

Nov. 29, 1960

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2,962,716

ANTENNA ARRAY

Filed June 21, 1957

2 Sheets-Sheet 1

Fig. 1

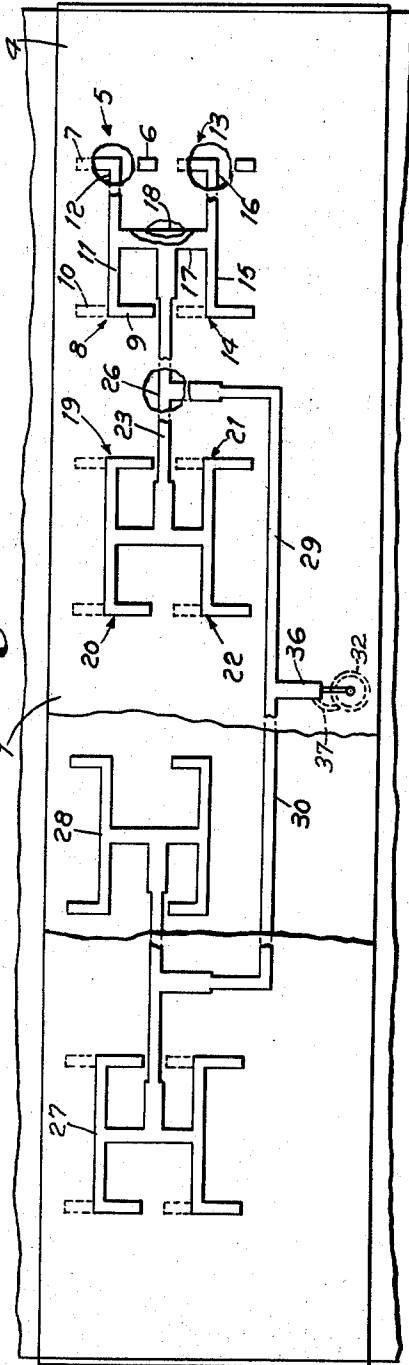
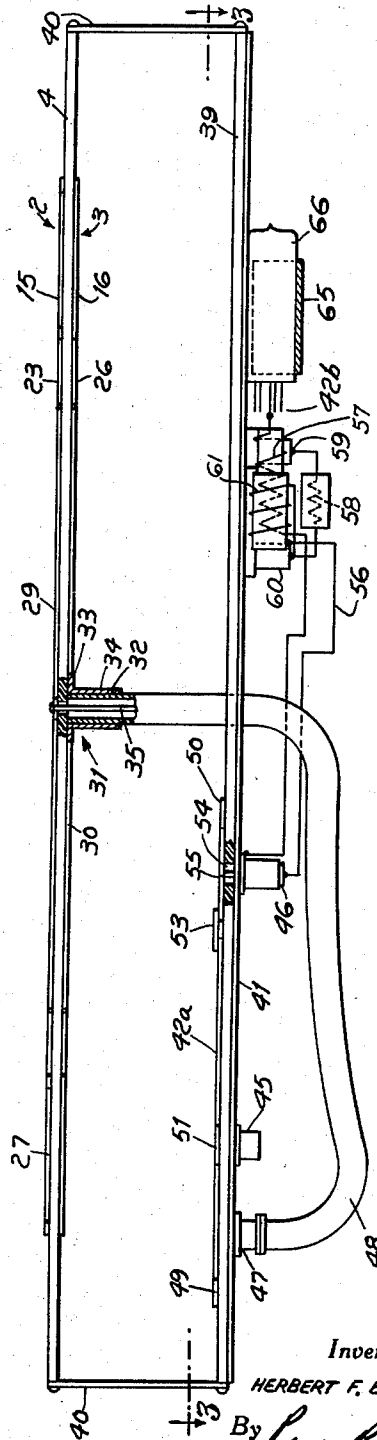


Fig. 2



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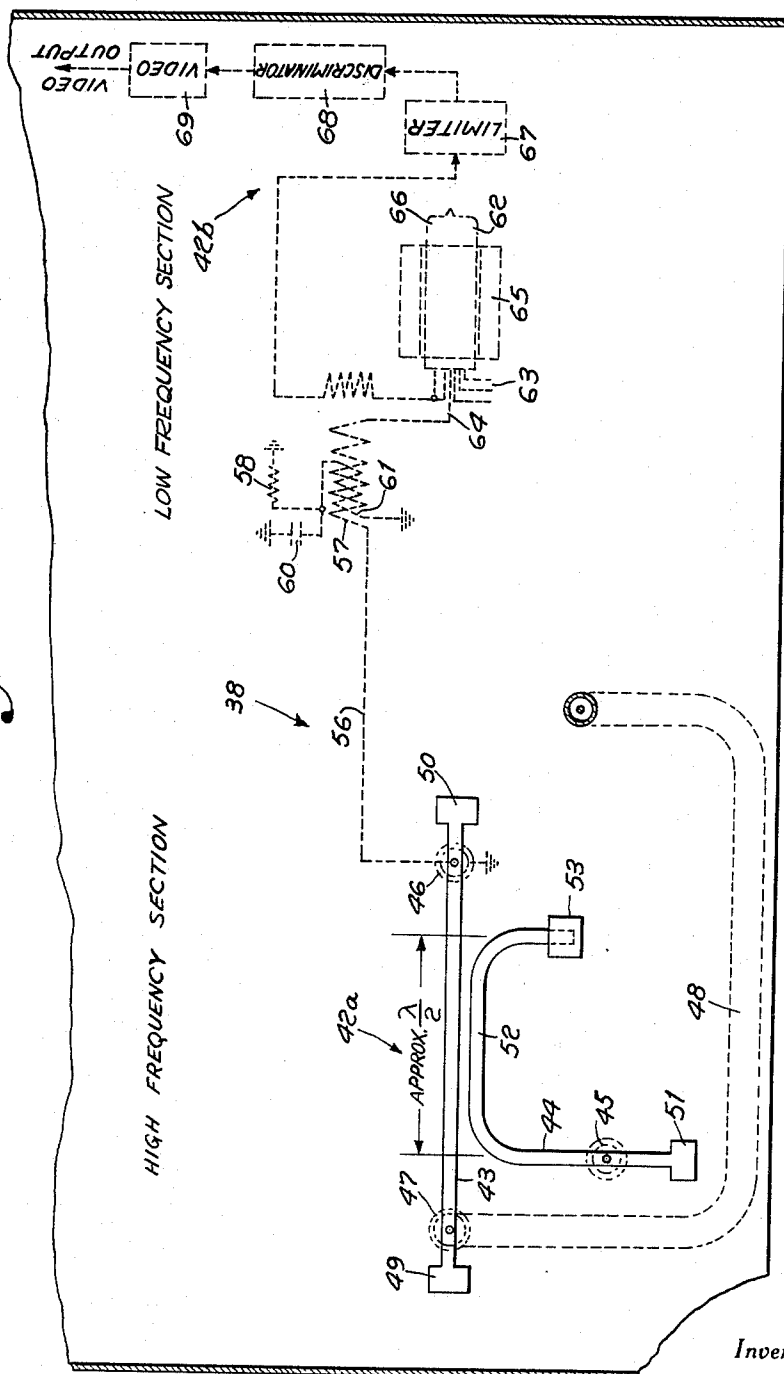
2,962,716

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Filed June 21, 1957

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Fig. 3



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2,962,716

ANTENNA ARRAY

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Filed June 21, 1957, Ser. No. 667,158

7 Claims. (Cl. 343—720)

This invention relates to antenna arrays and associated circuitry and more particularly to a dipole antenna array of printed transmission line construction and associated reflector which forms a part of the associated circuitry.

Antenna arrays and particularly dipole antenna arrays have heretofore required a substantial amount of space and cumbersome and bulky mounting equipment, such as the dipole elements themselves and the masts to mount them. The demand has increased for smaller, compact and more portable units, and in regard to radio transmitters and receivers this demand has been met especially by the use of microstrip technique and printed circuitry. By using the microstrip technique it has been possible to substitute for expensive and bulky microwave plumbing inexpensive and compact microstrip components. It has also been possible to design complete receivers using microstrip technique as is more fully set forth in the co-pending application of D. D. Grieg, H. F. Engelmann, and J. A. Kostriza, Serial No. 317,206, filed October 28, 1952, now abandoned, and the continuation-in-part of said application, Serial No. 2,321, filed January 4, 1960. The microstrip microwave transmission system employs usually two conductors, one a ground conductor and the other a line conductor spaced close together in substantially parallel relation. The so-called ground conductor which may be ground potential or some other given potential is considerably wider than the line conductor so that the surface thereof provides in effect an image reflection of the line conductor whereby the distribution of the electric and magnetic fields between the conductors is substantially the same as the distribution between one conductor and the neutral plane of a theoretically perfect, two conductor parallel system. By this system, microwaves can be easily propagated by a mode approximating the TEM mode along the line-ground conductor system since the microwaves flow in the regions of the concentrated electromagnetic field bounded substantially by the opposed surfaces of the line and ground conductors. It is clear that if an antenna array can be devised along the lines of printed transmission line technique to be utilized with a microstrip transmitter or receiver or both, that a great saving in cost and space could be obtained and portability of the equipment greatly increased.

It is therefore an object of this invention to provide a microwave antenna array such as is readily adapted for use of printed circuit techniques.

It is another object to provide a microwave antenna array that utilizes as a reflector for the antenna array the ground plane of a microstrip electronic circuit associated with the array.

A feature of this invention is an antenna array disposed in a first plane, a planar conductor in a second plane parallel to the first plane, the planar conductor serving as a reflector for the antenna array and a ground plane for an electronic circuit to which the antenna array is coupled.

A further feature is a dipole antenna array of printed circuit construction disposed on both sides of a first dielectric sheet in a first plane and a planar conductor disposed on a second dielectric sheet in a second plane parallel to the first plane. The opposite side of the second sheet has disposed thereon an electronic circuit made ac-

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cording to microstrip technique, and which is coupled to the antenna array.

The above-mentioned and other features and objects of this invention will become more apparent by reference to the following description taken in conjunction with the accompanying drawings, in which:

Fig. 1 is a plan view of the antenna array mounted on a wall of radio receiver;

Fig. 2 is a side elevation view of the embodiment of Fig. 1; and

Fig. 3 is a plan view of the radio receiver as viewed along line 3—3 of Fig. 2.

Referring now to Figs. 1 and 2, there is shown a parallel feed printed dipole antenna array 1 disposed on sides 2 and 3 of a dielectric sheet or panel 4. A typical dipole antenna 5 consists of a first section 6 on side 2, one-quarter wave length long, and a second section 7 on side 3 also one-quarter wave length long and extended directly opposite section 6. A second dipole antenna 8 with sections 9 and 10 is spaced three-quarters wave length away from and parallel to antenna 5. Sections 6 and 9 on side 2 are fed by means of connecting lead 11 and sections 7 and 10 on side 3 are connected by lead 12 shown in partial cut-away view. In the antenna array 1 there are shown 16 dipole antennas, though it is to be understood that more or less than 16 dipoles may be used depending on the bandwidth desired. Dipole antenna 13 is disposed adjacent dipole antenna 5, the center of antenna 13 being one-half wave length distant from the center of antenna 5. Antenna 13 is connected to dipole antenna 14 adjacent antenna 8 and opposite and parallel to antenna 13 by means of leads 15 on side 2 and 16 on side 3. Leads 11 and 15 on side 2 are center fed by lead 17 and leads 12 and 16 on side 3 are center fed by lead 18 directly underneath lead 17. Leads 17 and 18 are transformer sections and are made wider than leads 11, 12, 15 and 16 to match their impedance and to minimize power losses. Dipole antennas 19, 20, 21 and 22 are constructed in similar fashion. The quadruple dipole element group consisting of antennas 5, 8, 13 and 14 and the quadruple element group consisting of antennas 19, 20, 21 and 22 are center fed by lead 23 on side 2 which has transformer terminations of one-quarter wave length long for impedance matching of the feed lines to the dipole elements, and conductor strip 26 on side 3 which feeds the portions of the same dipole elements on side 3 and has like transformer terminations at its connection points. The other quadruple dipole element groups 27 and 28 embody the same construction. In group 28 only the dipole sections on side 3 are shown, the side 2 dipole sections and the dielectric plate 4 having been removed to show more clearly the side 3 construction. Conductor strip 29 on side 2 and conductor strip 30 on side 3 feed the 16 dipole antennas and have the same transformer coupling sections at the junctions of the feed lines. Conductor strip 29 and conductor strip 30 are connected to a balun 31 or balancing unit which consists of an outer conductor 32 fastened to the dielectric panel 4 by means of flange 33, a transformer section 34 disposed on the outer conductor 32 for impedance matching purposes and an inner conductor 35. The conductor strip 29 on side 2 is connected to the inner conductor 35 of the balun 31 by lead 36 and conductor strip 30 is coupled to the outer conductor 32 by lead 37, shown offset, on side 3 of the panel 4.

With reference to Figs. 2 and 3, a receiver 38 is shown disposed on both sides of a second dielectric panel 39, which lies in a plane parallel to the plane of panel 4, and at a distance from panel 4 of

$$\frac{\lambda}{4}$$

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or any odd multiple thereof as

$$\frac{3\lambda}{4}, \frac{5\lambda}{4}$$

etc. at the desired frequency. Two side plates 40 support the panel 4 parallel to the panel 39 in the position described. On the bottom side of panel 39 is a planar conductor 41 which underlies substantially the entire area of panel 39 and serves both as a ground plane for the receiver circuitry 38 and as a reflector for the antenna array 1. Side plates 40 may be made of conductive material and physically connected to ground plane 41, as by soldering, so that a continuous reflecting shield is formed by the two sides 40 and ground plane 41 to further minimize radiation losses from the antenna array 1. A high frequency microstrip section 42a of the receiver 38 is disposed on the surface of panel 39 opposite the planar conductor 41, and a low frequency section 42b is assembled on the planar conductor 41.

One of the preferred printed circuit techniques that may be employed for both the antenna array 1 and the high frequency microstrip section 42a comprises coating both sides of a dielectric strip with layers of conductive material, such as copper, printing on the conductors the desired circuitry, dipole elements and interconnecting leads, the printing process utilizing a material which protects the covered conductor parts from the action of the etching bath to which the panel is thereafter subjected. The uncovered conductor portions are etched away leaving the desired printed circuitry of the receiver and the antenna sections of the antenna array 1 with the connecting circuits and planar conducting areas. The covering material is then removed and necessary components are applied as desired.

Referring more particularly to the circuitry disclosed in Fig. 2, it will be observed that the high frequency section 42a is provided with the planar conductor 41 with respect to which line conductors printed on the dielectric sheet 39 cooperate to form high frequency transmission paths. While the planar conductor area 41 is shown to underlie the entire area of plate 39 this, of course, is not essential so long as sufficient planar conductor is provided to fully underlie the high frequency circuitry 42a and to provide an adequate reflecting surface for the antenna array 1. One advantage, however, of having the planar conductor 41 underlie all or substantially all of the high frequency section is that it provides an effective shield between the high frequency circuitry and the components of the low frequency sections 42b mounted on the planar conductor side of the panel. The planar conductor 41 also serves as a conductor for heat dissipation. The high frequency circuitry where shown comprises two strip conductors, 43 and 44. The two strips are so associated as to provide a hybrid coupling whereby incoming radio frequency signals may be mixed with the output of a local oscillator 45 for application to a crystal detector 46 from which is obtained an intermediate frequency for coupling to the low frequency section 42b. The strip 43 interconnects a junction 47 with the crystal 46, the junction 47 being a coaxial coupling for the coaxial lead 48 of the antenna array 1. The crystal 46 is coupled to the transmission path of strip 43. The strip 43 is terminated beyond the two junctions 46 and 47 by means of extended conductive areas 49 and 50, which form capacitive susceptances for impedance matching of the adjacent junctions.

The junction coupling the local oscillator 45 to the strip 44 is of the coaxial type which may be readily constructed by one skilled in the art. The oscillator 45 may be a klystron or any other suitable high frequency oscillator may be employed. A susceptance 51 is provided on an extension of the strip 44 for impedance matching of the junction to the local oscillator 45. The strip 44 is provided with a portion 52 disposed in close parallel relation to the strip 43 for a distance of approximately one-half wave length or multiple thereof to function as

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a directional coupler and in this illustration as a hybrid mixer. The other end of the strip 44 is provided with a terminal load 53.

In the operation of the circuitry of the high frequency section 42a the incoming radio frequency signals are coupled over coaxial line 48 to the transmission path formed by the line 43 and the adjacent surface of the planar conductor 41. The output of the local oscillator 45 is applied to the transmission path formed by the strip 44 and the adjacent planar surface of conductor 41. The two frequency waves are mixed in the directional coupling portion of the circuitry, the resulting waves dividing between the terminal load 53 and the crystal 46. The crystal 46 detects the waves of lower frequency for transmission to the intermediate frequency stages of the low frequency section 42b.

The planar conductor 41 is provided with an opening 54 through which a connector 55 couples the line conductor 43 to the crystal 46. The output of the crystal is coupled over conductor 56 to coupling coil 57 and from there through resistor 58 to a ground connection 59 made with the planar conductor 41. Any ground connection in the high frequency circuitry may be used as a D.-C. lead path for the crystal. An R.-F. by-pass condenser 60 is also coupled from the coil 57 to the conductor 41. For further details of crystal holders adapted to line-above-ground circuits, reference may be had to Patent No. 2,734,170 of H. F. Engelmann and J. A. Kostriza.

Coupled with the coil 57 is coil 61 which is connected in parallel, one side being connected to ground and the other to a control grid of the first stage 62 of the I.-F. section 63, as indicated by conductor 64. The I.-F. section may comprise several stages in which the vacuum tubes are supported on the panel 39 substantially as indicated by mounting bracket 65 carried by the ground conductor 41. The tube 66 is shown to be in the form of the miniature or subminiature type receivable in brackets such as indicated at 65. Larger tubes either in the I.-F. audio or power sections may be supported on panel 39 by conventional sockets. The conductor 41 may be cut away where desired in the low or intermediate frequency section without, however, diminishing the reflecting surface necessary for the antenna array 1. The output of the I.-F. section 63 is applied to the usual limiter 67 which is connected to a discriminator 68 to which is connected to a video amplifier stage 69 all of which may be carried by panel 1 or chassis walls associated therewith.

For other illustration of printed circuit microstrip receivers reference may be had to the various embodiments disclosed in the aforementioned patent application of Grieg et al. The low frequency section of the receiver may be of the printed circuit type and located on the same side of panel 41 as the high frequency section and adjacent thereto.

It is also feasible to utilize the antenna array described above with a receiver of the conventional chassis type wherein the chassis surface would serve as a reflector for the antenna array.

The antenna array described above has been reduced to practice using printed circuit technique and it has been found that the most satisfactory parameters for a frequency of 2500 megacycles indicate a length for each dipole section of one-quarter wave length, the width of the dipole section being .2 inch. The leads connecting each dipole section are .2 inch wide. The space between the dipole sections is three-quarters of a wave length. The distance between each pair of dipole elements is three-quarters of a wave length and the transformer sections at the ends of the lead conductors are one-quarter wave length long and .28 inch wide. The distance between the centers of adjacent dipole elements is one-half wave length. The thickness of the dielectric panel is preferably a fraction of a quarter wave length of the operating frequency.

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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. In combination, an antenna array disposed substantially in a first plane, a dielectric sheet, means disposing said dielectric sheet in a second plane parallel to said first plane, a planar conductor disposed on one side of said dielectric sheet whereby said planar conductor serves as a reflector for said antenna array, an electronic circuit configuration of at least one conductor disposed on said dielectric sheet in closely spaced parallel relation to said planar conductor to form therewith a waveguide path for radio frequency energy and means coupling said antenna array to said one conductor and said planar conductor for radio frequency circuit coupling for said antenna array.

2. In combination, an antenna array comprising a first sheet of dielectric material in a first plane and a plurality of antennas disposed on both sides of said sheet, a second sheet of dielectric material, means disposing said second sheet in a second plane parallel to said first plane, a planar conductor disposed on one side of said second sheet whereby said planar conductor serves as a reflector for said antenna array, an electronic circuit configuration of at least one conductor disposed on said second dielectric sheet in closely spaced parallel relation to said planar conductor to form therewith a waveguide path for radio frequency energy and means coupling said antenna array to said one conductor and said planar conductor for radio frequency circuit coupling for said antenna array.

3. In combination, an antenna array comprising a first sheet of dielectric material in a first plane and a plurality of antenna radiators disposed on both sides of said sheet, the antenna radiators on one side being disposed with respect to corresponding antenna radiators on the other side to present an array of dipole antennas, a second sheet of dielectric material, means disposing said second sheet in a second plane parallel to said first plane, a planar conductor disposed on one side of said second sheet whereby said planar conductor serves as a reflector for said antenna array, an electronic circuit configuration of at least one conductor disposed on said second dielectric sheet in closely spaced parallel relation to said planar conductor to form therewith a waveguide path for radio frequency energy, and means coupling said antenna array to said one conductor and said planar conductor for radio frequency coupling for said antenna array.

4. In combination, an antenna array of dipole antennas adapted to receive electromagnetic energy comprising a first sheet of dielectric material, a plurality of first strip-like conductors disposed on a first side of said sheet, a plurality of second strip-like conductors disposed on the second side of said sheet, each of said first conductors being in a dipole antenna relation to an adjacent one of said second conductors, and means coupling together said dipole antennas; a radio receiver comprising a second sheet of dielectric material, a planar conductor disposed on a first side of said second sheet, receiver elements disposed on said second sheet with conductor parts thereof disposed on the side of said second sheet opposite from that of said planar conductor for coaction with said planar conductor to form high frequency waveguide paths, means disposing said second sheet in parallel relation with said first sheet whereby said planar conductor serves as a reflector for said antenna array, and means coupling said antenna array to one of the high frequency waveguide paths of said radio receiver.

5. In combination, an antenna array disposed substantially in a first plane, means to support said antenna array comprising a first sheet of dielectric material coincident

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with said first plane, a receiver of radio frequency energy comprising at least a first group of radio frequency elements and a second group of other frequency elements, coupling means between said receiver and said antenna array, means to provide commonly as a reflector for said antenna array, as a support for and shield between said first and second groups and as part of a waveguide for radio frequency energy, said latter means comprising a second sheet of dielectric material having said first group disposed on a first side of said second sheet and said second group disposed on a second side thereof, a planar conductor disposed on said second side, said first group comprising at least one conductor disposed on said first side and in closely spaced parallel relationship with said planar conductor to form therewith the said waveguide, and means to maintain the planar conductor of said second sheet in a predetermined parallel spaced relationship with said first sheet to serve as the said reflector.

6. In combination, an antenna array, means supporting said array in a first plane, a radio circuit comprising at least one group of radio frequency circuit elements, means to provide commonly as a reflector for said antenna array, as a support for said group of circuit elements and as part of a waveguide for radio frequency energy, said latter means comprising a sheet of dielectric material disposed parallel to said first plane and having said group of elements disposed on one side of said sheet, a planar conductor disposed on said opposite side, said group comprising at least one conductor disposed on said one side and in closely spaced parallel relationship with said planar conductor to form therewith the said waveguide, means to maintain said planar conductor in a predetermined parallel spaced relationship with said array to serve as the said reflector, and a waveguide coupling said array to the waveguide formed by said one conductor and said planar conductor.

7. In combination, an antenna array disposed substantially in a first plane, means to support said antenna array comprising a first sheet of dielectric material coincident with said first plane, a radio circuit comprising at least a first group of radio frequency elements and a second group of other radio elements, means to provide commonly as a reflector for said antenna array, as a support for and shield between said first and second groups and as part of a waveguide for radio frequency energy, said latter means comprising a second sheet of dielectric material having said first group disposed on a first side of said second sheet and said second group disposed on a second side thereof, a planar conductor disposed on said second side, said first group comprising at least one conductor disposed on said first side and in closely spaced parallel relationship with said planar conductor to form therewith the said waveguide, means to maintain said first and second sheets in a predetermined parallel spaced relationship, whereby said planar conductor serves as the said reflector, a coaxial coupling having inner and outer conductors coupling said antenna array to the said waveguide of said radio frequency group, said inner conductor being coupled to said one conductor and said outer conductor being coupled to said planar conductor

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