OPTIMUM ANTENNA SPACING FOR DIGITAL RADIO LINKS

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B R A Z I L

1. INTRODUCTION

Digital radio links are subject to frequency selective fading due to multipath propagation. When this phenomenon occurs the transmission performance can be seriously affected. Space diversity reception with two vertically separated antennas is commonly used to protect digital radio systems against multipath fading. The basic question when employing this technique is how to fix the spacing between antennas. The geometrical nature of this type of fading induces the existence of an optimum spacing, which must be dependent on link data. Based on the two-ray model, this problem is discussed here together with some remarks about the difficulty to identify the origin of the main contribution to multipath fading (reflection from an atmospheric layer or from the ground surface).

2. MATHEMATICAL FORMULATION

According to the two-ray model shown in figure 1, the normalized received field is given by

$$E = 1 + K \exp\left[- j\, 2\, \pi\, f\, \tau\right] \qquad (1)$$

where f is the frequency, K is the normalized amplitude of the reflected ray and τ its relative delay. Assuming $h_{1,2} \ll d$, it is easy to show that

$$\tau \simeq \frac{2h_1h_2}{cd} \qquad (2)$$

being c the velocity of light.

In the case of dual space diversity reception (see figure 2) we have

$$E_1 = 1 + K_1 \exp \left[- j2\pi f\tau_1\right] \qquad (3)$$

for antenna 1, and

$$E_2 = 1 + K_2 \exp \left[- j2\pi f\tau_2\right] \qquad (4)$$

for antenna 2.

The vertical spacing s is given by

$$s = \frac{c\ d\ \Delta\tau}{2h_1} \qquad (5)$$

where $\Delta\tau = \tau_1 - \tau_2$

Assuming $K_1 = K_2$, it is clear from (3) and (4) that to cancel the reflected ray $\Delta\tau$ must satisfy

$$\Delta\tau = \frac{1}{2f} \qquad (6)$$

Introducing (6) in (5) we finally arrive at

$$s = \frac{cd}{4f\ h_1} \qquad (7)$$

In the application of (7) the major problem is to estimate the value of h_1. To solve this question it is necessary first to identify the origin of the reflected ray, i.e., from ground surface or from an atmospheric layer. In the case of ground reflection, once fixed the reference level the value of h_1 is clear. However, if there is any difficulty to define this reference an indirect procedure can be used. For instance, the height h_1 can be derived from the knowledge of the average delay ($\bar{\tau}$) in the propagation path. Taking equation (2) into account and introducing the path inclination

$$\varepsilon = \frac{h_1 - h_2}{d}, \qquad (8)$$

we obtain a second-order equation where h_1 is given by

$$h_1 = \frac{\varepsilon d + \sqrt{(\varepsilon d)^2 + 2\bar{\tau}\ cd}}{2} \qquad (9)$$

3. NUMERICAL EXAMPLE

The optimum spacing given by (7) will be compared with theoretical results derived from a computer simulation developed by Silva [1]. In this simulation the improvement associated to dual vertical space diversity is given by the relation between system signatures without and with diversity reception. The radio path treated by Silva has the following data:

$d = 40$ km

$f = 6$ GHz

$\varepsilon = 2{,}9$ mrad

$\bar{\tau} = 0{,}74$ ns

According to Silva [1] for an improvement better than 1000 the vertical spacing is located in the range from 3 m to 4.8 m. The corresponding optimum spacing given by (7) is 3.4 m.

4. REFERENCE

1. SILVA, R.E., "Space Diversity in Digital Radio Systems" (in Portuguese), MSc Thesis, Catholic University, Rio de Janeiro, March 1988.

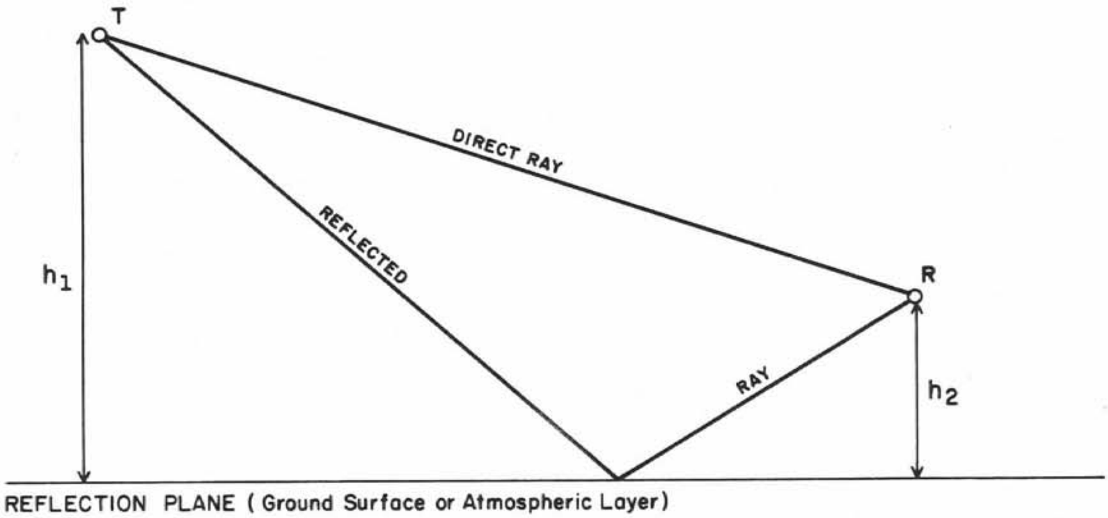

Fig. 1 - Two-ray Model

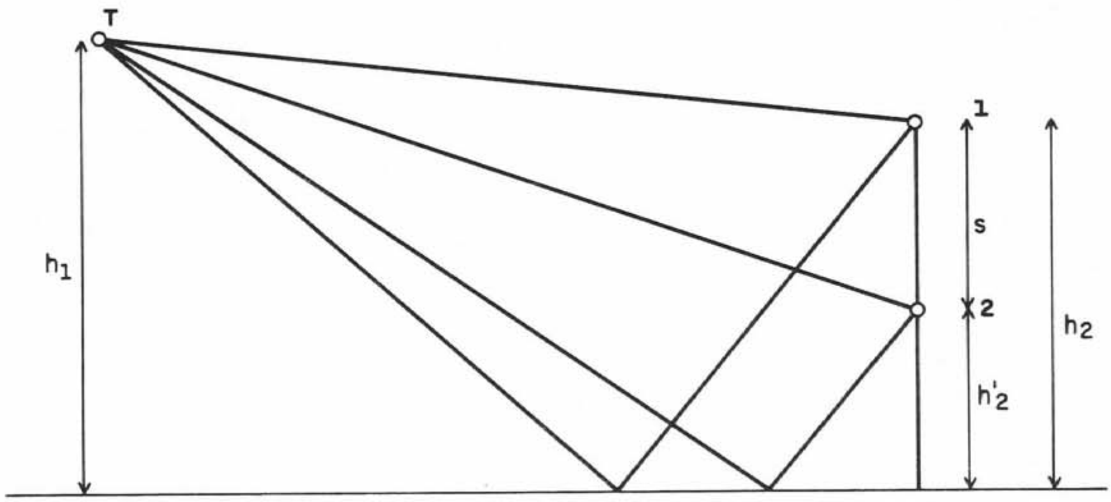

Fig. 2 - Dual Vertical Diversity Geometry