

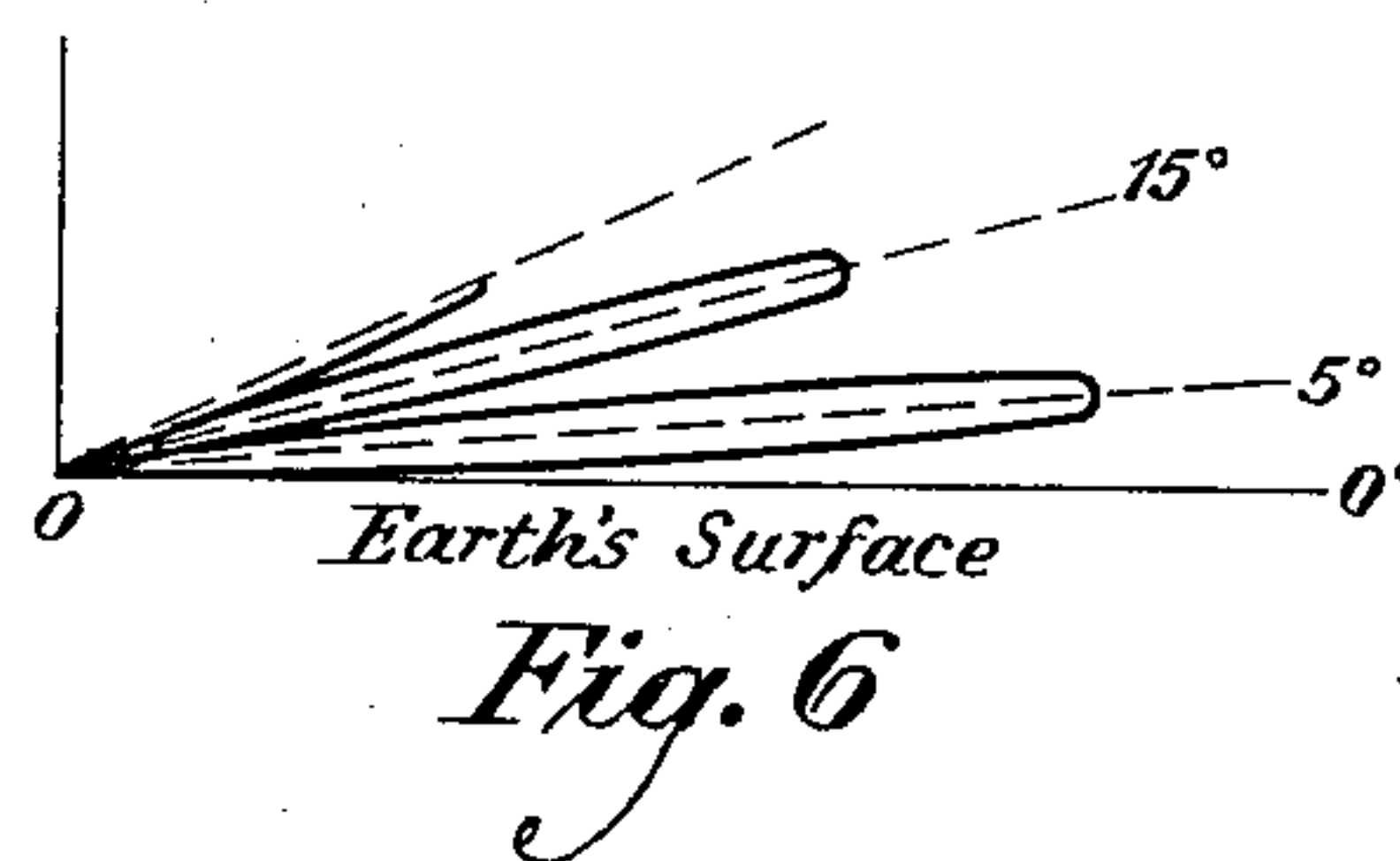
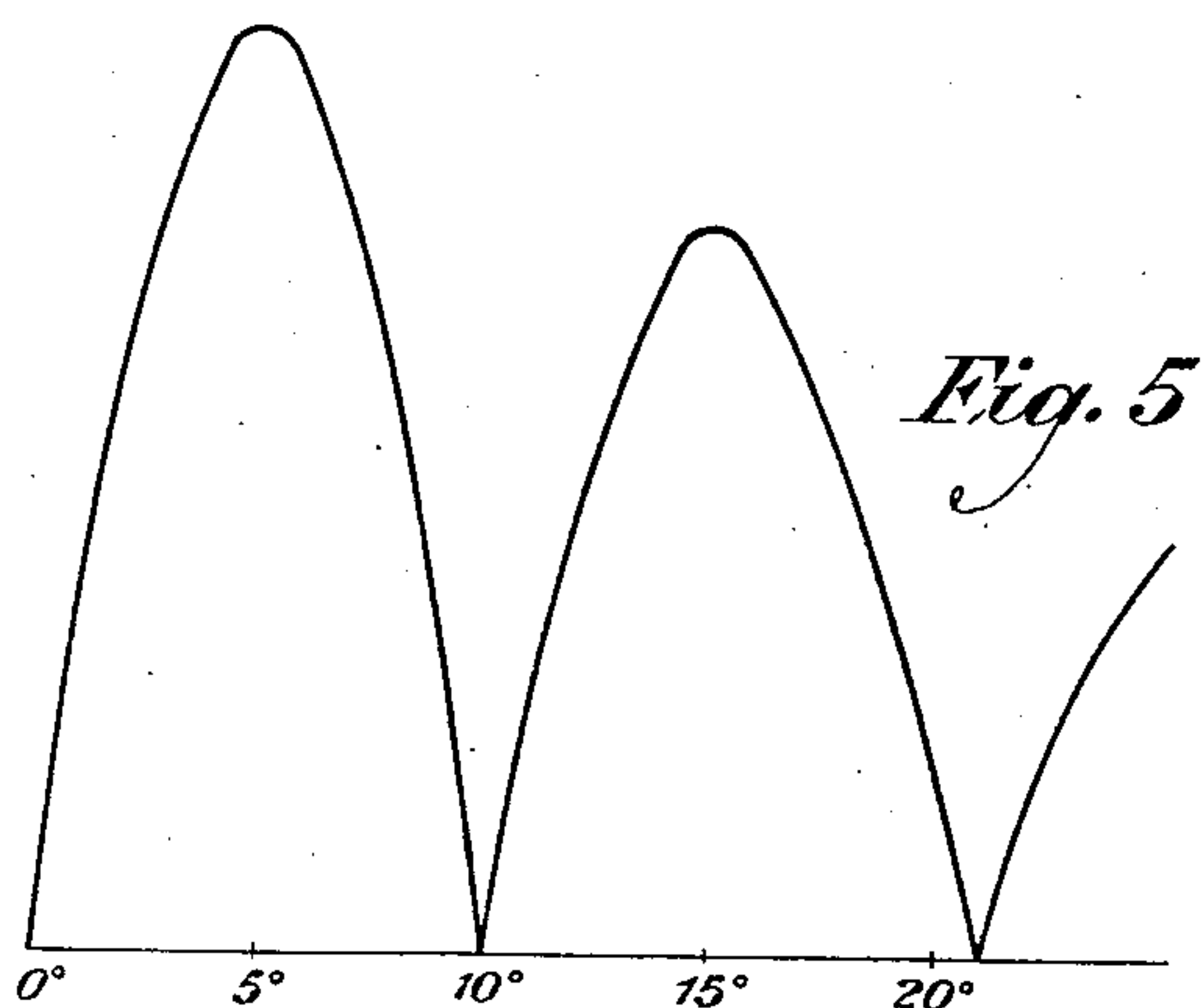
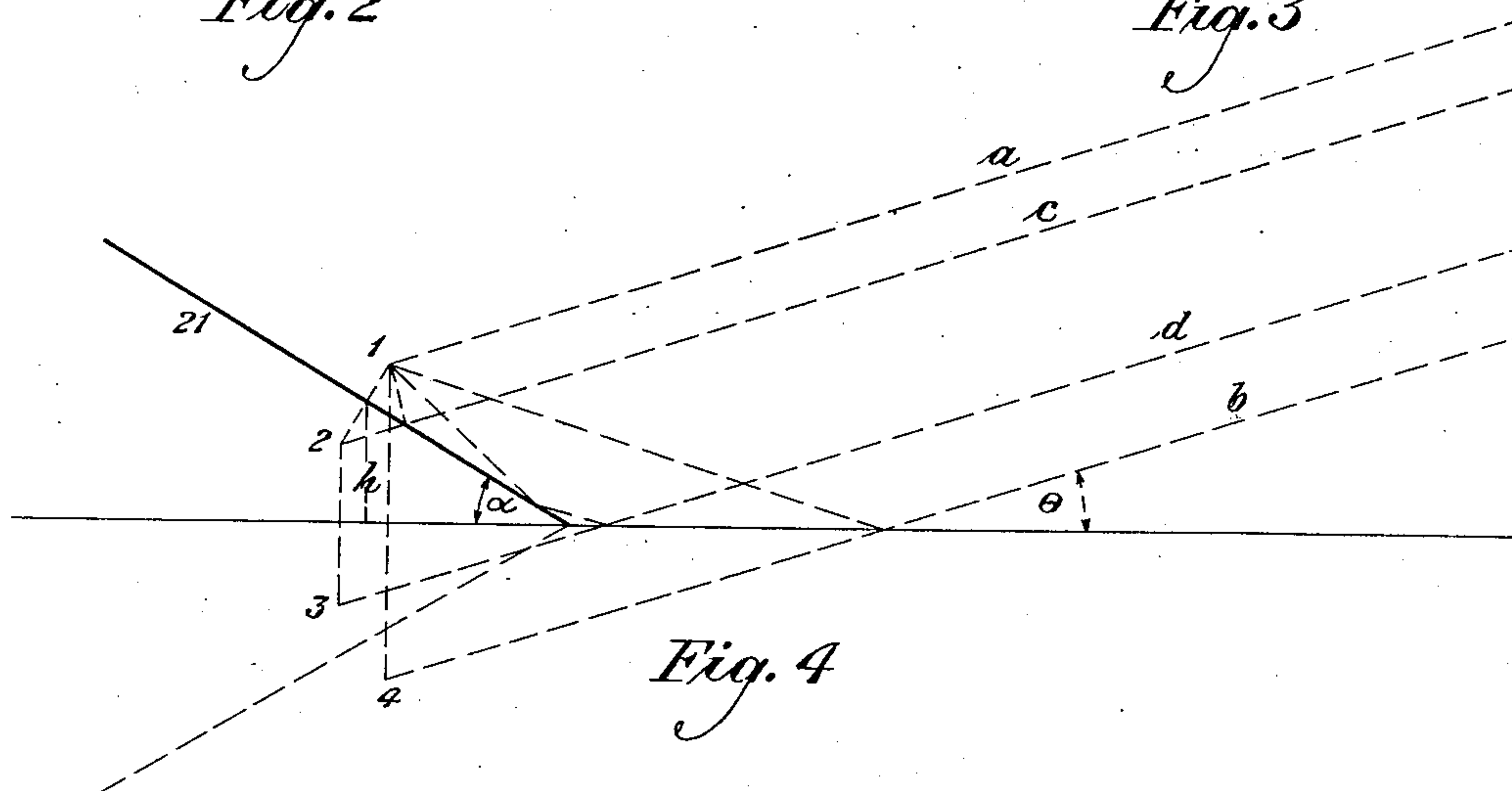
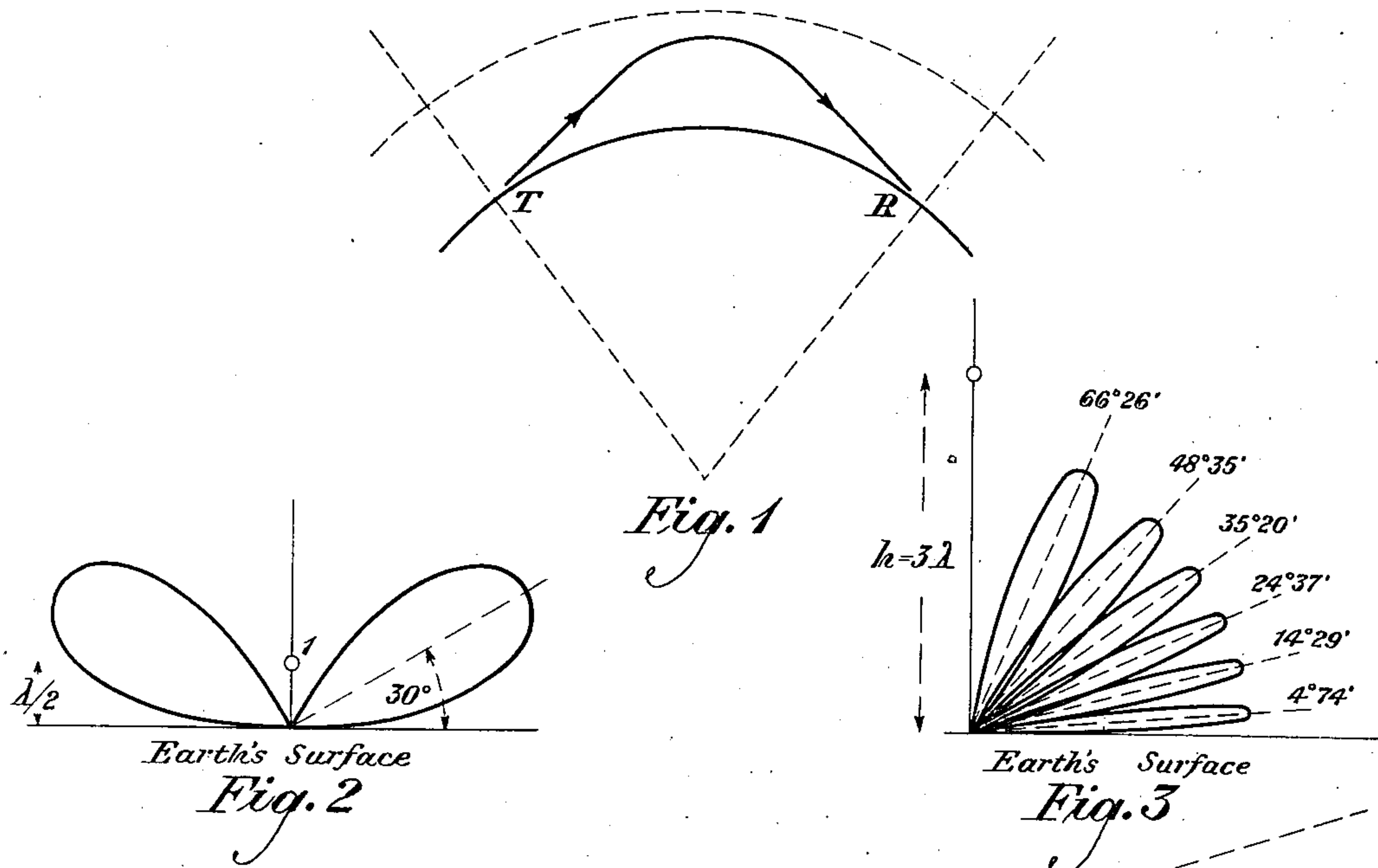
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RADIOANTENNA

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RADIOANTENNA

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5 Claims. (Cl. 250—11)

The principal object of the present invention is to provide a radio antenna or a set of radio antennas especially adapted for transmission or reception in a manner to obviate "fading" and otherwise to secure reliable operation. Another object of my invention is to provide an antenna with an inclined artificial ground surface beneath it so as to get advantageous directional selectivity in the vertical plane that contains the transmitting and receiving stations. Another object of my invention is to provide an antenna that shall operate with a narrow beam of transmission or reception in a direction inclined up a little to the horizontal direction connecting the transmitting and receiving stations. These objects and other objects of my invention will become apparent on consideration of a specific example of practice according to the invention which I have chosen for presentation in the following specification. It will be understood that this disclosure relates particularly to this example of my invention and its scope is intended to be indicated in the appended claims.

Referring to the drawing, Figure 1 is a diagrammatic section of the earth's surface showing transmission in relation to the "Heaviside" layer; Fig. 2 is a polar intensity diagram for a horizontal oscillator at a half wave length above the earth's surface; Fig. 3 is a similar diagram but at a distance of three wave lengths above the earth's surface; Fig. 4 is a diagram for a horizontal oscillator with an inclined artificial ground beneath it; Fig. 5 is a diagram in rectangular coordinates for the intensity of radiation from the system of Fig. 4; and Fig. 6 is a similar diagram in polar coordinates.

As is well understood in the art of radio transmission, the principles of directional selectivity are extensively applicable alike for transmission and reception. In the following specification I will confine my disclosure for the most part to transmission alone and it will be readily apparent to those skilled in the art how the principles of my invention may be employed in the case of reception.

In short wave transmission, as from the station T in Fig. 1 to the station R, radio waves of length comparable to the water waves in the ocean are seriously affected by random reflections from the water wave surfaces, especially in times of storm. This may make it desirable to send the waves initially in a direction that is somewhat inclined over the horizontal at the transmitting station, this direction lying in the vertical plane through the transmitting and receiving stations. On the other hand, if the waves are sent at too great an angle of elevation, they will soon strike the under side of the Heaviside layer and be reflected down to the water, as indicated in Fig. 1. This discussion shows that

there may be a decided optimum angle of elevation at which to transmit, and indeed, this view is confirmed by experience.

If transmission is at a wide range of angles of elevation the entire emitted wave front will be differently reflected in its parts and will be broken up into several different wave fronts in different phase at the receiving station and these will interfere more or less at different times, giving the phenomenon of fading. Therefore, it becomes desirable to transmit in a restricted beam lying along the optimum direction as indicated in Fig. 1.

Introductory to a presentation of the principles of the present invention, I direct attention to Fig. 2 which gives a polar intensity diagram for a horizontal oscillator 1 viewed endwise and spaced at a half-wave length distance above the earth's surface. This gives a beam at 30 degrees elevation, which angle will be too great in most cases of the practice of my invention. Moreover, the beam in this case is very wide—that is, there is substantial radiation in directions which depart considerably from the 30-degree direction.

For the theory underlying Fig. 2 and the following Fig. 3, I make reference to the paper by R. M. Foster at page 292 of the Bell System Technical Journal for April 1926 (volume V), particularly in Fig. 1 the diagrams for $\frac{1}{2}T$, λ , 2λ and 4λ . In the Foster diagrams there are assumed to be two parallel oscillators seen endwise and spaced horizontally. For the particular Foster diagrams to which reference is here made, the phase difference being $\frac{1}{2}$ a complete period, the image effect may be relied on—that is, a conductive plane is assumed that bisects perpendicularly a line joining the two oscillators and the oscillator on one side is discarded. This plane with the corresponding diagram is rotated 90 degrees about an axis perpendicular to the plane of the paper, whereupon the conductive plane may be taken as the earth's surface in present Figs. 2 and 3.

Whereas in present Fig. 2 the oscillator is at a half-wave length distance above the earth's surface and accordingly, at a full wave length distance from its image, and there is one beam of radiation in the quadrant, in Fig. 3 the oscillator is at a distance of three wave lengths above the earth's surface,—that is, six wave lengths from its image—and there are six beams of radiation in the quadrant, as shown. Furthermore, in Fig. 3 each beam is very much narrower than the beam of Fig. 2.

My invention involves the use of a horizontal oscillator as in Figs. 2 and 3. Such a horizontal oscillator is seen end on at 1 in Fig. 4. Beneath this, at the distance d , I place an extended inclined plane of a conductive material at the angle α to the horizontal and shown edgewise at

21 in Fig. 4. Consider an observer at a distance so great that the lines to him from the oscillator 1 and from neighboring points shown in Fig. 4 may all be taken as parallel, and let the direction which these lines make with the horizontal be θ . All the radiation to this observer may be classed under four heads: (a) the direct ray from the oscillator 1; (b) the ray reflected once from the ground which may be assigned to the image 4 with respect to the ground surface; (c) the ray reflected once from the inclined plane 21 which may be assigned to the image 2 with respect to that plane; and (d) the ray reflected from the inclined plane 21 to the ground and thence again reflected, which may be assigned to the image 3 which is the image with respect to the ground surface of the previously mentioned image 2.

The pair of oscillators 1 and 2 of Fig. 4 will give us a diagram like Fig. 2 or Fig. 3 according to the height of the oscillator 1 above the inclined plane 21. Similarly, the pair of oscillators 3 and 4 will give a diagram which, of course, will be differently orientated. The intensity at a distance from oscillators 1 and 2 is given by the equation

$$e_1 + e_2 = 2E \sin \left(\frac{2\pi}{\lambda} d \sin (\theta + \alpha) \right) \cos \omega t \quad (1)$$

There will be a similar equation for the pair 3 and 4 except that the angle $\theta + \alpha$ must be changed to $\theta - \alpha$ and the angular magnitude ωt must be changed to $\omega t - \phi$, where

$$\phi = \frac{2\pi}{\lambda} 2h \sin \theta,$$

all of which will be obvious from an inspection of Fig. 4, noting that this value of ϕ is determined by assumptions that have been made heretofore. Let

$$\phi = n\pi, \text{ when } \theta = \theta_0 \quad (2)$$

where n is odd. Then it follows that ϕ will disappear from the expression for the radiation from oscillators 3 and 4 and we shall have

$$e_3 + e_4 = -2E \sin \left(\frac{2\pi}{\lambda} d \sin (\theta - \alpha) \right) \cos \omega t \quad (3)$$

Under these circumstances the total effect of the oscillator 1 and its images is given by the equation

$$e_1 + e_2 + e_3 + e_4 = 2E \left[\sin \left(\frac{2\pi}{\lambda} d \sin (\theta_0 + \alpha) \right) - \sin \left(\frac{2\pi}{\lambda} d \sin (\theta_0 - \alpha) \right) \right] \cos \omega t \quad (4)$$

It will also follow that the optimum value for h as shown in Fig. 4 is given by

$$h = n\lambda/4 \sin \theta_0 \quad (5)$$

Now suppose we wish to develop a ray whose inclination to the earth's surface shall be, say, 5 degrees; we may substitute 5 degrees for θ in Equations (4) and (5). Then we may ascertain the values of d and α , which will make the amplitude of the right-hand member of Equation (4) a maximum. And having found α in this way, it determines the slope of the plane 21. Next from Equation (5) we may find the point on the plane 21 over which the oscillator 1 is to be located.

Letting $\theta = 5$ degrees, $n = 1$ and $d = \lambda/2$, it follows readily that $h = 2.87\lambda$, and the curve of Fig. 5 illustrates the amplitude of the effect at the distant point of reference for different values of θ . This

shows that to secure a maximum radiation in the direction $\theta = 5$ degrees, we must have $h = 2.87\lambda$, if we take $n = 1$ and $\alpha = 30$ degrees. The corresponding polar diagram for Fig. 5 is given in Fig. 6. This shows that by giving the proper values to the parameters of the equations corresponding to Fig. 4, we may have a narrow beam of great intensity in the desired direction of 5 degrees, and that the remaining beams will be of less intensity and at angles so widely different that they will cause very little interference at the receiving station. The curves of Figs. 5 and 6 are not continued beyond $\theta = 25$ degrees for two reasons: (1) the image 3 ceases to be "visible" at higher angles and (2) we are not particularly concerned with any but low angle radiation.

A comparison of Fig. 6 and Fig. 3 shows the decided advantage of the scheme of Fig. 4 as compared with merely elevating the oscillator above the earth's surface. The intensity of the low angle radiation is almost double while the intensity of the higher angle radiation progressively diminishes as the angle increases.

Referring to Fig. 4, the real source 1 and the image sources 2, 3 and 4 produce an interference pattern which is depicted in Fig. 6, and the design is adjusted so that in the preferred direction there is reenforcement of the waves from these sources, that is, there is a maximum beam of radiation in that direction.

I claim:

1. The method of sending a beam of radiation in a direction upwardly inclined relatively to the earth's surface which consists in generating radiation and partly reflecting it from each of two plane surfaces at an angle to each other so as to get a resultant reenforcement in the desired direction in the resultant interference pattern.

2. The method of establishing a beam of radiation at a desired angle of inclination to the earth's surface which consists in partially reflecting part of the radiation from a horizontal surface and part from an inclined surface to form an interference pattern with reenforcement of the direct and reflected parts along the desired direction.

3. In a radio signaling system, a horizontal oscillator and an inclined conductive plane under it sloping downwardly toward the direction of selective transmission, the angle of slope being adjusted to make the directly radiated beam and the earth reflected beam and the beam from the inclined plane all combine to give a resultant narrow beam inclined to the earth's surface.

4. Means for generating a beam of radiation and sending it in a direction upwardly inclined to the earth's surface comprising an oscillator and an inclined conductive plane under it sloping downwardly relatively to said direction, the slope being adjusted in relation to the other dimensions, and the frequency so that the direct and reflected beams shall give a resultant narrow beam of radiation in the said desired direction.

5. In a radio signaling system, a horizontal oscillator and an inclined conductive plane under it sloping downwardly toward the direction of selective transmission, the distance of the oscillator from this inclined plane and the distance from the normal earth level being of the order of a wave length, these distances and the angle of slope being adjusted to produce an interference pattern with a resultant narrow beam of selective transmission in a desired direction inclined slightly from the horizontal.

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