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ANTENNA COUPLING SYSTEM FOR ELIMINATING TRANSMITTER REFLECTIONS

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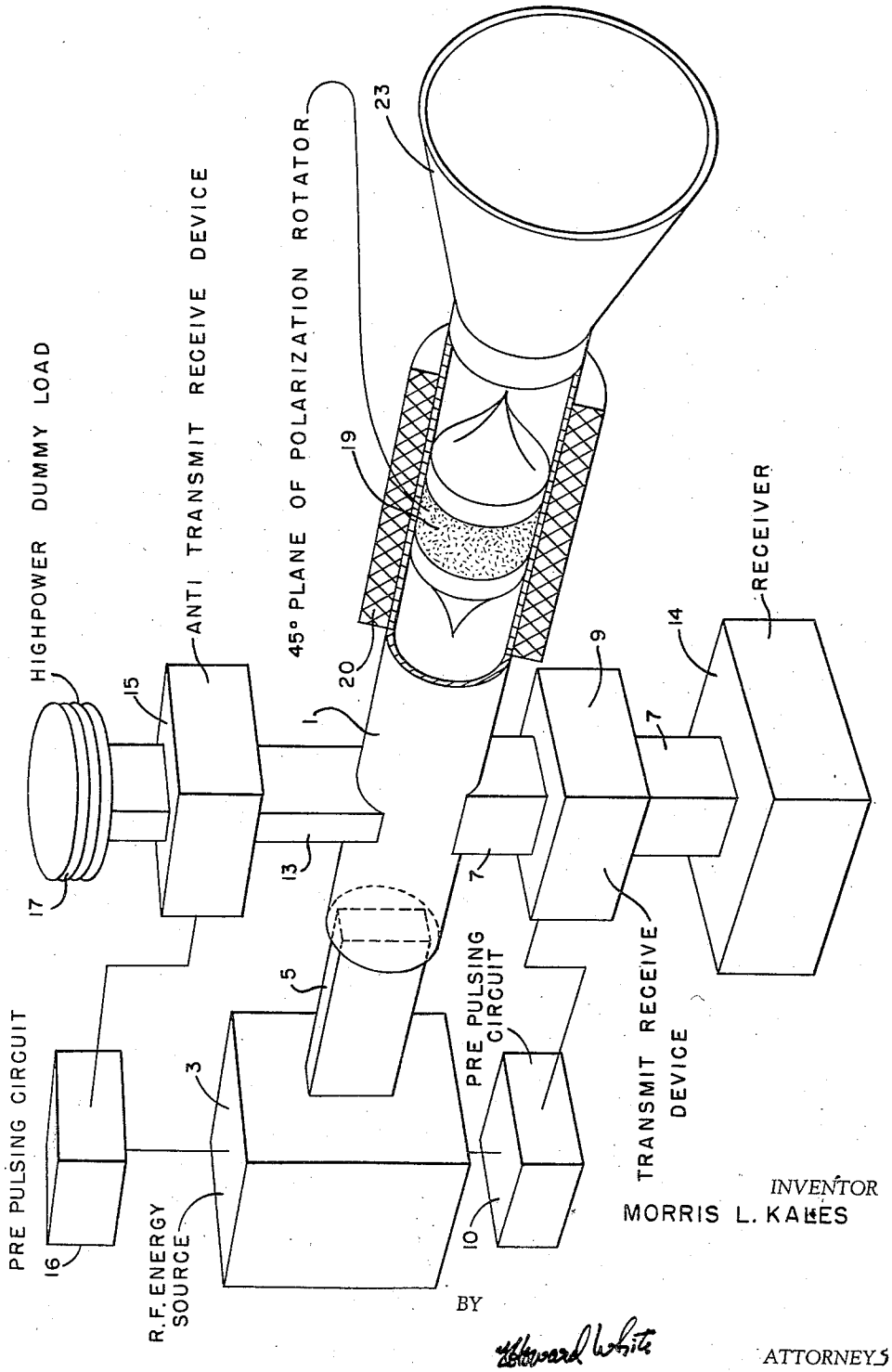

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ANTENNA COUPLING SYSTEM FOR ELIMINATING TRANSMITTER REFLECTIONS

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The present invention relates to coupling devices for use between radio frequency transmitting apparatus and antennas associated therewith, and more particularly to improvements in such devices for eliminating the effects of reflections caused by impedance mismatch between energy source and antenna.

In the past it has been common practice to use duplexing devices for coupling a radio frequency transmitter and receiver to a common antenna. Such devices protect the receiver while the transmitter is in operation, and prevent absorption by the transmitter of the signals received from the antenna while the transmitter is inoperative, but they do not protect the transmitter from the effects of energy reflections produced by impedance mismatch between transmitter and antenna. When a magnetron oscillator is used to generate radio frequency energy, such reflections are particularly serious inasmuch as they cause frequency instability, sparking at the output window, considerable power loss, and may even prevent the magnetron from oscillating. Under laboratory conditions where power losses are relatively unimportant, it has been possible to isolate the magnetron from the antenna by means of networks having at least 3 db attenuation factors. However, such an expedient is obviously impractical where efficiency is of primary concern.

One object of my invention is to provide a unilateral coupling means between a radio frequency energy source and its associated antenna.

Another object is to provide a means for isolating a radio frequency energy source from reflections due to impedance mismatching between the energy source and its associated antenna.

A further object is to provide a high efficiency output coupling for a radio frequency energy source that will isolate the source from reflections produced by a load having a poor impedance match therewith.

A still further object is to provide a means for coupling a radio frequency transmitter and receiver to a common antenna while isolating the transmitter from impedance variations produced by the load.

Other objects and features of the present invention will become apparent upon consideration of the following detailed description when taken in connection with the accompanying drawing the single figure of which illustrates one embodiment of the invention. It is to be expressly understood, however, that the drawing is designed for purposes of illustration only and not as a definition of the limits of the invention, reference for the latter purpose being had to the appended claims.

As one element in my invention I make use of a non-reciprocal, 45° plane-of-polarization rotator that will rotate plane polarized wave energy in the same direction (either clockwise or counterclockwise) regardless of the direction of propagation of the energy through the rotator. Linearly polarized energy reflected back to a source from a load through such a device after having

passed through the device in going from source to load, will be orthogonally polarized with respect to its original polarization. If the source is coupled to the rotator by means of a device that will propagate radiation of only a given polarity, it can be seen that it will be impossible for the orthogonally polarized reflected energy to re-enter the source. By coupling a dummy load or other device capable of absorbing a dissipating energy to the source end of the rotator by means of a device that will propagate energy of only the orthogonal polarity, the reflected energy and only the reflected energy will be absorbed by the dummy load, and the source will be effectively decoupled from the load. The absorption of the reflected energy by the dummy load is required in order to prevent re-radiation which would adversely affect the radiation characteristics of the antenna, or re-reflections which would permit the reflected wave to enter the waveguide leading to the transmitter.

In a more specific aspect, my invention comprises a non-reciprocal 45° plane-of-polarization rotating device in the coupling between the transmitter and the load (antenna). The rotating device is coupled at one end to a junction comprising a section of waveguide capable of supporting two orthogonal modes of propagation and two sections of rectangular waveguide one of which will couple to one and only one of the two orthogonal modes in the first section and the other of which will couple only to the other mode. One of these sections of rectangular waveguide is coupled to the transmitter and the other to a dummy load or other energy dissipating device. Electromagnetic energy from the transmitter will be rotated 45° in passing through the rotator to the antenna, and reflections back toward the transmitter will be rotated an additional 45° so as to be orthogonally polarized with respect to energy propagated by the transmitter waveguide. The reflected energy cannot enter the transmitter waveguide but can enter the waveguide coupled to the dummy load, and so will be absorbed by the dummy load.

When the invention is to be utilized in a radar system, a receiver is coupled to the transmitter end of the rotator by means of a transmit-receive duplexer and a waveguide section capable of transmitting the mode supported by the waveguide leading to the dummy load. Additionally, an anti-transmit-receive duplexer is coupled to the dummy load to prevent energy from being absorbed thereby when the transmitter is quiescent. Energy reflected due to a mismatch in impedance at the antenna and arriving at the transmitter end of the rotator cannot enter the receiver channel because of the action of the transmit-receive duplexer, and so must be absorbed by the dummy load. Radar echoes reflected when the transmitter is quiescent will be blocked by the anti-transmit-receive device and so will pass into the receiver.

Referring now to the single figure there is shown a preferred embodiment of my invention. In the figure, reference numeral 1 refers to a section of waveguide (conveniently a square or a tubular waveguide) capable of propagating plane polarized wave energy having either of two planes-of-polarization which are in orthogonal relation. Waveguide 1 represents the main coupling between the pulse transmitter 3 and antenna load designated 23. In the coupling, pulsed energy source 3, typically including a magnetron and suitable keying circuits therefor, is coupled to waveguide section 1 by means of waveguide section 5. This second waveguide section 5 is rectangular in cross-section and is capable of propagating radiation of only a given plane-of-polarization; for instance, of a horizontal plane-of-polarization. Receiver 14 is coupled to waveguide section 1 by means of waveguide section 7. Included within waveguide section 7 is a transmit-receive

device (TR) 9, such as is illustrated in volume XIV of the MIT Radiation Laboratory Series, titled Microwave Duplexers by Smullins and Montgomery. The function of the TR is to disconnect the receiver 14 from waveguide section 1 when the energy source 3 is in operation. A dummy load 17 is coupled to waveguide section 1 by means of a rectangular waveguide section 13 which is capable of propagating only radiation the plane-of-polarization of which is 90° from that of the radiation propagated through waveguide section 5. Dummy load 17 may be a device such as is described in volume XI of the MIT Radiation Laboratory Series by C. G. Montgomery, titled Techniques of Microwave Measurements, at section 12.6. Included in waveguide section 13 is an anti-transmit-receive device 15 (or ATR), the function of which is to connect dummy load 17 to waveguide section 1 when the magnetron is operating, and to disconnect the same when the magnetron is not operating. Such an ATR may be found in chapter 4 of the aforementioned volume XIV of the MIT Radiation Laboratory Series.

Disposed between waveguide sections 7 and 13 and load 23, typically a horn antenna, is a plane-of-polarization rotator, or gyrator, which may be a device such as described in the article by C. L. Hogan, appearing in Bell System Technical Journal, volume 13, page 1, tilted "The Microwave Gyrator." Briefly, the gyrator as described by Hogan comprises a cylinder of a ferromagnetic spinel 19, axially disposed within waveguide section 1 and magnetized along its length by a magnetizing winding 20 and a source of magnetizing current not shown. The magnetization of the cylinder to be utilized in the present invention is such that an electromagnetic wave passing therethrough will have its plane-of-polarization rotated through an angle of 45°. The gyrator is non-reciprocal in that the plane-of-polarization of an electromagnetic wave is rotated clockwise when it is passing in one direction through the gyrator, and counter-clockwise when it is passing through the gyrator in the opposite direction.

To insure operation of the TR and ATR whenever R. F. energy is being furnished by energy source 3, prepulsing circuits 10 and 16 are provided. These circuits may be actuated from a blocking oscillator or similar circuit properly timed with respect to the duty cycle of energy source 3; preferably, however, the prepulsing circuits are actuated by the keying circuit included within energy source 3. The prepulsing circuits are preferably coupled to the keep-alive electrodes of the ATR and TR in the manner shown and described in Microwave Duplexers at section 5.21.

Energy emanating from antenna 23 may be directed to a suitable reflector or lens system (not shown).

The operation of my invention is as follows. Assume that the energy source 3 is being pulse-modulated, periods of operation alternating with periods of inoperation. When the energy source is in operation, plane polarized energy of horizontal polarity will pass through waveguide sections 5 and 1, and thence through gyrator 19 where the polarization is rotated 45° to antenna 23. Simultaneously with the pulsing of the energy source 3, TR 9 and ATR 15 are actuated by prepulsing circuits 10 and 16 respectively. The greatest part of the energy from source 3 will be radiated from the horn antenna 23, but due to the aforementioned unavoidable impedance mismatch a certain amount of energy will be reflected back through gyrator 19 into waveguide section 1. This energy, having twice traversed the gyrator, will now have a plane-of-polarization oriented 90° from the plane-of-polarization of the energy capable of being propagated in waveguide section 5 and thus it will be impossible for the reflected energy to enter waveguide section 5. The only avenues of exit for the reflected energy are therefore into waveguide sections 7 and 13. Energy entering waveguide section 7 during the operation of source 3 will be prevented from passing into receiver 14 by TR device 9. Most of the reflected energy will therefore be directed into waveguide section 13 where it will pass through the ATR device 15, which is still actuated and thence will be absorbed by the dummy load 17. At the end of the operating period of the energy source, the TR device 9 will permit energy to enter receiver 14 and ATR device 15 will prevent energy from being absorbed by the dummy load 17. Energy reflected from targets external to the radar system will be picked up by antenna 23, and its plane-of-polarization will be rotated through an angle of 45° by gyrator 19. This energy cannot pass through waveguide section 5 as it has a plane-of-polarization orthogonal to the plane-of-polarization of radiation that waveguide section 5 is capable of transmitting. Likewise, this energy cannot proceed up waveguide 13 due to the high impedance presented by anti-TR device 15 when the magnetron is not oscillating. Therefore the only avenue of exit from waveguide 1 for such energy is through waveguide 7 and TR device 9 into the receiver 14.

Thus it can be seen that my invention is capable of isolating a source of radio energy from all reflections from its antenna. The device is highly efficient inasmuch as the gyrator 19 only slightly attenuates energy passing therethrough.

Although the embodiments disclosed in the preceding specification are preferred, other modifications will be apparent to those skilled in the art which do not depart from the scope of the broadest aspects of the present invention.

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

What is claimed is:

1. Apparatus for coupling a radio frequency transmitter and receiver to a common antenna, comprising: first means adapted to propagate energy of a given plane-of-polarization from said transmitter while rejecting energy of a plane-of-polarization orthogonal to said given plane-of-polarization; non-reciprocal, plane-of-polarization rotating means connected to the output of said first means and operable to rotate the plane-of-polarization of electromagnetic energy through an angle of 45° and adapted to couple said first means to said antenna; second means coupled to said rotating means at the juncture of said rotating means with said first means, operable to dissipate energy having a plane-of-polarization orthogonal to said given plane-of-polarization; third means coupled to said juncture and adapted to propagate energy of said orthogonal plane-of-polarization to a receiver; and means operable to allow transmission of energy to said receiver only when said transmitter is inoperative and to allow dissipation of energy by said second means only when said transmitter is in operation.

2. Apparatus for coupling a radio frequency energy source, a receiver, and an electromagnetic energy dissipating means to a common antenna comprising: first means coupled to said source operable to propagate energy having a given plane-of-polarization while rejecting energy of a plane-of-polarization orthogonal to said given plane-of-polarization; second means adapted to propagate energy to said receiver and to said energy dissipating means having a plane-of-polarization orthogonal to said given plane-of-polarization; a non-reciprocal plane-of-polarization rotating means coupling said first and second means to said antenna, said rotating means being operable to rotate the plane-of-polarization of electromagnetic energy through an angle of 45°; and means coupled to said second means adapted to decouple said receiver when said energy source is in operation and to decouple said energy dissipating means when said energy source is not in operation.

3. Apparatus for coupling a radio frequency transmitter and receiver to a common antenna comprising: rectangular waveguide means coupled to said radio fre-

quency transmitter operable to propagate energy of only a given plane-of-polarization; energy dissipating means operable to dissipate energy having a plane-of-polarization orthogonal to said given plane-of-polarization; a non-reciprocal 45° plane-of-polarization rotator coupling said receiver, said rectangular waveguide means, and said energy dissipating means to said antenna; and means adapted to decouple said receiver when said transmitter is in operation and to decouple said energy dissipating means when said transmitter is not in operation.

4. Apparatus for coupling a radio frequency energy source to an antenna comprising: a radio frequency transmission path coupling said source to said antenna including first rectangular waveguide means operable to propagate energy of only one plane-of-polarization from said energy source, and coupled thereto a non-reciprocal plane-of-polarization rotator operable to rotate the plane-of-polarization of radio frequency energy through an angle of 45°; energy dissipating means; second rectangular waveguide means coupling said energy dissipating means to said rotator at its juncture with said first waveguide means operable to propagate only energy orthogonally polarized with respect to the energy propagated by said first waveguide means; a radio frequency receiver; third wavegiude means coupled to said juncture operable to propagate radio frequency energy to said receiver; and means operable to decouple said receiver from said juncture when said energy source is in operation and to decouple said energy dissipating means from said juncture when said energy source is not in operation.

5. Apparatus for coupling a radio frequency energy source to an antenna comprising: a junction including a first waveguide means capable of supporting two orthogonal modes of propagation of plane polarized energy and first and second rectangular waveguide sections individually connected thereto one of which is adapted to couple to one of the modes in said first waveguide means and the other of which is adapted to couple to the other of said modes; a third rectangular waveguide section connected to said first waveguide means and adapted to couple to at least the mode of propagation supported by said first rectangular waveguide section; energy dissipating means coupled to said first section of rectangular waveguide; a non-reciprocal, 45° plane-of-polarization rotator adapted to couple said first waveguide means to said antenna; said second rectangular waveguide section being adapted to couple to said energy source; a receiver coupled to said third waveguide section; and means for decoupling said receiver from said junction when said energy source is in operation and to decouple said energy dissipating means from said junction when said energy source is not in operation.

6. In a radio echo location device, a radio frequency energy source, first means coupled to said energy source and operable to propagate energy of a given plane-of-polarization while rejecting energy of a plane-of-polarization orthogonal to said given plane-of-polarization, a non-reciprocal, plane-of-polarization rotating means connected to the output of said first means and operable to rotate the plane-of-polarization of electromagnetic energy through an angle of 45°, antenna means connected to the output of said rotating means, second means coupled to the input of said rotating means and operable to propagate only energy of said orthogonal plane-of-polarization, dissipating means responsive to the energy propagated by said second means, third means coupled to the input of said rotating means and operable to propagated energy of said orthogonal plane-of-polarization, receiver means responsive to the energy propagated by said third means, means operable to prevent transmission of energy to said receiver means when said energy source is in operation, and means operable to prevent transmission of energy to said dissipating means when said energy source is inoperative.

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