independent virtual sub-channels, between the virtual transmitted signal at the first unit 12 and the virtual received signal at the second unit 14. The second unit 14 provides the diagonal matrix D to a channel demodulator/decoder 36 which uses the diagonal matrix D to decode and demodulate the virtual received signal vector to form a single information stream which corresponds to the information stream provided to the channel coder/modulator 24 at the first unit 12. Additionally, the first unit 12 can use the diagonal matrix D to provide enhanced performance by sending more bits on the stronger virtual sub-channels according to the nonzero values of the diagonal matrix. If the amplitude of a nonzero value of the matrix D is below a certain level, the multiple antenna system can advantageously not use the corresponding virtual sub-channel, thereby a subset of the stronger virtual sub-channels can be used. As such, the multiple antenna system achieves higher data rates in a narrow bandwidth by effectively providing parallel independent virtual sub-channels within the same frequency band and enhanced performance.

[0023] FIG. 4 shows a block diagram of a transmitter 40 having the multiple antenna array 16 with three antennas 16a-c for use in any unit 12 or 14 according to the principles of the present invention. For ease of discussion, the transmitter 40 will be described as being included in the unit 12 (FIG. 3) because the multiple-element antenna communication system according to the principles of the present invention has been described in the context of transmissions from the first unit 12 (FIG. 3) to the second unit 14 (FIG. 3). The units 12 and 14 (FIG. 3) in this particular

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embodiment, however, can both transmit and receive signals according to the principles of the present invention. In doing so, the units 12 and 14 exchange training signals to estimate the propagation matrices (or propagation information which can be the actual training signals in certain embodiments) for communications between them. After learning the propagation matrix H for signals propagating from the first unit 12 (FIG. 3) to the second unit 14 (FIG. 3), the transmitter 40 provides the propagation matrix H to the singular value decomposition block 22.

[0024] The singular value decomposition block 22 performs a singular value decomposition of the propagation matrix H (which can be done for any H) to yield $H = \Phi \times D \times \psi^{\dagger}$, where D is a real-valued, non-negative, diagonal matrix and Φ and $\psi^{\dagger}$ are unitary matrices. The number of nonzero diagonal elements is less than or equal to the smaller of the number of antennas 16 at the transmitter 40 and at the second unit 14 (FIG. 3) and represents the number of parallel independent virtual sub-channels that are available within the same frequency band. Additionally, the sizes of the nonzero diagonal elements indicate the relative signal-to-noise ratios of the virtual sub-channels. In accordance with an aspect of the present invention, the transmitter 40 allocates power to the virtual sub-channels depending on the relative signal-to-noise ratios of the sub-channels as determined by the values of the nonzero diagonal elements of the diagonal matrix D. Thus, the better sub-channels can get more transmitter power and carry more data. In accordance with particular embodiments of this aspect of the present invention, the transmitter 40 has a total power restriction and generally allocates power to the different sub-channels to provide a higher, reliable bit rate. In doing so, the transmitter 40 can allocate power to the different subchannels using a version of a Water Pouring algorithm as disclosed by Robert G. Gallager, "Information Theory and Reliable Communication," John Wiley & Sons, 1968, pp. 343-345.

[0025] The transmitter 40 receives information signals from the information source 28, and the information stream is input into a buffer 43. According to certain aspects of the present invention, if all of the non-zero diagonal elements of the diagonal matrix D are equal or relatively similar in this particular embodiment, the channel coder/modulator 24 can direct the first bit of a bit stream 42 from the buffer 43 to encoder/modulator 44a, the second bit of the bit stream 42 to encoder/modulator 44b, and the third bit of the bit stream 42 to encoder/modulator 44c. If the amplitude of the nonzero diagonal value of the matrix D corresponding to a first virtual sub-channel is twice as large as the nonzero diagonal values of the matrix D corresponding to the second and third virtual sub-channels in this particular example, the channel coder/modulator 24 could send the first two bits of the bit stream 42 to the encoder/modulator 44a and the next two bits of the bit stream 42 being split between the encoder/modulator 44b and the encoder/modulator 44c. To combat the effects of noise, the channel coder/modulator 24 can use ordinary error-correcting codes of the types typically used for conventional additive Gaussian noise channels as would be understood by one of ordinary skill in the art in combination with conventional modulation schemes, such as Quadrature Phase Shift Keying (QPSK) modulation.

[0026] In this particular embodiment, the channel coder/modulator 24 produces three signal vector components y_{t1}, y_{t2} and y_{t3} of the virtual transmitted signal. The components of the virtual transmitted signal are digital complex values which can be fixed point or floating point depending on the implementation. The three components y_{t1}, y_{t2} and y_{t3} of the virtual transmitted signal from the encoder/modulators 44a-c are provided to the unitary transformation block 30. The unitary transformation block performs a 3×3 matrix multiplication on the components y_{t1}, y_{t2} and y_{t3} using a unitary matrix $\Phi^{\dagger}$. The result of the unitary transformation 30 is an actual transmitted signal having components s_{t1}, s_{t2} and s_{t3} which are sent to respective transmit circuits 48a-c and converted as necessary to the radio frequency (RF) domain. In this particular embodiment, the transmit circuitry 48a-c modulates the components s_{t1}, s_{t2} and s_{t3} of the actual transmitted signal onto the same carrier and transmits each component s_{t1}, s_{t2} and s_{t3} of the actual transmitted signal over a respective antenna 16a-c.

[0027] FIG. 5 shows a general diagram for an embodiment of the transmit circuitry 48. In this particular embodiment, each components s_{t1}, s_{t2} and s_{t3} of the virtual transmitted signal vector is split into real and imaginary parts by block 50. The real and imaginary parts of each component s_{t1}, s_{t2} and s_{t3} are input to digital-to-analog converters 51. Multipliers 52 multiply the analog real part of each component s_{t1}, s_{t2} and s_{t3} by $\cos\omega_c t$ with ω_c being the carrier frequency (radians/second) and multiply the analog imaginary part of each component s_{t1}, s_{t2} and s_{t3} by $\sin\omega_c t$. Afterward, respective real and imaginary parts of each component s_{t1}, s_{t2} and s_{t3} are added together by summers 53 to produce an RF signal for each component s_{t1}, s_{t2} and s_{t3} on the same carrier frequency ω_c. Each RF signal is then amplified by respective RF power amplifiers 54 and transmitted over respective antennas 16a-c in this particular embodiment. Alternative embodiments for the transmit circuitry 48 are possible.

[0028] FIG. 6 shows a block diagram of a receiver 60 having the multiple antenna array 18 with three antennas 18a-c for use in any unit 12 or 14 (FIG. 3) according to the principles of the present invention. For ease of discussion, the receiver 60 will be described as being included in the second unit 14 (FIG. 3) because the multiple-element antenna communication system according to the principles of the present invention has been described in the context of transmissions from the first unit 12 (FIG. 3) to the second unit 14 (FIG. 3). As mentioned above, the units 12 and 14 (FIG. 3) in this particular embodiment can both transmit and receive signals according to the principles of the present invention.

[0029] As described above for this particular embodiment, the receiver 60 receives training signals from the trans-

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mitter 40 (FIG. 4) and estimates the propagation matrix H for communications from the transmitter 40 (FIG. 4) to the receiver 60. After learning the propagation matrix H for signals propagating from the transmitter 40 (FIG. 4) to the receiver 60, the receiver 60 provides the propagation matrix H to the singular value decomposition block 32. As in the transmitter 40 (FIG. 4), the singular value decomposition block 32 performs a singular value decomposition of the propagation matrix H to yield $H = \Phi \times D \times \psi^{\dagger}$, where D is a real-valued, non-negative, diagonal matrix and Φ and $\psi^{\dagger}$ are 3 × 3 complex unitary matrices with the superscript "†" denoting the "conjugate transpose."

[0030] The receiver 60 receives the signals propagating from the transmitter 40 (FIG. 4) through the multiple antenna array 18, and receiver circuits 62a-c process the signals received from the respective antennas 18a-c down to baseband. In this particular embodiment, the actual received signal vector $\underline{x}_t$ is digitized before being provided to the unitary transformation block 34. The unitary transformation block 34 uses its propagation information derived from the propagation matrix H to multiply the actual received signal $\underline{x}_t$ by the 3 × 3 unitary matrix ψ to obtain a virtual received signal $\underline{r}_t = [r_{t1}, r_{t2}, r_{t3}] = \underline{x}_t \times \psi$. The channel demodulator/decoder 36 receives the virtual received signal $\underline{r}_t$ from the unitary transformation block 34 with respective parallel components r_{t1}, r_{t2} and r_{t3}. The components r_{t1}, r_{t2} and r_{t3} are provided to respective parallel demodulators/decoders 68a-c. The parallel demodulators/decoders 68a-c demodulate and decode the virtual received signal $\underline{r}_t$ according to the modulation and coding scheme used by the transmitter 40 (FIG. 4).

[0031] Using the nonzero diagonal values of the diagonal matrix D from the SVD block 32 and reflecting the use of the matrix D in the transmitter 40 (FIG. 4), the channel demodulator/decoder 36 constructs a single stream 70 of information bits from the parallel components r_{t1}, r_{t2} and r_{t3} of the virtual received signal. As such, the diagonal matrix D used to construct the information stream 70 from the parallel streams 64a-c in the receiver 60 is the same matrix D used to separate the single stream 42 (FIG. 4) into parallel streams 46a-c (FIG. 4) in the transmitter 40 (FIG. 4). The information stream 70 is then output to its destination 38 before which the information stream 70 can pass through additional processing or circuitry 72 which can include a data buffer.

[0032] FIG. 7 shows a general diagram for an embodiment of the receive circuitry 62. In this particular embodiment, the transmitted RF signals from the transmit circuitry 48 (FIG. 5) are received at the antennas 18a-c. The RF signals received at each antenna 18a-c are amplified by respective pre-amplifiers 80. Multipliers 82 multiply the respective RF signals by $\cos\omega_c t$ and $\sin\omega_c t$ with ω_c being the carrier frequency to produce analog versions of the real and imaginary parts of the components of the actual received signal which were modulated onto carriers of the same frequency ω_c. The analog versions of the real and imaginary parts for each component of the actual received signal are low pass filtered by filters 83 and provided to analog-to-digital converters 84 to produce digital versions of the real and imaginary parts of each component. Combiner 86 combine the real and imaginary parts of each component to produce the components x_{t1}, x_{t2} and x_{t3} of the actual received signal as complex digital values. In this particular embodiment as described above, the components x_{t1}, x_{t2} and x_{t3} of the actual received signal are provided to the unitary transformation block 34 (FIG. 6). The receive circuitry 62 is shown as a homodyne receiver, but alternative embodiments for the receive circuitry 62 are possible.

[0033] In accordance with certain embodiments of the present invention, the multiple antenna system updates the propagation matrix or information periodically or continuously as operating conditions change. As such, if an antenna 16 (FIG. 4) or 18 becomes unavailable, the multiple antenna system can update the propagation matrix(ices) or information at the two units 12 and 14, thereby maintaining the communications between the units 12 and 14 and still providing a high bit rate. Additionally, depending on the conditions of the virtual sub-channels (which can be measured by the nonzero diagonal values of the diagonal matrix D), the bit rate between the two units 12 and 14 using the multiple antenna system is scaleable. Accordingly, if the signal-to-noise ratio, virtual sub-channel gain or other measurement value for a virtual sub-channel drops below a certain threshold level and/or a relative level compared to the other sub-channels, the multiple antenna system can either reduce the number of bits transmitted over the virtual sub-channel or drop the virtual sub-channel, thereby reducing the bit rate, until updates of the propagation matrix or information show that the virtual sub-channel has risen above the threshold level and/or the relative level. Furthermore, in similar fashion, the multiple antenna system according to certain principles of the present invention can allocate power to the different virtual sub-channels based on the conditions of the different virtual sub-channels as determined by the nonzero values of the diagonal matrix D or other measurement values corresponding to the virtual sub-channels.

[0034] The multiple antenna system enables an increase in bit rate without an increase in power or bandwidth as compared to single antenna systems. In certain embodiments, the propagation of the signals is modeled as flat fading (no frequency dependence to fading). Additionally, in the event of receiver noise and external interference, the multiple antenna system can use a covariance matrix or the like which characterizes the receiver noise and/or the external interference to effectively alter the propagation information or to include the covariance matrix or the like as part of the propagation information. If the elements of the propagation matrix H are statistically independent, identically distributed, with Rayleigh-distributed magnitude and uniformly distributed phase, the capacity of the channel grows linearly with the smaller of the number of transmitter and receiver antennas. Theoretically, there is no limit to the number of antennas that can be utilized in the multiple antenna system, thereby providing the potential for enormous capacities in a narrow bandwidth. For example, if 170 antennas are used at the transmitter and the receiver in a 30 kHz bandwidth with signal-

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to-noise ratios of 20dB, 20Mb/s of High Definition TV (HDTV) may be sent over the multiple antenna channel after being decomposed to 170 virtual sub-channels according to the principles of the present invention.

[0035] The multiple-element antenna system according to the principles of the present invention can achieve such high bit rates in the narrow bandwidth and in a simple manner by using multiple antennas at both the transmitter and receiver to decompose the multiple antenna channel into multiple independent virtual sub-channels. A pair of units using the multiple antenna system use a distinct band of frequencies for communicating with each other over the multiple-antenna channel. Thus, different pairs of units can be frequency division multiplexed. A pair of units can take a variety of forms, such as units which can handle voice and/or data in a wireless local area network. Additionally, the multiple antenna system can provide security in communications between a pair of units because the propagation information characterizing the actual communications channel between the pair of units is unique to that pair. As such, even if a third party obtained the propagation information for the pair, it would be difficult for the third party to intercept the communications between the pair because the propagation information for an actual communications channels between the third party and each of the pair of units would be different.

[0036] In addition to the embodiments described above, alternative configurations of the multiple antenna system according to the principles of the present invention are possible which omit and/or add components and/or use variations or portions of the described multiple antenna system. For example, the multiple antenna system has been described with three antennas at both the first unit and the second unit to provide three virtual sub-channels, but different numbers of antennas can be employed at the first unit and the second unit. Additionally, the multiple antenna system has been described as being employed in terms of communications over a multiple antenna channel from the first unit to the second unit. The multiple antenna system, however, includes units which transmit and/or receive according to the principles of the present invention. In certain embodiments, the units use the same multiple antennas for both transmission and reception. Alternative embodiments of units employing the multiple antenna system are possible, however, which use a subset of the multiple antennas for transmission and/or reception depending on the number of antennas at the unit on the other end of the multiple antenna channel or upon the values of the diagonal matrix in the reverse direction.

[0037] The above-described multiple antenna system has been described as comprising several components or blocks, but it should be understood that the multiple antenna system and portions thereof can be implemented in application specific integrated circuits, software-driven processing circuitry, or other arrangements of discrete components as would be understood by one of ordinary skill in the art with the benefit of this disclosure. What has been described is merely illustrative of the application of the principles of the present invention. Those skilled in the art will readily recognize that these and various other modifications, arrangements and methods can be made to the present invention without strictly following the exemplary applications illustrated and described herein and without departing from the spirit and scope of the present invention.

Claims

1. A method for transmitting communication signals, said method CHARACTERIZED BY the step of:

   creating virtual sub-channels from an actual communications channel between M transmitter antennas of a first unit and N receiver antennas of a second unit, where M or N >1, by using at said first unit and said second unit propagation information characterizing said actual communications channel; and
   sending by said first unit a virtual transmitted signal over at least a subset of said virtual sub-channels using at least a portion of said propagation information.

2. The method of claim 1 CHARACTERIZED IN THAT said step of sending including the steps of:

   transforming said virtual transmitted signal into an actual transmitted signal using said at least a portion of said propagation information; and
   transmitting said actual transmitted signal over said M transmitter antennas onto said actual communications channel.

3. The method of claim 2 CHARACTERIZED IN THAT said step of transmitting including the step of:
   transmitting each component of said actual transmitted signal using a respective one of said M transmitter antennas.

4. The method of claim 2 CHARACTERIZED BY including the step of:
   producing a unitary matrix from said at least a portion of said propagation information.

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5. The method of claim 4 CHARACTERIZED BY the steps of:

using said unitary matrix to perform a unitary transformation of said virtual transmitted signal into said actual transmitted signal; and
transmitting each component of said actual transmitted signal onto carriers having the same frequency.

6. The method of claim 1 CHARACTERIZED BY the step of:

receiving by the first unit an information stream from an information source; and
separating said information stream into a plurality of signal streams using at least a portion of said propagation information to form said virtual transmitted signal.

7. The method of claim 6 CHARACTERIZED BY the step of:
producing a diagonal matrix D from at least said portion of said propagation information with the nonzero diagonal values corresponding to said virtual sub-channels of said actual communications channel.

8. The method of claim 6 CHARACTERIZED IN THAT said step of separating including the step of:
using values of a diagonal matrix D from at least said portion of said propagation information to separate said information stream into a plurality of signal streams according to said values of said diagonal matrix D.

9. The method of claim 8 CHARACTERIZED BY the step of:
using said values of said diagonal matrix D to allocate power for transmitting each component of said virtual transmitted signal.

10. A method of receiving communication signals, said method CHARACTERIZED BY the steps of:

creating virtual sub-channels from an actual communications channel between M transmitter antennas of a first unit and N receiver antennas of a second unit, where M or N >1, by using at said first unit and said second unit propagation information characterizing said actual communications channel; and
retrieving by said second unit a virtual received signal from at least a subset of said virtual sub-channels using at least a portion of said propagation information.

11. The method of claim 10 CHARACTERIZED IN THAT said step of retrieving including the step of:

receiving an actual received signal from said actual communications channel on said N receiver antennas; and
transforming said actual received signal into said virtual received signal using said at least a portion of said propagation information.

12. The method of claim 11 CHARACTERIZED IN THAT said step of retrieving including the step of:
receiving each component of said actual received signal using a respective one of said N receiver antennas.

13. A transmitter for transmitting information signals CHARACTERIZED BY:

a plurality of antennas;
processing circuitry configured to obtain propagation information for an actual communications channel between said plurality of antennas and a plurality of receiver antennas;
a channel coder configured to receive an information signal stream and at least a portion of said propagation information, said channel coder CHARACTERIZED BY configured to separate said information signal stream using said at least a portion of said propagation information to form a virtual transmitted signal of components corresponding to sub-channels of said communications channel;
said processing circuitry CHARACTERIZED BY configured to perform a unitary transformation on said virtual transmitted signal using at least another portion of said propagation information to form an actual transmitted signal; and
transmit circuitry coupled to said plurality of antennas and configured to transmit each component of said actual transmitted signal through a respective one of said plurality of antennas on carriers of the same frequency.

14. A receiver for receiving information signals CHARACTERIZED BY: a plurality of antennas;

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receive circuitry coupled to said plurality of antennas and configured to receive each component of an actual received signal through a respective one of said plurality of antennas;

processing circuitry configured to obtain propagation information for a communications channel between said plurality of antennas and a plurality of transmitter antennas, said processing circuitry CHARACTERIZED BY configured to perform a unitary transformation on said actual received signal using at least a portion of said propagation information to form a virtual received signal; and

a channel decoder configured to receive said virtual received signal and at least another portion of said propagation information, said channel decoder configured to combine said virtual received signal into an information stream using said at least another portion of said propagation information.

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FIG. 1

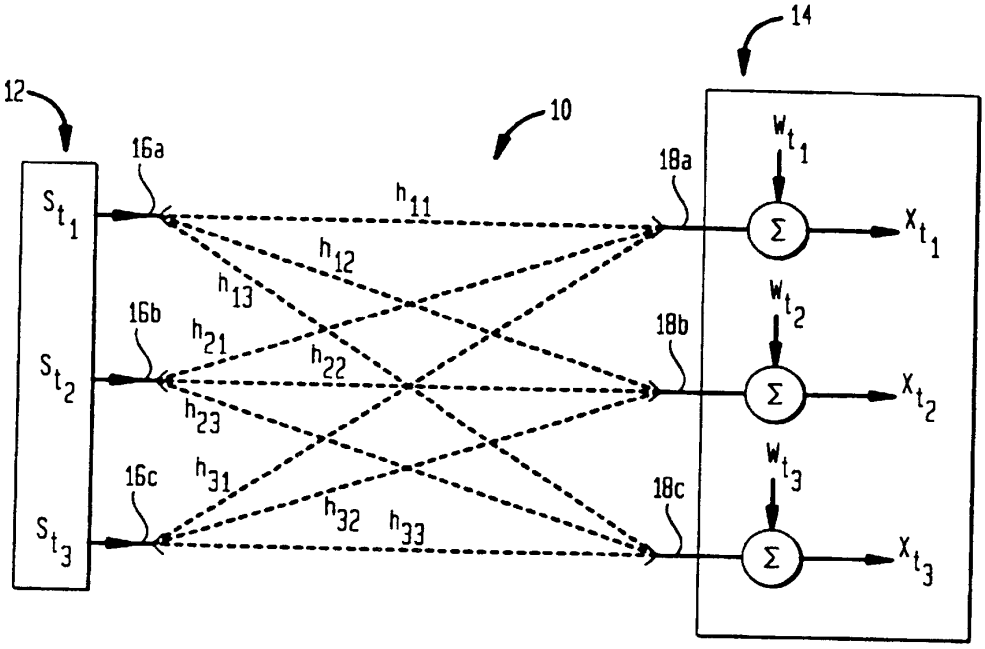
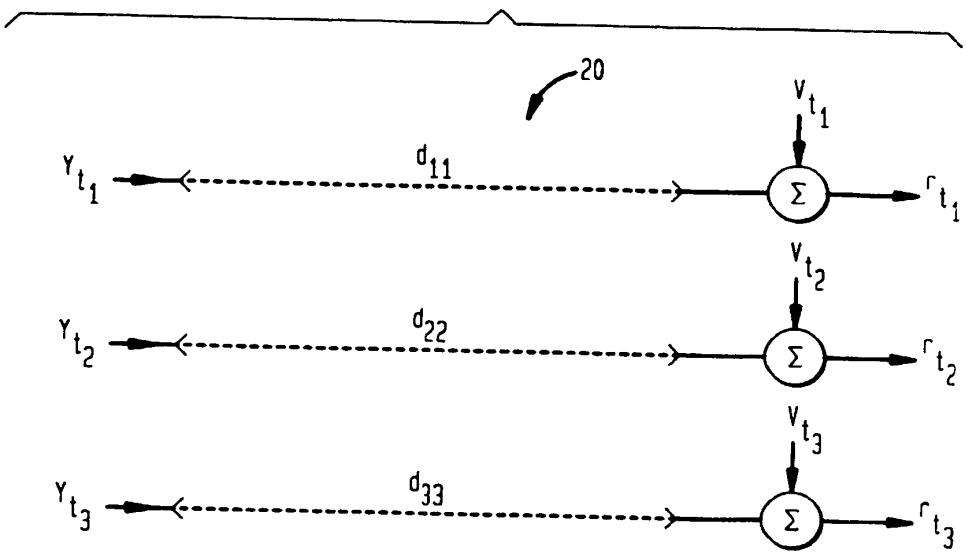


FIG. 2



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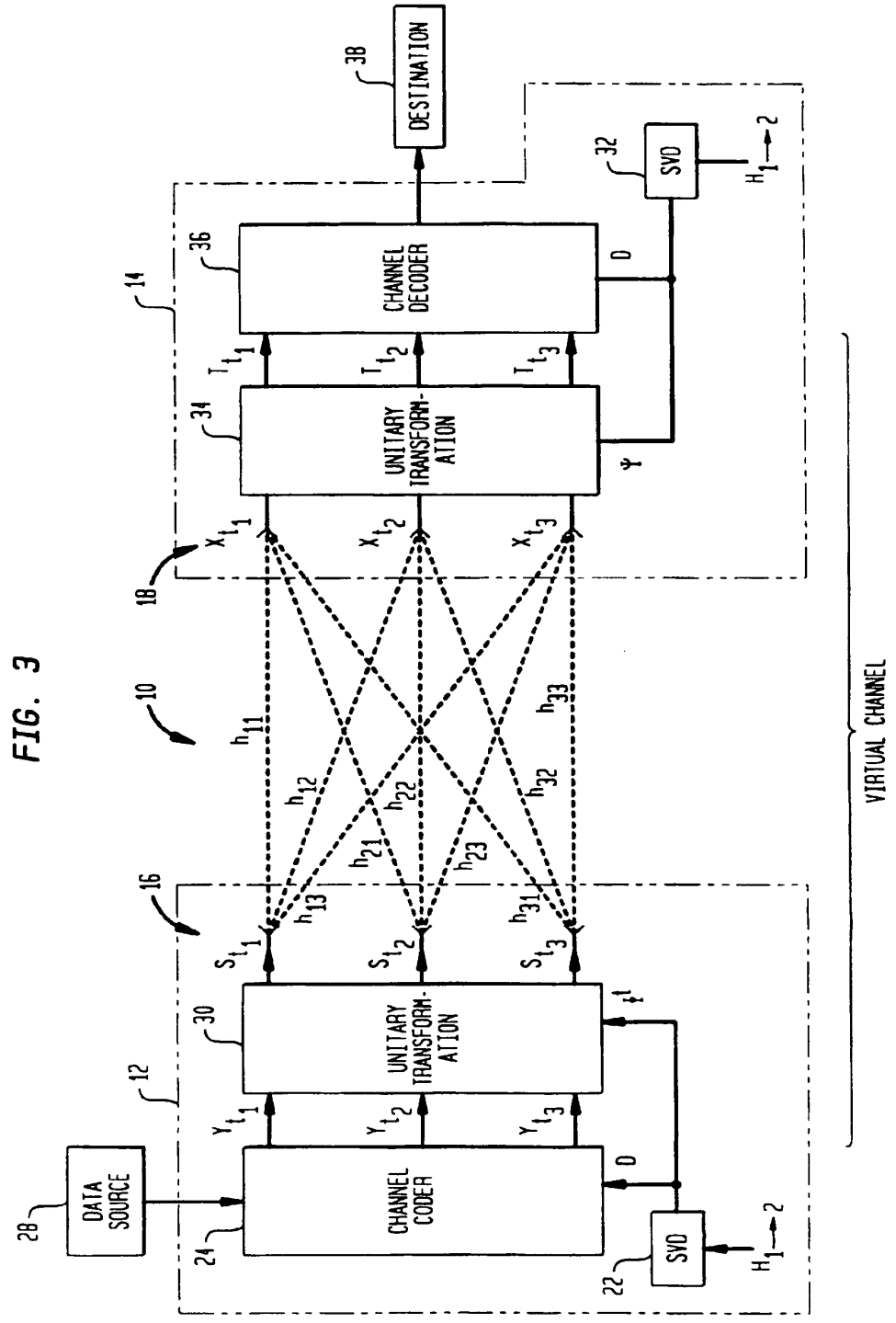


FIG. 3

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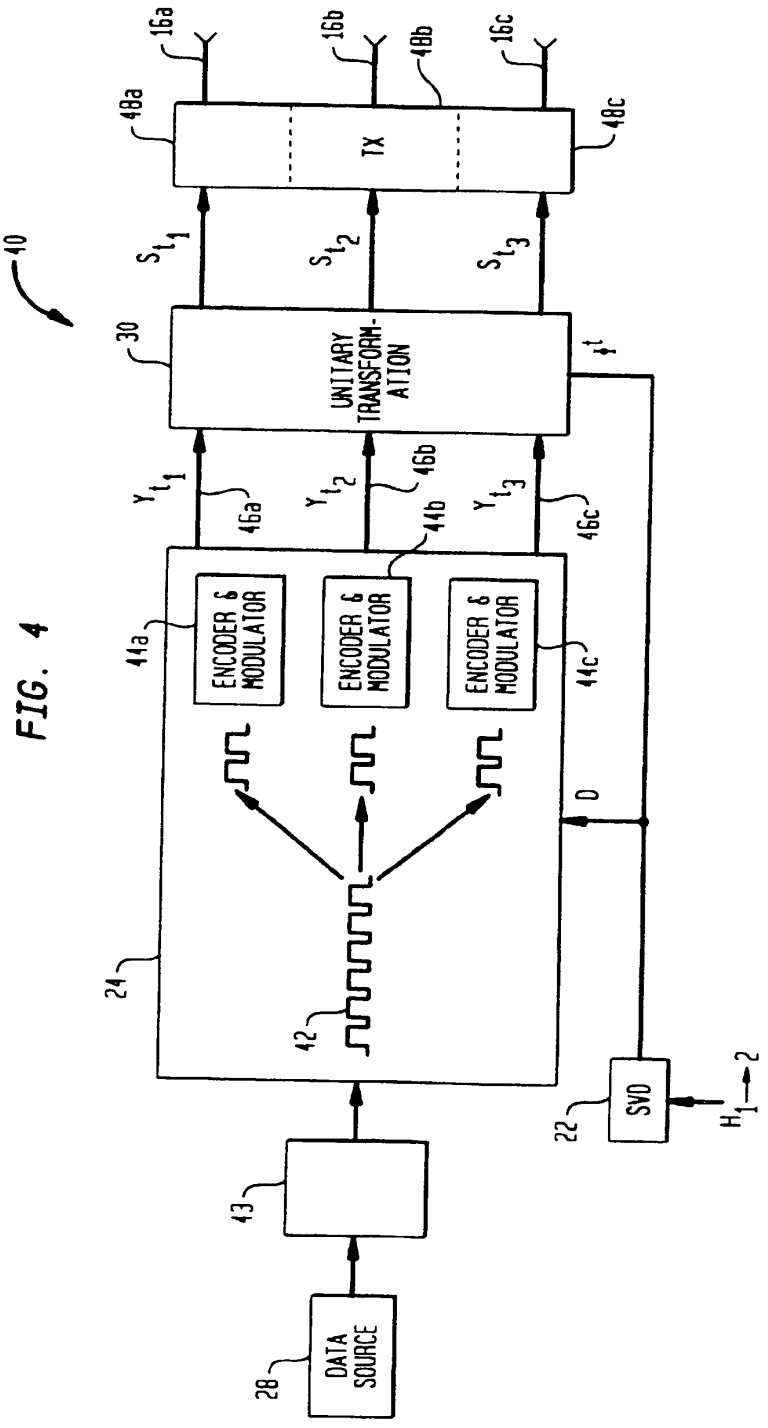


FIG. 4

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FIG. 5

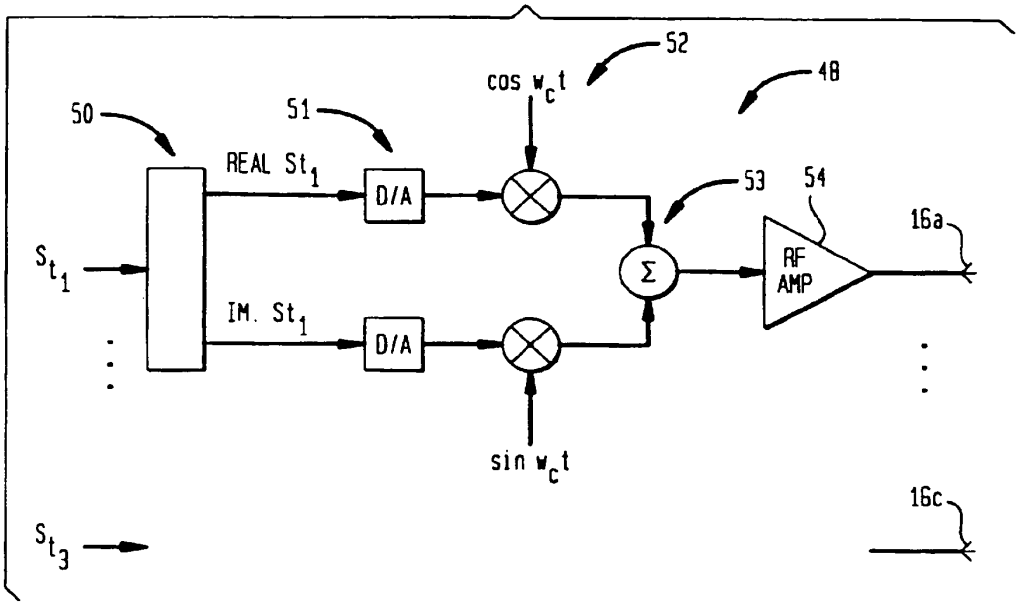
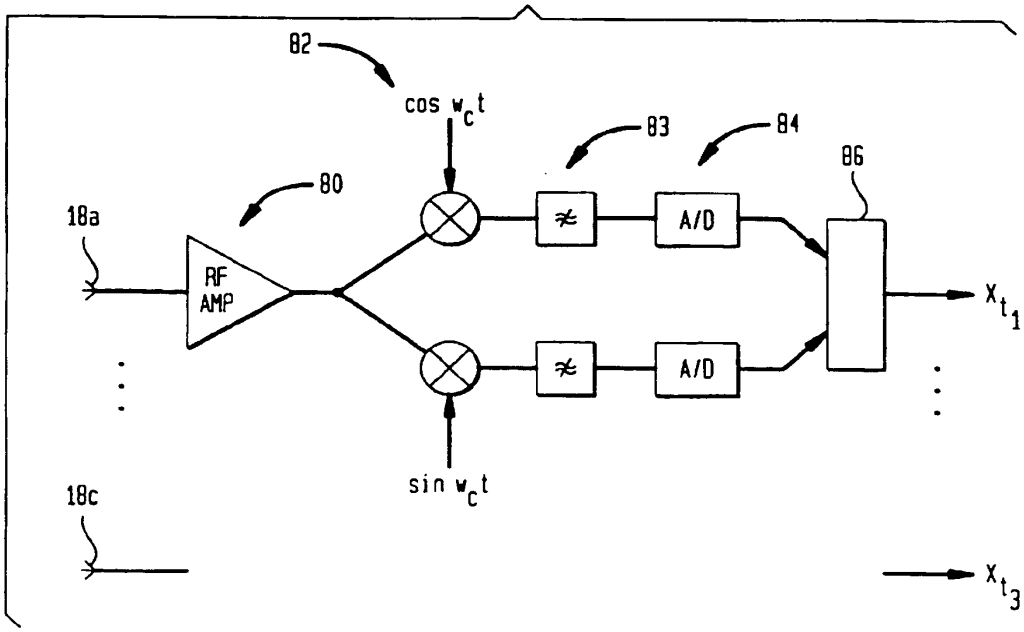


FIG. 7



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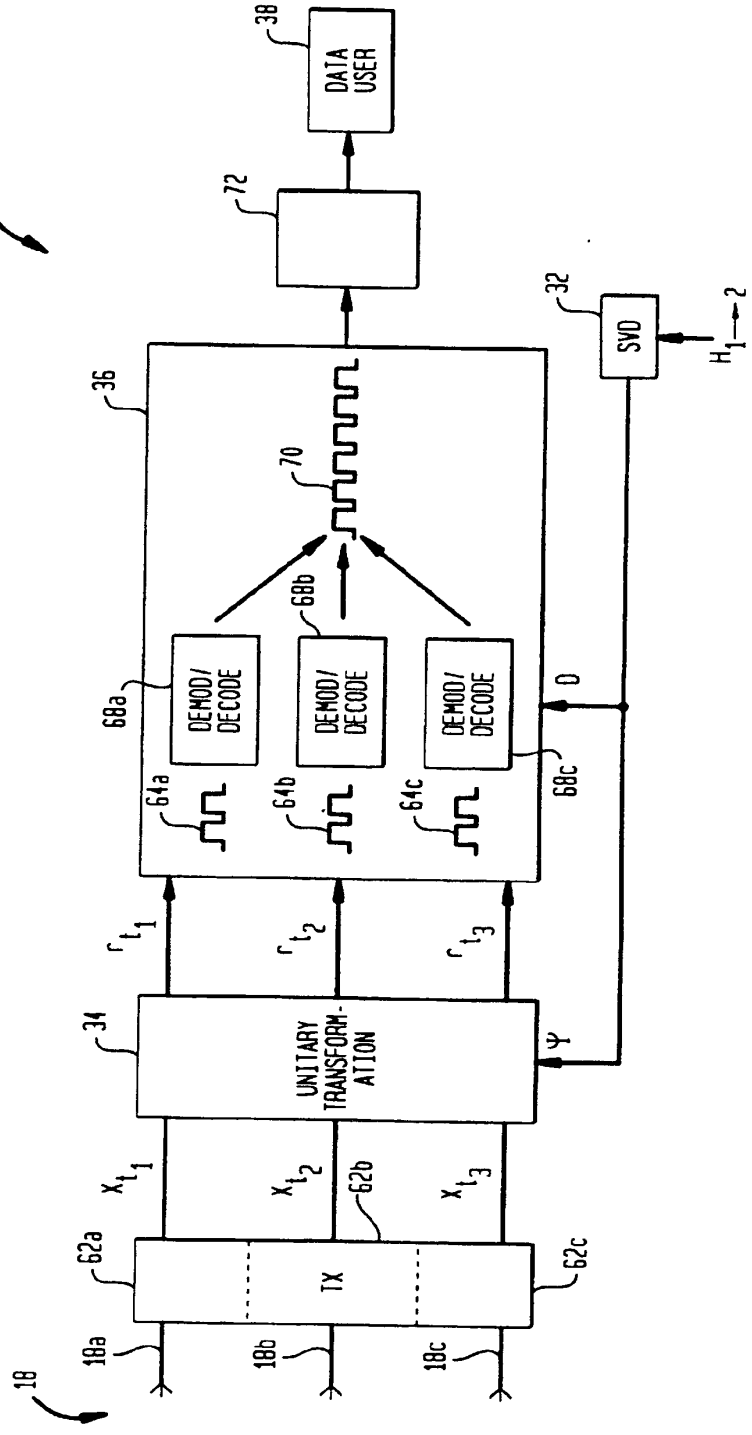


FIG. 6

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(71) Applicant:
Texas Instruments Incorporated
Dallas, TX 75251 (US)

(72) Inventors:
- **Negi, Rohit,**
  c/o Durand 112
  Stanford, CA 94305 (US)
- **Dabak, Anand G.**
  Richardson, TX 75082 (US)

(74) Representative: **Holt, Michael**
Texas Instruments Ltd.,
PO Box 5069
Northampton, Northamptonshire NN4 7ZE (GB)

(54) Space time block coded transmit antenna diversity for WCDMA

(57) A mobile communication system is designed with an input circuit coupled to receive a first plurality of signals ($r_j(i+\tau_j)$, i=0-N-1) during a first time (T0-T1) from an external source and coupled to receive a second plurality of signals ($r_j(i+\tau_j)$, i=N-2N-1) during a second time (T1-T2) from the external source. The input circuit receives each of the first and second plurality of signals along respective first and second paths (j). The input circuit produces a first input signal (610) (R_j^1) and a second input signal (614) (R_j^2) from the respective first and second plurality of signals. A correction circuit is coupled to receive a first estimate signal (302) (α_j^1), a second estimate signal (306) (α_j^2) and the first and second input signals. The correction circuit produces a first symbol estimate ($\tilde{S}_1$) in response to the first and second estimate signals and the first and second input signals. The correction circuit produces a second symbol estimate ($\tilde{S}_2$) in response to the first and second estimate signals and the first and second input signals.

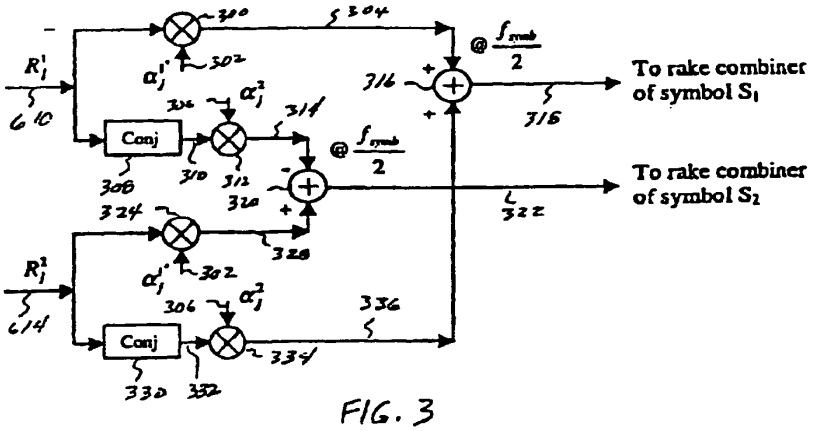


FIG. 3

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Description

FIELD OF THE INVENTION

[0001] This invention relates to wideband code division multiple access (WCDMA) for a communication system and more particularly to space time block coded transmit antenna diversity for WCDMA.

BACKGROUND OF THE INVENTION

[0002] Present code division multiple access (CDMA) systems are characterized by simultaneous transmission of different data signals over a common channel by assigning each signal a unique code. This unique code is matched with a code of a selected receiver to determine the proper recipient of a data signal. These different data signals arrive at the receiver via multiple paths due to ground clutter and unpredictable signal reflection. Additive effects of these multiple data signals at the receiver may result in significant fading or variation in received signal strength. In general, this fading due to multiple data paths may be diminished by spreading the transmitted energy over a wide bandwidth. This wide bandwidth results in greatly reduced fading compared to narrow band transmission modes such as frequency division multiple access (FDMA) or time division multiple access (TDMA).

[0003] New standards are continually emerging for next generation wideband code division multiple access (WCDMA) communication systems as described in European Patent Application No. EP 99201224.5 filed April 21, 1999, and incorporated herein by reference. These WCDMA systems are coherent communications systems with pilot symbol assisted channel estimation schemes. These pilot symbols are transmitted as quadrature phase shift keyed (QPSK) known data in predetermined time frames to any receivers within range. The frames may propagate in a discontinuous transmission (DTX) mode. For voice traffic, transmission of user data occurs when the user speaks, but no data symbol transmission occurs when the user is silent. Similarly for packet data, the user data may be transmitted only when packets are ready to be sent. The frames include pilot symbols as well as other control symbols such as transmit power control (TPC) symbols and rate information (RI) symbols. These control symbols include multiple bits otherwise known as chips to distinguish them from data bits. The chip transmission time (T_C), therefore, is equal to the symbol time rate (T) divided by the number of chips in the symbol (N).

[0004] Previous studies have shown that multiple transmit antennas may improve reception by increasing transmit diversity for narrow band communication systems. In their paper New Detection Schemes for Transmit Diversity with no Channel Estimation, Tarokh et al. describe such a transmit diversity scheme for a TDMA system. The same concept is described in A Simple Transmitter Diversity Technique for Wireless Communications by Alamouti. Tarokh et al. and Alamouti, however, fail to teach such a transmit diversity scheme for a WCDMA communication system.

[0005] Other studies have investigated open loop transmit diversity schemes such as orthogonal transmit diversity (OTD) and time switched time diversity (TSTD) for WCDMA systems. Both OTD and TSTD systems have similar performance. Both use multiple transmit antennas to provide some diversity against fading, particularly at low Doppler rates and when there are insufficient paths for the rake receiver. Both OTD and TSTD systems, however, fail to exploit the extra path diversity that is possible for open loop systems. For example, the OTD encoder circuit of FIG. 5 receives symbols S_1 and S_2 on lead 500 and produces output signals on leads 504 and 506 for transmission by first and second antennas, respectively. These transmitted signals are received by a despreader input circuit (FIG. 6). The input circuit receives the ith of N chip signals per symbol together with noise along the jth of L multiple signal paths at a time τ_j after transmission. Both here and in the following text, noise terms are omitted for simplicity. This received signal $r_j(i+\tau_j)$ at lead 600 is multiplied by a channel orthogonal code signal $C_m(i+\tau_j)$ that is unique to the receiver at lead 604. Each chip signal is summed over a respective symbol time by circuit 608 and produced as first and second output signals R_j^1 and R_j^2 on leads 612 and 614 as in equations [1-2], respectively. Delay circuit 610 provides a one-symbol delay T so that the output signals are produced simultaneously.

$$R_j^1 = \sum_{i=0}^{N-1} r_j(i+\tau_j) = \alpha_j^1 S_1 + \alpha_j^2 S_2 \qquad [1]$$

$$R_j^2 = \sum_{i=N}^{2N-1} r_j(i+\tau_j) = \alpha_j^1 S_1 - \alpha_j^2 S_2 \qquad [2]$$

[0006] The OTD phase correction circuit of FIG. 7 receives the signals R_j^1 and R_j^2 as input signals corresponding to the jth of L multiple signal paths. The phase correction circuit produces soft outputs or signal estimates $\tilde{S}_1$ and $\tilde{S}_2$ for symbols S_1 and S_2 at leads 716 and 718 as shown in equations [3-4], respectively.

$$\tilde{S}_1 = \sum_{j=1}^{L} (R_j^1 + R_j^2)\alpha_j^{1*} = \sum_{j=1}^{L} 2|\alpha_j^1|^2 S_1 \qquad [3]$$

$$\tilde{S}_2 = \sum_{j=1}^{L} (R_j^1 - R_j^2)\alpha_j^{2*} = \sum_{j=1}^{L} 2|\alpha_j^2|^2 S_2 \qquad [4]$$

Equations [3-4] show that the QTD method provides a

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single channel estimate α for each path j. A similar analysis for the TSTD system yields the same result. The OTD and TSTD methods, therefore, are limited to a path diversity of L. This path diversity limitation fails to exploit the extra path diversity that is possible for open loop systems as will be explained in detail.

SUMMARY OF THE INVENTION

[0007] These problems are resolved by a mobile communication system comprising an input circuit coupled to receive a first plurality of signals during a first time from an external source and coupled to receive a second plurality of signals during a second time from the external source. The input circuit receives each of the first and second plurality of signals along respective first and second paths. The input circuit produces a first input signal and a second input signal from the respective first and second plurality of signals. A correction circuit is coupled to receive a first estimate signal, a second estimate signal and the first and second input signals. The correction circuit produces a first symbol estimate in response to the first and second estimate signals and the first and second input signals. The correction circuit produces a second symbol estimate in response to the first and second estimate signals and the first and second input signals.

[0008] The present invention improves reception by providing at least $2L$ diversity over time and space. No additional transmit power or bandwidth is required. Power is balanced across multiple antennas.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] A more complete understanding of the invention may be gained by reading the subsequent detailed description with reference to the drawings wherein:

FIG. 1 is a simplified block diagram of a typical transmitter using Space Time Transit Diversity (STTD) of the present invention;
FIG. 2 is a block diagram showing signal flow in an STTD encoder of the present invention that may be used with the transmitter of FIG. 1;
FIG. 3 is a schematic diagram of a phase correction circuit of the present invention that may be used with a receiver;
FIG. 4A is a simulation showing STTD performance compared to Time Switched Time Diversity (TSTD) for a vehicular rate of 3 kmph;
FIG. 4B is a simulation showing STTD performance compared to TSTD for a vehicular rate of 120 kmph;
FIG. 5 is a block diagram showing signal flow in an OTD encoder of the prior art;
FIG. 6 is a block diagram of a despreader input circuit of the prior art; and
FIG. 7 is a schematic diagram of a phase correction circuit of the prior art.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0010] Referring to FIG. 1, there is a simplified block diagram of a typical transmitter using Space Time Transit Diversity (STTD) of the present invention. The transmitter circuit receives pilot symbols, TPC symbols, RI symbols and data symbols on leads 100, 102, 104 and 106, respectively. Each of the symbols is encoded by a respective STTD encoder as will be explained in detail. Each STTD encoder produces two output signals that are applied to multiplex circuit 120. The multiplex circuit 120 produces each encoded symbol in a respective symbol time of a frame. Thus, a serial sequence of symbols in each frame is simultaneously applied to each respective multiplier circuit 124 and 126. A channel orthogonal code C_m is multiplied by each symbol to provide a unique signal for a designated receiver. The STTD encoded frames are then applied to antennas 128 and 130 for transmission.

[0011] Turning now to FIG. 2, there is a block diagram showing signal flow in an STTD encoder of the present invention that may be used with the transmitter of FIG. 1. The STTD encoder receives symbol S_1 at symbol time T and symbol S_2 at symbol time $2T$ on lead 200. The STTD encoder produces symbol S_1 on lead 204 and symbol $-S_2^*$ on lead 206 at symbol time T, where the asterisk indicates a complex conjugate operation. Furthermore, the symbol time indicates a relative position within a transmit frame and not an absolute time. The STTD encoder then produces symbol S_1 on lead 204 and symbol S_1^* on lead 206 at symbol time $2T$. The bit or chip signals of these symbols are transmitted serially along respective paths 208 and 210. Rayleigh fading parameters are determined from channel estimates of pilot symbols transmitted from respective antennas at leads 204 and 208. For simplicity of analysis, a Rayleigh fading parameter α_j^1 is assumed for a signal transmitted from the first antenna 204 along the jth path. Likewise, a Rayleigh fading parameter α_j^2 is assumed for a signal transmitted from the second antenna 206 along the jth path. Each ith chip or bit signal $r_j(i+\tau_j)$of a respective symbol is subsequently received at a remote mobile antenna 212 after a transmit time τ_j corresponding to the jth path. The signals propagate to a despreader input circuit (FIG. 6) where they are summed over each respective symbol time to produce output signals R_j^1 and R_j^2 corresponding to the jth of L multiple signal paths as previously described.

[0012] Referring now to FIG. 3, there is a schematic diagram of a phase correction circuit of the present invention that may be used with a remote mobile receiver. This phase correction circuit receives signals R_j^1 and R_j^2 as input signals on leads 610 and 614 as shown in equations [5-6], respectively.

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$$R_j^1 = \sum_{i=0}^{N-1} r_j(i+\tau_j) = \alpha_j^1 S_1 - \alpha_j^2 S_2^* \quad [5]$$

$$R_j^2 = \sum_{i=N}^{2N-1} r_j(i+\tau_j) = \alpha_j^1 S_1 + \alpha_j^2 S_1^* \quad [6]$$

The phase correction circuit receives a complex conjugate of a channel estimate of a Rayleigh fading parameter α_j^{1*} corresponding to the first antenna on lead 302 and a channel estimate of another Rayleigh fading parameter α_j^2 corresponding to the second antenna on lead 306. Complex conjugates of the input signals are produced by circuits 308 and 330 at leads 310 and 322, respectively. These input signals and their complex conjugates are multiplied by Rayleigh fading parameter estimate signals and summed as indicated to produce path-specific first and second symbol estimates at respective output leads 318 and 322 as in equations [7-8].

$$R_j^1 \alpha_j^{1*} + R_j^{2*} \alpha_j^2 = (|\alpha_j^1|^2 + |\alpha_j^2|^2) S_1 \quad [7]$$

$$-R_j^{1*} \alpha_j^2 + R_j^2 \alpha_j^{1*} = (|\alpha_j^1|^2 + |\alpha_j^2|^2) S_2 \quad [8]$$

These path-specific symbol estimates are then applied to a rake combiner circuit to sum individual path-specific symbol estimates, thereby providing net soft symbols as in equations [9-10].

$$\tilde{S}_1 = \sum_{j=1}^{L} R_j^1 \alpha_j^{1*} + R_j^{2*} \alpha_j^2 \quad [9]$$

$$\tilde{S}_2 = \sum_{j=1}^{L} -R_j^{1*} \alpha_j^2 + R_j^2 \alpha_j^{1*} \quad [10]$$

These soft symbols or estimates provide a path diversity *L* and a transmit diversity *2*. Thus, the total diversity of the STTD system is *2L*. This increased diversity is highly advantageous in providing a reduced bit error rate. The simulation result of FIG. 4 compares a bit error rate (BER) of STTD with TSTD for various ratios of energy per bit (Eb) to noise (No) at a relative speed of 3 Kmph. The OTD and TSTD systems were found to be the same in other simulations. The simulation shows that a 7.5 dB ratio Eb/No corresponds to a BER of 2.0E-3 for TSTD. The same BER, however, is achieved with a 7.2 dB ratio Eb/No. Thus, STTD produces approximately 0.3 dB improvement over TSTD. The simulation of FIG. 5 compares the BER of STTD with TSTD for various values of Eb/No at a relative speed of 120 Kmph. This simulation shows a typical 0.25 dB improvement for STTD over TSTD even for high Doppler rates. By way of comparison, STTD demonstrates a 1.0 dB advantage over the simulated curve of FIG. 5 without diversity at a BER of 2.6E-3. This substantial advantage further demonstrates the effectiveness of the present invention.

[0013] Although the invention has been described in detail with reference to its preferred embodiment, it is to be understood that this description is by way of example only and is not to be construed in a limiting sense. For example, several variations in the order of symbol transmission would provide the same *2L* diversity. Moreover, the exemplary diversity of the present invention may be increased with a greater number of transmit or receive antennas. Furthermore, novel concepts of the present invention are not limited to exemplary circuitry, but may also be realized by digital signal processing as will be appreciated by those of ordinary skill in the art with access to the instant specification.

[0014] It is to be further understood that numerous changes in the details of the embodiments of the invention will be apparent to persons of ordinary skill in the art having reference to this description. It is contemplated that such changes and additional embodiments are within the spirit and true scope of the invention.

Claims

1. Circuitry, comprising:

   a correction circuit for receiving first and second input signals from an external source along a signal path of a plurality of signal paths, the correction circuit arranged for producing a first symbol estimate in response to first and second estimate signals and the first and second input signals, and for producing a second symbol estimate in response to the first and second estimate signals and the first and second input signals; and

   a combining circuit coupled for receiving a plurality of first symbol estimates including the first symbol estimate and for receiving a plurality of second symbol estimates including the second symbol estimate, the combining circuit arranged for producing a first symbol signal in response to the plurality of first symbol estimates and for producing a second symbol signal in response to the plurality of second symbol estimates.

2. A circuitry as in claim 1 further comprising:

   an input circuit arranged for receiving a first plurality of signals during a first period from the external source and for receiving a second plurality of signals during a second period from the external source, the input circuit arranged for receiving each of the first and second plurality of signals along respective first and second

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paths, the input circuit arranged for producing the first input signal and the second input signal from the respective first and second plurality of signals.

3. A circuitry as in claim 1 further comprising:

an input circuit arranged for receiving a plurality of signals from an external source along a plurality of signal paths, for producing a plurality of input signals including the first input signal and the second input signal corresponding to a respective signal path of the plurality of signal paths.

4. A circuitry as in any preceding claim, wherein the correction circuit and the combining circuit are formed on a single integrated circuit.

5. A circuitry as in any preceding claim, wherein each of the first and second symbol signals includes at least one of a pilot symbol, a transmit power control symbol, a rate information symbol and a data symbol.

6. A circuit as in any preceding claim, wherein the first period corresponds to a transmission time of one of the first and second symbol signals and the second period corresponds to a transmission time of the other of the first and second symbol signals.

7. A circuit as in any preceding claim, wherein a total path diversity of each of the first and second symbol signals is at least twice a number of transmitting antennas.

8. A circuit as in any preceding claim, wherein the first input signal is transmitted by a first antenna and a second antenna and wherein the second input signal is transmitted by the first antenna and the second antenna.

9. A circuit as in claim 8, wherein the first and the second input signal are wideband code division multiple access signals.

10. A method of processing signals in a communication circuit, comprising:

receiving a plurality of first signals during a first period, each first signal corresponding to a respective signal path;
receiving a plurality of second signals during a second period;
estimating a first Rayleigh fading parameter;
estimating a second Rayleigh fading parameter;
producing a first symbol signal in response to said plurality of first signals, said plurality of second signals and said first and second Rayleigh fading parameters; and
producing a second symbol signal in response to said plurality of first signals, said plurality of second signals and said first and second Rayleigh fading parameters.

11. A method of processing signals as in claim 10, further comprising the steps of:

determining a conjugate of said each first signal;
determining a conjugate of each second signal of said plurality of second signals;
determining a conjugate of each said first Rayleigh fading parameter; and
determining a conjugate of each said second Rayleigh fading parameter.

12. A method of processing signals as in claim 11, further comprising the steps of:

determining an approximate said first symbol by adding a product of said each first signal and each respective said conjugate of each said first Rayleigh fading parameter to a product of said conjugate of said each second signal and each respective said second Rayleigh fading parameter; and
determining an approximate said second symbol by adding a product of a complement of said conjugate of said each first signal and each respective second Rayleigh fading parameter to a product of said each second signal and each respective said conjugate of each said second Rayleigh fading parameter.

13. A mobile communication system, comprising:

a mobile antenna arranged for receiving a plurality of signals from an external source along a plurality of signal paths;
an input circuit arranged for receiving the plurality of signals from the antenna, and for producing a plurality of input signals including a first input signal and a second input signal corresponding to respective signal paths of the plurality of signal paths; and
a correction circuit arranged for receiving a first estimate signal, a second estimate signal and the first and second input signals, for producing a first symbol estimate in response to the first and second estimate signals and the first and second input signals, the correction circuit arranged for producing a second symbol estimate in response to the first and second estimate signals and the first and second input

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signals.

14. A mobile communication system as in claim 13, further comprising a combining circuit arranged for receiving a plurality of first symbol estimates including the first symbol estimate, and for receiving a plurality of second symbol estimates including the second symbol estimate, the combining circuit arranged for producing a first symbol signal in response to the plurality of first symbol estimates and producing a second symbol signal in response to the plurality of second symbol estimates.

15. A mobile communication system as in claim 14, wherein the input circuit, the correction circuit and the combining circuit are formed on a single integrated circuit.

16. A mobile communication system as in claim 14, wherein each of the first and second symbol signals include at least one of a pilot symbol, a transmit power control symbol, a rate information symbol and a data symbol.

17. A mobile communication system as in any of claims 13 to 16, wherein each of the first and second estimate signals is a Rayleigh fading parameter estimate.

18. A mobile communication system as in any of claims 13 to 17, wherein a total path diversity of each of the first and second symbol signals is at least twice a number of transmitting antennas.

19. A mobile communication system as in any of claims 13 to 18, wherein each of the first and second input signals is transmitted by a first antenna and a second antenna.

20. A mobile communication system as in claim 19, wherein each of the first and second input signals is a wideband code division multiple access signal.

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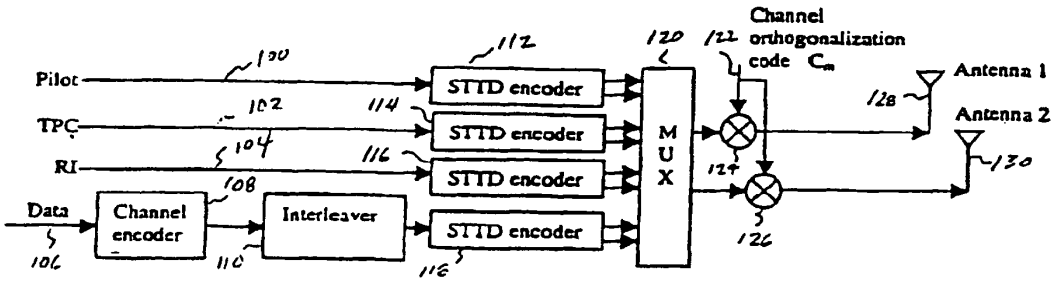


FIG. 1

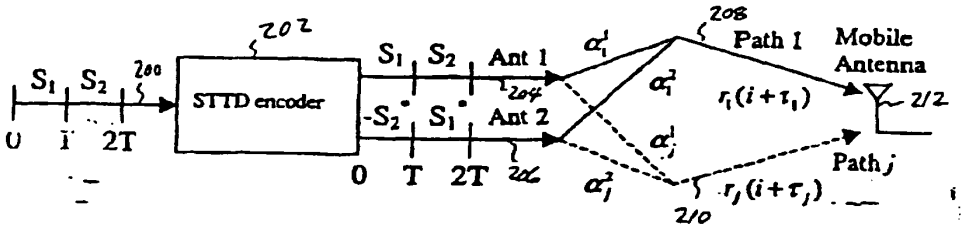


FIG. 2

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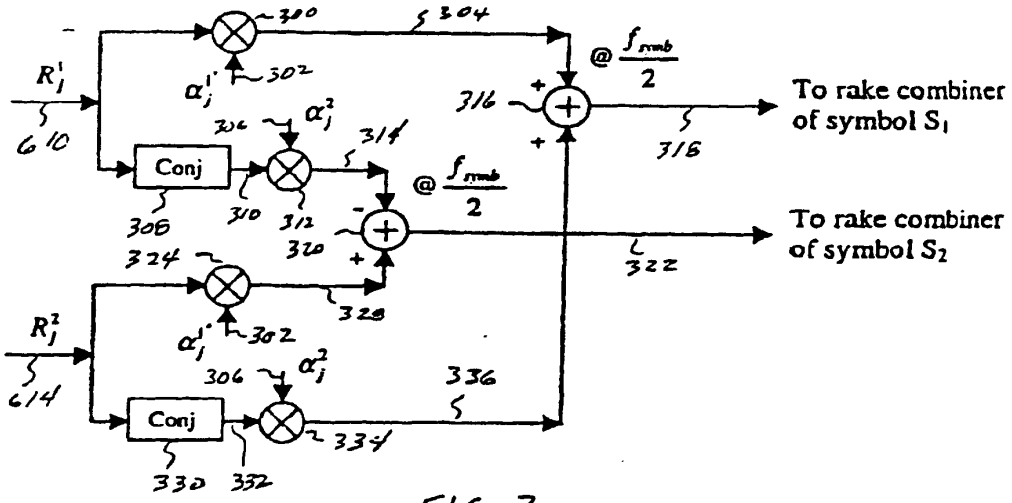


FIG. 3

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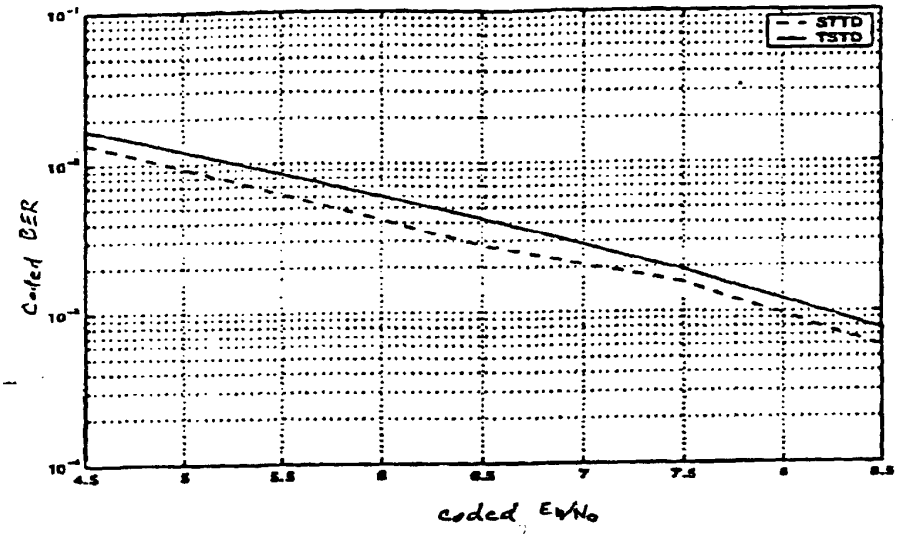


FIG. 4A

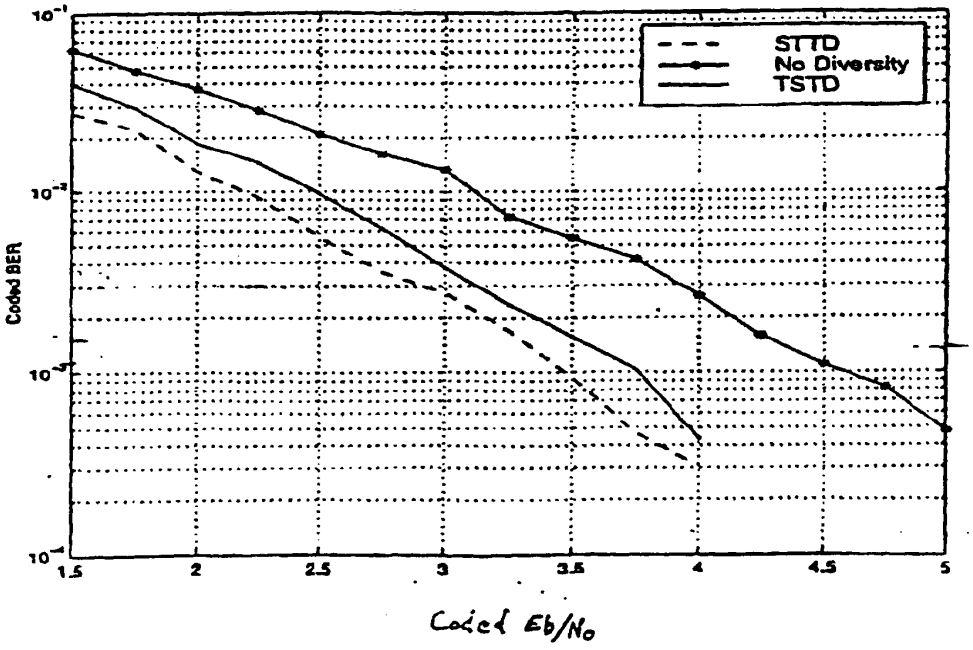


FIG. 4B

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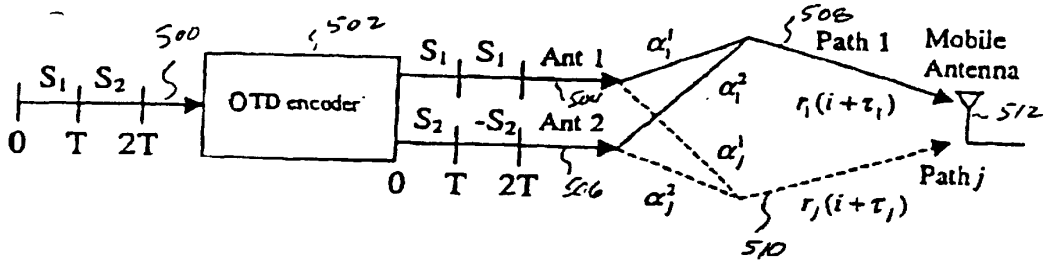


FIG. 5
(PRIOR ART)

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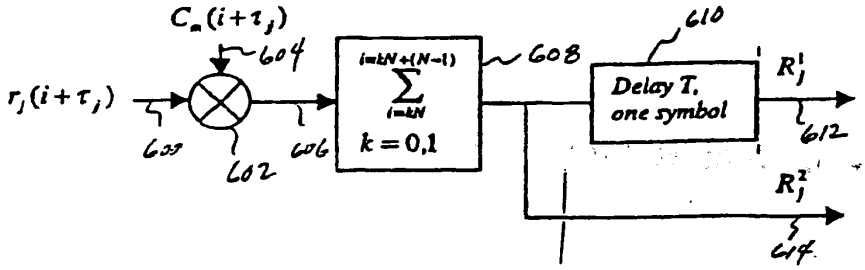


FIG. 6
(PRIOR ART)

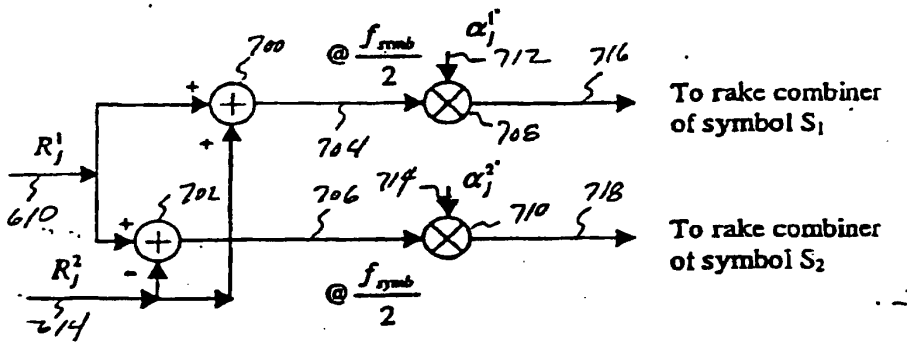


FIG. 7
(PRIOR ART)

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PLUS Search Results for S/N 10399859, Searched Mon Dec 18 08:47:43 EST 2006

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.

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PLUS Search Results for S/N 10399859, Searched Mon Jan 29 12:46:02 EST 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.

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/399,859	08/29/2003	Wen Tong	14316NP	9275

293 7590 03/20/2007

Ralph A. Dowell of DOWELL & DOWELL P.C.
2111 Eisenhower Ave
Suite 406
Alexandria, VA 22314

EXAMINER	
LEE, SIU M	
ART UNIT	**PAPER NUMBER**
2611	

SHORTENED STATUTORY PERIOD OF RESPONSE	MAIL DATE	DELIVERY MODE
3 MONTHS	03/20/2007	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)	
	10/399,859	TONG ET AL.	
	Examiner	Art Unit	
	Siu M. Lee	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 *4/23/2003*.

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) *24-36* 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) *24-36* is/are rejected.

7)☐ Claim(s) _____ 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 *23 April 2003* 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/SB/08) Paper No(s)/Mail Date *2/28/2006*.
4) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____.
5) ☐ Notice of Informal Patent Application
6) ☐ Other: _____.

DETAILED ACTION

Claim Rejections - 35 USC § 102

1. The following is a quotation of the appropriate paragraphs of 35 U.S.C. 102 that form the basis for the rejections under this section made in this Office action:

> A person shall be entitled to a patent unless –
>
> (e) the invention was described in (1) an application for patent, published under section 122(b), by another filed in the United States before the invention by the applicant for patent or (2) a patent granted on an application for patent by another filed in the United States before the invention by the applicant for patent, except that an international application filed under the treaty defined in section 351(a) shall have the effects for purposes of this subsection of an application filed in the United States only if the international application designated the United States and was published under Article 21(2) of such treaty in the English language.

2. Claims 24, 25, 26, 31, 32 are rejected under 35 U.S.C. 102(e) as being anticipated by Foschini et al. (US 7,050,510 B2).

(1) Regarding claim 24:

Foschini et al. discloses a transmitter comprising:

a space-time coding function (multiplexer 105 in figure 1) adapted to produce M space-time coded symbols per input set of M symbols, each input set of M symbols comprising one symbol per symbol substream, each of the M space-time coded symbols being included in a respective one of M space-time coded streams, wherein each symbol of the M symbol substream is represented in all M space-time coded streams, and for each symbol a time of representation of the symbol in the M space-time coded streams is different for each of the M space-time coded streams (multiplexer 105 process the symbols of each of the encoded data substreams supplies by encoders 103-1 to 103-L so as to form four transmit time sequences, each time sequence

comprise a representation of the input symbol (b1 to b4) and spanning at least L symbol period, each of the symbol is processed to develop its complex conjugate (a representation of the of the symbol), in one embodiment of the invention where L=4, the four symbols, their complex conjugates, the negative of the symbol and the negative of the conjugates are arranged by space time multiplexer 105 to form a matrix B (as shown in column 4, lines 30-39) corresponds to one of antennas 109, in the matrix B, where b1, b2, b3, b4 are the symbols from the encoded data substream supplied as outputs from encoders 103-1 to 103-4 while the columns represent different symbol periods (Ti, i=1-4), column 4, lines 13-45);

a plurality M of transmit antennas each adapted to transmit a respective one of the M space-time coded streams (antenna 109-1 to 109-4 in figure 1, each row of the matrix B represent the samples of a temporal sequence that is emitted by the corresponding one of antenna 109 (109-1 to 109-4), column 4, lines 23-25).

(2) Regarding claim 25:

Foschini et al. discloses a transmitter according to claim 24 further comprising the demultiplexing (demux 101 in figure 1, column 3, lines 65-66) and encoding functionality (encoder 103-1 to 103-L in figure 1) comprising a demultiplexer (demux 101 in figure 1, column 3, lines 65-66) having M outputs (L output), and M encoder/modulators (encoder 103-1 to 103-L in figure 1) each producing a respective one of the M symbol substreams, with each of the M encoder/modulators connected to receive a respective one of the demultiplexer outputs (column 3, line 66-column 4, lines 5).

(3) Regarding claim 26:

Foschini et al. discloses a transmitter according to claim 25 wherein the demultiplexing and encoding functionality is adapted to produce the M symbol substream from an input stream (demultiplexer 101 divides the source bit stream it receives as an input into L data substream, column 3, lines 65-66, encoders 103-1 to 103-L in figure 1 take the L output from the demux 101 and produce encoded data substream and may perform digital modulation, column 4, lines 3-5).

(4) Regarding claim 31:

Foschini et al. discloses a transmitter according to claim 24 further comprising encoder/modulator functionality integrated with the space-time coding function (encoders 103-1 to 103-L in figure 1 take the L output from the demux 101 and produce encoded data substream and may perform digital modulation, column 4, lines 3-5).

(5) Regarding claim 32:

Foschini et al. discloses a method of combined spatial multiplexing and space-time coding, comprising:

demultiplexing (demux 101 in figure 1) an input symbol stream into M symbol substreams (demultiplexer 101 divides the source bit stream it receives as an input into L data substream, column 3, lines 65-66);

performing coding and modulation on each of said M symbol substreams (encoders 103-1 to 103-L in figure 1 produce encoded data substream and may perform digital modulation, column 4, lines 3-5);

performing a space-time coding function adapted to produce M space-time coded symbols per input set of M symbols, each input set of m symbols comprising one symbol per symbol substream, each of the M space-time coded symbols being included in a respective one of M space-time coded streams, wherein each symbol of the M symbol substreams is represented in all M space-time coded streams, and for each symbol a time of representation of the symbol, in the M space-time coded streams is different for each of the M space-time coded streams (multiplexer 105 process the symbols of each of the encoded data substreams supplies by encoders 103-1 to 103-L so as to form four transmit time sequences, each time sequence comprise a representation of the input symbol (b1 to b4) and spanning at least L symbol period, each of the symbol is processed to develop its complex conjugate (a representation of the of the symbol), in one embodiment of the invention where L=4, the four symbols, their complex conjugates, the negative of the symbol and the negative of the conjugates are arranged by space time multiplexer 105 to form a matrix B (as shown in column 4, lines 30-39) corresponds to one of antennas 109, in the matrix B, where b1, b2, b3, b4 are the symbols from the encoded data substream supplied as outputs from encoders 103-1 to 103-4 while the columns represent different symbol periods (Ti, I=1-4), column 4, lines 13-45);

transmitting the M space-time coded streams on respective antennas (each row of the matrix B represent the samples of a temporal sequence that is emitted by the corresponding one of antenna 109 (109-1 to 109-4), column 4, lines 23-25).

Claim Rejections - 35 USC § 103

3. 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.

4. Claims 27, 28, 29, 30, 33, 34, 35, 36 are rejected under 35 U.S.C. 103(a) as being unpatentable over Foschini et al. (US 7,050,510 B2) in view of Ylitalo et al. (US 7,139,324 B1).

(1) Regarding claim 27:

Foschini et al. discloses all the subject matter as discuss in claim 26 except wherein the space-time coding function comprises an orthogonal transform adapted to produce M orthogonal outputs each of which is a function of the M substreams and a delay elements adapted to insert a respective different delay in M-I of file M orthogonal outputs to produce the M space-time coded streams.

However, Ylitalo et al. discloses the space-time coding function comprises an orthogonal transform adapted to produce M orthogonal outputs (multiplier 12 encodes signal CH_1 with a signature code (OC) that is mutually orthogonal to the signature code that is encoded in the signal CH_2 by multiplier 14 in figure 26, column 28, lines 19-21) each of which is a function of the M substreams and a delay elements adapted to insert a respective different delay in M-1 of the M orthogonal outputs to produce the M space-time coded streams (the programmable delay element in figure 26 insert a delay to the signal 15, column 28, lines 44-50).

It is desirable to have the space-time coding function comprises an orthogonal transform adapted to produce M orthogonal outputs each of which is a function of the M substreams and a delay elements adapted to insert a respective different delay in M-I of file M orthogonal outputs to produce the M space-time coded streams because it achieve greater spectral efficiency at the base station while minimizing co-channel interference (column 3, lines 1-3). Therefore, it would have been obvious to one of ordinary skill in the art at the time of invention to employ the teaching of Ylitalo et al. in the system of Foschini et al. to improve the efficiency of the transmitter.

(2) Regarding claim 28:

Ylitalo et al. discloses a programmable delay element to introduce a delay to the orthogonal output.

Ylitalo et al. fails to explicitly discloses the delay element introduce a delay of m-1 symbol period in the mth orthogonal output, where m=1 to M. It would have been obvious to one of ordinary skill in the art at the time of invention for the programmable delay line to adapted the delay element to insert a delay of M symbol period in each of the M substream and with the mth orthogonal output being delayed in said delay elements by m-1 symbol periods, since it has been held that discovering an optimum value of a result effective variable involves only routine skill in the art. Iii re Boesch, Eli f.2d 272, 205 USPQ 215.

(3) Regarding claim 29:

Foschini et al. discloses all the subject matter as discuss in claim 24 except:

delay elements adapted to insert a delay of M symbol periods in each of the M substreams;

an orthogonal transform adapted to produce M orthogonal outputs, with the mth orthogonal output being a function of the M substreams delayed in said delay elements by m-1 symbol periods,

However, Ylitalo et al. discloses a transmitter wherein the space-time coding function comprises:

an orthogonal transform adapted to produce M orthogonal outputs (multiplier 12 encodes signal CH_1 with a signature code (OC) that is mutually orthogonal to the signature code that is encoded in the signal CH_2 by multiplier 14 in figure 26, column 28, lines 19-21) with the mth orthogonal output being a function of the M substreams delayed in said delay elements.

Ylitalo et al. discloses the claimed invention except for explicitly discloses a delay elements adapted to insert a delay of M symbol periods in each of the M substreams and with the mth orthogonal output being delayed in said delay elements by m-1 symbol periods. It would have been obvious to one of ordinary skill in the art at the time of invention for the programmable delay line to adapted the delay element to insert a delay of M symbol period in each of the M substream and with the mth orthogonal output being delayed in said delay elements by m-1 symbol periods, since it has been held that discovering an optimum value of a result effective variable involves only routine skill in the art. Iii re Boesch, Eli f.2d 272, 205 USPQ 215.

(4) Regarding claim 33:

Foschini et al. discloses all the subject matter as discuss in claim 24 except:

executing an orthogonal transform to produce M orthogonal outputs each of which is a function of the M substreams (multiplier 12 encodes signal CH_1 with a signature code (OC) that is mutually orthogonal to the signature code that is encoded in the signal CH_2 by multiplier 14 in figure 26, column 28, lines 19-21) and;

delaying the M orthogonal outputs to produce M delayed orthogonal outputs such that each of the M delayed orthogonal outputs is a function of a given element of each of the M substreams at a different time (the programmable delay element in figure 26 insert a delay to the signal 15, column 28, lines 44-50).

It is desirable to have the space-time coding function comprises an orthogonal transform adapted to produce M orthogonal outputs each of which is a function of the M substreams and delaying the M orthogonal outputs to produce M delayed orthogonal outputs such that each of the M delayed orthogonal outputs is a function of a given element of each of the M substream at a different time because it achieve greater spectral efficiency at the base station while minimizing co-channel interference (column 3, lines 1-3). Therefore, it would have been obvious to one of ordinary skill in the art at the time of invention to employ the teaching of Ylitalo et al. in the system of Foschini et al. to improve the efficiency of the transmitter.

(5) Regarding claim 34:

Foschini et al. in view of Ylitalo et al. discloses all the subject matter as discuss in claim 34 except wherein the mth orthogonal output is delayed by m-1 symbol periods, where m=1 to M. It would have been obvious to one of ordinary skill in the art at the

time of invention for the programmable delay line to delay m^{th} orthogonal output by m-1 symbol period, since it has been held that discovering an optimum value of a result effective variable involves only routine skill in the art. Iii re Boesch, Eli f.2d 272, 205 USPQ 215.

(6) Regarding claim 35:

Foschini et al. discloses all the subject matter as discussed in claim 32 except wherein performing the space-time coding function comprises:

delaying by M symbol periods each of the M substreams;

executing an orthogonal transform adapted to produce M orthogonal outputs, with tile m^{th} orthogonal output being a function of the M substreams delayed m-1 symbol periods.

However, Ylitalo et al. discloses a transmitter wherein the space-time coding function comprises:

an orthogonal transform adapted to produce M orthogonal outputs (multiplier 12 encodes signal CH_1 with a signature code (OC) that is mutually orthogonal to the signature code that is encoded in the signal CH_2 by multiplier 14 in figure 26, column 28, lines 19-21) with the mth orthogonal output being a function of the M substreams delayed in said delay elements.

Ylitalo et al. discloses the claimed invention except for explicitly discloses a delay elements adapted to insert a delay of M symbol periods in each of the M substreams and with the mth orthogonal output being delayed in said delay elements by m-1 symbol periods. It would have been obvious to one of ordinary skill in the art at the time of

invention for the programmable delay line to adapted the delay element to insert a delay of M symbol period in each of the M substream and with the mth orthogonal output being delayed in said delay elements by m-1 symbol periods, since it has been held that discovering an optimum value of a result effective variable involves only routine skill in the art. Iii re Boesch, Eli f.2d 272, 205 USPQ 215.

5. Claims 30 and 36 are rejected under 35 U.S.C. 103(a) as being unpatentable over Foschini et al. (US 7,050,510 B2) in view of Ylitalo et al. (US 7,139,324 B1) as applied to claims 29 and 33 above, and further in view of Yamao et al. (US 6,351,498 B1).

Foschini et al. and Ylitalo et al. disclose all the subject matter as discuss in claims 29 and 33 except wherein the orthogonal transform comprises M M-ary mapping functions, each adapted to produce a respective sequence of M-ary symbols with the M-ary symbol of the mth M-ary mapping function being a function of the M substreams delayed in said delay elements by m-1 bit periods.

However, Yamao et al. discloses a orthogonal transform comprises M M-ary mapping function (M-ary encoder 1-1 to 1-N in figure 8), each adapted to produce a respective sequence of M-ary symbols with the M-ary symbol of the mth M-ary mapping function being a function of the M-substreams delayed in said elements (at the M-ary encoders 1-1 to 1-N, M-ary orthogonal codes corresponding to the respective inputs are generated, when the ordinary orthogonal codes with L=2 are used, the 2 bits data

entered into the M-ary encoder is converted into one of the 4 bits length orthogonal code, column 6, lines 7-14).

It is desirable for wherein the orthogonal transform comprises M M-ary mapping functions, each adapted to produce a respective sequence of M-ary symbols with the M-ary symbol of the mth M-ary mapping function being a function of the M substreams delayed in said delay elements by m-1 bit periods because it is capable of reducing errors due to fading while maintaining the characteristics of the M-ary modulation and demodulation scheme that is robust against interference (column 3, lines 12-13). Therefore, it would have been obvious to one of ordinary skill in the art at the time of invention to employ the teaching of Yamao et al. in the system of Foschini et al. and Ylitalo et al. to improve the performance of the system.

Conclusion

6. The prior art made of record and not relied upon is considered pertinent to applicant's disclosure. Raleigh (US 6,377,631 B1) discloses a transmitter incorporating spatio-temporal processing. Hammons, Jr. et al. (US 6,678,263 B1) discloses a method and constructions for space-time codes for PSK constellations for spatial diversity in multiple-element antenna system. Dabak et al. (US 6,775,260 B1) discloses a space time transmit diversity for TDD/WCDMA systems.

7. Any inquiry concerning this communication or earlier communications from the examiner should be directed to Siu M. Lee whose telephone number is (571) 270-1083.

The examiner can normally be reached on Mon-Fri, 7:30-4:00 with every other Friday off.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Chieh 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.

Siu M. Lee
3/14/2007

CHIEH M. FAN
SUPERVISORY PATENT EXAMINER

OIPE IAP20 FEB 28 2006 PATENT & TRADEMARK OFFICE

PTO/SB/08A (08-03)
Approved for use through 07/31/2006. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

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Substitute for form 1449/PTO

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Use as many sheets as necessary)

Sheet 1 of 2

Complete if Known	
Application Number	10/399,859
Filing Date	April 23, 2003
First Named Inventor	Wen Tong
Art Unit	2665
Examiner Name	Huy Duy Vu
Attorney Docket Number	14316NP

U.S. PATENT DOCUMENTS

Examiner Initials *	Cite No. [1]	Document Number Number-Kind code [2] (if known)	Publication Date MM-DD-YYY	Name of Patentee or Applicant of Cited Document	Page, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
		US-			
		US-			
		US-			
		US-			
		US-			
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FOREIGN PATENT DOCUMENTS

Examiner Initials *	Cite No. [1]	Foreign Patent Document Country Code[3] Number[4] Kind Code[5] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages Or Relevant Figures	T[6]
/SL/	AA	EP 0 905 920 A2	31.03.1999	Lucent Technolgoies Inc.		☐
/SL/	AB	EP 0 993 130 A2	12.04.2000	Texas Instruments Incorporated		☐
						☐
						☐
						☐

Examiner Signature	/Siu Lee/	Date Considered	03/12/2007

*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. [1] Applicant's unique citation designation number (optional). [2] See Kinds codes of USPTO patent Documents at www.uspto.gov or MPEP 901.04 [3] Enter Office that issued the document, by the two-letter code (WIPO Standard ST.3). [4] For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. [5] Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. [6] Applicant is to place a checkmark here if English language Translation is attached.

This collection of information is required by 37 CFR 1.97 and 1.98. 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 2 hours 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, 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.**

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OIPE IAP40 FEB 28 2006 PATENT & TRADEMARK OFFICE

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Use as many sheets as necessary)

Sheet 2 of 2

Complete if Known	
Application Number	10/399,859
Filing Date	April 23, 2003
First Named Inventor	Wen Tong
Art Unit	2665
Examiner Name	Huy Duy Vu
Attorney Docket Number	14316NP

NON PATENT LITERATURE DOCUMENTS

Examiner Initials *	Cite No. [1]	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, pages), volume-issue number(s), publisher, city and /or country where published.	T [2]
/SL/	AC	Hochwald, Marzetta; SPACE-TIME MODULATION FOR UNKNOWN FADING; Proceedings of the SPIE, Vol. 57, No. 8, April 1999, pgs 10-19, XP000914262	☐
/SL/	AD	Yumin Zhang & R. Blum; MULTISTAGE MULTIUSER DETECTION FOR CDMA WITH SPACE-TIME CODING; IEEE Workshop on Statistical Signal and Array Processing; 14-16 August 2000, pgs 1-5, XP002174378.	☐
/SL/	AE	Ben Lu; et al.; ITERATIVE RECEIVERS FOR MULTIUSER SPACE-TIME CODING SYSTEMS; IEEE International Conference on Communications, 18-22 June 2000, pgs 302-306, XP002174379.	☐
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Examiner Signature	/Siu Lee/	Date Considered	03/12/2007

*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.
[1] Applicant's unique citation designation number (optional). [2] Applicant is to place a checkmark here if English language Translation is attached.
This collection of information is required by 37 CFR 1.98. 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 2 hours 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, 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 (1-800-786-9199) and select option 2.

Notice of References Cited	Application/Control No. 10/399,859	Applicant(s)/Patent Under Reexamination TONG ET AL.	
	Examiner Siu M. Lee	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-7,050,510 B2	05-2006	Foschini et al.	375/299
*	B	US-7,139,324 B1	11-2006	Ylitalo et al.	375/267
*	C	US-6,351,498 B1	02-2002	Yamao et al.	375/260
*	D	US-6,775,260 B1	08-2004	Dabak et al.	370/342
*	E	US-6,678,263 B1	01-2004	Hammons et al.	370/342
*	F	US-6,377,631 B1	04-2002	Raleigh, Gregory G.	375/299
	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.

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Bib Data Sheet

CONFIRMATION NO. 9275

SERIAL NUMBER	FILING OR 371(c) DATE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.
10/399,859	08/29/2003 RULE	375	2611	14316NP

APPLICANTS

Wen Tong, Ottawa, CANADA;
Mikhail Bakulin, Klrova, RUSSIAN FEDERATION;
Vitaly B. Kreyndelin, Moskya, RUSSIAN FEDERATION;
Alexander M. Shloma, Zhukovsky, RUSSIAN FEDERATION;
Yuriy Shinakov, Moscow, RUSSIAN FEDERATION;

** CONTINUING DATA **********

This application is a 371 of PCT/RU00/00426 10/27/2000 ML 3/12/2007

** FOREIGN APPLICATIONS **********

-NONE- ML 3/12/2007

Foreign Priority claimed	STATE OR COUNTRY	SHEETS DRAWING	TOTAL CLAIMS	INDEPENDENT CLAIMS
☐ yes ☐ no	CANADA	8	23	3
35 USC 119 (a-d) conditions met ☐ yes ☒ no ☒ Met after Allowance				
Verified and Acknowledged _____ Examiner's Signature _____ Initials				

ADDRESS

293

TITLE

Combination of space-time coding and spatial multiplexing, and the use of orthogonal transformation in space-time coding ML

FILING FEE RECEIVED	FEES: Authority has been given in Paper	
1084	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

Index of Claims	Application/Control No.	Applicant(s)/Patent Under Reexamination
	10399859	TONG ET AL.
	Examiner	Art Unit
	Lee, Siu M	2611

✓	Rejected	-	Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

CLAIM		DATE								
Final	Original	03/14/2007								
	1	-								
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	35	✓								
	36	✓								

Index of Claims	Application/Control No.	Applicant(s)/Patent Under Reexamination
	10399859	TONG ET AL.
	Examiner	Art Unit
	Lee, Siu M	2611

✓	Rejected	-	Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	10399859	TONG ET AL.
	Examiner	Art Unit
	Lee, Siu M	2611

SEARCHED			
Class	Subclass	Date	Examiner
375	267, 260, 295, 299	3/13/2007	Siu M. Lee

SEARCH NOTES		
Search Notes	Date	Examiner
EAST	3/13/2007	Siu M. Lee
Discuss application with Chieh Fan	3/14/2007	Siu M. Lee

INTERFERENCE SEARCH			
Class	Subclass	Date	Examiner

OIPE IAP94 JUN 19 2007 PATENT & TRADEMARK OFFICE

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Appl. No.	: 10/399,859	Confirmation No.	9275
Applicant	: Wen Tong et al.		
Filed	: August 29, 2003		
TC/A.U.	: 2611		
Examiner	: Siu M. Lee		
Docket No.	: 14316NP		
Customer No.	: 000293		

Commissioner for Patents
Alexandria, VA 22313-1450
U.S.A.

Dear Sir:

In response to the Office Action dated March 20, 2007, the following is submitted:

Amendments to the Claims are reflected in the listing of claims which begin on page 2 of this paper.

Remarks/Arguments begin on page 6 of this paper.

JUN 19 2007

2611

AMENDMENT TRANSMITTAL LETTER (Large Entity) Applicant(s): TOMCZEWSKI et al.					Docket No. 14316NP
Application No. 10/399,859	Filing Date August 29, 2003	Examiner LEE, Siu M.	Customer No. 000293	Group Art Unit 2611	Confirmation No. 9275

Invention: **COMBINATION OF SPACE-TIME CODING AND SPATIAL MULTIPLEXING, AND THE USE OF ORTHOGONAL TRANSFORMATION IN SPACE-TIME CODING**

COMMISSIONER FOR PATENTS:

Transmitted herewith is an amendment in the above-identified application.

The fee has been calculated and is transmitted as shown below.

CLAIMS AS AMENDED

	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST # PREV. PAID FOR		NUMBER EXTRA CLAIMS PRESENT	RATE	ADDITIONAL FEE
TOTAL CLAIMS	13	-	23	=	0	x $50.00	$0.00
INDEP. CLAIMS	2	-	3	=	0	x $200.00	$0.00
Multiple Dependent Claims (check if applicable) ☐							$0.00
TOTAL ADDITIONAL FEE FOR THIS AMENDMENT							$0.00

☒ No additional fee is required for amendment.

☐ Please charge Deposit Account No. in the amount of

☐ A check in the amount of to cover the filing fee is enclosed.

☒ The Director is hereby authorized to charge payment of the following fees associated with this communication or credit any overpayment to Deposit Account **19-2550**

- ☒ Any additional filing fees required under 37 C.F.R. 1.16.
- ☒ Any patent application processing fees under 37 CFR 1.17.

☐ Payment by credit card. Form PTO-2038.

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Signature

Dated: June 19, 2007

Ralph A. Dowell
Reg. No. 26,868

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" [37 CFR 1.8(a)] on

_____ .
(Date)

Signature of Person Mailing Correspondence

Typed or Printed Name of Person Mailing Correspondence

Tel. No. (703) 415-2555

cc:

P11LARGE/REV09

Amendments to the Claims:

This listing of claims will replace all prior versions, and listings, of claims in the application:

Listing of Claims:

Claims 1-23 (Cancelled)

24. (Currently amended) A transmitter adapted to process a plurality M of symbol substreams, the transmitter comprising:

a space-time coding function adapted to produce M space-time coded symbols per input set of M symbols, each input set of M symbols comprising one symbol per symbol substream, each of the M space-time coded symbols being included in a respective one of M space-time coded streams, wherein each symbol of the M symbol substreams is represented in all M space-time coded streams, wherein the transmitter comprises a delay arrangement, arranged such that~~and~~ for each symbol a time of representation of the symbol in the M space-time coded streams is different for each of the M space-time coded streams, each space-time coded symbol comprising a representation of a symbol of each of the M symbol substreams;

a plurality M of transmit antennas each adapted to transmit a respective one of the M space-time coded streams.

25. (Previously presented) A transmitter according to claim 24 further comprising the demultiplexing and encoding functionality comprising a demultiplexer having M outputs, and M encoder/modulators each producing a respective one of the M symbol substreams, with each of the M encoder/modulators connected to receive a respective one of the demultiplexer outputs.

26. (Previously presented) A transmitter according to claim 25 wherein the demultiplexing and encoding functionality is adapted to produce the M symbol substreams from an input stream.

27. (Currently amended) A transmitter according to claim 26 wherein the space-time coding function comprises:

an orthogonal transform adapted to produce M orthogonal outputs each of which is a function of the M substreams;

wherein the delay arrangement comprises delay elements adapted to insert a respective different delay in M-1 of the M orthogonal outputs to produce the M space-time coded streams.

28. (Previously presented) A transmitter according to claim 27 wherein the delay elements are adapted to introduce a delay of m-1 symbol periods in the mth orthogonal output, where m=1, ..., M.

29. (Currently amended) A transmitter according to claim 24 wherein the delay arrangement comprises ~~space-time coding function~~ comprises:

delay elements adapted to insert a delay of M symbol periods in each of the M substreams; and

the space-time coding function further comprises an orthogonal transform adapted to produce M orthogonal outputs, with the mth orthogonal output being a function of the M substreams delayed in said delay elements by m-1 symbol periods.

30. (Previously presented) A transmitter according to claim 29 wherein the M substreams are bit streams, and wherein the orthogonal transform comprises M M-ary mapping functions, each adapted to produce a respective sequence of M-ary symbols with the M-ary symbol of the mth M-ary mapping function being a function of the M substreams delayed in said delay elements by m-1 bit periods.

31. (Cancelled)

32. (Currently amended) A method ~~of combined spatial multiplexing and space-time coding,~~ comprising:

demultiplexing an input symbol stream into M symbol substreams;

performing coding and modulation on each of said M symbol substreams;

performing a space-time coding function adapted to produce M space-time coded symbols per input set of M symbols, each input set of M symbols comprising one symbol per symbol substream, each of the M space-time coded symbols being included in a respective one of M space-time coded streams, wherein each symbol of the M symbol substreams is represented in all M space-time coded streams, wherein performing the space-time coding function comprises implementing a delay function, arranged such that~~and~~ for each symbol a time of representation of the symbol in the M space-time coded streams is different for each of the M space-time coded streams, each space-time coded symbol comprising a representation of a symbol of each of the M symbol substreams;

transmitting the M space-time coded streams on respective antennas.

33. (Currently amended) A method according to claim 32 wherein performing the space-time coding function comprises:

executing an orthogonal transform to produce M orthogonal outputs each of which is a function of the M substreams; and

implementing the delay function comprises delaying the M orthogonal outputs to produce M delayed orthogonal outputs such that each of the M delayed orthogonal outputs is a function of a given element of each of the M substreams at a different time.

34. (Previously presented) A method according to claim 33 wherein the mth orthogonal output is delayed by m-1 symbol periods, where m=1, ..., M.

35. (Previously presented) A method according to claim 32 wherein performing the space-time coding function comprises:

delaying by M symbol periods each of the M substreams;

executing an orthogonal transform adapted to produce M orthogonal outputs, with the mth orthogonal output being a function of the M substreams delayed m-1 symbol periods.

36. (Previously presented) A method according to claim 33 wherein the M substreams are bit

streams, and wherein the orthogonal transform comprises M M-ary mapping functions, each adapted to produce a respective sequence of M-ary symbols with the M-ary symbol of the mth M-ary mapping function being a function of the M substreams delayed in said delay elements by m-1 bit periods.

37. (New) A transmitter according to claim 24, wherein each of the M space-time coded symbols is included in a respective one of M space-time coded streams at a different time from the inclusion of each other of the M space-time coded symbols in their respective space-time coded stream.

38. (New) A method according to claim 32, wherein each of the M space-time coded symbols is included in a respective one of M space-time coded streams at a different time from the inclusion of each other of the M space-time coded symbols in their respective space-time coded stream.

REMARKS/ARGUMENTS

Status of Claims

Claims 24-30 and 32-36 remain in the application. Claim 31 has been cancelled from the application. New claims 37 and 38 have been added to the application.

Claim Amendments

The claims have been amended in the interest of expediting prosecution. All claims now include a recitation pertaining to a delay or delay arrangement. The embodiments of Figures 4 to 7 in particular all include delay elements.

35 U.S.C 102 Claim Rejections

The Examiner has rejected claims 24-26, 31 and 32 under 35 U.S.C. 102(e) as being anticipated by U.S. Patent No. 7,050,510 (Foschini et al, hereinafter Foschini).

The present application was filed as an international application under the terms of the Patent Cooperation Treaty. The international filing date of the application is October 27, 2000. The application entered the national phase in the United States on April 23, 2003. The Foschini reference has a filing date of December 29, 2000.

As the international filing date of the present application predates the Foschini reference by approximately two months, Applicant submits that the Foschini reference is not citable against the present application.

Applicant respectfully requests that the Examiner withdraw the anticipation rejection of claims 24-26, 31 and 32.

35 U.S.C 103 Claim Rejections

The Examiner has rejected claims 27-30 and 33-36 under 35 U.S.C. 103(a) as being unpatentable over Foschini in view of U.S. Patent No. 7,139,324 (Ylitalo).

As the Foschini reference is not citable against the present application, for at least the reasons discussed above, Applicant submits that the combination of Foschini and Ylitalo is also not citable against claims 27-30 and 33-36 of the present application.

Applicant respectfully requests that the Examiner withdraw the anticipation rejection of claims 27-30 and 33-36.

In view of the forgoing, early favorable consideration of this application is earnestly solicited.

Respectfully submitted,

DOWELL & DOWELL, P.C.

Ralph Dowell, Reg. No. 26,868

Date: June 19, 2007

DOWELL & DOWELL, P.C.
Suite 406, 2111 Eisenhower Avenue
Alexandria, VA 22314
Telephone: (703) 415-2555

RAB:MSS:mcg

PTO/SB/06 (07-06)
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PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875	Application or Docket Number 10/399,859	Filing Date 08/29/2003	☐ To be Mailed

APPLICATION AS FILED – PART I

	(Column 1)	(Column 2)	SMALL ENTITY ☐		OR	OTHER THAN SMALL ENTITY	
FOR	NUMBER FILED	NUMBER EXTRA	RATE ($)	FEE ($)		RATE ($)	FEE ($)
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A			N/A	
☐ SEARCH FEE (37 CFR 1.16(k), (l), or (m))	N/A	N/A	N/A			N/A	
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A			N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	minus 20 =	*	X $ =		OR	X $ =	
INDEPENDENT CLAIMS (37 CFR 1.16(h))	minus 3 =	*	X $ =			X $ =	
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $250 ($125 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).						
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))							
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL			TOTAL	

APPLICATION AS AMENDED – PART II

		(Column 1)		(Column 2)	(Column 3)	SMALL ENTITY		OR	OTHER THAN SMALL ENTITY	
	06/19/2007	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE ($)	ADDITIONAL FEE ($)		RATE ($)	ADDITIONAL FEE ($)
AMENDMENT	Total (37 CFR 1.16(i))	* 14	Minus	** 23	= 0	X $ =		OR	X $50=	0
	Independent (37 CFR 1.16(h))	* 2	Minus	***3	= 0	X $ =		OR	X $200=	0
	☐ Application Size Fee (37 CFR 1.16(s))									
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	**0**

		(Column 1)		(Column 2)	(Column 3)					
		CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE ($)	ADDITIONAL FEE ($)		RATE ($)	ADDITIONAL FEE ($)
AMENDMENT	Total (37 CFR 1.16(i))	*	Minus	**	=	X $ =		OR	X $ =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	X $ =		OR	X $ =	
	☐ Application Size Fee (37 CFR 1.16(s))									
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L 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.

Legal Instrument Examiner:
Rozenia Harmon

This collection of information is required by 37 CFR 1.16. 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.

EAST Search History

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
S1	0	10/399859	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/03/12 12:26
S2	575	transmitter and (space time coding)	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/03/12 12:26
S3	793	transmitter and (space near2 time near2 coding)	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/03/12 12:27
S4	652	S3 and ((multi$3 or plurality or array) near4 antenna)	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/03/12 12:41
S5	394	S4 and delay	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/03/12 14:58
S8	3	09/586561	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/03/13 08:18
S9	2	"3646443".pn.	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/03/13 08:36
S10	4491	375/267,295,299,260.ccls.	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/08/19 18:55

EAST Search History

S11	255	S10 and ((space near2 time near2 cod$3) and delay)	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/03/13 08:39
S12	230	S11 and ((plurality or multiple or multi) near2 antenna)	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/03/13 08:40
S13	3	("20030048857" | "5467367" | "6128330").PN.	US-PGPUB; USPAT; USOCR	ADJ	ON	2007/03/13 09:39
S14	1	("6934320").URPN.	USPAT	ADJ	ON	2007/03/13 09:42
S15	3	("20030048857" | "5467367" | "6128330").PN.	US-PGPUB; USPAT; USOCR	ADJ	ON	2007/03/13 10:32
S16	2335	delay same (add$3 or sum$4 or multiplex$3) same transmit$4 same antenna	US-PGPUB; USPAT; USOCR	ADJ	ON	2007/03/13 10:34
S17	92	S16 and (space near2 time near2 cod$3)	US-PGPUB; USPAT; USOCR	ADJ	ON	2007/03/13 10:57
S18	0	ep0993130 A2	US-PGPUB; USPAT; USOCR	ADJ	ON	2007/03/13 10:58
S19	0	"993130" A2	US-PGPUB; USPAT; USOCR	ADJ	ON	2007/03/13 10:57
S20	0	ep0993130A2	US-PGPUB; USPAT; USOCR	ADJ	ON	2007/03/13 10:58
S21	1	09/103443	US-PGPUB; USPAT; USOCR	ADJ	ON	2007/03/13 10:58
S22	1	08/103443	US-PGPUB; USPAT; USOCR	ADJ	ON	2007/03/13 10:59
S23	0	(texan instruments).as. and (space and time).ti.	US-PGPUB; USPAT; USOCR	ADJ	ON	2007/03/13 11:00
S24	14	(texas instruments).as. and (space and time).ti.	US-PGPUB; USPAT; USOCR	ADJ	ON	2007/03/13 11:05

EAST Search History

S25	20	(lucent).as. and (multiple and antenna).ti.	US-PGPUB; USPAT; USOCR	ADJ	ON	2007/03/13 11:07
S26	3	S25 and delay	US-PGPUB; USPAT; USOCR	ADJ	ON	2007/03/13 11:20
S27	2	(space near2 time near2 coding) and (mix$3 near3 substream)	US-PGPUB; USPAT; USOCR	ADJ	ON	2007/03/13 11:22
S28	0	(space near2 time near2 coding) and (mixing near3 substream)	US-PGPUB; USPAT; USOCR	ADJ	ON	2007/03/13 11:22
S29	46	(mixing near3 substream)	US-PGPUB; USPAT; USOCR	ADJ	ON	2007/03/13 11:37
S30	0	((space time cod$3 substream) with delay) same antenna	US-PGPUB; USPAT; USOCR	ADJ	ON	2007/03/13 11:38
S31	0	(space time cod$3 substream)	US-PGPUB; USPAT; USOCR	ADJ	ON	2007/03/13 11:39
S32	4	(space time cod$3 stream)	US-PGPUB; USPAT; USOCR	ADJ	ON	2007/03/13 11:39
S33	562	(demultiplex$3 with (cod$3) with (modulat$3))	US-PGPUB; USPAT; USOCR	ADJ	ON	2007/03/13 11:40
S34	21	S33 and (space near2 time near2 cod$3)	US-PGPUB; USPAT; USOCR	ADJ	ON	2007/03/13 13:10
S40	405	dabak.in.	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/03/13 14:18
S41	24	S40 and space time cod$3	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/03/13 14:20
S42	1	S41 and demultiplex$3	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/03/13 14:21

EAST Search History

S43	95	(space near2 time near2 cod$3) and (demultiplex$3 with symbol) and (cod$3 same modulat$3)	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/03/14 06:40
S44	98574	(combin$3 or add$3 or sum$4) with delay	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/03/14 06:42
S45	108046	(combin$3 or add$3 or sum$4 or mix$3) with delay	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/03/14 06:42
S46	112	S45 and space time cod$3	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/03/14 07:06
S47	2	mix$3 with substream with delay	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/03/14 07:09
S48	35	M-ary and space time coding	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/03/14 10:19
S49	31	M-ary and space time coding and map$4	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/03/14 10:55
S50	3	M-ary encoder and orthogonal$3	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/03/14 12:51

EAST Search History

S51	1	10/788420	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/03/14 12:52
S52	0	10/399859	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/08/19 08:15
S53	1	"6377631".pn. and delay	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/08/19 14:20
S54	1674	(space near3 time near3 cod$3) and transmitter	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/08/19 18:57
S55	247	S54 and @rlad<"20001027"	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/08/19 18:57
S56	207	S55 and delay	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/08/19 14:23
S57	133	S56 and ((plurality or multi or multiple or array) near3 antenna)	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/08/19 18:56
S58	0	09/883543	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/08/19 14:54

EAST Search History

S59	2	09/833543	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/08/19 15:33
S64	4972	375/267,295,299,260.ccls.	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/08/19 18:56
S65	2441	S64 and delay	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/08/19 18:56
S66	806	S65 and ((plurality or multi or multiple or array) near3 antenna)	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/08/19 18:56
S67	263	S66 and (space near3 time near3 cod$3) and transmitter	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/08/19 18:57
S68	47	S67 and @rlad<"20001027"	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/08/19 18:58
S69	0	S68 not S57	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/08/19 18:57
S70	788	S64 and spatial	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/08/19 18:58

EAST Search History

S71	221	S70 and temporal	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/08/19 18:58
S72	40	S71 and @rlad<"20001027"	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/08/19 18:58
S73	35	S72 and delay	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/08/19 18:58
S74	35	S72 and delay$3	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/08/19 18:58
S75	18	S74 not S57	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/08/20 10:34
S76	111	delay near3 diversity and @rlad<"20001027"	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/08/20 10:35
S77	31	S76 and space near3 time near3 cod$3	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/08/20 10:48
S78	80	S76 not S77	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/08/20 10:48

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/399,859	08/29/2003	Wen Tong	14316NP	9275

293 7590 09/06/2007

Ralph A. Dowell of DOWELL & DOWELL P.C.
2111 Eisenhower Ave
Suite 406
Alexandria, VA 22314

EXAMINER	
LEE, SIU M	

ART UNIT	PAPER NUMBER
2611	

MAIL DATE	DELIVERY MODE
09/06/2007	PAPER

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Office Action Summary	Application No.	Applicant(s)	
	10/399,859	TONG ET AL.	
	Examiner	Art Unit	
	Siu M. Lee	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 *19 June 2007*.

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) *24-30 and 32-38* 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) *24-30 and 32-38* is/are rejected.

7)☐ Claim(s) _____ 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 *23 April 2003* 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/SB/08) Paper No(s)/Mail Date _____.
4) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____.
5) ☐ Notice of Informal Patent Application
6) ☐ Other: _____.

DETAILED ACTION

Response to Arguments

1. Applicant's arguments, see page 6-7, filed 6/19/2007, with respect to the rejections of claims 24-36 under 35 U.S.C. §102(e) and 35 U.S.C. 103(a) have been fully considered and are persuasive. Therefore, the rejection has been withdrawn. However, upon further consideration, a new ground(s) of rejection is made in view of Hammons, Jr. et al. (US 6,678,263 B1) and Lindskog et al. (US 2004/0013211 A1).

Claim Objections

2. Claim 1 is objected to because of the following informalities:

Claim 1, line 8 recites "for **each symbol** a time of representation of the symbol in the M space-time coded streams is different for each of the M space-time coded stream". It is unclear what the "**each symbol**" is referring to; the space-time coded symbol or the input symbol.

Appropriate correction is required.

Claim Rejections - 35 USC § 103

3. 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.

4. Claims 24, 25, 26, 37 and 38 are rejected under 35 U.S.C. 103(a) as being unpatentable over Hammons, Jr. et al. (US 6,678,263 B1) in view of Lindskog et al. (US 2004/0013211 A1).

(1) Regarding claim 24 and 32 (the examiner interpret the each symbol in line 8 as the input symbol):

Hammons, Jr. et al. discloses a space time coding function adapted to produce M space-time coded symbols (output of modulator 118 in figure 4) per input set of M symbols (output of spatial formatter 114 in figure 4), each input set of M symbols comprising one symbol per symbol substream, each of the M space-time coded symbol of the M symbol substream is represented in a respective of M space–time coded streams (in figure 4, spatial formatter 114 separate the incoming signal into plurality of input signals to the inner coder 116a – 116c, which are coded by the inner code 116a – 116c and further modulated by the modulators 118aa – 118c, therefore, each input set of M symbols comprising one symbol per symbol substream, each of the M space-time coded symbol of the M symbol substream is represented in a respective of M space–time coded streams, column 8, lines 7-12).

Hammons, Jr. et al. fails to disclose wherein the transmitter comprises a delay arrangement, arranged such that for each symbol, a time of representation of the symbol in the M space-time coded streams is different for each of the M space-time coded stream, each space-time coded symbol comprising a representation of a symbol of each of the M symbol substream and wherein each symbol of the M symbol

substream is represented in all M space-time coded stream and a plurality of M transmit antenna each adapted to transmit a respective one of the M space-time coded stream.

However, Lindskog et al. discloses a time reversal block transmit diversity system that has a delay arrangement that for each symbol, a time of representation of the symbol in the M space-time coded streams is different for each of the M space-time coded stream, each space-time coded symbol comprising a representation of a symbol of each of the M symbol substream and wherein each symbol of the M symbol substream is represented in all M space-time coded stream and a plurality of M transmit antenna (antenna 11 and 12 in figure 5) each adapted to transmit a respective one of the M space-time coded stream (in transmit delay diversity artificial delay spread is introduced in the channel by transmitting the same signal from two or more antenna with some delay between the transmissions from the different antenna, the delay between the antennas would typically be of the order of a symbol interval, paragraph 0093, lines 5-11) (as shown in figure 5, the signal transmitted from antenna 11 contains a representation of $d_1(t)$ and $d_2(t)$ and the signal transmitted form the antenna 12 contains a representation of $d_1(t)$ and $d_2(t)$, with the combination of delay diversity, the representation of each symbol in the transmitted symbol stream will be delayed with different symbol interval).

It is desirable to have the transmitter comprises a delay arrangement, arranged such that for each symbol, a time of representation of the symbol in the M space-time coded streams is different for each of the M space-time coded stream, each space-time coded symbol comprising a representation of a symbol of each of the M symbol

substream and wherein each symbol of the M symbol substream is represented in all M space-time coded stream and a plurality of M transmit antenna each adapted to transmit a respective one of the M space-time coded stream because it increase the diversity in the transmission and result in creating less interference and thus allowing more users in the system (paragraph 0100, lines 1-13). Therefore it would have been obvious to one ordinary skill in the art at the time of invention to combine the teaching of Lindskog et al. with the system of Hammons, Jr. et al. to improve the capacity of the communication system.

(2) Regarding claim 25:

Hammons Jr. et al. discloses the transmitter further comprising the demultiplexing and encoding functionality comprising a demultiplexer (spatial formatter 114 in figure 4) having M output (a – c in figure 4), and M encoder/modulators (inner code 116a to 116c and modulator 118a to 118c in figure 4) each producing a respective one of the M symbol substream (output from modulator 118), with each of the M encoder/modulators connected to receive a respective one of the demultiplexer outputs (signals for the spatial formatter 114 are separated for coding at inner code 116a, 116b, 116c, and so on, which provide signal that are modulated, respectively, by modulators 118a, 118b, 118c, column 8, lines 3-9).

(3) Regarding claim 26:

Hammons Jr. et al. discloses a transmitter wherein the demultiplexing and encoding functionality is adapted to produce the M symbol substreams from an input stream (the coding sequence employs an outer code 112 which provides signal to a

spatial formatter 114, signals for the spatial formatter 114 are separated for coding at inner code 116a, 116b, 116c, and so on, which provide signal that are modulated, respectively, by modulators 118a, 118b, 118c, column 8, lines 3-9).

(4) Regarding claim 37 and 38:

Lindskog et al. further discloses wherein each of the M space-time coded symbols is included in a respective one of M space-time coded streams at a different time from the inclusion of each other of the M space-time coded symbols in their respective space-time coded stream (in transmit delay diversity artificial delay spread is introduced in the channel by transmitting the same signal from two or more antenna with some delay between the transmissions from the different antenna, the delay between the antennas would typically be of the order of a symbol interval, paragraph 0093, lines 5-11) (as shown in figure 5, the signal transmitted from antenna 11 contains a representation of $d_1(t)$ and $d_2(t)$ and the signal transmitted form the antenna 12 contains a representation of $d_1(t)$ and $d_2(t)$, with the combination of delay diversity, the representation of each symbol in the transmitted symbol stream will be delayed with different symbol interval).

5. Claim 27 is rejected under 35 U.S.C. 103(a) as being unpatentable over Hammons, Jr. et al. (US 6,678,263 B1) in view of Lindskog et al. (US 2004/0013211 A1) as applied to claim 26 above, and further in view of Ylitalo et al. (US 7,139,324 B1).

(1) Regarding claim 27:

Hammons Jr. et al. and Lindskog et al. discloses all the subject matter as discuss in claim 26 and Lindskog et al. except wherein the space-time coding function comprises an orthogonal transform adapted to produce M orthogonal outputs each of which is a function of the M substreams and a delay arrangement comprising delay elements adapted to insert a respective different delay in M-1 of file M orthogonal outputs to produce the M space-time coded streams.

However, Ylitalo et al. discloses the space-time coding function comprises an orthogonal transform adapted to produce M orthogonal outputs (multiplier 12 encodes signal CH_1 with a signature code (OC) that is mutually orthogonal to the signature code that is encoded in the signal CH_2 by multiplier 14 in figure 26, column 28, lines 19-21) each of which is a function of the M substreams and a delay arrangement comprising a delay element adapted to insert a respective different delay in M-1 of the M orthogonal outputs to produce the M space-time coded streams (when M=2, the programmable delay element in figure 26 insert a delay to the signal 15, column 28, lines 44-50).

It is desirable to have the space-time coding function comprises an orthogonal transform adapted to produce M orthogonal outputs each of which is a function of the M substreams and a delay arrangement comprising delay elements adapted to insert a respective different delay in M-1 of file M orthogonal outputs to produce the M space-time coded streams because it achieve greater spectral efficiency at the base station while minimizing co-channel interference (column 3, lines 1-3). Therefore, it would have been obvious to one of ordinary skill in the art at the time of invention to employ the

teaching of Ylitalo et al. in the system of Hammons Jr. et al. and Lindskog et al. to improve the efficiency of the transmitter.

(2) Regarding claim 28:

Ylitalo et al. further discloses a programmable delay element to introduce a delay to the orthogonal output.

Ylitalo et al. fails to explicitly discloses the delay element introduce a delay of m-1 symbol period in the mth orthogonal output, where m=1 to M. It would have been obvious to one of ordinary skill in the art at the time of invention for the programmable delay line to adapted the delay element to insert a delay of M symbol period in each of the M substream and with the mth orthogonal output being delayed in said delay elements by m-1 symbol periods, since it has been held that discovering an optimum value of a result effective variable involves only routine skill in the art. Iii re Boesch, Eli f.2d 272, 205 USPQ 215.

(3) Regarding claim 29:

Hammons Jr. et al. and Lindskog et al. discloses all the subject matter as discuss in claim 24, Lindskog et al. further discloses delay elements adapted to insert a delay of M symbol periods in each of the M substreams (in transmit delay diversity artificial delay spread is introduced in the channel by transmitting the same signal from two or more antenna with some delay between the transmissions from the different antenna, the delay between the antennas would typically be of the order of a symbol interval, paragraph 0093, lines 5-11) except an orthogonal transform adapted to produce M

orthogonal outputs, with the mth orthogonal output being a function of the M substreams delayed in said delay elements by m-1 symbol periods,

However, Ylitalo et al. discloses a transmitter wherein the space-time coding function comprises:

an orthogonal transform adapted to produce M orthogonal outputs (multiplier 12 encodes signal CH_1 with a signature code (OC) that is mutually orthogonal to the signature code that is encoded in the signal CH_2 by multiplier 14 in figure 26, column 28, lines 19-21) with the mth orthogonal output being a function of the M substreams delayed in said delay elements.

It is desirable for a an orthogonal transform adapted to produce M orthogonal outputs, with the mth orthogonal output being a function of the M substreams delayed in said delay elements by m-1 symbol periods because it achieve greater spectral efficiency at the base station while minimizing co-channel interference (column 3, lines 1-3). Therefore, it would have been obvious to one of ordinary skill in the art at the time of invention to employ the teaching of Ylitalo et al. in the system of Hammons Jr. et al. and Lindskog et al. to improve the efficiency of the transmitter.

(4) Regarding claim 33:

Hammons Jr. et al. and Lindskog et al. discloses all the subject matter as discuss in claim 32 except executing an orthogonal transform to produce M orthogonal outputs each of which is a function of the M substream; and implementing the delay function comprising delaying the M orthogonal outputs to produce M delayed orthogonal outputs

such that each of the M delayed orthogonal outputs is a function of a given element of each of the M substreams at a different time.

However, Ylitalo et al discloses executing an orthogonal transform to produce M orthogonal outputs each of which is a function of the M substreams (multiplier 12 encodes signal CH_1 with a signature code (OC) that is mutually orthogonal to the signature code that is encoded in the signal CH_2 by multiplier 14 in figure 26, column 28, lines 19-21) and; implementing the delay function comprising delaying the M orthogonal outputs to produce M delayed orthogonal outputs such that each of the M delayed orthogonal outputs is a function of a given element of each of the M substreams at a different time (the programmable delay element in figure 26 insert a delay to the signal 15 and each of the signal 12 and signal 15 is a function of S1 and S2, column 28, lines 44-50).

It is desirable to executing an orthogonal transform to produce M orthogonal outputs each of which is a function of the M substream; and implementing the delay function comprising delaying the M orthogonal outputs to produce M delayed orthogonal outputs such that each of the M delayed orthogonal outputs is a function of a given element of each of the M substreams at a different time because it achieve greater spectral efficiency at the base station while minimizing co-channel interference (column 3, lines 1-3). Therefore, it would have been obvious to one of ordinary skill in the art at the time of invention to employ the teaching of Ylitalo et al. in the system of Hammons Jr. et al. and Lindskog et al. to improve the efficiency of the transmitter.

(5) Regarding claim 34:

Ylitalo et al. further discloses a programmable delay element to introduce a delay to the orthogonal output.

Ylitalo et al. fails to explicitly discloses the delay element introduce a delay of m-1 symbol period in the mth orthogonal output, where m=1 to M. It would have been obvious to one of ordinary skill in the art at the time of invention for the programmable delay line to adapted the delay element to insert a delay of M symbol period in each of the M substream and with the mth orthogonal output being delayed in said delay elements by m-1 symbol periods, since it has been held that discovering an optimum value of a result effective variable involves only routine skill in the art. Iii re Boesch, Eli f.2d 272, 205 USPQ 215.

(6) Regarding claim 35:

Hammons Jr. et al. and Lindskog et al. discloses all the subject matter as discussed in claim 32, Lindskog et al. further discloses delay elements adapted to insert a delay of M symbol periods in each of the M substreams (in transmit delay diversity artificial delay spread is introduced in the channel by transmitting the same signal from two or more antenna with some delay between the transmissions from the different antenna, the delay between the antennas would typically be of the order of a symbol interval, paragraph 0093, lines 5-11) except wherein performing the space-time coding function comprises executing an orthogonal transform adapted to produce M orthogonal outputs, with the mth orthogonal output being a function of the M substreams delayed m-1 symbol periods.

However, Ylitalo et al. discloses a transmitter wherein the space-time coding function comprises an orthogonal transform adapted to produce M orthogonal outputs (multiplier 12 encodes signal CH_1 with a signature code (OC) that is mutually orthogonal to the signature code that is encoded in the signal CH_2 by multiplier 14 in figure 26; column 28, lines 19-21) with the mth orthogonal output being a function of the M substreams delayed in said delay elements (delay element in figure 26).

It is desirable to performing the space-time coding function comprises executing an orthogonal transform adapted to produce M orthogonal outputs, with the mth orthogonal output being a function of the M substreams delayed m-1 symbol periods because it minimizing co-channel interference (column 3, lines 1-3). Therefore, it would have been obvious to one of ordinary skill in the art at the time of invention to employ the teaching of Ylitalo et al. in the system of Hammons Jr. et al. and Lindskog et al. to improve the efficiency of the transmitter.

6. Claims 30 and 36 are rejected under 35 U.S.C. 103(a) as being unpatentable over Hammons, Jr. et al. (US 6,678,263 B1) in view of Lindskog et al. (US 2004/0013211 A1) and Ylitalo et al. (US 7,139,324 B1) as applied to claims 29 and 33 above, and further in view of Yamao et al. (US 6,351,498 B1).

Hammons Jr. et al., Lindskog et al. and Ylitalo et al. disclose all the subject matter as discuss in claims 29 and 33 except wherein the orthogonal transform comprises M M-ary mapping functions, each adapted to produce a respective sequence

of M-ary symbols with the M-ary symbol of the mth M-ary mapping function being a function of the M substreams delayed in said delay elements by m-1 bit periods.

However, Yamao et al. discloses a orthogonal transform comprises M M-ary mapping function (M-ary encoder 1-1 to 1-N in figure 8), each adapted to produce a respective sequence of M-ary symbols with the M-ary symbol of the mth M-ary mapping function being a function of the M-substreams delayed in said elements (at the M-ary encoders 1-1 to 1-N, M-ary orthogonal codes corresponding to the respective inputs are generated, when the ordinary orthogonal codes with L=2 are used, the 2 bits data entered into the M-ary encoder is converted into one of the 4 bits length orthogonal code, column 6, lines 7-14).

It is desirable for wherein the orthogonal transform comprises M M-ary mapping functions, each adapted to produce a respective sequence of M-ary symbols with the M-ary symbol of the mth M-ary mapping function being a function of the M substreams delayed in said delay elements by m-1 bit periods because it is capable of reducing errors due to fading while maintaining the characteristics of the M-ary modulation and demodulation scheme that is robust against interference (column 3, lines 12-13). Therefore, it would have been obvious to one of ordinary skill in the art at the time of invention to employ the teaching of Yamao et al. in the system of Hammons Jr. et al., Lindskog et al. and Ylitalo et al. to improve the performance of the system.

Conclusion

7. The prior art made of record and not relied upon is considered pertinent to applicant's disclosure. Naguib et al. (US 7,010,029 B1) discloses a equalization of transmit diversity space-time coded signals. Wallace et al. (US 6,473,467 B1) discloses a method and apparatus for measuring reporting channel state information in a high efficiency, high performance communications system.

Any inquiry concerning this communication or earlier communications from the examiner should be directed to Siu M. Lee whose telephone number is (571) 270-1083. The examiner can normally be reached on Mon-Fri, 7:30-4:00 with every other Friday off.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Chieh 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.

Siu M Lee
Examiner
Art Unit 2611
8/20/2007

CHIEH M. FAN
SUPERVISORY PATENT EXAMINER

Notice of References Cited	Application/Control No. 10/399,859	Applicant(s)/Patent Under Reexamination TONG ET AL.	
	Examiner Siu M. Lee	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-6,678,263 B1	01-2004	Hammons et al.	370/342
*	B	US-2004/0013211 A1	01-2004	Lindskog et al.	375/347
*	C	US-7,139,324 B1	11-2006	Ylitalo et al.	375/267
*	D	US-6,351,498 B1	02-2002	Yamao et al.	375/260
*	E	US-7,010,029 B1	03-2006	Naguib et al.	375/229
*	F	US-6,473,467 B1	10-2002	Wallace et al.	375/267
	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.

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BIB DATA SHEET

CONFIRMATION NO. 9275

SERIAL NUMBER	FILING or 371(c) DATE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.
10/399,859	08/29/2003 RULE	370	2611	14316NP

APPLICANTS

Wen Tong, Ottawa, CANADA;
Mikhail Bakulin, Klrova, RUSSIAN FEDERATION;
Vitaly B. Kreyndelin, Moskya, RUSSIAN FEDERATION;
Alexander M. Shloma, Zhukovsky, RUSSIAN FEDERATION;
Yuriy Shinakov, Moscow, RUSSIAN FEDERATION;

**** CONTINUING DATA ***************************

This application is a 371 of PCT/RU00/00426 10/27/2000 ML 8/20/2007

**** FOREIGN APPLICATIONS ***************************

**** IF REQUIRED, FOREIGN FILING LICENSE GRANTED **** -NONE- ML 8/20/2007

Foreign Priority claimed ☐ Yes ☑ No 35 USC 119(a-d) conditions met ☐ Yes ☑ No Verified and Acknowledged /SIU M LEE/ Examiner's Signature	☐ Met after Allowance Initials	STATE OR COUNTRY	SHEETS DRAWINGS	TOTAL CLAIMS	INDEPENDENT CLAIMS
		CANADA	8	23	3

ADDRESS

Ralph A. Dowell of DOWELL & DOWELL P.C.
2111 Eisenhower Ave
Suite 406
Alexandria, VA 22314
UNITED STATES

TITLE

Combination of space-time coding and spatial multiplexing, and the use of orthogonal transformation in space-time coding

FILING FEE RECEIVED	FEES: Authority has been given in Paper	☐ All Fees
1084	No._____ to charge/credit DEPOSIT ACCOUNT	☐ 1.16 Fees (Filing)
	No._____ for following:	☐ 1.17 Fees (Processing Ext. of time)
		☐ 1.18 Fees (Issue)
		☐ Other _____
		☐ Credit

Index of Claims	Application/Control No.	Applicant(s)/Patent Under Reexamination
	10399859	TONG ET AL.
	Examiner	Art Unit
	Lee, Siu M	2611

✓	Rejected	-	Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

CLAIM		DATE								
Final	Original	03/14/2007	08/20/2007							
	1	-	-							
	2	-	-							
	3	-	-							
	4	-	-							
	5	-	-							
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	22	-	-							
	23	-	-							
	24	✓	✓							
	25	✓	✓							
	26	✓	✓							
	27	✓	✓							
	28	✓	✓							
	29	✓	✓							
	30	✓	✓							
	31	✓	-							
	32	✓	✓							
	33	✓	✓							
	34	✓	✓							
	35	✓	✓							
	36	✓	✓							

Index of Claims	Application/Control No.	Applicant(s)/Patent Under Reexamination
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☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

CLAIM		DATE							
Final	Original	03/14/2007	08/20/2007						
	37		✓						
	38		✓						

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	10399859	TONG ET AL.
	Examiner	Art Unit
	Lee, Siu M	2611

SEARCHED			
Class	Subclass	Date	Examiner
375	267, 260, 295, 299	3/13/2007	Siu M. Lee
375	267, 260, 295, 299	8/20/2007	Siu M. Lee

SEARCH NOTES		
Search Notes	Date	Examiner
EAST	3/13/2007	Siu M. Lee
Discuss application with Chieh Fan	3/14/2007	Siu M. Lee
EAST	8/20/2007	Siu M. Lee
Disciss application with Chieh Fan	8/20/2007	Siu M. Lee

INTERFERENCE SEARCH			
Class	Subclass	Date	Examiner

PTO/SB/21 (09-04)
Approved for use through 07/31/2006. OMB 0651-0031
U.S. Patent and Trademark Office: U.S. DEPARTMENT OF COMMERCE



IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Appl. No.	: 10/399,859	Confirmation No.	9275
Applicant	: Wen Tong, et al.		
Filed	: April 23, 2003		
TC/A.U.	: 2611		
Examiner	: Siu M. Lee		
Docket No.	: 14316NP		
Customer No.	: 000293		

Commissioner for Patents
Alexandria, VA 22313-1450
U.S.A.

Dear Sir:

In response to the Office action of September 6, 2007, please amend this application as follows:

Remarks/Arguments begin on page 2 of this paper.

REMARKS/ARGUMENTS

Claim Objections

The Examiner objects to claim 24, arguing that it was unclear what the "each symbol" is referring to. It is respectfully submitted that it is clear that it is "each symbol of the M symbol substreams" that is being referred to. This is because what is being discussed is the representation of that symbol. Earlier in the claim, the claim recites "..wherein each symbol of the M symbol substreams is represented in all M space-time coded stream". The section of text referred to by the Examiner is referring to that representation, namely representation of the symbol in the M space-time coded stream. As such, it is respectfully submitted that no amendment is necessary.

Claim Rejections 35 U.S.C. 103

The Examiner rejects claims 24, 25, 26, 37 and 38 are rejected under 35 U.S.C. 103(a) as being unpatentable over Hammons, Jr. et al. (US 6,678,263 B1, hereinafter "Hammons") in view of Lindskog et al. (US 2004/0013211 A1, hereinafter "Lindskog"). In response, Applicant respectfully traverses the Examiner's rejection for reasons detailed below.

The law on obviousness under 35 U.S.C. 103 was recently addressed in ***KSR Int'l v. Teleflex, Inc.***, *No. 04-1350, slip op. at 14 (U.S., Apr. 30, 2007)*. Following this, examination guidelines were released on October 10, 2007 in regards to determining obviousness under 35 U.S.C. 103. According to these guidelines, the framework for the objective analysis for determining obviousness under 35 U.S.C. 103 is stated in ***Graham v. John Deere Co.*** *383 U.S. 1,148 USPQ 459 (1966)*. Obviousness is a question of law based on underlying factual inquiries. The factual inquiries enunciated by the Court are as follows:

(1) Determining the scope and content of the prior art;

(2) Ascertaining the differences between the claimed invention and the prior art; and

(3) Resolving the level of ordinary skill in the pertinent art.

The Graham factors, including secondary considerations when present, are the controlling inquiries in any obviousness analysis. Once the findings of fact are articulated, Office personnel must provide an explanation to support an obviousness rejection under 35 U.S.C. 103. According to KSR, for the Patent Office to properly combine references in support of an obviousness rejection, the Patent Office must identify a reason why a person of ordinary skill in the art would have sought to combine the respective teachings of the applied references.

Applicant's analysis below demonstrates that the Examiner has failed to properly conform to the aforementioned guidelines for a finding of obviousness under 35 U.S.C. 103.

Determining the Scope and Content of the Prior Art, Ascertaining Differences Between the Claimed Invention and the Prior Art

Hammons

The Examiner summarizes the relevance of Hammons on page 3 of the detailed action. With respect, some of the Examiner's comments respecting Hammons are inaccurate. To begin, the Examiner argues Hammons discloses "a space-time coding function adapted to produce M space-time coded symbols (output of modulator 118 in Figure 4) per input set of M symbols (output of spatial formatter at 114 in Figure 4)". This would obviously imply that the Examiner considers that inner codes 116a through 116c are performing the space-time coding function, since the space-time coding function produces M space-time coded symbols **per input set of M symbols**, and the examiner is equating the input symbols with the input to the inner codes. With respect, there is no reference anywhere in Hammons that these inner codes are performing a space-time coding operation. Rather, each inner code is performing a simple one dimensional code on its respective input.

Indeed, Hammons refers to the entire entity 110 (mis-labelled 118 in Figure 4) as implementing a "full-diversity space-time coding sequence (see col 8 lines 3 to 27). This includes an outer code 112, spatial formatter 114 and the inner codes 116a through 116c. There is no suggestion in Hammons that the space-time coding operation takes M input symbols and produces M space-

time coded symbols. This implementation produces some unspecified number of output symbols (determined from the number of inner codes = number of antennas) from a continuous input stream. There is no suggestion of what the outer code 112 is however, it appears this may be the same as the mobile channel encoder referred to elsewhere in the reference.

With respect, the above discussion establishes an error how the Examiner has determined the scope and content of the prior art. The result of this is a corresponding error in the difference between the claimed invention and the prior art.

The Examiner goes on to say "each input set of M symbols comprising one symbol per symbol substream, each of the M space-time coded symbols of the M symbol substream is represented in a respective of M space-time coded streams". The Examiner argues that "in Figure 4, spatial formatter 114 separate the incoming signal into plurality of input signals to the inner coder 116a – 116c, which are coded by the inner code 116a – 116c and further modulated by the modulators 118aa – 118c, therefore, each input set of M symbols comprising one symbol per symbol substream, each of the M space-time coded symbol of the M symbol substream is represented in a respective of M space-time coded streams, column 8, lines 7-12". The problem with this is the same as that discussed above. The Examiner is still referring to the "input set of M symbols" as being the output of the spatial formatter 114. There is no space-time coding between the spatial formatter 114 and the output of the inner codes. Rather, that is what is simply being executed is a set of M codes. Of course, the N outputs of the spatial formatter 114 are each represented in one of the output streams since each output of the spatial formatter is coded by a respective inner code. However, again it is to be emphasized that that is not a space-time coding operation. Rather, the combination of spatial formatter 114 and inner codes 116 is a space-time coding operation (referred to as such in Hammons), but there is nothing in the reference that suggests that this space-time coding operation operates in the manner recited in claim 24. This constitutes another error in the determination of the scope and content of the prior art and a corresponding difference between the cited references and Applicants claim 24.

Lindskog

The Examiner argues that Lindskog teaches a "delay arrangement" that for each symbol, produces a time of representation of the symbol in the M space-time coded streams that is different for each of the M space-time coded stream. To begin, it is respectfully submitted that what is going on in Lindskog is not a delay arrangement. Rather there is a "time reversal" operation that is implemented – see Figure 5 and associated description. The operation of Figure 5 operates on an input stream d1,d2,d3,d4 to produce two antenna outputs as follows (also see Figure 7):

d1 d2 d3 d4 → d1 d2 d3 d4

-d2* d1* -d4* d3*

With respect, time reversal (the flipping of the order of symbols on each antenna stream) is not the same as a delay arrangement. Another very important point to realize is that two input symbols d1,d2 produce four space-time coded symbols d1,d2,-d2*,d1*. In other words, M input symbols produce 2M space-time coded symbols. Thus the rate of the code taught in Lindskog et al. is one half. The next thing to realize is that each space-time coded symbol (d1,d2,-d2*,d1*) does not in fact include a representation of each symbol of the M symbol substreams as suggested by the Examiner, and as recited in Applicant's claim 24. Rather, each space-time coded symbol includes a representation only of a single input symbol. Clearly space-time coded symbol d1 contains a representation of d1 but not d2; d2 contains a representation of d2 but not d1; -d2* contains a representation of d2 but not d1, and d1* contains a representation of d1 but not d2. This constitutes another error in the determination of the scope and content of the prior art and a corresponding difference between the cited references and Applicants claim 24.

In summary, for the reasons noted above, it is respectfully submitted that the Examiner has failed to properly determine the scope and content of the prior art as required by the factual inquiries summarized above. Furthermore, there are differences between the prior art and Applicants claim 24 that have not been given proper weight.

Resolving the Level of Ordinary Skill in the Pertinent Art

The Examiner has not addressed this point in the obviousness rejection. This step is required as one of the three factual inquiries.

Explanation to Support an Obviousness Rejection

As noted above, for the Patent Office to properly combine references in support of an obviousness rejection, the Patent Office must identify a reason why a person of ordinary skill in the art would have sought to combine the respective teachings of the applied references. The examination guidelines indicate that "The key to supporting any rejection under 35 U.S.C. 103 is the clear articulation of the reason(s) why the claimed invention would have been obvious." The Court quoting In re Kahn, 441 F.3d 977, 988, 78 USPQ2d 1329, 1336 (Fed. Cir. 2006), stated that " '[R]ejections on obviousness cannot be sustained by mere conclusory statements; instead, there must be some articulated reasoning with some rational underpinning to support the legal conclusion of obviousness.''' Applicant appreciates that the Examiner has articulated a reason why the claimed invention would have been obvious. However, for reasons detailed below, the Examiner's articulated reason can not be regarded as being valid.

The Examiner argues that

> "it is desirable to have the transmitter comprises a delay arrangement, arranged such that for each symbol, a time of representation of the symbol in the M space-time coded streams is different for each of the M space-time coded stream, each space-time coded symbol comprising a representation of a symbol of each of the M symbol substream and wherein each symbol of the M symbol substream is represented in all M space-time coded stream and a plurality of M transmit antenna each adapted to transmit a respective one of the M space-time coded stream because it increase the diversity in the transmission and result in creating less interference and thus allowing more users in the system (paragraph 0100, lines 1-13). Therefore it would have been obvious to one ordinary skill in the art at the time of invention to combine the teaching of Lindskog et al. with the system of Hammons, Jr., et al. to improve the capacity of the communication system".

To begin, where the references relied upon by the Examiner do not teach all of the limitations, it is incumbent upon the Examiner to provide a reason why a person skilled in the art would nonetheless find the claimed invention obvious. As outlined above, there are various elements to the claimed invention that are not taught in either of the references and the Examiner has failed to address this. The Examiner refers to paragraph 100 of Lindskog. That paragraph is referring to the combination of time-reversal space-time block coding alone and transmit delay diversity which increases the diversity in the transmission. Note that "transmit delay diversity" in Lindskog refers to the re-transmission of the same information again at a later time on a different antenna as described above. This result in halving of a throughput of the system.

The Examiner not shown how the claimed combination would actually improve the system of Hammons as alleged. Hammons has a particular solution for dealing with multi-path fading that combines an outer code, spatial formatter, and inner code. What would be the result of applying a further, rate ½ Alamouti-style code in the context of Hammons? As detailed above, the result would not be Applicants claim 24. But the Examiner has not established that it would be anything of use at all. The Examiner has made the unsubstantiated statement that it would result in an increase in diversity, reduction in interference and more users.

It is further submitted that even if the Examiner were to successfully show motivation for combining a delay aspect with the teachings of Hammons, Jr., et al., it is respectfully submitted that this still would not lead a person skilled in the art to the particular system claimed in claim 24.

Regarding claim 25, the Examiner is referring to the demultiplexer function recited in that claim as being synonymous with the spatial formatter. Of course, if this is done, then Hammons would have no space-time coding function whatsoever since the demutiplexer simply separates the input signal into a set of output streams. This is a demultiplexing operation, not a space-time coding operation.

Regarding claims 37 and 38, as discussed previously, Lindskog produces two M space-time coded symbols from M input symbols. The subject matter of claims 37 and 38 relate the

inclusion of each of M space-time coded symbols in the output streams, something completely different from that taught in Lindskog.

The Examiner is respectfully requested to withdraw the rejection of the claims 24, 25, 26, 37 and 38.

The Examiner has rejected claim 27 under 35 U.S.C. 103(a) as being unpatentable over Hammons in view of Lindskog as applied to claim 26 above, and further in view of Ylitalo et al. (US 7,139,324 B1, hereinafter Ylitalo).

Claim 27 requires an orthogonal transform that produces M orthogonal outputs each of which is a function of the M substreams. The Examiner refers to Figure 26 of Ylitalo. Shown is yet another example of a system with half the throughput of applicants system. In particular, the inputs to the two multipliers 12,14 are s1,-s2*, and s2,s1* respectively. Furthermore, the signals produced by the arrangement of Figure 26 are transmitted from a multi-beam antenna such as shown in Figure 23. Specifically, signals 12 and 15 of Figure 26 are transmitted on beam D2 and D5 of Figure 23 respectively. The receiver can separate the signal received via direct path from beam D5 from the signal received via an indirect path from beam D2 as long as the codes remain orthogonal. Thus, the point of the orthogonal codes in Ylitalo is to allow separation of components sent on separate antenna beams in the receiver. The Examiner has asserted that the combination of Ylitalo is motivated because "it achieves greater spectral efficiency at the base station while minimizing co-channel interference". With respect, the Examiner has not established how this result would be achieved by combining Ylitalo with Hammons and Lindskog. It is not at all apparent that this would in fact be the case.

Similar comments apply to the remaining claims.

The Examiner is respectfully requested to withdraw all of the rejections of the claims under 35 U.S.C. 103, and to allow the application.

In view of the foregoing, early favorable consideration of this application is earnestly solicited.

Respectfully submitted,

WEN TONG, ET AL.

By _____

Ralph A. Dowell
Reg. No. 26,868
Tel.: (703) 415-2555

Date: February 6, 2008

RAB:rld

FEB 06 2008
PATENT & TRADEMARK OFFICE

1Fw 2611

COMBINED AMENDMENT & PETITION FOR EXTENSION OF TIME UNDER 37 CFR 1.136(a) (Large Entity)	Docket No. 14316NP/jas

In Re Application Of: **TONG, Wen et al.**

Application No.	Filing Date	Examiner	Customer No.	Group Art Unit	Confirmation No.
10/399,859	August 27, 2003	LEE, Siu M.	07380	2611	9275

Invention: **COMBINATION OF SPACE-TIME CODING AND SPATIAL MULTIPLEXING, AND THE USE OF ORTHOGONAL TRANSFORMATION IN SPACE-TIME CODING**

COMMISSIONER FOR PATENTS:

This is a combined amendment and petition under the provisions of 37 CFR 1.136(a) to extend the period for filing a response to the Office Action of **September 6, 2007** (*Date*) in the above-identified application.

The requested extension is as follows (check time period desired):

☐ One month ☒ Two months ☐ Three months ☐ Four months ☐ Five months

from: **December 6, 2007** (*Date*) until: **February 6, 2008** (*Date*)

The fee for the amendment and extension of time has been calculated as shown below:

CLAIMS AS AMENDED

	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST # PREV. PAID FOR		NUMBER EXTRA CLAIMS PRESENT	RATE	ADDITIONAL FEE
TOTAL CLAIMS	13	-	23	=	0	x $50.00	$0.00
INDEP. CLAIMS	2	-	3	=	0	x $200.00	$0.00
						FEE FOR AMENDMENT	$0.00
						FEE FOR EXTENSION OF TIME	$460.00
						TOTAL FEE FOR AMENDMENT AND EXTENSION OF TIME	**$460.00**

02/07/2008 CNGUYEN2 00000059 10399859
01 FC:1252 460.00 OP

P28LARGE/REV05

COMBINED AMENDMENT & PETITION FOR EXTENSION OF TIME UNDER 37 CFR 1.136(a) (Large Entity)	Docket No. 14316NP/jas

The fee for the amendment and extension of time is to be paid as follows:

☐ A check in the amount of for the amendment and extension of time is enclosed.

☒ Please charge Deposit Account No. **19-2550** in the amount of **$460.00**

☒ The Director is hereby authorized to charge payment of the following fees associated with this communication or credit any overpayment to Deposit Account No. **19-2550**

- ☒ Any additional filing fees required under 37 C.F.R. 1.16.
- ☒ Any patent application processing fees under 37 CFR 1.17.

☒ If an additional extension of time is required, please consider this a petition therefor and charge any additional fees which may be required to Deposit Account No. **19-2550** .

☐ Payment by credit card. Form PTO-2038 is attached.

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.

Signature

Dated: **February 6, 2008**

Ralph A. Dowell
Reg. No. 26,868

Tel. No. (703) 415-2555

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 the "Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450" [37 CFR 1.8(a)] on

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(Date)

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P28LARGE/REV05

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/399,859	08/29/2003	Wen Tong	14316NP	9275

293 7590 05/23/2008

Ralph A. Dowell of DOWELL & DOWELL P.C.
2111 Eisenhower Ave
Suite 406
Alexandria, VA 22314

EXAMINER	
LEE, SIU M	
ART UNIT	PAPER NUMBER
2611	

MAIL DATE	DELIVERY MODE
05/23/2008	PAPER

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Office Action Summary	Application No.	Applicant(s)	
	10/399,859	TONG ET AL.	
	Examiner	Art Unit	
	SIU M. LEE	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 *06 February 2008*.

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) *24-30 and 32-38* 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) *24-30 and 32-38* is/are rejected.

7)☐ Claim(s) _____ 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 *23 April 2003* 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/SB/08) Paper No(s)/Mail Date _____.
4) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____ .
5) ☐ Notice of Informal Patent Application
6) ☐ Other: _____.

DETAILED ACTION

Response to Arguments

1. Applicant's arguments with respect to claims 24-30 and 32-38 have been considered but are moot in view of the new ground(s) of rejection.

Claim Objections

2. Claims 25-28 are objected to because of the following informalities:

Claim 25 recites "A transmitter according to claim 24 further comprising the demultiplexing and encoding functionality". There is no antecedent basis for the demultiplexing and encoding functionality".

Appropriate correction is required.

Claim Rejections - 35 USC § 102

3. The following is a quotation of the appropriate paragraphs of 35 U.S.C. 102 that form the basis for the rejections under this section made in this Office action:

> A person shall be entitled to a patent unless –
>
> (e) the invention was described in (1) an application for patent, published under section 122(b), by another filed in the United States before the invention by the applicant for patent or (2) a patent granted on an application for patent by another filed in the United States before the invention by the applicant for patent, except that an international application filed under the treaty defined in section 351(a) shall have the effects for purposes of this subsection of an application filed in the United States only if the international application designated the United States and was published under Article 21(2) of such treaty in the English language.

4. Claims 24, 37 are rejected under 35 U.S.C. 102(e) as being anticipated by Lindskog et al. (US 2004/0013211 A1).

5. (1) Regarding claim 24:

Lindskog et al. disclose a transmitter comprising:

a space-time coding function adapted to produce M space-time coded symbols per input set of M symbols (the space time encoder (time reversal and complex conjugate as shown in figure 5 that generates 2 space–time coded symbol per an input set of symbol of $d_1(t)$ and $d_2(t)$ as shown in figure 5) ,

each input set of M symbols comprising one symbol per symbol substream (each symbol stream comprise one symbol per symbol stream ($d_1(t)$ and $d_2(t)$ as shown in figure 5),

each of the M space-time coded symbols being included in a respective one of M space-time coded streams (each space time coded symbol ($d_1(t)$ $-d_2^*(N-t)$ and $d_2(t)$ $d_1^*(N-t)$) is being included in a respective one of M space-time coded stream for transmitting from the respective antenna as shown in figure 7),

wherein each symbol of the M symbol substreams is represented in all M space-time coded streams (each of the space time coded symbol comprises a representation of the $d_1(t)$ and $d_2(t)$ as shown in figure 7),

wherein the transmitter comprises a delay arrangement, arranged such that for each symbol a time of representation of the symbol in the M space-time coded streams is different for each of the M space-time coded streams (paragraph 0093 states that in transmit delay diversity artificial delay spread is introduced in the channel by

transmitting the same signal from two or more antenna with some delay between the transmissions from the different antenna, the two space time coded symbols shown in figure 7 discloses that $d_1(t)$ is align with $d_2(t)$ and in the second block in the frame, $-d_2^*(N-t)$ is align with $d_1^*(N-t)$ (paragraph 0075), each space-time coded symbol comprising a representation of a symbol of each of the M symbol substreams (the space time coded symbol $d_1(t)$ $-d_2^*(N-t)$ and $d_2(t)$ $d_1^*(N-t)$ each comprises a representation of $d_1(t)$ and $d_2(t)$ as shown in figure 7);

a plurality M of transmit antennas each adapted to transmit a respective one of the M space-time coded streams (antenna 11 for transmitting $d_1(t)$ $-d_2^*(N-t)$ and antenna 12 for transmitting $d_2(t)$ $d_1^*(N-t)$ as shown in figure 5).

(2) Regarding claim 37:

Lindskog et al. further discloses wherein each of the M space-time coded symbols is included in a respective one of M space-time coded streams at a different time from the inclusion of each other of the M space-time coded symbols in their respective space-time coded stream (in transmit delay diversity artificial delay spread is introduced in the channel by transmitting the same signal from two or more antenna with some delay between the transmissions from the different antenna, the delay between the antennas would typically be of the order of a symbol interval, paragraph 0093, lines 5-11) (as shown in figure 5, the signal transmitted from antenna 11 contains a representation of $d_1(t)$ and $d_2(t)$ and the signal transmitted form the antenna 12 contains a representation of $d_1(t)$ and $d_2(t)$, with the combination of delay diversity, the

representation of each symbol in the transmitted symbol stream will be delayed with different symbol interval).

Claim Rejections - 35 USC § 103

6. 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.

7. Claim 25, 26, 32, 38 are rejected under 35 U.S.C. 103(a) as being unpatentable over Lindskog et al. (US 2004/0013211 A1) in view of Calderbank et al. (US 7,215,718 B1).

(1) Regarding claim 25:

Lindskog discloses all the subject matter in claim 24 and disclose the splitting of d(t) to $d_1(t)$ and $d_2(t)$ but fail to explicitly a demultiplexer and encoding functionality comprising a multiplexer having M outputs, and M encoder/modulators each producing a respective one of the M symbol substream, with each of the M encoder/modulators connected to receive a respective one of the demultiplexer outputs.

Calderbank disclose demultiplexer (demultiplexer 40 in figure 2) and encoding functionality (channel coder 41 and 51 in figure 2) comprising a demultiplexer having M output (2 outputs form the demultiplexer 40 as shown in figure 2), and M encoder/modulators (channel coder 40 and 51 in figure 2) each producing a respective

one of the M symbol substream, with each of the M encoder/modulators connected to receive a respective one of the demultiplexer outputs (each of the channel coder 41 and 51 receives an output from the demultiplexer 40 as shown in figure 2).

It is desirable to have a demultiplexer and encoding functionality comprising a multiplexer having M outputs, and M encoder/modulators each producing a respective one of the M symbol substream, with each of the M encoder/modulators connected to receive a respective one of the demultiplexer outputs because it increase the data rate of the system (column 4, lines 6-7). Therefore, it would have been obvious to one of ordinary skill in the art at the time of invention to combine the teaching of Calderbank with the system of Lindskog to improve the efficiency of the system.

(2) Regarding claim 26:

Calderbank further discloses in figure 2 that the demultiplexer and encoding functionality is adapted to produce the M symbol substream from an input stream (figure 2, info source).

(3) Regarding claim 32:

Lindskog et al. disclose a transmitter comprising:

a space-time coding function adapted to produce M space-time coded symbols per input set of M symbols (the space time encoder (time reversal and complex conjugate as shown in figure 5 that generates 2 space–time coded symbol per an input set of symbol of $d_1(t)$ and $d_2(t)$ as shown in figure 5) ,

each input set of M symbols comprising one symbol per symbol substream (each symbol stream comprise one symbol per symbol stream ($d_1(t)$ and $d_2(t)$ as shown in figure 5),

each of the M space-time coded symbols being included in a respective one of M space-time coded streams (each space time coded symbol ($d_1(t)$ $-d_2^*(N-t)$ and $d_2(t)$ $d_1^*(N-t)$) is being included in a respective one of M space-time coded stream for transmitting from the respective antenna as shown in figure 7),

wherein each symbol of the M symbol substreams is represented in all M space-time coded streams (each of the space time coded symbol comprises a representation of the $d_1(t)$ and $d_2(t)$ as shown in figure 7),

wherein the transmitter comprises a delay arrangement, arranged such that for each symbol a time of representation of the symbol in the M space-time coded streams is different for each of the M space-time coded streams (paragraph 0093 states that in transmit delay diversity artificial delay spread is introduced in the channel by transmitting the same signal from two or more antenna with some delay between the transmissions from the different antenna, the two space time coded symbols shown in figure 7 discloses that $d_1(t)$ is align with $d_2(t)$ and in the second block in the frame, $-d_2^*(N-t)$ is align with $d_1^*(N-t)$ (paragraph 0075), each space-time coded symbol comprising a representation of a symbol of each of the M symbol substreams (the space time coded symbol $d_1(t)$ $-d_2^*(N-t)$ and $d_2(t)$ $d_1^*(N-t)$ each comprises a representation of $d_1(t)$ and $d_2(t)$ as shown in figure 7);

a plurality M of transmit antennas each adapted to transmit a respective one of the M space-time coded streams (antenna 11 for transmitting $d_1(t)$ $-d_2^*(N-t)$ and antenna 12 for transmitting $d_2(t)$ $d_1^*(N-t)$ as shown in figure 5).

Lindskog fails to disclose demultiplexing an input symbol into M symbol substream; and performing coding and modulation on each of said M symbol substreams.

However, Calderbank disclose demultiplexer (demultiplexer 40 in figure 2) an input symbol (info source in figure 2) into 2 substreams and forward each substream to the channel coders (channel coder 41 and 51 in figure 2)

It is desirable to have a demultiplexer and encoding functionality comprising a multiplexer having M outputs, and M encoder/modulators each producing a respective one of the M symbol substream, with each of the M encoder/modulators connected to receive a respective one of the demultiplexer outputs because it increase the data rate of the system (column 4, lines 6-7). Therefore, it would have been obvious to one of ordinary skill in the art at the time of invention to combine the teaching of Calderbank with the system of Lindskog to improve the efficiency of the system.

(4) Regarding claim 38:

Lindskog et al. further discloses wherein each of the M space-time coded symbols is included in a respective one of M space-time coded streams at a different time from the inclusion of each other of the M space-time coded symbols in their respective space-time coded stream (in transmit delay diversity artificial delay spread is introduced in the channel by transmitting the same signal from two or more antenna

with some delay between the transmissions from the different antenna, the delay between the antennas would typically be of the order of a symbol interval, paragraph 0093, lines 5-11) (as shown in figure 5, the signal transmitted from antenna 11 contains a representation of $d_1(t)$ and $d_2(t)$ and the signal transmitted form the antenna 12 contains a representation of $d_1(t)$ and $d_2(t)$, with the combination of delay diversity, the representation of each symbol in the transmitted symbol stream will be delayed with different symbol interval).

8. Claim 29 is rejected under 35 U.S.C. 103(a) as being unpatentable over Lindskog et al. (US 2004/0013211 A1) in view of Ylitalo et al. (US 7,139,324 B1).

Lindskog et al. discloses all the subject matter as discuss in claim 24, Lindskog et al. further discloses delay elements adapted to insert a delay of M symbol periods in each of the M substreams (in transmit delay diversity artificial delay spread is introduced in the channel by transmitting the same signal from two or more antenna with some delay between the transmissions from the different antenna, the delay between the antennas would typically be of the order of a symbol interval, paragraph 0093, lines 5-11) except an orthogonal transform adapted to produce M orthogonal outputs, with the mth orthogonal output being a function of the M substreams delayed in said delay elements by m-1 symbol periods,

However, Ylitalo et al. discloses a transmitter wherein the space-time coding function comprises:

an orthogonal transform adapted to produce M orthogonal outputs (multiplier 12 encodes signal CH_1 with a signature code (OC) that is mutually orthogonal to the signature code that is encoded in the signal CH_2 by multiplier 14 in figure 26, column 28, lines 19-21) with the mth orthogonal output being a function of the M substreams delayed in said delay elements.

It is desirable for a an orthogonal transform adapted to produce M orthogonal outputs, with the mth orthogonal output being a function of the M substreams delayed in said delay elements by m-1 symbol periods because it achieve greater spectral efficiency at the base station while minimizing co-channel interference (column 3, lines 1-3). Therefore, it would have been obvious to one of ordinary skill in the art at the time of invention to employ the teaching of Ylitalo et al. in the system of Lindskog et al. to improve the efficiency of the transmitter.

9. Claims 27, 28, 33, 34, 35 are rejected under 35 U.S.C. 103(a) as being unpatentable over Lindskog et al. (US 2004/0013211 A1) in view of Calderbank et al. (US 7,215,718 B1) as applied to claim 26 above, and further in view of Ylitalo et al. (US 7,139,324 B1).

(1) Regarding claim 27:

Lindskog and Calderbank discloses all the subject matter as discuss in claim 26 except wherein the space-time coding function comprises an orthogonal transform adapted to produce M orthogonal outputs each of which is a function of the M substreams; and wherein the delay arrangement comprises delay arrangement adapted

to insert a respective different delay in M-1 of file M orthogonal outputs to produce the M space-time coded streams.

However, Ylitalo et al. discloses the space-time coding function comprises an orthogonal transform adapted to produce M orthogonal outputs (multiplier 12 encodes signal CH_1 with a signature code (OC) that is mutually orthogonal to the signature code that is encoded in the signal CH_2 by multiplier 14 in figure 26, column 28, lines 19-21) each of which is a function of the M substreams and a delay arrangement comprising a delay element adapted to insert a respective different delay in M-1 of the M orthogonal outputs to produce the M space-time coded streams (when M=2, the programmable delay element in figure 26 insert a delay to the signal 15, column 28, lines 44-50).

It is desirable to have the space-time coding function comprises an orthogonal transform adapted to produce M orthogonal outputs each of which is a function of the M substreams and a delay arrangement comprising delay elements adapted to insert a respective different delay in M-1 of file M orthogonal outputs to produce the M space-time coded streams because it achieve greater spectral efficiency at the base station while minimizing co-channel interference (column 3, lines 1-3). Therefore, it would have been obvious to one of ordinary skill in the art at the time of invention to employ the teaching of Ylitalo et al. in the system of Lindskog et al. and Calderbank to improve the efficiency of the transmitter.

(2) Regarding claim 28:

Ylitalo et al. further discloses a programmable delay element to introduce a delay to the orthogonal output.

Ylitalo et al. fails to explicitly discloses the delay element introduce a delay of m-1 symbol period in the mth orthogonal output, where m=1 to M. It would have been obvious to one of ordinary skill in the art at the time of invention for the programmable delay line to adapted the delay element to insert a delay of M symbol period in each of the M substream and with the mth orthogonal output being delayed in said delay elements by m-1 symbol periods, since it has been held that discovering an optimum value of a result effective variable involves only routine skill in the art. Iii re Boesch, Eli f.2d 272, 205 USPQ 215.

(3) Regarding claim 33:

Lindskog et al. and Calderbank discloses all the subject matter as discuss in claim 32 except executing an orthogonal transform to produce M orthogonal outputs each of which is a function of the M substream; and implementing the delay function comprising delaying the M orthogonal outputs to produce M delayed orthogonal outputs such that each of the M delayed orthogonal outputs is a function of a given element of each of the M substreams at a different time.

However, Ylitalo et al discloses executing an orthogonal transform to produce M orthogonal outputs each of which is a function of the M substreams (multiplier 12 encodes signal CH_1 with a signature code (OC) that is mutually orthogonal to the signature code that is encoded in the signal CH_2 by multiplier 14 in figure 26, column 28, lines 19-21) and; implementing the delay function comprising delaying the M

orthogonal outputs to produce M delayed orthogonal outputs such that each of the M delayed orthogonal outputs is a function of a given element of each of the M substreams at a different time (the programmable delay element in figure 26 insert a delay to the signal 15 and each of the signal 12 and signal 15 is a function of S1 and S2, column 28, lines 44-50).

It is desirable to executing an orthogonal transform to produce M orthogonal outputs each of which is a function of the M substream; and implementing the delay function comprising delaying the M orthogonal outputs to produce M delayed orthogonal outputs such that each of the M delayed orthogonal outputs is a function of a given element of each of the M substreams at a different time because it achieve greater spectral efficiency at the base station while minimizing co-channel interference (column 3, lines 1-3). Therefore, it would have been obvious to one of ordinary skill in the art at the time of invention to employ the teaching of Ylitalo et al. in the system of Lindskog et al. and Calderbank to improve the efficiency of the transmitter.

(4) Regarding claim 34:

Ylitalo et al. further discloses a programmable delay element to introduce a delay to the orthogonal output.

Ylitalo et al. fails to explicitly discloses the delay element introduce a delay of m-1 symbol period in the mth orthogonal output, where m=1 to M. It would have been obvious to one of ordinary skill in the art at the time of invention for the programmable delay line to adapted the delay element to insert a delay of M symbol period in each of the M substream and with the mth orthogonal output being delayed in said delay

elements by m-1 symbol periods, since it has been held that discovering an optimum value of a result effective variable involves only routine skill in the art. Iii re Boesch, Eli f.2d 272, 205 USPQ 215.

(5) Regarding claim 35:

Lindskog et al. and Calderbank discloses all the subject matter as discussed in claim 32, Lindskog et al. further discloses delay elements adapted to insert a delay of M symbol periods in each of the M substreams (in transmit delay diversity artificial delay spread is introduced in the channel by transmitting the same signal from two or more antenna with some delay between the transmissions from the different antenna, the delay between the antennas would typically be of the order of a symbol interval, paragraph 0093, lines 5-11) except wherein performing the space-time coding function comprises executing an orthogonal transform adapted to produce M orthogonal outputs, with the mth orthogonal output being a function of the M substreams delayed m-1 symbol periods.

However, Ylitalo et al. discloses a transmitter wherein the space-time coding function comprises an orthogonal transform adapted to produce M orthogonal outputs (multiplier 12 encodes signal CH_1 with a signature code (OC) that is mutually orthogonal to the signature code that is encoded in the signal CH_2 by multiplier 14 in figure 26, column 28, lines 19-21) with the mth orthogonal output being a function of the M substreams delayed in said delay elements (delay element in figure 26).

It is desirable to performing the space-time coding function comprises executing an orthogonal transform adapted to produce M orthogonal outputs, with the mth

orthogonal output being a function of the M substreams delayed m-1 symbol periods because it minimizing co-channel interference (column 3, lines 1-3). Therefore, it would have been obvious to one of ordinary skill in the art at the time of invention to employ the teaching of Ylitalo et al. in the system of Lindskog et al. and Calderbank to improve the efficiency of the transmitter.

10. Claims 30 is rejected under 35 U.S.C. 103(a) as being unpatentable over Lindskog et al. (US 2004/0013211 A1) in view of Ylitalo et al. (US 7,139,324 B1) as applied to claims 29 above, and further in view of Yamao et al. (US 6,351,498 B1).

Lindskog et al. and Ylitalo et al. disclose all the subject matter as discuss in claim 29 except wherein the orthogonal transform comprises M M-ary mapping functions, each adapted to produce a respective sequence of M-ary symbols with the M-ary symbol of the mth M-ary mapping function being a function of the M substreams delayed in said delay elements by m-1 bit periods.

However, Yamao et al. discloses a orthogonal transform comprises M M-ary mapping function (M-ary encoder 1-1 to 1-N in figure 8), each adapted to produce a respective sequence of M-ary symbols with the M-ary symbol of the mth M-ary mapping function being a function of the M-substreams delayed in said elements (at the M-ary encoders 1-1 to 1-N, M-ary orthogonal codes corresponding to the respective inputs are generated, when the ordinary orthogonal codes with L=2 are used, the 2 bits data entered into the M-ary encoder is converted into one of the 4 bits length orthogonal code, column 6, lines 7-14).

It is desirable for wherein the orthogonal transform comprises M M-ary mapping functions, each adapted to produce a respective sequence of M-ary symbols with the M-ary symbol of the mth M-ary mapping function being a function of the M substreams delayed in said delay elements by m-1 bit periods because it is capable of reducing errors due to fading while maintaining the characteristics of the M-ary modulation and demodulation scheme that is robust against interference (column 3, lines 12-13). Therefore, it would have been obvious to one of ordinary skill in the art at the time of invention to employ the teaching of Yamao et al. in the system of Lindskog et al. and Ylitalo et al. to improve the performance of the system.

11. Claim 36 is rejected under 35 U.S.C. 103(a) as being unpatentable over Lindskog et al. (US 2004/0013211 A1) in view of Calderbank et al. (US 7,215,718 B1) and Ylitalo et al. (US 7,139,324 B1) as applied to claim 33 above, and further in view of Yamao et al. (US 6,351,498 B1).

Lindskog et al., Calderbank and Ylitalo et al. disclose all the subject matter as discuss in claims 33 except wherein the orthogonal transform comprises M M-ary mapping functions, each adapted to produce a respective sequence of M-ary symbols with the M-ary symbol of the mth M-ary mapping function being a function of the M substreams delayed in said delay elements by m-1 bit periods.

However, Yamao et al. discloses a orthogonal transform comprises M M-ary mapping function (M-ary encoder 1-1 to 1-N in figure 8), each adapted to produce a respective sequence of M-ary symbols with the M-ary symbol of the mth M-ary mapping

function being a function of the M-substreams delayed in said elements (at the M-ary encoders 1-1 to 1-N, M-ary orthogonal codes corresponding to the respective inputs are generated, when the ordinary orthogonal codes with L=2 are used, the 2 bits data entered into the M-ary encoder is converted into one of the 4 bits length orthogonal code, column 6, lines 7-14).

It is desirable for wherein the orthogonal transform comprises M M-ary mapping functions, each adapted to produce a respective sequence of M-ary symbols with the M-ary symbol of the mth M-ary mapping function being a function of the M substreams delayed in said delay elements by m-1 bit periods because it is capable of reducing errors due to fading while maintaining the characteristics of the M-ary modulation and demodulation scheme that is robust against interference (column 3, lines 12-13). Therefore, it would have been obvious to one of ordinary skill in the art at the time of invention to employ the teaching of Yamao et al. in the system of Lindskog et al., Calderbank and Ylitalo et al. to improve the performance of the system.

Conclusion

12. The prior art made of record and not relied upon is considered pertinent to applicant's disclosure.

Bevan et al. (US 6,891,897 B1) discloses a space-time coding, and channel estimation scheme, arrangement and method.

Wallace et al. (US 6,473,467 B1) discloses a method and apparatus for measuring reporting channel state information in a high efficiency, high performance communication system.

The prior art of the instant application teaches using a demultiplexer (10) and cod/mod (12A to 12M) to generate M symbol substream from an input stream.

Any inquiry concerning this communication or earlier communications from the examiner should be directed to SIU M. LEE whose telephone number is (571)270-1083. The examiner can normally be reached on Mon-Fri, 7:30-4:00 with every other Friday off.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Chieh 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.

/Siu M Lee/
Examiner, Art Unit 2611
5/22/2008

/CHIEH M FAN/

Supervisory Patent Examiner, Art Unit 2611

Notice of References Cited	Application/Control No. 10/399,859	Applicant(s)/Patent Under Reexamination TONG ET AL.	
	Examiner SIU M. LEE	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-6,351,498	02-2002	Yamao et al.	375/260
*	B	US-7,139,324	11-2006	Ylitalo et al.	375/267
*	C	US-7,215,718	05-2007	Calderbank et al.	375/299
*	D	US-2004/0013211	01-2004	Lindskog et al.	375/347
*	E	US-6,473,467	10-2002	Wallace et al.	375/267
*	F	US-6,891,897	05-2005	Bevan et al.	375/265
	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
	10399859	TONG ET AL.
	Examiner	Art Unit
	Lee, Siu M	2611

✓	Rejected	-	Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

CLAIM		DATE								
Final	Original	03/14/2007	08/20/2007	05/22/2008						
	1	-	-	-						
	2	-	-	-						
	3	-	-	-						
	4	-	-	-						
	5	-	-	-						
	6	-	-	-						
	7	-	-	-						
	8	-	-	-						
	9	-	-	-						
	10	-	-	-						
	11	-	-	-						
	12	-	-	-						
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	21	-	-	-						
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	23	-	-	-						
	24	✓	✓	✓						
	25	✓	✓	✓						
	26	✓	✓	✓						
	27	✓	✓	✓						
	28	✓	✓	✓						
	29	✓	✓	✓						
	30	✓	✓	✓						
	31	✓	-	-						
	32	✓	✓	✓						
	33	✓	✓	✓						
	34	✓	✓	✓						
	35	✓	✓	✓						
	36	✓	✓	✓						

Index of Claims	Application/Control No.	Applicant(s)/Patent Under Reexamination
	10399859	TONG ET AL.
	Examiner	Art Unit
	Lee, Siu M	2611

✓	Rejected	-	Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

CLAIM		DATE								
Final	Original	03/14/2007	08/20/2007	05/22/2008						
	37		✓	✓						
	38		✓	✓						

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	10399859	TONG ET AL.
	Examiner	Art Unit
	Lee, Siu M	2611

SEARCHED			
Class	Subclass	Date	Examiner
375	267, 260, 295, 299	3/13/2007	Siu M. Lee
375	267, 260, 295, 299	8/20/2007	Siu M. Lee

SEARCH NOTES		
Search Notes	Date	Examiner
EAST	3/13/2007	Siu M. Lee
Discuss application with Chieh Fan	3/14/2007	Siu M. Lee
EAST	8/20/2007	Siu M. Lee
Disciss application with Chieh Fan	8/20/2007	Siu M. Lee
EAST	5/22/2008	Siu M. Lee
Discuss the amendment with Chieh Fan	5/22/2008	Siu M. Lee

INTERFERENCE SEARCH			
Class	Subclass	Date	Examiner

EAST Search History

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
S1	7311	mimo	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2008/05/21 13:13
S5	322	mimo and @pd<="20030101"	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2008/05/21 13:15
S6	5	S5 and (delay near3 profile)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2008/05/21 13:16
S7	8	(number near4 transmit$4 near2 antenna) same (delay near3 profile)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2008/05/21 13:18
S8	164	(number near4 transmit$4 near2 antenna) same (multipath or (mutli adj1 path))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2008/05/21 13:20
S9	148	(determin$5 or estimat$5) near3 number near3 (transmit $4 near2 antenna)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2008/05/21 13:35
S10	29	S9 and @ad<="20021220"	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2008/05/21 13:37
S11	3356	(demux or demultiplexer) with (encoder or modulator)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2008/05/21 14:25

S12	76	S11 and (space near2 time near2 cod$3)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2008/05/21 14:26
S13	21	S12 and (@pd<="20001027" OR @ad<="20001027" OR @rlad<="20001027" OR @prad<="20001027")	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2008/05/21 14:27
S14	1893	(demux or demultiplexer) with ((encoder or modulator) and modulat$3)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2008/05/21 15:12
S15	44	S14 and (space near2 time near2 cod$3)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2008/05/21 15:12
S16	14	S15 and (@pd<="20001027" OR @ad<="20001027" OR @rlad<="20001027" OR @prad<="20001027")	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2008/05/21 15:13
S17	446	channel coder with (modulat$3 and cod$3)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2008/05/21 15:21
S18	262	S17 and (@pd<="20001027" OR @ad<="20001027" OR @rlad<="20001027" OR @prad<="20001027")	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2008/05/21 15:22
S19	103	channel coder with (modulat$3 and coding)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2008/05/21 15:23
S20	63	S19 and (@pd<="20001027" OR @ad<="20001027" OR @rlad<="20001027" OR @prad<="20001027")	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2008/05/21 15:23

S21	186	(demux or demultiplexer) with (encoder with modulator)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2008/05/21 15:24
S22	71	S21 and (@pd<="20001027" OR @ad<="20001027" OR @rlad<="20001027" OR @prad<="20001027")	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2008/05/21 15:24
S23	4	S22 and (space near2 time near2 cod$3)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2008/05/21 15:33
S24	206	(channel identif$7) with spread $3	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2008/05/22 06:59
S25	187	S24 and (@pd<="20030129" OR @ad<="20030129" OR @rlad<="20030129" OR @prad<="20030129")	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2008/05/22 07:01
S26	77	S25 and "375".clas.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2008/05/22 07:01
S27	1	(channel identif$7) with (multipl $4 near2 orthogonal near2 code)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2008/05/22 07:12
S28	88	(channel near2 (identif$7 or code)) with (multipl$4 near2 orthogonal near2 code)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2008/05/22 07:12
S29	79	S28 and (@pd<="20030129" OR @ad<="20030129" OR @rlad<="20030129" OR @prad<="20030129")	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2008/05/22 07:13

5/22/2008 8:21:25 AM
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BIB DATA SHEET

CONFIRMATION NO. 9275

SERIAL NUMBER	FILING or 371(c) DATE RULE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.
10/399,859	08/29/2003	370	2611	14316NP

APPLICANTS

Wen Tong, Ottawa, CANADA;
Mikhail Bakulin, Klrova, RUSSIAN FEDERATION;
Vitaly B. Kreyndelin, Moskya, RUSSIAN FEDERATION;
Alexander M. Shloma, Zhukovsky, RUSSIAN FEDERATION;
Yuriy Shinakov, Moscow, RUSSIAN FEDERATION;

**** CONTINUING DATA ***************************

This application is a 371 of PCT/RU00/00426 10/27/2000

**** FOREIGN APPLICATIONS ***************************

**** IF REQUIRED, FOREIGN FILING LICENSE GRANTED ****

Foreign Priority claimed ☐ Yes ☑ No 35 USC 119(a-d) conditions met ☐ Yes ☑ No Verified and Acknowledged /SIU M LEE/ (Examiner's Signature)	☐ Met after Allowance Initials	STATE OR COUNTRY	SHEETS DRAWINGS	TOTAL CLAIMS	INDEPENDENT CLAIMS
		CANADA	8	23	3

ADDRESS

Ralph A. Dowell of DOWELL & DOWELL P.C.
2111 Eisenhower Ave
Suite 406
Alexandria, VA 22314
UNITED STATES

TITLE

Combination of space-time coding and spatial multiplexing, and the use of orthogonal transformation in space-time coding

FILING FEE RECEIVED		
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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Appl. No.	: 10/399,859	Confirmation No.	9275
Applicant	: Wen Tong, et al		
Filed	: October 27, 2000		
TC/A.U.	: 2611		
Examiner	: Siu M. Lee		
Docket No.	: 14316NP		
Customer No.	: 000293		

Commissioner for Patents
Alexandria, VA 22313-1450
U.S.A.

Dear Sir:

In response to the Office Action of May 23, 2008, please see below remarks:

Amendments to the Claim are reflected in the listing of claims which begin on page 2 of this paper.

Interview Summary begins on page 6 of this paper.

Remarks/Arguments begin on page 7 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:

Claims 1-23 (Cancelled)

24. (Currently amended) A transmitter adapted to process a plurality M of symbol substreams, the transmitter comprising:

a space-time coding function adapted to produce M space-time coded symbols per input set of M symbols, each input set of M symbols comprising one symbol per symbol substream, each of the M space-time coded symbols being included in a respective one of M space-time coded streams, wherein each symbol of the M symbol substreams is represented in all M space-time coded streams, wherein the transmitter comprises a delay arrangement, arranged such that-for each symbol a time of representation of the symbol in the M space-time coded streams is different for each of the M space-time coded streams, each space-time coded symbol comprising a representation of a symbol of each of the M symbol substreams;

a plurality M of transmit antennas each adapted to transmit a respective one of the M space-time coded streams, such that for each symbol of each input set of M symbols, the M space-time coded symbols that contain a representation of the symbol are transmitted at different times.

25. (Previously presented) A transmitter according to claim 24 further comprising the demultiplexing and encoding functionality comprising a demultiplexer having M outputs, and M encoder/modulators each producing a respective one of the M symbol substreams, with each of the M encoder/modulators connected to receive a respective one of the demultiplexer outputs.

26. (Previously presented) A transmitter according to claim 25 wherein the demultiplexing and encoding functionality is adapted to produce the M symbol substreams from an input stream.

27. (Previously presented) A transmitter according to claim 26 wherein the space-time coding function comprises:

an orthogonal transform adapted to produce M orthogonal outputs each of which is a function of the M substreams;

wherein the delay arrangement comprises delay elements adapted to insert a respective different delay in M-1 of the M orthogonal outputs to produce the M space-time coded streams.

28. (Previously presented) A transmitter according to claim 27 wherein the delay elements are adapted to introduce a delay of m-1 symbol periods in the mth orthogonal output, where m=1, ..., M.

29. (Previously presented) A transmitter according to claim 24 wherein the delay arrangement comprises:

delay elements adapted to insert a delay of M symbol periods in each of the M substreams; and

the space-time coding function further comprises an orthogonal transform adapted to produce M orthogonal outputs, with the mth orthogonal output being a function of the M substreams delayed in said delay elements by m-1 symbol periods.

30. (Previously presented) A transmitter according to claim 29 wherein the M substreams are bit streams, and wherein the orthogonal transform comprises M M-ary mapping functions, each adapted to produce a respective sequence of M-ary symbols with the M-ary symbol of the mth M-ary mapping function being a function of the M substreams delayed in said delay elements by m-1 bit periods.

31. (Cancelled)

32. (Currently amended) A method comprising:

demultiplexing an input symbol stream into M symbol substreams;

performing coding and modulation on each of said M symbol substreams;

performing a space-time coding function adapted to produce M space-time coded symbols per input set of M symbols, each input set of M symbols comprising one symbol per symbol substream, each of the M space-time coded symbols being included in a respective one of M space-time coded streams, wherein each symbol of the M symbol substreams is represented in all M space-time coded streams, wherein performing the space-time coding function comprises implementing a delay function, arranged such that-for each symbol a time of representation of the symbol in the M space-time coded streams is different for each of the M space-time coded streams, each space-time coded symbol comprising a representation of a symbol of each of the M symbol substreams;

transmitting the M space-time coded streams on respective antennas, such that for each symbol of each input set of M symbols, the M space-time coded symbols that contain a representation of the symbol are transmitted at different times.

33. (Previously presented) A method according to claim 32 wherein performing the space-time coding function comprises:

executing an orthogonal transform to produce M orthogonal outputs each of which is a function of the M substreams; and

implementing the delay function comprises delaying the M orthogonal outputs to produce M delayed orthogonal outputs such that each of the M delayed orthogonal outputs is a function of a given element of each of the M substreams at a different time.

34. (Previously presented) A method according to claim 33 wherein the mth orthogonal output is delayed by m-1 symbol periods, where m=1, ..., M.

35. (Previously presented) A method according to claim 32 wherein performing the space-time coding function comprises:

delaying by M symbol periods each of the M substreams;

executing an orthogonal transform adapted to produce M orthogonal outputs, with the mth orthogonal output being a function of the M substreams delayed m-1 symbol periods.

36. (Previously presented) A method according to claim 33 wherein the M substreams are bit streams, and wherein the orthogonal transform comprises M M-ary mapping functions, each adapted to produce a respective sequence of M-ary symbols with the M-ary symbol of the mth M-ary mapping function being a function of the M substreams delayed in said delay elements by m-1 bit periods.

37. (Previously presented) A transmitter according to claim 24, wherein each of the M space-time coded symbols is included in a respective one of M space-time coded streams at a different time from the inclusion of each other of the M space-time coded symbols in their respective space-time coded stream.

38. (Previously presented) A method according to claim 32, wherein each of the M space-time coded symbols is included in a respective one of M space-time coded streams at a different time from the inclusion of each other of the M space-time coded symbols in their respective space-time coded stream.

INTERVIEW SUMMARY

Applicant thanks the Examiner for the opportunity to discuss this application with Allan Brett both on September 16, 2008 and September 17, 2008.

It was discussed that the basis of the Examiner's objection, as supported by the Examiner's supervisor, is that the entire frame of Figure 7 in Lindskog is being construed a single "symbol" as referred to in Claim 1 in Applicant's application. The Examiner suggested that amending the claim to indicate that the space time coded symbols are transmitted at different times might overcome the references cited.

REMARKS/ARGUMENTS

The Examiner has rejected claims 24 and 37 under 35 U.S.C 102(e) as being anticipated by Lindskog et al. To begin, it is noted that corresponding European Patent No. 1 330 888 has granted containing a claim identical to pending claim 1. During prosecution, European Patent No. EP 0 993 130 A2 was cited, and in particular Figure 2 of that patent was cited. This is simply brought to the attention of the Examiner because Figure 2 of EP 0 993 130 A2 discloses the similar functionality to Figure 5 of the cited Lindskog reference.

Claim 1 includes the limitation:

"each space-time coded symbol comprising representations of M symbols of the M symbol substreams".

Each output of the orthogonal transformation is a function of all of the instantaneous inputs. In other words, "$x_1 = f_1(s_1, s_2,\ldots,s_M),\ldots, x_M = f_M(s_1, s_2,\ldots,s_M)$". For the sake of a really clear example, we can work through the example using the F matrix that appears at the top of page 9. Applying this to a pair of input symbols s_1, s_2, the matrix multiplication that would take place is as follows:

$$\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \frac{1}{\sqrt{2}} \begin{bmatrix} 1 & e^{j\Pi/4} \\ 1 & e^{-j\Pi/4} \end{bmatrix} \begin{matrix} S_1 \\ S_2 \end{matrix}$$

$$x_1 = \frac{S_1}{\sqrt{2}} + \frac{e^{j\Pi/4} S_2}{\sqrt{2}}$$

$$x_2 = \frac{S_1}{\sqrt{2}} + \frac{e^{-j\Pi/4} S_2}{\sqrt{2}}$$

For this particular example, the separation in time referred to in the claims, namely the fact that the time of representation of each symbol in the M space-time coded streams is different for each

of the M space-time coded stream is achieved by transmitting x_1 and x_2 at different times. In the illustrated example, x_1 has representations of the two symbol substreams as does x_2.

Referring back to the Figure 5 of Lindskog, the behaviour is as shown in Figure 7. The output streams are as follows:

Antenna 11: Tx_1: $d_1(t)$ $-d_2^*(N-t)$

Antenna 12: Tx_2: $d_2(t)$ $d_1^*(N-t)$

To simplify the discussion, assume N=2. Then the output streams are as follows where the known/training symbols have been omitted for clarity:

Tx_1 $d_1(1)$ $d_1(2)$ $-d_2^*(2)$ $-d_2^*(1)$

Tx_2 $d_2(1)$ $d_2(2)$ $-d_2(2)$ $-d_1(1)$

The instantaneous inputs are $d_1(1)$, $d_2(2)$, $d_2(1)$ and $d_2(2)$. Converting this to the notation of our example, s_1, s_2, s_3, s_4 yields:

Tx_1 s_1 s_2 $-s_3^*$ $-s_4^*$

Tx_2 s_3 s_4 $-s_1$ $-s_2$

Here it can be seen that each input symbol s_1, s_2, s_3, s_4 is represented in each of the two transmit streams as suggested by the Examiner. In addition, the time of representation is different in each of the two transmit symbols as identified by the Examiner. The difference here however is that each space-time coded symbol includes a representation of only one symbol. For example, the transmit symbol s_1 obviously only includes the representation of input symbol s_1, the transmit symbol s_2 includes a representation of s_2, the transmit symbol - s_2 contains a representation of s_2 and the transmit symbol - s_1 contains a representation of s_1. In other words, each of the "space-time coded symbols" includes one representation of one of the symbols of the M symbol substreams.

Thus, it cannot be said that each space time coded symbol is a function of all of the instantaneous inputs. Another difference is that the output of the encoding process of Lindskog is 4N symbols for 2N input symbols. For the detailed example described above, there are 8 output symbols for 4 input symbols. In contrast Applicant's claim 1 produces M encoded symbols from M input symbols, and one of those is sent on each of M transmit antennas. Clearly this results in a system with twice the throughput of Lindskog.

Turning now to the Examiner's contention that the combination of d_1 (t) and $-d_2^*(N-t)$ of Figure 7 is a single symbol, this interpretation being necessary for Lindskog to be relavent, Applicant respectfully notes that:

> During patent examination, we give the words in the claims their "broadest reasonable meaning of the words in their ordinary usage as they would be understood by one of ordinary skill in the art, taking into account whatever enlightenment by way of definitions or otherwise that may be afforded by the written description contained in the applicant's specification." In re Morris, 127 F.3d 1048, 1054 (Fed. Cir. 1997). "Giving claims their broadest reasonable construction 'serves the public interest by reducing the possibility that claims, finally allowed, will be given broader scope than is justified.'" *In re American Academy of Science Tech Center*, 367 F.3d 1359, 1364 (Fed. Cir. 2004) (internal citations omitted).

See [Ex parte Mary Ann Hettich; Appeal No. 2008-1419].

It is respectfully submitted that this construction of "symbol" is not consistent with the written description of Applicant's application nor is it consistent with the Lindskog reference on its own.

Referring first to the subject application, this definition of a "symbol" would require that multiple sequential outputs of each antenna be construed as a "single symbol". For example, referring to Figure 4, this would require z_1 (t1), z_z (t2) to be construed a single symbol.

Similarly, z_m (t1) and z_m (t2) would need to be considered a single symbol and so on. This is clearly inconsistent with the description of the figure in which z_1, z_m are each referred to as respective symbols. A "space-time coded symbol" is no different - it is simply a symbol as output by a space-time coded operation.

Turning now to Lindskog, the description of Figure 7 makes it clear that what is shown is a frame of symbols. The frame has a first block, referred to as an r_1 block and a second block, referred to as a r_2 block. The description and the figure itself makes it clear that each of these blocks is composed of a plurality of symbols. Throughout Lindskog, d_1 and d_2 (t) are referred to as "symbol streams". After space time coding, the combination of time reversal and complex conjugation is used to produce the frame structure of figure 7. The first block includes "at least n h known symbols" followed by some unknown symbols, followed by another set of at least n h known symbols. A similar structure is used for the second block of the frame. Each of the symbols in Figure 7 is the output of a space-time coding operation and as such is a space-time coded symbol.

Notwithstanding this, Applicant has amended claim 1 in the manner suggested by the Examiner to include the following limitation upon the symbols transmitted:

> "such that for each symbol of each input set of M symbols, the M space-time coded symbols that contain a representation of the symbol are transmitted at different times".

Using the Examiner's construction of "symbol", the entirety of Figure 7 that is transmitted on one antenna is a "single symbol". As such, the "symbol" transmitted on the first antenna that contains the representation of d_1 is transmitted simultaneously with the "symbol" transmitted on the second antenna containing a representation of d_1.

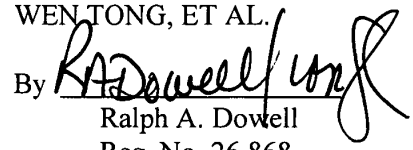
Due to the fact that multiple limitations are not taught in the 102(e) reference, the Examiner is respectfully requested to withdraw the anticipation rejections of the claims.

The 35 U.S.C. 103(a) rejections rely on the Examiner's interpretation of Lindskog. For this reason, Applicant respectfully requests the 35 U.S.C. 103(e) rejections be withdrawn as well.

In view of the foregoing, early favorable consideration of this application is earnestly solicited.

Respectfully submitted,

WEN TONG, ET AL.

By 

Ralph A. Dowell
Reg. No. 26,868
Tel.: (703) 415-2555

Date: September 23, 2008

RAB:rld:sng

OIPE
SEP 23 2008
PATENT & TRADEMARK OFFICE

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant	:	Tong et al.
Appl. No.	:	10/399,859
Filed	:	October 27, 2000
Title	:	COMBINATION OF SPACE-TIME CODING AND SPATIAL MULTIPLEXING, AND THE USE OF ORTHOGONAL TRANSFORMATION IN SPACE-TIME CODING
Grp./A.U.	:	2611
Examiner	:	Siu M. Lee

Docket No.: 14316NP

Honorable Commissioner of Patents
Alexandria, VA 22313-1450

REQUEST FOR EXTENSION OF TIME

It is respectfully requested that a one month extension of time, until September 23, 2008, be granted in which to respond to the Office Action dated May 23, 2008. The statutory fee of $120.00 for the one month extension is attached. Any deficiencies in the extension of time fees may be charged to Deposit Account No. 04-1577.

Respectfully submitted,

DOWELL & DOWELL, P. C.

Wendy M. Slade, Reg. No.: 53,604
Date: September 23, 2008

DOWELL & DOWELL, P. C.
Suite 406, 2111 Eisenhower Avenue
Alexandria, VA 22314
Telephone: (703) 415-2555

09/24/2008 MAHMED1 00000114 10399859
01 FC:1251 120.00 OP

PTO/SB/06 (07-06)
Approved for use through 1/31/2007. OMB 0651-0032
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.

PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875	Application or Docket Number 10/399,859	Filing Date 08/29/2003	☐ To be Mailed

APPLICATION AS FILED – PART I

	(Column 1)	(Column 2)	SMALL ENTITY ☐		OR	OTHER THAN SMALL ENTITY	
FOR	NUMBER FILED	NUMBER EXTRA	RATE ($)	FEE ($)		RATE ($)	FEE ($)
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A			N/A	
☐ SEARCH FEE (37 CFR 1.16(k), (l), or (m))	N/A	N/A	N/A			N/A	
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A			N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	minus 20 =	*	X $ =		OR	X $ =	
INDEPENDENT CLAIMS (37 CFR 1.16(h))	minus 3 =	*	X $ =			X $ =	
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $250 ($125 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).						
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))							
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL			TOTAL	

APPLICATION AS AMENDED – PART II

		(Column 1)		(Column 2)	(Column 3)	SMALL ENTITY		OR	OTHER THAN SMALL ENTITY	
	09/23/2008	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE ($)	ADDITIONAL FEE ($)		RATE ($)	ADDITIONAL FEE ($)
AMENDMENT	Total (37 CFR 1.16(i))	* 14	Minus	** 23	= 0	X $ =		OR	X $50=	0
	Independent (37 CFR 1.16(h))	* 2	Minus	***3	= 0	X $ =		OR	X $210=	0
	☐ Application Size Fee (37 CFR 1.16(s))									
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	**0**

		(Column 1)		(Column 2)	(Column 3)					
		CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE ($)	ADDITIONAL FEE ($)		RATE ($)	ADDITIONAL FEE ($)
AMENDMENT	Total (37 CFR 1.16(i))	*	Minus	**	=	X $ =		OR	X $ =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	X $ =		OR	X $ =	
	☐ Application Size Fee (37 CFR 1.16(s))									
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L 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.

Legal Instrument Examiner:
/KAREN VESTAL/

This collection of information is required by 37 CFR 1.16. 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.

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United States Patent and Trademark Office
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Alexandria, Virginia 22313-1450
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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/399,859	08/29/2003	Wen Tong	14316NP	9275

293 7590 09/25/2008

Ralph A. Dowell of DOWELL & DOWELL P.C.
2111 Eisenhower Ave
Suite 406
Alexandria, VA 22314

EXAMINER	
LEE, SIU M	
ART UNIT	PAPER NUMBER
2611	

MAIL DATE	DELIVERY MODE
09/25/2008	PAPER

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Interview Summary	Application No.	Applicant(s)	
	10/399,859	TONG ET AL.	
	Examiner	Art Unit	
	SIU M. LEE	2611	

All participants (applicant, applicant's representative, PTO personnel):

(1) *SIU M. LEE*. (3)_____.

(2) *Allan Brett*. (4)_____.

Date of Interview: *16 September 2008*.

Type: a)☒ Telephonic b)☐ Video Conference
c)☐ Personal [copy given to: 1)☐ applicant 2)☒ applicant's representative]

Exhibit shown or demonstration conducted: d)☐ Yes e)☒ No.
If Yes, brief description: _____.

Claim(s) discussed: *24 and 32*.

Identification of prior art discussed: *US 2004/0013211 A1*.

Agreement with respect to the claims f)☐ was reached. g)☒ was not reached. h)☐ N/A.

Substance of Interview including description of the general nature of what was agreed to if an agreement was reached, or any other comments: *The atorney and the examiner discuss about the difference between the application and the reference Lindskog US 2004/0013211 A1.*.

(A fuller description, if necessary, and a copy of the amendments which the examiner agreed would render the claims allowable, if available, must be attached. Also, where no copy of the amendments that would render the claims allowable is available, a summary thereof must be attached.)

THE FORMAL WRITTEN REPLY TO THE LAST OFFICE ACTION MUST INCLUDE THE SUBSTANCE OF THE INTERVIEW. (See MPEP Section 713.04). If a reply to the last Office action has already been filed, APPLICANT IS GIVEN A NON-EXTENDABLE PERIOD OF THE LONGER OF ONE MONTH OR THIRTY DAYS FROM THIS INTERVIEW DATE, OR THE MAILING DATE OF THIS INTERVIEW SUMMARY FORM, WHICHEVER IS LATER, TO FILE A STATEMENT OF THE SUBSTANCE OF THE INTERVIEW. See Summary of Record of Interview requirements on reverse side or on attached sheet.

/Siu M Lee/ Examiner, Art Unit 2611	

UNITED STATES PATENT AND TRADEMARK OFFICE

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Alexandria, Virginia 22313-1450
www.uspto.gov

NOTICE OF ALLOWANCE AND FEE(S) DUE

293 7590 12/31/2008

Ralph A. Dowell of DOWELL & DOWELL P.C.
2111 Eisenhower Ave
Suite 406
Alexandria, VA 22314

EXAMINER	
LEE, SIU M	
ART UNIT	PAPER NUMBER
2611	

DATE MAILED: 12/31/2008

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/399,859	08/29/2003	Wen Tong	14316NP	9275

TITLE OF INVENTION: COMBINATION OF SPACE-TIME CODING AND SPATIAL MULTIPLEXING, AND THE USE OF ORTHOGONAL TRANSFORMATION IN SPACE-TIME CODING

APPLN. TYPE	SMALL ENTITY	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	NO	$1510	$0	$0	$1510	03/31/2009

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. 08/07) Approved for use through 08/31/2010.

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)

293 7590 12/31/2008

Ralph A. Dowell of DOWELL & DOWELL P.C.
2111 Eisenhower Ave
Suite 406
Alexandria, VA 22314

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.
10/399,859	08/29/2003	Wen Tong	14316NP	9275

TITLE OF INVENTION: COMBINATION OF SPACE-TIME CODING AND SPATIAL MULTIPLEXING, AND THE USE OF ORTHOGONAL TRANSFORMATION IN SPACE-TIME CODING

APPLN. TYPE	SMALL ENTITY	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	NO	$1510	$0	$0	$1510	03/31/2009

EXAMINER	ART UNIT	CLASS-SUBCLASS
LEE, SIU M	2611	375-260000

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

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www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/399,859	08/29/2003	Wen Tong	14316NP	9275

293 7590 12/31/2008

Ralph A. Dowell of DOWELL & DOWELL P.C.
2111 Eisenhower Ave
Suite 406
Alexandria, VA 22314

EXAMINER	
LEE, SIU M	
ART UNIT	PAPER NUMBER
2611	

DATE MAILED: 12/31/2008

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 779 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 779 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.

PTOL-85 (Rev. 08/07) Approved for use through 08/31/2010.

Examiner-Initiated Interview Summary	Application No.	Applicant(s)	
	10/399,859	TONG ET AL.	
	Examiner	Art Unit	
	SIU M. LEE	2611	

All Participants:

(1) *SIU M. LEE*.

(2) *Ralph A. Dowell*.

Status of Application: _____

(3) _____.

(4) _____.

Date of Interview: *17 December 2008*

Time: *5:10 pm*

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:
Claims 24-27, 29, 32, 35-38

Prior art documents discussed:

Part II.

SUBSTANCE OF INTERVIEW DESCRIBING THE GENERAL NATURE OF WHAT WAS DISCUSSED:
The attorney agrees to the proposed changes to claims 24-27, 29, 32, 25-28.

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.

(Applicant/Applicant's Representative Signature – if appropriate)

Notice of Allowability	Application No.	Applicant(s)	
	10/399,859	TONG ET AL.	
	Examiner	Art Unit	
	SIU M. LEE	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 *9/23/2008*.

2. ☒ The allowed claim(s) is/are *24-30 and 32-36*.

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 _____.

DETAILED ACTION

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 Ralph A. Dowell on 12/17/2008.

(1) Regarding claim 24, replace claim 24 by the following:

---**A transmitter adapted to process a plurality M of symbol substreams, the transmitter comprising:**

a space-time coding block adapted to produce M space-time coded symbols per input set of M symbols, each input set of M symbols comprising one symbol per symbol substream, each of the M space-time coded symbols being included in a respective one of M space-time coded streams, wherein each symbol of the M symbol substreams is represented in all M space-time coded streams, wherein the transmitter comprises a delay arrangement, arranged such that for each symbol of the M symbol substreams a time of representation of the symbol in the M space-time coded streams is different for each of the M space-

time coded streams, each space-time coded symbol comprising a representation of a symbol of each of the M symbol substreams;

a plurality M of transmit antennas each adapted to transmit a respective one of the M space-time coded streams, such that for each symbol of each input set of M symbols, the M space-time coded symbols that contain a representation of the symbol are transmitted at different times.---

(2) Regarding claim 25, replace claim 25 by the following:

---**A transmitter according to claim 24 further comprising a demultiplexing and encoding block comprising a demultiplexer having M outputs, and M encoder/modulators each producing a respective one of the M symbol substreams, with each of the M encoder/modulators connected to receive a respective one of the demultiplexer outputs.**---

(2) Regarding claim 26, replace claim 26 by the following:

---**A transmitter according to claim 25 wherein the demultiplexing and encoding block is adapted to produce the M symbol substreams from an input stream.**---

(3) Regarding claim 27, replace claim 27 by the following:

---**A transmitter according to claim 26 wherein the space-time coding block comprises:**

an orthogonal transform adapted to produce M orthogonal outputs each of which is a function of the M substreams;

wherein the delay arrangement comprises delay elements adapted to insert a respective different delay in M-1 of the M orthogonal outputs to produce the M space-time coded streams.---

(4) Regarding claim 29, replace claim 29 by the following:

---**A transmitter according to claim 24 wherein the delay arrangement comprises:**

delay elements adapted to insert a delay in at least one of the M substreams; and

the space-time coding function further comprises an orthogonal transform adapted to produce M orthogonal outputs, with the mth orthogonal output being a function of the M substreams delayed in said delay elements by m-1 symbol periods.---

(5) Regarding claim 32, replace claim 32 by the following:

---**A method comprising:**

demultiplexing an input symbol stream into M symbol substreams;

performing coding and modulation on each of said M symbol substreams;

performing a space-time coding function adapted to produce M space-time coded symbols per input set of M symbols, each input set of M symbols comprising one symbol per symbol substream, each of the M space-time coded symbols being included in a respective one of M space-time coded streams, wherein each symbol of the M symbol substreams is represented in all M space-time coded streams, wherein performing the space-time coding function

comprises implementing a delay function, arranged such that-for each symbol of the M symbol substream, a time of representation of the symbol in the M space-time coded streams is different for each of the M space-time coded streams, each space-time coded symbol comprising a representation of a symbol of each of the M symbol substreams;

transmitting the M space-time coded streams on respective antennas, such that for each symbol of each input set of M symbols, the M space-time coded symbols that contain a representation of the symbol are transmitted at different times.---

(6) Regarding claim 35, replace claim 35 by the following:

---**A method according to claim 32 wherein performing the space- time coding function comprises:**

delaying at least one of the M substreams

executing an orthogonal transform adapted to produce M orthogonal outputs, with the mth orthogonal output being a function of the M substreams delayed m-1 symbol periods.---

(7) Regarding claim 36, replace claim 36 by the following:

---**A method according to claim 35 wherein the M substreams are bit streams, and wherein the orthogonal transform comprises M M-ary mapping functions, each adapted to produce a respective sequence of M-ary symbols with the M-ary symbol of the mth M-ary mapping function being a function of the M substreams delayed in said delay elements by m-1 bit periods.**---

(8) Regarding claim 37

Cancel claim 37.

(9) Regarding claim 38:

Cancel claim 38.

Allowable Subject Matter

2. Claims 24-30, 32-36 are allowed.

3. The following is an examiner's statement of reasons for allowance:

(1) Regarding claim 24-30:

The present invention describes a transmitter adapted to process a plurality M of symbol substreams, the transmitter comprising a space-time coding block adapted to produce M space-time coded symbols per input set of M symbols, each input set of M symbols comprising one symbol per symbol substream, each of the M space-time coded symbols being included in a respective one of M space-time coded streams, wherein each symbol of the M symbol substreams is represented in all M space-time coded streams, wherein the transmitter comprises a delay arrangement, arranged such that for each symbol of the M symbol substreams a time of representation of the symbol in the M space-time coded streams is different for each of the M space-time coded streams, each space-time coded symbol comprising a representation of a symbol of each of the M symbol substreams; and a plurality M of transmit antennas each adapted to transmit a respective one of the M space-time coded streams, such that for each symbol of each input set of M symbols, the M space-time coded symbols that contain a

representation of the symbol are transmitted at different times. The closest prior art, Lindskog et al. (US 2004/0013211 A1) discloses a similar space time coding system but fail to disclose a plurality M of transmit antennas each adapted to transmit a respective one of the M space-time coded streams, such that for each symbol of each input set of M symbols, the M space-time coded symbols that contain a representation of the symbol are transmitted at different times. This distinct feature has been added to the independent claim 24, thus rendering claims 24-30 allowable.

(2) Regarding claim 32-36:

The present invention describes a method comprising demultiplexing an input symbol stream into M symbol substreams; performing coding and modulation on each of said M symbol substreams; performing a space-time coding function adapted to produce M space-time coded symbols per input set of M symbols, each input set of M symbols comprising one symbol per symbol substream, each of the M space-time coded symbols being included in a respective one of M space-time coded streams, wherein each symbol of the M symbol substreams is represented in all M space-time coded streams, wherein performing the space-time coding function comprises implementing a delay function, arranged such that-for each symbol of the M symbol substream, a time of representation of the symbol in the M space-time coded streams is different for each of the M space-time coded streams, each space-time coded symbol comprising a representation of a symbol of each of the M symbol substreams; transmitting the M space-time coded streams on respective antennas, such that for each symbol of each input set of M symbols, the M space-time coded symbols that

contain a representation of the symbol are transmitted at different times. The closest prior art, Lindskog et al. (US 2004/0013211 A1) discloses a similar space time coding system but fail to disclose transmitting the M space-time coded streams on respective antennas, such that for each symbol of each input set of M symbols, the M space-time coded symbols that contain a representation of the symbol are transmitted at different times. This distinct feature has been added to the independent claim 32, thus rendering claims 32-36 allowable.

Any comments considered necessary by applicant must be submitted no later than the payment of the issue fee and, to avoid processing delays, should preferably accompany the issue fee. Such submissions should be clearly labeled "Comments on Statement of Reasons for Allowance."

Any inquiry concerning this communication or earlier communications from the examiner should be directed to SIU M. LEE whose telephone number is (571)270-1083. The examiner can normally be reached on Mon-Fri, 7:30-4:00 with every other Friday off.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Chieh 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.

/Siu M Lee/
Examiner, Art Unit 2611
12/18/2008

/Chieh M Fan/
Supervisory Patent Examiner, Art Unit 2611

EAST Search History

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L1	6813	375/260,267,295,299.ccls.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2008/12/18 07:35
L2	1838	1 and @pd>="20070819"	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2008/12/18 07:35
L3	129	2 and (@pd<="20001027" OR @ad<="20001027" OR @rlad<="20001027" OR @prad<="20001027")	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2008/12/18 07:36
L4	17	3 and (space near2 time near2 cod$3)	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2008/12/18 07:36
L5	11	("5491837" | "5781845" | "6031866" | "6141567" | "6144711" | "6434366" | "6473467" | "6804312" | "6888809" | "6952455" | "7236538").PN. OR ("7433416").URPN.	US-PGPUB; USPAT; USOCR	ADJ	ON	2008/12/18 07:45
L6	85	3 and delay	US-PGPUB; USPAT; USOCR	ADJ	ON	2008/12/18 07:46
L7	10	4 and 6	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2008/12/18 07:46
L8	611	455/101,103.ccls. and delay	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2008/12/18 07:52

L9	101	8 and (space near2 time near2 cod$3)	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2008/12/18 07:52
L10	26	9 and (@pd<="20001027" OR @ad<="20001027" OR @rlad<="20001027" OR @prad<="20001027")	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2008/12/18 07:59
L11	462	(delay with antenna) and (space near2 time near2 cod$3)	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2008/12/18 08:05
L12	143	11 and (@pd<="20001027" OR @ad<="20001027" OR @rlad<="20001027" OR @prad<="20001027")	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2008/12/18 08:05
S1	0	10/399859	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/03/12 12:26
S2	575	transmitter and (space time coding)	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/03/12 12:26
S3	793	transmitter and (space near2 time near2 coding)	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/03/12 12:27
S4	652	S3 and ((multi$3 or plurality or array) near4 antenna)	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/03/12 12:41
S5	394	S4 and delay	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/08/20 14:05

S8	3	09/586561	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/03/13 08:18
S9	2	"3646443".pn.	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/03/13 08:36
S10	4491	375/267,295,299,260.ccls.	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/08/19 18:55
S11	255	S10 and ((space near2 time near2 cod$3) and delay)	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/03/13 08:39
S12	230	S11 and ((plurality or multiple or multi) near2 antenna)	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/03/13 08:40
S13	3	("20030048857" | "5467367" | "6128330").PN.	US-PGPUB; USPAT; USOCR	ADJ	ON	2007/03/13 09:39
S14	1	("6934320").URPN.	USPAT	ADJ	ON	2007/03/13 09:42
S15	3	("20030048857" | "5467367" | "6128330").PN.	US-PGPUB; USPAT; USOCR	ADJ	ON	2007/03/13 10:32
S16	2335	delay same (add$3 or sum$4 or multiplex$3) same transmit$4 same antenna	US-PGPUB; USPAT; USOCR	ADJ	ON	2007/03/13 10:34
S17	92	S16 and (space near2 time near2 cod$3)	US-PGPUB; USPAT; USOCR	ADJ	ON	2007/03/13 10:57
S18	0	ep0993130 A2	US-PGPUB; USPAT; USOCR	ADJ	ON	2007/03/13 10:58
S19	0	"993130" A2	US-PGPUB; USPAT; USOCR	ADJ	ON	2007/03/13 10:57
S20	0	ep0993130A2	US-PGPUB; USPAT; USOCR	ADJ	ON	2007/03/13 10:58
S21	1	09/103443	US-PGPUB; USPAT; USOCR	ADJ	ON	2007/03/13 10:58
S22	1	08/103443	US-PGPUB; USPAT; USOCR	ADJ	ON	2007/03/13 10:59
S23	0	(texan instruments).as. and (space and time).ti.	US-PGPUB; USPAT; USOCR	ADJ	ON	2007/03/13 11:00

S24	14	(texas instruments).as. and (space and time).ti.	US-PGPUB; USPAT; USOCR	ADJ	ON	2007/03/13 11:05
S25	20	(lucent).as. and (multiple and antenna).ti.	US-PGPUB; USPAT; USOCR	ADJ	ON	2007/03/13 11:07
S26	3	S25 and delay	US-PGPUB; USPAT; USOCR	ADJ	ON	2007/03/13 11:20
S27	2	(space near2 time near2 coding) and (mix$3 near3 substream)	US-PGPUB; USPAT; USOCR	ADJ	ON	2007/03/13 11:22
S28	0	(space near2 time near2 coding) and (mixing near3 substream)	US-PGPUB; USPAT; USOCR	ADJ	ON	2007/03/13 11:22
S29	46	(mixing near3 substream)	US-PGPUB; USPAT; USOCR	ADJ	ON	2007/03/13 11:37
S30	0	((space time cod$3 substream) with delay) same antenna	US-PGPUB; USPAT; USOCR	ADJ	ON	2007/03/13 11:38
S31	0	(space time cod$3 substream)	US-PGPUB; USPAT; USOCR	ADJ	ON	2007/03/13 11:39
S32	4	(space time cod$3 stream)	US-PGPUB; USPAT; USOCR	ADJ	ON	2007/03/13 11:39
S33	562	(demultiplex$3 with (cod$3) with (modulat$3))	US-PGPUB; USPAT; USOCR	ADJ	ON	2007/03/13 11:40
S34	21	S33 and (space near2 time near2 cod$3)	US-PGPUB; USPAT; USOCR	ADJ	ON	2007/03/13 13:10
S40	405	dabak.in.	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/03/13 14:18
S41	24	S40 and space time cod$3	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/03/13 14:20
S42	1	S41 and demultiplex$3	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/03/13 14:21
S43	95	(space near2 time near2 cod$3) and (demultiplex$3 with symbol) and (cod$3 same modulat$3)	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/03/14 06:40
S44	98574	(combin$3 or add$3 or sum$4) with delay	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/03/14 06:42

S45	108046	(combin$3 or add$3 or sum$4 or mix$3) with delay	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/03/14 06:42
S46	112	S45 and space time cod$3	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/03/14 07:06
S47	2	mix$3 with substream with delay	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/03/14 07:09
S48	35	M-ary and space time coding	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/03/14 10:19
S49	31	M-ary and space time coding and map$4	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/03/14 10:55
S50	3	M-ary encoder and orthogonal$3	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/03/14 12:51
S51	1	10/788420	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/03/14 12:52
S52	0	10/399859	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/08/19 08:15
S53	1	"6377631".pn. and delay	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/08/19 14:20

S54	1674	(space near3 time near3 cod$3) and transmitter	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/08/19 18:57
S55	247	S54 and @rlad<"20001027"	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/08/19 18:57
S56	207	S55 and delay	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/08/19 14:23
S57	133	S56 and ((plurality or multi or multiple or array) near3 antenna)	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/08/19 18:56
S58	0	09/883543	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/08/19 14:54
S59	2	09/833543	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/08/19 15:33
S64	4972	375/267,295,299,260.ccls.	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/08/19 18:56
S65	2441	S64 and delay	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/08/19 18:56
S66	806	S65 and ((plurality or multi or multiple or array) near3 antenna)	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/08/19 18:56

S67	263	S66 and (space near3 time near3 cod$3) and transmitter	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/08/19 18:57
S68	47	S67 and @rlad<"20001027"	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/08/19 18:58
S69	0	S68 not S57	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/08/19 18:57
S70	788	S64 and spatial	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/08/19 18:58
S71	221	S70 and temporal	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/08/19 18:58
S72	40	S71 and @rlad<"20001027"	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/08/19 18:58
S73	35	S72 and delay	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/08/19 18:58
S74	35	S72 and delay$3	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/08/19 18:58
S75	18	S74 not S57	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/08/20 10:34

S76	111	delay near3 diversity and @rlad<"20001027"	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/08/20 10:35
S77	31	S76 and space near3 time near3 cod$3	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/08/20 10:48
S78	80	S76 not S77	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/08/20 10:48
S79	2	"6351498".pn.	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2007/08/20 14:06
S80	106	(texas near2 instrument) and ((space adj1 time)near2 cod$3)	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2008/05/09 22:32
S81	0	S80 and (ep adj1 a adj1 "0")	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2008/05/09 22:33
S82	12	S80 and (ep)	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2008/05/09 22:33
S83	531	transmitter with (space near2 time near2 cod$3)	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2008/05/18 13:57
S84	264	S83 and delay and antenna	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2008/05/18 13:58

S85	51	S84 and (@pd<="20001027" OR @ad<="20001027" OR @rlad<="20001027" OR @prad<="20001027")	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2008/05/18 13:59
S86	22	S85 and (delay with antenna)	US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2008/05/18 15:25

12/18/2008 8:36:07 AM
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Index of Claims	Application/Control No.	Applicant(s)/Patent Under Reexamination
	10399859	TONG ET AL.
	Examiner	Art Unit
	SIU M LEE	2611

✓	Rejected	-	Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

CLAIM		DATE								
Final	Original	03/14/2007	08/20/2007	05/22/2008	12/18/2008					
	1	-	-	-	-					
	2	-	-	-	-					
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	14	-	-	-	-					
	15	-	-	-	-					
	16	-	-	-	-					
	17	-	-	-	-					
	18	-	-	-	-					
	19	-	-	-	-					
	20	-	-	-	-					
	21	-	-	-	-					
	22	-	-	-	-					
	23	-	-	-	-					
1	24	✓	✓	✓	=					
2	25	✓	✓	✓	=					
3	26	✓	✓	✓	=					
4	27	✓	✓	✓	=					
5	28	✓	✓	✓	=					
6	29	✓	✓	✓	=					
7	30	✓	✓	✓	=					
	31	✓	-	-	-					
8	32	✓	✓	✓	=					
9	33	✓	✓	✓	=					
10	34	✓	✓	✓	=					
11	35	✓	✓	✓	=					
12	36	✓	✓	✓	=					

Index of Claims	Application/Control No.	Applicant(s)/Patent Under Reexamination
	10399859	TONG ET AL.
	Examiner	Art Unit
	SIU M LEE	2611

✓	Rejected	-	Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

CLAIM		DATE								
Final	Original	03/14/2007	08/20/2007	05/22/2008	12/18/2008					
	37		✓	✓	-					
	38		✓	✓	-					

Issue Classification

Application/Control No.	Applicant(s)/Patent Under Reexamination
10399859	TONG ET AL.
Examiner	**Art Unit**
SIU M LEE	2611

ORIGINAL		INTERNATIONAL CLASSIFICATION									
CLASS	SUBCLASS	CLAIMED					NON-CLAIMED				
375	260	H	0	4	K	1 / 10 (2006.0)					

CROSS REFERENCE(S)

CLASS	SUBCLASS (ONE SUBCLASS PER BLOCK)				
375	267	295	299		
455	101	103			

☐ 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	Final	Original
1	24														
2	25														
3	26														
4	27														
5	28														
6	29														
7	30														
8	32														
9	33														
10	34														
11	35														
12	36														

/SIU M LEE/ Examiner.Art Unit 2611 (Assistant Examiner)	12/18/2008 (Date)	**Total Claims Allowed:** 12
/Chieh M Fan/ Supervisory Patent Examiner.Art Unit 2611 (Primary Examiner)	12/19/2008 (Date)	O.G. Print Claim(s): 1 O.G. Print Figure: 5

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. 9275

SERIAL NUMBER	FILING or 371(c) DATE RULE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.
10/399,859	08/29/2003	370	2611	14316NP

APPLICANTS
Wen Tong, Ottawa, CANADA;
Mikhail Bakulin, Klrova, RUSSIAN FEDERATION;
Vitaly B. Kreyndelin, Moskya, RUSSIAN FEDERATION;
Alexander M. Shloma, Zhukovsky, RUSSIAN FEDERATION;
Yuriy Shinakov, Moscow, RUSSIAN FEDERATION;

**** CONTINUING DATA ***************************
This application is a 371 of PCT/RU00/00426 10/27/2000

**** FOREIGN APPLICATIONS ***************************

**** IF REQUIRED, FOREIGN FILING LICENSE GRANTED ****

Foreign Priority claimed ☐ Yes ☑ No 35 USC 119(a-d) conditions met ☐ Yes ☑ No Verified and Acknowledged /SIU M LEE/ (Examiner's Signature)	☐ Met after Allowance Initials	STATE OR COUNTRY	SHEETS DRAWINGS	TOTAL CLAIMS	INDEPENDENT CLAIMS
		CANADA	8	23	3

ADDRESS
Ralph A. Dowell of DOWELL & DOWELL P.C.
2111 Eisenhower Ave
Suite 406
Alexandria, VA 22314
UNITED STATES

TITLE
Combination of space-time coding and spatial multiplexing, and the use of orthogonal transformation in space-time coding

FILING FEE RECEIVED		
1084	FEES: Authority has been given in Paper 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

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	10399859	TONG ET AL.
	Examiner	Art Unit
	Lee, Siu M	2611

SEARCHED			
Class	Subclass	Date	Examiner
375	267, 260, 295, 299	3/13/2007	Siu M. Lee
375	267, 260, 295, 299	8/20/2007	Siu M. Lee

SEARCH NOTES		
Search Notes	Date	Examiner
EAST	3/13/2007	Siu M. Lee
Discuss application with Chieh Fan	3/14/2007	Siu M. Lee
EAST	8/20/2007	Siu M. Lee
Disciss application with Chieh Fan	8/20/2007	Siu M. Lee
EAST	5/22/2008	Siu M. Lee
Discuss the amendment with Chieh Fan	5/22/2008	Siu M. Lee
EAST	12/18/2008	Siu M. Lee
Discuss the amendment with Chieh Fan	12/10/2008	Siu M. Lee

INTERFERENCE SEARCH			
Class	Subclass	Date	Examiner
375	260, 267, 295, 299	12/18/2008	Siu M. Lee
455	101, 103	12/18/2008	Siu M. Lee

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)

293 7590 12/31/2008

Ralph A. Dowell of DOWELL & DOWELL P.C.
2111 Eisenhower Ave
Suite 406
Alexandria, VA 22314

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.
10/399,859	08/29/2003	Wen Tong	14316NP	9275

TITLE OF INVENTION: COMBINATION OF SPACE-TIME CODING AND SPATIAL MULTIPLEXING, AND THE USE OF ORTHOGONAL TRANSFORMATION IN SPACE-TIME CODING

APPLN. TYPE	SMALL ENTITY	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	NO	$1510	$0	$0	$1510	03/31/2009

EXAMINER	ART UNIT	CLASS-SUBCLASS
LEE, SIU M	2611	375-260000

03/26/2009 MAHMED2 00000008 141315 10399859
01 FC:1501 1510.00 DA
02 FC:8001 6.00 DA

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: NORTEL NETWORKS LIMITED

(B) RESIDENCE: (CITY and STATE OR COUNTRY): ST. LAURENT, QUEBEC, CANADA

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 2

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 141315 (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 March 25, 2009

Typed or printed name Ralph A. Dowell Registration No. 26,868

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.

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www.uspto.gov

APPLICATION NO.	ISSUE DATE	PATENT NO.	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/399,859	05/05/2009	7529305	14316NP	9275

293 7590 04/15/2009

Ralph A. Dowell of DOWELL & DOWELL P.C.
2111 Eisenhower Ave
Suite 406
Alexandria, VA 22314

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 887 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):

Wen Tong, Ottawa, CANADA;
Mikhail Bakulin, Klrova, RUSSIAN FEDERATION;
Vitaly B. Kreyndelin, Moskya, RUSSIAN FEDERATION;
Alexander M. Shloma, Zhukovsky, RUSSIAN FEDERATION;
Yuriy Shinakov, Moscow, RUSSIAN FEDERATION;

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 for the District of Delaware on the following

☐ Trademarks or ☑ Patents. (☐ the patent action involves 35 U.S.C. § 292.):

DOCKET NO.	DATE FILED	U.S. DISTRICT COURT
	2/14/2017	for the District of Delaware

PLAINTIFF	DEFENDANT
BlackBerry Limited	Nokia Corporation, Nokia Solutions and Networks Oy, Nokia Solutions and Networks Holdings USA Inc., and Nokia Solutions and Networks US LLC

	PATENT OR TRADEMARK NO.	DATE OF PATENT OR TRADEMARK	HOLDER OF PATENT OR TRADEMARK
1	6,996,418	2/7/2006	BlackBerry Limited
2	8,254,246	8/28/2012	BlackBerry Limited
3	8,494,090	7/23/2013	BlackBerry Limited
4	7,529,305	5/5/2009	BlackBerry Limited
5	8,861,433	10/14/2014	BlackBerry Limited

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
1		
2		
3		
4		
5		

In the above---entitled case, the following decision has been rendered or judgement issued:

DECISION/JUDGEMENT

CLERK	(BY) DEPUTY CLERK	DATE

Copy 1---Upon initiation of action, mail this copy to Director Copy 3---Upon termination of action, mail this copy to Director
Copy 2---Upon filing document adding patent(s), mail this copy to Director Copy 4---Case file copy