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POLARIZATION SENSITIVE ANTENNA SYSTEM

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2 Sheets-Sheet 1

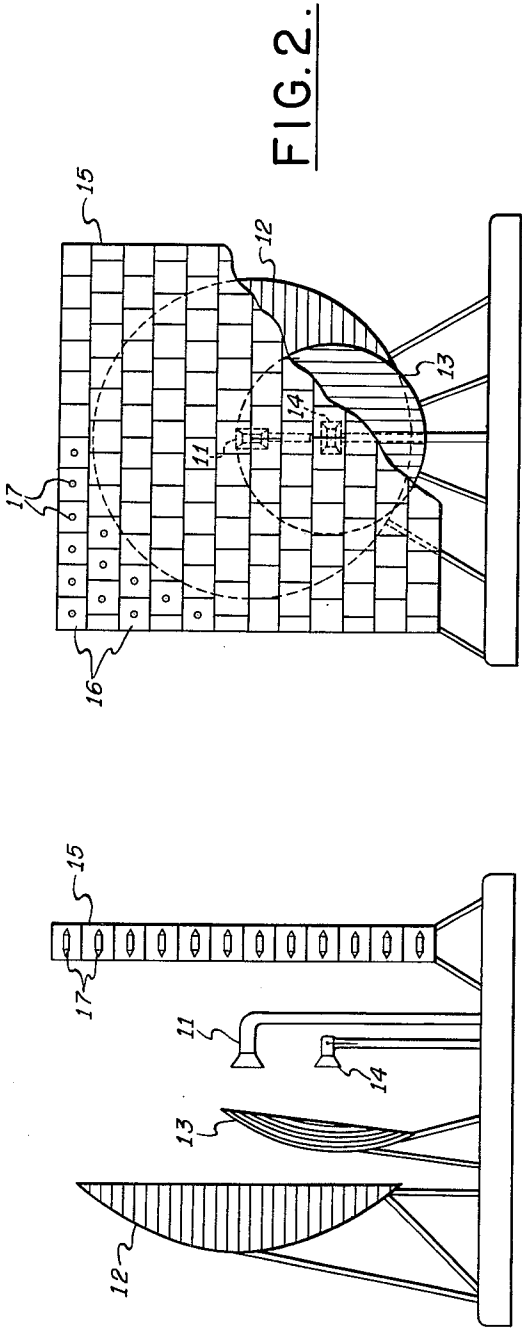
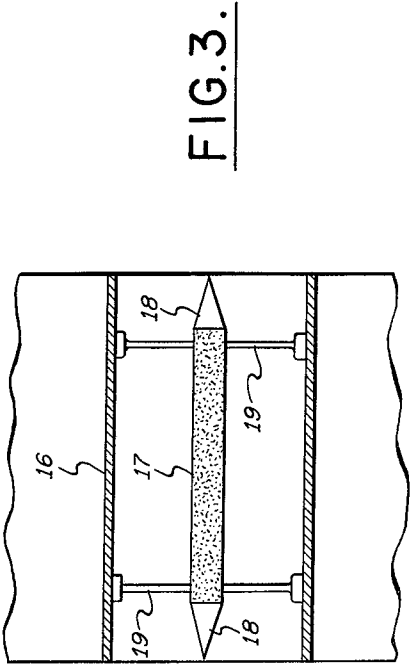


FIG. 1.

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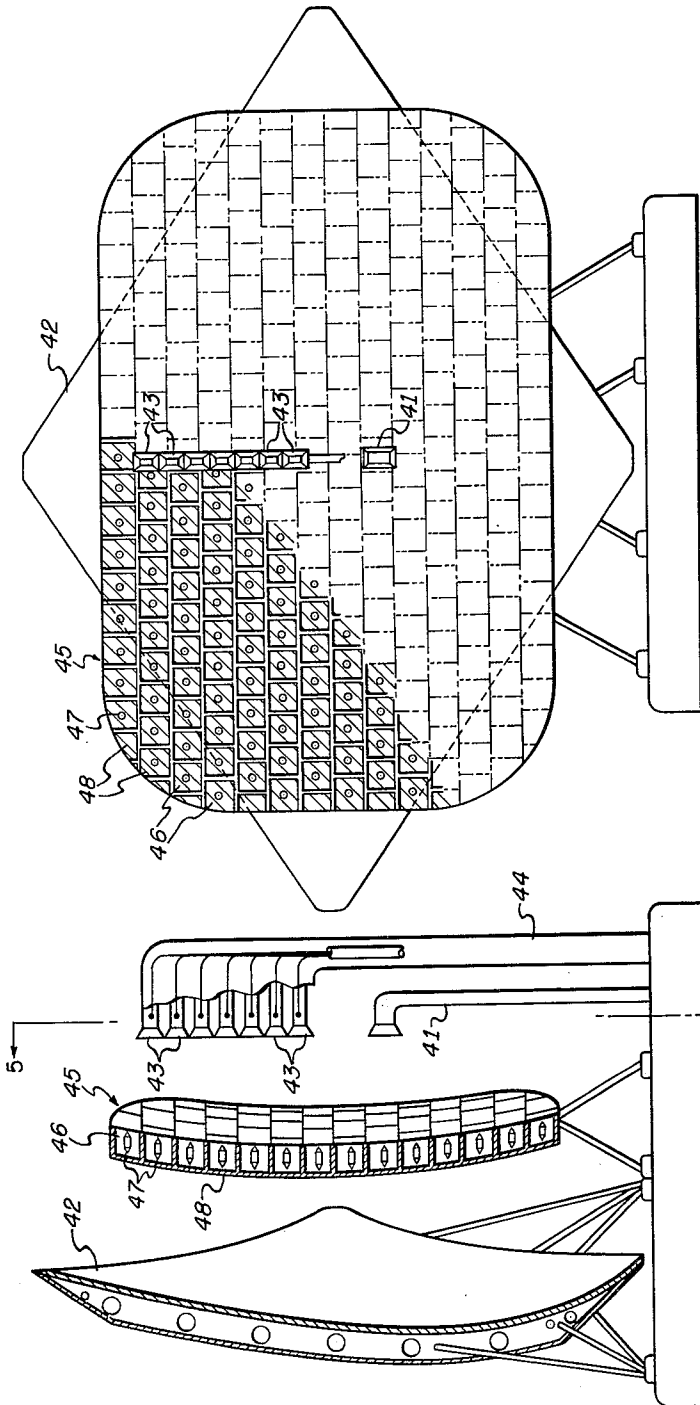


FIG. 5.

FIG. 4.

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1

3,049,708

POLARIZATION SENSITIVE ANTENNA SYSTEM
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The present invention relates to microwave antenna systems.

Most microwave radar systems operating at low and medium power levels employ duplexers comprised of conventional transmit-receive (TR) tubes and anti-transmit-receive (ATR) tubes which operate in the well known manner to protect the receiver during transmission of microwave energy, and to direct received energy to the receiver. Duplexers of this type perform well at low and medium power levels. However, in radar systems intended for use at high power levels the TR and ATR tubes very often constitute serious limiting factors in the power handling capabilities of the high power radar systems. In the design of a high power radar system, therefore, it is desirable to provide a microwave transmission and radiating system which avoids the use of these power limiting devices.

In certain types of radar systems, notably in height-finding systems, a shaped radiation beam such as a cosecant-squared beam is employed. The microwave system required to produce such shaped beams often require a plurality of radiators and receivers. This involves complex microwave circuitry resulting from the requirement that the microwave energy radiated and received from the plurality of radiators have critical phase relationships with respect to each other. The resulting physical structures for accomplishing these results comprise large bulky waveguide structures at the antenna. These waveguide structures present large inertial loading to scanning antennas, and may sometimes constitute large obstacles in the path of radiated and received microwave energy and reduce the effectiveness of the antenna system.

It is an object of this invention to provide an antenna system for use in a relatively high power microwave system.

Another object of the present invention is to provide a microwave antenna system in which conventional TR and ATR tubes may be completely eliminated, or wherein the power incident on such protective devices, if employed, is considerably reduced to well within the power handling capabilities of conventional protective devices.

It is a further object of this invention to provide a microwave antenna system employing separate transmit and receive antennas wherein high isolation is maintained between said antennas without the use of TR and ATR tubes.

The above-described and other objects of this invention which will become more apparent from the specification and claims below are achieved in one embodiment of the invention by providing means for radiating linearly polarized waves, and separate means adjacent said radiating means for receiving waves of but one linear polarization. First and second spaced reflectors are disposed in front of said radiating and receiving means, and the reflector disposed nearest said radiating and receiving means is polarization selective to linearly polarized waves for reflecting only waves of a first linear polarization. A cellular wave transmitting structure adapted to transmit orthogonally polarized waves is positioned on the side of said radiating and receiving means opposite said reflecting means in the path of the radiated and received waves, and polarization rotating means for rotating the plane of polarization of linearly polarized waves by 45° are positioned in each cell of said cellular member. The apparatus described op-

2

erates to initially radiate linearly polarized waves of a first polarization which pass through the polarization selective reflector to the second reflector. The waves then are reflected from the first reflector back through the polarization selective reflector in a desired radiation pattern. The waves then pass through the cellular structure and are rotated 45° in polarization by polarization rotating means. Upon reflection from a remotely located object, the waves again pass through the cellular structure and are rotated in polarization by another 45°, or a total of 90° from said first polarization. The waves at this orthogonal polarization then are reflected by the polarization selective reflector back into the separate receiving means positioned in front thereof.

The present invention will be explained in connection with the attached illustrations wherein:

FIG. 1 is a diagrammatic illustration of a side view of a microwave antenna system constructed in accordance with the present invention;

FIG. 2 is a front view of the microwave antenna system of FIG. 1;

FIG. 3 is an enlarged view illustrating the structural details of a part of the antenna system of FIG. 1;

FIG. 4 is a diagrammatic illustration of a side view of an alternative microwave antenna system constructed in accordance with the present invention; and

FIG. 5 is a front view of the antenna system illustrated in FIG. 4.

Referring now more particularly to FIG. 1, there is illustrated a microwave radiating horn 11 which is adapted to radiate only horizontally polarized electromagnetic waves. Radiator 11 is located at the focal point of shaped wave reflector 12 which is adapted to radiate into space the horizontally polarized waves from radiator 11. Reflector 12 may be comprised of a plurality of spaced horizontal wires which provide a polarization-selective reflector in a manner well known in the art. Alternatively, reflector 12 may be comprised of a dish having a continuous conducting surface. In either event, the reflecting surface of reflector 12 is shaped to produce a desired radiation pattern in space. Disposed between radiator 11 and reflector 12 is a polarization-selective reflector 13 which presents a shaped reflecting surface to vertically polarized waves, but transmits substantially unaffected horizontally polarized waves. Reflector 13 may be comprised of a plurality of spaced vertical wires which form a curved grid-like structure, as previously described. A receiving antenna horn 14 is disposed adjacent radiating antenna horn 11 at the focal point of polarization-selective reflector 13. Receiving horn 14 is responsive only to vertically polarized waves, and will not accept horizontally polarized waves.

A cellular microwave transmitting structure 15 is disposed in front of radiators 11 and 14 on the side thereof opposite reflectors 12 and 13. Cellular member 15 is so positioned, and so shaped, as to be in the path of substantially all the microwave energy radiated from reflector 12 and received by reflector 13. As best seen in FIG. 2, cellular structure 15 is comprised of staggered rows of cells 16, each cell comprising a waveguide which is capable of propagating orthogonal linearly polarized waves. Cells 16 may be square, round or polygonal in cross section, and are adapted to propagate orthogonal linearly polarized waves with equal phase velocity. Cellular structure 15 may be constructed of a plastic dielectric material having a conductive coating applied thereto to form the conductive surfaces of the waveguiding cells. Structures of this type, and methods for producing them, are well known to those familiar with the art. Disposed within each cell of cellular member 16 is a rod of gyromagnetic material 17, FIG. 3, which when magnetized is capable of rotating the plane of polarization of linearly polarized microwave energy.

3

Gyromagnetic members 17 produce non-reciprocal Faraday rotation of the plane of polarization of microwave energy, as is now well understood in the art. As an example, gyromagnetic member 17 may be a ferromagnetic material known generally as ferrite. Conductive tapers 18 are located at each end of gyromagnetic member 17 and provide impedance matching means in the well known manner. Members 18 may be permanently magnetized in order to magnetize gyromagnetic member 17. Alternatively, conductive tapers 18 could be eliminated and a permanently magnetized tapered ferrite rod could be employed. Each of the gyromagnetic members 17 located in cells 16 is magnetized, or polarized, in a direction parallel to its longitudinal axis to produce a 45° rotation in the plane of polarization of linearly polarized waves incident thereon. Gyromagnetic members 17 should be substantially lossless to microwave energy at the frequency of operation. The ferrite material known as R-1 manufactured by General Ceramics Corp., Keasbey, New Jersey, may be used for this purpose.

For reference purposes, it will be assumed that the energy radiated from horn 11 is at a polarization angle of 0°, and that its electric vector is in a horizontal plane and points toward the right. It further will be assumed that each of the gyromagnetic members 17 rotates the plane of polarization of linearly polarized energy by an angle of 45° clockwise, looking into the cells from the right side of FIG. 1. (All polarization angles described below are as viewed from right to left in FIG. 1.) It is to be understood that the above assumptions are examples only, and are not intended to be limitations in the operating capabilities of the antenna systems of the present invention.

In the operation of the antenna system illustrated in FIGS. 1-3, radiating horn 11 radiates horizontally polarized energy at 0° which passes through polarization-selective reflector 13 substantially unaffected thereby, and illuminates reflector 12. Reflector 12 substantially completely reflects the horizontally polarized energy, which, upon experiencing a 180° reversal in polarization at the reflecting surface, is re-radiated through polarization-selective reflector 13 and toward cellular member 15 as horizontally polarized energy at a polarization angle of 180°. This energy propagates through the plurality of wave-guiding cells 16 of cellular member 15 and the plane of polarization of the energy in each cell is rotated clockwise by an angle of 45°, and emerges at an angle of 135°. This linearly polarized energy at a polarization angle of 135° is then radiated into space in a beam whose pattern is determined by the shape of reflecting surface 12 and the radiation pattern of horn 11.

Energy reflected from a target remotely located from the antenna system experiences an additional 180° polarization reversal upon reflection from the target and is incident on the right sides of cellular member 15, FIG. 1, with a polarization angle of 315°. This energy then passes through the cells 16 and is again rotated 45° by gyromagnetic members 17 and emerges as vertically polarized energy at a polarization angle of 270°. Polarization-selective reflector 13 reflects this vertically polarized energy, which experiences another 180° reversal in polarization upon reflection from said reflector 13. The received energy reflected from reflector 13 therefore is incident on receiving horn 14 as vertically polarized energy at a polarization angle of 90°. Because horn 14 is adapted to receive vertically polarized energy, the received energy will be accepted by horn 14 and will be coupled to a receiver (not shown) coupled thereto.

It will be noted that radiated energy reflected from reflector 12 during transmission was polarized at an angle of 180° so that it will not be accepted by polarization-selective receiving horn 14. The receiver therefore will be effectively isolated from the transmitter during transmission of the energy. In a similar manner, received energy is reflected from reflector 13 as vertically polarized

4

energy which will not be accepted by radiating horn 11. Duplexing action therefore has been achieved.

An alternative embodiment of this invention which is particularly useful in height-finding radars is illustrated in FIGS. 4 and 5, wherein transmitting horn 41 is polarization-selective to radiate only horizontally polarized energy, and is positioned at the focal point of shaped reflector 42 which may be a polarization-selective reflector of the wire grid type to reflect only energy polarized 45° clockwise to a horizontal plane, or may be comprised of a shaped, completely conducting surface as illustrated in FIG. 4. All polarization angles will be relative to the same reference as previously defined. Reflecting surface 42 may be shaped to produce a cosecant squared radiation beam. Disposed adjacent radiating horn 41 are a plurality of receiving horns 43 which are adapted to receive only horizontally polarized energy. Each of the individual horns 43 is coupled to a respective receiver (not shown) through a respective coaxial cable contained within a boom 44.

Disposed between horns 41 and 43 and reflector 42 is a cellular member 45, similar in construction to cellular member 15 of FIGS. 1 and 2. Rods 47 of gyromagnetic material are disposed within the individual cells 46 of cellular member 45 in the manner illustrated in FIG. 3. Rods 47 are adapted to rotate the plane of polarization of linearly polarized waves 45° clockwise, looking from right to left in FIG. 4. A polarization-selective reflecting surface 48 is disposed on the back surface of cellular member 45, and provides a substantially complete reflecting means for waves polarized 45° counterclockwise to a horizontal plane, looking from right to left in FIG. 4, but passes substantially unaffected waves polarized 45° clockwise to said horizontal plane. Reflecting surface 48 may be comprised of a plurality of closely spaced conductive wires, lines or rods which extend at an angle of 45° counterclockwise to the horizontal plane. The conductors of reflecting surface 48 may be formed integrally with cellular member 45 in the event that member 45 is molded. Polarization-selective reflecting surface 48 is so shaped and the plurality of receiving antennas are so positioned relative to reflecting surface 48 that received energy from different portions of space is respectively directed into different ones of the plurality of receiving antennas 43 in order that height information may be derived concerning targets in space. For this purpose, reflecting surface 48 may have a parabolic shape.

In the operation of the antenna system illustrated in FIGS. 4 and 5, horizontally polarized energy at a polarization angle of 0° radiated by radiating antenna 41 passes through cellular member 45 and is rotated therein 45° in the clockwise direction. This energy is polarized perpendicularly to the spaced conductors of polarization-selective reflecting surface 48, so will pass therethrough substantially unaffected. The energy then will be incident on shaped reflector 42, will experience a 180° polarization reversal upon reflection therefrom, will again pass through polarization-selective reflector 48, and will pass through cellular member 45 wherein it again will be rotated 45° clockwise, and will be radiated into space in a desired shaped beam, such as a cosecant squared beam, as vertically polarized energy at a polarization angle of 90°. Energy reflected from a target in space will experience a 180° polarization reversal and will return to the antenna system at a polarization angle of 270°. This energy will pass through cellular member 45, and will be rotated 45° clockwise to an angle of 225° by gyromagnetic members 47 in the individual cells 46. The polarization of the energy is now parallel to the spaced conductors of polarization-selective reflector 48, so that said energy will be reflected from reflector 48 at an angle of 45°, and will again propagate through cellular member 45 wherein it again will be rotated 45° clockwise by gyromagnetic members 47. The energy will emerge from cellular member 45 as horizontally polarized energy at

0°, and will be distributed to the plurality of receiver horns 43 in accordance with their respective positions relative to the focal point of polarization-selective reflector 48.

By employing a single separate radiating horn 41 and separate shaped reflector 42, a desired complex radiation pattern may be provided without requiring a plurality of radiating horns and the complex circuitry required to establish the required phase relationships of the energy at the different horns.

From the above discussion, it may be seen that energy radiated into space passes receiving horns 43 as vertically polarized energy, but because received horns 43 will accept only horizontally polarized energy, isolation of the receiver will be affected.

Because both the radiating horn 41 and receiving horns 43 are adapted to be responsive to energy of the same polarization, some "spill-over" energy from transmitting horn 41 may be received by receiving horns 43. However, judicious positioning of the two horns will reduce the seriousness of the problem, and if necessary, TR tubes can be employed. If so, the TR tubes may be low power tubes since the "spill-over" energy picked up by antennas 43 will be at a relatively low power level. Thus, even though TR tubes might be used, the power incident on them will be a small fraction of the power of the system and presently available low power TR tubes may be employed.

In an alternative embodiment of the antenna system illustrated in FIGS. 4 and 5, the radiating and receiving horns may be oriented to radiate or receive energy polarized at 45° to said horizontal plane. Otherwise, the operation would be similar to the operation described above in connection with FIGS. 4 and 5.

Substantially the same results as described above in connection with the two illustrated embodiments of this invention may be achieved if the polarization selectivity of the two reflectors is reversed. That is to say that either of the reflecting surfaces may be employed to reflect the transmitted energy, so long as the reflecting surface nearest the radiating antenna is polarization selective.

Although the antenna systems illustrated above may be propagating microwave energy at high power levels, the microwave energy incident on any one of the gyromagnetic members is only a small fraction of the radiated energy because the radiating beam pattern is distributed over substantially all the cells of the cellular member in each of the embodiments. Thus, objectionable high power effects characteristic of known ferrite materials are avoided without sacrificing output power.

While the invention has been described in its preferred embodiment, it is to be understood that the words which have been used are words of description rather than limitation and that changes within the purview of the appended claims may be made without departing from the true scope and spirit of the invention in its broader aspects.

What is claimed is:

1. An antenna system comprising means for radiating linearly polarized waves, means adjacent said radiating means for receiving linearly polarized waves, first and second spaced wave reflecting means disposed in front of said radiating and receiving means, the first of said reflecting means being polarization selective to reflect only waves having a first linear polarization, a cellular wave transmitting structure comprised of a plurality of waveguiding cells positioned in the path of both of said radiated and received waves and each cell adapted to transmit orthogonal linearly polarized waves, and non-reciprocal polarization rotating means disposed in each cell of said cellular structure for rotating by 45° the polarization of linearly polarized waves propagating therethrough, thereby to permit waves from said radiating means to pass through said polarization-selective reflecting means with a polarization orthogonal to said first linear polarization

and to be reflected by said second reflecting means and radiated into space, and to permit waves reflected from a remotely located object to be incident with said first linear polarization on said polarization-selective reflecting means for reflection therefrom to said receiving means.

2. The combination as claimed in claim 1 wherein the cellular structure is positioned on the side of said radiating and receiving means opposite said two reflecting means.

3. The combination as claimed in claim 1 wherein the cellular structure is positioned on the side of said radiating and receiving means nearest said reflecting means.

4. The combination as claimed in claim 1 wherein said polarization rotating means are comprised of elements of polarized gyromagnetic material which rotate the plane of polarization of linearly polarized waves propagating therethrough.

5. The combination claimed in claim 1 wherein said means for receiving linearly polarized waves is comprised of a plurality of adjacent polarization-selective receiving antennas.

6. A microwave antenna system comprising means for radiating linearly polarized waves, means adjacent said radiating means for receiving linearly polarized waves, a polarization-selective reflecting means disposed in front of said radiating and receiving means and adapted to reflect only waves having a first linear polarization, a second reflecting means disposed in front of said radiating and receiving means and behind said polarization-selective reflective means and adapted to reflect waves linearly polarized orthogonally to said first linear polarization, a cellular waveguide structure comprised of a plurality of waveguiding cells positioned in the path of both said radiated and received waves and each cell adapted to transmit said orthogonal linearly polarized waves, and non-reciprocal wave polarization rotating means disposed in each of the cells of said cellular structure for rotating by 45° the polarization of waves propagating therethrough.

7. The combination claimed in claim 6 wherein said wave radiating means radiates waves polarized at said first linear polarization.

8. The combination claimed in claim 6 wherein said wave radiating means radiates waves polarized at 45° to said first polarization.

9. A microwave antenna system comprising transmitting antenna means for radiating linearly polarized energy of a first polarization, first reflecting means opposite said transmitting antenna means for reflecting said linearly polarized radiated energy for producing a beam having a prescribed radiation pattern, means in the path of said beam for rotating the polarization of the radiated energy by 45°, said last-named means rotating the polarization of received energy by another 45° for producing a second polarization that is orthogonal to said first polarization, second polarization-selective reflecting means positioned between said first reflecting means and said transmitting antenna in the path of received energy for reflecting only linearly polarized energy of said second polarization, and receiving antenna means opposite said second reflecting means for responding to received energy having said second polarization to the exclusion of energy having said first polarization.

10. A microwave system comprising transmitting antenna means for radiating linearly polarized energy of a first polarization, means adjacent said transmitting antenna in the path of said radiated energy for rotating its polarization by 45°, shaped reflecting means for reflecting the rotated energy back through said rotating means for rotating the polarization another 45° to provide a second polarization that is orthogonal to said first polarization, the energy at said second polarization being radiated into space in a prescribed beam pattern determined by said shaped reflecting means, said rotating means being in the path of received energy for rotation

7

of the polarization of the received energy by another 45°, second polarization-selective means for reflecting the received energy back through said rotating means for rotating its polarization by another 45° to produce said first polarization, and receiving antenna means opposite

11. The combination as claimed in claim 10 wherein said receiving antenna means is comprised of a plurality of receiving antennas which are positioned relative to said second polarization-selective reflecting means so that received energy from different portions of space is respectively directed into different ones of the plurality of receiving antennas.

12. An antenna system comprising polarization-selective antenna means for radiating linearly polarized waves, polarization-selective antenna means for receiving linearly polarized waves, first and second spaced wave reflecting means positioned in front of said radiating and receiving means, the reflecting means positioned nearest said radiating and receiving means being adapted to reflect only waves having a first linear polarization and being adapted to transmit substantially unaffected waves polar-

8

ized orthogonally to said first polarization, a cellular structure comprised of a plurality of waveguide cells adapted to propagate waves having both of said orthogonal polarizations, said cellular member being positioned in the path of radiated and received waves, and non-reciprocal polarization rotating means positioned in each of said waveguide cells for rotating the polarization of waves propagating therethrough by an angle of 45°.

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