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MICROWAVE DIVERSITY ANTENNA SPACING FOR SPECULAR REFLECTION PATHS

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An important problem in over-water paths is reflection fading. One solution to reduce this effect is the application of space diversity (vertically spaced antennas) or frequency diversity. The basic question is to achieve optimum spacing between antennas or frequencies. In a flat-earth geometry the spacing is easily obtained [1]. An empirical correction to improve this result was suggested by Boithias and Battesti [2]. Another approach was proposed more recently by Vigants [3], where the reference was also the flat-earth case. However the best way to analyze this problem is to take into account the statistical behaviour of the effective earth radius. This approach is considered in this paper for the case of dual space diversity. Although our results can be applied to any refractive index gradient distribution, they are considered here in connection with a normal distribution.

The basic geometry is shown in figure 1. The necessary, but not sufficient, condition for simultaneous fading (received signal in both antennas below a specified level L) is given by,

$$n\pi - \theta \leq \frac{\pi\Delta}{\lambda} \leq n\pi + \theta \quad ; \quad n=1,2,... \tag{1}$$

where

$$\theta = \cos^{-1}\left(1-\frac{L^2}{2}\right) \quad ; \quad \Delta = \frac{2\ell}{d}\left[h_1 - \frac{h_1^2\, d^2}{2a_e(h_1+h_2)^2}\right]$$

$a_e = ka$ - effective earth radius; $k = \dfrac{1}{1+a\ dn/dh}$

dn/dh - refractive index gradient; λ - wavelength

From (1) we can define an upper bound for simultaneous fading probability $P(E_1 \leq L, E_2 \leq L)$, i.e.,

$$P(E_1 \leq L, E_2 \leq L) \leq \sum_{n=-\infty}^{\infty} P\left[n\pi - \theta \leq \frac{\Delta\pi}{\lambda} \leq n\pi + \theta\right] = P(\Delta)$$

If we know the refractive index distribution the probability density function $p(\Delta)$ can be computed. The expression for $P(\Delta)$ then reads,

$$P(\Delta) = \sum_{n=-\infty}^{\infty} \int_{\lambda(n-\theta/\pi)}^{\lambda(n+\theta/\pi)} p(\Delta)\, d\Delta \tag{2}$$

In the special case where the refractive index gradient in normally distributed, $p(\Delta)$ will follow the same distribution. In this case $P(\Delta)$ is given by,

$$P(\Delta) = \sum_{n=-\infty}^{\infty} \{Q\left[\frac{\lambda(n-\theta/\pi)-m}{\sigma}\right] - Q\left[\frac{\lambda(n+\theta/\pi)-m}{\sigma}\right]\} \tag{3}$$

where

$$Q(x) = \int_{x}^{\infty} e^{-\alpha^2/2}\, d\alpha$$

and m and σ are, respectively, the median and standard deviation of Δ distribution.

In the numerical example presented here we will assume the median value of k as 4/3 and the value exceeded in 99,9% of time as 0,8 (typical values for temperate dimate). For these values me have,

$$m = \frac{2\ell}{d}\left[h_1 - \frac{3h_1^2 d^2}{8a(h_1+h_2)^2}\right] \tag{4}$$

and

$$\sigma = 0,16\, \frac{\ell}{a}\, \frac{h_1^2 d}{(h_1+h_2)^2} \tag{5}$$

Introducing (4) and (5) in (3), we finally arrive at,

$$P(\Delta) = \sum_{n=-\infty}^{\infty} \{ Q\left[(\frac{n-\theta/\pi}{\ell_n} - 1)c - 4,69\right] - Q\left[(\frac{n+\theta/\pi}{\ell_n} - 1)c - 4,69\right]\} \tag{6}$$

where

$$c = 12,5\, \frac{(h_1+h_2)^2}{h_1\, d^2}\, a$$

and

$$\ell_n = \frac{2h_1}{\ell d}\,\ell \quad \text{- normalized spacing}$$

An application of (6) can be described in the following steps. The value of c is fixed from link data (distance and antenna heights). Once it is specified the reference level L, from (6) we can compute $P(\Delta)$ as a function of normalized spacing ℓ_n. This procedure is exemplified in figure 2 for the case of c=12 (typical value for a microwave link) and L=20dB. In this situation we must choose the ℓ_n=0,65, correspondig to minumum value of $P(\Delta)$.

Other numerical results and universal curves will be presented in the final form of this paper, including a discussion on the application of flat-earth geometry. According the development here, it will be shown that this result is valid for large c. This case is important when h_1 is small and h_2 large.

REFERENCES

1. H. Brodhage and W. Hormuth, "Planning and Engineering of Radio Relay Links", Siemens Aktiongesellschaft, 7th edition, Berlin 1968.

2. L. Boithias and J. Battesti, Ann. des Télécom. vol. 22, pp. 230-242, September- October 1967.

3. A. Vigants, Bell System Technical Journal, vol. 54, pp 103-142, January 1975.

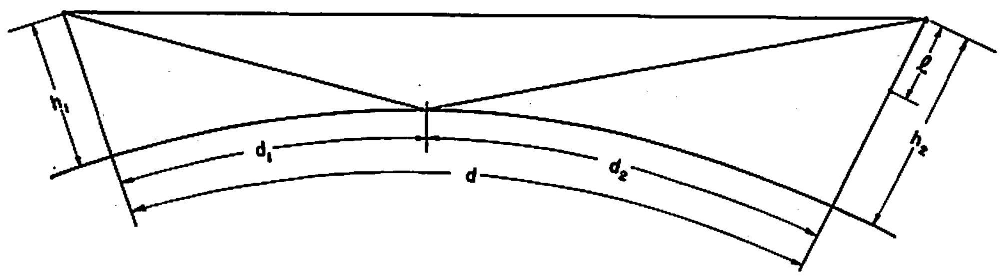

Figure 1

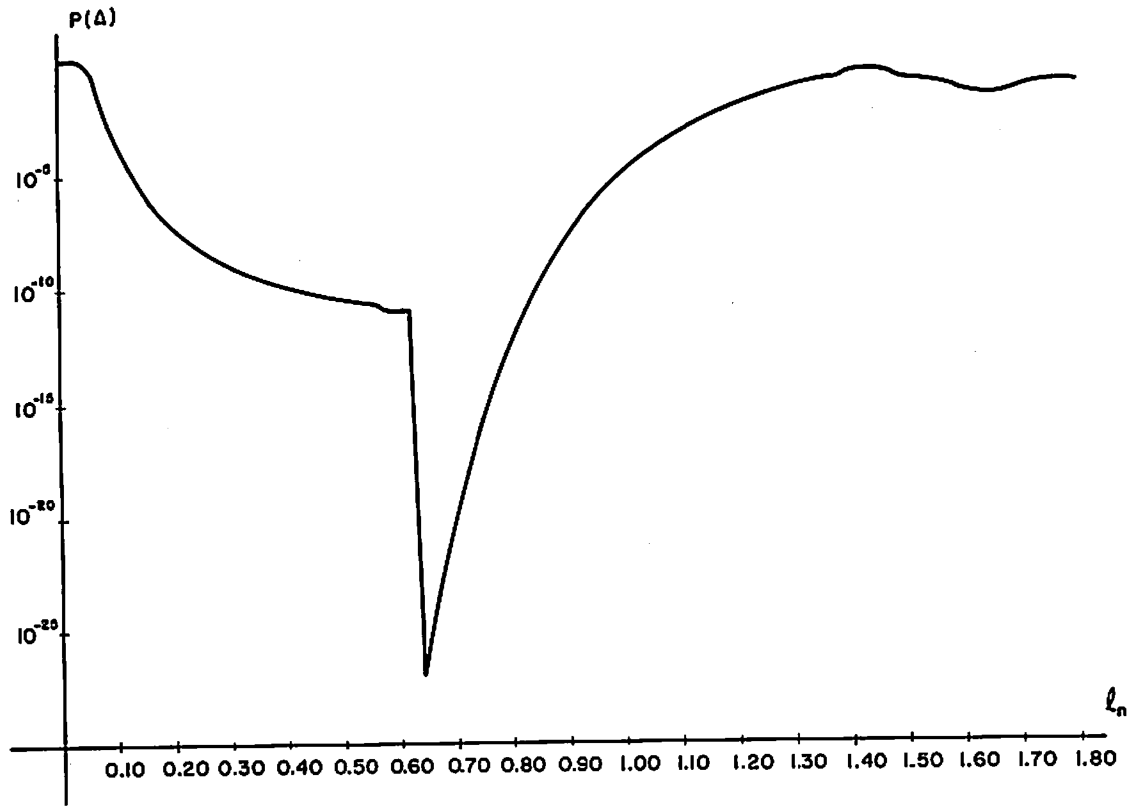

Figure 2