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[54] **CONSTANT BEAMWIDTH ANTENNA**

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[52] **U.S. Cl.** **343/754;** 343/853; 343/909

[51] **Int. Cl.**[2] **H01Q 19/06**

[58] **Field of Search** 343/754, 909, 853

[56] **References Cited**

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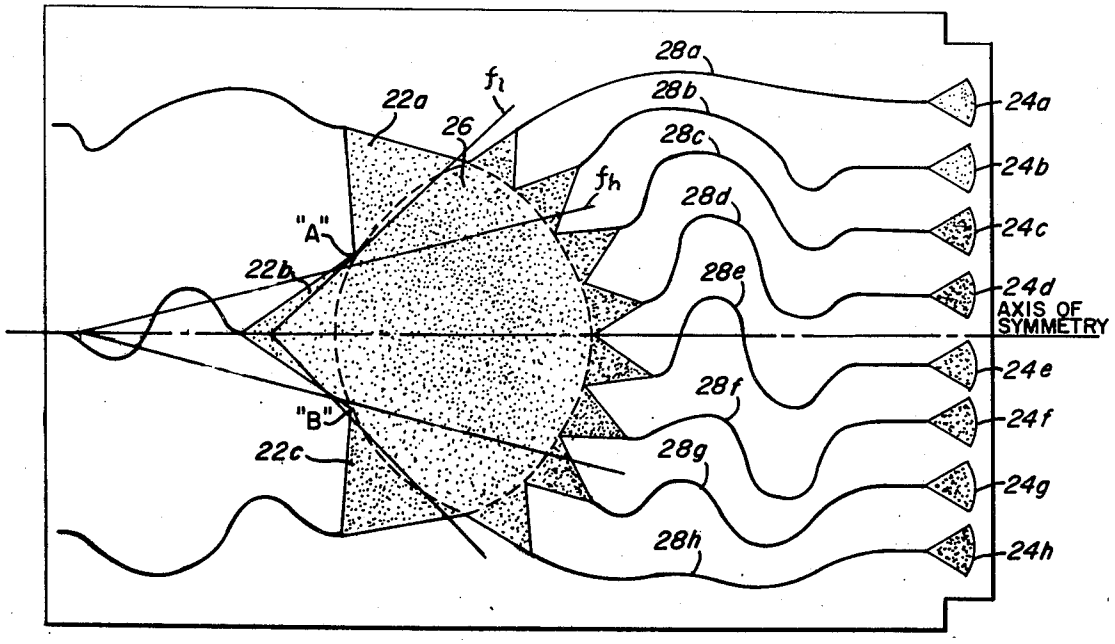
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Attorney, Agent, or Firm—Philip J. McFarland; Joseph D. Pannone; Richard M. Sharkansky

[57] **ABSTRACT**

An antenna assembly for radio frequency energy is disclosed wherein individual antenna elements making up an array are fed in an improved manner so that the width of a directive beam formed by such elements is maintained substantially constant over a wide band of operating frequencies. The feed, here in a form equivalent to a horn, is made to have frequency dependent characteristics such that the amplitude taper across the aperture defined by the array is increased as operating frequency is increased.

2 Claims, 2 Drawing Figures



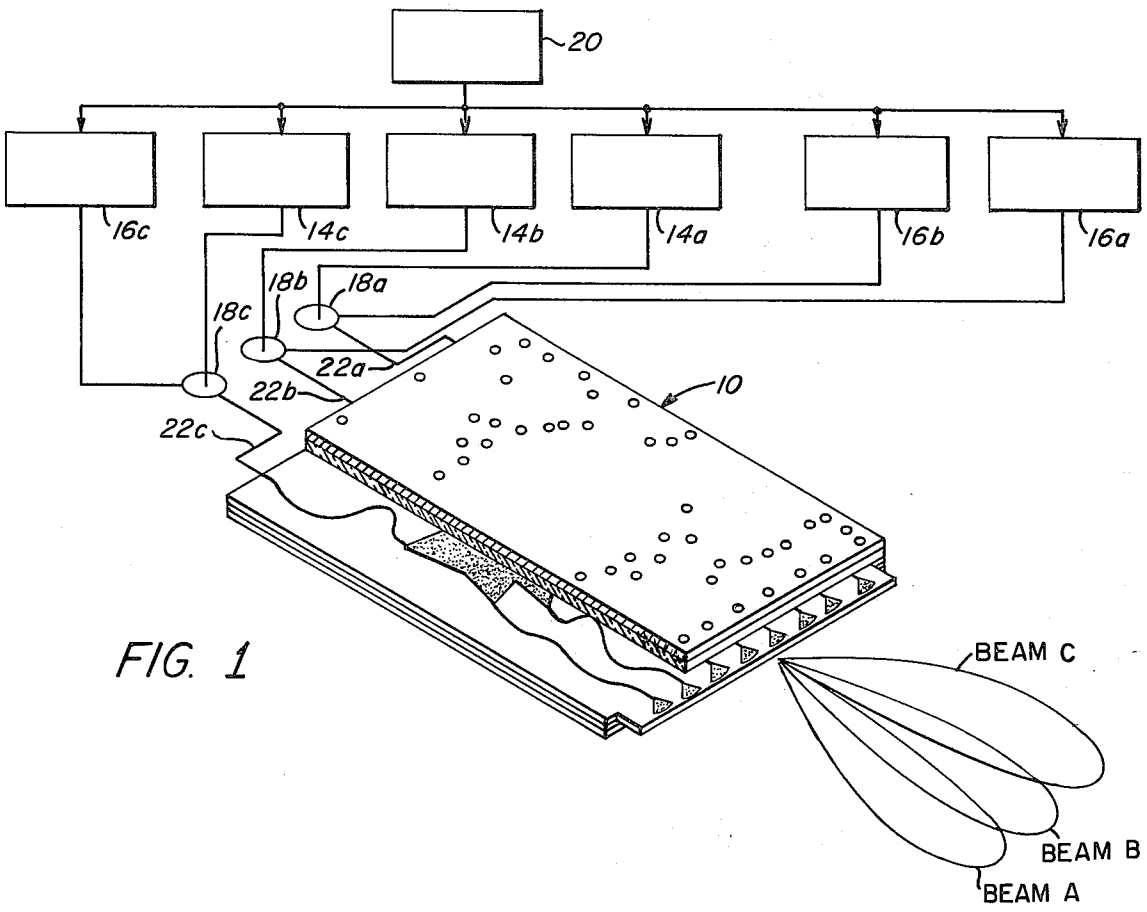
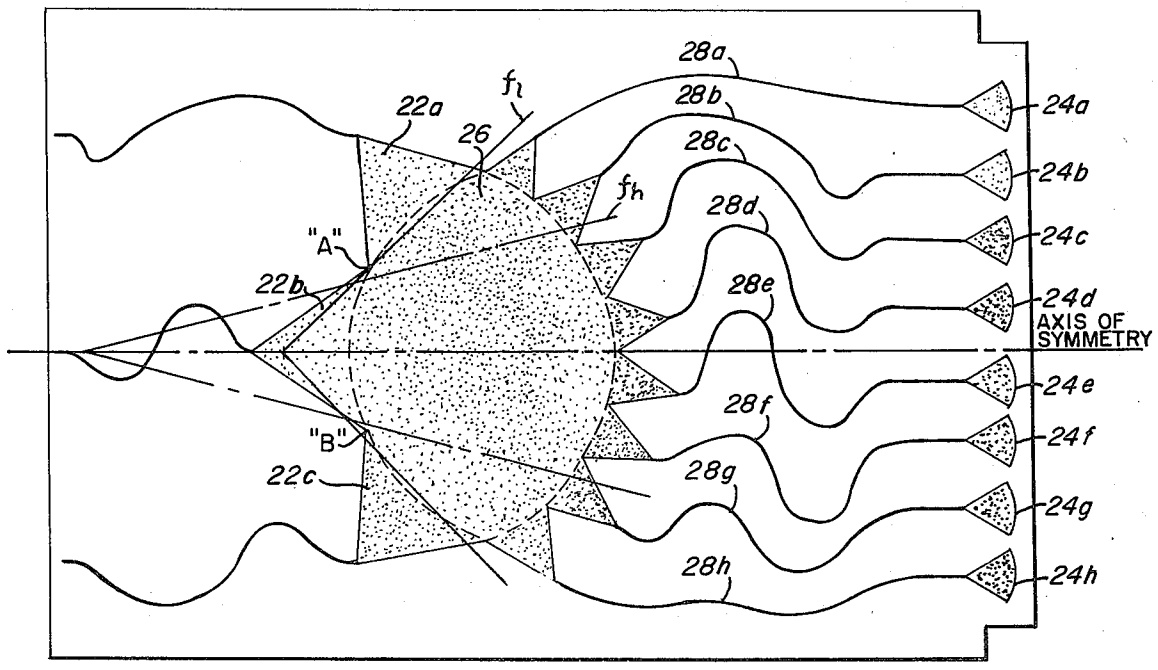

20
16c
14c
14b
14a
16b
16a
18b
18a
18c
22a
22b
22c
10
BEAM C
BEAM B
BEAM A

FIG. 1

FIG. 2


28a
f_l
22a
28b
24a
26
28c
24b
f_h
28d
24c
"A"
22b
28e
24d
AXIS OF SYMMETRY
24e
28f
"B"
24f
22c
28g
24g
28h
24h

CONSTANT BEAMWIDTH ANTENNA

BACKGROUND OF THE INVENTION

This invention pertains generally to directive antennas for radio frequency energy and particularly to wide-band directive antennas for radio frequency energy.

It is known in the art that an array of antenna elements may be fed through a parallel plate lens, i.e., a "microwave" lens, and a plurality of transmission lines in such a manner that one, or more, beams of radio frequency energy are formed. With proper design, such an assembly may be operative over a wide band of frequencies, say an octave band. Because the principle of reciprocity applies, such an antenna assembly is also adapted to receive radio frequency energy within the same frequency band from one, or more, directions.

In one known antenna assembly of the type just mentioned, a design defining a linear array of antenna elements, transmission lines, microwave lens and a plurality of feedports are formed on a common dielectric substrate using printed circuit techniques. After the so printed dielectric substrate is assembled in operative relationship with one or two ground planes (depending upon whether a microstrip or a stripline assembly is desired), constrained paths in the dielectric substrate are defined for radio frequency energy within a relatively wide frequency band. The dimensions of, and spacing between, the various parts of the printed design determine the characteristics of the completed antenna assembly. In particular, with a plurality of feedports along a focal arc, the printed design is so arranged that the electrical lengths of the paths between each feedport and the antenna elements are systematically controlled. When all of the feedports are energized, the phase shifts experienced by radio frequency energy passing from each feedport to the antenna elements are such that a plurality of simultaneously existing beams of radio frequency energy is formed, each pointing in a different direction. The same antenna assembly may be operated to form a single one of the beams by simply energizing a single one of the feedports. While such an antenna assembly is adapted to operation over a wide band of frequencies, experience has proven that the beamwidth of its radiated beam, or beams, varies inversely with frequency.

While a variation in beamwidth due to a change in operating frequency may be tolerated in many applications, cases exist where such a variation seriously affects proper performance. For example, if (when the antenna assembly is to produce a plurality of simultaneously existing beams) it is desired to maintain the power level at the crossover point between adjacent beams, any variation in beamwidth due to a change in operating frequency obviously should be avoided. Similarly, if (when the antenna assembly is to produce a single beam) it is desired to reduce clutter when a beam is pointed so as to graze an extended area, as the sea or a land mass, it is also obvious that any variation in beamwidth due to a change in operating frequency should be avoided.

SUMMARY OF THE INVENTION

Therefore, it is a primary object of this invention to provide an improved antenna assembly adapted to produce one, or more, beams of electromagnetic energy, such beam, or beams, having a beamwidth which is substantially invariant over a wide band of operating frequencies.

This object, and other objects to be discerned, are achieved by providing, in a directional antenna of the type here considered, a feedport, or a plurality of feedports, so dimensioned and positioned that the amount of radio frequency energy passed to individual antenna elements in a linear array is varied in a controlled manner as operating frequency is changed. Such a controlled variation is effective over a given band of operating frequencies to maintain the electrical size (measured in wavelength) of the aperture defined by the linear array of antenna elements at a substantially constant value.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of this invention, reference is now made to the following description of the accompanying drawings wherein:

FIG. **1** is a diagram, greatly simplified, of an antenna assembly according to this invention showing the manner in which such an assembly is related to transmitters and receivers in a system, the illustrated antenna assembly being partially broken away to show details of construction of such assembly; and

FIG. **2** is a plan view of the dielectric substrate of the antenna assembly of FIG. **1** showing the printed design of the various elements in such antenna assembly and also illustrating how the amount of radio frequency energy passing to each antenna element is controlled as operating frequency is changed.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Before referring to the drawings, it should be understood that the beam forming elements of our preferred antenna assembly are parts of a single "stripline" or "microstrip" antenna assembly. That is, a printed circuit defining constrained paths for electromagnetic energy is formed on one side of a dielectric substrate and a metallic ground is formed on the other side of such substrate (if a microstrip antenna assembly is desired), or a dielectric slab is placed over the printed circuit with a second metallic ground plane covering the exposed side of the dielectric slab (if a stripline antenna assembly is desired). For convenience, then, the various parts of the printed circuit will be referred to as though they are, in fact, complete elements. For example, the part of the printed circuit in FIG. **2** defining a plan view of a "feedport" will be referred to as the feedport itself, it being understood that electromagnetic energy actually passes through the portion of the dielectric substrate (and the dielectric slab, if used) underlying the "feedport."

Referring now to FIG. **1**, it may be seen that our contemplated antenna assembly **10** may be connected in a conventional manner to a plurality (here three) of transmitters **14***a*, **14***b*, **14***c* and a like plurality of receivers **16***a*, **16***b*, **16***c* through, respectively, transmit/receive switches **18***a*, **18***b*, **18***c*. The various transmitters and receivers are synchronized by a common system synchronizer **20** of conventional design. Each one of the transmit/receive switches **18***a*, **18***b*, **18***c* is connected to a different one of three feedports **22***a*, **22***b*, **22***c* through lines (not numbered). The feedports **22***a*, **22***b*, **22***c* will be described hereinafter; suffice it to say here that each is designed to launch radio frequency energy through constrained paths in such a manner that

the relative amount of such energy reaching each one of a plurality of antenna elements **24***a*.....**24***h* varies with operating frequency.

The feedports **22***a*, **22***b*, **22***c* are disposed along a focal arc and contiguous with a microwave lens **26** which in turn is connected, through matching sections (not numbered) to a plurality (here eight) of transmission lines **28***a* through **28***h* to define constrained paths for electromagnetic energy to each one of the antenna elements **24***a*.....**24***h*. For reasons discussed in detail in U.S. Pat. No. 3,761,936 entitled "Multi-Beam Array Antenna," issued Sept. 25, 1973, directive beams of electromagnetic energy then are formed, as shown, when all of the transmitters **14***a*, **14***b*, **14***c* are energized.

A detailed exposition of the reasons why the directive beams of electromagnetic energy from our antenna assembly **10** remain substantially constant in width as operating frequency is changed will now be made. For convenience, only the manner in which a "broadside" beam (Beam "B" in FIG. **1**) is produced will be explained in detail, it being deemed obvious that other beams are similarly produced. Referring now particularly to FIG. **2**, it will be observed that the field pattern (sometimes referred to hereinafter as the "primary illumination pattern") of electromagnetic energy from feedport **22***b*may be caused to change as operating frequency is changed. That is, the primary illumination pattern of the electromagnetic energy from feedport **22***b* may be relatively broad (as indicated by the ine marked "f_l") at the lower end of an operating frequency band and relatively narrow (as indicated by the line marked "f_h") at the upper end of such band. It follows that, at the lower end of the operating frequency band, the electromagnetic energy passing through the microwave lens **26** from the feedport **22***b* to the various transmission lines **28***a*.....**28***h* may be directed so as to be almost equally between such lines. This means that the amount of radio frequency energy passing from each of the antenna elements **24***a*.....**24***h* is the same. To put it another way, the amplitude taper across the aperture defined by antenna elements **24***a*.....**24***h* at the lower end of the operating frequency band is such that all such elements are substantially equally illuminated. At the upper end of the operating frequency band, the primary illumination pattern, f_h, is such that a relatively greater amount of radio frequency energy is passed to the centrally located ones of the antenna elements **24***a*.....**24***h* than the end ones of such elements. It is apparent then that the amplitude taper across the aperture defined by the antenna elements **24***a*.....**24***h* is, in this case, such that the elements in the center of the array are illuminated and the elements at the edge of the array are not illuminated. At any operating frequency intermediate "f_l" and "f_h", the primary illumination pattern produced by the feedport **22***b* is intermediate the illustrated patterns. That is, as the operating frequency is increased from f_l toward f_h, the amount of amplitude taper across the aperture defined by the antenna elements **24***a*.....**24***h* is correspondingly increased. As a result, the width of beam B is maintained substantially constant.

It has been found that the width of the feedport **22***b*, i.e., the distance between the points marked "A" and "B" in FIG. **2**, is of primary importance if the primary illumination pattern is to be changed in a controlled manner in accordance with a change in operating frequency. For example, in one particular design for an antenna to produce a nominal beamwidth of 20° over an operating frequency band of 7 to 17 GHz the optimum width of the feedport **22***b* was found to be 1.2 inches. Expressed in wavelengths at the upper end of the operating frequency band (17 GHz), such width is approximately equal to 1.73 wavelengths. At the lowr end of the operating frequency band (7 GHz), such width is approximately equal to 0.75 wavelengths. At the midpoint of the operating frequency band (12 GHz) such width is approximately equal to 1.0 wavelengths. The ratio of the beamwidth of the resulting beam at 7 GHz to the beamwidth of the resulting beam at 17 GHz (with feedports **22***a* and **22***c* terminated in matched loads) is 1.35 to 1. This contrasts with a beamwidth ratio of 2.43 to 1 in a conventional design for a feedport having a width of approximately 0.35 inch (one-half wavelength at 17 GHz).

It will be noted here in passing that, if desired, the resulting beam from the antenna elements **22***a*.....**22***h* need not be broadside, but may be skewed at any desired angle within broad limits by incrementing, in a known manner, the lengths of the transmission lines **28***a*.....**28***h* and changing the spacing between adjacent antenna elements to prevent grating lobes from being formed. Even though the resulting beam may be skewed, the primary illumination pattern from feedport **22***b* remains symmetric about the axis of symmetry.

It will now be obvious that, if either feedports **22***a*, **22***c* are energized (along with feedport **22***b* to produce two or three directional beams simultaneously), the primary illumination patterns from feedports **22***a*, **22***c* will not be symmetric about the axis of symmetry. The asymmetric disposition of such primary illumination patterns may permit some greater change in beamwidth, as operating frequency is changed, than is experienced in the case of a symmetric primary illumination pattern; any such greater change is, however, far less than would be experienced with feedports having a width in the order of one-half wavelength. The result, then, is that the power level at the crossover points between adjacent beams remains far more nearly constant.

Having described a preferred embodiment of our invention, it will be apparent to one of skill in the art that our inventive concepts may be applied to antenna assembies other than that illustrated. The idea that an array of antenna elements may be fed in a manner such that the amplitude taper of electromagnetic energy may (to maintain beamwidth) be a function of operating frequency is obviously applicable to antenna assembies of the type illustrated regardless of particular operating frequency band or beamwidth required. Further, the same idea may be applied to a space fed planar array antenna. It is felt, therefore, that this invention should not be restricted to its illustrated embodiment, but rather should be limited only by the spirit and scope of the appended claims.

What is claimed is:

1. In an antenna assembly for simultaneously providing a plurality of overlapping beams of electromagnetic energy, such beams being formed by interference between electromagnetic energy passed through constrained electrical paths including printed circuit lens having an irregular geometrical shape and radiated from an array of antenna elements, the electromagnetic energy in each one of the plurality of overlapping beams having any frequency within a band of frequencies, the improvement comprising:

a plurality, corresponding to the number of overlapping beams of electromagnetic energy to be radiated, of feedports for said lens, each one of such feedports being responsive to electromagnetic energy having a frequency within a desired band of frequencies, to form a like plurality of beams of electromagnetic energy within said lens and each one of such feedports having a width equal to the wavelength, at the center of the band of frequencies, of the electromagnetic energy.

2. In an antenna assembly for providing a directive beam of electromagnetic energy, such beam being formed by interference between electromagnetic energy radiated from an array of antenna elements energized, through constrained electrical paths including a printed circuit lens having an irregular geometrical shape, by electromagnetic energy from a source thereof, such source being adapted to produce electromagnetic energy at any frequency within a band of frequencies, the improvement comprising: Means coupling a source of electromagnetic energy to said lens, such means including a feedport having a width equal to the wavelength, at the center of a band of operating frequencies, of the electromagnetic energy out of such source.

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