Feb. 10, 1953 N. E. LINDENBLAD 2,628,311

MULTIPLE SLOT ANTENNA

Filed Nov. 4, 1948 2 SHEETS—SHEET 1

Fig. 1.

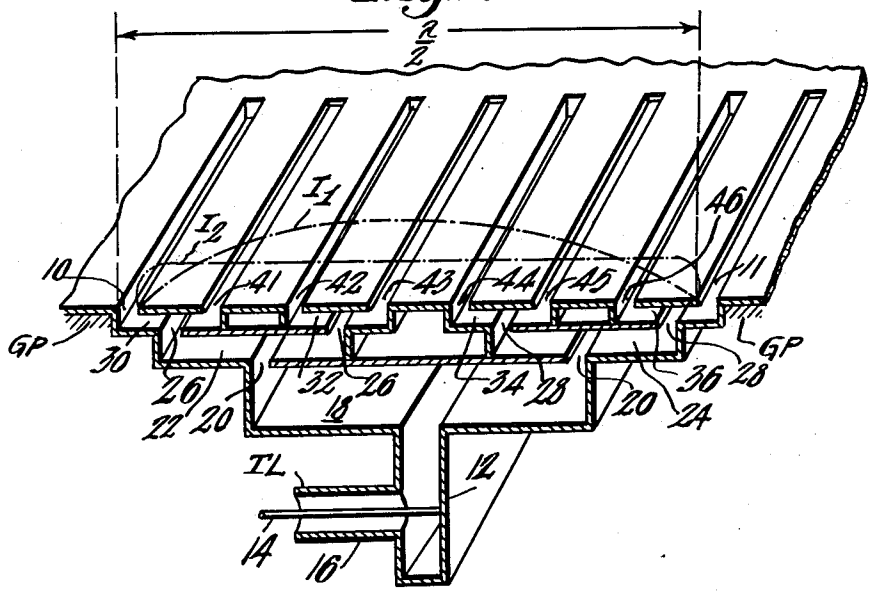
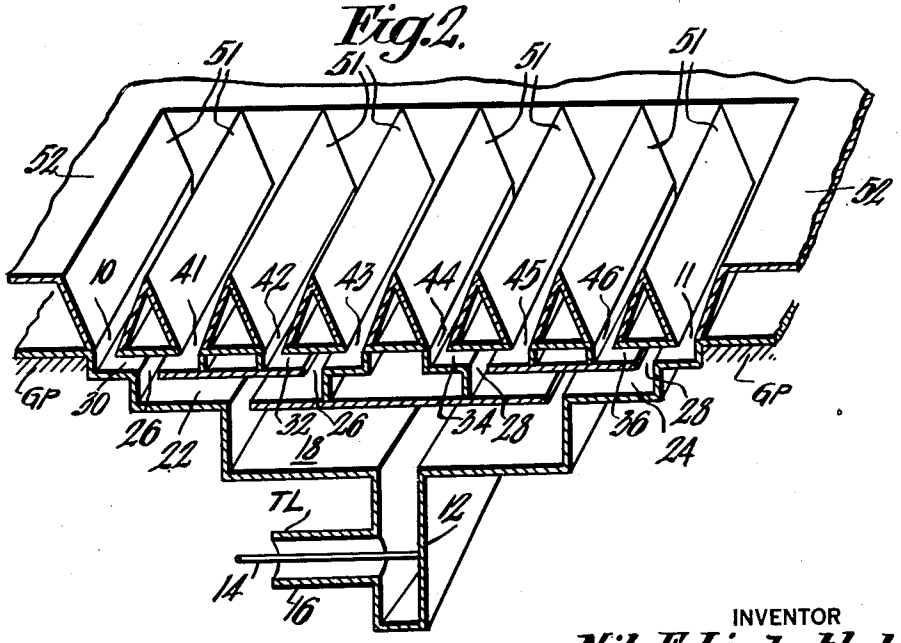


Fig. 2.



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Fig. 3.

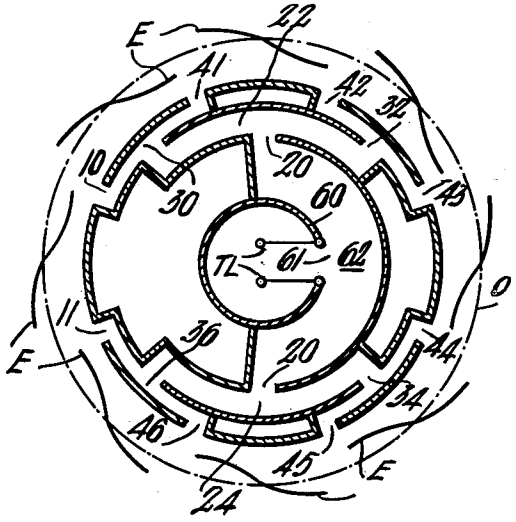
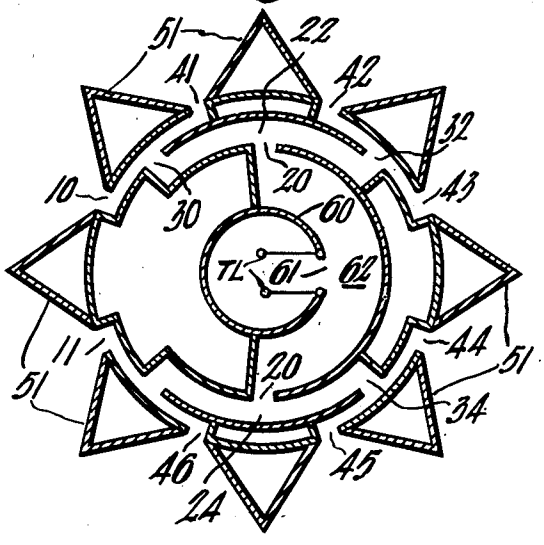


Fig. 4.



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MULTIPLE SLOT ANTENNA

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15 Claims. (Cl. 250—33.63)

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The present invention relates to antenna systems and more particularly to antenna systems which utilize slots arranged in a conductive sheet as radiating elements.

An object of the present invention is to provide a multiple slot antenna system in which distribution effects are avoided.

Another object of the present invention is the provision of a balanced wave guide branch feed system for a multiple slot antenna.

A further object of the present invention is the provision of a multiple slot antenna in which variations in antenna characteristics with respect to frequency are reduced.

A further object of the present invention is the provision of a wide band slot antenna system.

The foregoing objects and others which may appear from the following detailed description are attained by providing a feed system for a multiple slot antenna in which several branches of the feed system include symmetrically arranged sections of wave guides. The multiple branching waveguides feed individual slots arranged along a conductive sheet in such a way that the resultant radiating current over the surface of the radiating portion of the conductive sheet is substantially uniform. Thus the gain reducing distribution phenomena affecting the radiation pattern of the antenna are avoided.

The present invention should be clearly distinguished as to its intention from a branched feeder arrangement used to connect individual antennas to a multiple unit array. In the present invention, the "elements" are so closely joined both in their interior and in their external connection that they form a unit energized by a branching feeder system.

The present invention will be more fully understood by reference to the following detailed description which is accompanied by a drawing in which:

Figure 1 illustrates in transverse section an embodiment of the present invention.

Figure 2 illustrates a modified form of the structure shown in Figure 1.

Figure 3 illustrates in sectional plan view a further modification of the present invention, particularly adapted for broadcast use, and

Figure 4 illustrates a further modification of Figure 3.

Referring now to Figure 1, there is shown a conductive ground plane GP which has an intermediate portion separated from the remainder of the plane by a pair of limiting slots 10, 11. Thus, the portion of the ground plane between

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slots 10, 11 acts as a single antenna. The slots may have a length of the order of a half of the operating wavelength. The antenna is energized from a suitable source of radio frequency power (not shown) through a transmission line TL. The transmission line in this modification includes an inner conductor 14 concentrically arranged within a tubular outer shell 16. The transmission line is coupled to a resonant chamber 12 by having an inner conductor 14 passing through the chamber 12. The outer tubular conductor 16 is connected to the outer casing of chamber 12. The feed impedance of chamber 12 may be adjusted to the characteristic impedance of transmission line TL by properly adjusting the height of the point of connection of conductor 14 from the bottom of the chamber 12. Chamber 12 communicates with a larger chamber 18 which is provided, at its two opposite ends, with feeding slots 20 in communication with further chambers 22 and 24. Chamber 22 is provided with a pair of slots 26, one of which is in communication with chamber 30 and the other with chamber 32. Similarly chamber 24 has a pair of feed slots 28 in communication with further chambers 34 and 36. The energy arriving at chamber 30 is fed to the exterior of the antenna for radiation through slots 10 and 41, that in chamber 32 is fed out through slots 42 and 43, that in chamber 34 through slots 44 and 45 and that in chamber 36 through slot 46 and slot 11. Due to the sub-division of the feed to the antenna through slots 10, 41, 42, 43, 44, 45, 46 and 11, the resultant current distribution over the outer face of the antenna is substantially uniform and may be represented approximately by the dotted line I_2. It will be noted that between the two slots 10, 11 the current is substantially uniform over the entire surface of the radiator in contrast to the current distribution indicated by curve I_1, which is that obtained by previously known radiating systems of the current sheet type. The distance between any pair of adjacent slots on the radiating surface being extremely small in terms of the operating wavelength, the characteristic current distribution and the resultant radiation pattern is not greatly effected by a comparatively great change in frequency. Thus, the present antenna is capable of efficient operation over a wide band of frequencies and there is subtantially no variation in the antenna feed characteristics with a change in frequency.

The modification of the present invention shown in Figure 2 differs from that in Figure 1 only in the portion of the antenna above the

ground plane GP. Therefore, the feed arrangement will not be described again. However, between each pair of adjacent slots, such as between 10 and 41, there is provided a triangular wedge arrangement 51. Thus, the slot apertures 10 and 41 to 46 gradually expand into the full width of the radiating area. The operating band width for a given amount of mismatch is thereby increased. The wedges 51, while shown as being constructed of a conductive material, may if desired equally well be constructed of an insulating material. All that is required is that the dielectric constant of the insulating material need be high enough that a boundary is formed between the dielectric constant of the space within the expanding slot and within the wedges 51. At each end of the antenna arrangement are provided filler pieces 52, tapered on one edge to correspond to the edges of wedges 51. The remote edges of filler pieces 52 may be smoothly tapered down to the level of the upper surface of ground plane GP if desired.

The modification of the present invention shown in Figure 3 is particularly adapted for broadcast operation. It may be considered to be the antenna of Figure 1 bent around a scale axis to form the outer surface of a cylinder. Therefore, the radiating slots and the feed chambers for the slots are given the same reference numerals as in the case of Figure 1. In this modification I have indicated by means of the dotted circle O and the curves E intersecting the dotted circle O the approximate voltage distribution around the cylinder. A broadcast antenna thus constructed is not critical in its dimensioning with respect to the operating wavelength. Within reasonable limits no matter what operating frequency is applied to the antenna a substantially uniform radiation pattern in the horizontal plane is obtained. In order to energize the antenna of Figure 3 from a balanced two-wire transmission line instead of from the coaxial transmission line as was the case in Figures 1 and 2, a somewhat different coupling means between the transmission line and the branching waveguide arrangement is shown. Here the balanced two-wire transmission line TL passes up through the center of the antenna within a slotted cylinder 60. At some convenient point near the midpoint of the length of the cylinder the transmission line is coupled across the edges of slot 61. Preferably cylinder 60 is concentrically arranged about the axis of symmetry of transmission line TL. Thus energy on transmission line TL is coupled through slot 61 into an outer resonant chamber 62 corresponding to chamber 18 of Figure 1. From there on the arrangement of coupling slots and branching chambers is the same as shown in Figure 1.

Figure 4 is a modification of Figure 3, bearing the same relationship to Figure 3 as Figure 2 bears to Figure 1. That is, between adjacent slots on the outside surface of the cylinder radiator, there is provided a plurality of triangular wedges 51 to gradually taper the feed slots to free space. Thus an improved matching is obtained between the surrounding space and the interior branching cavities of the antenna and a wide band operation is obtained.

While the invention has been described in terms of express embodiments, it is understood that various modifications will be suggested to those skilled in the art without departing from the spirit and scope of the invention.

I claim:

1. An antenna structure including a conductive sheet having a plurality of radiation slots therein and means to apply radio frequency energy to said slots in common phase relationship, said slots being spaced apart by a distance small with respect to the operating wavelength, said means comprising a resonant chamber having a plurality of feeding slots therein, further chambers coupled to said resonant chamber by means of one of said feeding slots and having a plurality of further feeding slots therein, and loading chambers coupled to said further chambers by means of one of said further feeding slots and coupled to said conductive sheet to apply said radio frequency energy to a portion of said slots whereby the resultant current distribution over the outer surface of said antenna structure is substantially uniform.

2. An antenna system comprising a conductive ground plane sheet having a plurality of radiation slots therein, waveguide members intercoupling pairs of slots of said plurality of radiation slots, waveguide elements intercoupling pairs of said waveguide members, a waveguide chamber coupled to said waveguide elements, and means to produce a radio frequency wave in said waveguide chamber, the path lengths of said waveguide elements and said waveguide members being substantially equal, thereby to convey the energy of said wave in the same phase to said plurality of radiation slots.

3. An antenna structure comprising a conductive sheet having a plurality of radiation slots therein, conductive members arranged on one side of said conductive sheet to form chambers communicating with pairs of said radiation slots, conductor members arranged beyond said conductive members to form a further chamber communicating with the first said chambers, and a hollow conducting member communicating with said further chamber and adapted to receive radio frequency waves for transmission to said radiation slots, the paths of said waves from said hollow conducting member to adjacent radiation slots being substantially equal.

4. An antenna system comprising an integral structure including a conductive sheet having a plurality of radiation slots therein, conductive wall members arranged on one side of said sheet to form a plurality of waveguide sections intercoupling pairs of said radiation slots to a common chamber adapted to receive radio frequency energy and transmit the same to said waveguide section, the path lengths of said sections being substantially equal whereby said energy is applied in the same phase relationship to all of said plurality of radiation slots, there being common wall portions between said waveguide sections formed by said conducting wall members.

5. An antenna structure including a conductive sheet arranged to form a cylindrical surface having a plurality of radiation slots therein and means to apply radio frequency energy to said slots in common phase relationship, said slots being spaced apart by a distance small with respect to the operating wavelength, said means comprising a resonant chamber having a plurality of feeding slots therein, further chambers coupled to said resonant chamber by means of one of said feeding slots and having a plurality of further feeding slots therein, and loading chambers coupled to said further chambers by means of one of said further feeding slots and coupled to said conductive sheet to apply said radio frequency energy to a portion of said slots,

the paths of said waves from said resonant chamber to said slots being equal whereby the resultant current distribution over the outer surface of said antenna structure is substantially uniform.

6. An antenna structure comprising a conductive sheet arranged to form a cylindrical surface having a plurality of radiation slots therein arranged longitudinally of the axis thereof, conductive members arranged on the inner side of said surface to form chambers communicating with pairs of said radiation slots, conductor members arranged beyond said conductive members to form a further chamber communicating with the first said chambers, and a hollow conducting member communicating with said further chamber and adapted to receive radio frequency waves for transmission to said radiation slots, the paths of said waves from said hollow conducting member to adjacent radiation slots being substantially equal.

7. An antenna system comprising an integral structure including a conductive cylindrical member having a plurality of radiation slots therein arranged longitudinally of the axis thereof, conductive wall members arranged on the inner side of said member to form waveguide sections coupling pairs of said radiation slots to a common chamber adapted to receive radio frequency energy and transmit the same to said waveguide section, the path lengths of said sections being substantially equal whereby said energy is applied in the same phase relationship to said plurality of radiation slots, there being common wall portions between said waveguide sections formed by said conducting wall members.

8. An antenna structure including a conductive sheet having a plurality of radiation slots therein, said radiation slots being spaced apart at a distance small with respect to the operating wavelength, wedge-shaped members arranged between said slots to gradually expand the same into the full width of the radiating area defined by the outermost extremities of said plurality of slots and means to apply radio frequency energy to said slots in common phase relationship, said means comprising a resonant chamber having a plurality of feeding slots therein, further chambers coupled to said resonant chamber by means of one of said feeding slots and having a plurality of further feeding slots therein, and loading chambers coupled to said further chambers by means of one of said further feeding slots and coupled to said conductive sheet to apply said radio frequency energy to a portion of said slots whereby the resultant current distribution over the outer surface of said antenna structure is substantially uniform.

9. An antenna system comprising a conductive ground piane sheet having a plurality of radiation slots therein, waveguide members coupled to pairs of slots of said plurality of radiation slots, waveguide elements coupling pairs of said waveguide members, a waveguide chamber coupled to said waveguide elements, and means to produce a radio frequency wave in said waveguide chamber, the path lengths of said waveguide elements and said waveguide members being substantially equal, thereby to convey the energy of said wave in the same phase to adjacent ones of said plurality of radiation slots, said slots being expanded in the direction of radiation from said antenna system thereby to increase the band width thereof.

10. An antenna structure comprising a conductive sheet having a plurality of radiation slots therein, wedge-shaped conductors arranged between said slots to present the same gradually to the full width of the radiating area defined by the outermost extremities of said plurality of slots, conductive members arranged on one side of said conductive sheet to form chambers communicating with pairs of said radiation slots, conductor members arranged beyond said conductive members to form a further chamber communicating with the first said chambers, and a hollow conducting member communicating with said further chamber and adapted to receive radio frequency waves for transmission to said radiation slots, the paths of said waves from said hollow conducting member to adjacent radiation slots being substantially equal.

11. An antenna structure including a conductive sheet having a plurality of radiation slots therein and means to apply radio frequency energy to said slots in common phase relationship, said slots being spaced apart by a distance small with respect to the operating wavelength, said means comprising a coaxial transmission line, a resonant chamber having the conductors of said transmission line terminating on opposing walls thereof, further chambers each coupled to said resonant chamber by means of a feed slot and having a plurality of further feeding slots therein, and loading chambers coupled to said further chambers by means of one of said further feeding slots and coupled to said conductive sheet to apply said radio frequency energy to a portion of said slots, the path lengths over which said radio frequency is applied to said slots being equal whereby the resultant current distribution over the outer surface of said antenna structure is substantially uniform.

12. An antenna system comprising a conductive ground plane sheet having a plurality of radiation slots therein, waveguide members coupled to pairs of slots of said plurality of radiation slots, waveguide elements coupling pairs of said waveguide members, a waveguide chamber coupled to said waveguide elements, and a coaxial cable having the conductors thereof terminated in opposing walls of said chamber, the path lengths of said waveguide elements and said waveguide members being substantially equal, thereby to introduce radio frequency waves in said waveguide chamber to convey the energy of said waves in the same phase to said plurality of radiation slots.

13. An antenna structure including a hollow conductive cylinder having a radiation slot therein, means to apply radio frequency energy to said slot, a resonant chamber surrounding said cylinder and having a plurality of feeding slots therein, further chambers coupled to said resonant chamber by means of one of said feeding slots and having a plurality of further feeding slots therein, and loading chambers coupled to said further chambers by means of one of said further feeding slots, and a further conductive cylinder having a plurality of radiation slots therein, said radiation slots being spaced apart at a distance small with respect to the operating wavelength, said further conductive cylinder surrounding all of said first named chambers and having pairs of said radiation slots coupled to said further chambers to apply said radio frequency energy to said radiation slots, the path lengths from the radiation slot of the first said cylinder to said radiation slots being substantially equal where-

by the resultant current distribution over the outer surface of said antenna structure is substantially uniform.

14. An antenna structure including a hollow conductive cylinder having a radiation slot therein, a transmission line located within said cylinder to apply radio frequency energy to said slot, a resonant chamber surrounding said cylinder and having a plurality of feeding slots therein, further chambers coupled to said resonant chamber by means of one of said feeding slots and having a plurality of further feeding slots therein, and loading chambers coupled to said further chambers by means of one of said further feeding slots, and a further conductive cylinder having a plurality of radiation slots therein, said radiation slots being spaced apart at a distance small with respect to the operating wavelength, triangular conductive members interposed between said slots to present the same gradually ambient space about said antenna structure, said further conductive cylinder surrounding all of said first named chambers and having pairs of said radiation slots coupled to said further chambers to apply said radio frequency energy to said radiation slots, the path lengths from the radiation slot of the first said cylinder to said radiation slots being substantially equal whereby the resultant current distribution over the outer surface of said antenna structure is substantially uniform.

15. An antenna structure including a conductive surface element having a plurality of radiation slots therein, a plurality of chambers arranged on one side of said element intercoupling said slots in pairs, each of said chambers having a feeding slot therein equidistantly located from the individual slots of the pair of radiation slots intercoupled by said chamber, a further chamber arranged beyond said chamber to intercouple a pair of said feeding slots, said further chamber having a further feeding slot therein equidistantly located from the individual feeding slots of the first said chambers, and another chamber beyond said further chamber and adapted to receive radio frequency energy to transmit the same to said radiation slots by way of said further and first said chambers.

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