Skyward facing directional antennas are easy prey for ionospheric reflection interference. How to determine the possibilities of subjection to this source is this article's objective.

Interference from the

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GROUND to air communications systems, radars or other radio links with directional antennas that point skyward are subject to two main sources of interference propagated via the ionosphere.

In the first case, static interference and man-made signals may be reflected from the ionosphere and enter the beam of the radar receiving antenna, Fig. 1.

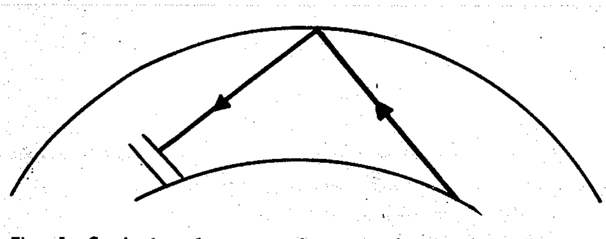
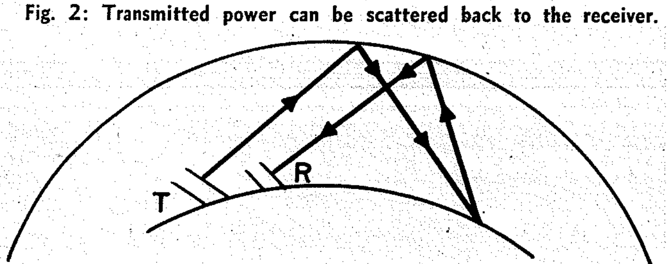


Fig. 1: Static interference and man-made signals, reflecting from the ionosphere, may enter the beam of a radar receiving antenna.

Fig. 2: Transmitted power can be scattered back to the receiver.



In the other case, transmitted power can be scattered back along the path transmitter—ionosphere—ground—ionosphere—receiver, as show in Fig. 2.

In either case interference is only possible when the ionosphere reflects the "operating frequency" (f_c) at an angle of incidence ϕ, Fig. 3.

Theory

Consider the passage of a plane electromagnetic wave across the boundary of two media of refractive indices n and n', Fig. 4. Snell's law states that $n \sin \phi = \sin \phi'$. For the ionosphere

$$n' = \sqrt{1 - [Ne^2 / (m \epsilon_o \omega^2)]} \qquad (1)$$

Where N = number of electrons per cubic meter

e = electronic charge

m = mass of electron

ϵ_o = permittivity of free space

$\omega = 2\pi \times$ the frequency of the electromagnetic wave

Critical reflection exists when $\angle\phi = 90°$ or $\sin \phi = n'$.

In this case

$$\sin \phi = \sqrt{1 - [Ne^2 / (m \epsilon_o \omega^2)]} \qquad (2)$$

$$\omega^2 = Ne^2 / (m \epsilon_o \cos^2 \phi) \qquad (3)$$

Hence

$$f_c' = (1 / \cos \phi) \sqrt{Ne^2 / (4\pi^2 m \epsilon_o)} \qquad (4)$$

where f_c' is the critical frequency for forward reflections at an angle of incidence, ϕ.

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Table 1

MAIN LOBE FREQUENCY

α	h	f_o	Layer
[illegible]	50 km	19.5 MC	
40	100	19.7	E and E_s
40	200	19.9	F_2
40	300	20.2	

Ionosphere

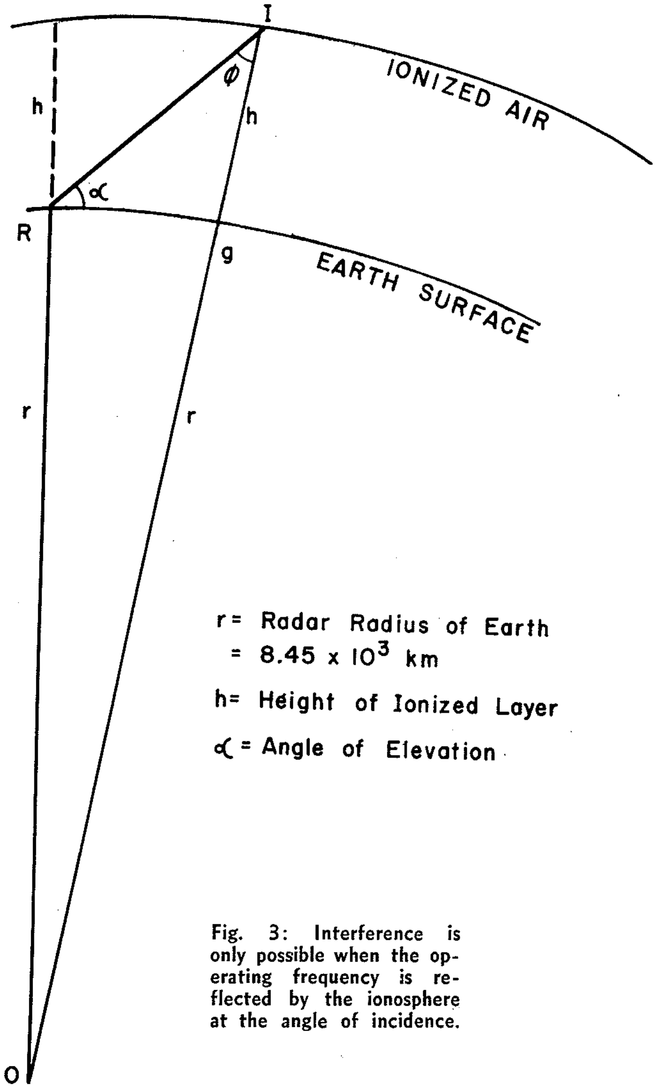

Fig. 3: Interference is only possible when the operating frequency is reflected by the ionosphere at the angle of incidence.

Now reflections at vertical incidence occur at a critical frequency of f_o which is given by making $\phi = 0°$ in Eq. (4),

$$f_o = \sqrt{[Ne^2 / (4\pi^2 m \epsilon_o)]}. \quad (5)$$

Hence, substituting in Eq. (4), we may relate the critical frequency f_c' at oblique incidence to the critical frequency at vertical incidence by the expression

$$f_o = f_c' \cos \phi. \quad (6)$$

The angle ϕ is shown in triangle RIO, Fig. 3, where O is the center of the earth and R is the radar site. From triangle RIO

$$r / \sin \phi = (r + h) / [\sin (90 + \alpha)] \quad (7)$$

$$\sin \phi = (r \cos \alpha) / (r + h) \quad (8)$$

and from Eq. (6)

$$f_o = f_c' \sqrt{1 - [(r \cos \alpha) / (r + h)]^2} \quad (9)$$

Thus when the vertical sounding of the ionosphere shows that f_o is greater than the value given by Eq. (9), oblique reflection will occur at a frequency f_c' and transmission angle α. Conversely we may assume that no interference from ionospheric reflection will occur when f_o is below this value.

Example

Assume: (1) a desired operating frequency, f_c, of 30 MC,
(2) a beam elevation of 40°,
(3) the operating site to be Washington, D. C., and
(4) the equipment will operate during sun-spot maxima.

Using these assumptions in Eq. (9), the computed vertical critical frequency f_o indicates that oblique reflections are possible. Table 1 shows values obtained for heights from 50 to 300 km. Under these conditions, f_o does not vary appreciably with the height of the ionized layer, and therefore it is necessary to

Table 2

VERTICAL CRITICAL FREQUENCY

F_2 Layer Over Washington, D. C. – National Bureau of Standards

Frequency MC	Dec. '46	Jan. '47	Feb. '47	Mar. '47	Apr. '47	May '47	June '47	July '47	Aug. '47	Sept. '47	Oct. '47	Nov. '47
	Hours Per Month											
15 – 15.9	—	—	—	—	—	—	—	—	—	—	1	—
14 – 14.9	—	1	5	1	—	—	—	—	—	—	3	29
13 – 13.9	6	15	61	37	4	—	—	—	—	—	61	120
12 – 12.9	57	76	133	106	41	—	—	—	—	36	116	73
11 – 11.9	108	94	46	56	83	14	—	—	—	55	42	28
10 – 10.9	51	47	14	30	80	47	3	1	11	87	34	25

Ionospheric Interference

(Concluded)

consider only the layer with highest electron density, irrespective of its height in the ionosphere.

National Bureau of Standards measurements of vertical critical frequencies centered at Washington, D. C., were used as a basis for the data collected here.

On all occasions during the day the highest electron densities occurred in F_2 region. Table 2 shows the number of hours per month in which the vertical critical frequency of the F_2 region was greater than 10 MC. The year 1947 has been chosen as it corresponds to the maximum of the sunspot cycle. The records of 1952 (not shown) were also examined. These records correspond to the minimum of the sunspot cycle and show that the critical frequencies of the F_2 layer were much less than in 1947.

It can be seen that f_o is never greater than 20 MC and hence no reflections are expected in the main beam from the F_2 layer.

During the night the highest electron densities occurred in the E region, but on no occasion were the critical frequencies as great as the F_2 values given in Table 2.

Side Lobes

From Eq. (9) the vertical critical frequency for oblique reflections at an angle of elevation may be computed. These values are given for α between 0° and 40° in Table 3.

Sample Calculation

$$f_o = f_c' \sqrt{1 - [\,(r \cos \alpha) \,/\, (r + h)\,]^2} \qquad (9)$$

$$= 30 \text{ MC} \sqrt{1 - \left(\frac{8.45 \times 10^3 \text{ km} \cos 25^0}{8.45 \times 10^3 \text{ km} + 200 \text{ km}}\right)^2}$$

$$= 30 \times 10^6 \sqrt{1 - \left(\frac{8.45 \times 10^6 \times 0.906}{8.45 \times 10^6 + 200 \times 10^3}\right)^2}$$

$$= 30 \times 10^6 \sqrt{1 - (7.66 / 8.65)^2}$$

$$= 30 \times 10^6 \sqrt{1 - (0.855)^2}$$

$$= 30 \times 10^6 \sqrt{1 - 0.784}$$

$$= 30 \times 10^6 \sqrt{0.216}$$

$$= 30 \times 10^6 \times 0.465$$

$$= 14.0 \text{ MC}$$

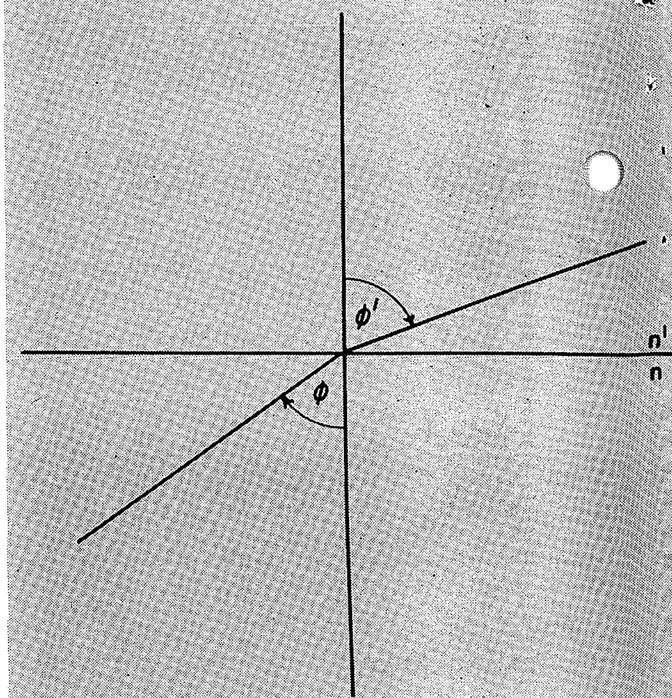

Fig. 4: Refraction from one medium to another.

Table 3
SIDE LOBE ANGLE

α	ϕ	f_o
0°	78°	6.72 MC
5	76	6.9
10	74	8.5
15	71	9.9
20	67	12
25	62	14
30	58	16
35	53	18
40	48	19.9

In the preceding example no interference will be obtained in the main lobe by reflection from the ionospheric layers. However, since it is difficult to design an antenna with no side lobes, it is necessary to examine the chart to avoid side lobes where they will degrade the system operation.

Acknowledgment

The author wishes to acknowledge that this article has been prepared from information derived from research conducted while a member of the Scientific Staff of Harvard College Observatory, working under the direction of Dr. Gerald S. Hawkins and Prof. Fred L. Whipple. In effect, this article is a general case of a specific problem faced by the Harvard Radio Meteor Project and debated by Dr. Gerald S. Hawkins (Radio Astronomer) and Mr. Martin L. Shapiro (Radio Engineer) in their paper, "Oblique Reflections at 32.8 MC."

References

1. Lovell, Clegg, *Radio Astronomy.*
2. Pawsey, Bracewell, *Radio Astronomy.*
3. Hawkins, Dr. Gerald S. and Shapiro, Martin L., "Oblique Reflection at 32.8 MC."
4. Revised edition of the Final Summary Report of The Harvard Radio Meteor Project, Sept. 14, 1956, by Prof. Fred L. Whipple, Dr. Gerald S. Hawkins—Contract AF 19 (122)—458 Subcontract 57.