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SUB-ARRAY HORN ASSEMBLY FOR PHASED ARRAY APPLICATION

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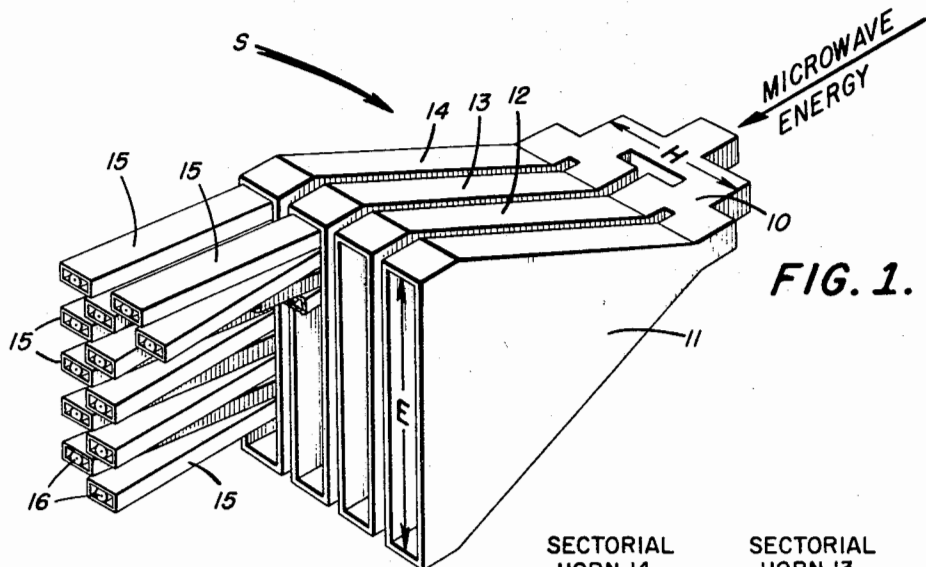


FIG. 1.

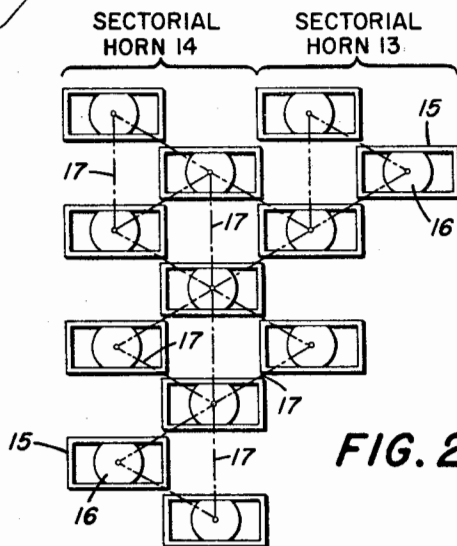


FIG. 2.

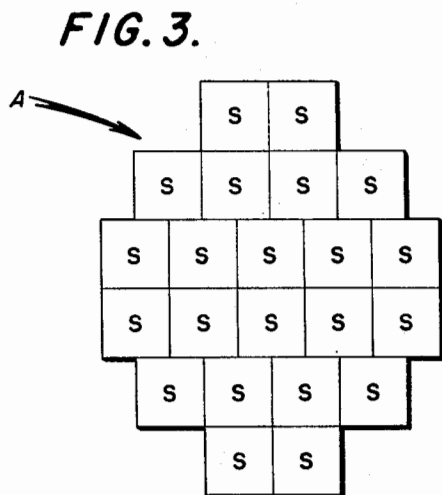


FIG. 3.

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1

3,500,422

SUB-ARRAY HORN ASSEMBLY FOR PHASED
ARRAY APPLICATION

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9 Claims

ABSTRACT OF THE DISCLOSURE

A sub-array assembly adapted for use in phase-steered antenna systems. Essentially constant power distribution is maintained throughout the sub-array for the suppression of grating lobes. The sub-array comprises a plurality of sectorial horns which are fed from a power divider assembly so as to provide equal power inputs to the horns. Each horn distributes the input energy at constant amplitude across its output mouth end for radiation by a plurality of radiating members.

The present invention generally relates to phased array antenna systems and particularly pertains to an improved sub-array assembly particularly adapted to be used as the basic building block for a planar phase-steered array antenna system capable of forming a radar beam which may be electronically scanned in azimuth and elevation.

Planar phase-steered array antenna systems capable of producing electronically scanned radar beams are receiving increasing attention for modern multi-purpose three dimensional radar systems, primarily because of the inherent ability to electronically steer the radar beam without the necessity of moving large mechanical structures. Heretofore, many of the previously proposed planar array antenna systems have been rather bulky, hard to assemble and thus are relatively expensive to build and maintain. Moreover, many of the previously proposed planar array systems have been found to be relatively inefficient.

With the above in mind, it is proposed in accordance with the present invention to provide a sub-array assembly capable of being used as the basic building block for a planar phase-steered array antenna system and constructed such that essentially constant power amplitude distribution exists throughout the sub-array structure for the suppression of grating lobes. The result is an efficient antenna system which has a simpler power dividing structure for the antenna radiating elements than was heretofore achieved, thus leading to a reduction in the weight and assembly time of the proposed sub-array and, more importantly, the weight, assembly time and cost of the over-all antenna system.

More specifically, the proposed sub-array assembly generally comprises a power divider structure which splits or divides the input microwave energy equally, in the H-plane, into a plurality of E-plane sectorial horns which are disposed adjacent one another. Each of these sectorial horns stretches the associated E-vector to obtain constant amplitude distribution of the microwave energy across the mouth of each horn, where a plurality of radiating waveguide elements are stacked. The use of the E-plane sectorial horns to provide constant amplitude distribution of the microwave energy at the radiating elements not only helps to decrease the weight and complexity of the over-all sub-array and therefore the entire array antenna system, in that it obviates the need for employing a great number of 2:1 power dividers, but, also helps to suppress the so-called grating lobes.

In order to effect the desired electronic scanning of the radar beam, each of the radiating waveguide members

2

or elements includes a phase shifter device controllable to impart distinctive phase shifts to the energy radiated by the associated radiating element. As will be described in detail hereinafter, when discussing the preferred embodiment of the present invention, this phase shifter may be of the ferrite bit type.

It is moreover proposed, in accordance with the present invention, to arrange or interlace the individual radiating elements of the proposed sub-array assembly with substantially equilateral spacing, preferably about 0.5–0.6 wavelength, in order to further aid in suppressing the development of grating lobes within the sub-array assembly. In other words, the radiating elements of each sectorial horn and of adjacent sectorial horns are arranged to form substantially equilateral triangles with one another.

In view of the above discussion, one object of the present invention is to provide an improved sub-array assembly for phased array antenna application.

Another object of the present invention is to provide an improved sub-array assembly which is relatively lightweight and is easily assembled.

A further object of the present invention is to provide an improved sub-array assembly particularly adapted to be used as the basic building block in a phased array antenna and being constructed so as to reduce the so-called grating lobes throughout both the sub-array assembly and the over-all phased array antenna.

Other objects, purposes and characteristic features of the present invention will in part be pointed out as the description of the invention progresses and in part be obvious from the accompanying drawings, wherein:

FIG. 1 is a simplified pictorial representation of one embodiment of the improved sub-array assembly proposed in accordance with the present invention;

FIG. 2 is an enlarged diagrammatic illustration of the embodiment shown in FIG. 1, showing the equilateral spacing of the sub-array radiating elements; and

FIG. 3 is a diagrammatic illustration of one manner of disposing a plurality of the proposed sub-array assemblies shown in FIG. 1, in a planar, phase-steered, array antenna system.

Referring now to FIG. 1 of the drawings and the preferred embodiment of the proposed sub-array assembly S, input microwave energy is split or divided, in the illustrated H-plane, by a power dividing wave-guide structure 10 to feed four adjacent E-plane sectorial horns 11, 12, 13 and 14. This method of power dividing gives a constant amplitude distribution across the sub-array assembly S shown in FIG. 1. In an array of sub-arrays, this constant amplitude distribution is essential in order to suppress the previously mentioned grating lobes.

Each of the sectorial horns 11 through 14 is then effective to stretch the E-vector of the input microwave energy, as shown in the drawings, so as to attain constant amplitude distribution at the mouth or enlarged end of each horn and thereby apply equal amounts of the microwave energy into a plurality of waveguide radiating members 15 which are mounted in stacked relationship within the mouth of each sectorial horn. As mentioned previously, this constant amplitude distribution of the microwave energy to the radiating elements is necessary to suppress the development of grating lobes within an array of sub-arrays. By employing the sectorial horn for this purpose, it is not necessary to have an individual power dividing structure for each radiating element and, as a result, the proposed sub-array is relatively lightweight and easier to assemble, when compared with similar assemblies heretofore attained.

More specifically, one end of each of the radiating waveguide members 15 is secured one above the other, in the mouth end of the associated sectorial horn. The

IPR2023-00796

3

radiating or extending ends of the waveguide members 15 are displaced relative to one another, in a manner best seen in FIG. 2, such that there is substantially equilateral spacing of about $0.5-0.6\lambda$ between the center lines of adjacent radiating waveguides 15; i.e., the center lines approximately form equilateral triangles 17. This geometry also aids in suppressing the development of grating lobes within the sub-array S during scanning. Although not shown in the drawings, suitable spacers may be secured in the mouth of the sectorial horn between the waveguide members 15, in order to attain the desired equilateral triangle geometry.

Only a few of the sub-array radiating members 15 are shown in FIGS. 1 and 2, for the purpose of simplifying the drawings. The exact number of radiating members mounted in each sectorial horn depends upon the requirements of practice. For example, in the presently preferred operational version of the proposed sub-array, each sectorial horn feeds twelve radiating members; making a total of forty-eight per sub-array.

Each of the radiating waveguide members 15 preferably includes a ferrite phase shifter device, shown generally at 16, adapted to impart the desired value of phase shift to the microwave energy emanating from each of the waveguide members 15, in accordance with the desired positioning, in azimuth and elevation, of the array radar beam. In practical application of the present invention, where non-reciprocal phase shifters are employed, the phase shifters preferably have a rapid switching time so as to permit rapid transition between transmit and receive modes. Furthermore, it is preferable to use a phase shifter requiring relatively low switching currents, so that it may be driven with a simple transistor circuit.

If desired, a matched dielectric lens can be placed in the mouth of each sectorial horn 11 through 14, in a manner well-known to those skilled in the art, so as to correct for inherent spherical phase front. This spherical phase front results from the fact that microwave energy must travel an increasingly longer distance, inside a sectorial horn, at increasing distances from the horn center-line.

One manner of building a planar, phase-steered, array antenna with a plurality of the proposed sub-array assemblies of the present invention is depicted in FIG. 3. More specifically, assume there are an even number (for example, twelve) of radiating waveguide elements or members 15 in each of the sectorial horns 11-14 of each sub-array S. Therefore, when the individual sub-arrays S are arranged in an array A, as shown in FIG. 3, the $0.5-0.6\lambda$ equilateral spacing between adjacent radiating elements 15 is substantially maintained throughout the entire array A in order to minimize grating lobes. Moreover, each sub-array S is constructed, as previously discussed, with the sectorial horns 11-14 which achieve constant amplitude distribution of the input microwave energy to the radiating elements, without the need for an individual power divider structure for each radiating element. Consequently, both the array and the sub-array structures are relatively lightweight and easy to assemble.

Obviously, many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. A sub-array assembly for phased array application comprising,

a plurality of juxtapositioned sectorial horn waveguide members, each having an input end and an enlarged output mouth end and adapted to provide constant amplitude distribution across said output mouth end of microwave energy applied to said input end,

a plurality of microwave radiating members disposed across the output mouth end of each sectorial horn waveguide member, and

4

a power divider waveguide having a single input adapted to be energized with microwave energy and a plurality of outputs each of which is connected to the input end of a different one of said sectorial horn waveguide members for dividing and applying said microwave energy in equal amounts to each input end of said sectorial horn waveguide members.

2. The sub-array specified in claim 1 wherein, said power divider waveguide divides said microwave energy along its H-plane into an equal amount for input to each sectorial horn waveguide member, and each of said sectorial horn waveguide members stretches its input microwave energy along the E-plane of said input microwave energy to attain constant amplitude distribution of said input microwave energy across said output mouth end thereof.

3. The sub-array assembly specified in claim 1, further including phase shifter means operable to impart desired phase shifts to the microwave energy radiated by each of said plurality of radiating members.

4. The sub-array specified in claim 1 wherein, each of said radiating members for a given sectorial horn waveguide member has a radiating end extending away from said sectorial horn, the radiating ends of said radiating members for adjacent ones of said sectorial horn waveguide members being arranged with substantially equilateral triangular spacing between the radiating ends of the radiating members for said adjacent sectorial horn waveguide members, said spacing being substantially equal to one-half of the wavelength of the microwave energy being radiated.

5. The sub-array specified in claim 1 wherein, each of said sectorial horn waveguide members has a rectangular cross-section, and said plurality of microwave radiating members comprises a plurality of stacked radiating waveguide members each having one end thereof mounted within the output mouth end of said sectorial horn waveguide member and the opposite end thereof extending away from said sectorial horn waveguide member, the extending end of alternate ones of said stacked plurality of radiating waveguide members being displaced relative to the remaining ones of said plurality of radiating waveguide members to attain equilateral triangular spacing between the extending ends of said radiating waveguide members.

6. The sub-array specified in claim 5 wherein each of said radiating waveguide members contains a phase shifting means operable to impart desired phase shifts to the microwave energy radiated thereby.

7. The sub-array assembly as specified in claim 4 wherein,

the radiating ends of the radiating members of adjacent ones of said sectorial horn waveguide members are arranged relative to one another with substantially equilateral triangular spacing between adjacent ones of said radiating ends throughout said sub-array, the spacing between adjacent radiating ends being substantially 0.5λ , where λ is the wavelength of the microwave energy being radiated.

8. An array of sub-arrays, each of which is as specified in claim 7, and further including,

phase shifting means adapted to impart predetermined phase shifts to the microwave energy radiated by each radiating member in said array of sub-arrays, whereby said array of sub-arrays is capable of radiating a microwave beam whose position is controllable in azimuth and elevation.

9. An array of sub-arrays as specified in claim 8 wherein the radiating ends of the radiating members included in said array of sub-arrays are arranged relative to one another such that substantially equilateral triangular spacing of substantially 0.5λ exists between adjacent radiating ends

5

throughout said array, where λ is the wavelength of the microwave energy being radiated.

6

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