SKYLINE BLOCKAGE

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One problem which sometimes faces DXers is that of signal blockage. High mountains or tall buildings can block signal paths, thus making DXing in certain directions very difficult. I faced this problem when I was DXing from Ojai, California, at a site about 700 feet above sea level, but in a valley surrounded by mountains up to 6000 feet high less than ten miles away. Fortunately it was a quiet location, and weaker signals could be heard there than in my present location in San Diego.

In this article I will show how you can figure out why particular stations which everyone else is hearing might not be heard by you, or why you can hear some station which you don't think you should.

In general, radio signals leave a transmitter at an angle close to the ground in order to travel as far as possible. The closer a signal path is to the vertical, the further it has to travel into the ionospheric layer in order to be refracted back to earth. Since it must travel further, it will also be absorbed more. On the other hand, a wave leaving the transmitter at a low angle will barely enter the ionospheric layer before it is refracted back to earth. (Figure 1)

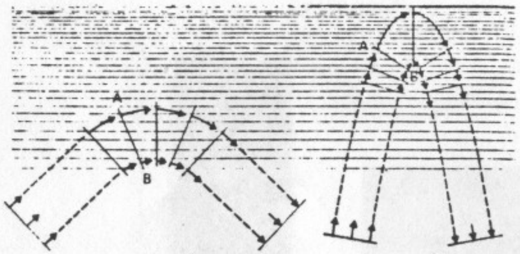


FIG. 1

If the earth were an infinitely long flat surface with a flat ionosphere above it, a wave leaving the ground would bounce back and forth between ionosphere and ground. A wave at a very small angle would travel an extremely long distance. Each reflection of the wave from the ground would cause a certain amount of energy to be lost; the same would be true for each refraction from the ionosphere. Consequently, a signal gets weaker as it travels further and makes more bounces. If two possible paths exist for a signal, the one which has the smaller number of skips ordinarily will retain more of its energy and bring a stronger signal to the receiver. (Figure 2)

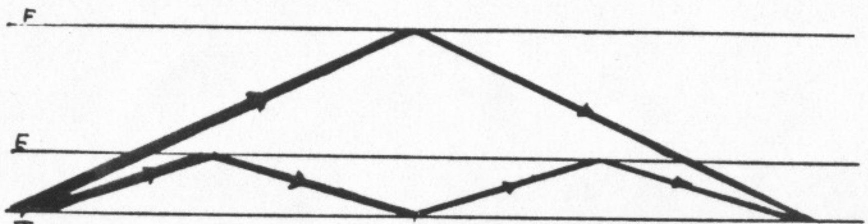


FIG. 2

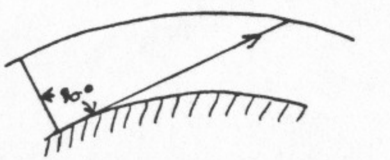


FIG. 3a

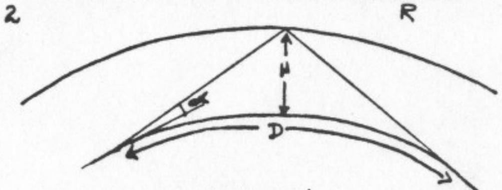


FIG. 3b

On the curved earth, skip distances increase also as the angle of the signal decreases. However, with a round earth, there is a maximum skip distance. When the angle of the wave is 0°, the signal comes in right along the horizon. (Figure 3a). Most stations, however, do not lie at exactly the proper distance for such an occurrence. Instead, they are at some other distance, and the signal arrives at the receiver at some other angle (Figure 3b). From geometric considerations, the following relationship can be derived between the angle at the center of the earth (which is related to the distance along the earth's surface), the height of the ionospheric layer, and the angle at which the signal arrives at the receiver:

$$\alpha = \sin^{-1}\frac{(H + R)\cos\theta - R}{\sqrt{2R(R + H)(1 - \cos\theta)}}$$

where R is the radius of the earth, θ is the angle at the center of the earth, and H is the height of the layer.

The following algorithm can be used to figure out at what angle a signal will arrive at the receiver site. A table of sines and cosines of angles is needed, as is some means of finding out square roots (a slide rule will do).

D = Distance in statute miles between transmitter and receiver.
N = 2 if D is less than 2400 miles
    4 if D is between 2400 and 4800 miles
    6 if D is between 4800 and 7200 miles
    8 if D is between 7200 and 9600 miles
V1 = D/N
V2 = V1 x 0.0144
V3 = cos V2
V4 = 1 - V3
V5 = 6680 x V3
V6 = V5 - 6380
V7 = $0.85 \times 10^8 \times$ V4
V8 = $\sqrt{V7}$
V9 = V6/V8
$\alpha = \sin^{-1}$ (V9); i.e., the angle whose sine is V9

The above algorithm applies to F-skip. For E-skip, the same procedure is used, with the following substitutions:

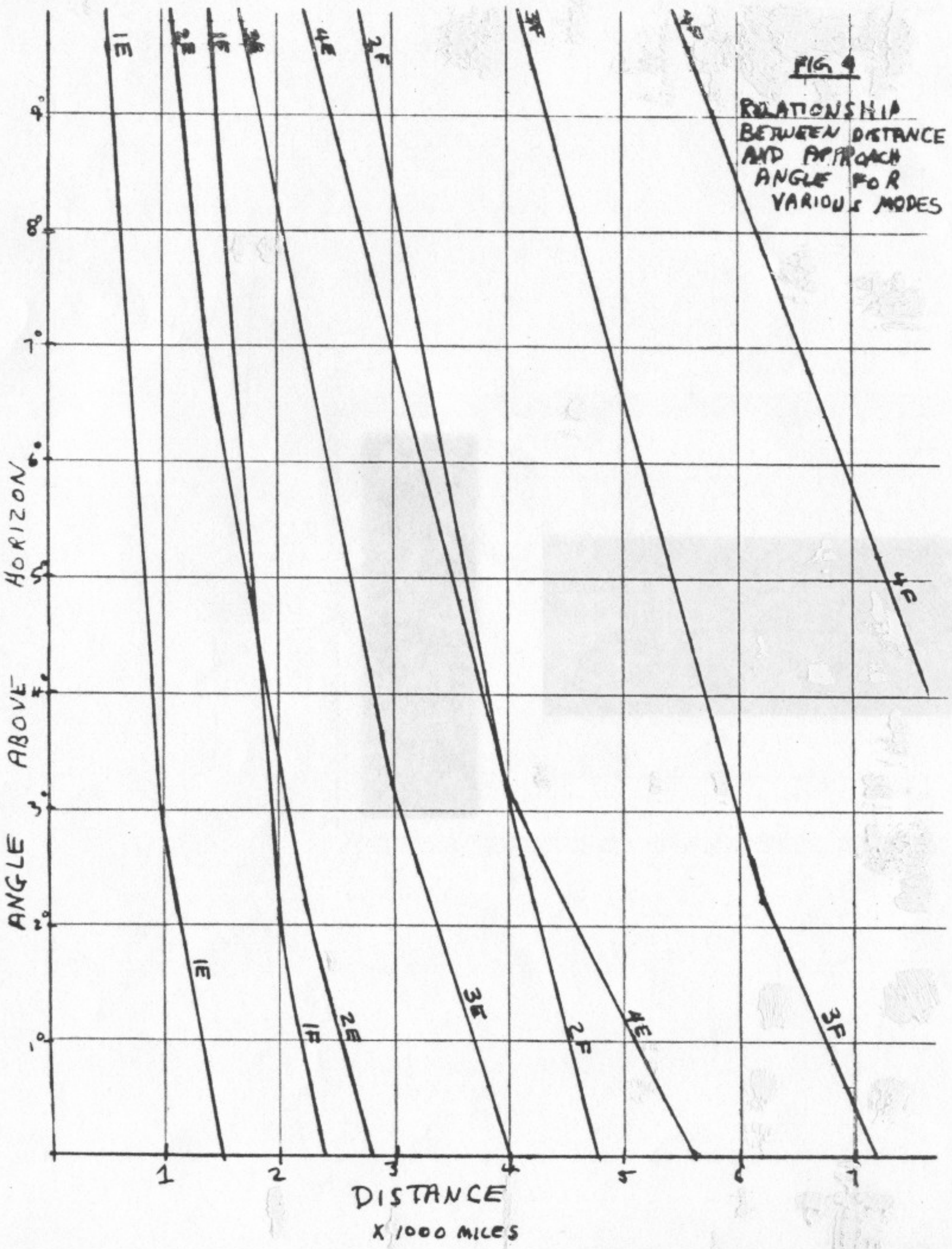
N = 2 if D is less than 1380 miles
    4 if D is between 1380 and 2760 miles
    6 if D is between 2760 and 4140 miles
V5 = 6480 x V3
V8 = $0.825 \times 10^8 \times$ V4

In these calculations, it is presumed that the F layer is at a height of 300 kilometers above the surface, and the E-layer at 100 kilometers. These values are not quite correct for every path. As mentioned above, a wave travelling at a steeper angle will penetrate further into the layer. However, for simplicity, the values above are presumed.

Examples: San Diego to Mexico City

1-F skip	2-E skip
D = 1435 miles	D = 1435 miles
N = 2	N = 4
V1 = 718	V1 = 359
V2 = 10.3°	V2 = 5.18°
V3 = .9839	V3 = .9959
V4 = .0161	V4 = .0041
V5 = 6560	V5 = 6450
V6 = 180	V6 = 70
V7 = 1.37×10^6	V7 = 33.8×10^4
V8 = 1.17×10^3	V8 = 5.81×10^2
V9 = .156	V9 = .124
$\alpha = 9^\circ$	$\alpha = 7^\circ 7'$

In the example, the E-layer wave arrives at a smaller angle than the F layer. This will not always be the case. It is also be possible to figure out in many cases, other modes which might be operating, such as 2-F or 3-E. Figure 4 is a chart showing possible propagation modes existing at different distances.



Now to get down to the problem at hand. A mountain on the horizon will block out waves approaching at a low angle if it is tall enough, or close enough, to form an angle larger than that of the approaching wave. For nearby hills, a simple approximation that the earth is flat can be used. (Figure 5). In this case, tan β = H/D, where H is the height of the hill and D is the distance away from you. Both H and D must be expressed in the same units--feet, yards, miles, etc.

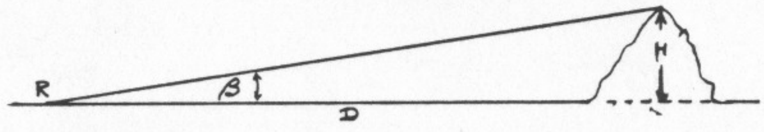


FIG. 5

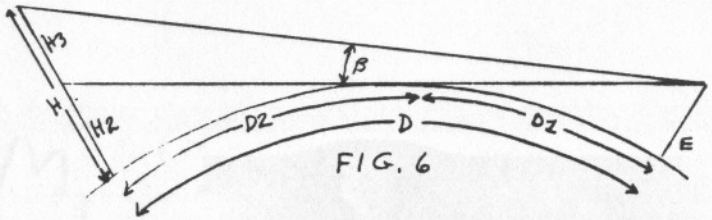


FIG. 6

For hills or mountains which are farther away, it is necessary to take the curvature of the earth into consideration. In this case, the bottom of the mountain will be hidden by the horizon, and the mountain will not subtend the same angle as it would if it were up close. To figure out the apparent height of the mountain, a relationship from Bowditch's American Practical Navigator, relating the height of an observer above sea level and the distance to the horizon, will be used. In Figure 6, E represents your elevation above sea level; H represents the height of the mountain above sea level, and D is the distance in miles between you and the mountain.

The apparent height of the mountain will be H - H2, where H2 is the part of the mountain hiddent by the horizon. Once the apparent height H3 is figured out, then the angle of blockage can be approximated by the method used above.

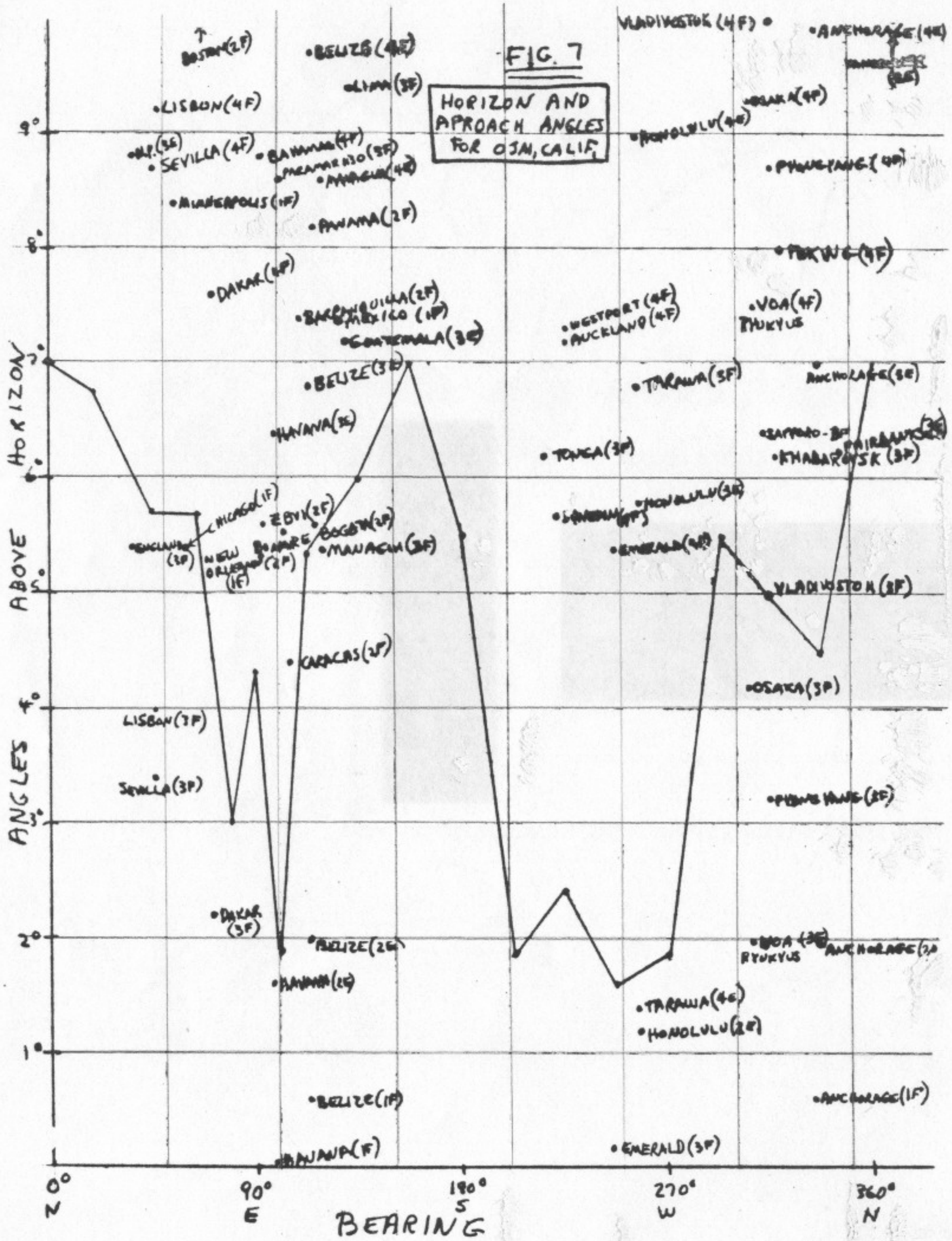
The following algorithm can be used to figure out the angle of blockage. A trig table of tangents of angles is needed.

E = Your elevation above sea level in feet
H = Height of the mountain above sea level, in feet
D = Distance to mountain in miles

1. Look up E in Table 1, call the corresponding value of d D1.
2. Compare D and D1. If D is larger than D1, then go to step 7. If D is smaller than D1, go on to step 3.
3. D3 = d x 5280.
4. H3 = H - E
5. T = H3/D3
6. Look up T in tangent table; find corresponding value of β
7. D2 = D - D1
8. Look up D2 in Table 1, find corresponding value of H2
9. H3 = H - H2
10. D3 = D x 5280
11. T = H3/D3
12. Same as step 6.

Once you have figured out the angles that are blocked by your local terrain and the angles of the incoming signals, it is easy to prepare a chart showing your horizon and the location of imcoming signals in relationship to it. Figure 7 is a chart which I recently prepared for my previous location in Ojai. (My horizon is pretty clear here in San Diego, so only signals coming in at the very lowest angles would be blocked in a couple directions.)

Notice that in several cases (Emerald, Australia, for instance), the signal arriving from the third F-layer skip is blocked, but the signal arriving from the fourth F-layer comes in over the local terrain. That means that I could pick up the signal, but much weaker than someone sitting on a hilltop overlooking the Pacific.



Fourth skip signals from Europe would have arrived above the mountains, but probably would have been so weakened by that extra skip in the auroral zone that they would not have gotten above the background noise. In fact, the only TA noted in Ojai was BBC-1214. Either a fourth skip did get through on that occasion, or my calculations of the angle of blockage and/or 3F skip angle are slightly inaccurate.

As can be noted from the chart, the only really clear portion of the horizon was to the Southwest. Experience bears this out. In the two years or so I DXed in Ojai, five or six Zedders were definitely logged and verified, whereas almost no Asiatic stations were even tentatively heard.

Havana poses an interesting problem. As can be seen, the only really clear path is by means of 3rd skip E-layer. Someone better versed in propagation might be able to say whether such a mode is possible, or whether it is more likely that second skip F-layer reception, at about 12° above the horizon, would be more probable.

I hope that these charts and algorithms will interest a few into doing some research into their blockage problems. If so, I hope to see the results published in the bulletins so that others can learn from our common problems.

TABLE I

Distance to horizon for various heights

Height, feet	Distance, miles	Height, feet	Distance, miles
50	9.3	2400	64.7
100	13.2	2500	66.0
150	16.2	2600	67.3
200	18.7	2700	68.6
250	20.9	2800	69.8
300	19.9	2900	71.1
350	24.7	3000	72.3
400	26.4	3100	73.5
450	28.0	3200	74.7
500	29.5	3300	75.9
550	31.0	3400	77.0
600	32.3	3500	78.1
650	33.6	3600	79.2
700	34.9	3700	80.3
750	36.2	3800	81.4
800	37.3	3900	82.4
850	38.5	4000	83.5
900	39.6	4100	84.5
950	40.7	4200	85.6
1000	41.7	4300	86.6
1100	43.8	4400	87.6
1200	45.6	4500	88.5
1300	47.6	4600	89.5
1400	49.4	4700	90.5
1500	51.1	4800	91.4
1600	52.8	4900	92.4
1700	54.4	5000	93.3
1800	56.0	6000	102.2
1900	57.5	7000	110.5
2000	59.0	8000	118.1
2100	60.5'	9000	125.2
2200	61.9	10000	132.0
2300	63.3		

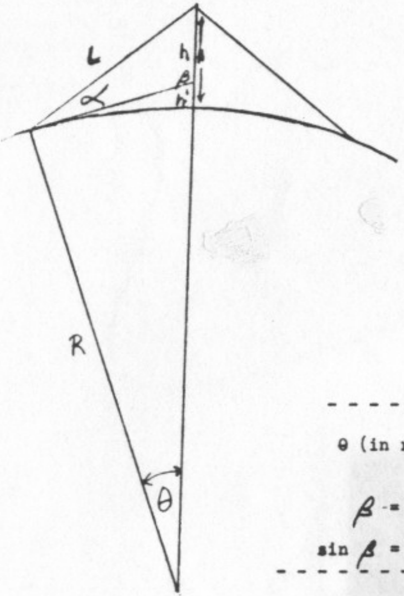
TABLE II

Data on local terrain, Ojai, California

Bearing degrees	Height, feet	Distance, miles	
0	3800	4.8	7°
22.5	5200	7	6°47'
45	5200	8.5	5°43'
67.5	6000	10	5°43'
80	4840	15	3°
90	1700	2.5	4°20'
100	1000	1.8	1°50'
117.5	2725	4	5°23'
135	2500	3.25	6°
152.5	2000	2	7°
180	2000	2.5	5°29'
202.5	1200	3	1°50'
225	850	0.7	2°21'
247.5	1800	7.5	1°37'
270	2200	9	1°50'
292.5	4400	7.3	5°30'
315	3000	5	5°
337.5	3600	7	4°30'

E = 700 feet

T3-4-4



Derivation of formula used for figuring out angle of arrival of signals

R = radius of earth
h' = height added to R to reach tangent line AJ
h = apparent height
θ = angle at center of earth
D = distance from transmitter T to receiver A

From law of sines, $\frac{L}{\sin\beta} = \frac{h}{\sin\alpha}$,

$\sin\alpha = \frac{h \sin\beta}{L}$ (Equation 1)

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θ (in radians) $= \frac{D}{2R}$

$\beta = 90 + \theta$

$\sin\beta = \cos\theta$ (Equation 2)

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$h = H - h'$

$\cos\theta = \frac{R}{R+h'}$

$h' = \frac{R}{\cos\theta} - R$

$h = H + R - \frac{R}{\cos\theta}$ (Equation 3)

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from law of cosines, $L^2 = R^2 + (R + H)^2 - 2R\,(R + H)\cos\theta$

$L^2 = 2R(R + H)(1 - \cos\theta)$ (Equation 4)

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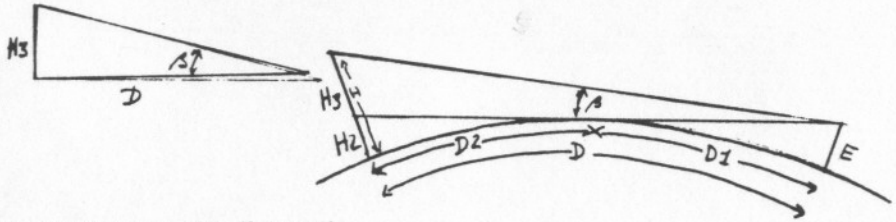
Substituting Equations 2, 3 and 4 into Equation 1, we get

$$\alpha = \sin^{-1} \frac{(H + R - R/\cos\theta)\cos\theta}{\sqrt{2R(R+H)(1 - \cos\theta)}} = \sin^{-1} \frac{(H + R)\cos\theta - R}{\sqrt{2R(R + H)(1 - \cos\theta)}}$$

Derivation of formula used for blockage angle



For approximation with flat earth,

$\beta = \tan^{-1} \frac{H3}{D}$

For curved earth,

$H3 = H - H2$

$D2 = D - D1$

$D1 - 1.32\sqrt{H1}$, where D is in miles and H1 is in feet

$D2 = 1.32\sqrt{H2}$

$H2 = \left(\frac{D2}{1.32}\right)^2$

$H3 = H - \left(\frac{D2}{1.32}\right)^2$

$H3 = H - \left(\frac{D - D1}{1.32}\right)^2$

$H3 = H - \left(\frac{D}{1.32} - \sqrt{H1}\right)^2$

$\beta = \tan^{-1}\left(\frac{H3}{D}\right)$

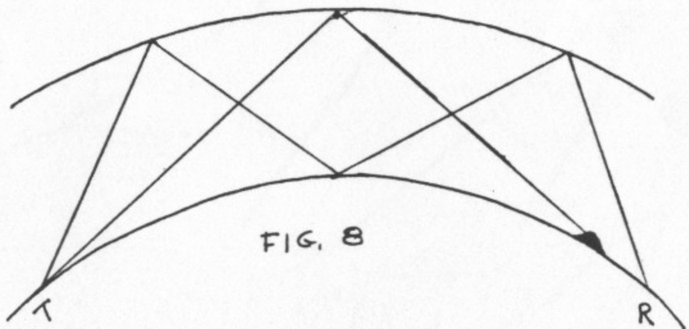


FIG. 8