UNCORRELATED ANTENNA SIGNALS FOR MOBILE COMMUNICATIONS

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1. Introduction

In the mobile environment the incident field on the antenna originate from a multitude of directions due to the multiple reflections. Any antenna with a single output port will deliver a Raleigh-fading signal to the receiver in this environment. It is well known that by using several antennas sufficiently spaced (a diversity arrangement) and combining the signals, a much improved communications channel results. In order to achieve the proper diversity gain it is important that the antenna signals are uncorrelated (or at least somewhat decorrelated). This may be achieved by proper spacing, which however has its disadvantages. The purpose of this paper is to discuss the correlation properties of closely spaced antennas or antenna ports from one antenna and show how these properties are related to such wellknown and measurable quantities like mutual impedances. Furthermore some results for a compact array of sloping monopoles with common feed point are presented.

2. Relation between ρ_{12} and z_{12}

A statistical model of the sources in the mobil environment is needed. It is assumed that the sources contain both polarizations and that they are evenly distributed in azimuth but limited to some angle, say 30°, in elevation. Thus we may assume that the indicent field at the mobile is described by

$$\bar{h}(\theta, \varphi) = h_\theta(\theta, \varphi)\hat{\theta} + h_\varphi(\theta, \varphi)\hat{\varphi} \tag{1}$$

It is further assumed that the two polarizations are uncorrelated at each point, i.e.

$$E\{h_\theta \cdot h_\varphi\} = 0 \quad , \tag{2}$$

that the sources are uncorrelated in space

$$\left.\begin{aligned} E\{h_\theta(\theta + \theta_1, \varphi + \varphi_1)\} &= S_\theta(\theta, \varphi)\delta(\theta_1)\ \delta(\varphi_1) \\ E\{h_\varphi(\theta + \theta_1, \varphi + \varphi_1)\} &= S_\varphi(\theta, \varphi)\delta(\theta_1)\ \delta(\varphi_1) \end{aligned}\right\} \tag{3}$$

and that finally the power density of the two polarizations is the same

$$S_\theta = S_\varphi = S(\theta, \varphi) = S(\theta) \tag{4}$$

These assumptions corresponed to assumptions made when calculating antenna temperature from a given temperature distribution in the sky. The main difference here is that the quantity of interest is time-coherent signals instead of the incoherent noise fields.

The open-circuit received voltage at port k is given by

$$V_k = \iint \bar{E}_k(\theta, \varphi) \cdot \bar{h}(\theta, \varphi)\ \sin\theta\ d\theta\ d\varphi \tag{5}$$

where $\bar{E}_k$ is the radiated field from port k when used as a transmitter. The correlation coefficient between two port-voltages is given by

$$\rho_{kj} = E(V_k \, V_j{}^*) \tag{6}$$

$$\rho_{kj} = \iint \bar{E}_k(\theta, \varphi) \cdot \bar{E}_j^*(\theta, \varphi) \; S(\theta) \; \sin\theta \;\; d\theta \; d\varphi \tag{7}$$

under the assumptions stated above. Thus it is possible in a simple way to express the correlation between the received voltages in the mobile case to the far field patterns of the antennas.

As a simple example, assume that there are incoming waves only from the horizontal direction,

$$S(\theta) = \delta(\theta - \frac{\pi}{2}) \tag{8}$$

and two identical omnidirectional antennas spaced a distance d,

$$\rho_{12} = \int_0^{2\pi} e^{jkd \cos\varphi} d\varphi = J_0(kd), \tag{9}$$

a wellknown result.

The mutual impedance between two antennas may also be expressed in terms of the radiated far fields and if only the real part, r_{12} , is considered there results

$$r_{kj} = \iint \bar{E}_k \cdot E_j^* \sin\theta \; d\theta \; d\varphi \quad . \tag{10}$$

The only difference between ρ_{12} and r_{12} is the factor $S(\theta)$ describing the distribution of sources. If they are distributed over the half-space or if the radiation pattern of the antennas are limited to the angles where $S(\theta)$ is significant, then

$$\rho_{12} \sim r_{12} \tag{11}$$

This relationship has been exploited in the design of compact mobile antennas with low correlation.

3. Sloping monopoles with common feed point

As an example, a circular array of three outward sloping monopoles has been described (Vaughan and Bach Andersen, 1985). The basic technique for deriving the antenna is to vary the feedpoint spacing, element length L and element elevation angle to find antennas with low correlations and mutual resistances. It turns out that the feedpoint spacing can be arbitrarily small (limited by practical mounting problems) if the element length can be increased from the ubiquitous quarter wavelength. Figure 1; a, b,are the open circuit correlation, normalized mutual resistance and terminated (matched load) correlations for a variety of antenna configurations, but all with a feedpoint spacing of 0.01 λ. The open circuit correlations are indeed similar to the mutual resistances for this example.

A diversity antenna figure of merit can be defined (Vaughan, 1985) as the (maximal ratio) combined <SNR> over a reference <SNR> for a probability that it exceeds the reference. This is basically the diversity gain for the given probability with the effects of mutual coupling included. Figure 2 is the figure of merit for the antenna example. The reference <SNR> is that from a quarter wave monopole. The probability value used is 0.995, although the figure of merit is rather intensitive to probabilities greater than 0.9. The figure shows that a three branch antenna, with element lengths of 0.6 λ can have colocated feedpoints, elevation angles of 40^0-60^0 and provide an improvement at the 0.995 probability level of about 17.5 dB. This is as good as three quarter wave monopoles spaced 0.4 λ apart.

Another example is the circular rooftop mounted multiport patch antenna (Vaughan and Bach Andersen, 1984). Higher order modes and decreasing patch diameter (increasing permitivity) give better illumination of the incident sources. Calculation of the mutual resistance for a two port circular parch using the N=3 (the number of azimuthal field periods) mode indicate that the antenna will provide efficient two port diversity over a typical receive band configuration. A third port could be used for transmission. The third port need not feed the same patch. It could, for example, lead through the centre of the patch to a monopole, or another patch stacked above the first.

References

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Vaughan, R.G., Bach Andersen, J., "A multiport patch antenna for mobile communications", 1984, Proceedings of the 14th European Microwave Conference, Liege, pp. 607-612, September, 1984.

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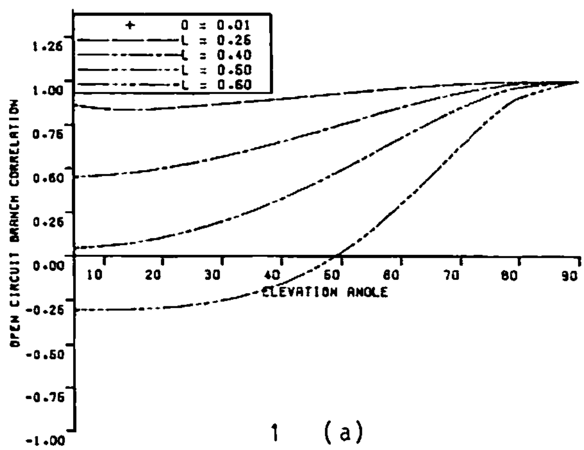
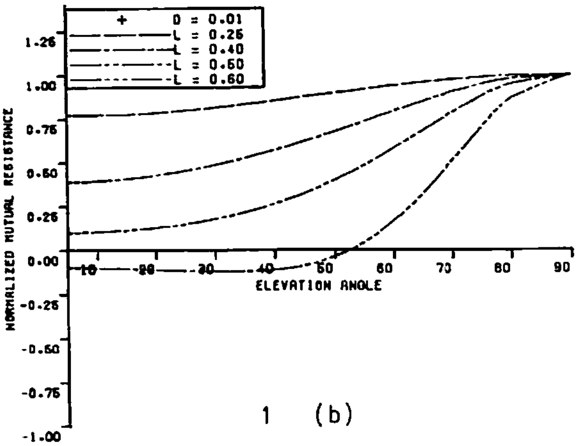


1 (a)



1 (b)

Figure 1. The similarity in open circuit correlation (a) and mutual resistance (b) is clear for this example of a symmetric 3 element array of outward sloping monopoles. The feedpoint spacing is 0.01 λ.

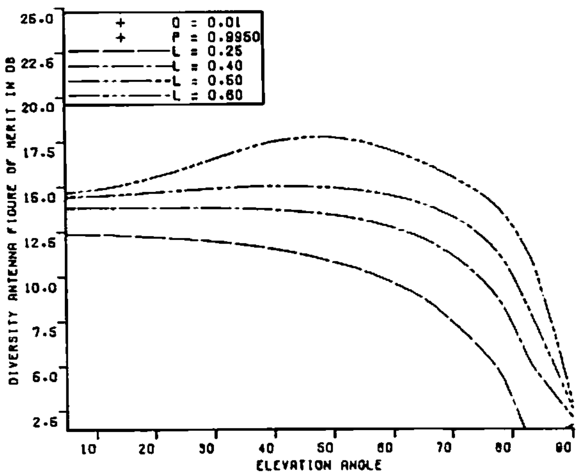


Figure 2. The ratio of the maximal ratio combined <SNR> to the <SNR> of a single quarter wave monopole antenna, at the 0.995 probability level, for the antenna of figure 1.