L-O-S RADIO LINKS, CLEARANCE ABOVE TALL BUILDINGS

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SUMMARY

Tall buildings can obscure Line-of-Sight radio links. This paper outlines an algorithm for checking whether or not a given obstacle is likely to cause disruption of communication.
We have developed an engineering data-base which includes all R-F emitters in Israel[3], as well as DTM, propagation-path loss, graphics etc. Thus we can ensure making optimal use of the R-F spectrum without causing harmful interference.

This computer-aided program also checks that any new 7-storey or higher building will not penetrate protected Fresnel zone of radio links. We do not use the method for the design of new radio links against obstructions because our DTM does not include buildings. We do, however, provide maps drawn to scale, representing the L-O-S radio links and the restrictions on the max. height of any building along the path. Thus the algorithm enables us to build, in expensive areas, up to the max. permissible height, without deterioration in performance.

INTRODUCTION

1. The national data-base provides all the needed data of the radio link.
Sites A & B coordinates ; height of the tower above sea level and that of the antenna above ground. Topographic profile is obtained by Digital Terrain Mapping. Frequency is taken as the average of the two receiving together with the two transmitting frequencies.

2. The graphics provide maps of all links as required, including Fresnel zones. These drawings are very helpful for the prediction of RFI among links[3]. When drawn on a map to scale, we thus have a useful tool for planning committees, for the determination of restrictions on the permissible height of new buildings being planned.

3. This paper deals with obstruction in the far-field zone. Fresnel zone considerations apply only to obstacles in the far-field zone which is defined by the inequality $d > 2DxD/\lambda$ where:
d=distance
D=antenna diameter measured in the same units as λ.

A. FRESNEL ZONES

1. Fig. 1 shows Fresnel zones 1 and 2. The first Fresnel zone is defined by the boundary of the indirect paths of length $d + \lambda/2$, where d is the the total direct path distance, and λ is the wave-length. This is the inner circle.
The second Fresnel zone is the circle, perpendicular to the path, for which all possible indirect paths trace a length of $d+2\lambda/2$ ref(2). The Fresnel boundary is an ellipsoid in space, whose perpendicular distance from the L-O-S of the link is an essential factor in the determination of the required clearance from obstacles in radio links.

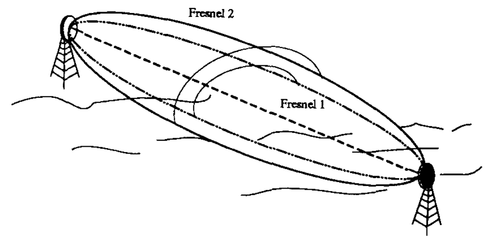


Fig. 1 : Fresnel zones

2. Using the Pythagoras theorem, and the linear approximation of square root, F_1 - the first Fresnel radius is given by :

$$\sqrt{\{(\lambda d_1 \times d_2)/d\}}$$

where

d_1 = distance to the near end of the path ;

d_2 = distance to the far end of the path ;

d = total path length .

F_1 is in the same units as d_1, d_2, d .

Taking d in km , f in GHz - we get

$$F_1 = 17.32\sqrt{\{(d_1 x d_2) / (fxd)\}} ;$$

$$F_2 = 24.5 \sqrt{\{(d_1 x d_2) / (fxd)\}} .$$

Similary, the radius Fn of the n'th zone is given by: $\mathbf{F_n = (\sqrt{n}) x F_1}$.

The Fresnel zone grows with increasing distance d_1 from the near-end, reaching it's maximum halfway along the link. The zone decreases with increasing frequency.

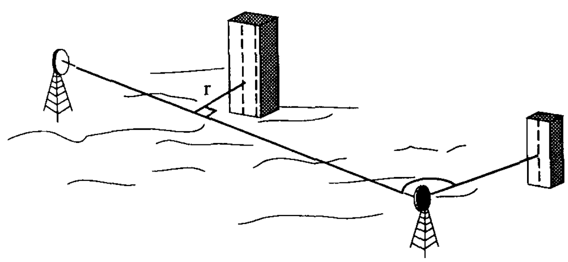


Fig. 2 : Obstructions to R-F links

Diffraction attenuation occurs *if more than* 0.5-0.7 of the first Fresnel zone is obstructed by obstacles, consequently such a situation must be avoided.

3. The analysis of the problem is performed in two orthogonal planes. In dealing with a national data-base of µwave links, we begin by screening the links in the horizontal plane. The search for obstructions is made as indicated in Fig. 3.

B. TOP-VIEW

4. R in Fig. 3 represents Fresnel zone + the approximate size of the inspected building at C. The computer extracts all the links whose distance from point C is less than R.

a. To save computing time, we search only for those links which cross a square (not a circle) of 2R side : A_2-B_2 & A_3-B_3 only (see Fig. 3).

b. we distinguish between two different cases
   - building <u>on</u> the line joining the two end-points of the link : cos A > 0 ;
   - building <u>off</u> the above mentioned line: cos A < 0.

c. For the first case, the distance C to A_2-B_2, is the height of the triangle ABC; r is a distance from "point to line".

d. In the second case, r is the distance C to A_3-B_3 (to the nearest end-point). Distance to the link is irrelevant.

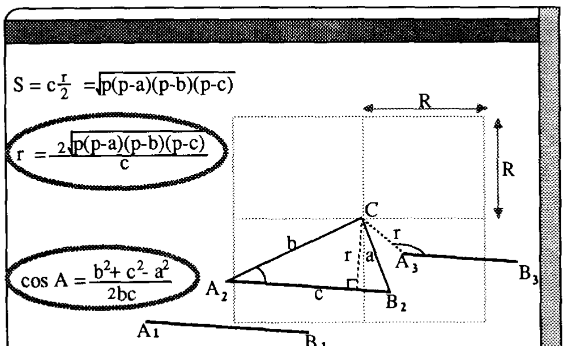


Fig. 3 : *POINT "C" TO LINK "AB"*

e. Even though the most disturbing reflections enter through the mainlobe, there is an interference caused by reflections from the building at point C (near the antenna at A_3) to the link. Those reflections enter via the side-lobes.

f. Fig. 5 describes the antenna pattern envelope. Fig. 6 details the algorithm of our approximation to ant' side-lobe levels. Fig. 7 displays a typical calculated pattern.

(Those Fig's appear in appendix A).

g. The approximation is based on references 4, 5. We compared our estimate pattern with the radiation pattern envelope of Antenna type number P6-122D.

   The calculated side lobes envelope lies between the given vertical and horizontal patterns.

5. Throughout the analysis in the horizontal plane we assume an Euclidean geometry. For links shorter than 100 km the assumption of "flat earth" allows determination of ranges with adequate accuracy (unlike determination of angles).

The distance from the building to the path of the radio link in Fig. 3 is : Twice the triangle area divided by the path-length of the link, see formulae in Fig. 3.

The least significant digit in UTM coordinates (6 digits for longitude, 7 for latitude) represents meters. Thus the square root of the sum of squares of coordinates δX & δY gives the values of a, b, c in meters.

The approximation avoids the need for the transformation to geographical coordinates and calculations. Such transformation is utilized only for the accurate determination of angles. That is important for antenna installations and directions relative to the north.

Cartographic examination of the range errors, has proven that "δd" is less than d/1000 , if the distance is measured in the eastern part of extended sector number 36; δd ≈ d/6000 near the southern border of ISRAEL.

C. SIDE VIEW

6. Only those links which are less than distance R from the specified building, are further analysed in the vertical plane.

Here the examination is more complicated. We check that the building does not obscure the extended Fresnel zone. In addition to diffraction problems, in the vertical plane the R-F propagation is affected by changes in "n"- the refractive index of the air.

The k-factor is the effective earth-radius factor. The nominal value k=4/3 does not represent the severe cases when the effective radius of the earth is smaller than Ro=6370 km.

The ray of the µwave radio link bends downwards for k > 1, the earth is "flattened" ; conversely, the ray bends upwards for k < 1 - the earth is "bulging". The design range of k is from 2/3 to 4/3.

The "earth bulge" at any point on a radio path is given by: $h = (d_1 d_2) / (12.75K)$; (m).
d_1, d_2 in km to the near and far ends, respectively.

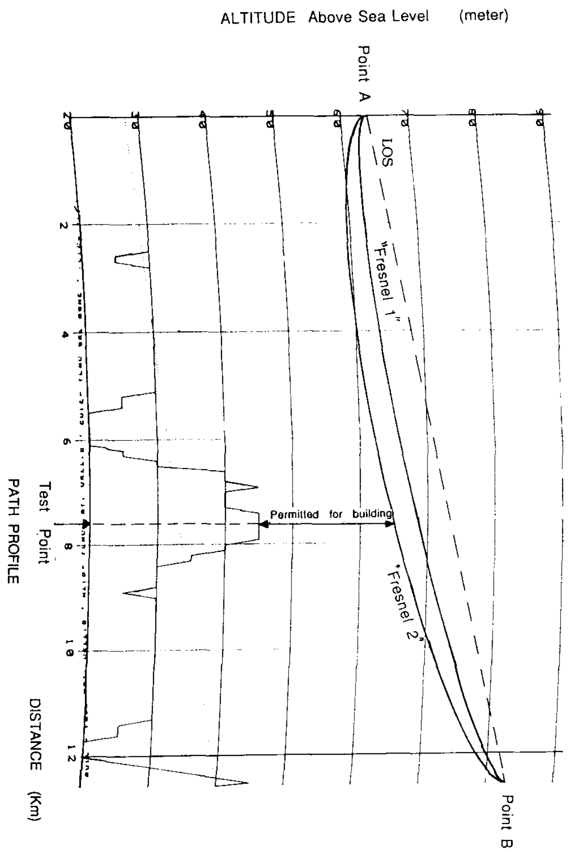


Fig. 4: Path Profile

Fig. 4 shows a path profile from our computer, it is a graphical representation of a radio link-12.5 km distance between end-points.

The range - from the corrected Fresnel ellipse to the topographic map - is the permitted height of the specific building.

The building location, in the grid on the profile, is not trivial. Only in the case when point "C" lies on the segment AB (cos A = 1), is "C" exactly on the path profile in Fig. 3.
Else, we need the third dimension in the profile - depth. The horizontal distance r("C from AB" in Fig. 3) is small (≈ Fresnel -); so only in extreme topographical conditions an error may occur : the range from the building to the Fresnel profile above is different from the one presented.

7. References (1,2) detail some rules used for determining the maximum height permitted for the potentially obstructing building. For high reliability radio links, all rules are tested. On some occasions the result is objection to the high building, or requirement for higher antennas at the end-points.

The rules are Ref(2):

a. clearance of $.577F_1$ over obstructions with k=0.7

b. clearance of 1.0 F_1 over obstructions with k=4/3

c. clearance of 0.3 F_1 over obstructions with k=2/3

Ref(1) Freeman uses k = 0.92 $r = 0.6F_1$

(Where F_1 is the first Fresnel zone radius).

Thus in the elevation path profile, we add 3 elements to check clearance:

a. Fresnel zone
b. Earth curvature or earth bulge
c. Building height

8. In the output shown in Fig. 4

d = 12584 m, λ = 2.3 cm, F_1 = 8,5 m, k=4/3, bulge=2m

Point A is an antenna mounted on a tower 64 meters A.S.L, 36 meters above ground.

Point B is an antenna mounted on a tower 83 meters A.S.L, 42 meters above ground.

We see different scales in horizontal and vertical coordinates. Obstacles are obstructions when the height of the building touches the relevant ellipse joining the end-points.

CONCLUSION

This program works and provides quick answers to planning committees with regard to the permissible height of buildings in urban areas. Our system is also useful in checking for possible obstruction of μwave links by wind-driven generators, as these are erected on hilltops.

The algorithm may be used to protect other R-F systems from the effects of obstacles, especially Acquisition & Search RADAR.

Communications on frequencies below 0.5 Ghz are less affected by obstacles, and thus not protected by this method.

REFERENCES

1. Freeman, R.L.: RADIO SYSTEM DESIGN FOR TELECOMMUNICATIONS (1-100 GHz) ; (Wiley, 1987).

2. Townsend, A.A.R.: ANALOG LINE OF SIGHT RADIO LINKS. A TEST MANUAL (Prentice/Hall 1987).

3. Mazar (Madjar) Haim & Monovich Avishai : LINEAR INTERFERENCE ALGORITHM & RELIABILITY OF R.F. SYSTEMS (EIGHTH INTERNATIONAL CONFERENCE OF THE ISQA - JERUSALEM); Nov' 1990.

4. ITU/CCIR Recommendation 465-2: RADIATION PATTERN IN FREQ. 2-30 GHz.

5. ITU RADIO REGULATIONS, edition 1990; Receiving antennas AP30 (Orb-85) - 251

APPENDIX A.

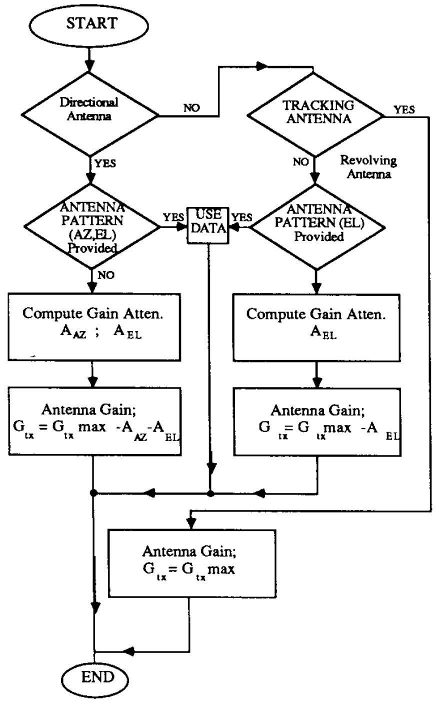


Fig. 5: **ANTENNA PATTERN ENVELOPE**

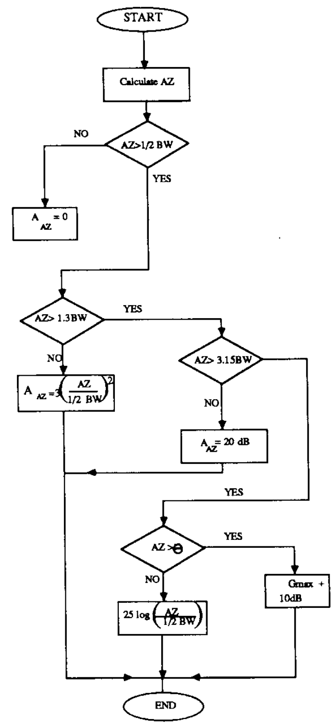
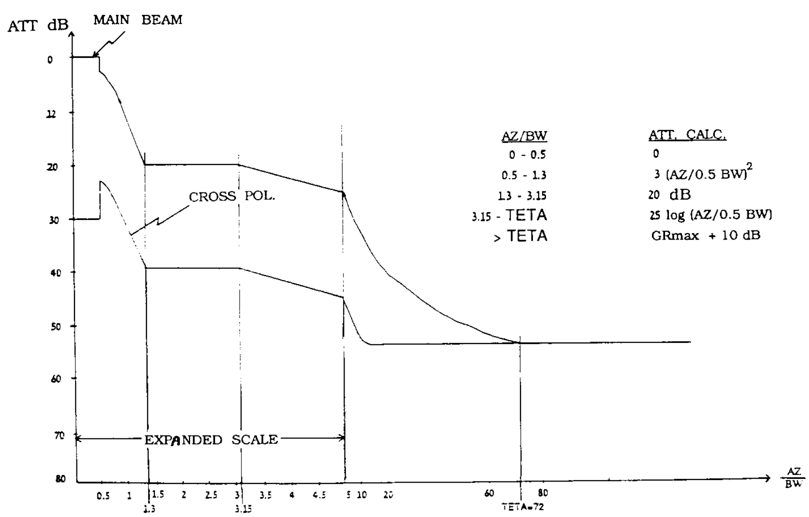


Fig. 6: **ANTENNA PATTERN CALCULATION**



CALCULATED ANTENNA ENVELOPE

Fig. 7: displays a typical calculated pattern