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(54) Distributed antenna system

(57) The present invention provides a distributed antenna system comprising a primary antenna (14A, 16A) and a plurality of secondary antennas (36, 40), a fibre optic network (20, 22) connected between the primary antenna (14A, 16A) and the secondary antennas (36, 40), first means (16, 44) associated with a first one of the antennas (16A, 40) which transmits signals received by that antenna (16A, 40) into the fibre optic network (20, 22), and second means (32, 50) associated with a second one of the antennas (36, 14A) which causes that antenna (36, 14A) to transmit signals received by the second means (32, 50) from the fibre optic network (20, 22).

Preferably, the use of a heterodyne circuit is avoided and the light signals travelling within the fibre optic networks (20, 22) are modulated at radio frequency.

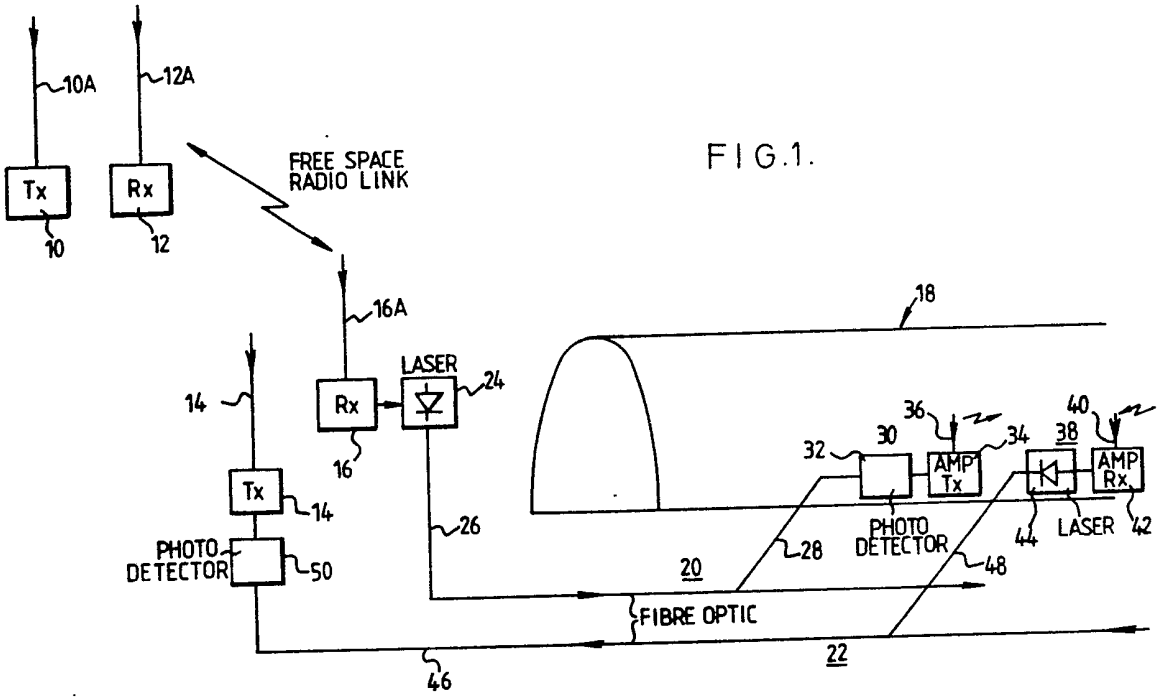

FIG.1.

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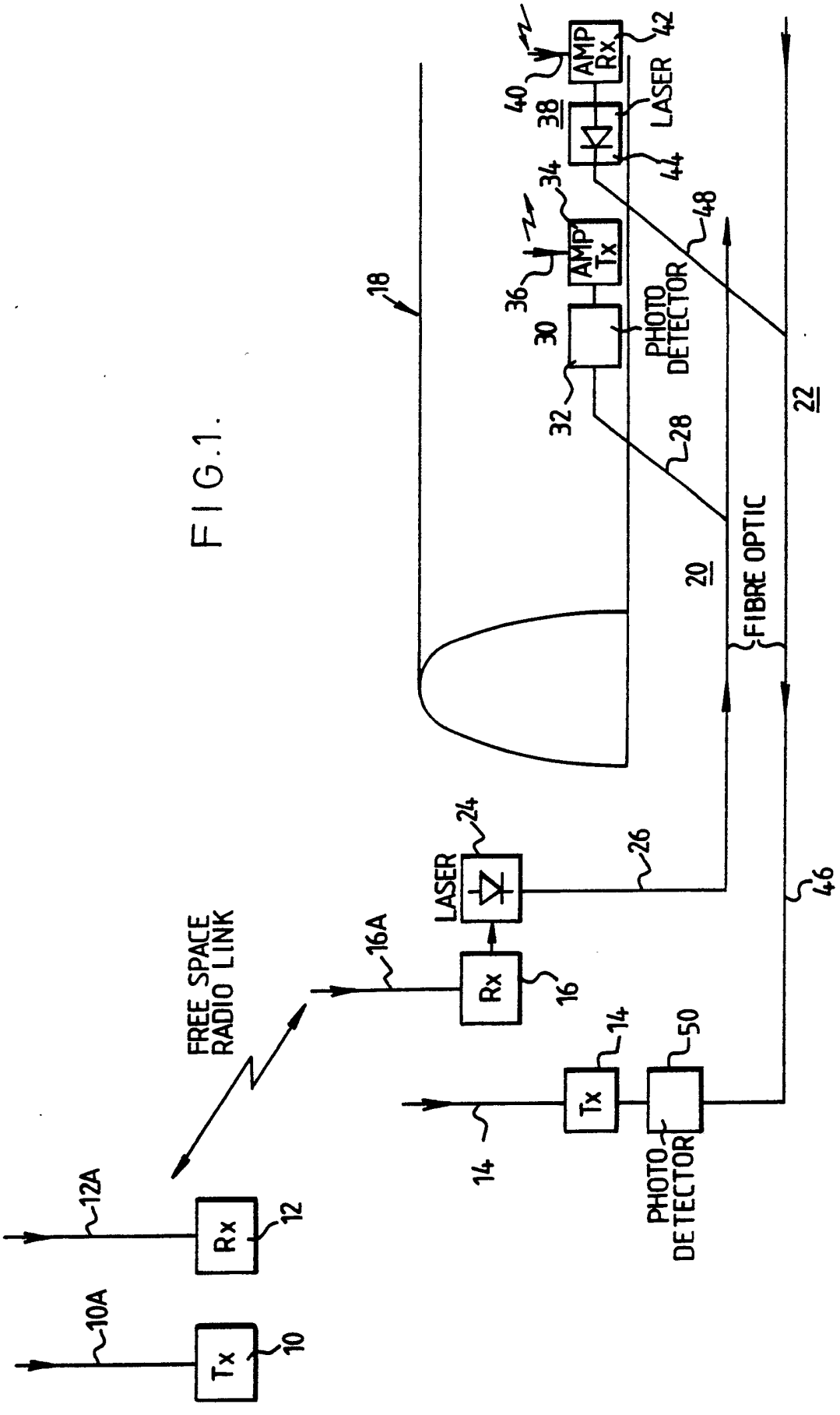
At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.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10
10A
Rx
12
12A
FREE SPACE
RADIO LINK
16A
Rx
16
LASER
24
26
Tx
14
14
PHOTO
DETECTOR
50
46
FIBRE OPTIC
20
22
18
28
32
30
PHOTO
DETECTOR
36
AMP
Tx
34
48
38
LASER
44
40
AMP
Rx
42

FIG.1.

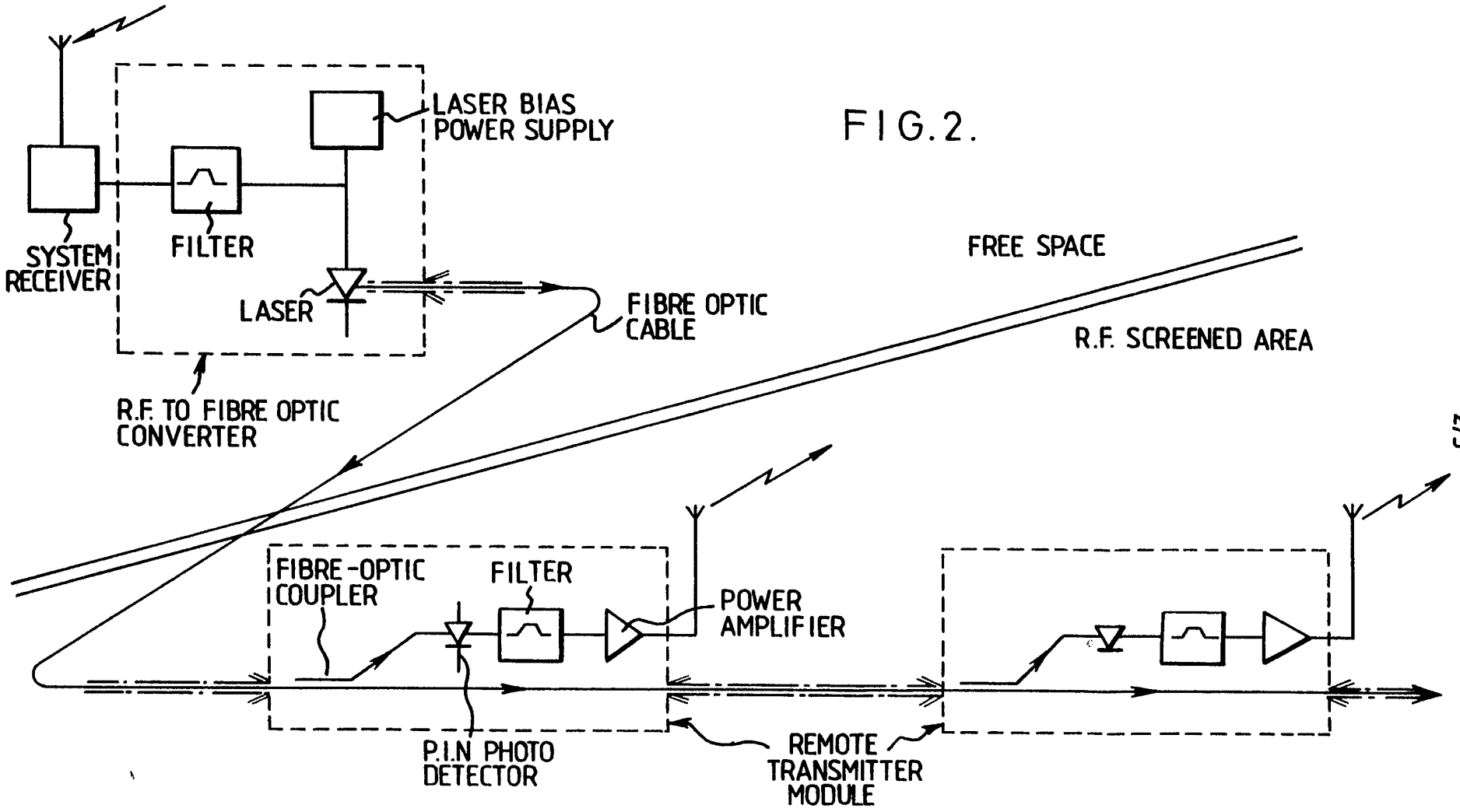

FIG.2.

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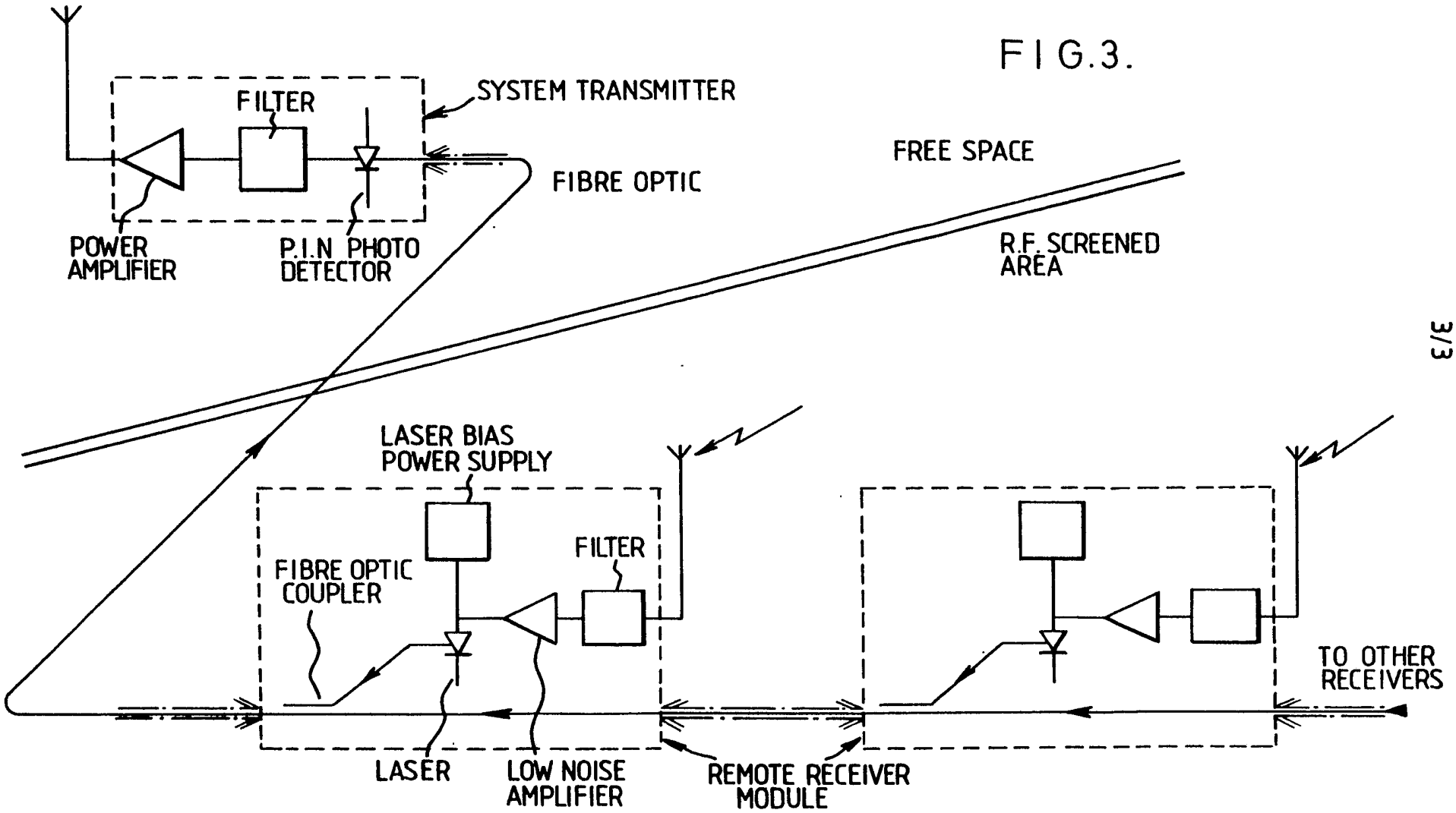
FIG.3.



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Distributed Antenna System

The present invention relates to a distributed antenna system.

It is well known that the transmission and reception of electromagnetic radiation at frequencies such as radio frequencies is severely impaired by any significant mass of solid material such as the walls of a building or the ground above a tunnel. The inability to transmit and/or receive radio signals within a tunnel or from one part of a building to another can be a severe disadvantage.

In order to mitigate the described disadvantage, it has previously been proposed to establish a distributed antenna system, which system is sometimes referred to as a "leaky feeder". This comprises the provision of a co-axial cable with holes in the shielding of the cable at strategic locations whereby a radio frequency signal injected into the cable "leaks out" at the strategically placed holes. This arrangement does, to some extent, mitigate the above described disadvantage. However, attenuation of the radio frequency signal within the cable is severe and typically a repeater may be required at 100 yard intervals with a maximum practical length of

cable being about 1 mile. Beyond this distance, it is extremely difficult to distinguish the original signal from the background noise, despite the use of the repeaters. It will be appreciated that a relatively high power signal is used and consequently the co-axial cable must have relatively high power specifications, which inevitably result in a relatively high expense. The "leaky feeder" co-axial system is not appropriate for use with radio signals at the frequencies used for cellular radio telephone systems.

With a view to providing an improved system, the present invention provides a distributed antenna system comprising a primary antenna and a plurality of secondary antennas, a fibre optic network connected between the primary antenna and the secondary antennas, first means associated with a first one of the antennas which transmits signals received by that antenna into the fibre optic network, and second means associated with a second one of the antennas which causes that antenna to transmit signals received by the second means from the fibre optic network.

In one embodiment, the first antenna is the primary antenna and each of the secondary antennas is provided with a respective one of said second means. In another embodiment, the second antenna is the primary antenna

and each of said secondary antennas is provided with a respective one of said first means. More preferably, an embodiment of the invention provides a distributed antenna system in which both the aforementioned arrangements are provided. That is, the system provides for distributed transmission and distributed reception.

Most beneficially, the signal transmitted into the fibre optic network comprises direct radio frequency modulation of the output of a laser.

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

Figure 1 is a schematic diagram illustrating an embodiment which provides for both distributed transmission and distributed reception, and

Figure 2 is a more detailed block diagram illustrating the reception and distributed transmission system of Figure 1, and

Figure 3 is a more detailed block diagram illustrating the distributed reception and central re-transmission system shown in Figure 1.

A preferred embodiment of the invention is illustrated schematically in Figure 1. A conventional radio transmission and reception system is indicated by units 10-16, each of which has an associated antenna, 10A-16A. Units 10 and 12 are respectively a transmitter and a receiver established at a first location. Units 14 and 16 are respectively a transmitter and a receiver established at a second location. Two way radio communication between the first and second locations takes place in a purely conventional manner, as is to be found in any free space radio link. However, units 14 and 16 act as the input and output of a distributed antenna system.

In the example illustrated in Figure 1, it is desired to provide a full free space radio transmission and reception system within a tunnel. The tunnel is indicated by reference numeral 18. One circuit, 20, provides distributed transmission of a radio signal within the tunnel and another circuit, 22, provides for the distributed reception of radio signals from within the tunnel. Of course, in practice, there may only be a requirement for either distributed reception or distributed transmission, in which case only one of the circuits 20 and 22 would be provided. However, the illustrated two circuit arrangement may be desirable, for example if the aim is to provide cellular radio

telephone facilities within the tunnel.

Each circuit 20 and 22 comprises a primary antenna and a plurality of secondary antennas, with the primary antenna being connected to the secondary antennas via a fibre optic network. In the case of circuit 20 the receiver units 16 associated with primary antenna 16A provides control signals to modulate the output of a laser 24. Laser 24 transmits light signals into fibre optic network 26 which has network branches 28 which feed respective secondary antenna systems 30. The secondary antenna system 30 comprises a photo detector 32 which receives light signals from fibre optic branch 28, and a transmitter amplifier 34. Amplifier 34 receives electrical signals from the photo detector 32 and supplies signals to secondary antenna 36, whereby the original radio frequency signal is re-transmitted within the tunnel. A number of secondary antenna units 30 may be spaced along the length of the tunnel, effectively providing local "drop off" nodes for the radio frequency signal.

Circuit 22 is of similar configuration except for the fact that the signals travel in the opposite direction. That is, each secondary antenna unit 38 comprises a secondary antenna 40 which receives radio frequency signals from within the tunnel and supplies these to a

receiver amplifier unit 42 which uses the received signals to control the output of a laser 44. Laser 44 transmits light signals into the fibre optic network 46 via a fibre optic network branch 48. A photo detector 50 is associated with primary antenna 14A and transmitter 14. That is, photo detector 50 receives light signals from fibre optic network 46 and supplies transmitter 14 with radio frequency electrical signals which are used to cause primary antenna 14A to re-transmit the radio signals. A plurality of secondary antenna units 38 may be provided along the length of the tunnel.

The lasers employed in the illustrated arrangement are of conventional construction. These lasers are, however, of the so-called "linear" type and operate in an analog rather than a digital mode. The components used for the various transmitter and receiver units are also conventional. More detail of these units is given with reference to Figures 2 and 3. It is to be noted that in the arrangement described with reference to Figure 1, the light signals travelling within the fibre optic networks are modulated at radio frequencies. The only conversion is between electrical and light signals. No heterodyne circuit is used.

Figures 2 and 3 illustrate in more detail the respective circuits 20 and 22 shown in Figure 1. That is, Figure 2 shows the detail of a circuit suitable for a 'Base to Mobile' distributed attenna system whereas Figure 3 shows the detail of a circuit suitable for a "Mobile to Base" distributed attenna system. As stated above, it is expected that the two circuits will usually be used together, although each could be used separately as the circumstances requires. Essentially, Figures 2 and 3 show that the radio frequency to fibre optic converters and fibre optic to radio frequency converters comprise conventional components. Specifically, the radio frequency to fibre optic converters comprise a filter, a laser power supply circuit and the laser itself. The fibre optic to radio frequency to fibre optic converters comprise a photodetector, a filter and an amplifier. The design of these components is within the skill of the person skilled in the art and consequently will now be described herein.

In comparison with the co-axial cable used in the known "leaky feeder" system, a suitable fibre optic network could be established at a very significantly reduced cost, perhaps as high as an 80% saving. Propagation of light signals within the fibre optic network, as is commonly known, are subject to remarkably little attenuation. It is considered possible for a signal to

be transmitted in the fibre optic network over a distance of about 30 miles before it is necessary to introduce a repeater. This is a very striking contrast with the above described use of repeaters in the co-axial system and may well be of profound significance for many modern vehicle tunnels. The fibre optic network is, of course, physically very flexible and easily conforms to the configuration required by the structure within which it is located. Signals travelling within the fibre optic network are unaffected by radio frequency interference and thus the network may be located adjacent power cables, which is not possible with the conventional co-axial system. Moreover, the bandwidth of the fibre optic network is considerably better than that of a co-axial system. The fibre optic bandwidth can cover essentially all radio frequencies and in particular those used by the cellular radio telephone systems.

In particular, the receiver units and respective lasers comprise a linear analog system. That is, the laser is modulated in its linear region of operation. Specifically, the receiver units modulate the radio frequency on the DC power supply of the laser. This results in radio frequency baseband signals being transmitted in the form of light waves. Typically, the radio frequencies used with the above described

embodiment might be in the range 100MHz to 1GHz.

For use in the described tunnel system, the power of the signal transmitted at each secondary antenna 36 may be of the order of a few milliwatts. In a conventional system using a "leaky feeder" co-axial system or an injection aerial located at the entrance to the tunnel, the power of the transmitted signal would typically be of the order of ten's of watts and the maximum penetration into the tunnel will be significantly less than can be achieved with the described fibre optic network system. It is to be noted that the fibre optic network may take any suitable form whether tree-like or linear.

One application of the present invention, namely use in tunnels, has been described. However, it will be readily apparent to those skilled in the art that the present invention has numerous applications. As a further example, the system is particularly useful within buildings, especially larger office accommodation and hospitals or the like. Such application of the invention is particularly beneficial in combination with cordless telephone systems and cellular radio telephones. With use of the present invention, it may be feasible to locate a radio telephone "cell" within a single building.

Claims:

1. A distributed antenna system comprising a primary antenna and a plurality of secondary antennas, a fibre optic network connected between the primary antenna and the secondary antennas, first means associated with a first one of the antennas which transmits signals received by that antenna into the fibre optic network, and second means associated with a second one of the antennas which causes that antenna to transmit signals received by the second means from the fibre optic network.

2. A distributed antenna system as claimed in claim 1, wherein the first antenna is the primary antenna and wherein each of said secondary antennas is provided with a respective one of said second means.

3. A distributed antenna system as claimed in claim 1, wherein the second antenna is the primary antenna and wherein each of said secondary antennas is provided with a respective one of said first means.

4. A distributed antenna system as claimed in claim 2 in combination with a distributed antenna system as claimed in claim 3.

5. A distributed antenna system as claimed in any preceding claim, wherein the said first means includes a linear analog laser and said second means includes a photo detector.

6. A distributed antenna system as claimed in claim 5, wherein said first means imposes radio frequency signals on the output of said laser.

7. A distributed antenna system substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.

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