

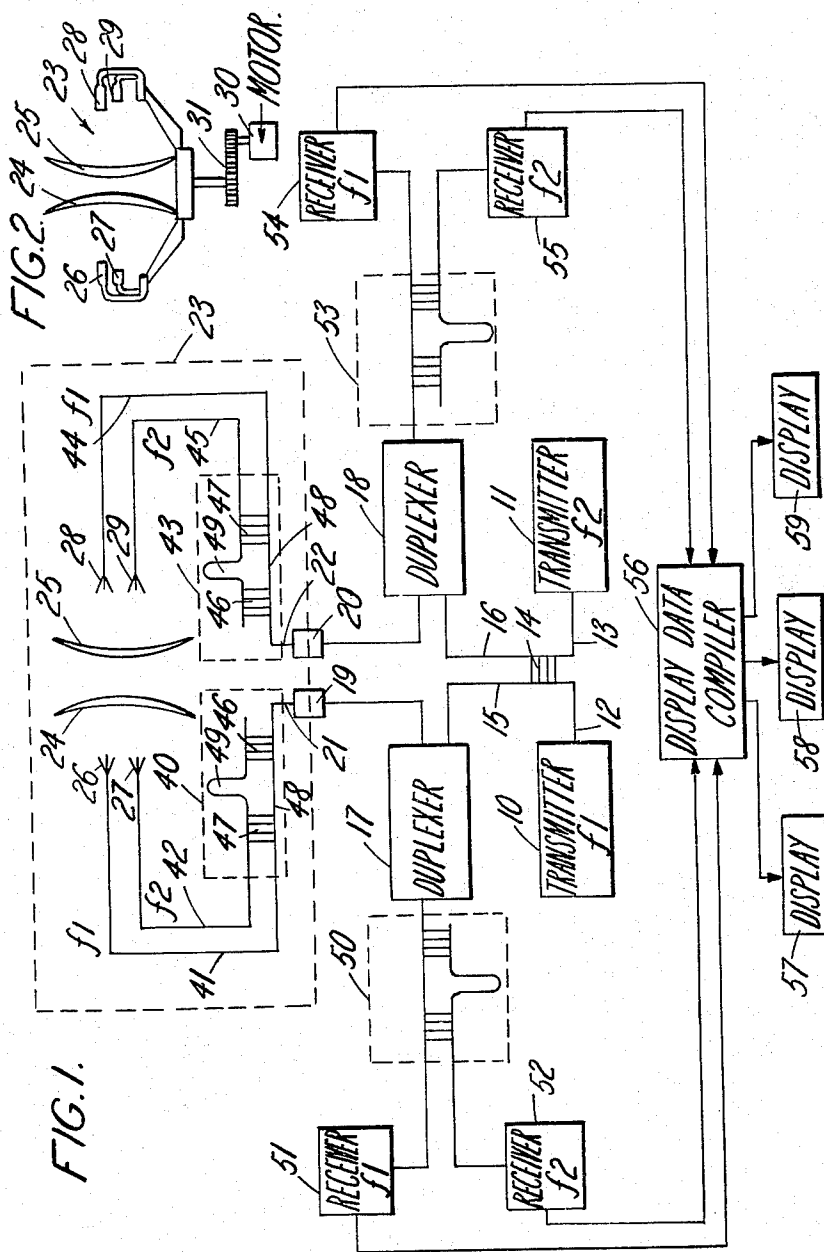
Aug. 22, 1961

M. H. EASY ET AL
MULTI-FREQUENCY RADAR APPARATUS WITH ROTATABLE
BACK-TO-BACK ANTENNAS

2,997,706

Filed Jan. 28, 1959

4 Sheets-Sheet 1



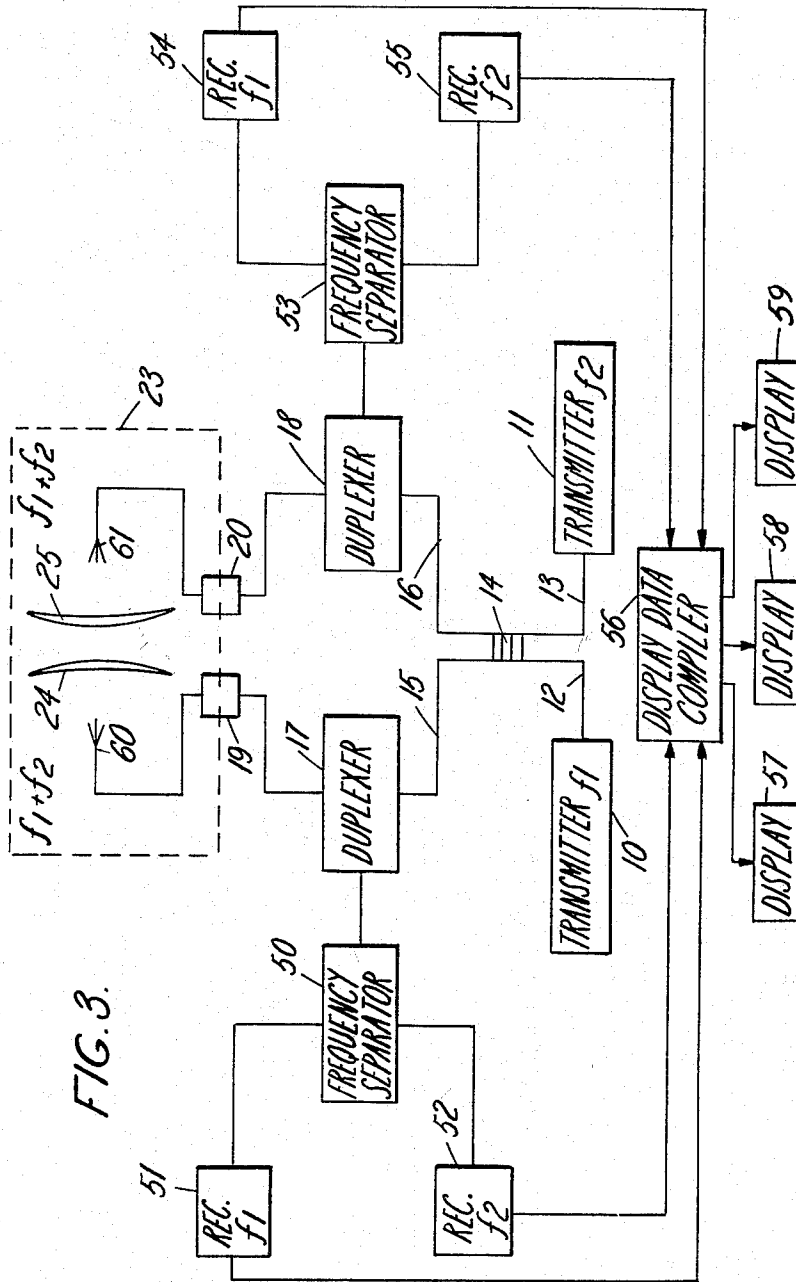
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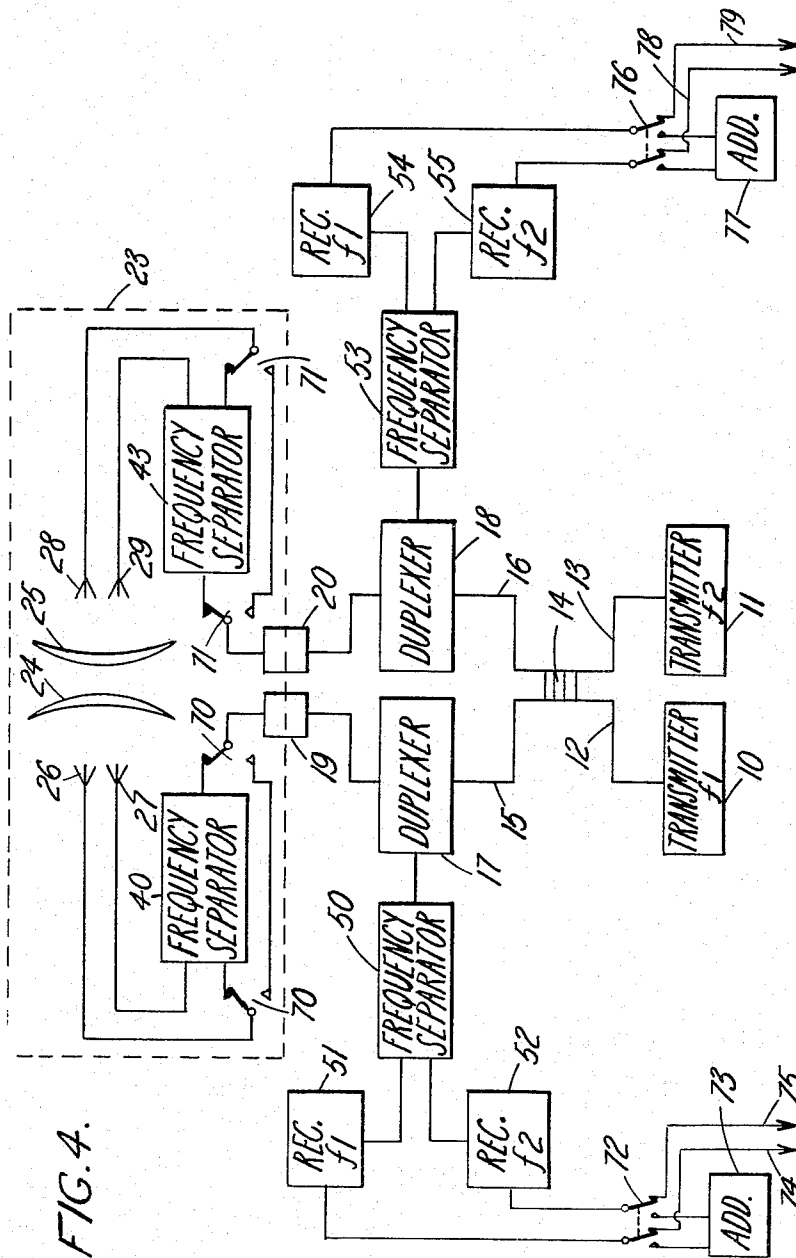
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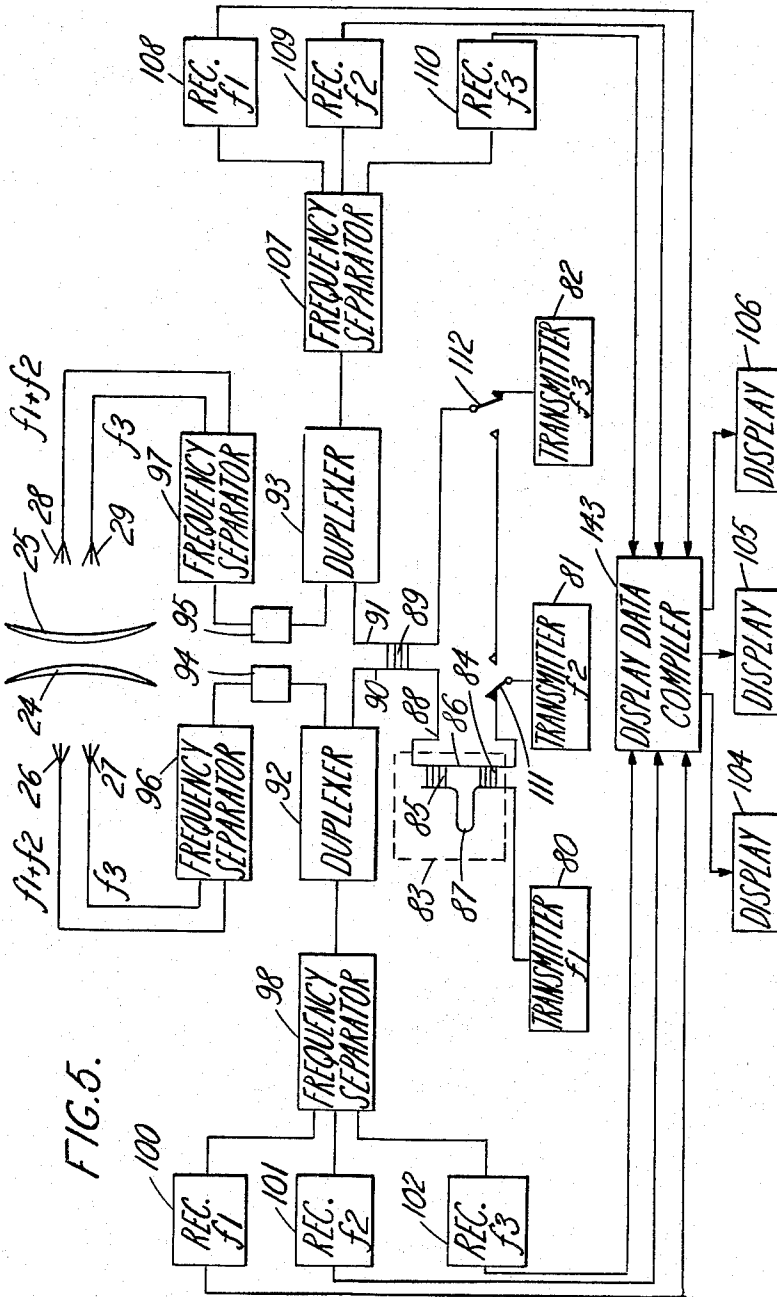


FIG. 5.

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MULTI-FREQUENCY RADAR APPARATUS WITH ROTATABLE BACK-TO-BACK ANTENNAS

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11 Claims. (Cl. 343-5)

This invention relates to radar apparatus of the kind having a rotatable aerial system.

According to the invention in radar apparatus having a rotatable aerial system, the aerial system has two aerials mounted back-to-back and two rotatable couplers for coupling respectively the two aerials to fixed feed systems, there are provided two or more transmitters arranged to operate on different frequencies, and coupling means for combining the outputs from the transmitters into a single feed system and for dividing the combined output between the two rotatable couplers for feeding respectively the two aerials whereby signals of all the transmitted frequencies are radiated in two opposite directions. Each aerial may comprise a single radiating element arranged to radiate signals of two or more different frequencies. Alternatively each aerial may comprise two or more radiating elements, e.g. horns, associated with a single reflector, frequency separating means being provided for separating the signals from the transmitters into different frequency components for each of the radiating elements. These frequency separating means may be mounted in the rotatable part of the aerial system so that each rotatable coupler may be used for signals of two or more frequencies.

The radiating elements may be positioned and the frequencies chosen so that each aerial provides two or more beams in the same azimuthal direction but having different coverage patterns in the vertical plane. It is thus possible to obtain different coverage patterns with only one rotating aerial system.

The invention may be applied not only to pulse radar apparatus but also to frequency-modulated radar apparatus provided the frequencies employed are such that the frequency separating means can separate the frequency bands of the separate transmitters.

If two frequencies are to be radiated, the frequency separating means may conveniently comprise a pair of 3 db directional couplers connected together by transmission lines of different effective length.

As is the general practice with radar apparatus at the present day, the aerial system may be used both for radiating signals from the transmitters and for receiving echoes of the radiated signals from distant targets. In one such arrangement, duplexers are arranged between the coupling means and each rotatable coupler and frequency separating devices are provided (which may be similar to that employed for separating the signals to be radiated) for separating the received signals passing through each duplexer into components of the two or more frequencies, which received signals are fed into separate receiving units. The received signals after rectification may be fed to separate display units and/or may be combined in a common display unit.

The following is a description of a number of embodiments of the invention, reference being made to the accompanying drawings in which:

FIGURE 1 is a block diagram of a radar apparatus;

FIGURE 2 is a diagram illustrating a construction of an aerial system for use in the radar apparatus of FIGURE 1; and

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FIGURES 3, 4 and 5 are block diagrams illustrating further forms of radar apparatus.

Referring to FIGURE 1, there are illustrated diagrammatically two transmitters 10 and 11 which in this particular embodiment are pulse transmitters producing short duration pulses of microwave frequency signals. The radio frequencies of the transmitters 10 and 11 will be referred to hereinafter as f_1 and f_2 respectively. The outputs of these two transmitters 10, 11 are fed by means of waveguides 12, 13 into two inputs of a 3 db branched guide directional coupler 14 so that the signals are combined and divided equally between each of two output waveguides 15, 16 from this directional coupler 14. These two guides 15, 16 will thus each carry signals of frequencies f_1 and f_2 , the power from each of the two transmitters being divided equally between the two guides. This output power from the transmitters is fed through duplexers 17, 18 to two rotatable couplers 19, 20 which feed the transmitted power into waveguide feeds 21, 22 on a rotatable aerial system 23. As shown in FIGURE 2, which illustrates the aerial system diagrammatically, this rotatable aerial system has two parabolic reflectors 24, 25 mounted back-to-back, the reflector 24 being illuminated by a pair of horns 26, 27, whilst the reflector 25 is illuminated by a pair of horns 28, 29. The aerial system may be rotated in any convenient manner illustrated diagrammatically in FIGURE 2 as being by a motor 30 through gearing 31. The reflectors may be shaped and the horns positioned to give required directional patterns to the beams in the well known manner.

Referring again to FIGURE 1, the output through waveguide 21 from the rotatable coupler 19 contains transmitted signals of the frequencies f_1 and f_2 and these signals are applied to a frequency separating device 40 which separates the two frequencies and feeds signals only of frequency f_1 through a waveguide 41 to the horn 26 and feeds signals only of frequency f_2 through a waveguide 42 to the horn 27. Similarly the output from the rotatable coupler 20 is applied to a second frequency separating device 43 which divides signals into the components of frequencies f_1 and f_2 which are fed respectively by means of waveguides 44, 45 to the horns 28, 29. Each of the frequency separating devices 40, 43 is illustrated diagrammatically in FIGURE 1 as comprising two 3 db branched guide directional couplers 46, 47. For each frequency separator, the output from the associated rotatable coupler 19 or 20 is fed into one input of the directional coupler 46 and the two outputs of that directional coupler are connected by separate transmission lines 48, 49 of different lengths to the two inputs of the second directional coupler 47. The transmission line 49 preferably contains an adjustable phase shifter (not shown) to form an adjustable line lengthener. In such a frequency separating device, which is known per se, the relative lengths of the two connections 48, 49 between the two couplers 46, 47 can be adjusted so that an input signal containing components of the two frequencies is separated into its two components in the two outputs from the second directional coupler 47. In such an arrangement, at the first coupler 46, signals of both frequencies are divided equally between the two connecting lines and thus equal components are fed into the two inputs of the second coupler. By a suitable adjustment of the relative lengths of the two connecting lines, in any one output of the second coupler, signals of only one frequency are present as any signals of the other frequency can be cancelled out owing to the two inputs after mixing in the second coupler being in phase opposition due to the different lengths of the two lines. In the second output, only components of this other frequency would be present, components of the first frequency being cancelled out.

It will be seen that the arrangement thus far described provides for transmission on four different directional beams making use of two different radiated frequencies. It will be appreciated that it is readily possible to provide two rotatable couplers on one rotating aerial assembly, but it is very difficult to provide more than two such couplers. By the above-described arrangement it is thus possible to make use of one rotating aerial system to provide four different directional beams making use of two different radiated frequencies and having only two rotatable couplers. In the particular embodiment described the aerial system is rotated for scanning in the azimuthal plane and these four beams may conveniently be at different elevations so that a very wide elevation coverage may be obtained. The two signals fed into any one reflector are of different frequencies. Since the reflectors are mounted back-to-back, no interference would arise due to the use of the same frequencies for two radiating elements feeding two different reflectors. In the particular embodiment described, the outputs of the two transmitters 10, 11 are combined by a 3 db coupler 14 so that the output of each transmitter is divided equally between the two rotatable couplers 19, 20. In some cases it may be desired, however, to divide the power unequally; for example, it may be required to radiate more power in a long range low elevation beam than in a higher elevation beam and the coupling means 14 in that case can be arranged to divide the power appropriately.

The aerial system of FIGURES 1 and 2 is used both for radiating signals from the transmitters and for receiving echoes of the radiated signals from distant targets. Each of the horns 26-29 will pick up signals of the two reflected frequencies. It will readily be seen, however, that the frequency separating device 40 will serve to combine signals of frequency f_1 from horn 26 and f_2 from horn 27 and to feed the combined signals into the rotatable coupler 19 whilst the frequency separating device 43 will serve to combine signals of frequency f_1 from horn 28 and f_2 from horn 29 and feed the combined signals into the rotatable coupler 20. Considering the received signals passing through the rotatable coupler 19, these are fed through the duplexer 17 into a further frequency separating device 50, which may be similar to the frequency separating device 40, 43 and which separates the received signals into the two frequency components f_1 and f_2 which are fed respectively to separate receiving units 51, 52. Similarly the duplexer 18 feeds the received signals from horns 28, 29 into a frequency separator 53, which may be similar to the frequency separators 40, 43 and which feeds signals of frequency f_1 to a receiving unit 54 and signals of frequency f_2 to a receiving unit 55. The receiving units 51, 52, 54 and 55 contain local oscillators and mixers to provide intermediate frequency output signals which are then fed to a display data compiler 56, where the appropriate signals are selected and fed to various display units such as the units 57, 58, 59 as required. The data compiler 56 may have switching means so that such display units may display signals received on any single one or any combination of the horn 26 to 29. If coverage is only required over 180° azimuth, π switching may be employed. That is to say the received signals from two different beams in directions 180° apart are switched alternately to a display as the aerial rotates so that signals from each beam are displayed as that beam sweeps through the required sector.

FIGURE 3 illustrates a modified form of the arrangement of FIGURE 1 and similar reference characters are used to indicate similar components. In the following description mention will only be made of the distinctive features of FIGURE 3. In FIGURE 3, instead of having two separate horns associated with each of the reflectors 24, 25, the reflector 24 has a single horn 60 whilst the reflector 25 has a single horn 61. No frequency separating means are provided in the rotatable aerial system

23 and the two horns 60, 61 are thus each separately fed with signals of both frequencies f_1 and f_2 . The received signals are separated in frequency as in the arrangement of FIGURE 1 and, assuming that the aerial system is not appreciably frequency sensitive so that the signals of frequency f_1 and f_2 from a single horn give the same directional pattern, the arrangement of FIGURE 3 provides two beams in opposite directions, which may be at different elevations if desired, with dual frequency diversity in each beam and the possibility of selecting received signals of either one of the frequencies in each beam or of using the combined signals as desired. It will be appreciated that such an arrangement offers very considerable advantages over a single frequency system in conditions of interference by enabling separate displays to be given of received signals on two different frequencies.

The arrangement of FIGURE 4 is generally similar to that of FIGURE 1 and similar reference characters are used to indicate corresponding components. In the arrangement of FIGURE 4, however, switch means 70 are provided for feeding the output from the rotatable coupler 19 directly into the horn 26 instead of feeding it via the frequency separator 40 into the two horns 26, 27. Likewise switch means 71 enable the output of the directional coupler 20 to be fed directly into the horn 28 instead of being fed via the frequency separator 43 into the two horns 28, 29. Switch means 72 are provided for feeding the outputs of the receivers 51, 52 into an adding unit 73 or alternatively into two separate output circuits 74, 75 whilst the switch means 76 enable the output from the receiving units 54, 55 to be fed together into an adding unit 77 or to be fed separately to output circuits 78, 79. The arrangement of FIGURE 4 thus is in effect a combination of the arrangements of FIGURES 1 and 3 providing alternatively a four beam system or a two beam system with dual frequency diversity on each beam.

In the arrangement of FIGURE 5 there are three transmitters 80, 81, 82 which operate to produce short duration microwave pulses on three different radio frequencies f_1 , f_2 and f_3 respectively. The outputs from the transmitters 80 and 81 are combined in a combining unit 83 which is illustrated as comprising two 3 db branched guide directional couplers 84, 85 connected together with two transmission lines 86, 87 of different lengths arranged so that when outputs of frequencies f_1 , f_2 are fed into the two inputs respectively of the directional coupler 84, the whole of these two output signals are combined and fed into a single output guide 88. This output guide is connected to one input of a 3 db directional coupler 89 the other input of which is connected to the transmitter 82. This directional coupler thus combines the outputs of all three transmitters and divides them equally between two output guides 90, 91 which lead respectively via duplexers 92, 93 to two rotatable couplers 94, 95. Thus half the power of all the three transmitters is fed through one of the rotatable couplers and the other half of the power is fed through the other rotatable coupler.

The aerial system illustrated in FIGURE 5 is similar to that of FIGURE 1 and comprises two reflectors 24, 25, the reflector 24 having two associated horns 26, 27 whilst the reflector 25 has two horns 28, 29. The signals from the rotatable coupler 94 are fed into a frequency separator 96 which separates the signals of frequency f_3 and feeds these signals into the horn 27 whilst the signals of frequencies f_1 and f_2 are fed together into the horn 26. Similarly the output from the rotatable coupler 95 is fed to a frequency separator 97 which feeds the signals of frequency f_3 into the horn 29 and the signals of frequencies f_1 and f_2 together into the horn 28. The received signals from the horns 26, 27 are combined by the frequency separator 96 and fed through the rotatable coupler 94 and duplexer 92 to a frequency separator

98 which separates the signals into the three different frequency components and feeds them to separate receiving units 100, 101, 102. These receiving units feed separate intermediate frequency signals to a display data compiler 103 similar to the compiler 56 of FIGURE 1 which enables the required information to be selected and displayed on display units such as the units 104, 105 and 106. Likewise the signals received by the horns 28, 29 are combined by the frequency separator 97 and fed through the rotatable coupler 95 and duplexer 93 to a further frequency separator 107 which separates the signals into the three separate frequency components and feeds them respectively to three receiving units 108, 109, 110. The outputs of these receiving units are then fed to the aforementioned display data compiler 103.

It will be seen that the arrangement of FIGURE 5 provides a four beam system with dual frequency diversity on two of the beams. This is particularly advantageous since the dual frequency diversity may only be required on the lower elevation beams used for detecting from distant targets. It will further be noted that with the arrangement of FIGURE 5 any failure of either the transmitter 80 or the transmitter 81 leaves the system working without any necessity for any attention to the equipment. Switches 111 and 112 are provided, which switches are arranged so that, if the third transmitter 82 should fail, by the operation of these switches 111 and 112, the output of the second transmitter 81 may be fed directly into the 3 db directional coupler 89 in place of the output from the third transmitter 82 so immediately restoring operation to a four beam system.

It will be immediately apparent that the system of FIGURE 5, by the omission of the frequency separators 96, 97, might be arranged to feed signals of all three frequencies into a single horn associated with one reflector as in the aerial system of FIGURE 3 thereby giving a two beam system with triple frequency diversity on each beam. In another modification of the arrangement of FIGURE 5, three horns might be associated with each of the reflectors 24, 25 and each of the frequency separators 96, 97 of FIGURE 5 arranged to separate the signals into the three separate frequencies which are fed respectively to different horns so thereby giving a six beam system.

We claim:

1. In radar apparatus having a rotatable aerial system with two aerials mounted back-to-back; the combination of at least two transmitters arranged to operate on different frequencies, two fixed feed systems, two rotatable couplers coupling the fixed feed systems respectively to the two aerials, and coupling means between the transmitters and said fixed feed systems combining the outputs from the transmitters and dividing the combined output between said two fixed feed systems whereby signals of all the transmitter frequencies are radiated in two opposite directions.

2. The combination as claimed in claim 1 wherein each aerial comprises a single radiating element arranged to radiate signals of all the transmitted frequencies.

3. The combination as claimed in claim 1 wherein each aerial comprises a plurality of radiating elements not exceeding the number of transmitted frequencies and wherein, for each aerial, frequency separating means are provided between the rotatable coupler and the radiating elements to separate the signals from the transmitters into different frequency components for each of the radiating elements.

4. In radar apparatus having a rotatable aerial system with two aerials mounted back-to-back; the combination of at least two transmitters arranged to operate on different frequencies, two fixed feed systems, two rotatable couplers coupling the fixed feed systems respectively to the two aerials, coupling means between the transmitters and said fixed feed systems combining the outputs from the transmitters and dividing the combined output be-

tween said two fixed feed systems whereby signals of all the transmitter frequencies are radiated in two opposite directions, two duplexers arranged one in each of said fixed feed systems, and two frequency separating means coupled respectively to said two duplexers to separate received signals passing through each duplexer into components of the different frequencies.

5. The combination as claimed in claim 4 wherein, to each of said two frequency separating means are coupled a number of separate receiving units, one for each of the separated frequencies.

6. Radar apparatus comprising a rotatable aerial system with two aerials mounted back-to-back, each aerial having two radiating elements, two transmitters arranged to operate on different frequencies, two fixed feed systems, coupling means between the transmitters and said fixed feed systems combining the outputs of the two transmitters and dividing the combined output between said two fixed feed systems to feed signals of both said different frequencies into each of said fixed feed systems, two frequency separating means mounted on said rotatable aerial system and associated respectively with the two aerials, each frequency separating means being arranged to separate signals of said two different frequencies and being coupled to the associated radiating elements to feed signals of different frequencies to the two elements, and two rotatable couplers coupling said two fixed feed systems respectively to said two frequency separating means.

7. Radar apparatus as claimed in claim 6 wherein said coupling means are arranged to divide the combined output of the two transmitters equally between said two fixed feed systems.

8. Radar apparatus comprising a rotatable aerial system with two aerials mounted back-to-back, each aerial having two radiating elements, two transmitters arranged to operate on different frequencies, two fixed feed systems, coupling means between the transmitters and said fixed feed systems combining the outputs of the two transmitters and dividing the combined output between said two fixed feed systems to feed signals of both said different frequencies into each of said fixed feed systems, two frequency separating means mounted on said rotatable aerial system and associated respectively with the two aerial, each frequency separating means being arranged to separate signals of said two different frequencies and being coupled to the associated radiating elements to feed signals of different frequencies to the two elements, two rotatable couplers coupling said two fixed feed systems respectively to said two frequency separating means, the frequency separating means being arranged to act as frequency combining means for received signals, two duplexers arranged one in each of said fixed feed systems and two further frequency separating means coupled respectively to said two duplexers to separate received signals passing through each duplexer into components of said two different frequencies.

9. Radar apparatus as claimed in claim 8 wherein the two radiating elements of each aerial have a common reflector, the two reflectors being mounted back-to-back.

10. Radar apparatus comprising a plurality of transmitters arranged to operate on different frequencies, a rotatable aerial system having two aerials mounted back-to-back, each aerial having a number of radiating elements equal to the number of different frequencies, two fixed feed systems, coupling means between the transmitters and said fixed feed systems combining the outputs of the transmitters and dividing the combined output between said two fixed feed systems to feed signals of all said different frequencies into each of said fixed feed systems, two frequency separating means one for each aerial mounted on said rotatable aerial system, each frequency separating means being arranged to separate signals of said different frequencies and coupled to the associated radiating elements to feed signals of the vari-

ous different frequencies separately to the radiating elements, and two rotatable couplers coupling said two fixed feed systems respectively to said two frequency separating means.

11. Radar apparatus as claimed in claim 10 wherein the frequency separating means are arranged to act as frequency combining means for received signals and wherein there are provided two duplexers arranged one in each of said fixed feed systems and two further frequency separating means coupled respectively to said 5 10

two duplexers to separate received signals passing through each duplexer into components of said different frequencies.

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