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CIRCULARLY POLARIZED ANTENNA ARRANGEMENT FOR RADAR

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Fig. 1

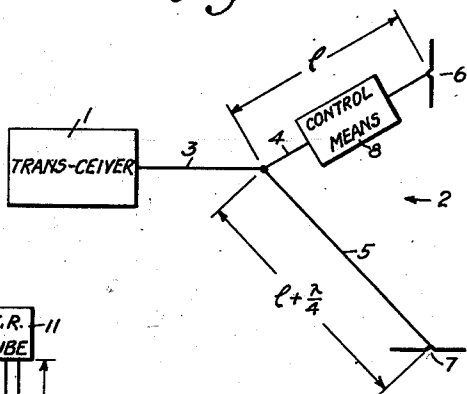


Fig. 2

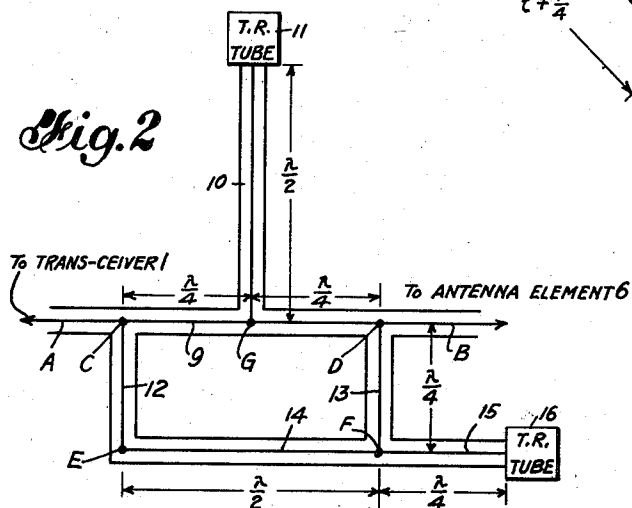


Fig. 3

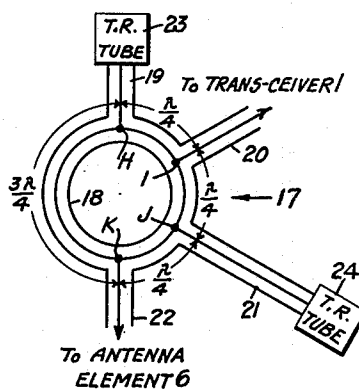
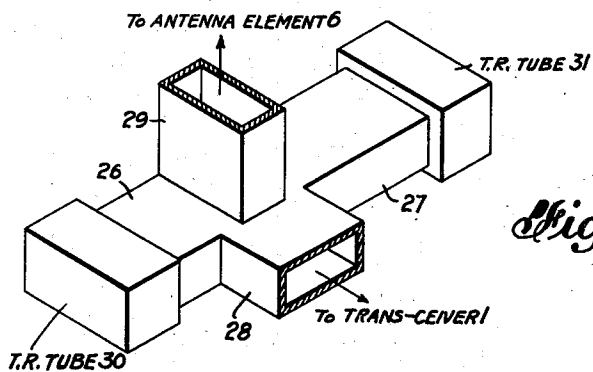


Fig. 4



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ARRANGEMENT FOR RADARWilliam Sichak, Lyndhurst, N. J., assignor to In-
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The present invention relates to circularly polarized antenna arrangements for use especially with radar and particularly to such an arrangement which transmits circularly polarized waves of one screw sense and is adapted to receive circularly polarized wave of the opposite screw sense.

It has heretofore been proposed to use circularly polarized antennas for radar. See article in the Proceedings of the I. R. E., August 1943 page 997 etc. "Antennas for Circular Polarization." When however a circularly polarized wave of one screw sense is transmitted and strikes a highly conducting smooth surface the reflected wave will have the opposite screw sense. Heretofore circularly polarized antennas have had the property that they will not receive a wave with a screw sense opposite to that which they transmit. Since in radar practice it is desirable and customary to use the same antenna arrangement for transmitting and receiving, the problem of screw sense has proven an obstacle to the use of circularly polarized antennas for radar.

An object of the present invention is the provision of a circularly polarized antenna arrangement adapted to transmit circularly polarized waves in one screw sense and to receive circularly polarized waves according to the opposite screw sense.

A circularly polarized wave may be produced using two orthogonally polarized elements such as a set of vertically polarized dipoles and a set of horizontally polarized dipoles. Circular polarization is obtained when the line feeding one polarized element, such as one set of these dipoles, is a quarter wave longer at the operating frequency of said arrangement than the line feeding the other set. It is theoretically possible to reverse the screw sense of this arrangement by rotating one of said elements through 180 degrees. As a practical matter this is not feasible for high speed operation such as would be required for radar operation.

In accordance with a feature of the present invention it is proposed to provide a circularly polarized antenna arrangement adapted to transmit a wave having a given screw sense and to receive a wave having the opposite screw sense, the particular screw sense being controlled according to the amplitude of the energy being fed through the arrangement. According to one aspect of the invention the reversal of the screw sense is accomplished by effectively shifting the energy in one of the transmission lines or wave guides leading to one of the two orthogonally

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polarized antenna elements by 180° or an odd multiple thereof.

According to another aspect of the present invention the reversal of the screw sense is accomplished by effectively adding or subtracting an extra half wave length transmission section or odd multiple thereof in one of the lines or wave guides leading to one of said antenna elements.

The above-mentioned and other features and objects of this invention and the manner of attaining them will become more apparent and the invention itself will be best understood, by reference to the following description of an embodiment of the invention taken in conjunction with the accompanying drawings, wherein:

Fig. 1 is a schematic and block diagram of an antenna arrangement in conjunction with a radar transmitter and receiver in which the antenna arrangement is provided with screw sense reversing control means.

Fig. 2 is a schematic diagram of a coaxial form of screw sense control means.

Fig. 3 is a coaxial form of ring circuit providing such control means and

Fig. 4 is a magic T wave guide arrangement providing such control means.

Referring now to Fig. 1 a transceiver 1 for radar is coupled to an antenna arrangement generally designated by the numeral 2, by means of a main line 3 which has two branches 4 and 5 connected respectively to antenna elements 6 and 7 which antenna elements are orthogonally polarized with respect to each other and which are used to provide circular polarization by having one of the branch lines, for Example 5, a quarter wave length longer than the other branch line 4. Thus for example if branch line 4 is a length l , the length of branch line 5 is

$$l + \frac{\lambda}{4}$$

The transceiver 1 is adapted to transmit pulses of relatively high amplitude or energy content to the antenna arrangement 2, the antenna arrangement then receiving the relatively low amplitude or energy content echo pulses and feeding them via lines 3, 4 and 5 back to the transceiver 1. The transceiver 1 may include all the usual radar arrangements such as TR boxes to keep the transmitted pulse out of the receiver and if desired to keep the received pulses out of the transmitter.

The coupling means for coupling the transmitter-receiver to main line 3 may be conventional. While we have referred to elements 3,

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4 and 5 as lines hereinbefore, this term is being used in a very broad sense to cover all forms of transmission media in which the transmitted energy follows a limited predetermined path and includes wave guides, dual transmission lines, "G" lines and coaxial lines, etc. While the plane polarized antenna elements 6 and 7 are illustrated as single dipoles, each of these may consist of a number of antenna elements and may be of any conventional form for producing circularly polarized radiant action.

The screw sense of the circularly polarized wave transmitted by the antenna arrangement will be determined by the length l in branch lines 4 and 5 and by the position of the antenna elements. Thus for example if one of the dipoles is rotated 180° it will change the screw sense of the wave. Likewise if the length of one of the branch lines 4 or 5 is increased or decreased a half wave length or an odd multiple thereof, the screw sense will likewise be reversed. This increase or decrease of the length of either of the branch lines produces an 180° phase shift, or odd multiple thereof in the energy transmitted through the line whose length has been altered and it is also therefore possible to change the screw sense by altering the phase shift of the energy in one of the branch lines by 180° or odd multiple thereof. In accordance with the present invention a control means 3 is provided in one of the branch lines, such as for example in branch line 4, to effectuate this 180° or odd multiple thereof additional phase shift of the energy in said line. Such control means may take a variety of forms such as those indicated in Figs. 2, 3 and 4.

The control means illustrated in Fig. 2 physically causes the energy therethrough to traverse an extra half wave length when transmitting, which half wave length is removed from the path when receiving. The network or circuit of Fig. 2 is illustrated as being a coaxial line and consists of a direct or main section 9 of coaxial line which may form part of branch line 4. One end A of said section being towards the transmitter-receiver side and the other end B being towards antenna element 6. At an intermediate point between these ends or points A and B there is provided a stub line 10 which is half a wave length long and is terminated by a TR box or tube 11 (see Microwave Duplexers Radiation Lab. series 14 McGraw-Hill page 5 etc.) This tube is adapted to short circuit the stub line 10 when a pulse of the amplitude of the transmitted pulse passes along the section 9. At a quarter wave length from stub line 10, two additional stub lines 12 and 13 are provided each a quarter wave length long, the points at which they meet the main section being designated by the letters C and D. These two stub lines 12 and 13 are open ended and are connected together at their outer ends E and F by a half wave length line 14, lines 12, 13 and 14 providing a shunt path for the energy when transmitting pulses, in contrast to the direct path between points C and D when receiving. To aid in controlling this shunt path a quarter wave length stub line 15 terminated in a T. R. tube 16 is connected at point E with lines 13 and 14.

The operation of this arrangement is as follows. When a pulse is being transmitted, the leading edge of this pulse (the initial energy thereof) causes TR tube 11 to fire and short the end of line 10. Since line 10 is a half wave length line, the short appears across section 9 at point

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G in parallel with said section and since the distance from G to C is a quarter wave length this short at G will appear as an open circuit at C and the transmitted pulse cannot go from point A into the portion of section 9 between C and D but instead follows the path through stub line 12 and half wave length line 14 to point F. The initial portion of the energy at point F enters stub line 15 causes the TR tube 16 to fire shorting the outer end of stub line 15 and producing an open circuit at point F so that the rest of the energy of the transmitted pulse travels up through stub line 13 until it arrives at point D. Since at point G there is effectively a short and D and F are a quarter wave length apart, an open circuit is produced looking to the left into the portion of section 9 between D and G and therefore the energy arriving at D proceeds towards the end B of the network and towards the antenna element 6.

When energy is being received from antenna element 6 it travels from point B directly along section 9 to point A and cannot follow the indirect path through stub lines 13, 14 and 12. The reason for this is as follows. When pulses are being received their amplitude is insufficient to fire tubes 11 and 16. Since the distance from TR tube 16 to point D is a half wave length and the stub line 14 is open-ended at 16, an open circuit appears at point D looking into stub line 13. Therefore the received pulse travelling from B to D will not enter stub line 13. On the other hand looking into the section 9 from D towards G a closed circuit will appear in parallel with the section 9 at point D since the distance from tube 11 to point D is three quarters of a wave length and section 10 is open at tube 11. This open circuit is inverted in the quarter wave length of the line between G and D to produce a closed circuit in parallel with the portion between D and G. The received pulse travels from D to G and continues towards C. It cannot enter stub line 10 because looking into the stub line from point G an open circuit is presented. At point C the received pulse continues on to A for it cannot enter stub line 12 since from the outer end of stub line 15 to point V via half wave section 14 is a full wave length and the outer end of stub line 15 is open circuited (tube 16 unfired), so that an open circuit is presented looking into stub section 12 from line C. Thus the energy of the received pulse goes on towards point A and towards the transceiver 1.

It will thus be seen that the received pulse travels between points C and D a distance equal to half a wave length. On the other hand the transmitted pulse travels between points C and D via stub lines 12, 14 and 13 a distance of a full wave length. Thus the transmitted pulse travels a half wave length more than the received pulse and is shifted in phase by 180° more than the received pulse by virtue of its passage through the network. Accordingly, the antenna arrangement has its circularly polarized screw sense during transmission, reversed with respect to its screw sense during reception.

In Fig. 3 a magic T in the form of a ring circuit is illustrated which serves to reverse the screw sense by, in effect, producing 180° additional phase shift on the transmitted pulse over the phase shift effected on the received pulse. The ring circuit generally designated by the numeral 17 is in the form of a coaxial line arrangement and includes a coaxial ring 18 to which coaxial lines 19, 20, 21 and 22 are connected at

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points H, I, J and K, the distance between points H and I, I and J, J and K, being one quarter wave length and between K and H being three quarters of a wave length. Lines 19 and 21 may be referred to herein as the side arms and are terminated by TR tubes 23 and 24 respectively. One of the arms 19 and 21, for example line 19, has a length l and the other arm 21 has a length

$$l + \frac{x}{4}$$

Of the other two arms 20 and 22 one is connected to the trans-ceiver 1 and the other is connected to antenna element 6. Arms 20 and 22 being inserted in a break in a branch line 4. Arms 20 and 22 may be considered as the main arms and 19 and 21 as the side arms.

This arrangement operates as follows. During transmission a pulse is fed into line 20 and upon reaching point 1 divides equally and goes into lines 19 and 21. The TR tubes 23 and 24 fire thus making lines 19 and 21 appear as short-circuited lines. The energy is reflected from the outer ends of these lines back to points H and J where the energy appears 180° out of phase due to the extra quarter wave length in line 21. Since the reflected energy at H and J is now 180° out of phase it will not feed back to line 20 but will be fed to point K and into line 22 towards the antenna element 6.

Upon reception of the echo pulse on antenna element 6 the energy thereof is fed along line 22 to point K where it divides and is fed to point H and J where it appears 180° out of phase. The energy then goes into side arms 19 and 21 which now are open ended at both ends since the energy of the received pulse is insufficient to operate TR tubes 23 and 24. Since there is an extra quarter wave length in line 21 the reflected energy at J and at H will be in phase. This energy will then not go back to line 22 but will be fed out of line 20 to trans-ceiver 1. It is to be noted that when a line is open as are lines 21 and 23 during reception of a pulse it is the same as if this open end were an extra quarter wave-length shorted stub away from the open end. In other words the effect of the open end is to produce 180° phase shift in the energy reflected from that open end as contrasted with what would occur if the end were shorted. Thus during reception the transfer of energy between lines 22 and 20 is increased by 180° as contrasted with the phase shift produced during transmittal when the TR tubes 23 and 24 short circuit the side arms 19 and 21. Accordingly the requisite 180° phase shift for changing the screw sense of the circularly polarized wave is produced in the ring circuit of Fig. 3. While the ring of circuit of Fig. 3 has been disclosed as a coaxial arrangement a ring circuit composed of wave guide sections is obviously substitutable in place thereof especially for higher frequencies. Likewise a wave guide type magic T arrangement could be used to produce the required 180° phase shift for changing the screw sense of the circularly polarized wave emitted by the antenna arrangement as indicated in Fig. 4.

The magic T wave guide network or arrangement 25 provided in Fig. 4 consists of the usual two side arms 26 and 27 lying in the same phase as the H section 28, the E section 29 extending from between the arms in a plane at right angles to the aforementioned plane. Details of such structures may be found in the book referred to

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hereinbefore entitled "Microwave Marker Wave Duplexers" on page 361 etc. For the purposes of the present invention, one side arm, for example 27, is made a quarter wave length longer than the other arm and both arms 26 and 27 are provided with TR boxes 30 and 31 respectively at their outer ends.

The trans-ceiver may be connected to either arm 28 or 29 and the antenna element 6 may be connected to the other of said two arms. In Fig. 4 arm 28 is shown as connected to the trans-ceiver whereas arm 29 is connected to the antenna element 6. The arrangement operates in a manner similar to the arrangement of Fig. 3 and will be but briefly described herein. A pulse from the trans-ceiver passes from arm 28 into lines 26 and 27 causing the T. R. boxes to operate and reflect the energy into the arm 29. When an echo pulse is received it is fed via arm 29 into the side arms 26 and 27. Since the received echo pulses are of insufficient amplitude to ignite the T. R. tubes the energy reflected back from said side arms 26 and 27 into arm 28 in effect travels a half wave length longer in each of said side arms, or is shifted 180° in phase in each of the side arms, more than in the case of the high amplitude pulse from the transmitter. This additional phase shift is due to the fact that the side arms 26 and 27 when open-ended produce a 180° shift in phase more than the same length of side-arm when closed by firing of the T. R. boxes. It will thus be seen that there is provided the required 180° extra phase shift for the received pulse than for the transmitted pulse, so that consequently the screw sense of the antenna arrangement is reversed in changing from transmission to reception.

While I have hereinbefore described several devices for effectuating this change of screw sense it will be seen that other arrangements such as transmission line bridges or their wave guide equivalents may be employed for this same purpose.

While I have described above the principles of my invention in connection with specific apparatus, it is to be clearly understood that this description is made only by way of example and not as a limitation to the scope of my invention as set forth in the objects thereof and in the accompanying claims.

I claim:

1. A circularly polarized antenna arrangement for a radar transmitter and receiver comprising a first antenna element providing radiant action in a given plane of polarization, a second antenna element providing radiant action in a plane of polarization substantially at right angles to said given plane, a transmitter producing pulses of relatively high amplitude, a receiver for receiving pulses which are of relatively lower amplitude, means coupling said transmitter and receiver to said antenna elements, said means providing two transmission paths, one of said paths being an odd multiple of quarter wave lengths longer than the other of said paths and means coupled in one of said paths for varying the effective length by an odd multiple of half wave lengths thereof, said varying means including a switching device operative in response to the higher amplitude of the transmitted pulses and unresponsive to the lower amplitude of the received pulses.

2. A circularly polarized antenna arrangement according to claim 1 wherein said switching device is a gaseous discharge gap adapted to fire in response to the transmitted pulses but not in re-

sponse to the lower amplitude received pulses, said varying means including a transmission section coupled in one of said paths, said gap coupled to said transmission section and adapted upon firing to vary the transmission characteristics thereof.

3. A circularly polarized antenna arrangement according to claim 2 wherein said section is an open-ended section, said gap is a TR tube coupled to the outer end of said section and adapted upon firing to electrically close said outer end of said section.

4. A circularly polarized antenna arrangement according to claim 3 wherein said section has a length which is a multiple, including one, of a quarter wave section.

5. A circularly polarized antenna arrangement according to claim 1 wherein said coupling means is a magic T having two side arms and two main arms, one of said main arms being coupled to said transmitter and receiver and the other to one of said antenna elements, one of said side arms being an odd multiple including one of a quarter wave length longer than the other of said side arms, said switching device comprising two TR tubes each coupled to the outer end of a separate one of said side arms and adapted upon firing to electrically close its outer end.

6. A circularly polarized antenna arrangement according to claim 5 wherein said magic T is in the form of a ring circuit with a center transmission ring to which said arms are each connected at their inner ends, the inner ends of said arms being spaced, as measured around the ring going in one direction as follows: beginning from one side arm one quarter wave length to the one main arm, from the latter arm one quarter wave length to the other side arm from the latter side arm one quarter wave length to the other main arm, from the last mentioned main arm three quarters of a wave length back to the beginning.

7. A circularly polarized antenna arrangement according to claim 5 wherein said magic T is constructed of wave guide sections, one of the main arms and the two side arms lying in one plane, the other main arm extending in a plane at right angle to said one plane.

8. A circularly polarized antenna arrangement according to claim 1 wherein one of said paths comprises a main path and a shunt path cou-

pling two points of said main path, the shunt path being an odd multiple, including one, of a half wave length longer than the distance between said two points, said switching device comprising an open ended transmission section associated with said main path, said switching device being in the form of a TR tube positioned at the outer end of said section and adapted to be fired by a transmitted pulse to close said outer end and electrically block the main path between said two points thereby causing the transmitted pulse from the transmitter to travel around the shunt path.

9. A circularly polarized antenna arrangement for use with a radar transmitter and receiver comprising a transmitter for transmitting pulses of relatively high amplitude; a receiver for receiving pulses which are of relatively lower amplitude; an antenna arrangement coupled to said transmitter receiver and providing circular polarization of a given screw sense comprising a first antenna element radiantly acting with a given plane of polarization, a second antenna element radiantly acting with a plane of polarization substantially at right angles to said given plane, and means coupling said transmitter and receiver to said antenna elements, said coupling means including two transmission paths each to a separate one of said elements, one of said paths being an odd multiple including one of a quarter wave length longer than the other of said paths, and means for reversing the screw sense of said circularly polarized antenna arrangement including a resonant transmission section coupled to one of said paths, means responsive to the transmitted pulses for shorting said section and means responsive to the shorting of said section for varying the effective length of said path by an odd multiple including one, of a half wave length.

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