ANALYSIS OF MULTIPATH FADING WITH APPLICATION TO MICROWAVE LINKS IN EGYPT

by

Samir F.Mahmoud*, Hoda N.Baghdady** and Osman L.El-Sayed*

*Electronic Engineering, Dept., Cairo Univ., Giza, Egypt

**National Telecom. Institute , Nasr City, Cairo, Egypt.

Summary:-

Multipath propagation on microwave line of sight (LOS)links present one of the most severe problems to high performance communication on such links. Beside the strong signal fluctuation at times of fading, it leads to signal distorsion caused by ferfrequency selective fades.

Considerable effort has been devoted to the study of multipath propagation on LOS links during the last two decades. Ikegami [1] defined attenuation and interference regions associated with a modified refractive index profile made up of linear segments of distinct slopes. Ruthroff [2], in one of the most quoted articles, gives a rigorous analysis for the case of a refractive index of a bilinear profile. The major limitation of his model, however, is that earth's curvature has been completely ignored. To alleviate this limitation, Pickering and DeRosa [3] have used a modified refractive index with a flattened earth's model. More recently, Webster[4],[5] has obtained the angles of arrival, amplitudes and time delays of the rays by numerical ray tracing. Such numerical approach is expected, however, to consume considerable computer time and will not provide the much-sought insight into the interplay of the various physical parameters of interest.

In the present paper,we adopt the model in [3] and arrive at a novel graphical solution to the launching and arrival angles of the rays. Simple formulae and graphs are presented for the number of received rays for a given geometry and refractive index profile. In addition, the time delay and amplitude of each ray are derived in simple forms, hence the transfer function of the link is obtained. Finally comparison with measured signal on existing LOS links in Egypt in the 6.6 and 11 GHz bands is made.

The basic geometry is shown in Fig. 1 a,b along with some of the first few rays. The modified refractive index is used to account for earth's curvature, and is assumed to have a bilinear profile as shown. An example of higher order rays (multiply refracted) is shown in Fig. 1 c. Now, consider the situation in Fig. 1a and define the following quantities:

$$H_s = \tfrac{1}{2}(h_t+h_r)8R_o/L^2, \quad H_d = \tfrac{1}{2}(h_r-h_t)8R_o/L^2$$

$$k_{1,2} = (R_o/ L)(\sin \theta_r \mp \sin \theta_t),$$

then it is shown that k_1, k_2 and H_s are related by:

$$\frac{[k_1 - 1/(y^2+1)]^2}{(Ky)^2} + \frac{k_2^2}{(K(y^2-1)^{\frac{1}{2}})^2} = 1 \qquad .... \quad (1)$$

where $y = \ell(1 + R/R_o)$

$K = [1 - (y^2-1)H_s]/(y^2+1)$

and $\ell = 1,2$ ... accounts for the multiple refraction of the ray. Equation (1) is obviously the equation of set of ellipses centered at $(1/(y^2+1), 0)$ in the (k_1,k_2) plane, each has a major axis = Ky, minor axis = $K(y^2-1)^{\frac{1}{2}}$ and a focal length =K which is a function of H_s. Another relation exists between k_1, k_2 and H_d and is:

$$2\, k_1\, k_2 = H_d \qquad .... \quad (2)$$

which is the equation of a set of hyperbolas in the (k_1,k_2)plane with H_d as a parameter.

The desired solutions for k_1 and k_2(hence for θ_t and θ_r) are thus given by the intersection of the ellipse given by(1) for the given H_s and the hyperbola in (2) corresponding to the given H_d. Such graphical solution is illustrated in Fig. 2 for the special case y=5/4 (ℓ= 1 and R/R_o = 1/4). Notice that H_s has an upper limit equal to $1/(y^2-1)$ at which the ellipse collapses into a point and then the direct ray is the only ray that reaches the receiver. For a given $H_s < 1/y^2$, there are values of H_d between which two refracted rays exist, above which no refracted ray exist and below which there are four such rays. To count the number of refracted rays easily, relation between H_d and H_s for coincident solutions (two equal roots of k_1 and k_2) are derived. Regions corresponding to 0,2 and 4 rays in the (H_s-H_d) plane are shown in Fig. 3 for y=5/4.

Similar graphical solution is obtained for the case when one of the terminals inside the inversion layer (Fig. 1b) and when both terminals are inside the layer. The time delay and amplitude of each ray are derived.

In conclusion, we find that in ranges of heights h_t and h_r that allow 3 or 5 rays to exist deep fading is more probable to occur than at lower heights, where more than 5 rays exist. In the later, signal enhancement occurs since the inversion layer acts then as a duct and the antennas are well comled to it. In this case mode theory would be more appropriate [6] than the ray approach. Finally, signal recordings on existing links in Egypt are interpreted in view of the present model results.

References:-

[1] F. Ikegami, "Analysis of microwave fading ..", Review of the electrical communication laboratory, Vol.15, No. 7,8, July-Auguat 1967.

[2] C.L. Ruthroff, "Multipath fading on line ...", Bell System Tech. Journal, Vol. 50, No. 7, pp. 2375-2389, 1971.

[3] L.W. Pickering and J.K. DeRosa, "Refractive multi- path model ...", IEEE Trans. on Comm. CoM. 27, No. 8, 1979.

[4] A.R. Webster, "Raypath parameters ...", IEEE Trans. on AP., Vol. 30, No. 4, pp. 796-800 April 1982.

[5] A.R. Webster, "Angles of arrival ...", IEEE Trans. AP. Vol. 31, No. 1, pp. 12-17, Jan. 1983.

[6] J.R. Wait and K.P. Spies, "Internal guiding of microwaves ...", Radio Science, Vol. 4, No. 4, pp. 319-326, 1969.

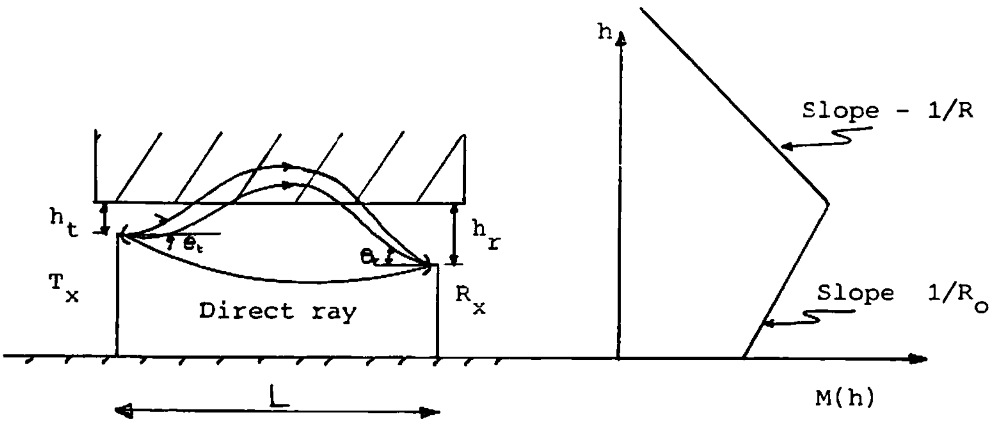

Fig. 1.a Flattened earth's model

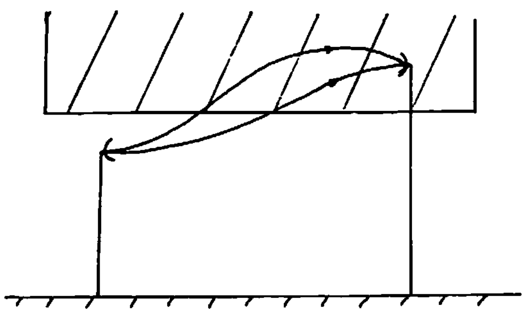

Fig. 1.b

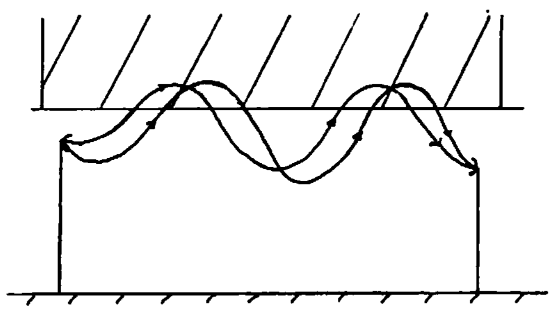

Fig. 1.c Example of multi - refracted rays.

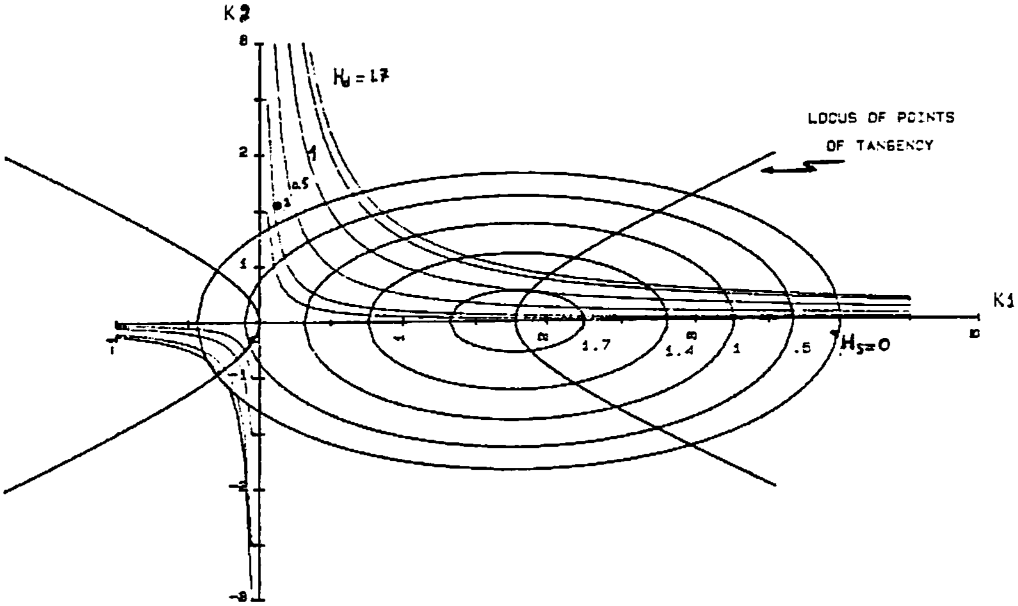

Fig 2 GRAPHICAL SOLUTION FOR K1 AND K2

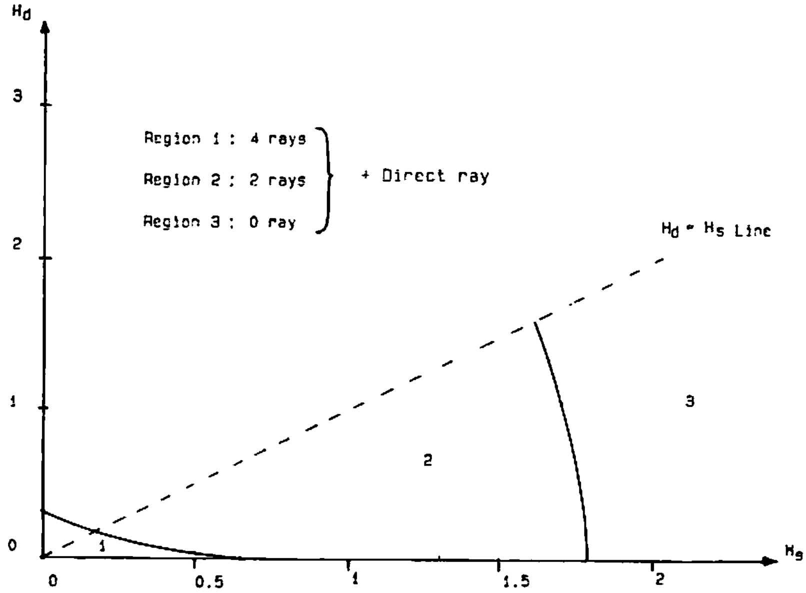

Fig 3 REGIONS OF 0, 2 and 4 RAYS IN THE H_s - H_d PLANE