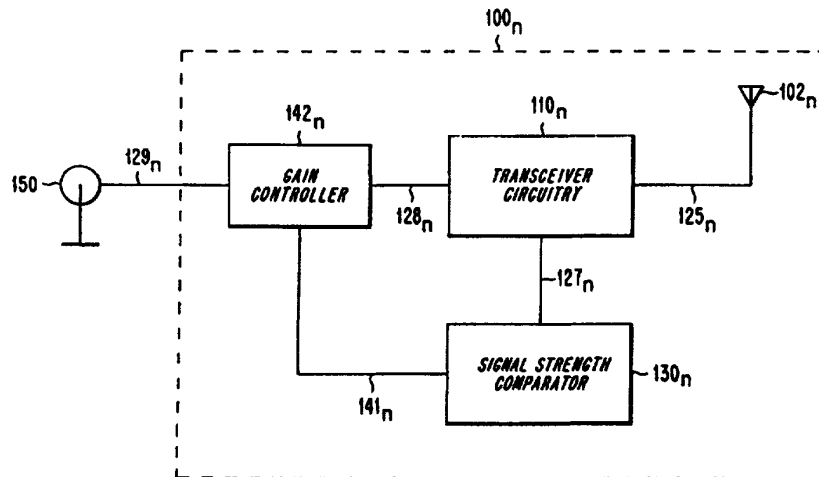




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(21) International Application Number: PCT/US97/10126 (22) International Filing Date: 13 June 1997 (13.06.97) (30) Priority Data: 08/674,875 2 July 1996 (02.07.96) US (71) Applicant: ERICSSON INC. [US/US]; 7001 Development Drive, P.O. Box 13969, Research Triangle Park, NC 27709 (US). (72) Inventors: NAIDU, Arun; 9628 Berryville Court, Raleigh, NC 27613 (US). MORELEN, Steven; 100 Hobblebrook Court, Cary, NC 27511 (US). (74) Agents: GRUDZIECKI, Ronald, L. et al.; Burns, Doane, Swecker & Mathis, L.L.P., P.O. Box 1404, Alexandria, VA 22313-1404 (US).		(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, HU, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, TJ, TM, TR, TT, UA, UG, UZ, VN, ARIPO patent (GH, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG). Published <i>With international search report.</i>

(54) Title: **SYSTEM AND METHOD FOR CONTROLLING THE LEVEL OF SIGNALS OUTPUT TO TRANSMISSION MEDIA IN A DISTRIBUTED ANTENNA NETWORK**



(57) Abstract

A system and method are provided for controlling the gain of signals transported over transmission media in a distributed antenna network. The system includes a plurality of remote antenna units where each remote antenna unit includes a signal level comparator for comparing the level of the signals received by the respective antenna unit with a predetermined reference level, and a gain controller for reducing the gain of the remote antenna unit when the signal level comparator determines that the level of the received signal exceeds said predetermined reference level. The system may accommodate TDMA systems when a gain controller is used that is fast enough to respond within the time slots of the received signals. As a result, the signal levels output from the remote antenna units are prevented from exceeding a maximum signal level.

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**SYSTEM AND METHOD FOR CONTROLLING THE
LEVEL OF SIGNALS OUTPUT TO TRANSMISSION
MEDIA IN A DISTRIBUTED ANTENNA NETWORK**

BACKGROUND

5 The present invention is directed to a system and method for controlling the level of signals output from remote antenna units to transmission media in a distributed antenna network. More particularly, the present invention reduces the gain of a remote antenna unit when its output signal level is determined to be greater than the maximum output level which may be received by the
10 transmission media. Accordingly, received signals that are stronger than the maximum output level may be transmitted across the transmission media without saturating the system.

 As personal communication services (PCS) evolve as the next generation of cellular telephone technology, systems and techniques for simply and
15 efficiently transmitting and receiving communication signals are being investigated. One known system is a distributed antenna network (which is also referred to as a multicast network) which provides coverage over substantial areas by a plurality of remote antenna units. An example of a distributed antenna network is illustrated in Figure 1 where an individual transceiver 10 is
20 connected to a plurality of cells $20_1, \dots, 20_n$ by transmission media 30 which transports radio signals between the transceiver unit 10 and the cells $20_1 \dots 20_n$. Each of the cells $20_1, \dots, 20_n$ include remote antenna units $21_1, \dots, 21_n$. The remote antenna units $21_1, \dots, 21_n$ may be connected to the transmission media 30 by frequency converting circuitry $22_1, \dots, 22_n$ for certain applications.

25 Various infrastructures are being developed and modifications of existing infrastructures are of great interest as alternatives for PCS because they are fully capable of providing high quality signals at lower costs than traditional cellular infrastructures. For example, CATV infrastructures have been modified for use in PCS. Such modifications include the CATV infrastructures using a hybrid

fiber/coax (HFC) cable infrastructure to increase capacity and improve service quality. Although it is theoretically possible for any CATV infrastructure to support PCS with the proper modifications, the HFC cable infrastructure offers an attractive option as an economical alternative to wireless providers seeking to avoid the high cost of network construction.

Figure 2 illustrates the basic components of a CATV infrastructure used to support PCS. In Figure 2, base station equipments 50₁ and 50₂ are connected to a public network such as a public switched telephone network. Remote antenna signal processors (RASPs) 52₁ and 52₂ connect the base station equipments 50₁ and 50₂ to a fiber equipment 54. The fiber equipment 54 is connected to a fiber node 58 by fiber optic cable 56 and the fiber node 58 is connected to remote antenna driver (RAD) nodes 62₁ and 62₂ by two-way coaxial cable 60. The RAD nodes 62₁ and 62₂ each include a group of RADs 64₁ and 64₂ and 66₁ and 66₂ respectively connected to antennas 68₁, 68₂, 70₁, and 70₂. This CATV infrastructure converts radio frequency signals into CATV frequency signals usable in the existing CATV infrastructure and converts CATV frequency signals back into radio frequency signals for broadcast. More specifically, the RASPs 52₁ and 52₂ convert the radio frequency signals from the base station equipments 50₁ and 50₂ and then send the converted signals in the downlink path toward the appropriate fiber node 58 and onto the coaxial cable 60.

The RADs 64₁, 64₂, 66₁ and 66₂ are connected to the coaxial cable 60 for converting CATV frequency signals into assigned radio frequency signals. Radio frequency signals may be received by the RADs 64₁, 64₂, 66₁ and 66₂ which convert these signals into signals of frequencies suitable for transmission in the uplink path of the CATV infrastructure. Thereafter, the RASPs 52₁ and 52₂ convert the upstream CATV frequency signals back into radio frequency signals for processing by the base station equipments 50₁ and 50₂. This CATV infrastructure also may accommodate equipment for multiple modulation schemes, such as time division multiple access (TDMA), code division multiple access (CDMA) and frequency division multiple access (FDMA).

Radio telephony systems may utilize this CATV infrastructure by operating on available portions of the radio frequency spectrum over fiber optic and coaxial cables which are widely available in urban areas so that such systems may be installed to take advantage of this existing infrastructure. The large
5 installed base of fiber optic and coaxial cables used by CATV operators may thereby be effectively exploited at a minimal cost by this infrastructure which distributes the signals to the appropriate antenna locations. To efficiently provide RF coverage in new cellular and PCS communication systems, it is becoming increasingly common to use distributed antenna systems. In distributed antenna
10 systems, it is often necessary to transmit RF signals covering a wide range of amplitudes across transmission media with a limited and more narrow range of amplitudes for the signals. Conventional automatic gain control (AGC) techniques for controlling the gain are insufficient in allowing the wide range of signals to be fully transmitted over the transmission media of a limited dynamic
15 range. In conventional AGC techniques, even though stronger signals, which exceed the maximum signal level for the transmission media, from sources relatively near the remote antenna units are limited to be below the maximum signal level for transmission across the transmission media, weak signals from sources relatively far away from the remote antenna units are undesirably
20 reduced below the noise floor and effectively cut off. The conventional techniques do not adequately control gain so that strong signals do not saturate the system and weak signals are not unnecessarily reduced below the noise floor.

SUMMARY

One object of the present invention therefore is to provide a system and
25 method for controlling the level of signals transmitted from remote antenna units over transmission media in a distributed antenna network so that signals covering a wide range of amplitudes may be transmitted over transmission media having a more narrow range of amplitudes for transmitting signals.

Another object of the present invention is to provide a system and method for comparing a predetermined reference level with the level of signals received by each remote antenna unit in a distributed antenna network, and controlling the gain of the respective remote antenna units based upon this comparison to prevent strong signals from saturating the system.

According to one embodiment of the present invention, the foregoing and other objects are attained in a system and method for controlling the gain of signals transported over transmission media in a distributed antenna network. The system comprises a plurality of remote antenna units where each remote antenna unit includes a signal level comparator for comparing the level of the signals received by the respective antenna unit with a predetermined reference level, and a gain controller for reducing the gain of the remote antenna unit when the signal level comparator determines that the level of the received signal exceeds said predetermined reference level. As a result, the signal levels output from the remote antenna units are prevented from exceeding a maximum signal level so that strong signals do not saturate the system.

In a further embodiment of the present invention, the predetermined reference level is set to correspond with the maximum level for transmitting signals over the transmission media. Thereby, the level of the signals output over the transmission media are prevented from saturating the system without being unduly restricted.

In a still further embodiment of the present invention, the signal level comparator generates an error signal when the received signal exceeds the predetermined reference level which is used for reducing the gain in proportion to the error signal. The system may accommodate TDMA standards when a gain controller is used that is fast enough to respond within the time slots specified by the standards.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be more fully understood by reading this description in conjunction with the accompanying drawings, which are given by way of illustration only, and thus are not limitative of the present invention, wherein:

5 Figure 1 illustrates a conventional distributed antenna network;

 Figure 2 illustrates a block diagram of a known CATV infrastructure which supports PCS;

 Figures 3a and 3b are block diagrams showing embodiments of the system for controlling the gain in a distributed antenna network according to the present
10 invention; and

 Figure 4 is a block diagram showing a system infrastructure in which a gain control system according to an embodiment of the present invention is implemented.

DETAILED DESCRIPTION

15 This invention is directed to a system and method which controls the gain in a plurality of remote antenna units of a distributed antenna network. Often in distributed antenna networks, signals covering a wide range of amplitudes are attempted to be transported from the remote antenna units across transmission media which are not capable of handling such a wide range of amplitudes. In
20 particular, when a strong signal is received by a remote antenna unit (for instance, when a mobile station is directly under a remote antenna unit), it is desirable to reduce the gain of the remote antenna unit so that the strong signal does not saturate the system. Accordingly, the system and method of the present invention reduce the level of signals produced by remote antenna units when the
25 received signal level exceeds a predetermined reference level.

 Figure 3(a) illustrates one example of a system that is used in each remote antenna unit for controlling the gain in a distributed antenna network according to the present invention. In this system, a plurality of remote antenna units 100_n are connected to a network output 150 but only a representative remote antenna

unit 100_n is shown in Figure 3(a). An antenna 102_n provides an RF input signal 125_n to transceiver circuitry 110_n in this system. The transceiver circuitry 110_n is connected to a signal strength comparator 130_n which compares a predetermined reference level with a signal 127_n which is output from the transceiver circuitry 110_n and corresponds to the signal 125_n received by the antenna 102_n. The signal strength processor 130_n outputs an error signal 141_n when the signal 127_n is determined to exceed the predetermined reference level. A gain controller 142_n receives the error signal 141_n and a signal 128_n which is output from the transceiver circuitry 110_n and corresponds to the signal 125_n received by the antenna 102_n. The gain controller 142_n controls the gain of the remote antenna unit 100_n based on the error signal 141_n such that the output signal 129_n has the proper level.

The signal strength comparator 130_n determines whether the level of the signal 129_n exceeds the maximum level permitted by the transmission media. Therefore, the predetermined reference level is selected to correspond to the maximum permitted level. Typically, this predetermined reference level is set in each remote antenna unit 100_n upon installation to correspond with maximum signal level capable of being transmitted over the transmission media. However, this predetermined reference level may be later modified after installation for use with different transmission media. The signal strength comparator 130_n determines whether the signal 127_n indicates that the signal 129_n exceeds the predetermined reference level; if so, the error signal 141_n is generated in proportion to the difference between the signal 127_n and the predetermined reference level. The error signal 141_n is input to the gain controller 142_n and the level of signal 128_n is reduced in proportion to the level of the error signal 141_n. As a result, the signal 129_n output to the network across the transmission media is prevented from saturating the system.

Figure 3(b) illustrates in more detail components that may be preferably used in the block diagram of Figure 3(a). The transceiver circuitry 110_n includes a low noise amplifier 112_n connected to the antenna 102_n for amplifying RF

signals 125_n generated by the antenna 102_n. The amplified signal is further processed by a preselecting filter 114_n, a mixer 116_n connected to a first local oscillator 118_n, and an intermediate frequency filter 120_n. A standard coupler 122_n sends a portion of this processed signal 127_n to the signal strength
5 comparator 130_n and a portion to a mixer 124_n. The mixer 124_n is connected to a second local oscillator 126_n and outputs signal 128_n to the gain controller 142_n.

The signal strength comparator 130_n includes a diode 132_n for converting the signal 127_n to a DC level for comparison with the predetermined reference level. A reference level generator 134_n is used for generating the predetermined
10 reference level. The reference level generator 134_n is set based on the transmission media as described above. A differential amplifier 136_n compares the output of the diode 132_n with the signal output by the reference level generator 134_n. The comparison output of the differential amplifier 136_n is further processed by a half wave rectifier 137_n and a scale and offset amplifier
15 138_n for outputting the error signal 141_n. The half wave rectifier 137_n and the scale and offset amplifier 138_n process the signal output from the differential amplifier 136_n so that the gain controller 142_n may reduce the signal 129_n to a level below the maximum permitted output level of the transmission media. It will be appreciated that modifications and other circuitry may be used for
20 generating the error signal 141_n which controls the gain controller 142_n.

The gain controller 142_n includes a variable gain amplifier 144_n. This variable gain amplifier 144_n controls the level of the signal 129_n in response to the error signal 141_n. By choosing the variable gain amplifier 144_n to be sufficiently fast, the present system may be used in TDMA applications. For
25 example, an analog device AD603 integrated circuit may be used for the variable gain amplifier 144_n so that the gain of the amplifier responds to the error signal 141_n within the time slots of TDMA standards.

Figure 4 illustrates an example of a CATV system infrastructure that may advantageously utilize Applicants' system and method for equalizing delay. The
30 infrastructure includes fiber nodes 200₁,...200_n which are connected to a CATV

head-end 300 by respective optical fibers $250_1, \dots, 250_n$. The CATV head-end 300 may support a number of fiber nodes $200_1, \dots, 200_n$, each of which may generally support approximately 500 to 1500 homes or subscribers through a plurality of remote antenna units $202_1, \dots, 202_n$. The remote antenna units $202_1, \dots, 202_n$ are
5 respectively connected by the optical fibers $250_1, \dots, 250_n$ to the CATV head-end 300. Also, a plurality of the remote antenna units $202_1, \dots, 202_n$ are connected to an amplifying and optical/electrical converting circuit 206_n by coaxial cabling 204_n .

The CATV head-end 300 includes an amplifying and electrical/optical
10 converting circuit 302 which is used for interfacing the CATV head-end 300 to the optical fibers $250_1, \dots, 250_n$. The amplifying and electrical/optical converting circuit 302 is connected to combining and splitting circuitry 304 which is connected to a video source 306 and cable access processing (CAP) units $308_1, \dots, 308_n$ which at least correspond in number to the fiber nodes $200_1, \dots, 200_n$
15 in the system. The CAP units $308_1, \dots, 308_n$ are connected to radio base stations (RBS) $314_1, \dots, 314_n$ and a hub 310. The hub 310 is further connected to a remote antenna management system (RAMS) 312. The CAP units $308_1, \dots, 308_n$ are also connected to an operation support system/switching center (OSS/SC) 350. The OSS/SC 350 includes a mobile switching center 352, a base station controller
20 354, an operation support system 356 and its own RAMS 358. The RAMS 358 of the OSS/SC 350 may communicate with the RAMS 312 of the CATV head-end 300 so that a plurality of CATV head-ends may be controlled at a central location. The base station controller is also connected to a macrocell 360 which includes a (RBS) 362. The CAP units $308_1, \dots, 308_n$ provide the frequency
25 conversion and power level adjustments for placing telephony carrier signals on the CATV infrastructure as well as controlling and monitoring the status of the remote antenna units $202_1, \dots, 202_n$.

The remote antenna units $202_1, \dots, 202_n$ are located in desired areas and convert the CATV base communication signals back to their proper air
30 frequencies and power levels. Each of the remote antenna units $202_1, \dots, 202_n$ is

associated with a specific transceiver radio unit (TRU) in the RBS 314₁,...314_n so that the CATV network is totally transparent to the radio operation. The operating frequencies of the CAP units 308₁,...308_n are set to exactly match the operating frequencies of the remote antenna transmitters. Up to six TRUs in a specific one of the RBS 314₁,...314_n feed a single one of the CAP units 308₁,...308_n which in turn serves several fiber nodes 200₁,...200_n in the CATV network. A combiner within the CAP units 308₁,...308_n provide six transmit input ports from the RBS 314₁,...314_n in order to support a maximum of six TRUs. The CAP units 308₁,...308_n convert the telephony carrier signals to CATV frequency signals and feed them to the CATV head-end 300 over a bi-directional coaxial cable.

In the CATV head-end 300, the telephony carrier signals are combined with the video signals and both signals are transmitted over the fiber optic cables 250₁,...250_n to fiber nodes 200₁,...200_n. At the fiber nodes 200₁,...200_n, the signals are converted back to electrical signals and distributed over a tree and branch coaxial network. Each individual one of the remote antenna units 201₁,...202_n taps off the coaxial cabling 204_n, filters the carrier signals, converts the frequency and transmits the carrier signals over the air interface. The video signals continue unaltered to each CATV subscriber. For the uplink, the remote antenna units 202₁,...202_n receive two diversity signals from the air, downconvert the frequency, and transmit the different frequency diversity carrier signals over the CATV infrastructure. In the CATV infrastructure at the fiber nodes 200₁,...200_n, the electrical signals are converted to optical signals and transmitted back to the CATV head-end 300. These signals are then converted back to electrical signals and routed to the CAP units 308₁,...308_n over the bi-directional cable. The CAP units 308₁,...308_n convert the uplink carrier signals back up to frequencies for input to the TRUs. The CAP units 308₁,...308_n receive digital control information from the RAMS 312 and forward remote antenna control information to the desired one of the remote antenna units 202₁,...202_n.

The invention being thus described, it will be obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the invention, which is determined by the following claims. All such modifications as would be obvious to one skilled in the art are

5 intended to be included within the scope of the following claims.

CLAIMS:

1. A system for controlling the gain of signals transported over transmission media in a distributed antenna network, comprising:
a plurality of remote antenna units, each of said remote antenna units
5 including,
a signal level comparator for comparing the level of the signal received by the remote antenna unit with a predetermined reference level, and
a gain controller for reducing the gain of the remote antenna unit when said signal level comparator determines that the level of the received signal
10 exceeds said predetermined reference level.
2. A system according to claim 1, wherein said predetermined reference level corresponds to the maximum level for transmitting signals over the transmission media.
3. A system according to claim 1, wherein said signal level comparator
15 generates an error signal when the received signal exceeds said predetermined reference level.
4. A system according to claim 3, wherein said gain controller reduces the gain in proportion to said error signal.
5. A system according to claim 4, wherein said gain controller
20 comprises a fast variable amplifier for operating within time slots for TDMA standards.
6. A method for controlling the gain of signals transported over transmission media in a distributed antenna network, comprising the steps of:
(a) comparing the levels of the signals received by each of a plurality of
25 remote antenna units with a predetermined reference level; and

(b) reducing the gain of each of the remote antenna units when said step (a) determines that the levels of the received signals exceed said predetermined reference level.

7. A method according to claim 6, wherein said predetermined reference
5 level corresponds to the maximum level for transmitting signals over the transmission media.

8. A method according to claim 6, wherein an error signal is generated when the received signal is determined to exceed said predetermined reference level.

10 9. A method according to claim 8, wherein the gain is reduced in proportion to said error signal at said step (b).

10. A method according to claim 9, wherein said step (b) reduces the gain by fast variable amplifier which operates within time slots for TDMA standards.

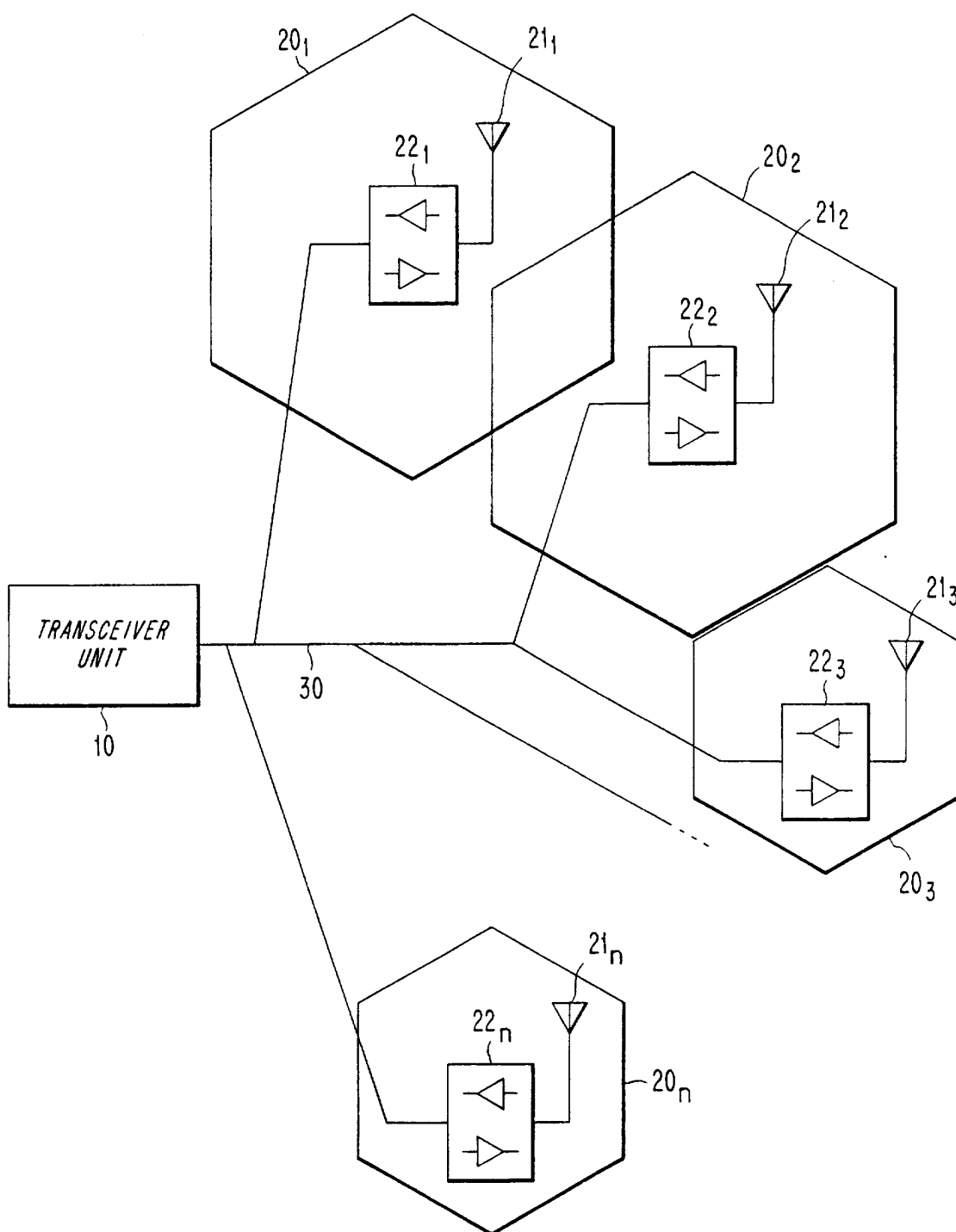


Fig. 1
PRIOR ART

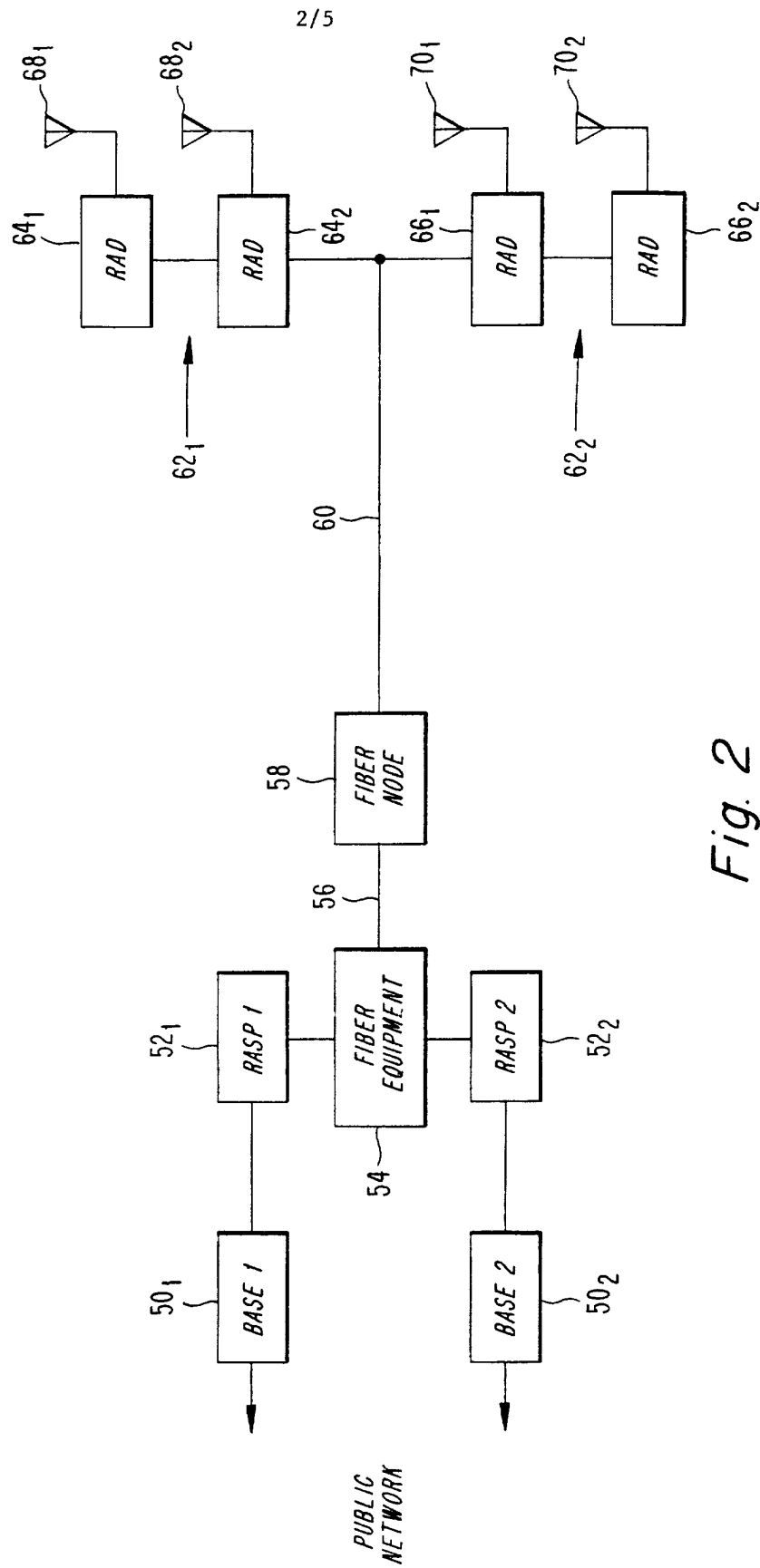


Fig. 2
PRIOR ART

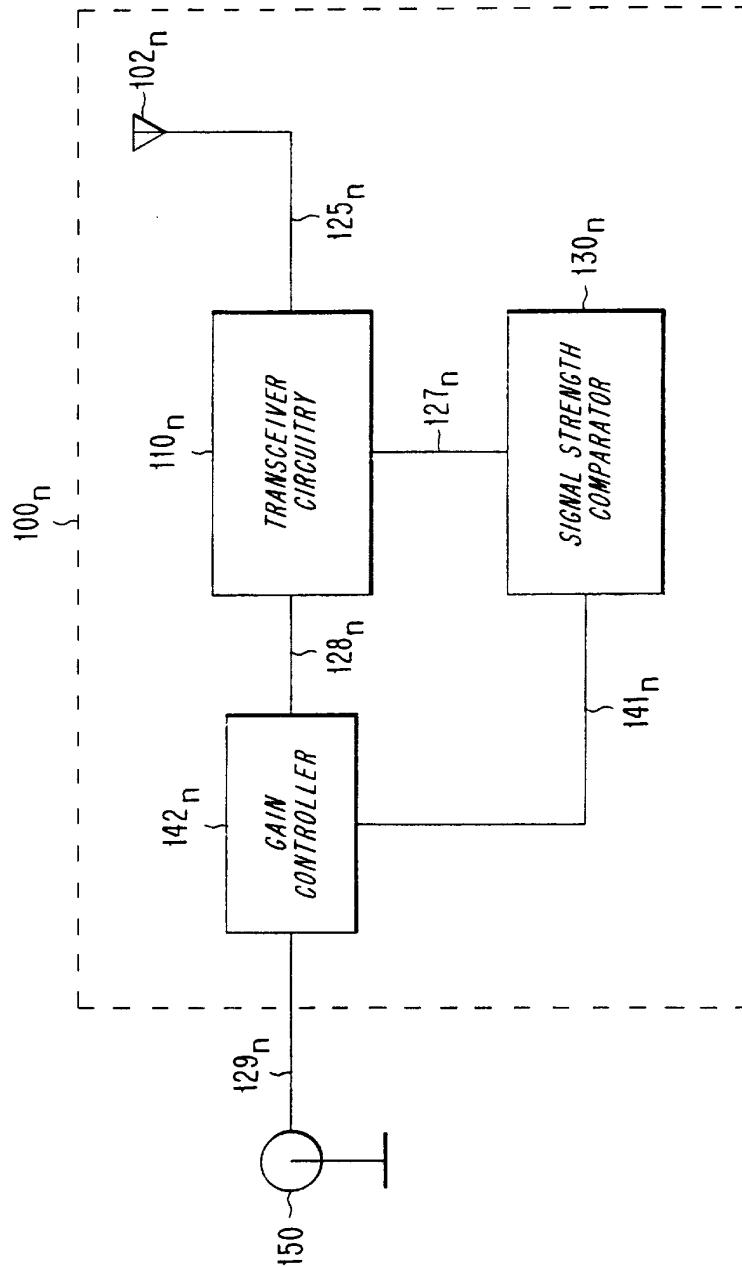


Fig. 3(a)

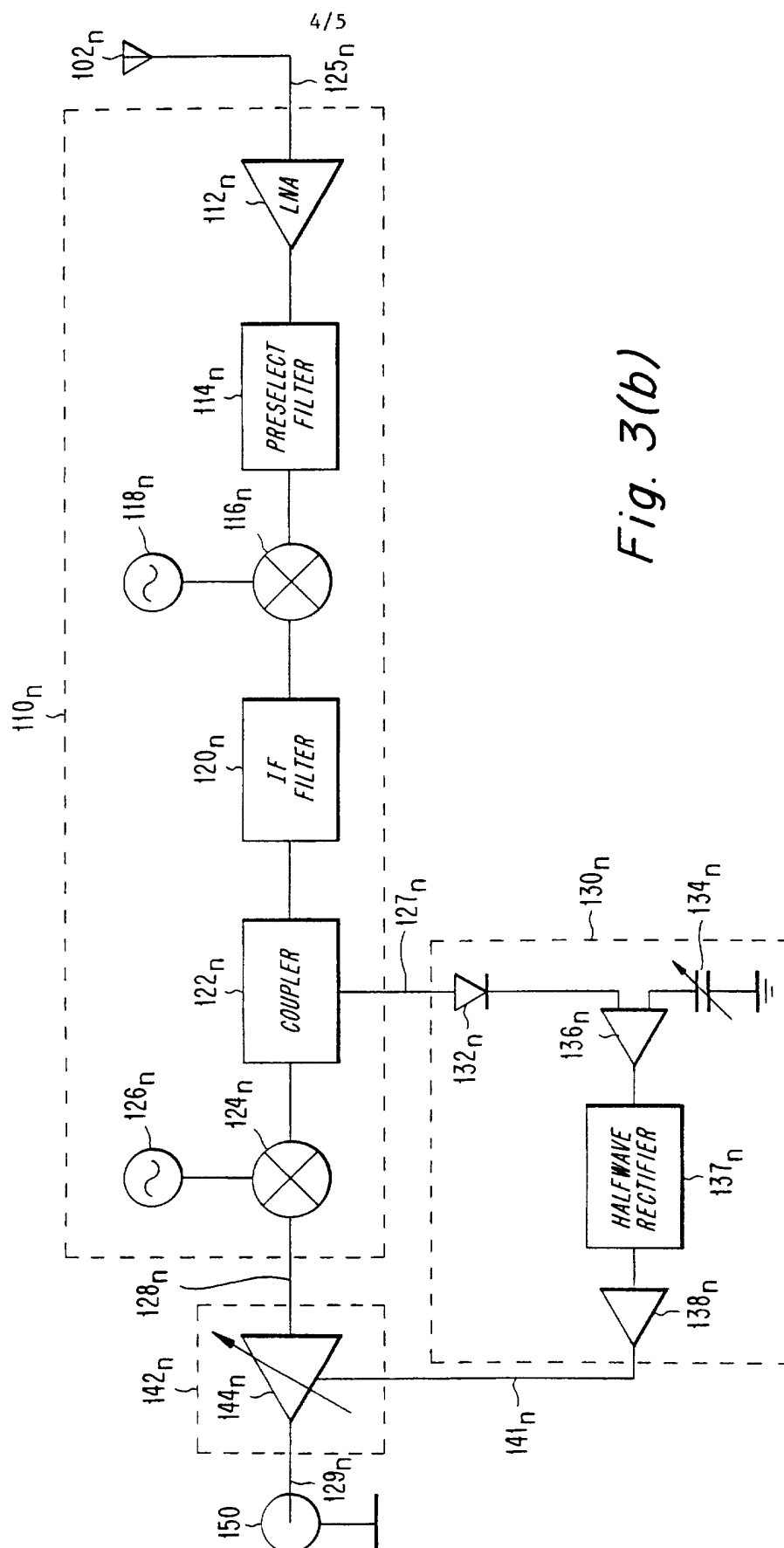
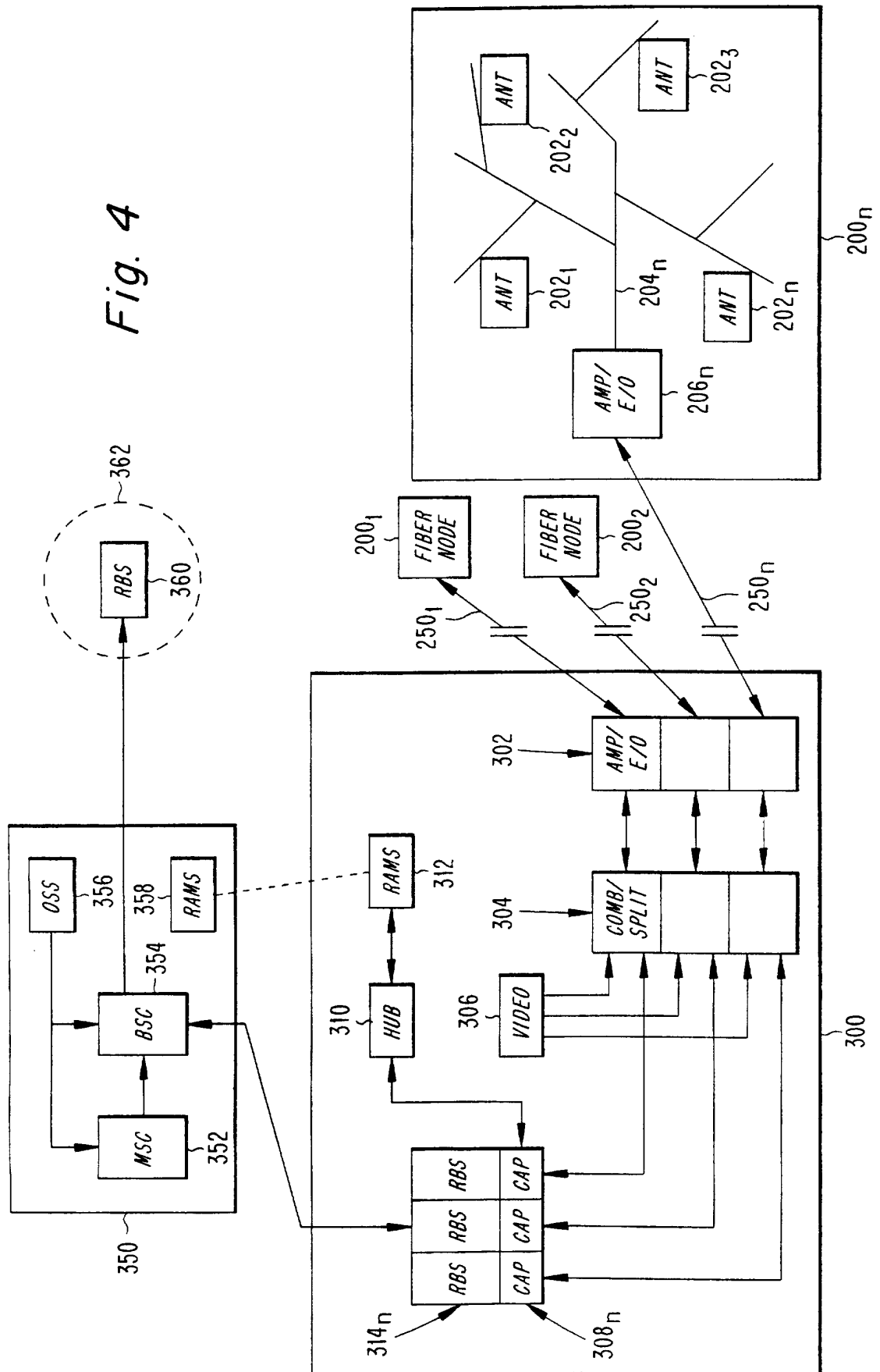


Fig. 3(b)

Fig. 4



INTERNATIONAL SEARCH REPORT

International Application No
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A. CLASSIFICATION OF SUBJECT MATTER IPC 6 H04Q7/36		
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 6 H04Q H04B		
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Electronic data base consulted during the international search (name of data base and, where practical, search terms used)		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
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Name and mailing address of the ISA 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	Authorized officer Breusing, J	

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