

Jan. 9, 1962

KIYO TOMIYASU ET AL

3,016,531

ANTENNA DISTRIBUTION SYSTEM

Filed March 14, 1955

3 Sheets-Sheet 1

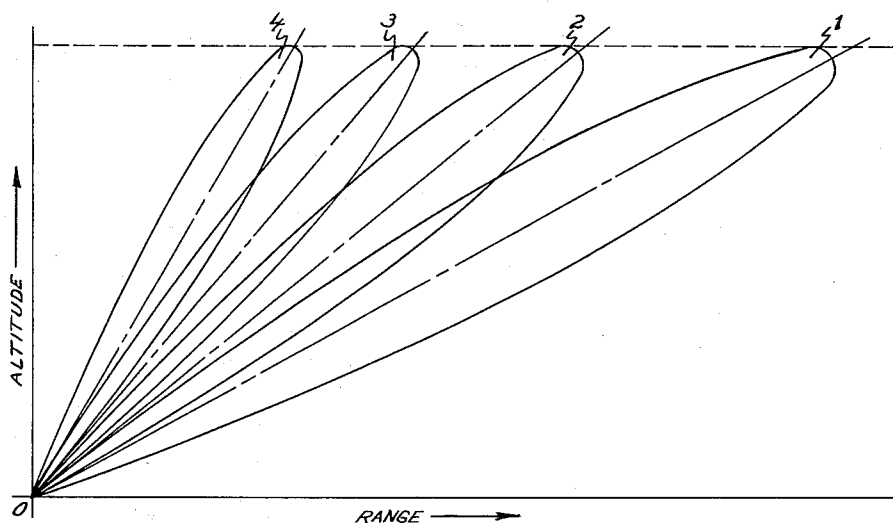


Fig. 1.

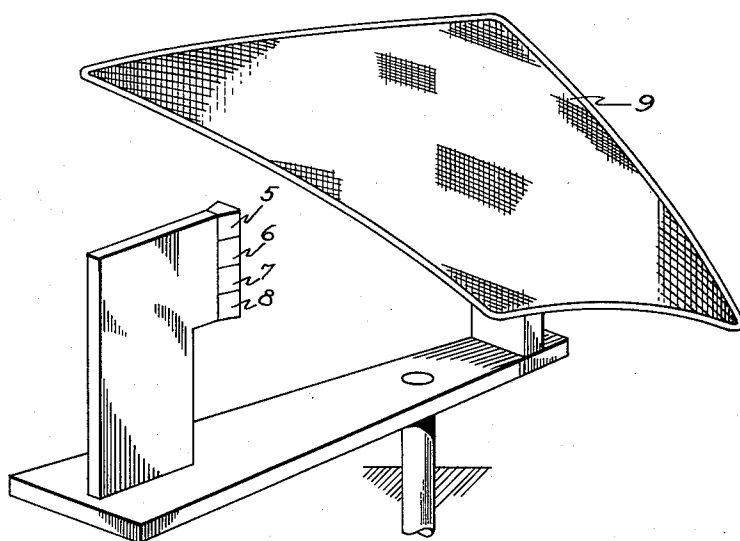


Fig. 2.

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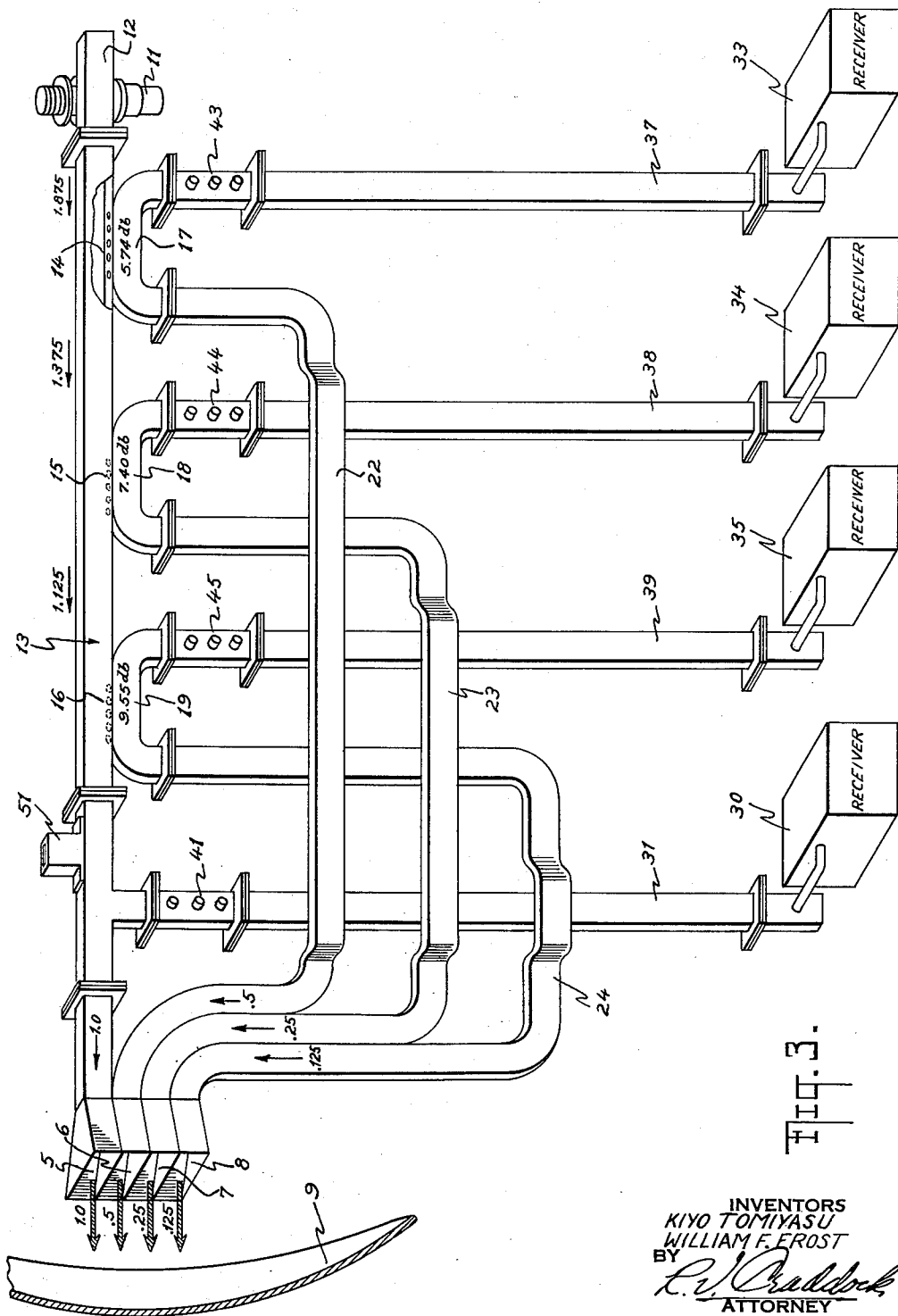
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3 Sheets-Sheet 2



Jan. 9, 1962

KIYO TOMIYASU ET AL
ANTENNA DISTRIBUTION SYSTEM

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3 Sheets-Sheet 3

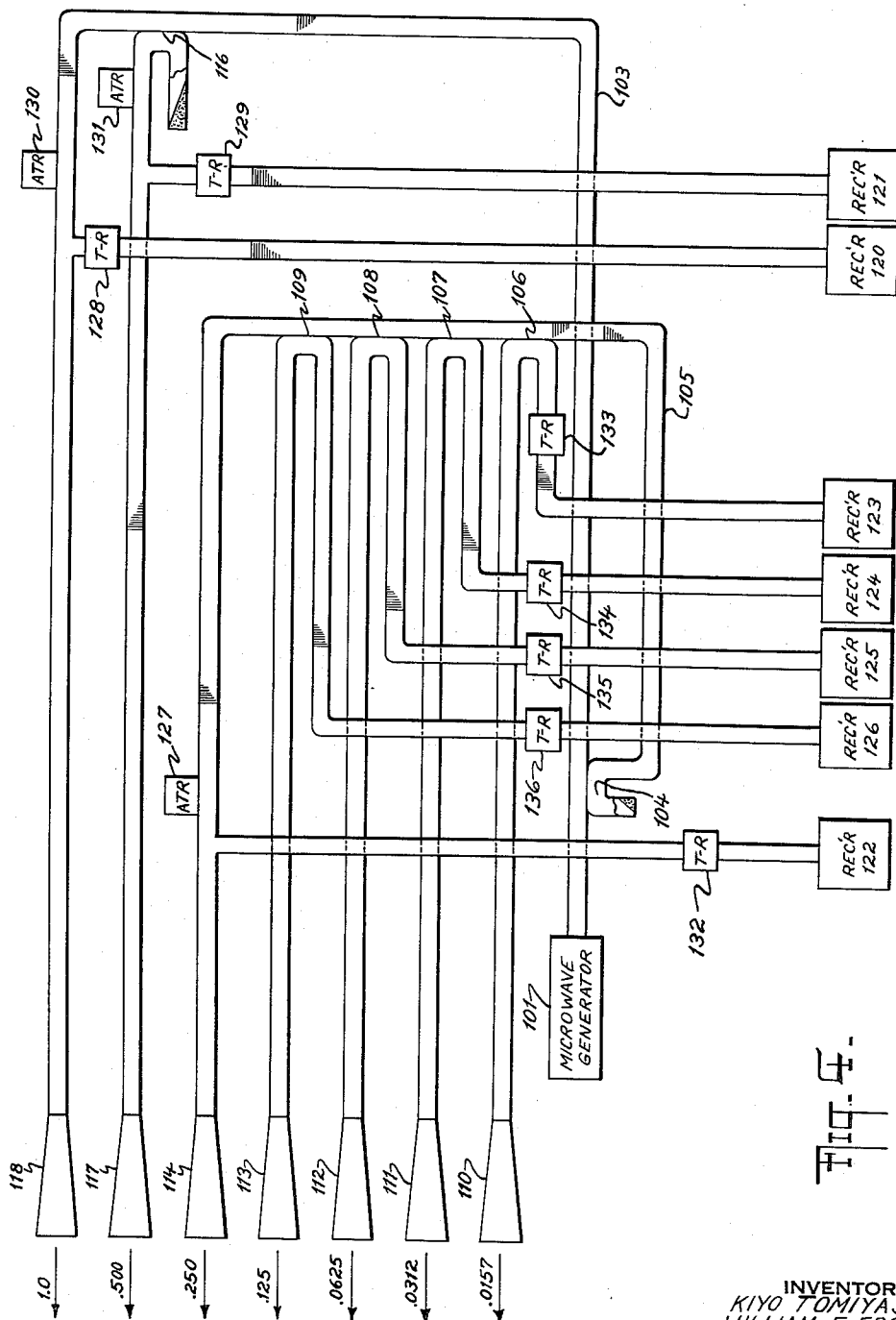


FIG. 4

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1

3,016,531

ANTENNA DISTRIBUTION SYSTEM

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14 Claims. (Cl. 343—17.1)

This invention concerns microwave distribution networks and, more particularly, is concerned with a microwave power distribution system for a stacked beam radar.

In a stacked beam radar system, it is desirable to transmit the energy from a common source of microwave power in a plurality of radio beams, all beams having a common azimuth angle, but each beam having a different elevation angle. It is necessary, in such a system, to provide an individual radar receiver for each beam. Such a radar must have a microwave distribution system which divides and subdivides the power generated by the microwave source, finally delivering power in proper proportion to each of a plurality of radiating means, each radiating means generating one of the radio beams. The distribution system must return the reflected power received by each radiating means to the particular receiver associated with this radiating means.

In prior art microwave distribution systems for stacked beam radars, the power generated by the microwave source is delivered into a first waveguide section. By means of a series of waveguide power dividers, the energy is then divided into further waveguide sections. After further subdivision, the proper proportion of power is delivered to each radiating means by final waveguide sections. A receiver is also interconnected to the final waveguide section feeding each radiating means in order to amplify and detect the signals received by said radiating means. In order to protect these receivers from the high powers which occur in the distribution system during the transmission period, a transmit-receive switch, also known as a TR switch, is interposed between each receiver and the final waveguide section to which the receiver is connected. This TR switch is fired during transmission of the pulsed energy from the radar, thereby preventing the high power signals which pass through the final waveguide section to the radiating means from reaching and damaging or incapacitating the receiver. In the same final waveguide section, feeding each radiating means, is an anti-transmit-receive switch, also known as an ATR switch. The ATR switch is provided to decouple the remainder of the distribution system from the final waveguide section during the reception period, in order that all of the energy received will be coupled to the receiver and none lost in the other portions of the distribution system. Thus, associated with each radiating means of the prior art microwave distribution systems are an ATR switch and a TR switch. These TR and ATR switches employ gas tubes and become more costly and more liable to failure as the microwave power to which they are subjected is increased.

It is therefore an object of this invention to provide an improved microwave distribution system.

Another object of this invention is to provide a stacked beam radar microwave distribution system which is simple in operation and construction.

Another object of this invention is to provide a stacked beam radar microwave distribution system which is economical in its use of gas tube switching devices.

Another object of this invention is to provide a stacked beam radar microwave distribution system employing the directive properties of directional couplers to enable the operation of TR switches at substantially lower power levels than the powers being radiated.

Another object of this invention is to provide a stacked

2

beam radar microwave distribution system which employs fewer ATR switches than prior art systems.

Another object of this invention is to provide a stacked beam radar microwave distribution system which employs only one ATR switch.

In accordance with the present invention, there is provided a system of distributing microwave power in a stacked beam radar wherein the power from the microwave source is first delivered to one end of a main microwave transmission line. The end of the main transmission line remote from the microwave source is terminated in a radiating means. At spaced points along the main transmission line, a predetermined amount of power is tapped by directional coupling elements and fed into auxiliary microwave transmission line sections to a plurality of radiating means which terminate one end of these auxiliary lines. The end of each auxiliary transmission line remote from the end connected to the radiating means is connected to a receiving means through an intermediate TR switch. Because of the high directivity of the directional coupling elements, only a small portion of the transmitted power delivered to each radiating element impinges on the associated TR switch, thereby permitting utilization of TR switches of lower power rating. By reciprocity, since only a small portion of the transmitted power in the main transmission line is tapped by each directional coupler, only a small portion of the received power being transferred from the radiating means to the receiving means will be lost from each auxiliary line. Thus, in each auxiliary line, no ATR switch is necessary. The only position where an ATR switch must be used is in the main transmission line between the directional coupling element nearest the radiating means and said radiating means.

Other objects and advantages of the present invention will become apparent from the specification, taken in connection with the accompanying drawings, wherein,

FIG. 1 is a schematic representation of a system of four stacked radio beams in a selected azimuthal plane,

FIG. 2 is a view in perspective of a stacked-beam radar antenna,

FIG. 3 is a perspective diagrammatical view, partially in section useful in explaining the preferred form of the invention,

FIG. 4 is a diagrammatical view, partially in section of a modified form of the invention.

A system of stacked radio beams 1, 2, 3 and 4 is shown in FIG. 1 as a two-dimensional plot of the beams on an altitude-range coordinate system. The radar which produces the stacked beams is located at the origin of this graph as indicated by point 0. The microwave powers introduced into each beam are such as to produce a uniform return for a constant altitude target independently of the range of the target. An antenna which will produce such a stacked beam radiation pattern is that of FIG. 2. A vertical array of radiating means, such as the adjacent electromagnetic horns 5, 6, 7 and 8, illuminate a reflector 9. In order to produce a beam which provides relatively uniform signals for targets at a specified altitude, each horn must radiate a different quantity of microwave power. For example, if the horns 5, 6, 7 and 8 are to generate respective beams 1, 2, 3 and 4, horn 5 will have to radiate more electromagnetic power than horn 6, etc. This invention is primarily concerned with the microwave system which distributes the proper amount of power to these radiating means from a common microwave source, and receives reflected power at each radiating means and directs it to a receiver associated with each radiating means.

A microwave distribution system for a four horn stacked beam radar is shown diagrammatically in FIG. 3. The proportionate amounts of powers which are to

be radiated by the four horns are indicated at the arrows opposite the apertures of the four horns. As shown by way of example, horns 5, 6, 7 and 8 are to radiate respective proportionate powers of 1.0, 0.5, 0.25, and 0.125. The source of microwave power to be transmitted is a microwave generator 11, such as a microwave klystron amplifier or microwave magnetron, either of which may be pulsed. The output of generator 11 is supplied to the system through output waveguide section 12. Output waveguide section 12 transfers the power generated to a main waveguide section 13. While the embodiment described is shown utilizing waveguide components this invention is not limited to the use of waveguide structure but is applicable to the use of any type of microwave transmission line such as waveguide sections or coaxial line sections.

At spaced points along main waveguide section 13, directional couplers 14, 15 and 16 are connected. Each directional coupler comprises a primary arm, which in this instance is a portion of main waveguide section 13, a secondary arm designated by the respective numerals 17, 18 and 19, and a directional coupling element which serves to transfer power from the primary to the secondary arm in a directional manner. Directional couplers which are suitable for use in this system include those described in U.S. Patent 2,602,859 by Moreno and those described in U.S. patent application S.N. 417,072 by Sferrazza, now Patent Number 2,820,203. One end of the secondary arm of each of directional couplers 14, 15 and 16 is connected to respective auxiliary waveguide sections 22, 23 and 24, said auxiliary waveguide sections in turn being connected respectively to electromagnetic horns 6, 7 and 8.

During transmission a short burst or pulse of microwave power is produced by microwave generator 11. This power is transferred from generator 11 to main waveguide section 13. The power propagates to the left in FIG. 3 along waveguide section 13, a portion thereof being transferred to each of the secondary arms of the directional couplers which are interconnected to waveguide 13. The power remaining after the wave has passed directional coupler 16 is all transferred to horn 5 where it is radiated in radio beam 1. The portion of power which is transferred out of waveguide section 13 by directional couplers 14, 15 and 16 is transmitted to respective horns 6, 7 and 8 and radiated in respective beams 2, 3 and 4. In the exemplary case considered, the total portions of power to be radiated add up to 1.875. Because horn 6 is to radiate a proportionate power of 0.5, its associated directional coupler 14 must tap from main waveguide section

$$\frac{0.5}{1.875}$$

of the total power propagating in guide 13. This corresponds to a power ratio of 5.74 db and is the value about which directional coupler 14 must be designed. In a similar manner directional coupler 15 must be designed for a 7.4 db division of power and directional coupler 16 for a 9.55 db division of power.

During the receiving period, a receiver is actively connected to each radiating means in order to amplify and detect the reflected signals returning from each beam. To accomplish this a receiver 30 is connected to horn 5 by a microwave transmission path including a receiver microwave transmission line 31 and waveguide section 13. The reflected energy received by horns 6, 7 and 8 is directed to respective receivers 33, 34 and 35 through the respective auxiliary waveguide sections 22, 23 and 24, the respective secondary arms 17, 18 and 19, and the respective receiver microwave transmission lines 37, 38 and 39. The receiver microwave transmission lines 31, 37, 38 and 39 may be sections of waveguide or other types of micro-

wave transmission lines, such as sections of coaxial line or strip line.

In order to protect receiver 30 from the high power microwaves propagating in waveguide section 13 during transmission, a TR switch 41 is interposed between main waveguide section 13 and transmission line 31. The high powers generated during transmission cause this switch to break down and effectively short circuit the line 31 thereby preventing passage of microwave energy to the receiver 30. TR switch 41, because of its location, must be capable of handling and preventing the passage to receiver 30 of the full power which is being delivered by waveguide section 13 to horn 5.

Receivers 33, 34 and 35 are protected during transmission by the respective TR switches 43, 44 and 45, which are interposed between said receivers and respective secondary arms 17, 18 and 19. In accordance with this invention receivers 33, 34 and 35 are located at the opposite ends of respective secondary arms 17, 18 and 19 from which the power is directed toward the radiating horns during transmission. Consequently, by employing couplers of high directivity, this directivity being designed into the couplers substantially independently of the amount of coupling provided, only a very small portion of the power being transmitted in each secondary arm is directed toward the respective receivers. For example, directional couplers may be designed having directivities of 20 db or higher. Therefore, because of the very small proportion of power tending to impinge upon the receivers during transmission, TR switches of relatively small power handling capability may be employed, thereby achieving economy and efficiency of operation. Hence TR switches 43, 44 and 45 may be of relatively small power handling capacity as compared to TR switch 41 in order to protect their respective receivers.

Since the microwave powers striking these TR switches may be relatively low, it may be necessary to employ TR switches containing keep-alive electrodes in order to facilitate breakdown of the included gases during the transmission period. While the TR switches shown in the drawings do not patently disclose whether they employ keep-alive electrodes, it is to be understood that such switches are shown only in symbolic form, and where necessary they will employ keep-alive electrodes, as well as the necessary circuits for applying proper voltages to those electrodes.

In some of the receiver transmission lines, such as line 39, the power impinging upon the TR switch, such as TR switch 45, during transmission may be too small to fire any commercially available TR switch. In such instance, the TR switch may be often dispensed with without harm to the radar receiver. If, however, it is desired to maintain receiver protection by means of TR switches, two alternative steps may be taken to increase the power directed toward the receiver during transmission in order to fire the TR switch: (a) the directivity of the directional coupler which feeds energy to the TR switch may be reduced by proper design, or (b) a reflective post may be inserted in the side of the secondary arm toward the radiating means in order to reflect a small portion of the power toward the TR switch.

During reception reflected power returning from beam 1 and entering horn 5 should be transmitted with as small a loss as possible to receiver 30. Any reflected power received by the radar and not delivered to the receiver is equivalent to a decrease in the range of the radar. To prevent reflected power which enters horn 5 from travelling to the right along waveguide section 13 beyond transmission line 31, which connects receiver 30, an ATR switch 51 is connected to waveguide 13 between directional coupler 16 and TR switch 41. This ATR switch breaks down during transmission and does not interfere with the transfer of energy from generator 11 to horn 5. However, during reception when the ATR switch is not energized, it is so situated with respect to

transmission line 31 that none of the power passing toward the right in waveguide section 13 can propagate past ATR switch 51 but instead all of said power is directed toward receiver 30. Because of its location, ATR switch 51 must be capable of handling the full power which is being delivered by waveguide section 13 to horn 5 during transmission.

Reflected power returning in beam 2 enters horn 6 and is directed along waveguide section 22 and secondary arm 17 of directional coupler 14. Directional coupler 14 was designed to admit only a small portion of the power propagating in waveguide 13 into secondary arm 17. By reciprocity only a small portion of the reflected power travelling to the left in secondary arm 17 will be transmitted and lost in main waveguide section 13. The major portion of the power in secondary arm 17 will continue on to receiver 33. Thus it is not necessary to use an ATR switch in connection with the receiver associated with directional coupler 14. In a similar manner no ATR switches are necessary for the receivers associated with directional couplers 15 and 16.

Therefore, as described, this invention permits the use of TR switches of lower power handling capacity than would ordinarily be required and obviates the need for ATR switches in many parts of the microwave distribution system.

While the foregoing has described the preferred embodiment of this invention, alternative embodiments also lie within its scope, such as that of FIG. 4. In this microwave distribution system power is directed during transmission from microwave generator 101 into main waveguide section 103. A portion of the power is tapped from waveguide section 103 by directional coupler 104 and directed into auxiliary waveguide section 105. Portions of the microwave energy propagating in waveguide 105 are tapped by respective directional couplers 106, 107, 108 and 109 and are fed to respective horns 110, 111, 112 and 113, where power is radiated into beams in an amount proportional to the quantities indicated on the figure. The power remaining in waveguide section 105 is radiated from horn 114. The power propagating in main waveguide section 103 is further divided at directional coupler 116 and a portion is led from the secondary arm of coupler 116 to horn 117. The power remaining in section 103 is directed to horn 118 where it is radiated. Thus a microwave distribution system is provided for an antenna system producing seven stacked beams.

Reflected powers received by horns 118 and 117 are directed to respective receivers 120 and 121. TR switches 128 and 129 are provided to protect respective receivers 120 and 121 from the full powers directed toward the respective horns 118 and 117 during transmission. ATR switches 130 and 131 are provided to insure that all of the reflected powers received by respective horns 118 and 117 are directed into respective receivers 120 and 121 during reception. Reflected energy received by horn 114 is directed into receiver 122, which is protected by TR switch 132 during transmission. ATR switch 127 is provided to insure that all of the reflected power received by horn 114 is directed into receiver 122 during reception. TR switches 133, 134, 135 and 136 protect respective receivers 123, 124, 125 and 126 during transmission of energy to respective horns 110, 111, 112 and 113. TR switches 133, 134, 135 and 136 need be capable of handling but relatively small powers due to the fact that only a small portion of the transmitted powers directed toward respective horns 110, 111, 112 and 113 impinges upon them.

Since many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. A microwave distribution system for an antenna array comprising a main microwave transmission line section, a plurality of directional couplers having primary and secondary arms, each of said couplers having its primary arm interconnected to said main transmission line section, a plurality of radiating means, a plurality of auxiliary microwave transmission line sections, each of said auxiliary line sections interconnecting a respective one of said radiating means with one end of the secondary arm of a respective one of said directional couplers, and a plurality of receiver microwave transmission lines, each of said receiver transmission lines connected to the other end of the secondary arm of a respective one of said directional couplers.

2. In a stacked beam radar system, a source of microwave energy, a first microwave transmission line section for transferring microwave energy from said source, a plurality of radiating means, a plurality of directional couplers, each directional coupler having a primary and a secondary arm, said primary arms being interconnected along said first transmission line section, a plurality of auxiliary microwave transmission line sections, each auxiliary line section interconnecting one end of the secondary arm of a respective one of said directional couplers with a respective one of said radiating means, and a plurality of receiver microwave transmission lines, each receiver transmission line connected to the other end of the secondary arm of a respective one of said directional couplers.

3. A microwave distribution system for an antenna array comprising a first microwave transmission line section, a plurality of directional coupling elements disposed along said first transmission line section, a plurality of additional transmission line sections, each additional transmission line section being coupled to said first transmission line section by a respective one of said coupling elements, a plurality of radiating means, each radiating means being connected to one end of a respective one of said additional transmission line sections, and a plurality of receiver microwave transmission lines, each receiver line being connected to the other end of a respective one of said plurality of transmission line sections.

4. A distribution system for an antenna array comprising a main microwave transmission line for distributing microwave power to the system, a plurality of additional transmission lines, a plurality of radiating means, a plurality of receiving means, each of said additional transmission lines interconnecting a respective one of said radiating means and a respective one of said receiving means, and a plurality of directional coupling elements, each of said directional coupling elements being common to said main transmission line and a respective one of said additional transmission lines, whereby each element couples a respective one of said additional lines to said main line.

5. In a stacked beam radar system a source of microwave energy, a microwave transmission line section, a first radiating means, said source being connected to one end and said radiating means connected to the other end of said transmission line section, a plurality of directional couplers, each directional coupler having a primary and a secondary arm, said primary arms being interconnected along said transmission line section, a plurality of additional radiating means, each of said additional radiating means being connected to one end of the secondary arm of a respective one of said directional couplers, a plurality of receiving means, each of said receiving means being connected to the other end of the secondary arm of a respective one of said directional couplers, a T-R switch and an anti-T-R switch interconnected to the transmission line section between said first radiating means and said plurality of directional couplers.

6. A distribution system for an antenna array comprising a microwave transmission line section, a plurality

of directional couplers, each directional coupler having a primary and a secondary arm, said primary arms being interconnected along said transmission line, a plurality of radiating means, each of said radiating means being connected to one end of the secondary arm of a respective directional coupler, and a plurality of receiving means, each receiving means being connected to the other end of the secondary arm of a respective directional coupler.

7. A radar system comprising a plurality of radiating means, a source of microwave power, a plurality of receiving means, and a microwave transmission line system for distributing power from said source to said radiating means during transmission and from said radiating means to said receiving means during reception, comprising a plurality of directional couplers having primary and secondary arms, each of said secondary arms connecting a respective one of said radiating means to a respective one of said receiving means, and a microwave transmission line section connected to said source of microwave power and having interconnected along its length the primary arms of said directional couplers.

8. An antenna distribution system arranged to radiate power from a plurality of radiating means wherein each radiating means radiates a different proportion of the total available power, comprising a source of microwave power, a main microwave transmission line section, one end thereof being connected to the source of microwave power, a plurality of radiating means, the first of said radiating means being connected to the other end of said main microwave transmission line section whereby a portion of the total power available will be radiated from said means, a plurality of additional microwave transmission line sections, one end of each of said additional line sections being connected to a respective one of the remainder of said plurality of radiating means, a plurality of directional coupling elements disposed along said main transmission line section and coupling said plurality of additional transmission line sections to said main transmission line section whereby a portion of the total power is transferred to each of said remainder radiating means, the portion of power transferred to each of said remainder radiating means being less than that radiated from said first radiating means, and a plurality of receiving means, each of said receiving means being connected to the other end of a respective one of said additional transmission line sections.

9. A distribution system for an antenna array comprising a first waveguide section, a plurality of directional couplers having primary and secondary arms, each of said couplers having its primary arm interconnected to said main waveguide section, a plurality of radiating means, each of said radiating means connected to one end of the secondary arm of a respective one of said directional couplers, a plurality of receiving means, a plurality of T-R switches, and a plurality of receiver microwave transmission lines each having first and second ends, the first end of each of said transmission lines being connected to a respective one of said receiving means, the second end of each of said transmission lines being connected to a respective one of said T-R switches, and each of said T-R switches being connected to the other end of the secondary arm of a respective one of said directional couplers.

10. In a stacked beam radar system, a source of microwave energy, a main waveguide section, a first radiating means, said main waveguide section being connected between said source of microwave energy and said first radiating means, a plurality of directional couplers having primary and secondary arms, each of said couplers having its primary arm interconnected to said main waveguide section, a T-R switch, an anti-T-R switch, said T-R switch and said anti-T-R switch being interconnected to said main waveguide section between said directional couplers and said first radiating means, a plurality of additional

radiating means, each of said additional radiating means being connected to one end of the secondary arm of one of a respective said directional couplers, a plurality of receiving means, and means for connecting each of said receiving means to the other end of the secondary arm of a respective one of said directional couplers.

11. In a stacked beam radar system, a source of microwave energy, a first waveguide section, a first radiating means, said first waveguide section being connected between said source and said first radiating means, a first directional coupler having a primary and a secondary arm, said first coupler having its primary arm interconnected to said first waveguide section, a first T-R switch, a first anti-T-R switch, said first T-R switch and said first anti-T-R switch being connected to said first waveguide section between said first directional coupler and said first radiating means, a second waveguide section, a second radiating means, said second waveguide section being connected between one end of the secondary arm of said first directional coupler and said second radiating means, a plurality of additional directional couplers, each directional coupler having a primary and a secondary arm, each of said additional couplers having its primary arm interconnected along said second waveguide section, a second T-R switch, a second anti-T-R switch, said second T-R switch and said second anti-T-R switch being connected to said second waveguide section between said additional directional couplers and said second radiating means, a plurality of additional radiating means, each of said additional radiating means being connected to one end of the secondary arm of a respective one of said additional directional couplers, a plurality of receiving means, and means for coupling each of said receiving means to the other end of the secondary arm of a respective one of said additional couplers.

12. A distribution system for an antenna array comprising a plurality of waveguide directional couplers, each coupler having a primary and a secondary waveguide arm, said primary arms being connected together to form a continuous waveguide section, a plurality of radiating means, a plurality of receiving means, a plurality of T-R switches, each T-R switch having input and output terminals, each of said radiating means being connected to one end of the secondary arm of a respective one of said directional couplers, one terminal of each of said T-R switches being connected to the other end of a respective one of said secondary arms, and each of said receiving means being connected to the other terminal of a respective one of said T-R switches.

13. A microwave distribution system comprising a source of microwave energy, a microwave transmission line section, means for coupling microwave energy from said source into said line section near one end thereof, a plurality of directional couplers, each coupler having a primary and a secondary arm, said primary arms being interconnected along said line section, a plurality of microwave utilization means, each of said utilization means being connected to one end of a respective one of said secondary arms, and a plurality of microwave receiving means, each of said receiving means being connected to the other end of a respective one of said secondary arms.

14. Apparatus as in claim 5 further including a further receiving means, and means for connecting said further receiving means to said TR switch.

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