July 10, 1956 G. J. E. GOUBAU 2,754,513

ANTENNA

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Fig.1.

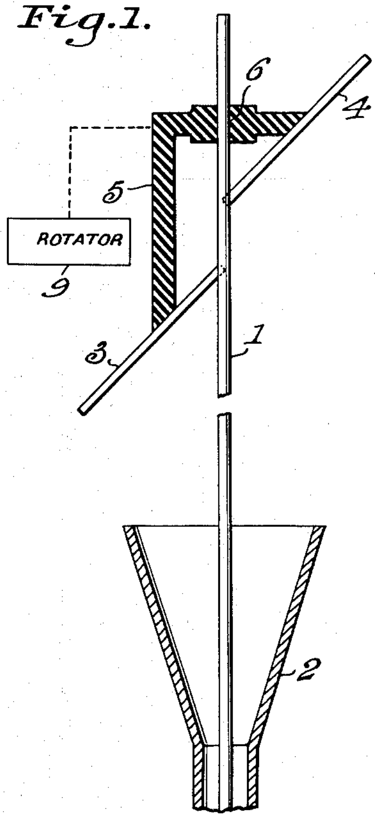
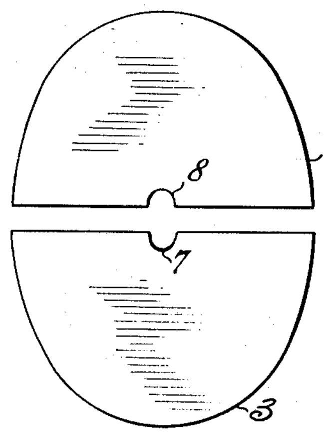


Fig.2.



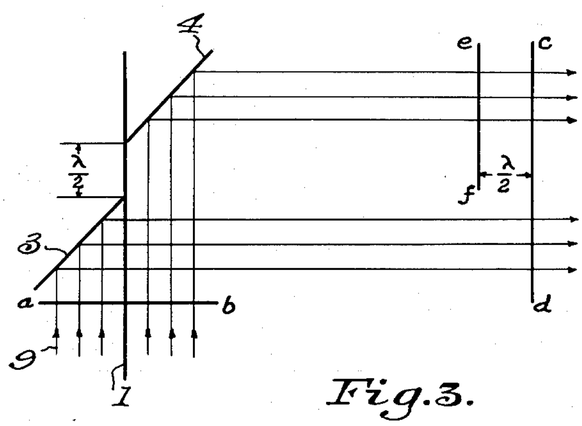


Fig.3.

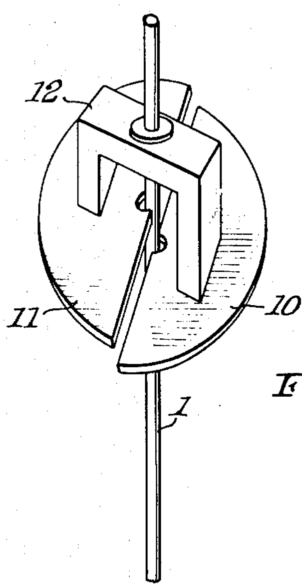


Fig.4.

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Fig. 5.

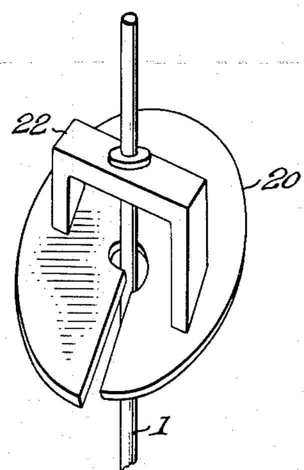
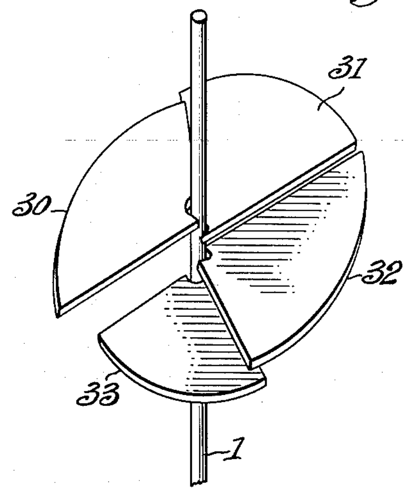


Fig. 7.



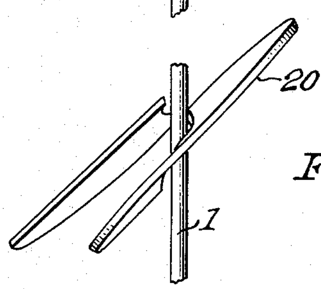


Fig. 6.

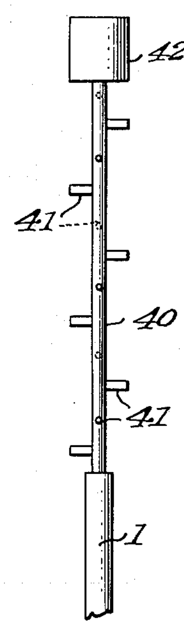


Fig. 9.

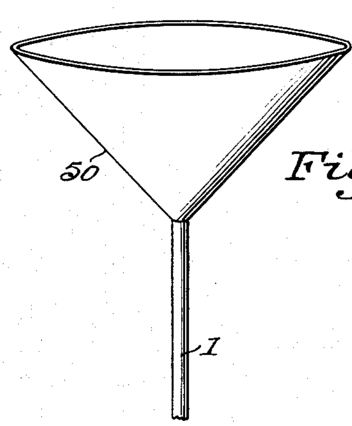


Fig. 8.

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Application December 4, 1951, Serial No. 259,875

9 Claims. (Cl. 343—761)

(Granted under Title 35, U. S. Code (1952), sec. 266)

This invention may be manufactured and used by or for the Government for governmental purposes without the payment to me of any royalty thereon.

This invention relates to antennas for use with surface wave transmission lines.

The surface wave transmission line, which is fully described in my patent application, Ser. No. 151,025, filed March 21, 1950, now Patent 2,685,068, issued July 27, 1954, has a broad field of utility in the transmission of radio energy. The present invention relates to antennas for transforming electromagnetic surface wave energy to polarized wave energy for space radiation. These antennas, which are utilized at the microwave frequencies encountered in surface wave transmission line applications, are designed to radiate electromagnetic energy in space at an angle to the transmission line. Several modifications provide a beam of energy narrow in azimuth while other modifications provide omni-directional radiation in a narrow vertical sector. The first mentioned antennas may be rotated for use in scanning with the narrow beam of energy. The use of a surface wave transmission line as the antenna mast obviates the need of a separate antenna feed system.

It is therefore an object of this invention to provide antennas for transmitting and receiving electromagnetic wave energy for use with surface wave transmission lines.

It is another object of this invention to provide a highly directive reflector type antenna for use with a surface wave transmission line.

It is a further object of this invention to provide a directive antenna for a surface wave transmission line wherein different surfaces of the antenna are axially spaced one half wave length along a surface wave transmission line.

It is yet a further object of this invention to provide an antenna for a surface wave transmission line that transforms electromagnetic wave energy in a non-radiating mode to electromagnetic energy in a radiating mode.

It is still another object of this invention to provide an antenna system that generates a scanning beam of electromagnetic energy.

It is yet another object of this invention to provide an antenna for use with a surface wave transmission line that utilizes spaced stubs to terminate the line.

These and further objects of this invention will be more fully understood when the following description is read in connection with the accompanying drawing in which:

Figure 1 illustrates one form of the invention in a partially sectioned elevation;

Figure 2 shows the antenna reflector plates of Figure 1;

Figure 3 is a diagrammatic sketch for use in the explanation of the operation of the invention;

Figures 4 through 8 are modifications of the invention shown in perspective; and

Figure 9 is a further modification of the invention in elevation.

In general terms, this invention comprises placing an antenna on a surface wave transmission line so that the energy that is being propagated along the line will be radiated at an angle to the line. This is accomplished either by reflection or by the use of radiating stubs spaced axially and horizontally along the transmission line.

Examining Figures 1 and 2 in detail, a surface wave transmission line **1** is shown connected to a suitable launching device **2**, in this instance shown as a horn. Means for launching the electromagnetic energy upon line **1** are described in detail in my above referred to patent. The energy propagated by the line, which will be referred to herein as surface wave electromagnetic energy, is wave energy in a non-radiating mode as is fully explained in my above referred to application. Located on line **1** and preferably terminating the line is a directional antenna preferably formed by semi-elliptical plates **3** and **4**. Such plates are metal for optimum antenna efficiency although other materials including dielectric material may be utilized if a lower antenna efficiency is desired. For example, if a dielectric material is used and the plates positioned on a line, a portion of the wave energy will be reflected and a portion will continue along the line. It can be seen that this type of operation makes possible any desired radiation pattern by selectively positioning several reflecting antennas along the line at various angles to the line.

Plates **3** and **4** are positioned by a supporting member **5** shown in Figure 1 constructed of insulating material. However, the support **5** may be metallic in nature, if desired, for additional strength. It is obvious that member **5** could be formed in a variety of ways, the showing being illustrative only. Support **5** has a bearing surface **6** so that it may be rotated, with the line as the axis of rotation, by a rotator **9**. Plates **3** and **4** are arranged at an angle with the line, here shown as 45 degrees, and axially spaced along the line. It is to be understood that the invention is not limited to any specific angle of the plates with the line, 45 degrees being illustrative only. The amount of spacing is determined by the wave length of the electromagnetic waves, being in all cases, for optimum operation, one-half the wave length of the propagated energy. However, it is to be understood that some deviation from the specified one-half wave length spacing may be made without rendering the system inoperative.

The plates **3** and **4** do not contact the line but are separated therefrom due to cut out portions **7** and **8** shown in Figure 2. The size of plates **3** and **4** is determined by the radius of the field about line **1**, which is dependent upon the wave length being utilized and the surface conditions of the line. For optimum operation of the antenna system, the reflecting plates **3** and **4** should be approximately the same size as the field of the surface waves propagated along line **1** to provide proper illumination of plates **3** and **4** by the electromagnetic field.

The plates are preferably semi-elliptical since the projection of these plates normal to the lines will be a circle. Such a configuration provides a narrow conical beam of energy which is desirable. For example, with one experimental antenna a beam of wave energy of 2 degrees width, as normally defined, was obtained. It is of course obvious that various shaped plates may be used to provide beams that have different characteristics, and if the plates are at angles other than 45 degrees to the line, their shape will have to be altered accordingly.

The operation of the system will be explained with particular reference being made to Figure 3. Surface wave electromagnetic energy that is traveling along line **1** is indicated by lines **9** with arrow heads showing the direction of energy propagation. This wave energy will encounter reflecting plates **3** and **4** and be radiated therefrom in the direction indicated. The electric field of the surface wave energy can be though of as a number of radial E lines about line **1**. It can be seen that if plates **3** and **4** were not axially spaced, the wave energy reflected therefrom would not be properly polarized since the wave energy E line components from plate 3 that are in the plane of the paper would be 180 degrees out of phase with similar E lines of the energy reflected from plate **4.** Therefore, the two antenna plates are spaced one-half wave length to provide a suitable phase shift. By following the path of wave energy from line *a—b,* the principle of operation will be clear.

The wave energy *a—b,* upon travelling to plate **3,** will be reflected and after a certain period of time arrive at line *c—d.* This same wave energy on the opposite side of the line will, during the the same period, be reflected from plate 4 and travel to line *e—f,* one half wave length from line *c—d.* At this instant, the E line components, in the plane of the paper, of the wave energy at line *c—d* will be 180 degrees out of phase with similar E lines at *e—f.* However, it is well known that in one half wave length of travel, the electric field reverses phase 180 degrees. Therefore, when the wave energy from *e—f* travels to *c—d,* the E lines will be 180 degrees reversed in phase and consequently in phase with the E lines of energy reflected from plate **3.** It is easily seen that the components of the E lines that are perpendicular to the plane of the drawing will cancel. Thus, vertically polarized electromagnetic wave energy will be propagated by this antenna arrangement.

Stated more simply, the half wave length spacing between the antenna plates is for the purpose of providing electromagnetic wave energy, reflected from plates **3** and 4, having cophasal electric fields.

This embodiment and the below described embodiments of the invention may be utilized for receiving as well as transmitting antennas. Thus, electromagnetic wave energy from space that impinges upon an antenna in accordance with the invention will be transformed to surface wave energy for the same reasons the reverse action is true. In other words, the transforation phenomenon discussed above is reversible.

Fig. 4 is a modification of Fig. 1 and operates in substantially the same manner except that the polarization of the propagated wave energy is 90 degrees rotated from the polarization of the energy radiated by the antenna of Fig. 1. This is due to the different orientation of the antenna reflecting plates. The antenna of Fig. 4 consists of plates **10** and **11** positioned at an angle of 45 degrees with line **1** and axially displaced along the line one half wave length. These plates are preferably positioned by a support **12** which is free to rotate about the line in the same manner as described in connection with Fig. 1. It is of course obvious that various other types of supports could be utilized, the specific embodiment being illustrative only.

Figs. 5 and 6 illustrate another modification of the invention. In this modification, in place of the two reflector plates previously described, a single helical plate **20** is utilized. This plate is preferably at an angle of 45 degrees with the line and is positioned by a support **22,** which is free to rotate. The extremities of the plate are spaced one quarter wave length axially on the line for the purpose more fully set forth in connection with Fig. 1. If the analysis of Fig. 1 is applied to this modification, it will be seen that a circularly polarized wave will be radiated by the antenna. The plate **20** is preferably shaped substantially elliptically, so that the projection of the plates normal to the line **1** will be a circle. Such a configuration will provide a sharp conical beam which is desirable.

Fig. 7 shows another modification of the invention. Plates **30, 31, 32** and **33** are placed at an angle of preferably 45 degrees with line **1.** Plates **30** and **33** are spaced three quarters wave lengths apart, plates **31** and **32** being spaced at equal intermediate points along the line between them. The supports for these plates have been omitted for purposes of clarity but many take the form of the supports illustrated in Figs. 1, 4 or 5. Again the general shape of the reflector plates is preferably elliptical so that the projection of the plates will be a circle. If the analysis of Fig. 1 is applied to this modification, it will be seen that this configuration will radiate circularly polarized wave energy.

It is to be noted that the lower reflecting surfaces in Figs. 4, 5, 6 and 7 are of a different configuration than the upper surfaces. This difference is due to the half wave spacing between the reflecting plates which makes necessary the use of dissimilarly shaped plates if a true circle projection of the reflecting surfaces is desired.

Another modification of the invention is illustrated in Fig. 8. The antenna comprises a reflecting cone **50** terminating line **1.** The surface wave energy will be reflected as vertically polarized wave energy in a narrow vertical sector over 360 degrees of azimuth.

It should be noted that all spacings are measured in wave length of the guided wave energy. Usually the difference between free space wave length and wave length on the guide is small, an exception being the modification described below. In this case, the wave length on the antenna section is considerably smaller than the free space wave length.

Figure 9 shows another modification of the invention. Line **1** is connected to a conductor **40** to which stubs **41** are joined. A terminating element **42** may be employed to cap the conductive line **40** so that the wave energy traveling from line **1** proceeds along section **40** as a traveling wave. Stubs **41** spiral about the section **40** to provide points of discontinuity from which the wave energy is radiated, such energy being horizontally polarized. In the most general case, the displacement in degrees wave length of two consecutive elements **41** along the line is equal to the displacement in degrees phase angle about the line. In the arrangement illustrated, these stubs are spaced along the line at 90 degree intervals, i. e., a quarter wave length, and are displaced horizontally by 90 degrees phase angle about the line. More or fewer stubs may be employed so long as they are spaced according to the above described pattern. For example, if the phase angle between two consecutive stubs about the line is 50 degrees, the distance between the stubs along the line is

$$\frac{50\lambda}{360}$$

where λ is the wave length on section **40.** This antenna will radiate energy omi-directionally in a narrow vertical sector with horizontal polarization.

Attention is again directed to the double utility of the surface wave transmission line which is utilized both as an antenna feed system and as an antenna mast.

While preferred embodiments of this invention have been particularly described and illustrated, it will be understood that various other modifications and improvements may be made without departing from the spirit of the invention. Therefore, it is not desired that the invention be limited to the precise details set forth.

What is claimed is:

1. A microwave antenna system comprising a plurality of reflecting surfaces and a surface wave transmission line, said surfaces being positioned around said line and being disposed at an angle with said line, said surfaces taken in combination being substantially elliptical and said surfaces being axially displaced from each other a total of one half wave length.

2. A microwave antenna system for electromagnetic energy of a predetermined frequency comprising an elongated conductor having a surface conditioned to slightly reduce the phase velocity to concentrate the field of the energy near the conductor in a non-radiating mode, launching means coupled to said conductor for producing a field distribution which matches the field distribution on the conductor, directional antenna means positioned along said conductor at a point spaced from said launching means and illuminated by said field for converting

said nonradiating mode to a radiating mode, and means for rotating said directional antenna about said conductor.

3. A microwave antenna system for electromagnetic energy of a predetermined frequency comprising an elongated conductor having a surface conditioned to slightly reduce the phase velocity to concentrate the field of the energy near the conductor in a non-radiating mode, launching means coupled to said conductor for producing a field distribution which matches the field distribution on the conductor, directional antenna means positioned along said conductor at a point spaced from said launching means and illuminated by said field for converting said non-radiating mode to a radiating mode, said directional antenna being formed by a plurality of surfaces for reflecting electromagnetic wave energy, said surfaces positioned around said conductor and disposed at an angle to said conductor so that said electromagnetic energy is radiated by said surfaces at an angle to said conductor.

4. A system as defined in claim 3 which includes means for rotating said antenna about said line.

5. A microwave antenna system for electromagnetic energy of a predetermined frequency comprising an elongated conductor having a surface which slightly reduces the phase velocity of the energy to concentrate the field of the energy near the conductor in a non-radiating mode, launching means coupled to said conductor for producing a field distribution at said predetermined frequency which matches the field distribution on the conductor and radiating means having a plurality of reflecting surfaces positioned along said conductor and spaced from said launching means and illuminated by said concentrated field for converting said non-radiating mode into a radiating mode at said radiating means.

6. An antenna system as in claim 5 wherein said surfaces are positioned around said line and being disposed at an angle with said line, said surfaces being axially displaced from each other.

7. A system as defined in claim 6 wherein said angle is 45 degrees.

8. A system as defined in claim 6 which includes means for rotating said reflecting surfaces about said line.

9. A microwave antenna system for electromagnetic energy of a predetermined frequency comprising an elongated conductor having a surface conditioned to slightly reduce the phase velocity to concentrate the field of the energy near the conductor in a non-radiating mode, launching means coupled to said conductor for producing a field distribution which matches the field distribution on the conductor, directional antenna means illuminated by said field for converting said non-radiating mode to a radiating mode said directional antenna comprising a plurality of reflecting plates mounted at a predetermined angle to said conductor, said plates being spaced along said conductor, said spacing along the conductor being directly proportional to the radial displacement of the plates from one another around said conductor so that said spacing along the conductor will be substantially one half wavelength at 180° radial displacement between any pair of plates.

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