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

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
8 March 2001 (08.03.2001)

PCT

(10) International Publication Number
WO 01/17059 A1

(51) International Patent Classification[7]: H01Q 1/00

(21) International Application Number: PCT/US00/23772

(22) International Filing Date: 31 August 2000 (31.08.2000)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/152,129 2 September 1999 (02.09.1999) US

(71) Applicant (*for all designated States except US*): **TELIGENT, INC.** [US/US]; 8065 Leesburg Pike, Suite 400, Vienna, VA 22182 (US).

(72) Inventor; and
(75) Inventor/Applicant (*for US only*): **NESBIT, Gerald** [US/US]; Teligent, Inc., 8065 Leesburg Pike, Suite 400, Vienna, VA 22182 (US).

(74) Agent: **SCHNEIDER, Jerold, I.**; Arter & Hadden LLP, 1801 K Street, N.W., Suite 400K, Washington, DC 20006 (US).

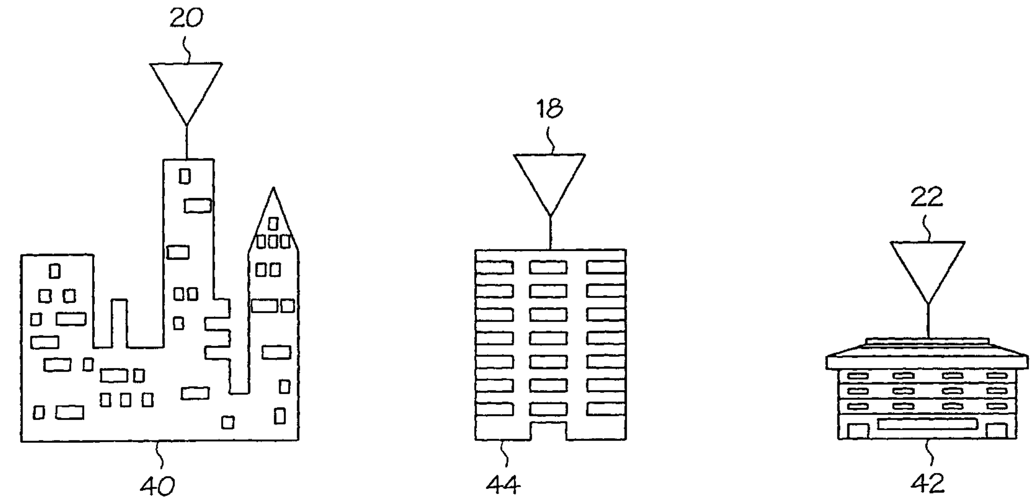
(81) Designated States (*national*): AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL,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

*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.*

(54) Title: ACTIVE REPEATER ANTENNA




(57) Abstract: An active repeater antenna (18) and a method of use of an active repeater antenna for providing communication to a receiver or node (22') outside the line-of-sight of a primary transmission node (20). In addition, the active repeater antenna and method of use may be applied to extend the radius of a primary transmission node in a telecommunications system.

WO 01/17059 A1

# ACTIVE REPEATER ANTENNA

Cross Reference

The present invention is based upon United States Provisional Application No. 60/152,129, filed 2 September 1999, which is hereby incorporated by reference and the priority of which is hereby claimed.

Technical Field

The present invention relates to an active repeater antenna and a method of use of an active repeater antenna for providing communication to a receiver outside the line-of-sight of a first transmitter. In addition, the active repeater antenna and method of use may be applied to extend the radius of a first transmitter in a telecommunications system.

Background Art

Cellular/wireless telephone communication systems are a relatively new and important global business. These systems utilize a variety of antenna and active repeater antenna components. One significant advantage of a wireless telephone communication system is that it provides ubiquitous coverage of wide areas, allowing individuals to communicate by telephone away from a fixed telephone outlet. Such systems dramatically increase efficiency and facilitate various activities and commerce.

In a typical analog cellular telephone system, a plurality of contiguous cells, each having a different set of assigned transmission frequencies, are arranged with handoff means for maintaining continuous communication with mobile telephones moving from cell to cell. As a mobile unit travels along a path that passes from one cell to another, a handoff occurs which switches the mobile unit from a frequency in the set assigned to the cell it is leaving to a new frequency in the set assigned to the cell it is entering. The handoff command is typically generated when the signal received from the mobile telephone falls below a preselected signal strength thus indicating that the mobile telephone is at the cell boundary.

Such cellular telephone communication systems must necessarily incorporate some type of radio signal repeater. A repeater is a receiver-transmitter combination, often referred to as a transceiver, for receiving a signal at one frequency and retransmitting the signal on a second frequency. Depending upon application, the transmitted frequency may be relatively close to the received frequency, e.g., 600 kHz, or greatly displaced from the received signal. Depending upon application, frequency, and government regulations, the transmitter in a repeater may be relatively powerful (hundreds of watts) or may be rated at just a few watts.

The present system and method, however, are not limited to mobile systems. For example, telecommunication between users in two buildings, where there is an antenna on each building, while not subject to the procedure of the handoff associated with mobile systems, is subject to government regulations, government assignment of frequencies, and power output limitations.

One issue of concern with prior systems, both mobile and fixed, is the power output limitations for each transceiver. Another issue of concern of prior systems, both mobile and fixed, lies in the fact that many systems cannot provide communication coverage for buildings or individuals that are outside the line-of-sight. The concept of line-of-sight is intended to refer to systems where the signal from one antenna does not reach the second antenna because of one or more of (a) a physical obstruction, which may be relatively permanent, e.g.,. a building, or relatively temporary, e.g., a swaying branch of a tree; (b) misalignment, primarily but not limited to point-to-point systems; and/or (c) a power output limitation. The misalignment problem may be further understood depending upon with width of the beam transmitted from a first antenna in the context of aligning the second antenna.

One problem associated with prior mobile systems, when a repeater antenna is used, is that the signal frequency shifts that occur from antenna to antenna markedly decrease the signal strength and reduce the ability of the signal to travel between antenna that are not in a line-of-sight. This frequency shifting necessitates large investment in capital equipment and large numbers of cells (each including a repeater, an antenna, and typically either ownership or lease of the associated real estate where the cell is located) to cover densely developed urban and suburban areas.

## Disclosure of Invention

The present invention relates to a method and apparatus for telecommunication between two locations, where there is an antenna at each location, and where there is no line-of-sight between the antennas at the two locations. The present invention also relates to a method and apparatus for telecommunication between two relatively fixed locations using active repeater antennas.

In a non-limiting example, this invention relates to the use of an active repeater antenna operating generally in the high frequency domain. This reduces, if not eliminates, the components heretofore found in active repeater antennas which function to first lower the frequency (e.g., through the use of an extra mixer and/or local oscillator) and thereafter to raise the frequency.

Currently, when developing a telecommunication system, especially (but not limited) to an area where there are buildings of varying heights, the top of each building is not within the line-of-sight of the top of all the other buildings. Thus, if an antenna was to be placed on the top of each building, a substantial number of antenna within a given radius from a first antenna (frequently referred to as a cell, although not limited to cellular communications systems) do not have a line-of-sight to the first antenna. In fact, it would often be true that no single antenna is within the line-of-sight of all other antenna. The present invention permits telecommunication between systems or users in, those buildings, or in communication with those buildings, which are outside of the line-of-sight of systems or users in (or in communication with systems in) other buildings. Additionally, for certain buildings located outside a telecommunication radius from an antenna, the present invention may be used to extend the telecommunication radius to include users in those buildings. The active repeater antenna and method of the present invention can be used, inter alia, for both Point-to-Point ("PTP") and Point-to-Multipoint ("PMP") applications.

It is known that radio frequency waves propagate in a straight path. Thus if there is an obstruction such as a building, between two antennas, there will be "gaps" or "holes" in the radio frequency waves on the side of a building distal from the first antenna. These "gaps" or "holes" are regions where the radio frequency waves do not reach, and thus are not received, by an antenna or receiver. This phenomenon is frequently explained by the statement that the radio frequency beams do not "bend" around a building. Thus if there was a first antenna from which the signals are propagated, and a second antenna to receive the signals, if the second antenna was located in a coverage gap or coverage hole, the second antenna would not receive the signals.

The present invention provides a method and apparatus to eliminate these gaps or holes as follows. The transmitted signal from a first antenna is directed to a repeater antenna which is within the line-of-sight of the first antenna. This repeater antenna receives incoming signal, amplifies the signal, and then transmits the amplified signal along a line-of-sight to the second antenna which is located in what was previously the coverage gap.

Brief Description of the Drawings

Reference should now be had to the following description taken in conjunction with the following drawings.

Fig. 1 is a block diagram of a passive repeater antenna;

Fig. 2A is a block diagram of one embodiment of an active repeater antenna;

Fig. 2B is a block diagram of an alternate embodiment of an active repeater antenna;

Fig. 3 is a diagrammatic illustration of a passive repeater antenna used to overcome non line-of-sight coverage;

Fig. 4 is a diagrammatic illustration of an embodiment of the present invention, wherein an active repeater assembly is used to overcome non line-of-sight coverage; and

Fig. 5 is a diagrammatic illustration of another embodiment of the present invention, wherein an active repeater assembly may be used to extend the range of coverage.

Description of the Preferred Embodiments

One embodiment of an active repeater antenna is as part of a system designed to interface with a telecommunications system which is operating in the frequency range which has been referred to as the millimeter range. This nomenclature is intended to refer to signal frequencies broadly in the 18 to 325 GHz range, where the signal length is so short that the signals will not penetrate a physical obstruction such as a tree limb or a building. The active repeater antenna embodiment is designed to provide coverage for those buildings that are outside the line-of-sight of a first antenna, which may be, but is not limited to, a standard telecommunications system node. In addition, this embodiment of an active repeater antenna is provided to help extend the coverage from the first antenna.

A repeater antenna is classified as either passive or active, depending on whether active devices are used or not. Interconnecting two antennas 10, 12, with an interconnect medium 14, such as a waveguide, as shown in Fig. 1, configures the antenna as a passive repeater 16. In use, the entire assembly of Fig. 1 is attached to a common platform. The primary disadvantage of a passive repeater antenna is the difficulty of optimizing antenna alignment without the aid of external test equipment. Furthermore, the use of the passive repeater antenna is interrupted when it is desired to monitor the status of the antenna. Finally, a passive repeater antenna may not be able to provide sufficient gain.

A second type of repeater antenna and the one preferred in the present invention in one or more embodiments as described herein, uses active components, such as a low noise amplifier, a driver amplifier and a power amplifier, for relaying the RF signal as is generally shown in Figs. 2A and 2B. The advantages of the active repeater antenna include, for example, that it provides greater coverage distance compared to passive repeater, that it provides an external monitor port for aligning the antennas, and that the system can be monitored without interrupting service.

Referring again to Fig. 2A, an embodiment of the active repeater antenna will be explained. In this embodiment, an active repeater antenna 18 is positioned for line-of-sight communication between a first node 20 and a second node 22. The first node could be a base station or a service provider, and the second node could be the location of a customer. This nomenclature, however, is merely for illustrative purposes.

For understanding the breadth of the present invention, it should be appreciated that the repeater antenna is to facilitate telecommunication between two or more entities. One entity may be a service provider and the other entities may be customers. One entity may be business headquarters and the other entities may actually be branch offices. One or more of the entities may be located in a building, or one or more may be remote from a building, and one or more of the entities may even be mobile. For the purpose of explanation, while a first antenna is illustrated and will be described as being located on a first building, the term node refers to a user, which may or may not be located in the first building. For convenience, but not for purposes of limitation, this may also be referred to as a first or primary node. Similarly, while other antenna are illustrated and will be described as being located on a other buildings, the term node refers to a user which may or may not be located in one of the other buildings. Again, for convenience, but not for purposes of limitation, this may be referred to as a second node. Each node may be considered, inter alia, as a source of signals to be transmitted and a destination for signals to be received. Diagrammatically, for ease of illustration, a primary or secondary node may be illustrated merely as an antenna.

Thus the term node is not limited to a building or a customer or user physically located in the building, but is to be thought of in the broadest sense. For example, a service provider may be located in a building, with a system which is hard wired to an antenna on top of that building. As another example, a service provider may be located remote from a building, and may be in either wireless or hard wire telecommunication with the system which is coupled to an antenna on top of a building.

A signal from a first node 20 is received at a first antenna 24 of the repeater antenna 18. This signal is fed to a diplexer 25, and, as is known, the use of a diplexer permits full duplex communication between the nodes 20 and 22. The link or path from the first node 20 to the second node 22 will be referred to as downlink signal flow. The diplexer 25 allows the desired frequency to pass through while blocking or rejecting or filtering out all other frequencies. This permits the diplexer to pass signals in two directions, with those signals being isolated from each other, thus preventing potential feedback oscillation. The diplexer 25 permits the desired frequency signal from source or first node 20 to pass to the input of a low noise amplifier/driver amplifier stage 26. The low noise amplifier, or LNA, functions to amplify the weak high frequency signal without contributing additional noise to the signal, while the driver amplifier, or DA, boosts the signal level from the LNA further. The output from the driver amplifier is then fed to a power amplifier or PA 28. A typical, but non-limiting gain for a high frequency LNA and driver stage may be between 20 to 30 dB. The overall gain requirement for the repeater may be achieved by cascading several LNA and driver stages in series. The LNA, driver amplifier and PA may have different noise figures and output power ldB compression points.

The amplified signal from the output of the PA stage 28 is coupled to a detector diode 30 through a directional coupler 31. The typical coupling value for the directional coupler for this application may be between -15 dB to -20 dB. The detector diode converts the high frequency component to DC voltage, which can be amplified further if desired. The DC voltage can be connected to any commercially available voltmeter for aid in the alignment of the repeater antenna to the first node. The voltmeter reading varies in proportion to the accuracy of alignment. Thus, the higher the reading on the voltmeter, the closer the first node or source 20 and the repeater antenna 24 are in alignment. The signal from the directional coupler 31 is then passed to a second diplexer 25'. The second diplexer has the same filtering characteristic as the first diplexer 25 and will route the amplified signal to the second antenna 32 of the active repeater antenna. The output from the second antenna 32 is transmitted to the second node 22. As may be appreciated, the second node 22 may be a customer or user, located in a building which is not in the line-of-sight from the building where the first node 20 is located.

Since full duplex operation is preferred, although not mandatory since messages can be transmitted in a broadcast mode, the path of a signal from the second node 22 back through the active repeater antenna 18 to the first node 20 will now be explained. The signal transmitted from the second node 22 is received at the second antenna 32 and this may be considered the uplink path. The signal from the second antenna 32 is passed through the second diplexer 25' and, through the diplexer filtering, is provided to a low noise amplifier/driver amplifier (LNA/DA) 26'. The output of the LNA/DA 26' is the input to a power amplifier (PA) 28', the output of which goes through another directional coupler 31', and detector diode 30'. As may be appreciated, the detector diode 30' in the uplink signal flow path is used to aid in the alignment between the antenna 32 in the active repeater 18, and the antenna 32 at the second node.

The DC/gain adjustment circuit 34 supplies the necessary power to all the active amplifiers in the repeater antenna 18. In addition to supplying the DC power, the gain adjustment through the entire repeater antenna 18 can be changed by adjusting the DC operating point of the amplifiers. By incorporating the gain adjustment functionality in the repeater antenna, saturating the input of the intended receiver is eliminated. This result may also be achieved by an in-line, variable attenuator in lieu of adjusting the DC operating point.

With reference to Fig. 2B, another active repeater antenna system is illustrated in block diagram form. One difference between the system of Fig. 2A and the system of Fig. 2B is the following. Fig. 2A, it will be remembered, included directional coupling with a detector diode in both the downlink and uplink paths. In the system of Fig. 2B, instead of directional coupling with a detector diode, an isolator 36 is provided in the downlink path between the output of the low noise amplifier driver amplifier 26 and the power amplifier 28. Similarly, in the uplink path, an isolator 36' is provided in the between the output of the low noise amplifier driver amplifier 26' and the power amplifier 28'. Each isolator is a passive component which does not require any DC power. The isolator provides impedance matching between the output of the LNA/driver amplifier and the input of PA, and prevents any undesired frequency components propagating in the reverse direction. Thus isolator 36 prevents undesired frequency components from propagating back toward antenna 24 and node 20, while isolator 36' prevents undesired frequency components from propagating back toward antenna 32 and node 22.

A second difference between the active repeater antenna 18 of Fig. 2A as compared to the active repeater antenna of Fig. 2B is that the active repeater antenna of Fig. 2B does not include the DC voltage detection circuitry for either the downlink or uplink paths. The DC voltage detection circuitry is not required for the repeater to function properly, but it does simplify the alignment of the repeater with respect to antennas at the first node 20 and the second node 22. Better alignment, of course, will improve overall system performance.

The active repeater antennas of both Figs. 2A and 2B operate in the high frequency domain. The main advantage of maintaining an active repeater in high frequency operation is the elimination of the need for a high frequency mixer and highly stabilized local oscillator. The use of a mixer, which is a non-linear component, it is undesirable because of the non-linearity. A local oscillator, which might otherwise be required in repeater antenna systems which first reduce and then increase the frequency, is that local oscillators are extremely susceptible to fluctuation in response to outdoor temperature variations. While a stabilized local oscillator could theoretically be designed, at a higher cost and with undesirable complicated phased-locked loop control circuitry, it is not known if such an oscillator would actually perform satisfactorily for the desired purpose in the present environment. An additional advantage of operating the active repeater antenna of the present invention at high frequency is the elimination of restrictions on the data throughput capability between the nodes 20, 22 due to wider bandwidth operation. Additionally, high frequency operation allows the elimination of RF and IF dependency.

Both passive and active repeater antennas can be used for non line-of-sight coverage, as will now be explained. An example of non line-of-sight coverage application by a passive repeater antenna is shown in Fig. 3. In this example, the first node 20 is located at a first building 40. It is desired to provide telecommunication with one or more of the second nodes 22, 22', 22" located on buildings 42, 42', 42", respectively. However, a building 44 is located between the first building 40 and the buildings 42, 41', 42" and building 44 has a height which is sufficient so as to block line-of-sight communication from node 20 to each of nodes 22, 22', 22". It must be remembered that the signal from node 20 is at high frequencies, such as 24 GHz. Since the ratio of wavelength to frequency is based upon the formula $f = 1/\lambda$, the wavelength at such frequencies is too short to penetrate the structure or building. Thus the signal from node 20 can not penetrate through the building 44, and building 44 is sufficiently high so as to block signals to and from node 20.

For purpose of comparison, consider a passive repeater antenna 16 positioned on building 44. Thus, even though the shorter buildings 42, 42' and 42"are not in the line-of-sight of the node 20, the use of the repeater antenna provides for full duplex communication between the first node 20 and each of the second nodes 22, 22', 22".

One passive repeater antenna which will provide the aforementioned duplex communication function can have the following specifications:

Repeater configuration – 30 cm parabolic antenna and 15° sector antenna
Path 1 loss = 126 dB, 2 Km at 25 GHz
Path 2 loss = 98.5 dB, 0.08 Km at 25 GHz
Total antenna gain = 15 dBi + 34.5 dBi +22 dBi + 34.5 dBi = 106 dBi
Transmit output power = +24 dBm
Receive signal level = +24 dBm + 106 dBi - 126 dB - 98.5 dB = -94.5 dBm
Receiver threshold = -88dBm
Fade margin = 20 dB (rain zone K)
Required receive level = -68 dBm
Delta gain = - 94.5 dBm +68 dBm = -26.4 dB

Another passive repeater antenna for non line-of-sight full duplex communication will have the following specifications:

Repeater configuration -- Two 60 cm parabolic antennas
Path 1 loss = 120.4 dB, 1 Km at 25 GHz
Path 2 loss = 114 dB, 0.5 Km at 25 GHz
Total antenna gain = 15 dBi + 40 dBi + 40 dBi + 34.5 dBi = 129.5 dBi
Transmit output power = +24 dBm
Receive signal level = +24 dBm + 129.5 dBi - 120.4 dB - 98.5 dB = -65.4 dBm
Receiver threshold = -88 dBm
Fade margin = 12 dB

Required receive level = -66 dBm

Delta gain = -65.4 dBm + 66 dBm = 0.6 dB

Based upon the above examples and resultant delta gain, the passive repeater antenna has very limited application. The non line-of-sight buildings must be located close to the node and larger size 60 cm diameter parabolic antennas are required to close the link.

The following example, in the context of Fig. 4, evaluates the use of an active repeater antenna of the present invention for non line-of-sight coverage. Specifically, a first node 20 is located on the top of a first building 40 and the first node, e.g., a customer or base station, may be located within or near the building. The signal transmissions between the base station or customer and the first node 20 may be either in hard-wired or wireless form as previously described. It is desired to provide telecommunication with a customer or base station in or near building 42 and, for this reason, a second node 22 is located on top of building 42. The second node, e.g., customer or base station, may be located within or near building 42, and again, the signal transmissions between the base station or customer and the second node 22 may be either in hard-wired or wireless form. As illustrated, there is the absence of a line-of-sight between node 20 and node 22. Thus, a building 44 is provided with an active repeater antenna 18. Building 44 is in the proper location and has the proper height to provide line-of-sight communication between its antenna 18 and both of nodes (antennas) 20 and 22.

An active repeater antenna for non line-of-sight duplex communication may have the following specifications:

Repeater configuration – 30cm parabolic antenna, amplifier, and 15° sector antenna

Path 1 loss = 126 dB, 2 Km at 25 GHz

Path 2 loss = 126 dB, 2 Km at 25 GHz

Total antenna gain = 15 dBi + 34.5 dBi +22 dBi + 34.5 dBi = 106 dBi

Repeater amplifier gain = 70 dB

Transmit output power = +24 dBm

Receive signal level = +24 dBm + 106 dBi + 70 dB - 126 dB - 126 dB 52 dBm

Receiver threshold = -88 dBm

Fade margin = 30 dB

Required receive level = -58 dBm

Delta gain = -52 dBm + 58 dBm = 6 dB

Based upon the resulting Delta gain in this example, the active repeater antenna offers greater flexibility for implementing non line-of-sight coverage. Thus, for further example, if the antenna on building 44 was a regular antenna rather than a repeater antenna, there would be a gap or hole in the coverage since transmissions from primary node 20 could not reach the antenna on building 42.

Another aspect of the present invention is to utilize the active repeater antenna to extend the range of coverage. This feature is illustrated and explained in the context of Fig. 5. In the non-limiting example of Fig. 5, there is an antenna/primary node 20 associated with building 40. At a frequency of 24 GHz, the transmission range of signals may be generally from about 3.0 km to about 5.0 km, based upon present day government regulations and power limitations. If we assume that the buildings 42, 42', 42" and 44 are all within the line-of-sight of antenna/node 20, and within 5.0 km, then the use of a repeater antenna 18 on building 44 will permit transmission between node 20 and antennas/nodes 46, 46', 46" on buildings 48, 48', and 48", respectively, notwithstanding that those buildings 48, 48', and 48", are beyond the range of transmissions from antenna/node 20.

In the situation where the system at antenna/node 20 has excess capacity, i.e., antenna/node 20 is not fully utilized in communications with nodes 22, 22' and 22", then the use of the active repeater 18 to extend the range of coverage reduces the need for another "primary" node, thus minimizing the outlay for capital equipment in the nature of another "primary" node or base station. This is beneficial in various situations including, but not limited, to the situation where a service provider is located at building 40 and is providing service to customers in buildings 48, 48', and 48'. The use of a repeater antenna 18 at building 44 avoids the need for the service provider to install another "base station".

An example of an active repeater antenna may have the following characteristics:

Repeater configuration – 30 cm parabolic antenna, amplifier, and 30 cm parabolic antenna

Path 1 loss = 132 dB, 4 Km at 25 GHz

Path 2 loss = 126 dB, 2 Kin at 25 GHz

Total antenna gain = 15 dBi + 34.5 dBi + 34.5 dBi + 34.5 dBi = 118.5 dBi

Repeater amplifier gain = 75 dB

Transmit output power = +24 dBm

Receive signal level = +24 dBm + 118.5 dBi + 75 dB - 132 dB - 126 dB 40.5 dBm

Receiver threshold = -88 dBm

Fade margin = 45 dB

Required receive level 43 dBm

Delta gain = - 40.5 dBm + 43 dBm = 2.5 dB

Further examples of active repeater antenna systems will now be explained. The primary node or antenna 20 may be a 90° sector antenna, whose signals are received at the repeater antenna with a 30 cm parabolic antenna. The output from the active repeater antenna is via a 45° sector antenna, with a 30 cm parabolic antenna as the secondary node 22. Another alternative is a 60 cm parabolic antenna 20 and a 30 cm parabolic antenna 22, where the active repeater antenna includes a 60 cm parabolic and a 45° sector antenna, respectively.

Another variation of the active repeater system is as follows. While a 90° sector antenna may be used at node 20, the repeater antenna may benefit from a more narrow beam. For example, a 3° beam antenna at both sides of the repeater antenna may provides satisfactory functionality. Furthermore, if multiple nodes 22, 22' are geographically close together, then a repeater antenna beam of 15° or less may provide adequate coverage to both secondary nodes.

While the overall range, under present governmental regulations, is about 3.0 to about 5.0 km, the actual proximity of a second node 22 to the active repeater antenna can not always be predicted in advance. Thus it is helpful to have an adjustable gain for the active repeater antenna. This adjustable gain, however, is preferable set at the time of physical installation, to avoid antenna saturation.

Various other combinations of sector horn antennas and parabolic antennas maybe selected and fall within the scope of the present invention. Any shortage of gain anticipated by a particular configuration of an active repeater antenna for extended cell radius coverage may be overcome by increasing the gain requirement of the amplifier in the active repeater antenna.

A passive repeater antenna has limited application for non line-of-sight coverage, and it is not feasible for extended radius application. The active repeater antenna offers greater flexibility for non line-of-sight coverage as compared to the passive repeater antenna and is useful for extending cell radius coverage, provided a high performance amplifier (such as, for example, one designed for 70 dB net gain) is used.

As a non-limiting example, a 30 cm antenna and a 15° antenna may be obtained from Radio Waves, of North Billerica, Massachusetts, USA, as part numbers HPLPD1-24 and HRND – 24-15-23, respectively, and the remaining electronics for a repeater antenna may be obtained from Remec Wireless, Inc., of San Diego, California, USA, as part number W 30322-001.

Without further elaboration, one skilled in the art with the preceding description can utilize the present invention to its fullest extent. The preceding examples are illustrative only, and not intended to limit the present invention in any way. Other embodiments of the invention will be apparent to those skilled in the art from consideration of the specification and practice of the invention disclosed herein. It is intended that the specification and examples be considered as exemplary only.

What Is Claimed Is:

1. An antenna system comprising:

a first antenna at a first location;

a second antenna at a second location;

said first and second locations not being within a line-of-sight of each other; and

an active repeater antenna positioned at a third location which is within the line-of-sight of each of said first and second locations, to receive signals from said first antenna and transmit said signals to said second antenna.

2. An antenna system comprising:

a first antenna at a first location;

a second antenna at a second location;

said first and second locations not being within a line-of-sight of each other; and

a repeater antenna positioned at a third location which is within the line-of-sight of each of said first and second locations, to receive signals from said first antenna and transmit said signals to said second antenna; said signals being transmitted at a frequency in excess of 10 GHz.

3. A method of data transmission including:

positioning a first antenna at a first location;

positioning a second antenna at a second location;

said first and second locations not being within a line-of-sight of each other; and

positioning a repeater antenna at a third location which is within the line-of-sight of each of said first and second locations, to receive signals from said first antenna and transmit said signals to said second antenna; said signals being transmitted at a frequency in excess of approximately 18 GHz.

4. The invention according to any of the previous claims, wherein at least one of said locations is fixed.

5. The invention according to any of the previous claims, wherein a physical obstruction prevents the first and second locations from being with a line-of-sight of each other.

6. The invention according to any of the previous claims, wherein physical distance prevents the first and second locations from being with a line-of-sight of each other.

7. The invention according to any of the previous claims, wherein the active repeater antenna operates in the duplex mode.

8. The invention according to any of the previous claims, wherein the repeater antenna transmits a signal in a sector of generally less than 30°.

9. The invention according to any of the previous claims, wherein the repeater antenna is free of frequency shifts between received and transmitted signals.

10. The invention according to any of the previous claims, wherein the first antenna transmits signals in a point-to-multipoint mode.

11. The invention according to any of the previous claims, wherein the repeater antenna transmits in a point-to-point mode.

12. The invention according to any of the previous claims, wherein the repeater antenna includes at least one of (a) DC power adjustment; (b) gain adjustment; and (c) DC voltage detection circuitry.

13. The invention according to any of the previous claims, wherein the repeater antenna provides greater than 70dB gain.

14. The invention according to any of the previous claims, wherein the repeater antenna includes a sector horn antenna transmitting over a sector of approximately 15°.

15. The invention according to any of the previous claims, wherein the repeater antenna includes a parabolic antenna transmitting a beam of approximately 3°.

16. The invention according to any of the previous claims, wherein the repeater antenna includes gain adjustment.

17. The invention according to claim 16 wherein the gain adjustment is based on adjusting the DC operating point.

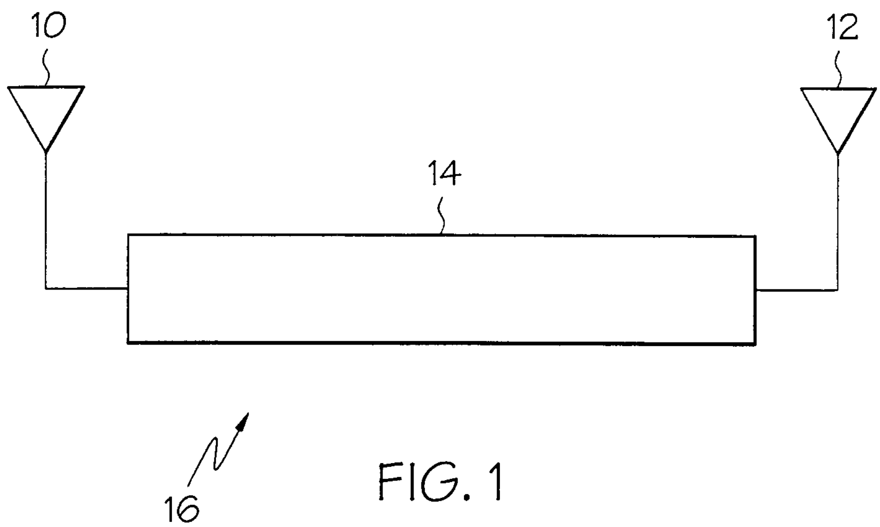



FIG. 1

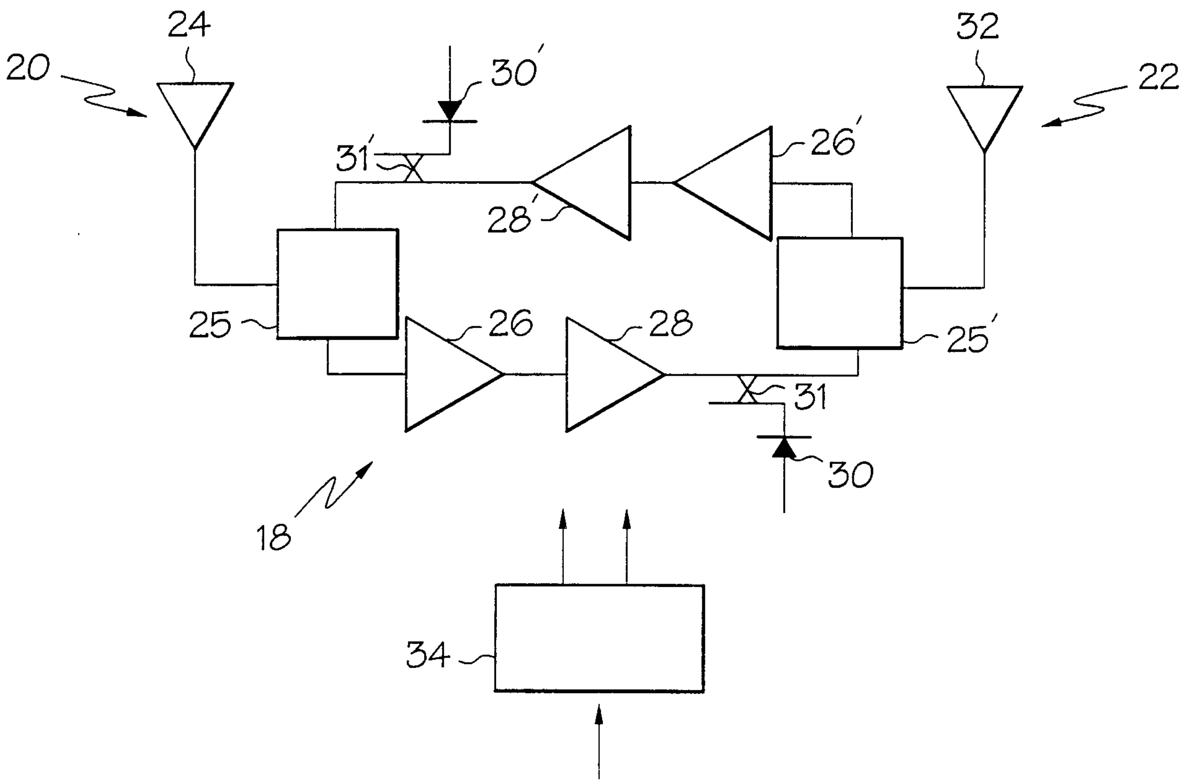



FIG. 2A

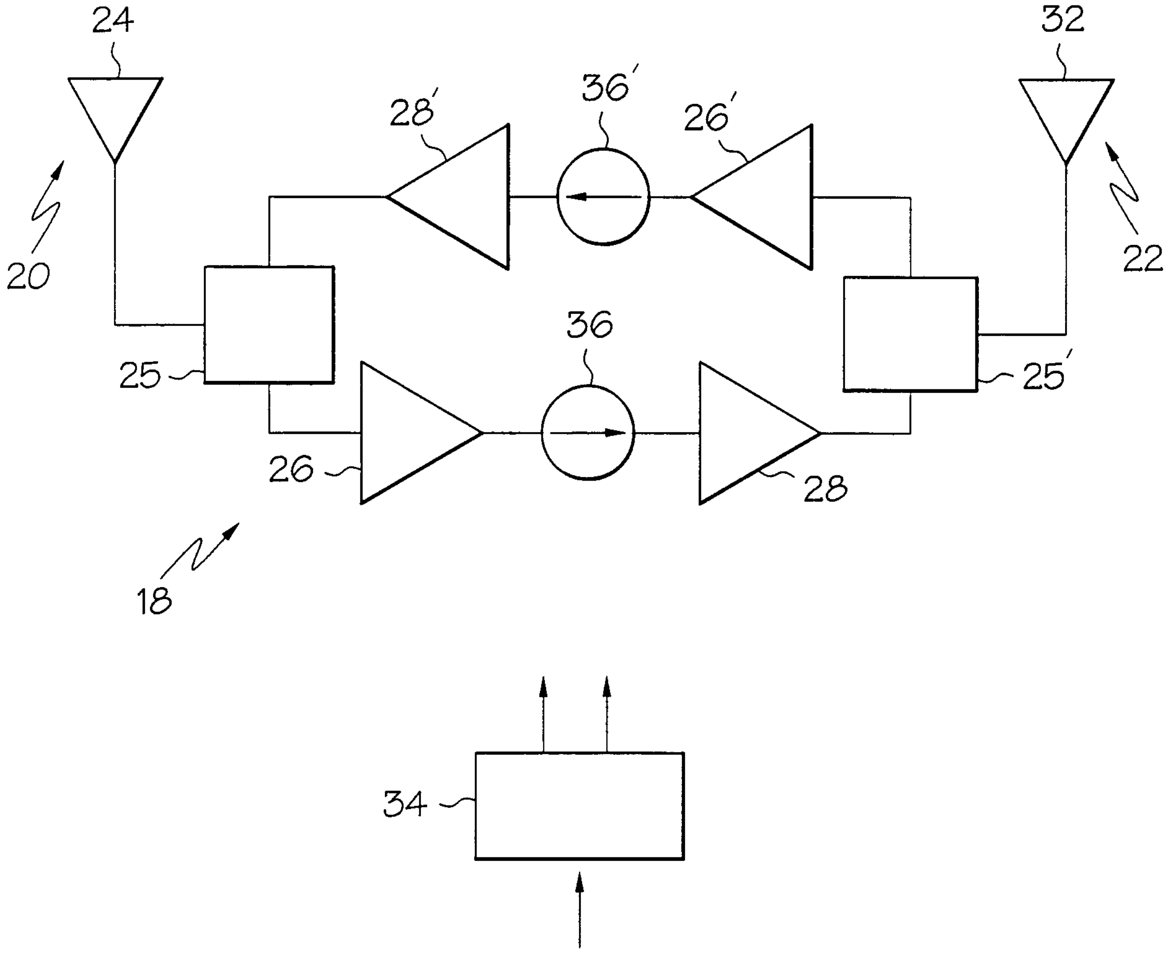



FIG. 2B

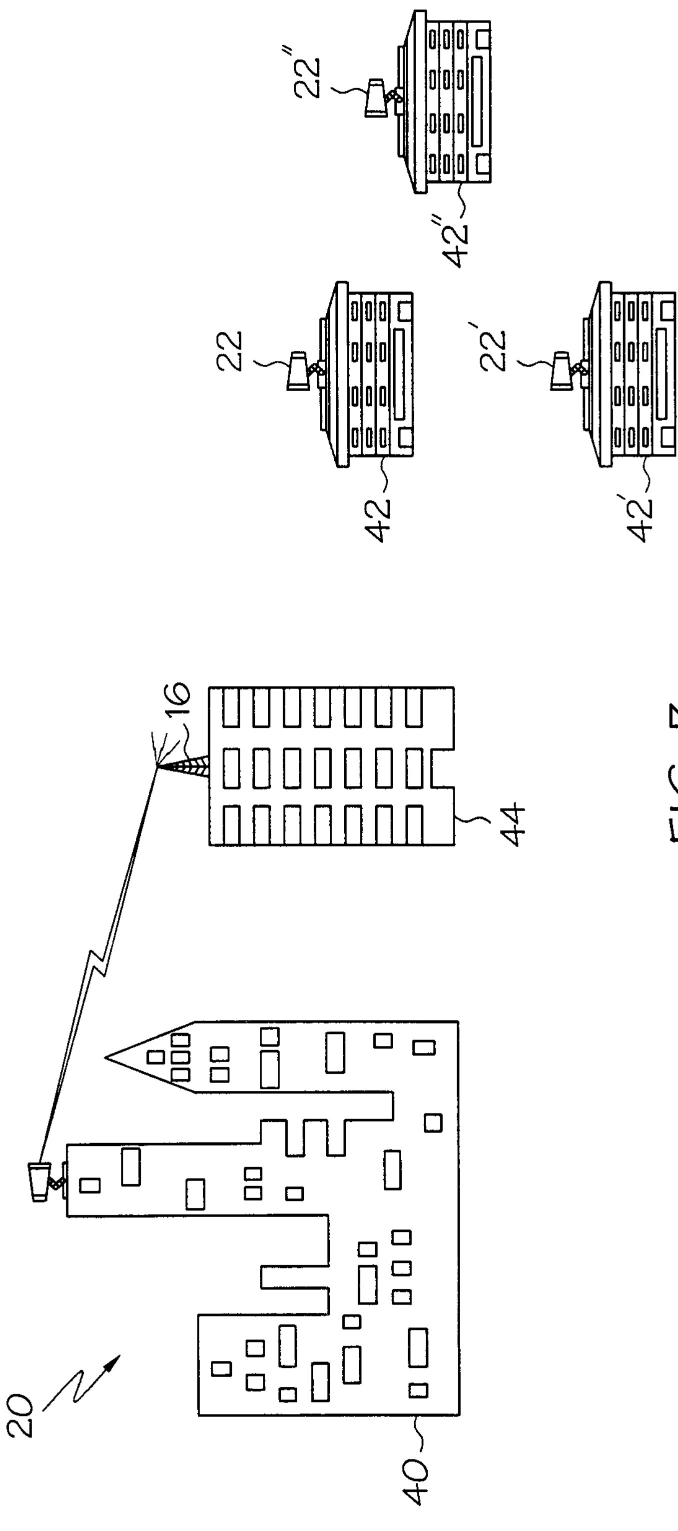



FIG. 3

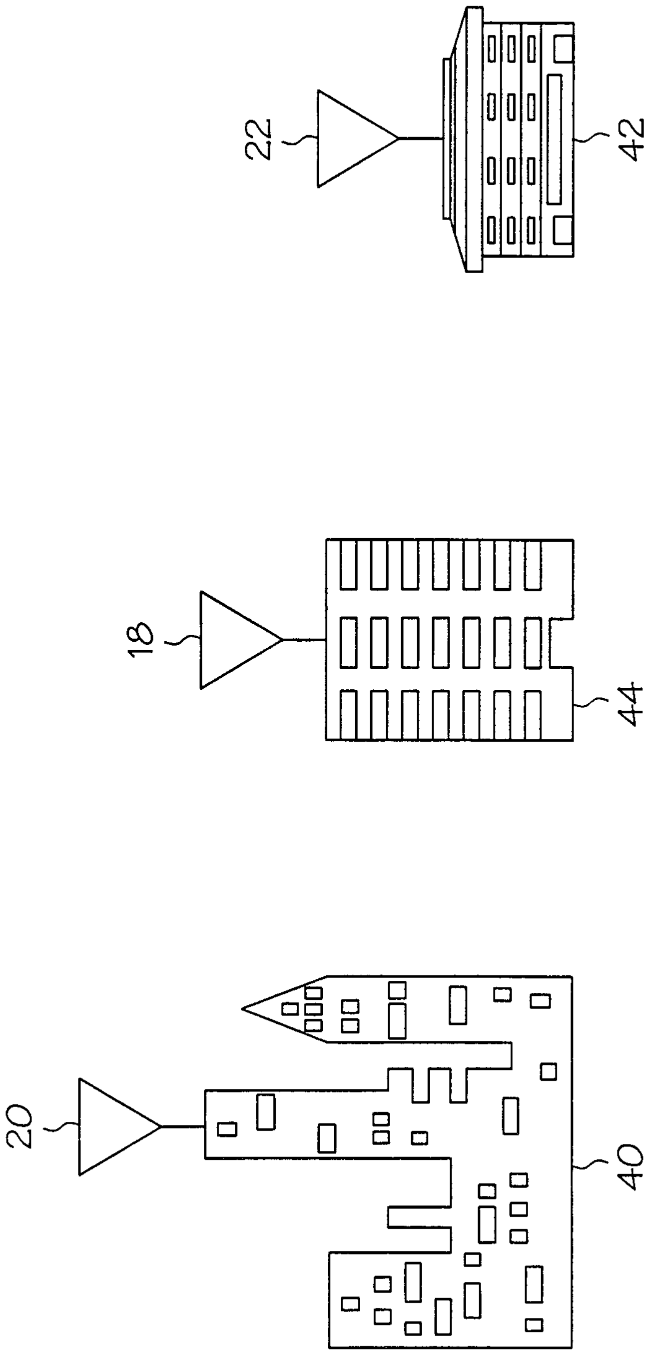



FIG. 4

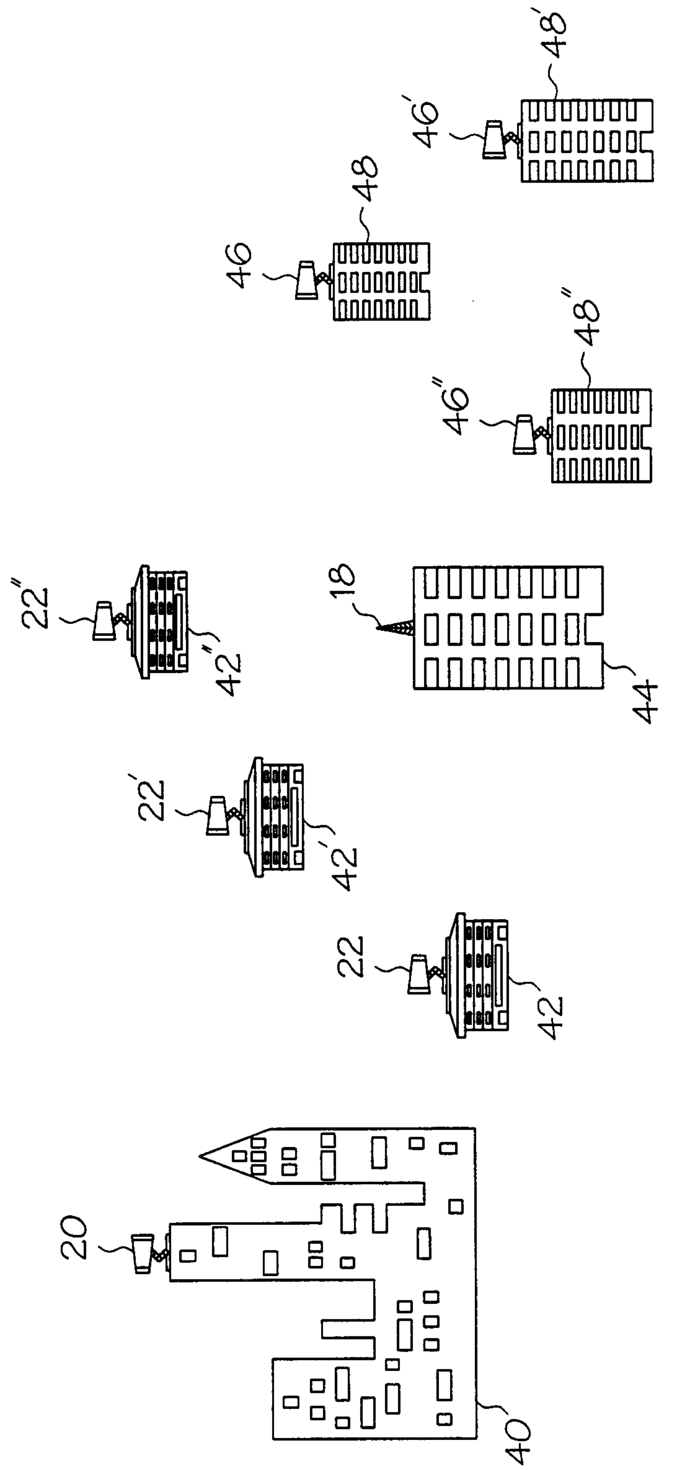



FIG. 5

# INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 00/23772

**A. CLASSIFICATION OF SUBJECT MATTER**
IPC 7 H01Q1/00

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 H01Q

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)

EPO-Internal, WPI Data, PAJ

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category ° | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | US 5 257 405 A (REITBERGER PETER) 26 October 1993 (1993-10-26) column 11, line 13 -column 12, line 16; figure 1 column 1, line 55 -column 1, line 58 --- | 1-17 |
| X | WO 97 46040 A (WHITAKER CORP) 4 December 1997 (1997-12-04) page 5, line 32 -page 5, line 34; figure 1 page 1, line 8 -page 1, line 24 --- | 1-17 |
| X | US 4 747 160 A (BOSSARD BERNARD) 24 May 1988 (1988-05-24) column 9, line 64 -column 10, line 49; figures 5A-5B --- -/-- | 1-17 |

[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 |
|---|---|
| 4 December 2000 | 11/12/2000 |

| 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 | Villafuerte Abrego |

1

# INTERNATIONAL SEARCH REPORT

Intern: al Application No
PCT/US 00/23772

**C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category ° | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| A | EP 0 833 403 A (LUCENT TECHNOLOGIES INC) 1 April 1998 (1998-04-01) column 2, line 57 -column 3, line 35; figure 1 | 1-17 |

1

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

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US 00/23772

| Patent document cited in search report | | Publication date | Patent family member(s) | | | Publication date |
|---|---|---|---|---|---|---|
| US 5257405 | A | 26-10-1993 | DE | 4017234 | A | 05-12-1991 |
| | | | DE | 59101259 | D | 05-05-1994 |
| | | | EP | 0459236 | A | 04-12-1991 |
| WO 9746040 | A | 04-12-1997 | EP | 0903048 | A | 24-03-1999 |
| | | | US | 6141557 | A | 31-10-2000 |
| US 4747160 | A | 24-05-1988 | AT | 122837 | T | 15-06-1995 |
| | | | AU | 602064 | B | 27-09-1990 |
| | | | AU | 1303288 | A | 15-09-1988 |
| | | | CA | 1333089 | A | 15-11-1994 |
| | | | DE | 3853790 | D | 22-06-1995 |
| | | | DE | 3853790 | T | 08-02-1996 |
| | | | EP | 0282347 | A | 14-09-1988 |
| | | | ES | 2074438 | T | 16-09-1995 |
| | | | GR | 3017045 | T | 30-11-1995 |
| | | | JP | 2064813 | C | 24-06-1996 |
| | | | JP | 7095815 | B | 11-10-1995 |
| | | | JP | 63283288 | A | 21-11-1988 |
| | | | MX | 164756 | B | 22-09-1992 |
| EP 0833403 | A | 01-04-1998 | US | 5832365 | A | 03-11-1998 |
| | | | CA | 2213369 | A | 30-03-1998 |
| | | | JP | 10126325 | A | 15-05-1998 |