Jan. 23, 1934. G. G. KRUESI 1,944,563

DIRECTIONAL RADIO BEAM SYSTEM

Filed July 29, 1931

Fig 1

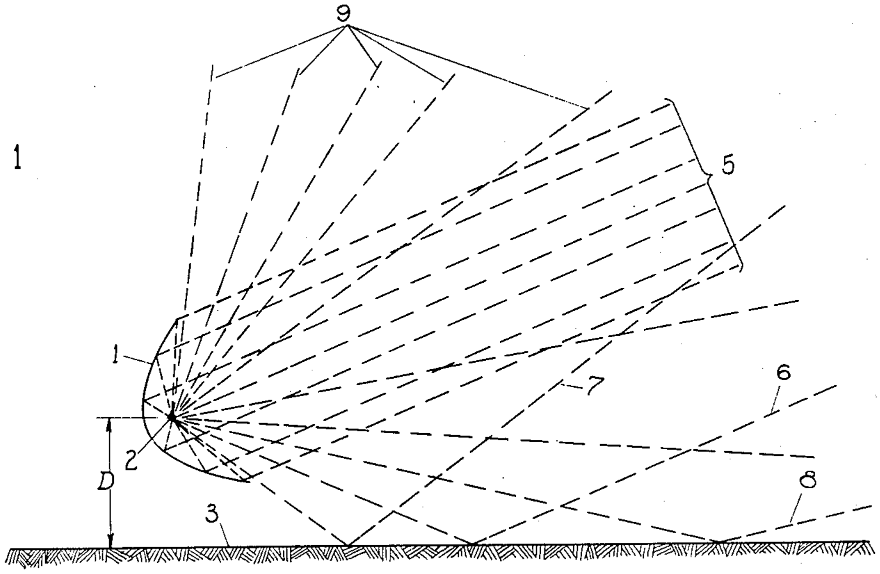


Fig 2

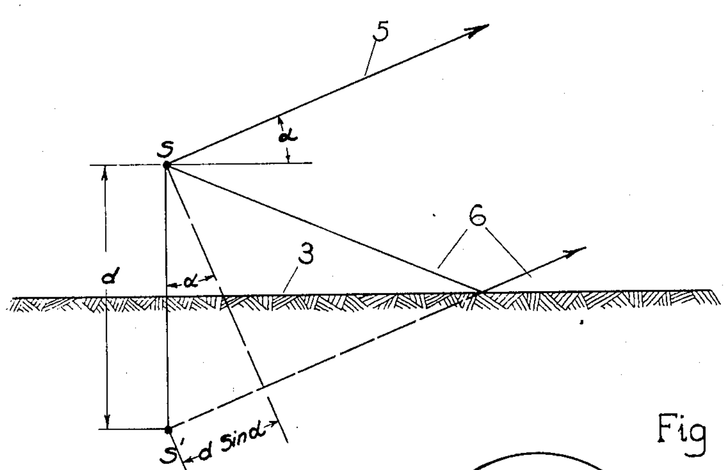


Fig 3

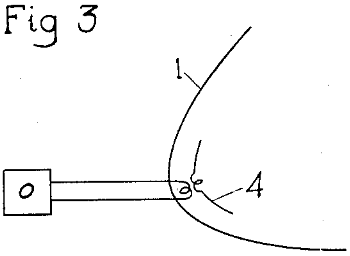
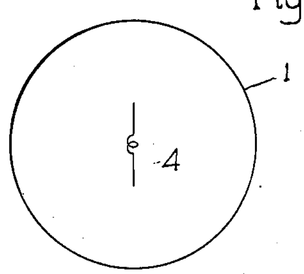


Fig 4



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DIRECTIONAL RADIO BEAM SYSTEM

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5 Claims. (Cl. 250—11)

This invention relates to radio antenna systems, particularly to short wave systems and has as an object to improve the efficiency of transmission in such systems.

In a radio transmitting system, particularly a short wave system for communication over great distances, most of that energy which arrives at the receiving station left the transmitting antenna at an angle above the horizontal, the exact angle depending upon the wave length and whether transmission takes place during day or night. Obviously the efficiency of transmission may be increased by the use of a directive antenna which tends to concentrate the energy in the proper direction. However, even with directive antennæ, some of the radiated waves emanate in a downward direction, and are reflected from the earth's surface at the optimum angle to reach the receiving station. This energy will augment or weaken the received signal depending on whether it is in phase or in phase opposition to the main body of energy emanating directly from the source. I have discovered that by suitably positioning the radiating source above the surface of the earth, the waves reaching the receiving station after reflection from the earth's surface will always be in phase with the waves received directly from the source.

The invention will now be described in detail, with reference to the drawing, in which:

Fig. 1 is a diagram showing the directions in which energy is radiated from a conductor positioned at the focus of a parabolic reflector;

Fig. 2 is a diagram illustrating the theory on which the present invention is based;

Fig. 3 is a schematic diagram showing a cross-sectional view of one form of radiating conductor positioned within a paraboloidal reflector; and

Fig. 4 is a view looking into the open end of the same reflector.

It is a generally accepted fact that for long range radio communication using a directive transmitting antenna, the highest efficiency is obtained when the energy is directed upward at a slight angle, rather than horizontally. The most effective angle of elevation depends upon the wave-length employed and whether it is day or night. Thus, it has been suggested that for daytime transmission at 17 meters wave-length, the angle of elevation for most efficient transmission is 23°.

Referring to Fig. 1, a parabolic reflector 1, having a radiating conductor positioned at its focus 2, is positioned a distance D above the surface of the earth 3 and directed at a desired angle above the horizontal. Assuming that energy is radiated from the point 2 in all directions in the plane of the drawing, all energy intercepted by the parabolic reflecting surface is reflected in a direction parallel to the axis of the parabola as indicated by dotted lines 5. However, most of the energy radiated from the point 2 that is not intercepted by the reflector surface never reaches the same destination as the reflected energy. Thus, that indicated by lines 9 is projected at a high angle, while much of that projected downward and forward, impinges on the surface of the earth and is reflected at a high angle as indicated by line 7, or at a low angle as indicated by line 8. Some of the energy, however, will be reflected parallel to the main beam, as indicated by line 6, and this energy will be received at the receiving station. If received in phase with the energy of the direct beam, this energy following the path 6 will increase the signal strength. On the other hand, if received in phase opposition, it will tend to neutralize the effect of the direct beam. A method of determining the relative phase of the received energy following path 6 as compared to that following paths 5 will now be outlined.

It is a well established law of physics that, disregarding any polarization phenomena due to reflection, the characteristics of a reflected beam are those of a beam emanating from the image of the original source. The position of the image may be determined by extending the perpendicular bisector from the original source to the reflecting surface. Thus, referring to Fig. 2, if S is the original source and 3 the reflecting surface, S′ is the image source. The phase characteristics of the reflected energy following path 6 are, therefore, the same as those of energy radiated from the image source S′, and differ from those of energy following the path 5, because the energy from the image source S′ has travelled the additional distance represented by the formula

$$d \sin \alpha$$

where d=distance between the real and image sources and α=angle of elevation of the beams 5 and 6.

If the distance $d \sin \alpha$ is a whole wavelength, or multiple thereof, the reflected wave will be in phase with the direct wave, providing that, as mentioned above, the reflection itself has not altered the phase. I have found, in the case of radio energy, that if the plane of polarization of the waves before reflection is parallel to the plane of incidence of the wave, there is no phase shift due to the reflection, and that the distance $d \sin \alpha$

should be a wavelength, or an integral multiple thereof. In Fig. 1 this would be the condition for vertically polarized waves. However, I have found that if the real source of energy supplies horizontally polarized waves, the reflected waves have the characteristics of those radiated from an image source 180° out of phase with the real source. Therefore, if the real source supplies horizontally polarized waves the distance $d \sin \alpha$ should be half a wave length or an odd integral multiple thereof.

Referring again to Fig. 1, it will be seen that the distance D of the radiating source above the ground surface is ½ d. Therefore, for most efficient transmission of vertically polarized waves of length λ

$$D \sin \alpha = \frac{(\lambda)}{(2)}$$

or an integral multiple thereof

$$D = \frac{\lambda}{2 \sin \alpha}$$

or an integral multiple thereof.

For most efficient transmission of horizontally polarized waves

$$D \sin \alpha = \frac{(\lambda)}{(2x2)}$$

or an odd integral multiple thereof

$$D = \frac{(\lambda)}{(4 \sin \alpha)}$$

or an odd integral multiple thereof.

Thus, in the previously assumed case of daylight transmission at 17 meters, it is known that the optimum angle of radiation is 23°. Therefore, if vertically polarized waves are transmitted, the distance D that the radiating source should be positioned above the ground is

$$\frac{17}{2 \sin 23^\circ} \text{ or } \frac{17}{2x.39} = 21.8 \text{ meters}$$

or an integral multiple thereof.

If horizontally polarized waves are transmitted the distance D should be

$$\frac{17}{4 \sin 23^\circ} \text{ or } \frac{17}{4x.39} = 10.9 \text{ meters}$$

or an odd integral multiple thereof.

For the reason indicated, it is readily seen that the proper elevation of a radiating source above the ground is a factor of considerable importance in securing efficient transmission.

Although described particularly with reference to transmission, the invention is equally applicable to receiving antenna systems, for, considering the apparatus shown in Fig. 1 to be at a receiving station, only that energy from the distant station arriving over paths 5 and 6 can reach the point 2, and the effect of energies received over the different paths at that point will be dependent on their relative phases, which, as in the case of waves transmitted from point 2, are dependent on the difference in the lengths of the two paths.

Therefore, although the claims are directed to a transmitting system, they are intended to cover similar methods and apparatus used for reception.

I claim:

1. In a radio system, a horizontal reflecting surface, and means for radiating approximately vertically polarized radio waves of wave-length λ, said waves being in part radiated in a predetermined direction making a vertical angle α with said surface, said means being positioned above said surface a distance equal to an integral multiple of

$$\frac{\lambda}{2 \sin \alpha}.$$

2. In a radio system, a horizontal reflecting surface, and means for radiating approximately horizontally polarized radio waves of wave-length λ, said waves being in part radiated in a direction at a desired vertical angle α, said means being positioned above said surface a distance equal to

$$\frac{\lambda}{4 \sin \alpha}$$

or an odd multiple thereof.

3. Apparatus as described in claim 1 in which said radiating means comprises a conductor located at the focus of a paraboloidal reflector.

4. Apparatus as described in claim 2 in which said radiating means comprises a conductor in a paraboloidal reflector.

5. In a radio system, the combination of a horizontal reflecting surface, and means for radiating polarized radio waves of wavelength λ in a predetermined direction at a vertical angle α with respect to said surface, said radiating means being positioned above said surface a distance directly proportional to λ and inversely proportional to the sin α.

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