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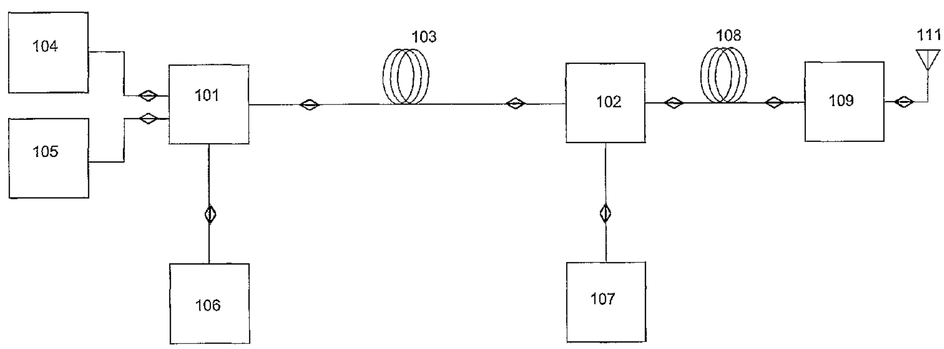


(57) Abstract: A hub for use in an optical communication system receives, combines and distributes signals including radio frequency and baseband digital signals over an optical fibre communication system. Embodiments of the invention restrict the set of modes launched into the optical fibre, for example, by preventing very high order modes and/or very low order modes from being excited in the fibre or by limiting the amount of power in these mode groups relative to other mode groups.

WO 2006/136811 A1

# Optical Transmission System

The present invention relates to an optical transmission system, to a hub and to a multiservice distribution unit.

An embodiment receives a plurality of signals; combines the plurality of signals, and distributes the combined signal concurrently over an optical communications system. The plurality of signals comprise at least one digital baseband signal and at least one radio frequency (RF) signal.

In another embodiment a communication system is provided carrying a plurality of RF signals. In yet another embodiment, the communication system carries one or more RF signals and the embodiment has a plurality of optical paths.

The term "baseband" as used herein means that the signal is transferred without other modulation or frequency shifting. The term "radio frequency" as used herein means that the signal is transferred after modulation by a carrier having a radio frequency, or after frequency shifting.

In some embodiments, the digital baseband signal comprises a Gigabit Ethernet (GbE) signal. In further embodiments, the RF signal comprises at least one of the group comprising: wireless local area network (WLAN), for example IEEE 802.11a, IEEE 802.11b, IEEE 802.11g, IEEE 802.11n, IEEE 802.16 (WiMax); and mobile telecommunication signals (e.g. third generation mobile (UMTS (Universal Mobile Telecommunication System) or 3G), DECT (Digital Enhanced Cordless Telecommunications), TETRA, AMPS (Advanced Mobile Phone System), PDC (Personal Digital Cellular), PACS (Personal Advanced Communication System), PHS (Personal Handyphone System), GSM (Global System for Mobile Communications), GPRS (General Packet Radio Service), EDGE (Enhanced Data for GSM Evolution), CDMA (Code Division Multiple Access), W-CDMA (wideband CDMA), TD-SCDMA (Time Division Synchronous CDMA)). The combination of digital baseband and RF signals may be transmitted over multimode optical fibre to a multiservice distribution unit where the signal may be separated or split and the component signals may be directed to respective antenna units, base stations, access points and/or switches.

A typical area of application of embodiments of the present invention is to optical communication systems involving multimode fibres installed in or connecting compartmented spaces such as residential buildings, corporate office buildings, shopping centres, subways and airports, and wherein the optical communications system provides indoor wired GbE connection, WLAN and 3G coverage.

There is currently much interest in the implementation of distributed antenna systems (DAS's) for providing wireless service coverage for mobile equipment users. Most existing DAS's are currently constructed using coaxial cables to connect a central distribution unit to each distributed antenna. To extend the range of area that may receive services provided by the DAS's, the use of optical fibre is preferred to coaxial cable since optical fibre may have a lower signal transmission loss per unit length. Further, optical fibre is preferred because it has a wider usable bandwidth for a predefined acceptable signal loss over a certain distance than coaxial cable and so may provide a wireless service operated in a higher radio frequency (RF) band. Hence, operators can extend the range of services provided by their DAS's beyond that achievable with a coaxial cable-based system.

Most optical fibres that have already been installed in buildings are of a multimode type. These dominate existing networks because they are relatively easy to install. Existing multimode fibres are frequently used for carrying baseband digital services such as the Ethernet local area network (LAN). However, due to the modal dispersion the achievable modulation bandwidth-length product is relatively limited e.g. for a 62.5 micron diameter fibre the bandwidth-length product is limited to around 160 MHz.km for the transmission of a signal having a 850 nm wavelength and 500 MHz.km for the transmission of a signal having a 1300 nm wavelength. Hence, multimode fibres have been mainly used for relatively low bit-rates or low frequency applications with short fibre spans.

It would therefore be advantageous if existing multimode fibres originally intended only for LAN signals could also be used to carry out the higher frequency wireless services in addition to the baseband digital signal. Such an approach would be cost-effective since pre-installed multimode fibres are already in use in a plurality of locations. However, a number of problems must be overcome before simultaneous baseband and RF signals can be transported over the same multimode fibre. One such problem is the relatively low bandwidth-length product of multimode fibre as described above. Another problem is additional noise generated in multimode fibre when both baseband and RF optical signals are carried on a fibre at the same time.

Multimode optical fibres are also used in new installations of optical communication systems, primarily because they are relatively easy to install and the terminal equipment is relatively cheap. Such communication systems are frequently used for carrying baseband digital signals to and from a plurality of user terminals throughout an area. The components associated with multimode fibres such as photodetectors, optical adaptors and couplers may also be cheaper than those used with single mode fibres.

Embodiments of the invention relate to an optical communications system for simultaneous transmission and distribution of baseband digital and RF signals over a optical fibre. The optical fibre may be a multimode optical fibre or a single mode optical fibre.

Embodiments of the present invention restrict the set of modes launched into the multimode fibre, for example by preventing very high order modes and/or very low order modes from being excited in the fibre or by limiting the amount of power in these mode groups relative to other mode groups. In alternative embodiments the amount of power in some mode groups is greatly reduced relative to another mode group, for example the amount of power in very high order modes and/or very low order modes of the fibre may be much less than that in a group of medium order modes. Some restricted mode launches provide a substantially uniform passband response in a multimode fibre.

In embodiments of the present invention an offset launch is used to couple a signal from an optical transmitter to a multimode fibre so as to enhance the fibre bandwidth-length product such that this is sufficient for robust RF transmission. Offset launch is an example of a restricted mode launch. Restricted mode launches may enable transfer simultaneously of baseband and RF signals in an optical fibre without the signals being swamped by noise. Restricted mode launch thus may allow operators to make use of existing fibre-based LAN infrastructure or backbone to carry and distribute additional RF signals such as IEEE 802.11, WLAN and 3G. This allows the system operators to provide indoor wireless service coverage without installing new fibres into a pre-existing building. This is advantageous in a building constructed such that GHz radio signals are quickly attenuated via the structure of the building.

Other examples of restricted mode launches are: ring launches, vortex launches, angled launches and the centre launch (which predominantly couples into low order modes). Typically, a restricted mode launch limits the amount of power that is input into a first group of modes in an optical fibre, and concentrates the power into exciting a second group of modes in the optical fibre.

In an embodiment of the present invention, there is provided a hub wherein GbE, WLAN and 3G signals are multiplexed or combined and then conveyed as a combined modulated optical signal to a multiservice distribution unit (MDU) over at least one multimode fibre or existing fibre-based local area network (LAN).

In another embodiment of the present invention, a hub is connected to individual GbE, WLAN and 3G service units. The hub receives individual signals from the service units, combines the signals to generate a combined signal and transmits the combined signal to both an MDU and a plurality of remote antenna units (RAU's) over a respective plurality of multimode fibres. A plurality of passive multimode optical splitters is used so as to create a RF/GbE network. This represents a simple and cost-effective way of extending both WLAN and 3G coverage. In situations where embodiments of the present invention are used, mobile devices using WLAN and 3G connections communicate primarily via remote antenna units. In order to provide sufficient indoor service coverage area, it must be possible to deploy remote antenna units with minimal constraints. One such constraint would be the requirement of a relatively low maximum fibre distance between the RAU and the service units such as GbE switch, router or access point.

In an alternative embodiment of the present invention, there is provided a multiservice distribution unit (MDU) that is connected to a hub via an optical fibre or a backbone fibre network carrying GbE, WLAN and 3G signals. The MDU splits the baseband digital GbE signal and the RF WLAN and 3G signals. The MDU directs the GbE signal to the GbE switch or router using coaxial cable or multimode fibre and directs the WLAN and 3G signals to at least one remote antenna unit using optical fibres. The optical fibre may be a multimode fibre or a single mode fibre. The use of multimode fibre with offset launch for connecting the remote antenna unit to the MDU allows for much increased connection distance and so substantially removes the constraint of the fibre connection to a GbE switch of the fibre backbone for deployment of the remote antenna units.

The service coverage area can be greatly extended according to the embodiments of the present invention, the MDU can drive a plurality of remote antenna units using passive multimode optical splitters.

Embodiments of the present invention will now be described by way of example with reference to the accompany drawings, in which:

Figure 1 shows a basic arrangement of an optical communications system;

Figure 2 shows an optical communications system similar to that of Figure 1 but having multimode fibre connecting the hub and MDU to each respective Gigabit Ethernet switch;

Figure 3 shows a hub down representation of an optical communications system illustrating the versatility of the use of the multimode fibres provided for by the hub;

Figure 4 shows a hub down representation of an optical communications system illustrating the use of passive multimode optical splitting;

Figure 5 shows another hub down representation of an optical communications system, this one showing an alternative arrangement of the passive multimode optical splitters;

Figure 6 shows an internal layout of a basic hub design;

Figure 7 shows an internal layout of a more complex hub design;

Figure 8 shows traditional inbuilding deployment of a network for supplying a cellular and WLAN support as known in the prior art; and

Figure 9 shows inbuilding deployment of a network utilising the hub according to the present invention for supplying a cellular and WLAN.

Figure 1 shows a hub 101 connected to a multiservice distribution unit (MDU) 102 by a multimode fibre 103. The multimode fibre 103 carries both RF and baseband signals. In the embodiment shown, multimode fibre 103 carries a baseband GbE signal and RF WLAN and 3G signals. Hub 101 is connected to service units 104, 105, 106. In the embodiment shown, service unit 104 is a WLAN access point, service unit 105 is a 3G base station, and service unit 106 is a GbE switch. Further connections between the service units 104, 105, 106 are provided but are not shown in Figure 1. The connections between service units 104, 105, 106 and hub 101 are electrical connections.

MDU 102 is connected to service units 107, 109. Service unit 107 is shown as a GbE switch and is connected via an electrical connection to MDU 102. Service unit 109 is a remote antenna unit which is connected to MDU 102 by a multimode fibre 108. Remote antenna unit 109 has an antenna attached thereto, this is labelled 110 in Figure 1.

The operation of the apparatus shown in Figure 1 will now be described.

Hub 101 receives and transmits signals to each of the service units 104, 105, 106. In a downlink direction, hub 101 receives WLAN, 3G and GbE signals from the wireless LAN access point 104, 3G base station 105, and GbE 106 respectively. Hub 101 operates to combine the received signals and transmit these via a mode restrictive launch over multimode fibre 103. Hub 101 also operates in an uplink direction, wherein it receives combined WLAN, 3G and GbE signals, splits these signals and transmits them to the respective service unit 104, 105, 106. Each hub has electrical ports for connection to RF services such as 3G base stations or WLAN access points. Each hub further has additional electrical or optical ports for connecting to baseband digital services such as a GbE switch. Hub 101 contains combiners for multiplexing or combining the baseband digital and RF signals. Optical radiation transmitters in hub 101 operate so as to combine signals as optical signals over multimode fibres to at least one MDU 102.

Each hub contains at least one optical radiation transmitter to convert a combined signal into an optical signal for transmission over at least one multimode fibre. The remote antenna units receive and convert optical signals received from a hub or MDU into electrical signals which are then electronically filtered so as to remove the baseband digital signal such that the resulting RF signal may be amplified before being radiated from an at least one antenna attached to the RAU.

In a downlink direction multiservice distribution unit 102 receives combined baseband and RF signals from hub 101 via multimode fibre 103. MDU 102 operates so as to split the received signal and distribute the appropriate component signals to an appropriate service unit. For example, as shown in Figure 1, multiservice distribution unit 102 operates so as to split the GbE signal received along multimode fibre 103 and forwards this to GbE switch 107 via an electrical connection. MDU 102 further operates to separate the RF signals from the combined signal received on multimode fibre 103 and sends this via a second multimode fibre 108 to a remote antenna unit 109.

The MDU 102 contains a plurality of multimode optical splitters to split incoming optical signals arriving from hub 101 via multimode fibre 103 into two optical parts. A first part is unprocessed and conveyed to remote antenna unit 109 via multimode fibre 108. In particular, the restricted mode nature of the incoming optical signal is preserved in the first part, which is conveyed onwards to other components. The restricted mode nature of the first part of the optical signal, as split by the MDU, is preserved because the split retains a substantially flat passband characteristic.

A second part of the incoming optical signal is processed by a photodetector and an electronic filter in MDU 102. This processing functions so as to filter off the RF signal component so as to leave only the baseband digital signal, which in the example shown is a GbE signal. This GbE signal is then conveyed to an appropriate service unit, shown as GbE switch 107 in Figure 1. The baseband digital signal may be conveyed to a service unit via an electrical connection, or the baseband digital service signal may be first converted to the optical domain before being conveyed to the service unit as an optical signal via a multimode fibre. Such an arrangement is shown in Figure 2.

In an uplink direction MDU 102 operates so as to receive a GbE signal from GbE switch 107 and WLAN and 3G signals via multimode fibre 108 from remote antenna unit 109. MDU 102 then operates so as to combine the received signals and transmit them via the offset launch into multimode fibre 103 for transmission to hub 101.

Remote antenna unit 109 operates so as to receive the WLAN and 3G signals from MDU 102 via multimode fibre 108. Remote antenna unit 109 receives and converts the optical signal received via multimode fibre 108 into an electrical signal which is then electronically filtered to remove the digital baseband component, in this case GbE, to leave only the RF signals. These RF signals are amplified and transmitted via antenna 110.

Figure 2 shows a system arranged in a similar manner to that of Figure 1; like components have like reference numerals and operate in a substantially identical way as described above with reference to Figure 1. For brevity, only the differences will be described herein.

Hub 201 is connected via a multimode fibre to service unit 206, which is a GbE switch. Similarly, multiservice distribution unit (MDU) 202 is connected via a multimode fibre 206 to service unit 207, which is a GbE switch also.

In this arrangement, in a downlink direction hub 201 operates to convert RF signals received from service unit 204, 205 into a combined optical signal and then further combining this with the digital baseband optical signal received via multimode fibre 215. The optical combined baseband and RF signal is transmitted via a restricted mode launch over multimode fibre 203 to MDU 202. MDU 202 contains multimode optical splitters, and in this arrangement transmits the RF and digital baseband signal via multimode fibre 206 to GbE switch 207 for processing therein. GbE switch 207 processes the incoming signal by photodetecting it and electronically filtering the RF components.

Hub 201, multiservice distribution unit 202, and GbE switches 206, 207 operate bidirectionally in both an uplink and downlink direction.

Figure 3 shows a communications system in hub down view only, wherein a plurality of multimode fibres are connected to the hub 301. Hub 301 operates substantially similarly to hub 101 or hub 201 as described above. Instead of having a single restricted mode launch into a single multimode fibre, hub 301 has a plurality of restricted mode launches each transmitting an optical signal into a respective multimode fibre. In Figure 3, three multimode fibres 317, 318, 319 are shown as being connected to hub 301. Each multimode fibre 317, 318, 319 carries a combined RF and digital baseband signal which in the example shown comprises WLAN, 3G and GbE signals. Multimode fibres 317, 318 terminate at respective remote antenna units 311, 313. These remote antenna units function substantially similarly to the remote antenna unit 109 as described above. Multimode fibre 309 is connected to a multiservice distribution unit 302. MDU 302 is connected via a multimode fibre 320 to a remote antenna unit 309. MDU 302 is also connected via a multimode fibre 308 to a GbE switch 307. The MDU 302, remote antenna unit 309 and GbE switch 307 operate in a substantially identical way to the corresponding apparatus described above in relation to figures 1 and 2. The multimode split in the MDU 302 maintains the mode restriction imparted by the restricted mode launch in the Hub 301.

An advantage of the apparatus shown in Figure 3 is that a relatively large number of remote antenna units may be required in order to provide sufficient wireless service coverage (e.g. WLAN and 3G) over a required area, but only a single central GbE switch may be required at a remote location. For this reason, only a single MDU 302 and GbE switch 307 are needed, thus reducing hardware cost.

Figure 4 shows a hub down view of an alternative optical communication system which implements passive multimode optical splitters. Figure 4 shows a hub 401 connected via a single multimode fibre 430 to a first passive multimode optical splitter 421 which in turn is connected to a second and third passive multimode optical splitter 422, 423 respectively. Each passive multimode optical splitter shown in Figure 4 provides a 1 to 2 split. In a downlink direction each passive optical splitter has a single input and two outputs; in an uplink direction each passive optical splitter has two inputs and a single output. Passive multimode optical splitter 422 is connected to two remote antenna units which may be advantageously physically separated so as to increase service coverage area. A third passive multimode optical splitter 423 is directly connected to a single remote antenna unit, the other connection being to a multiservice distribution unit 402. MDU 402 has the same connections and operates in a substantially identical manner to that of MDU 302 as described above.

The multimode optical splitters are used to split incoming optical signals arriving from a hub or another passive optical splitter into two optical parts.

Figure 5 shows a further alternative arrangement in which the passive optical mode fibres are used to convey a single combined RF and baseband signal from an MDU to four remote antenna units. A hub 501 and MDU 502 are arranged in a substantially identical manner to that of Figure 2 as described above. A single optical output from MDU 502 is connected to a first passive multimode optical splitter 524 which in turn is connected to a second and third passive multimode optical splitter 525, 526 respectively. Each of these second and third passive multimode optical splitters has two outputs connected to a remote antenna unit (RAU) 531, 533, 535, 537 via a respective multimode fibre 541, 542, 543, 544.

In another embodiment, one of the RAUs, for example 531, is used to monitor the transmitted RF power and/or transmitted RF spectrum emitted from the other RAUs, for example 533, 535 and 537. The monitoring is performed for management purposes. The results of the monitoring of the transmitted RF power and transmitted RF spectrum emitted from the other RAUs 533, 535 and 537 are relayed by RAU 531 back to the Hub 501.

The multimode optical splitters that are used to split incoming optical signals into two optical parts may operate so as to split an incoming optical signal into two equivalent parts. In this case, each RAU receiving a part of the optical signal will transmit substantially identical signals. This is advantageous because it increases the spatial diversity of the signal in the coverage area.

The remote antenna units (RAUs) described above are shown in the figures as each having one respective antenna that is used for both transmission an reception. Alternatively, each RAU may have a single antenna with an RF circulator. In alternative embodiments, each remote antenna unit has a plurality of antennas. For example, two antennas may be used, one for transmission and one for reception of RF signals. Further, multiple antennas also allow for the implementation of: spatial diversity, multiple input multiple output (MIMO), transmit cancellation, and a plurality of other radio communication techniques known in the art. In further alternative embodiments, each remote antenna unit has multiple spatially-separated receive antennas for increased coverage area and diversity. Further, each remote antenna unit may have a plurality of communication specific receive antennas with either single or banded frequency ranges; this allows a remote antenna unit to receive WLAN broadcasts on one antenna and 3G broadcasts on another.

In order to allow both uplink and downlink communications, one of a plurality of techniques may be used. Two parallel multimode fibres may be used in order to have one fibre dedicated to uplinking communication and the other fibre dedicated to downlink communication. Alternatively, where the number of fibres in place is limited, or where the bandwidth requirements are not particularly high, a single multimode fibre is used for both uplink and downlink communication; the bandwidth of a single fibre used in such a manner is divided up using for example a multiplexing technique such as: wavelength division multiplexing, time division multiplexing, code division multiplexing, synchronous channel multiplexing or frequency domain multiplexing. Alternatively, a first channel is sent in raw form and a second channel is sent as the difference between the first and second channel, i.e. in difference form. This must be mixed down to baseband in a difference process.

Embodiments of the present invention allow for enhanced monitoring of a wireless service coverage area, whereby one remote antenna unit is used to monitor signals transmitted by at least one other remote antenna unit in order to verify signal penetration.

In the above description, numerous references are made to WLAN and 3G service provision. It should be appreciated that such references are made by way of example only and do not limit the scope of the present application. In particular, WLAN as used above refers to any of the IEEE 802.11 standards and moreover, any other wireless networking standard. Similarly, 3G has been used with reference to third generation mobile telecommunication services by way of example only and the present invention is similarly applicable to GSM, GPRS, CDMA, TETRA or any other mobile telecommunications standard.

Figure 6 shows a block functional diagram of a hub 651. Hub 651 contains a radio frequency splitter/combiner 652 which translates a single RF input/output into eight separate input/outputs, each of which is connected to an Optical Module (OM) 653a to 635h respectively. Each OM 653 is connected to an appropriate launch and in turn an optical fibre. In operation, each OM 653 generates an optical signal suitable for transmission by multimode fibre. Typically, such an optical signal has a wavelength of 1310 nm. Hub 651 is also arranged to receive control data input/output which may determine how the input RF signal is distributed between each OM 653 by RF splitter/combiner 652.

An example of a more advanced hub layout is shown in Figure 7. Hub 751 comprises a data input/output controller 754, a switch/router 755 and a control function unit 770. Control function unit 770 comprises a first and second AP 756, 757 respectively, a first and second 1x2 RF splitter/combiner 758, 759 respectively, a 1x4 RF splitter/combiner 760 and 8 OM's 753a to 753h respectively.

In an alternative embodiment, one or more of the RF splitter/combiners 758, 759 and 760 are replaced with one or more programmable RF combiners. Programmable RF combiners allow for dynamic reconfiguration of the Hub functionality; for example: dynamic bandwidth allocation, gain variation or bringing on-line new services without downtime of existing services. Furthermore, programmable RF combiners allow the possibility of signals from each AP being combined with signals external to the Hub. A signal external to the hub that is combined with signals from the AP may be an external RF signal.

The data input/output controller 754 receives a plurality of inputs: two 10-1000BT Cu (an electrical Ethernet interface), two management functions connections, two RF I/O (shown as passing straight through to the RF splitter/combiner 760), two GbE connections. There are two connections for each type of connection to provide redundancy for resilience or back up in case of failure, in alternative embodiments only one of at least one or each type of connection may be provided. Redundancy may alternatively be provided by having at least two hubs operating in parallel. More than one pair of RF I/O may be provided in order to increase bandwidth. The GbE connections may be, for example 850nm connections.

Data input/output controller 754 also receives two optical GbE connections. Data input/output controller 754 controls data flow into switch/router 755, which in turn sends each GbE signal to a respective AP within the control function unit 770. Each AP 756, 757 in the control function 770 is connected to a 1x2 RF splitter/combiner 758, 759 respectively, which in turn are connected to 2 OM's. Accordingly, in the arrangement shown in Figure 7 OM1 to OM4 753a to 753d receive a GbE signal. RF splitter/combiner 1x4 760 directly receives an RF input/output which is split/combined between 4 OM's, OM5 to OM8 753e to 753h respectively. As mentioned above, each OM 753 is connected via an appropriate mode restrictive launch to a multimode optical fibre.

In an alternative arrangement, the or each hub has electrical ports for connections to the RF service base stations or access points, and has electrical or optical ports for connections to the baseband digital service points such as a GbE switch.

In alternative arrangements, there is provided in the or each hub one or more splitters/combiners for multiplexing/demultiplexing the baseband digital and wireless RF signals.

Figure 8 shows an example of traditional inbuilding deployment of a network supplying a building with a distributed antenna system (DAS) and wireless local area network (LAN). The example building in Figure 8 has six floors 801-806 and each floor is supplied with a plurality of WLAN access points, e.g. 833, and a plurality of DAS auxiliary units, e.g. 831. Each floor, e.g. 803, has a network switch e.g. 823 which receives Ethernet from an Ethernet source 855 via an existing multimode fibre infrastructure 860. Each switch, e.g. 823, supplies the WLAN access points, e.g. 833, using an unshielded twisted pair communications line, e.g. 813, as known to the skilled reader.

A base transceiver system 850 and primary hub 851 supply a secondary hub, e.g. 821, on each floor, e.g. 803. Communications between the primary hub 951 and the plurality of secondary hubs, e.g. 821, is conducted over a custom single mode fibre infrastructure. Each secondary hub, e.g. 821, feeds a plurality of DAS auxiliary units, e.g. 831, using a coax transmission line as known to the skilled reader. Figure 8 shows that a mix of coax and single mode fibre is required to provide cellular support throughout the building. The cellular and WLAN cable infrastructures are separate with single mode fibre cable used for cellular and a combination of multimode fibre and UTP used for the WLAN. Many access points are needed to merely achieve adequate coverage leading to more access point capacity than necessary. The system suffers from being difficult and expensive to maintain and upgrade.

Figure 9 shows inbuilding deployment of the hub according to the present invention. The example building in Figure 9 has six floors 901-906 and utilises only the existing multimode fibre infrastructure 960 as already found in many modern office buildings. A pair of hubs 953 and 955 according to the present invention connect a plurality of access points 950 and base transceiver systems 951 to the multimode fibre infrastructure 960. Each floor, e.g. 903, is supplied with a plurality of multipurpose auxiliary units, e.g. 940, and only a standard multimode fibre infrastructure is necessitated.

Figure 9 shows how the operational expenditure and capital expenditure of the network is reduced by providing a single cable infrastructure for multiple wireless services. The system utilises existing multimode fibre infrastructures within buildings and no additional coax or single mode fibre is needed. The present invention shows how the number of base stations and other capital intensive hardware can be reduced. Furthermore, maintenance upgrades are performed centrally without need for disruptive maintenance to the infrastructure. The system is technology-neutral; multiple operators can utilise the single DAS infrastructure. Thus, new wireless technologies can be introduced to the network with minimal effort. Management of the wireless resources is performed centrally and this improves security and flexibility.

According to another embodiment, there is provided a method of coupling optical radiation into a multimode fibre. The method comprises coupling optical radiation from at least one optical radiation transmitter into a respective multimode fibre using a launch which restricts the number of modes excited in the fibre. Restricting the number of modes excited in the fibre enhances the bandwidth of the multimode fibre to a level sufficient for RF signal transmission. Further, restricting the number of modes excited in the fibre suppresses background noise in any demodulated signals present. Signals are received from the multimode fibre via a photodetector. Each optical radiation transmitter is a single transverse mode laser emitter, and is arranged to couple transmission signals into the multimode fibre. In alternatives, the optical radiation transmitter is a multi-transverse mode laser transmitter, wherein the launch functions so as to filter and restrict the number of modes excited in the fibre.

There may be provided an optical connector for connecting light into a multimode fibre so as to produce a launch which is co-linear but at an offset to the fibre access.

There may be provided a direct offset from an optical source into a multimode fibre without an intermediate connector.

The or each laser transmitter may have a linear frequency response whereby it is responsive to both baseband and RF inputs.

Although the described embodiments relate to signal transmission over multimode fibres, further embodiments relate to signal transmission over single mode fibres. Furthermore, still other embodiments provide apparatus allowing signal transmission over mixed networks comprising both single mode and multimode optical fibres. Yet other embodiments may use copper cabling in some sections as well as optical fibres; such copper cabling may comprise, for example, coaxial cable, CAT5 or CAT6 cables.

Various embodiments of the invention have been described. The scope of the invention is not however limited to the features of the embodiments.

CLAIMS

1. A hub for use in an optical communications system, said hub comprising:
at least one electrical port for connection to an RF service device; and
at least one optical port for connecting the hub to a respective optical fibre.

2. A hub as claimed in claim 1, wherein the optical fibre is a multimode optical fibre.

3. A hub as claimed in claim 1, wherein the optical fibre is a single mode optical fibre.

4. A hub as claimed in any preceding claim, wherein the hub comprises at least one further electrical port for connection to a baseband digital service device.

5. A hub as claimed in claim 4, wherein the hub is operable to receive:
an RF signal from the RF device;
a baseband digital signal from the baseband digital device;
and to transmit the signals over the or each optical fibre.

6. A hub as claimed in claim 5, wherein the hub is arranged to transmit and receive both the RF signal and the baseband digital signal through the optical port.

7. A hub as claimed in any preceding claim, wherein the RF service device is a base station or an access point.

8. A hub as claimed in any of claims 4 to 7, wherein the baseband digital service device is a Gigabit Ethernet switch or a Gigabit Ethernet router.

9. A hub as claimed in any of claims 4 to 8, wherein the port for connection to a baseband digital service device is one of the group comprising: a baseband electrical port and a baseband optical port.

10. A multiservice distribution unit arranged to receive a combined signal, the combined signal comprising a combination of RF and baseband signals, wherein the multiservice distribution unit is arranged to split the combined signal into a first and a second part, the multiservice distribution unit being arranged to:

output the first part as an unprocessed first part; and

electronically process and filter the second part to leave only the baseband signal which is output as a processed second part.

11. An optical transmission system arranged to carry at least one of the group comprising plural RF-modulated signals, one or more RF-modulated signals over plural transmission paths and one or more baseband signals together with one or more RF-modulated signals.

12. A transmission system according to claim 11 further comprising at least one passive optical splitter to split the RF-modulated signal, in the corresponding at least one transmission paths, into two transmission paths.

13. A transmission system according to claim 12 wherein the transmission paths are multimode optical fibres.

14. A transmission system according to claim 12 wherein the transmission paths are single mode optical fibres.

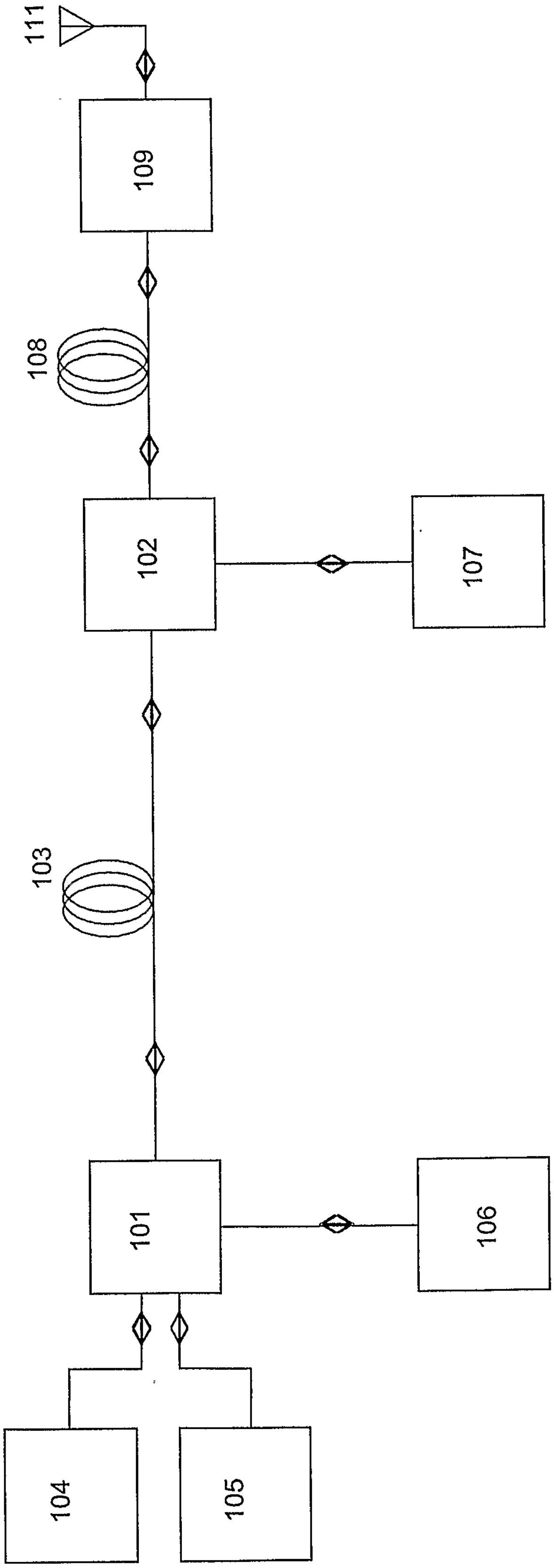


Figure 1

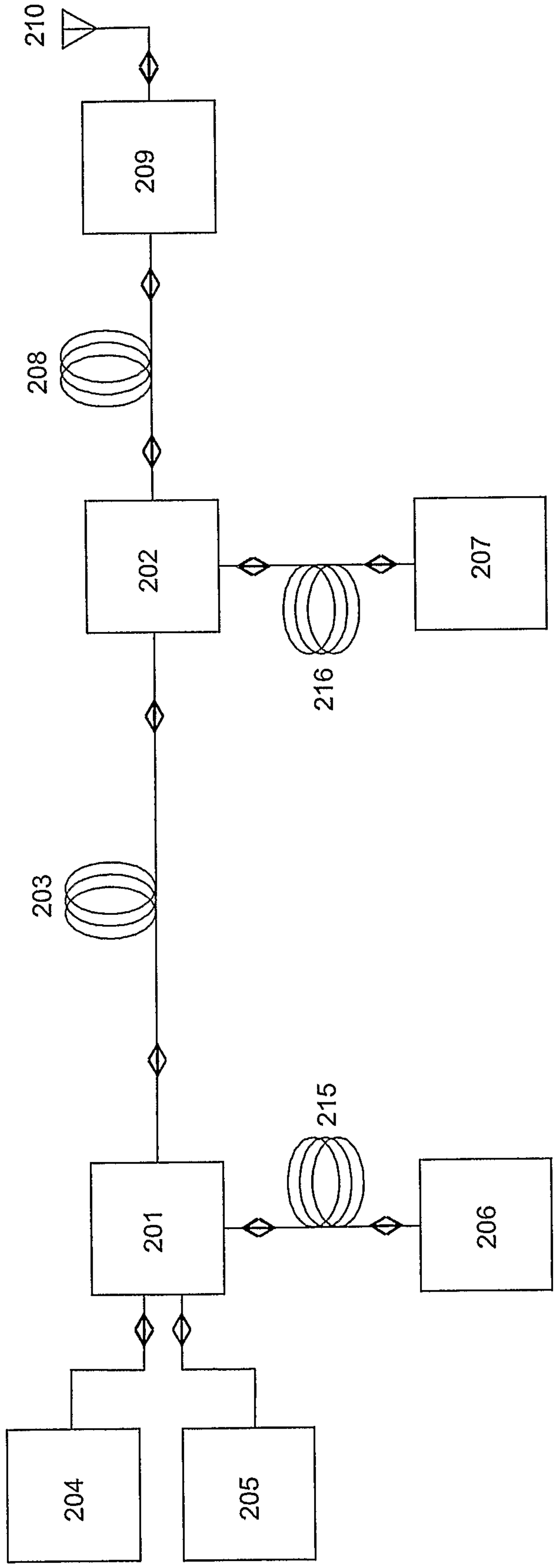


Figure 2

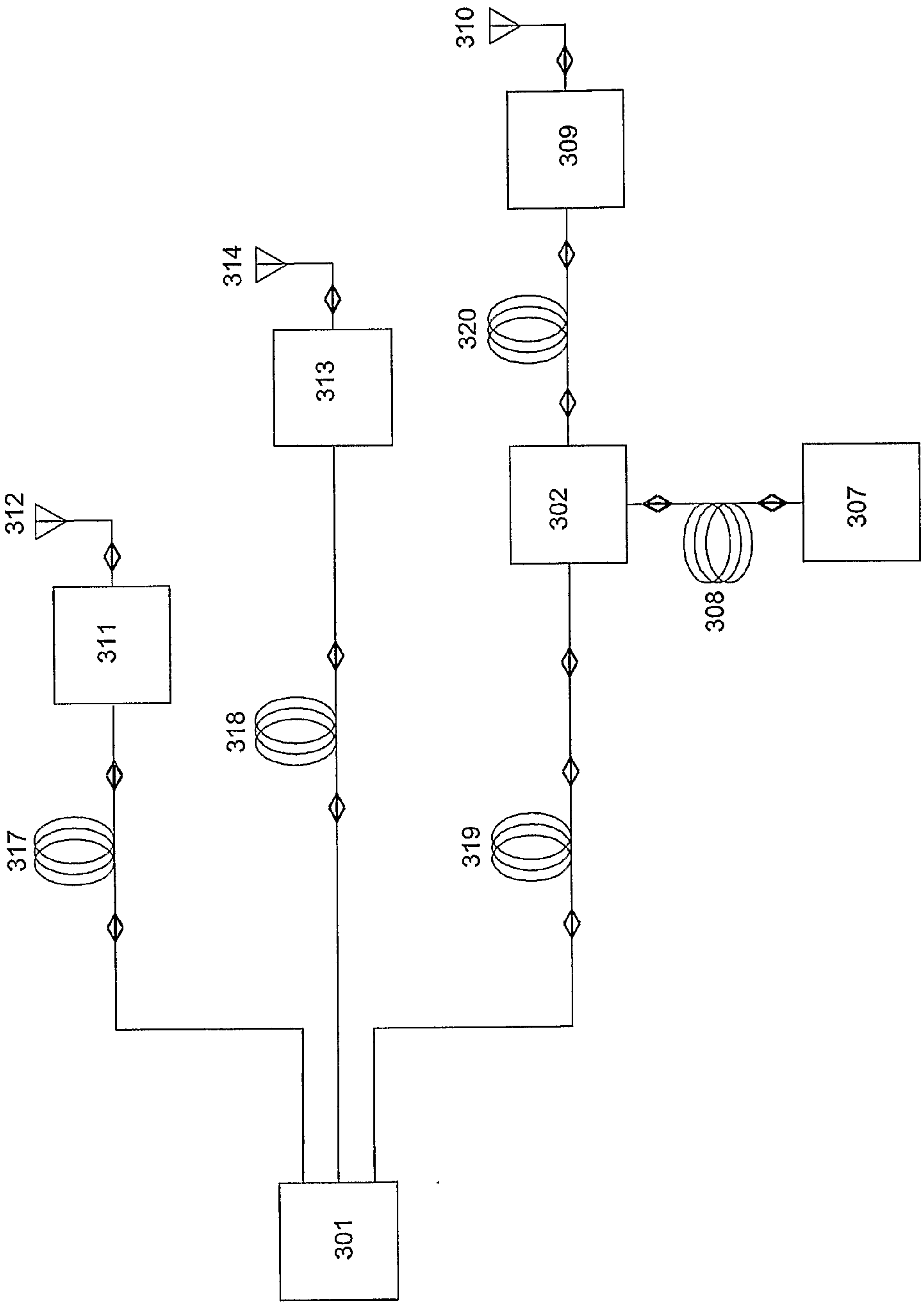


Figure 3

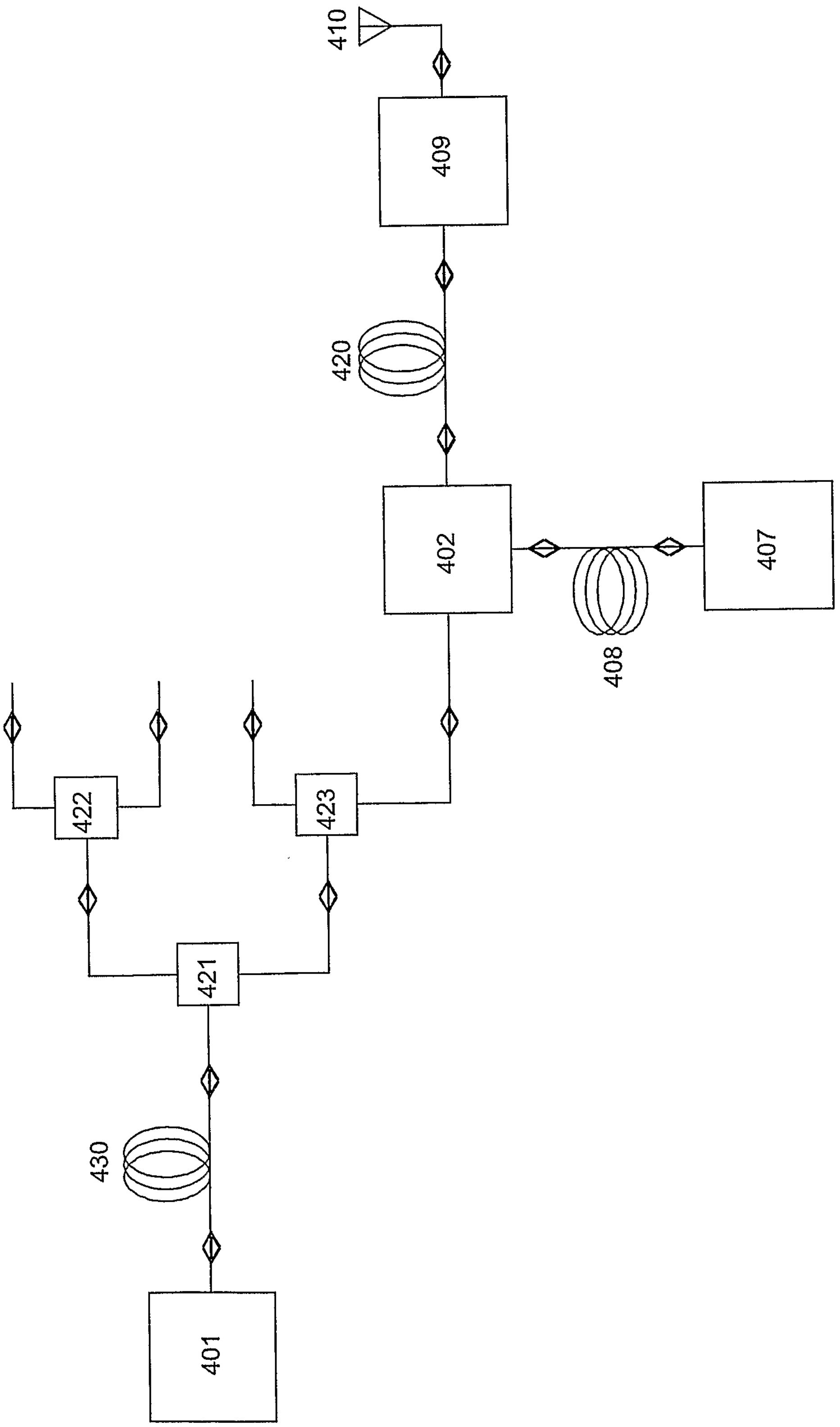


Figure 4

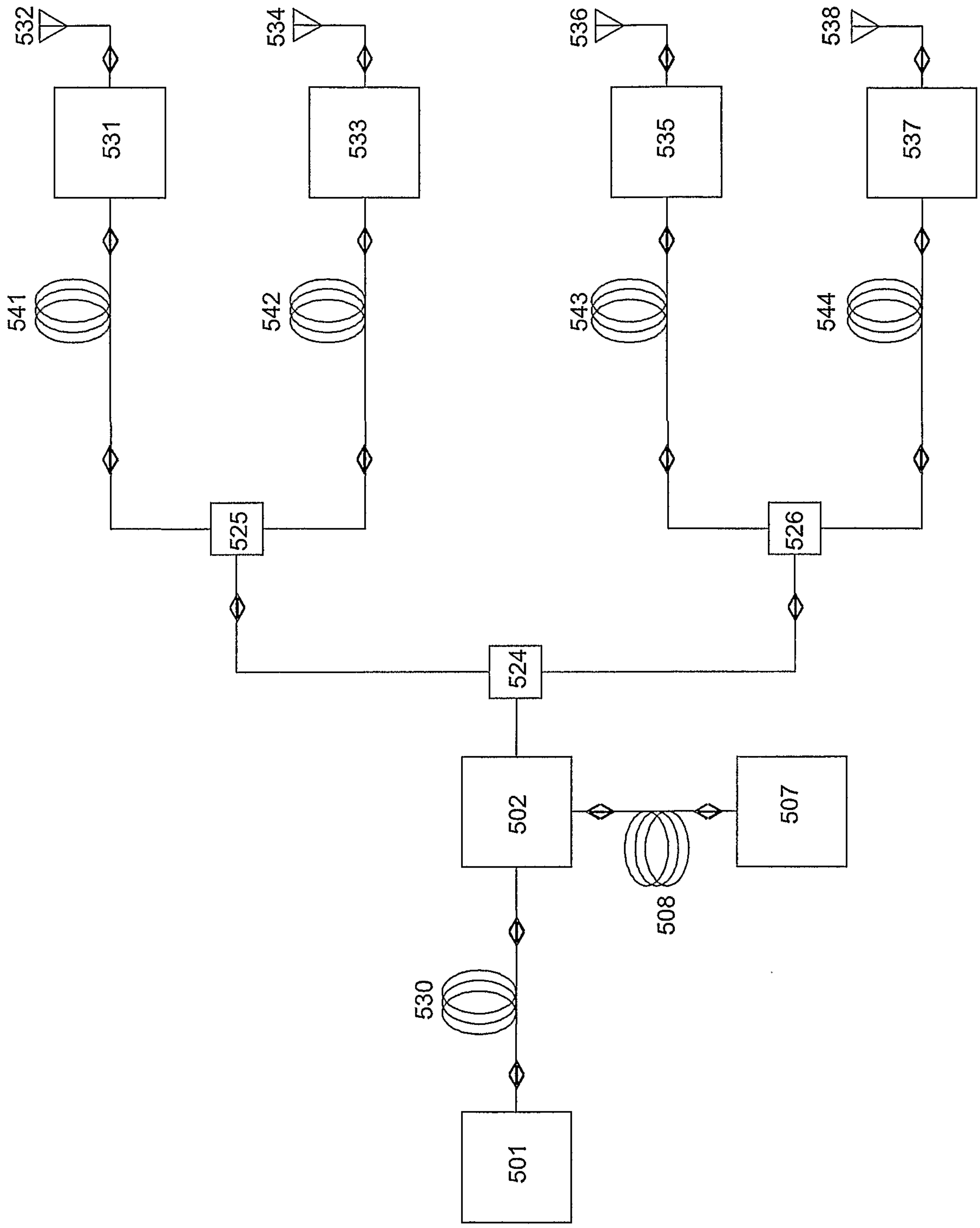
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Figure 5

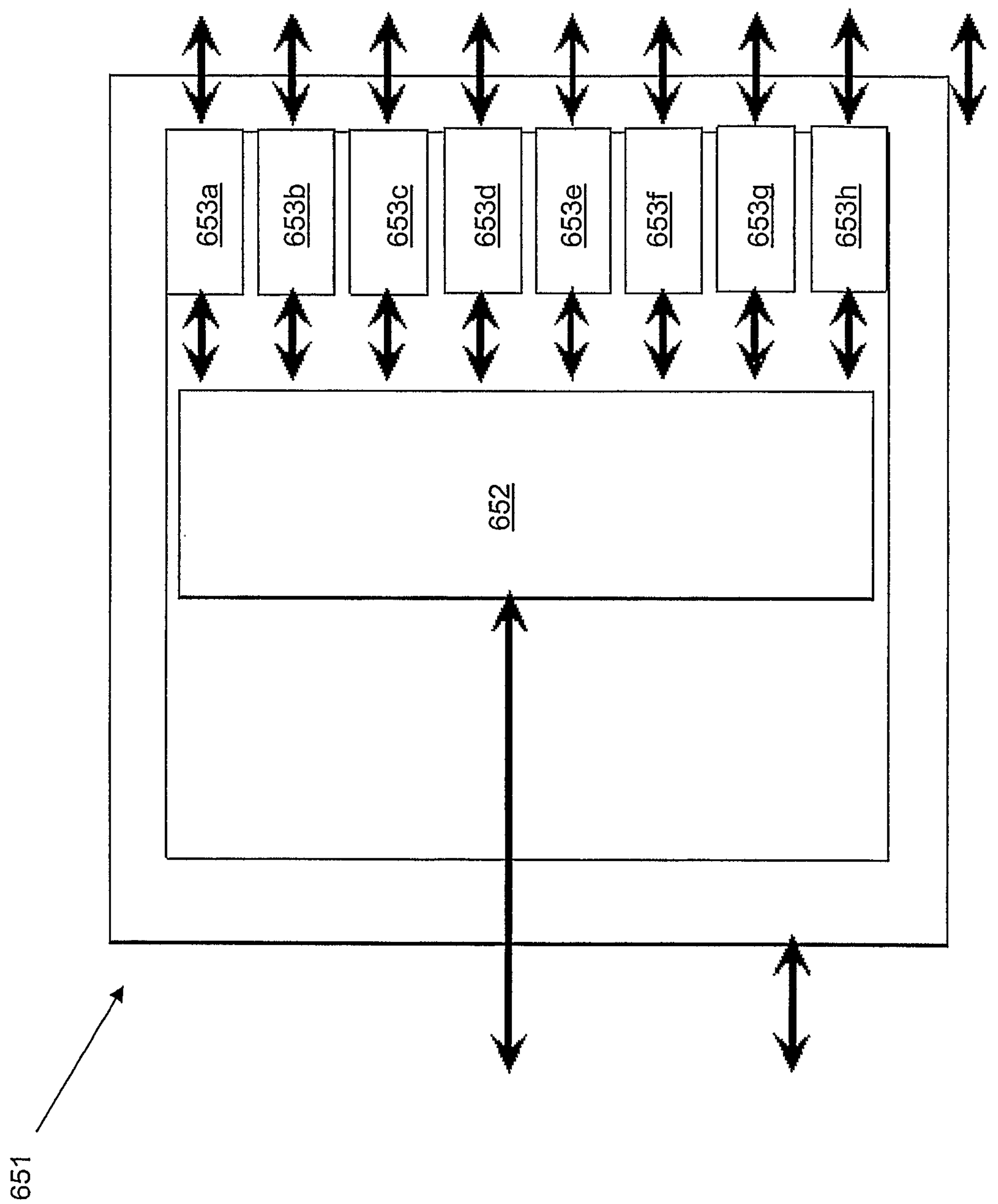


Figure 6

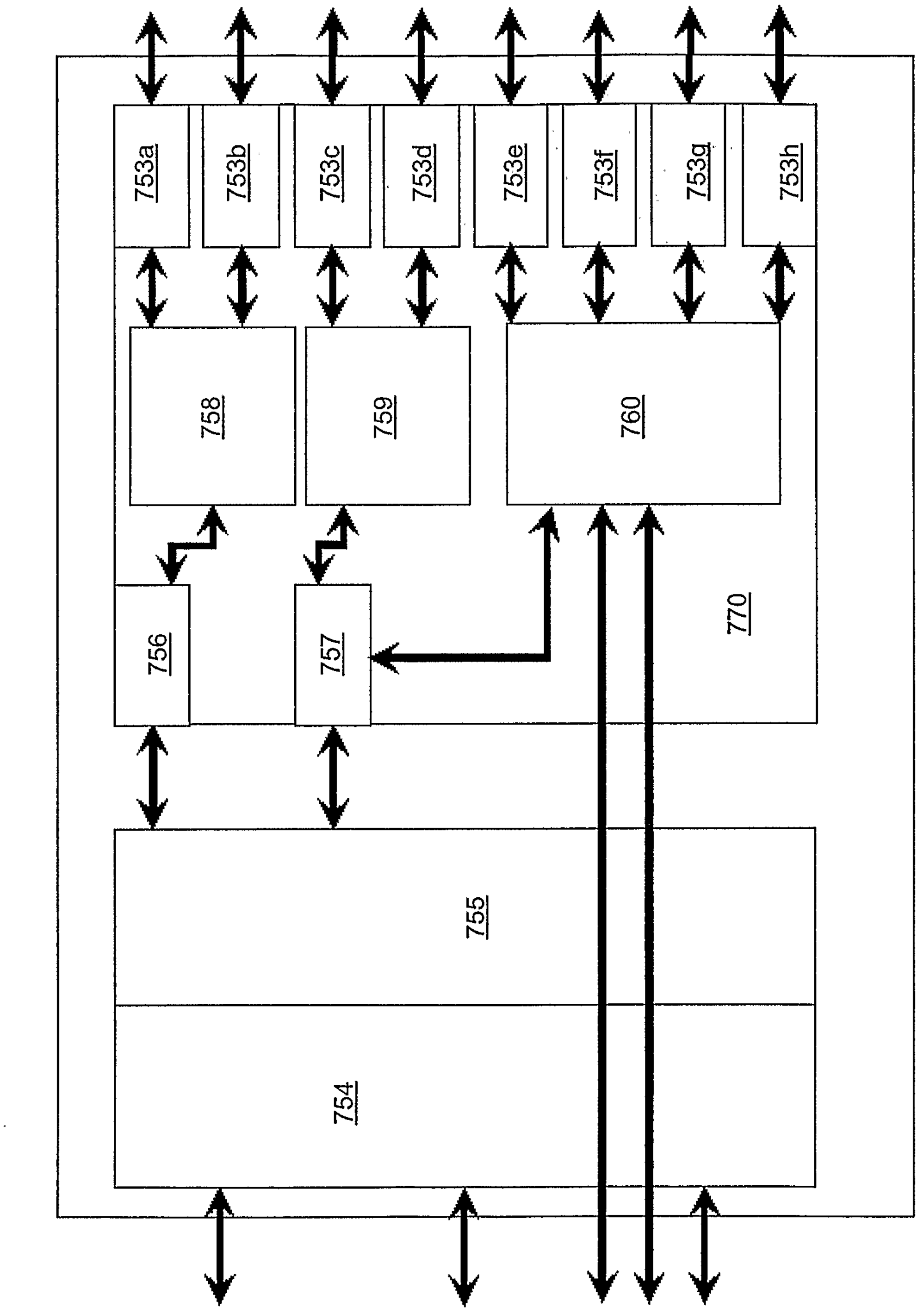
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Figure 7

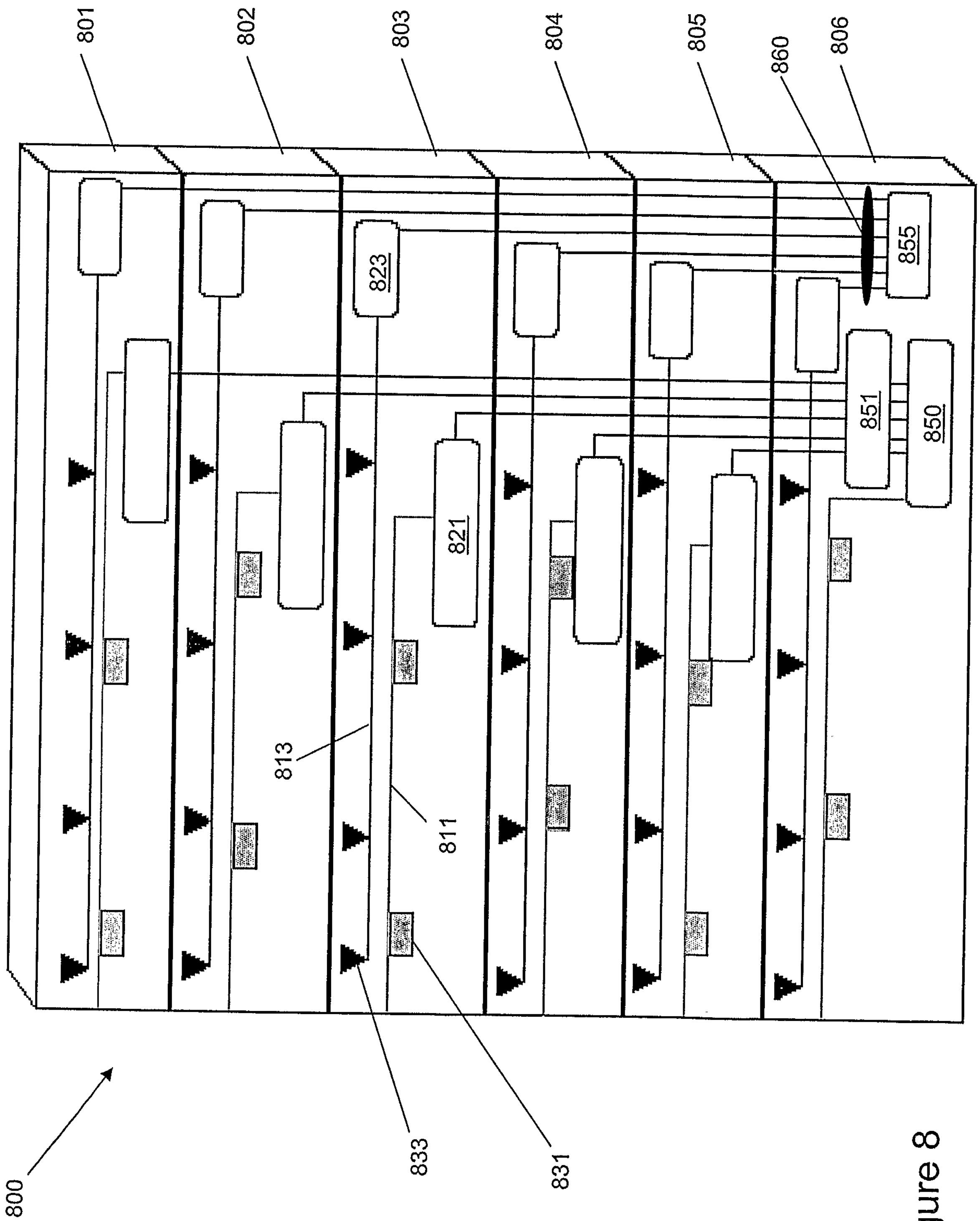
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Figure 8

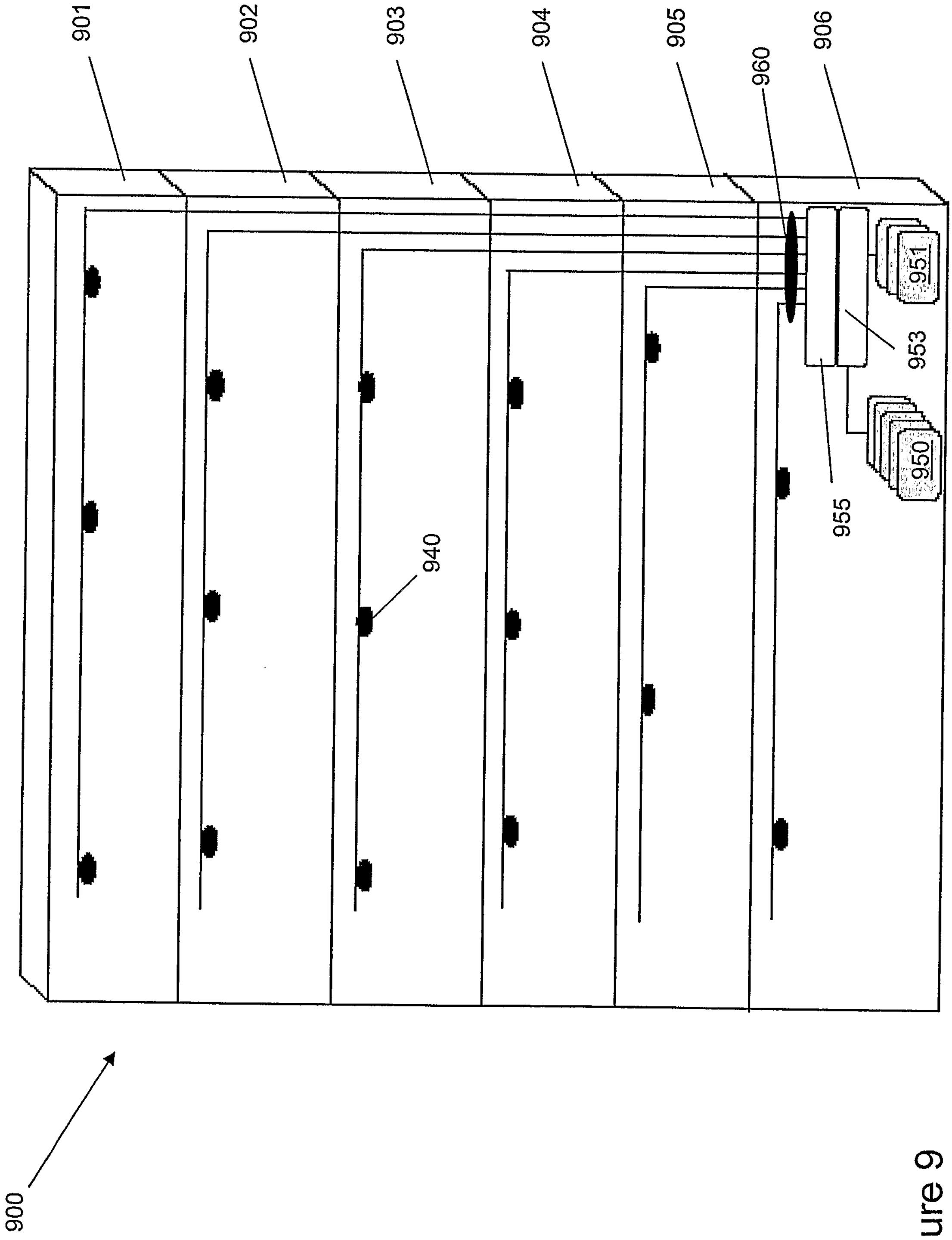


Figure 9

# INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2006/002258

**A. CLASSIFICATION OF SUBJECT MATTER**
INV. H04B10/12 H04B10/207

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)
H04B 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)

EPO-Internal, WPI Data, PAJ, INSPEC

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
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| X | US 2003/016418 A1 (WESTBROOK LESLIE D ET AL) 23 January 2003 (2003-01-23)<br>figures 1,8,19<br>paragraph [0001]<br>paragraphs [0046], [0047]<br>paragraph [0060]<br>paragraphs [0063], [0064]<br>paragraph [0129]<br>paragraph [0139]<br>----- | 1-9 |

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

[X] See patent family annex.

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| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 11 September 2006 | 19/09/2006 |

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

# INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2006/002258

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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