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WAVE GUIDE ANTENNA

Original Filed March 31, 1942

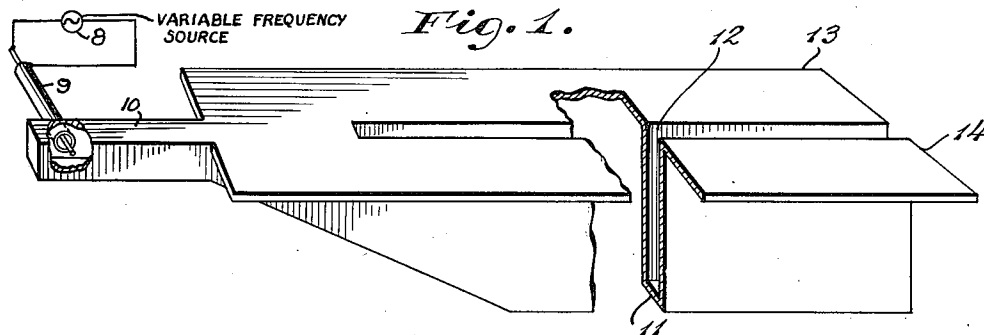


Fig. 1.

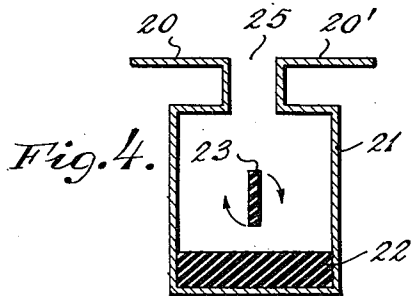


Fig. 4.

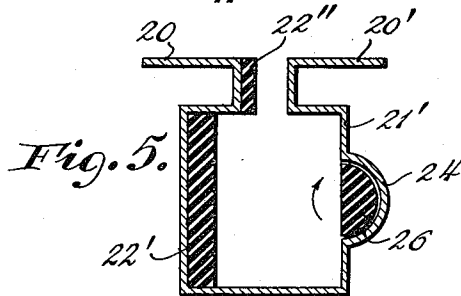


Fig. 5.

Fig. 6.

Fig. 7.

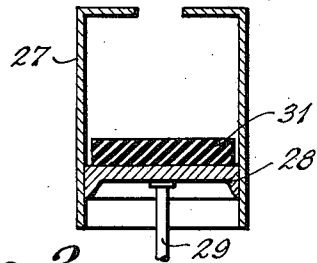


Fig. 2.

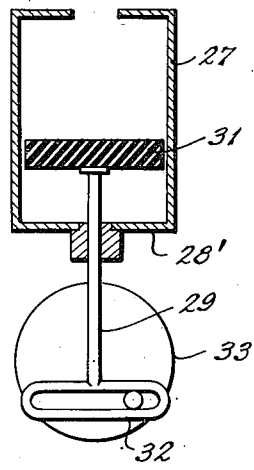
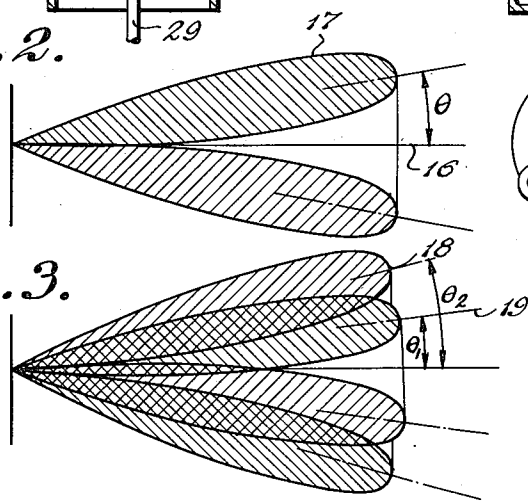


Fig. 3.



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WAVE GUIDE ANTENNA

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Original application March 31, 1942, Serial No. 437,004, now Patent No. 2,433,368, dated December 30, 1947. Divided and this application July 17, 1943, Serial No. 495,101

17 Claims. (Cl. 250—33.63)

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This invention relates generally to ultra high frequency energy radiating or receiving devices and, more particularly, to an improved type ultra high frequency substantially end-fire wave guide radiator or antenna having an adjustable or periodically variable directivity pattern. The present invention constitutes a division of prior co-pending application Serial No. 437,004, filed March 31, 1942, now Patent No. 2,433,369, issued December 30, 1947.

In the above application Serial No. 437,004, a wave guide antenna is disclosed and claimed, which is adapted to produce a substantially end-fire radiation pattern. The present invention is directed toward the provision of scanning means for periodically varying the directivity pattern of antennas of the type shown in said prior application. The present invention is also directed toward the utilization of such antenna in instrument landing systems for aircraft and in pulse or other systems.

One object of the present invention is to provide an improved antenna device whose directivity may be adjusted or periodically varied.

Another object of the present invention is to provide an improved wave guide antenna having an adjustable or variable directivity pattern.

Still another object of the present invention is to provide simple mechanical or electrical means for varying the effective directivity axis of a wave guide antenna.

Another object of the present invention is to provide improved high frequency apparatus having a pair of overlapping directivity characteristics suitable for use in instrument landing or automatic landing of aircraft.

Other objects and advantages of the present invention will become apparent from the specification, taken in connection with the accompanying drawings wherein the invention is embodied in concrete form.

In the drawings,

Fig. 1 is a perspective view, partly in section, of a wave guide antenna of the type disclosed in said prior application;

Fig. 2 illustrates one type of directivity pattern obtainable by use of the wave guide antenna of Fig. 1;

Fig. 3 illustrates a pair of overlapping directivity patterns obtainable by proper excitation of the antenna of Fig. 1 and useful in instrument landing systems;

Fig. 4 shows a transverse cross-sectional view of a wave guide antenna similar to that of Fig. 1, incorporating means for adjusting or varying the directivity pattern thereof; and

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Figs. 5, 6, and 7 are similar cross-sectional views of modifications of the device of Fig. 4.

As is described more in detail in the above-identified application, the directional radiation pattern or receptivity characteristic of a wave guide antenna of the type shown in Fig. 1, comprising a substantially rectangular wave guide 11 having a slot 12 formed in the upper face thereof and with side ground plates or launching 14 in the plane of slot 12, will be of the type shown in Fig. 2, namely, a cone having an axis 16 extending along the length of the wave guide antenna 11 and produced by rotation of a narrow lobe 17 about the axis 16. The semi-angle θ of this conical radiation pattern will have a value given by

$$\cos \theta = \frac{k}{k_0} = \frac{\lambda_0}{\lambda}$$

where λ_0 is the wavelength of the high frequency energy in free space and k_0 is the free space propagation constant, or

$$\frac{2\pi}{\lambda_0}$$

λ and k are correspondingly the wavelength and propagation constant for energy traveling within the wave guide 11 along the length thereof.

By properly selecting the relationship between the wavelengths of the energy in free space and in the wave guide, any angle θ may be produced as desired. For example, the theoretically perfect end-fire condition is obtained for $\theta=0$ when the propagation constant is the same within the wave guide as in free space.

As is seen from the above equation, the angle θ is a function of the exciting wavelength λ_0 in the guide. Thus the angle θ may be selected by suitably selecting the wavelength of the exciting energy in relation to the dimensions of the wave guide. For this purpose, high frequency source 8 is coupled in any conventional manner, as by coupling line 9, to the wave guide section 10 feeding the slotted guide 11. By varying the exciting frequency of source 8 in any suitable manner, such as by frequency modulation thereof, the radiation pattern of beam of radiant energy may be caused to scan between two limits, the amount of swing being determined by the frequency swing of the frequency modulated wave. For instrument landing purposes, the beam may be swung between two extreme positions indicated by the directivity patterns 18 and 19 of Fig. 3, having respective angles θ_1 and θ_2 and providing an equi-signal surface which may be used to define an instrument landing path for aircraft if desired.

The present invention may also be utilized to provide pulses of high frequency energy with a highly directive characteristic. Thus, as is well known, wave guides have a sharp cut-off frequency below which they will pass no energy. It is at this cut-off frequency that the true broad-side condition takes place. Thus, by frequency modulating the exciting energy derived from source 8 (which may then be a frequency-modulated oscillator) about a mean frequency substantially or exactly equal to the cut-off frequency of the wave guide radiator 11 or section 10, the radiating energy may be periodically cut off, so that pulses of radiant energy will be transmitted with a highly directive characteristic perpendicular to the length of the wave guide antenna. The character and duration of the pulses may be varied by corresponding variation of the mean frequency of the frequency modulated wave or of the frequency swing or of the modulating frequency of this wave.

As another way of utilizing the invention for instrument landing or similar purposes, two separate frequencies may be fed to or received by the antenna of Fig. 1. Such separate frequencies may be fed to antenna 11 by substituting two series-connected sources for the source 8 shown in Fig. 1. If these frequencies are selected so as to provide the respective directional characteristics 18 and 19 shown in Fig. 3, their overlapping will again provide a sharply defined path for instrument landing purposes or any similar function.

As has been discussed above and is discussed more in detail in the above-mentioned application Serial No. 437,004, the angle θ of Fig. 2 depends upon the phase velocity of the energy within the wave guide antenna. This is merely another way of stating that this angle θ depends upon the wavelength of the energy within the wave guide of the antenna or upon the propagation constant of this high frequency energy. By periodically varying this phase velocity, the lobe 17 may be periodically scanned between two limits in a manner similar to that produced by frequency modulating the produced energy.

Figs. 4, 5, 6 and 7 show various devices for varying the physical geometry of the wave guide as a desired function of time to produce a corresponding variation of the wave phase velocity and to thereby scan the directivity pattern.

Fig. 4 shows a wave guide 21 of the low slot impedance type described in the above-mentioned application Serial No. 437,004, which may be partially filled with dielectric material in the form of a slab of dielectric material 22 extending along the bottom of this wave guide 21. Guide 21 may have ground plates or launching plates such as 20, 20' adjacent the slot 25 therein. If desired, plates 20, 20' may be inclined or curved to modify the directivity of the device. Running through the length of wave guide 21 is a rotatable rectangular rod 23 of dielectric or conducting material, which may be uniformly or otherwise rotated to correspondingly vary the phase velocity of the energy within the guide and thereby vary the directivity characteristic of the radiated energy or received energy. If desired, the rectangular rod 23 may merely be positioned to adjust the directivity characteristic as desired, for example, to provide that shown in Fig. 2 or to approach the end-fire condition.

Fig. 5 shows a modification of the device of Fig. 4 in which the wave guide 21' may have a slab of dielectric material 22' lining one side thereof,

and also a slab of dielectric material 22'' lining the slot walls. The side wall of wave guide 21' is extended to form a semi-cylindrical portion 24 in which is located a rotatable semi-cylindrical member 26 of dielectric or conducting material. Rotation of member 26 to vary its position within wave guide 21' will correspondingly vary the wave phase velocity in a manner similar to that of Fig. 4, and will produce the same results as in Fig. 4.

Fig. 6 shows still another form of the invention applied to a slightly different form of wave guide 27. In this instance one wall, such as 28, of the wave guide 27 may be made movable as by means of a suitable rod 29 or in any other manner. By varying the dimensions of the wave guide in this manner, the phase velocity of the energy in the guide will be correspondingly varied to either periodically vary or to adjust the directivity characteristic thereof. If desired, a slab of dielectric material 31 may be moved with the wall 28, and will modify the wave guide as discussed in application Serial No. 437,004.

In place of moving the entire wall 28, resort may be had to the device of Fig. 7, in which the wall 28' is fixed, but the slab 31 is shown as movable under the action of rod 29, actuated, for example, from a Scotch yoke mechanism 32 driven from a wheel 33. In Fig. 7 the movable slab 31 may be made of dielectric material or conducting material, as desired.

In this manner I have provided an adjustable or variable directivity pattern by use of a wave guide antenna adapted to radiate or receive ultra high frequency energy. It is to be understood that the dielectric filling or lining used in Figs. 4, 5, and 6 may be dispensed with where its added effect is not desired. It will be clear that the adjustable antenna or scanner of the present invention may be utilized equally well for receiving or transmitting, its directivity characteristic being determined by the considerations mentioned above for either use. The term "antenna" is intended as generic both to a receiving antenna and to a radiating antenna.

As many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. A substantially end fire directive radiator comprising a rectangular conducting wave guide partially filled with solid dielectric material and excited by electromagnetic waves of substantially linear polarization, and a dielectric rod within and extending along said guide, said rod being turnable about its longitudinal axis for altering the phase velocity of said waves within said guide.
2. A substantially end fire directive radiator comprising a rectangular conducting wave guide partially filled with solid dielectric material and excited by electromagnetic waves of substantially linear polarization, a dielectric rod within and extending along said guide, said rod being turnable about its longitudinal axis for altering the phase velocity of said waves within said guide, said guide having distributed radiating means extending along the length of the same at right angles to the electric vector of said waves for propagating said waves into space, the direction of said propagation being shifted as the phase

velocity of said waves within said guides is altered by said turnable rod.

3. A substantially end fire directive radiator comprising a rectangular conducting wave guide partially filled with solid dielectric material and excited by electromagnetic waves of substantially linear polarization, and an adjustable dielectric member for varying the phase velocity of said waves therein, said guide being apertured to enable the radiation of said waves into space, the adjustment of said member changing the radiation pattern of the guide.

4. An end fire directive radiator as defined in claim 3 wherein said member constitutes a portion of the wall of the guide, whereby the adjustment of the member varies the cross-sectional area of the guide.

5. A substantially end fire directive radiator comprising a rectangular conducting wave guide partially filled with solid dielectric material and excited by electromagnetic waves of substantially linear polarization, an adjustable member for varying the phase velocity of said waves therein, said guide being apertured to enable the radiation of said waves into space, the adjustment of said member changing the radiation pattern of the guide, and means for continuously adjusting said member to thereby continuously vary the radiation pattern to effect a scanning operation.

6. A high frequency antenna comprising an elongated hollow-pipe wave guide apertured along the major dimensions thereof, and means for periodically varying the phase velocity of energy within said hollow-pipe wave guide to thereby periodically vary the directivity pattern produced by said antenna, said last-named means comprising a member extending longitudinally within said wave guide, and means for periodically varying the position of said member relative to said guide.

7. A high frequency antenna comprising an elongated hollow-pipe wave guide apertured along the major dimensions thereof, and means for periodically varying the phase velocity of energy within said hollow-pipe wave guide to thereby periodically vary the directivity pattern produced by said antenna, said last-named means comprising a non-circular rod of dielectric material extending along the length of said wave guide, and means for rotating said rod about an axis parallel to said wave guide.

8. A high frequency antenna comprising an elongated hollow-pipe wave guide apertured along the major dimension thereof, and means for periodically varying the phase velocity of energy within said hollow-pipe wave guide to thereby periodically vary the directivity pattern produced by said antenna, said last-named means comprising a member of dielectric material extending along the length of said wave guide, and means for periodically and linearly varying the position of said member relative to a wall of said wave guide.

9. A high frequency antenna comprising an elongated wave guide apertured along the length thereof, and means for periodically varying the cross-section of said wave guide to vary the directivity pattern of said antenna.

10. A high frequency antenna having a pulsed directivity characteristic comprising an elongated hollow-pipe wave guide apertured along one dimension thereof to have a directive characteristic and adapted to contain high frequency energy,

and means for periodically varying the frequency of said energy above and below the cut-off value thereof, whereby said antenna is periodically swung below cut-off and a pulsed directivity characteristic is produced.

11. A high frequency pulse transmitter for transmitting high frequency energy having a predetermined frequency, comprising a hollow-pipe wave guide radiator adapted to be excited by said energy and having a cut-off frequency only slightly different from said predetermined frequency, and means for periodically varying said predetermined frequency above and below said cut-off frequency, whereby only pulses of said energy are radiated by said radiator.

12. In a radio system, a dielectric channel having a uniform cross-sectional area, and means for cyclically and uniformly varying said area.

13. In a radio system, a dielectric channel connected to a translation device and having a uniform phase velocity characteristic, and means for varying said phase velocity characteristic cyclically and equally along the length of said channel.

14. A high frequency antenna comprising an elongated wave guide apertured along the major dimension thereof, and means for periodically varying the phase velocity of energy within said wave guide to thereby periodically vary the directivity pattern produced by said antenna, said phase velocity varying means comprising means physically varying the propagation characteristics of said wave guide for energy of a given frequency.

15. A high frequency antenna comprising an elongated wave guide apertured for distributed radiation along the major dimension thereof, and means including a movable element in said wave guide for periodically varying the phase velocity of energy of a predetermined frequency within said wave guide to thereby periodically vary the directivity pattern produced by said antenna.

16. A high frequency antenna as defined in claim 15, wherein said movable element comprises one wall of said wave guide.

17. A high frequency antenna as defined in claim 15, wherein said wave guide comprises fixed conductive boundaries, and said movable element comprises a longitudinally extensive element inside the walls of said wave guide.

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