(12) UK Patent Application (19) GB (11) 2 145 570 A

(43) Application published 27 Mar 1985

(21) Application No **8419391**

(22) Date of filing **30 Jul 1984**

(30) Priority data
(31) **8320615** (32) **30 Jul 1983** (33) **GB**

(51) INT CL[4]
H01Q 3/02

(52) Domestic classification
H1Q FS HX
G2J GEE
U1S 2139 H1Q

(56) Documents cited
None

(58) Field of search
H1Q

(71) Applicant
The General Electric Company plc (United Kingdom), 1 Stanhope Gate, London W1A 1EH

(72) Inventor
Christopher Ralph Pescod

(74) Agent and/or Address for Service
Roger K Tolfree, The General Electric Company plc, Central Patent Dept, Marconi Research Centre, Great Baddow, Chelmsford, Essex

(54) **Apparatus for use in an antenna arrangement**

(57) A radar includes a rotatable array of antenna elements 11, 12, 13, 14, 15 and 16 which receives pulses reflected by a target. The received signals are mixed with local oscillator signals L01, L02, L03, L04, L05 and L06, the phases of which are controlled by phase shifters, only one of which, 39, is shown. The phase control signal is generated at 19 at the fixed part of the radar, converted into optical form at 20 and colour multiplexed with the local oscillator signal from generator 17 on to a line 24. The signals are passed via an optical rotary joint 26 to the rotating part of the radar where they are demultiplexed and converted into electrical form at 34 and 35.

A frequency multiplexing signal generator 21 is also located at the fixed part and generates a fixed frequency signal which is converted into optical form at 22 and passed via the optical rotary joint 26 to a frequency multiplexer 48. This produces a comb of spaced frequencies which are mixed with respective signals from the antenna elements to give a wide bandwidth signal. This is converted into optical form by a laser diode 51 and passed to the fixed part of the radar where it undergoes further processing. The construction of the optical rotary joint, which has several optical lines, is also disclosed.

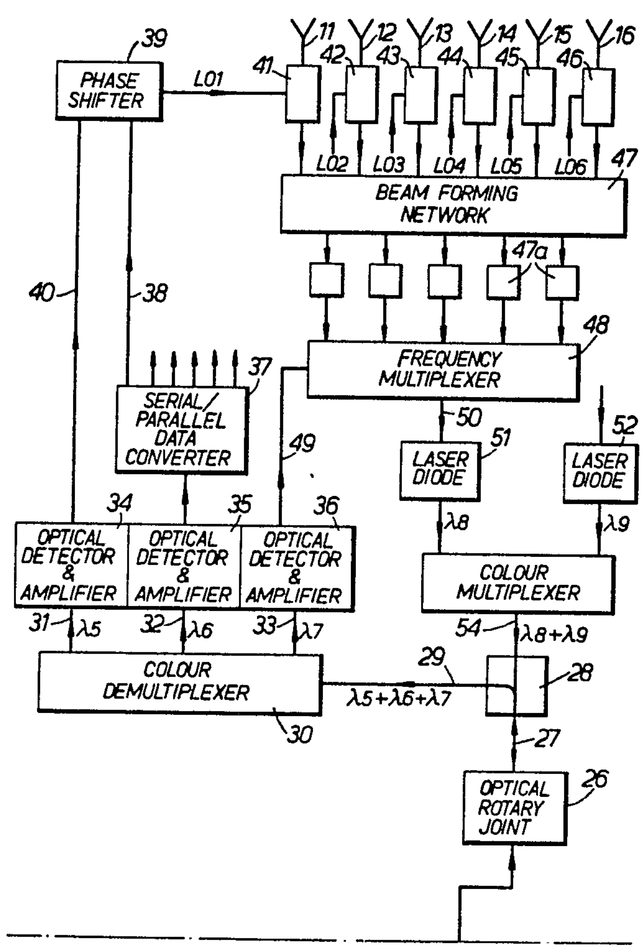


FIG.1a.

The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

GB 2 145 570 A

1/7

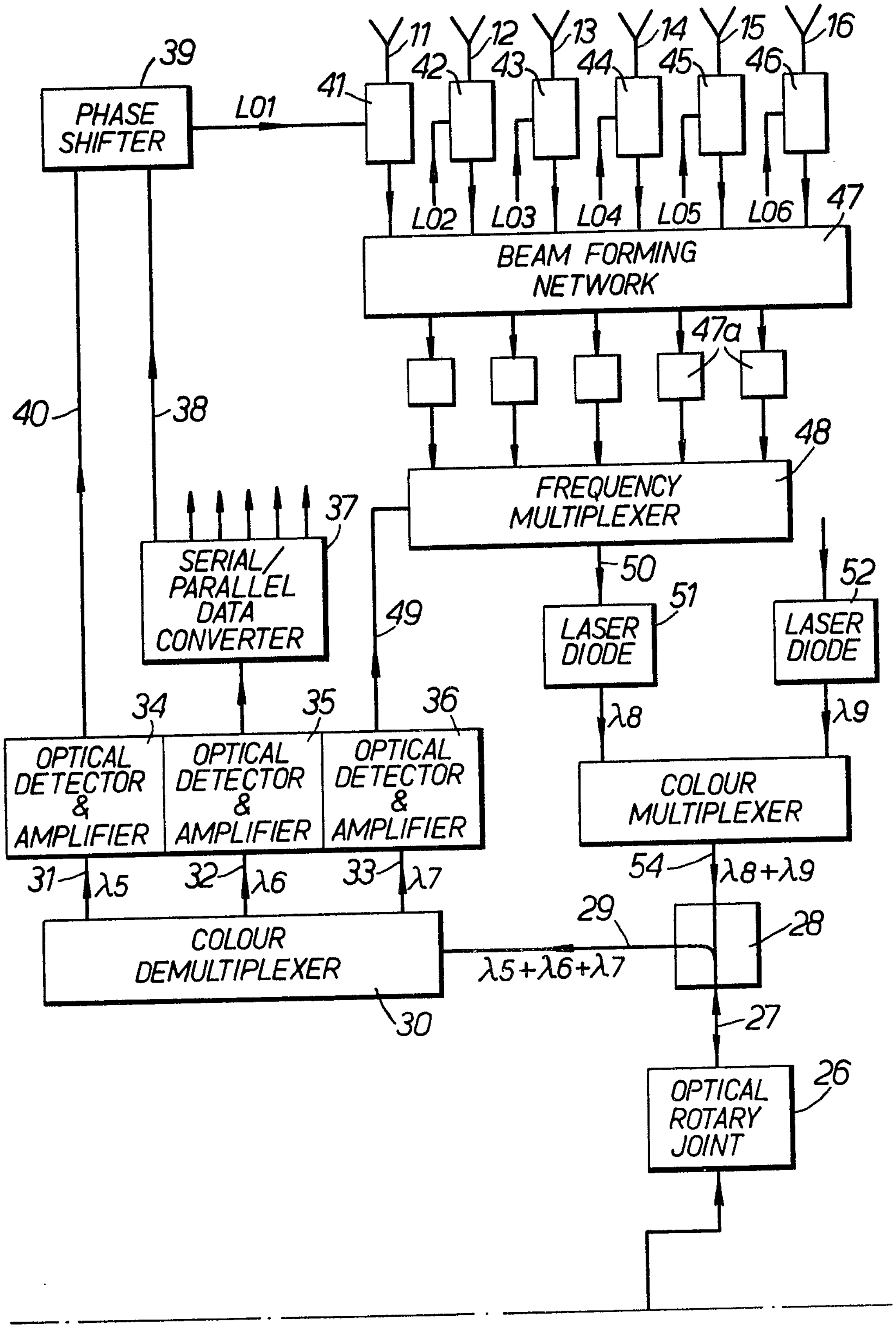
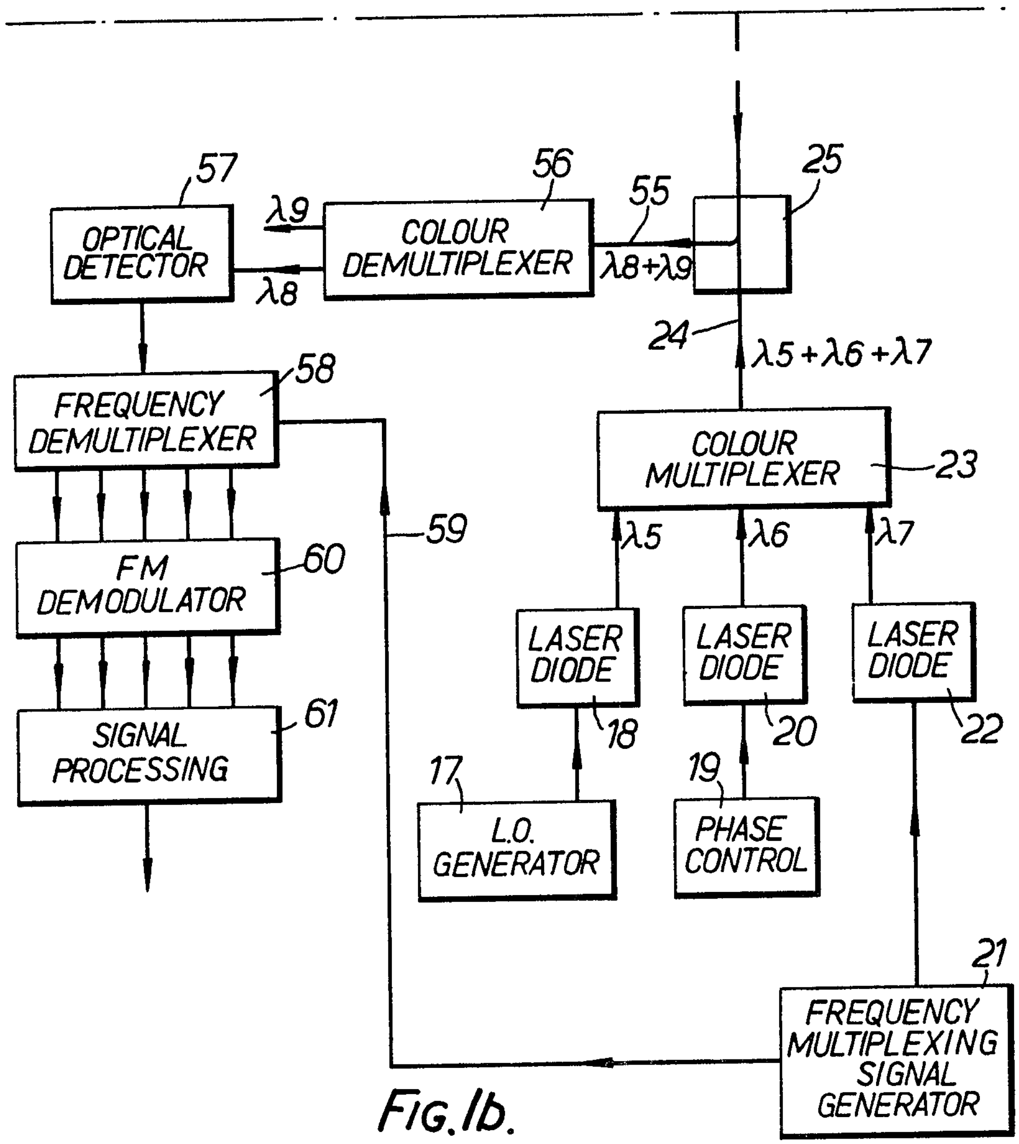

11
12
13
14
15
16
39
PHASE SHIFTER
LO1
41
42
43
44
45
46
LO2
LO3
LO4
LO5
LO6
47
BEAM FORMING NETWORK
47a
40
38
48
FREQUENCY MULTIPLEXER
37
SERIAL/ PARALLEL DATA CONVERTER
49
50
51
LASER DIODE
52
LASER DIODE
λ8
λ9
34
35
36
OPTICAL DETECTOR & AMPLIFIER
OPTICAL DETECTOR & AMPLIFIER
OPTICAL DETECTOR & AMPLIFIER
COLOUR MULTIPLEXER
31
λ5
32
λ6
33
λ7
54
λ8+λ9
29
28
COLOUR DEMULTIPLEXER
λ5+λ6+λ7
30
27
26
OPTICAL ROTARY JOINT

FIG.1a.



57
OPTICAL DETECTOR
λ9
λ8
56
COLOUR DEMULTIPLEXER
55
λ8+λ9
25
24
λ5+λ6+λ7
58
FREQUENCY DEMULTIPLEXER
COLOUR MULTIPLEXER
23
59
FM DEMODULATOR
60
λ5
λ6
λ7
SIGNAL PROCESSING
61
LASER DIODE
LASER DIODE
LASER DIODE
18
20
22
17
L.O. GENERATOR
19
PHASE CONTROL
21
FREQUENCY MULTIPLEXING SIGNAL GENERATOR

Fig. 1b.

2145570

3/7

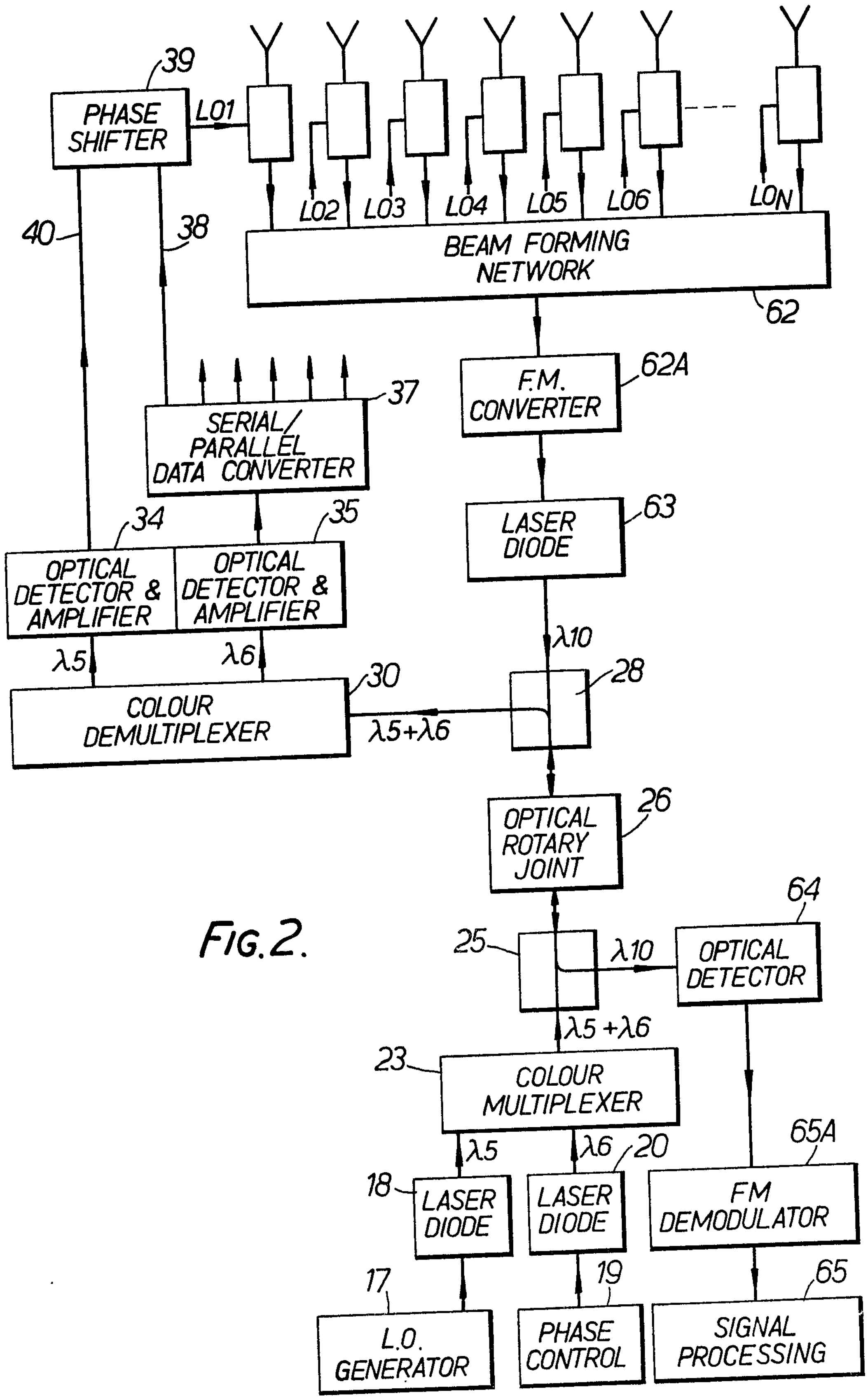


FIG. 2.

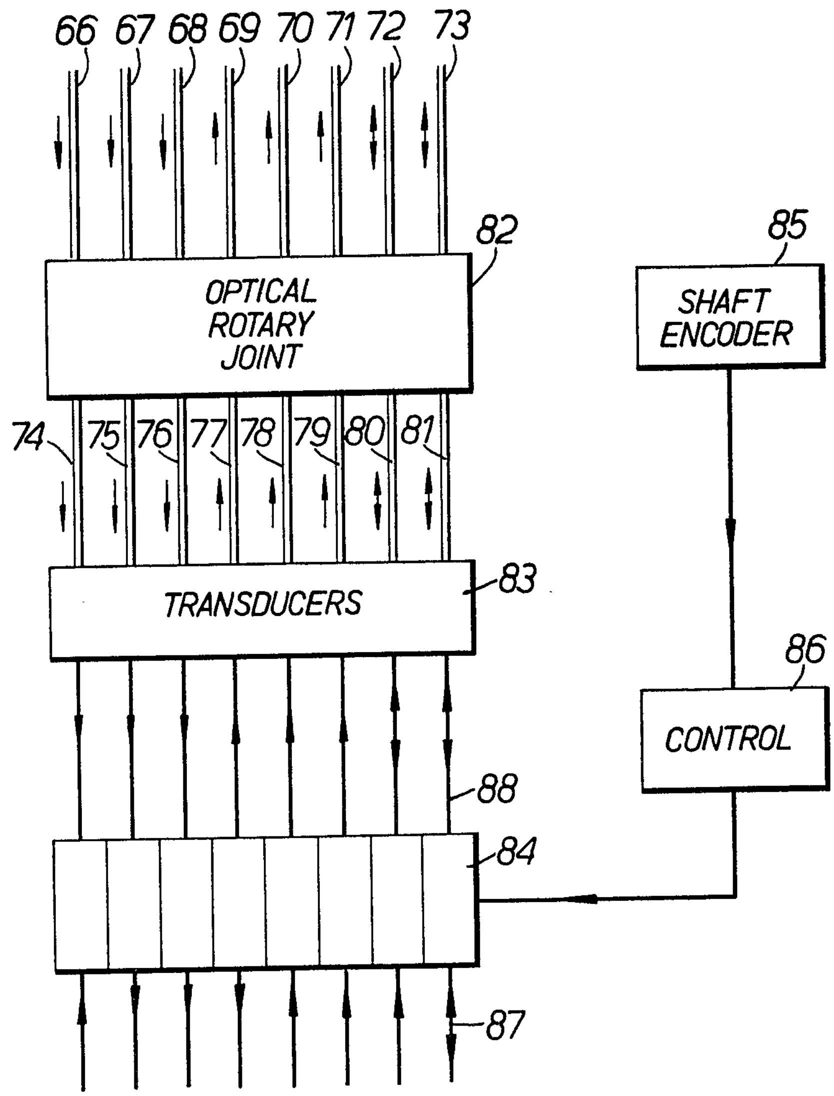

66
67
68
69
70
71
72
73
82
OPTICAL ROTARY JOINT
85
SHAFT ENCODER
74
75
76
77
78
79
80
81
TRANSDUCERS
83
86
CONTROL
88
84
87

FIG. 3.

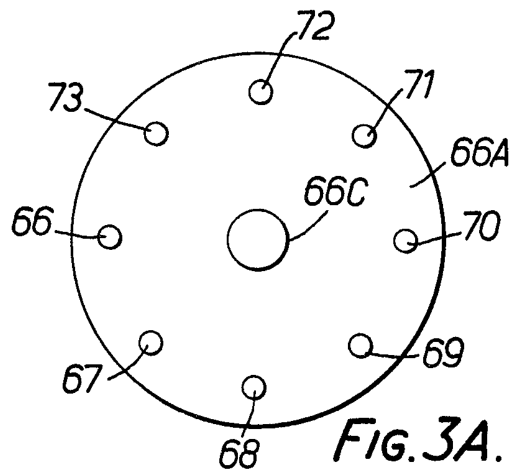

72
73
71
66A
66C
66
70
67
69
68

FIG. 3A.

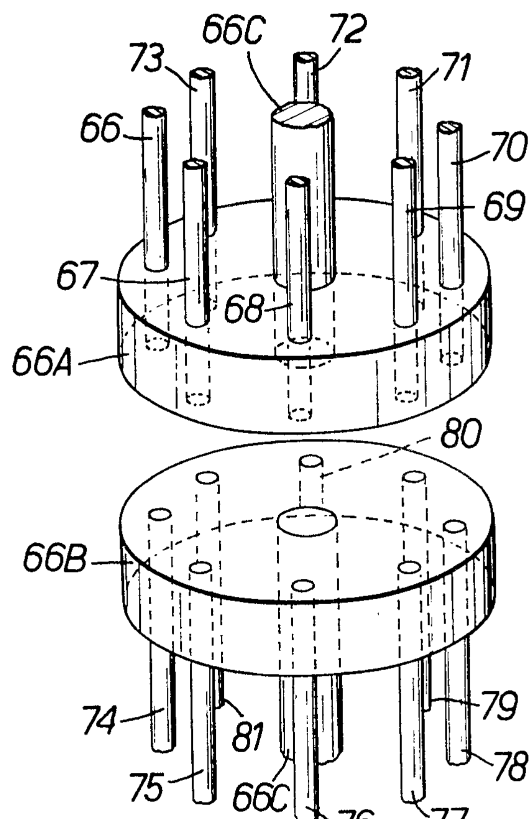

66C
72
73
71
66
70
69
67
68
66A
80
66B
74
81
79
75
66C
76
77
78

FIG. 3B.

2145570

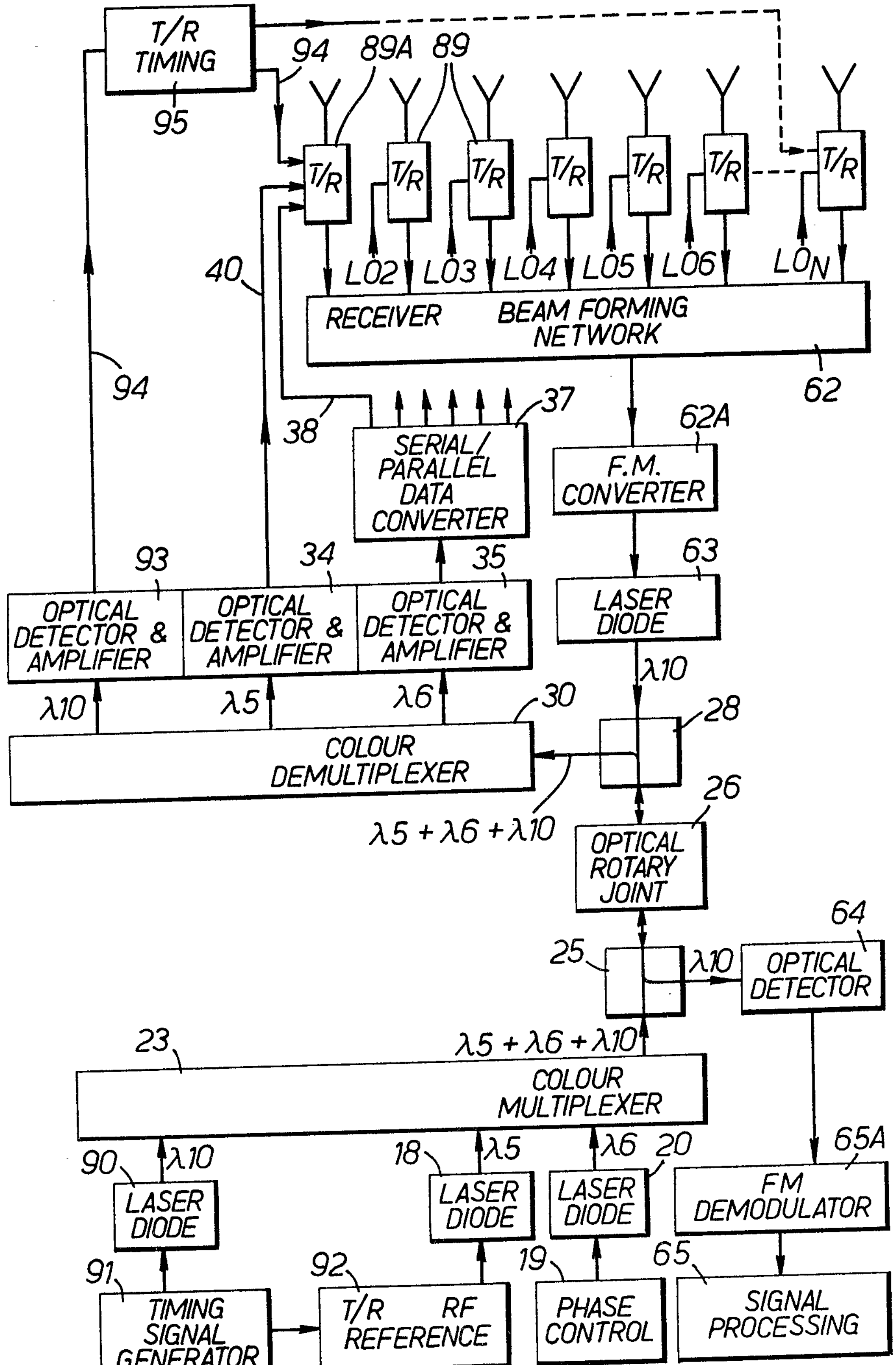


FIG. 4.

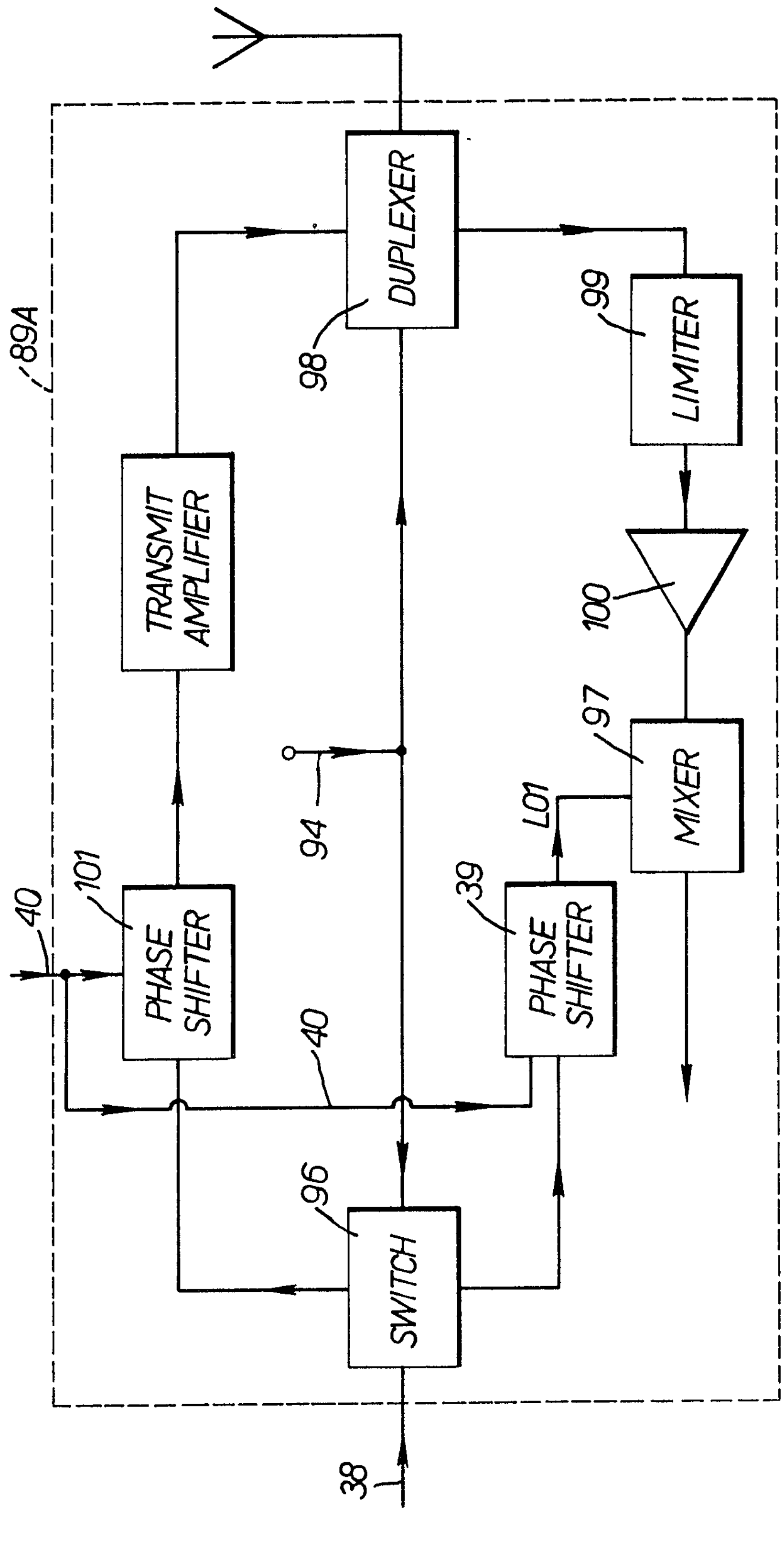

89A
DUPLEXER
98
TRANSMIT AMPLIFIER
LIMITER
99
100
97
MIXER
LO1
94
PHASE SHIFTER
101
40
PHASE SHIFTER
39
40
96
SWITCH
38

FIG.5.

SPECIFICATION

An antenna arrangement

This invention relates to an antenna arrangement and more particularly to one in which optical signals are employed to carry information between a rotating antenna and its fixed supporting structure.

It has been normal practice in the past for information in the form of electrical signals to be carried via slip rings from a rotatable antenna to its supporting structure. A similar system using optical signals and so-called "optical slip rings" has also been proposed, but there are problems associated with these optical slip rings which are not as satisfactory as their electrical counterparts, being suitable only for relatively low data rates. There is also a problem in picking off the optical signals from the optical slip rings.

According to the invention there is provided an antenna arrangement comprising a group of output lines carrying received signals, means for mixing signals from the output lines with respective frequencies from a source or sources of different spaced frequencies to obtain a wide bandwidth signal, different parts of whose bandwidth carry the different signals, means for using the wide bandwidth signal to modulate the output of a laser diode, and an optical line for transmitting the output of the laser diode from the antenna arrangement.

Thus, by employing the invention it is possible to carry a number of received signals from the antenna along a single optical channel, making use of the fact that a typical laser diode can handle a wide bandwidth input signal. In this way the need for optical slip rings can be eliminated, their function being replaced by a simple optical rotating joint.

The different parts of the wide bandwidth signal can be contiguous or can be frequency spaced. 'Wide' in this context means wider than the bandwidth which would be occupied by only one of the received signals after being mixed with one of the spaced frequencies. There must be at least two different spaced frequencies, the actual number being dependent upon the number of received signals. When there are more than two spaced frequencies they may be spaced at equal or different intervals. The characteristics of the laser diode enable it to handle the wide bandwidth.

Preferably the antenna arrangement includes a second group of output lines, means for mixing signals from the output lines of the second group with respective frequencies from a source or sources of different spaced frequencies to obtain a second wide bandwidth signal; means for using the second wide bandwidth signal to modulate a second laser diode whose output frequency is different from that of the first mentioned laser diode and an optical frequency multiplexer for multiplexing the outputs of the laser diodes on to the said optical line.

By using frequency (or colour) multiplexing as described in the immediately preceding paragraph, an even larger number of channels may be obtained and a large array of antenna elements may be handled.

According to a second aspect of the invention there is provided radar apparatus comprising a first array of antenna elements mounted on a structure arranged to rotate relative to a base; an optical rotary joint linking the structure to the base; first colour multiplexing means for establishing a plurality of multiplexed colour channels through the optical rotary joint; a frequency multiplexing signal generator associated with the base for generating a reference frequency signal and passing it along one of the channels through the optical rotary joint; means associated with the structure for using the reference frequency signal to establish a comb of different frequencies and mix them with signals from respective antenna elements; and means for combining the results of such mixing and applying the resulting signal to a first laser diode to modulate the output thereof, which output is passed through another of said channels through the optical rotary joint to receiving circuitry associated with the base.

Preferably there is included a second array of antenna elements; means for using signals received from the second array to modulate the output of a second laser diode; and second colour multiplexing means for multiplexing the modulated outputs of the first and second laser diodes on to an optical line and passing them through the optical rotary joint.

According to a third aspect of the invention there is provided radar apparatus, comprising: a suport and a rotatable structure arranged to rotate relative to the support; an array of antenna elements fixed relative to the rotatable structure; a local oscillator signal generator and a phase control signal generator fixed relative to the support; first and second laser diodes fixed relative to the support, the outputs of which are arranged to be modulated by the local oscillator signal and phase control signal respectively; colour multiplexing means, fixed relative to the support for multiplexing the modulated outputs on to a line; an optical rotary joint linking the support and the rotatable structure; means for transmitting multiplexed signals from the said line through the optical rotary joint; a colour demultiplexer fixed relative to the rotatable structure for demultiplexing the multiplexed signals; phase shift means fixed relative to the rotatable structure for shifting the phase of the local oscillator signal by different amounts; mixing means fixed relative to the rotatable structure for mixing the local oscillator signal, after being phase shifted by the different amounts, with respective different antenna element outputs; means fixed relative to the rotatable structure for combining the outputs of the mixing means and for using the result of such combination to control a third laser diode so as to modulate the output thereof; means for passing the resulting modulated output through the optical rotary joint; and receiving circuitry fixed relative to the support to receive the modulated output of the third laser diode.

According to a fourth aspect of the invention there is provided an optical rotary joint comprising two members arranged for relative rotation, a first group of optical lines connected to the first member, a second group of optical lines connected to the second member so that signals on different lines of the first group are communicated to respective lines of the second group according to the relative rotational position of the members and means for producing a signal indicative of the position of rotation so as to indicate from what line of the first group a signal on a line of the second group is derived.

Preferably an optical rotary joint as described above includes a single optical fibre located at the axis of rotation of the two members. The single optical fibre may then carry analogue signals, whilst the first and second groups carry digital signals.

Some ways in which the invention may be performed will now be described with reference to the accompanying drawing in which:

Figures 1a and 1b are a schematic block diagram of radar apparatus in accordance with the invention;

Figure 2 is a schematic block diagram of another radar apparatus in accordance with the invention;

Figure 3 is a schematic block diagram of apparatus in accordance with the invention;

Figure 3A is a plan view of the apparatus shown in Figure 3;

Figure 3B is a schematic perspective view of part of the apparatus shown in Figure 3;

Figure 4 is a schematic block diagram of a further radar apparatus in accordance with the invention; and

Figure 5 shows part of the apparatus of Figure 4 in greater detail, with like references being used for like parts throughout.

With reference to Figure 1 a radar system includes an array of receiver elements 11, 12, 13, 14, 15 and 16 mounted on a member which is rotatable relative to a fixed base and spaced in the vertical plane, thereby giving azimuthal scanning of elevationally spaced receive beams.

A local oscillator signal generator 17 is located at the fixed base and produces an RF signal which is coherent with the transmitted signal of the radar system. The RF system is then used to amplitude modulate the output of a laser diode 18, having an output of optical wavelength λ5, at a modulation frequency which depends on the frequency of the local oscillator signal.

A phase controller 19 is also positioned at the base and generates a digital signal containing information about the phase shift of the local oscillator required at each element of the array. The information is given in serial form, an element address code being followed by a phase code specifying the desired phase at that element. The output of the phase controller 19 amplitude modulates the output of a laser diode 20 having an optical wavelength λ6 at a modulation frequency which varies with the coded signal.

A frequency multiplexing signal generator 21 produces a signal having a fixed frequency and modulates a laser diode 22, having an output at an optical wavelength λ7, in a similar manner to that by which the local oscillator signal modulates the output of laser diode 18.

The three optical signals at wavelengths λ5, λ6 and λ7 are applied to a colour multiplexer 23 which multiplexes them on to an optical line 24. They are passed via a first directional coupler 25 to an optical rotary joint 26 where they are transferred to another optical line 27 which moves with the rotating member.

A second directional coupler 28 causes the optical signals to be sent along a line 29 to a colour demultiplexer 30 which demultiplexes those at wavelengths λ5, λ6 and λ7 into lines 31, 32 and 33 respectively. Each of the signals on lines 31, 32 and 33 is then applied to optical detectors 34, 35 and 36 respectively which also amplify the detected signals.

The signal from detector 35, which carries the information regarding the phase shift of the local oscillator signal at each element, is applied to a serial-to-parallel data converter 37. The converter 37 has a plurality of output lines each of which is associated with a respective element of the array. The converter 37 recognises the element address code of an incoming signal and applies the phase code which follows it on to the line specified by the address code. The signal to one of the lines 38 is transmitted to a phase shifter 39 as is the local oscillator signal from detector 34 via line 40. The local oscillator signal is phase shifted by an amount which is determined by the signals on line 38 and results in a signal LO1 which is applied to receive module 41 associated with element 11 of the array. Signals on the remainder of the output lines of the converter 37 are applied to respective phase shifters (not shown) which also receive the local oscillator signals and introduce respective phase shifts to produce signals LO2, LO3, LO4, LO5 and LO6 applied to receive modules 42, 43, 44, 45 and 46 respectively associated with elements 12, 13, 14, 15 and 16.

The phase shifts of the local oscillator signal at respective modules are used to compensate for differences in the nominally identical receive modules and elements.

Signals received at the elements 11, 12, 13, 14, 15 and 16 are mixed with local oscillators LO1, LO2, LO3, LO4, LO5 and LO6 respectively in respective receive modules and the resulting signals passed to the input lines of a beam forming network 47. It acts to weight parts of each input signal by certain amounts and then sum the resulting signals from respective inputs. This gives a plurality of receive beams having fixed directions of sensitivity, spaced in elevation, which scan in azimuth because of the rotating member. Each of the plurality of beams results from a respective different set of weightings. The beam forming network 47 has a number of output lines, the signal on each one representing a single receive beam.

These received signals are converted into frequency modulated form at converters 47A by means of voltage controlled oscillators, there being a converter on each of the output lines. The frequency modulated signals are then passed to a frequency multiplexer 48 which also receives the fixed frequency signal detected at 36 on line 49. A comb of frequencies having a fixed frequency spacing is produced from the signal on line 49 at the multiplexer 48. The incoming receive beams on respective input lines of the frequency multiplexer 48 are mixed with respective frequencies of the comb of frequencies and the upper sideband taken. This gives a wideband signal containing information from all the receive beams which is applied to an output line 50 and a laser diode 51 which is able to handle the bandwidth. It is necessary to convert the signals to be applied to the laser diode 51 into frequency modulated form because of the limited dynamic range of the laser diode 51, which precludes successful amplitude modulation of its outputs to the desired extent. Instead, its output at an optical wavelength $\lambda 8$ is amplitude modulated at a frequency which is dependent on the signal applied.

Signals received by another array of elements (not shown) are similarly treated to those already mentioned and their resulting output is also applied to a laser diode 52 operating at an optical wavelength $\lambda 9$. The signals from the two laser diodes 51 and 52 are applied to a colour multiplexer 53 which multiplexes them on to a line 54. They are transmitted, via the second directional coupler 28, line 27 and the optical rotary joint 26, to the first directional coupler 25 at the fixed base which sends them along a line 55 to a colour demultiplexer 56.

The demultiplexer 56 separates the signals from the two sets of receive arrays and passes that at wavelength $\lambda 8$ to an optical detector 57 followed by a frequency demultiplexer 58 which separates out the received beams on to five output lines, corresponding to the output lines of the beam forming network 47, using the reference fixed frequency signal from generator 21 applied to the demultiplexer 58 on line 59. The signals on the output lines are then further processed by an FM demodulator 60 to convert them back into amplitude modulated form and at 61 to extract the information determined by the received array. The signal at optical wavelength $\lambda 9$ is similarly processed.

In this embodiment only a small number of receiver elements are illustrated but in practice a much larger number are employed. In this apparatus signals representing receive beams are processed and sent through the optical rotary joint 26. In other apparatus, signals from the modules 41, 42, 43, 44, 45 and 46 could be multiplexed and transmitted through the joint 26 to a beam forming network associated with the fixed base.

Although in this embodiment one laser diode 51 follows the frequency multiplexer 48, it would be possible to use a number of laser diodes receiving the outputs from the beam forming network 47 and passing the emitted radiation directly to the colour multiplexer 53.

Referring to Figure 2, this shows apparatus similar to that described with reference to Figure 1 but in which a single steered received beam is employed. Signals from a local oscillator signal generator 17 and phase controller 19 are applied to laser diodes 18 and 20, modulating their output signals which have optical wavelengths $\lambda 5$ and $\lambda 6$ respectively. These output signals are applied to a colour multiplexer 23 and passed via a first directional coupler 25 and optical rotary joint 26 to a second directional coupler 28 which in turn passes them to a colour demultiplexer 30. This sends the local oscillator signal at an optical wavelength $\lambda 5$ to optical detector 34 and the phase control signal at an optical wavelength $\lambda 6$ to optical detector 35. The phase control signal is applied to a serial-to-parallel data converter 37 which transmits data concerning the phase shift to the local oscillator signal at each element of the receiver array along appropriate ones of output lines 38 as specified by the address code of the signal. The signals on lines 38 are applied to phase shifters, one of which is shown 39, which varies the phase of the local oscillator signal, transmitted to it from detector 34 along a line 40, to give a number of outputs LO1, LO2, LO3, LO4, LO5, LO6 and LON which are applied to respective receive modules associated with each element of the receiver array. The phase shifts imposed by the phase shifter 39 are varied to steer the received beam.

A beam forming network 62 combines the outputs of the receiving modules by summing them to give a single signal representing the steered receive beam. This signal is converted by a voltage controlled oscillator at 62A to a frequency modulated signal and is used to modulate a laser diode 63 with the amplitude of the laser diode output,(at an optical wavelength $\lambda 10$),being modulated at a frequency which depends on the signal from the beam forming network 62.

The output of the laser diode 63 is transmitted to the second directional coupler 25, via the first directional coupler 28 and the optical rotary joint 26. The radiation then passes to an optical detector 64 where it is converted into electrical form and via an FM demodulator 65A to a signal processing circuit 65, which carries out the remaining operations.

In many cases a single optical fibre on to which optical signals are multiplexed is adequate. However, there may be occasions where such a number of signals are required to be transmitted that one optical fibre is not able to handle them, for example in a radar having a large array of elements. This may be improved by employing a plurality of optical fibres on the rotating part of apparatus corresponding to another plurality of respective fibres on the fixed part. Thus a large number of fibres may be used, each of which may carry a number of multiplexed signals, in addition to a single optical fibre including an optical rotating joint at the axis of rotation. These plurality of fibres, which may be spaced around the single optical fibre, are most suited to carrying digital signals, such as those, for example, from the phase controller 19 of Figure 1.

Referring to Figures 3, 3A and 3B, a cylindrical rotating member 66A carries a first plurality of optical fibres, eight of which 66, 67, 68, 69, 70, 71, 72 and 73 are shown. These carry digital optical signals in either or both directions and are distributed around the circumference of the rotating member 66A. A cylindrical fixed member 66B having a common axis with the rotating member carries a second plurality of optical fibres 74, 75, 76, 77, 78, 79, 80 and 81. A single optical fibre 66C lies along the common axis, and has an optical rotating joint enabling the member 66A to rotate freely with respect to the fixed member 66B. The single optical fibre 66C carries analogue signals. The rotating member 66A moves in steps and at each position one end of each of the first plurality of optical fibres is adjacent to an end of one of the second plurality, the one it lines up with depending on the step position. The first and second pluralities are positioned sufficiently close together for light passed along one to be transferred to another without great attenuation, the fixed and rotating members 66A and 66B forming part of an optical rotary joint 82.

The digital optical signals passed to the second plurality are converted into electrical form by transducers 83 and stored in a cyclic shift register 84. Similarly, signals sent in the other direction are taken from the shift register 84 and passed via the transducers 83 to the second plurality.

A shaft encoder 85 is positioned close to the rotating member 66A and reads a code attached to it to determine its position relative to the fixed member 66B. This information is passed to a control circuit 86 which controls the number of clock pulses applied to the shift register 84 depending on the position of the rotating member 66A. The clock pulses cause the data in the shift register 84 to be circulated so that signals from it are applied to the correct lines. In the example shown, bidirectional signals are present on line 87 and these are cylically shifted one to the left by the shift register 84 so that they are applied and received from lines 88 and 81 and hence optical fibre 73 on the rotating member 66A. When the rotating member 66A progresses to its next step position, the shift register 84 is correspondingly altered so that information on line 87 is still applied to and taken from optical fibre 73 even though it has a different position relative to the fixed member 66B.

In such an arrangement shown in Figures 3, 3A and 3B the first and second pluralities of optical fibres distributed about the circumferences of the relatively rotating members 66A and 66B are most suited to carrying digital signals since breaks in transmission as the step positions alter are less critical than would be the case with analogue signals. The digital signals carried on these fibres may by those which control the phase of phase shifters, for example as shown in Figure 1. In this case, transmission may occur when the fibres are aligned, and the signals sent may be stored at the phase shifters until an activating pulse is applied. Thus continuous communication between signals carried by the first and second pluralities is not necessary. Digital signals may also be received from performance monitoring of elements in a rotating antenna array, and sent to the fixed member 66B via the first and second pluralities. If continuous digital communication is required, say from antenna array elements receiving signals which are converted from analogue to digital form, this could be achieved by storing incoming digitized signals, whilst the pluralities are not aligned. Then when they are aligned, the stored signals could be transmitted at a faster rate than that at which they are received. However, such a method would require careful monitoring to ensure that signals received by the elements simultaneously were also transferred to fibres of the second plurality simultaneously.

Where real time signals are required, or analogue signals, these can be transmitted via the single optical fibre 66C.

Digital signals are also more suited than analogue signals to transmission along the pluralities of fibres, because when the first and second pluralities are not exactly aligned, information in digital form may still be sent between them without distortion.

The closest fibres may be spaced together is one half of a diameter of a fibre, so that confusion does not arise between signals from adjacent fibres on one member being transmitted to one fibre on the other.

An arrangement like that shown in Figures 3, 3A an 3B may be used for the rotary joint 26 of Figure 1 in circumstances where a large number of elements are included in the array and signals from them cannot all be multiplexed on to a single line. In such an arrangement, all the parts shown above and below the rotary joint 26 of Figure 2 are duplicated for each of the optical fibres included in the joint.

Referring to Figure 4, apparatus similar to that described with reference to Figure 2 is illustrated but includes transmit/receive modules 89 rather than modules capable of receiving only, as in the Figure 2 embodiment.

A laser diode 90 having an output with an optical wavelength of λ10 is located at the fixed base part of the radar system and is modulated by the output of a timing signal generator 9 which also controls the frequency of a T/R RF reference signal generator 92 depending on whether the radar system is in the transmit or receive mode. The output of the laser diode 90 is multiplexed by the colour multiplexer 23 on to a line which also carries the outputs of laser diodes 18 and 20. The three optical signals having optical wavelengths λ5, λ6 and λ10 are passed via the first directional coupler 25, the optical rotary joint 26 and the second directional coupler 28 to the colour demultiplexer 30. The optical signals having wavelengths λ5, λ6 and λ10 are demultiplexed and converted into electrical signals by optical detectors 34, 35 and 93 respectively. The output of the detector 93 is applied to a line 94 and constitutes a timing signal which is applied to a T/R timing circuit 95. T/R timing circuit 95 has a plurality of output lines corresponding to the number of transmit/receive modules 89, one of which 89A is illustrated in greater detail in Figure 5.

When the radar system is in the receive mode the timing signal on line 94 from circuit 95 causes a switch 96 to be set such that the data carried on line 38 is applied to the phase shifter 39. This ensures that the reference signal applied on line 40 is shifted by the required amount to produce the signal LO1 which is mixed at a mixer 97 with the received signal. The received signal is routed to the mixer 97 via a duplexer 98, also set by the signal on line 94, a limiter 99 and an amplifier 100. The output of the mixer 93 is applied to the receiver beam forming network 62.

The radar system remains in the receive mode for a period determined by the output of the timing signal generator 91 when it is then switched to its transmit mode. The output of generator 91 causes the frequency of the reference signal from generator 92 to be increased accordingly, and changes the settings of the switch 96 and duplexer 98 of the transmit/receive module 89A, and those of the other modules 89. Thus the information on line 38 is applied to another phase shifter 101 which receives the reference signal on line 40. The output of the phase shifter 101 is amplified by an amplifier 102 and passed via the duplexer 98 to be transmitted.

Where, as in the embodiment of Figures 4 and 5, a facility for transmission is included, conventional electrical slip-rings or a beam-waveguide can be used to provide power to the transmitter, and in particular to the transmitter amplifiers shown on Figure 5.

CLAIMS

1. An antenna arrangement comprising a group of output lines carrying received signals, means for mixing signals from the output lines with respective frequencies from a source of different spaced frequencies to obtain a wide bandwidth signal, different parts of whose bandwidth carry the different signals, means for using the wide bandwidth signal to modulate the output of a laser diode, and an optical line for transmitting the output of the laser diode from the antenna arrangement.

2. An antenna arrangement according to claim 1 designed to rotate relative to a support structure and in which the optical line is connected to an optical rotary joint.

3. An antenna arrangement according to claim 1 or 2 comprising a second group of output lines, means for mixing signals from the output lines of the second group with respective frequencies from a source or sources of different spaced frequencies to obtain a second wide bandwidth signal, means for using the second wide bandwidth signal to modulate a second laser diode whose output frequency is different from that of the first mentioned laser diode and an optical frequency multiplexer for multiplying the outputs of the laser diodes on to the said optical line.

4. Radar apparatus comprising a first array of antenna elements mounted on a structure arranged to rotate relative to a base; an optical rotary joint linking the structure to the base; first colour multiplexing means for establishing a plurality of multiplexed colour channels through the optical rotary joint; a frequency multiplexing signal generator associated with the base for generating a reference frequency signal and passing it along one of the channels through the optical rotary joint;

means associated with the structure for using the reference signal to establish a comb of different frequencies and mix them with signals from respective antenna elements; and means for combining the results of such mixing and applying the resulting signal to a first laser diode to modulate the output thereof, which output is passed through another of said channels through the optical rotary joint to receiving circuitry associated with the base.

5. Radar apparatus as claimed in claim 4 and including a second array of antenna elements; means for using signals received from the second array to modulate the output of a second laser diode; and second colour multiplexing means for multiplexing the modulated outputs of the first and second laser diodes on to an optical line and passing them through the optical rotary joint.

6. Radar apparatus comprising: a support and a rotatable structure arranged to rotate relative to the support; an array of antenna elements fixed relative to the rotatable structure; a local oscillator signal generator and a phase control signal generator fixed relative to the support; first and second laser diodes fixed relative to the support, the outputs of which are arranged to be modulated by the local oscillator signal and phase control signal respectively; colour multiplexing means, fixed relative to the support, for multiplexing the modulated outputs on to a line; an optical rotary joint linking the support and the rotatable structure; means for transmitting multiplexed signals from the said line through the optical rotary joint; a colour demultiplexer fixed relative to the rotatable structure for demultiplexing the multiplexed signals; phase shift means fixed relative to the rotatable structure for shifting the phase of the local oscillator signal by different amounts; mixing means fixed relative to the rotatable structure for mixing the local oscillator signal, after being phase shifted by the different amounts, with respective different antenna element outputs; means fixed relative to the rotatable structure for combining the outputs of the mixing means and for using the result of such combination to control a third laser so as to modulate the output thereof; means for passing the resulting modulated output through the optical rotary joint; and receiving circuitry fixed relative to the support to receive the modulated output of the third laser diode.

7. An optical rotary joint comprising two members arranged for relative rotation, a first group of optical lines connected to the first member, a second group of optical lines connected to the second member so that signals on different lines of the first group are communicated to respective lines of the second group according to the relative rotational position of the members and means for producing a signal indicative of the position of rotation so as to indicate from what line of the first group a signal on the line of the second group is derived.

8. An optical rotary joint as claimed in claim 7 and including a single optical fibre located at the axis of rotation of the two members.

9. Apparatus substantially as illustrated in and described with reference to Figure 1 of the accompanying drawings.

10. Apparatus substantially as illustrated in and described with reference to Figure 2 of the accompanying drawings.

11. Apparatus substantially as illustrated in and described with reference to Figures 3, 3A and 3B of the accompanying drawings.

12. Apparatus substantially as illustrated in and described with reference to Figures 4 and 5 of the accompanying drawings.

Printed in the United Kingdom for
Her Majesty's Stationery Office. Dd 8818935. 1985. 4235
Published at The Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained