A–5–3 FREQUENCY DEPENDENT CROSS CORRELATION IN MOBILE VHF-SPACE-DIVERSITY ANTENNA SYSTEMS

Gerhard Flachenecker

University of the German Armed Forces Munich,
Werner-Heisenberg-Weg 39, 8014 Neubiberg
Federal Republic of Germany

1. Introduction

The reception of electromagnetic waves in reflecting environs can be disturbed if the actual free-space wavelength is in the same order of magnitude or less compared to the dimensions of the reflecting objects. In this case multipath effects lead to interfering fields with maximums, minimums and even zeros of the electric and magnetic field strength components. Moving the receiving antenna through this interfering field produces random FM and AM effects of the antenna output voltage. In the most interesting case of mobile radio reception in built-up areas this AM includes deep fades below the noise level with finite probability. This fact is well known from FM-broadcast receiption in cities with car radios.

Since the early 1950's a number of papers dealt with the basics of this problem /1,2,3/. Mathematical models have been worked out to describe the statistical scattered field theoretically. The results are fields with Gaussian, Rice, or Rayleigh distributed probability of the magnitude of the field components. The kind of distribution depends on the percentage of the power which is incident directly compared to the whole interfering field. In the case the direct wave can be neglected against the sum of the reflected waves, a Rayleigh distribution is obtained.

Whereas most recent papers deal with the random effects at microwave frequencies received in cars moving with medium speed /4,5,6/, this paper is concerned with the problems of "Military Operations in Built-up Areas (MOBA)". In this case a car bearing a receiving system slowly moves or stands in the statistically distributed electromagnetic field which is generated by the reflecting environ. Because of the car's low speed and the low military carrier frequencies (20 MHz through 300 MHz) the random FM processes usually are neglectable. The problem are the deep fades of the output voltage of the antenna which can be observed at statistically distributed locations within the scattered field. If the car stops while its antenna is situated in such a minimum of the received field strength component the communication link drops out until the car moves away.

2. Space diversity

To improve the availability of the communication link antenna-space-diversity techniques on the car can be used. The diversity gain depends on the correlation between the antenna output voltages. For two antennas located on a plane ground and excited from a spacially Rayleigh distributed electromagnetic field the correlation factor can be calculated with the help of theoretical models. Following /3/ the normalized covariance function $\varrho(d)$ depending on the distance of the two antennas is

$$\varrho(d) \approx J_0^{\,2}\left(2\pi \frac{d}{\lambda_0}\right), \qquad [1]$$

where d is the antenna distance, λ_0 is the free space wavelength, and J_0 is the zero-order Bessel function. The diversity gain achievable with certain values of ϱ can be determined with the help of wellknown methods /6/.

At microwave frequencies the assumption of the plane ground sufficiently is fulfilled also in the case of antennas mounted on a car. The reason for this is the mainly low curvature of the metal skin of the car compared to the wavelength. At the lower military frequencies, however, the complicated field distribution along the car's surface structure has to be taken into account. There are many frequencies in the VHF band where parts of the car's structure are excited to resonances. This resonances lead to an increased correlation if both antennas adjoin the resonance field of the particular structure.

3. Measurements

To determine the effect of the additional correlation depending on the frequency and the shape of the car measurements have been carried out. Six transistorized broadband antennas were mounted on a car at six different locations as illustrated in Fig. 1. For each possible combination of two antennas measuring drives were performed at eight different frequencies. The transmitting antenna was vertically polarized and located within the reflecting environ, too. No direct line of sight was possible between transmitting antenna and car at all positions during the measuring drives. The driving course was chosen to provide as much reflections as possible.

Fig. 1a and b describe the measuring equipment. The magnitudes of the output voltages of the two actual antennas are received with the help of two receivers providing linear rectification over a wide dynamic range. The receiver output voltages are recorded on a DC-FM tape (Fig. 1a).

To evaluate the records the tape is decreases in speed by the factor 10. The tape output voltages are sampled, A-D converted, and picked up from the desk calculator. To eliminate slow fading effects, the mean values of the tape outputs are eliminated with the help of high-pass filters.

The cut-off frequency of the high-pass filter determines how much the slow fades influence the value of the correlation factor. Slow fades are mostly due to extended shadowing effects and show strong correlation of the field components along a car. On the other hand the performed measurements pointed out that the slow fadings create deep fadings only with heavily reduces probability compared to the fast Rayleigh fadings. The major interest, therefore, concerns the correlation of the fast fadings.

Fig. 2 describes the measured results of cross correlation vs. frequency between two antennas rather closely mounted. The measured cross-covariance shows a certain similarity to the theory, but the predicted increase of the correlation is evident. The different measured values were obtained with different cut-off frequencies of the high-pass filters, i.e. with different consideration of the slow fades.

The results on an antenna combination more seperated in space are given in Fig. 3. At certain frequencies cross-correlation factors could be measured which are as low as the theory for plane grounds predicts. At other frequencies, however, increased correlation occurs.

To detect frequencies where correlation spikes are obtained we now try to test a simple resonance coupling measurement between the actual antennas.

(The research reported in this paper was supported by the European Research Office, Department of the US Army, under Grant Nr. DAERO-77-G-049)

References:

/1/ W.R. Young, Jr.:
Comparison of Mobile Radio Transmission at 150, 450, 900 and 3700 Mc.
BSTJ, Nov. 1952, pp. 1068 - 1085

/2/ J.F. Ossanna, Jr.:
A Model for Mobile Radio Fading Due to Building Reflections: Theoretical and Experimental Fading Waveform Power Spectra.
BSTJ, Nov. 1964, pp. 2935 - 2971

/3/ R.H. Clarke:
A Statistical Theory of Mobile-Radio Receiption.
BSTJ, July-August 1968, pp. 957 - 1000

/4/ D.O. Reudink:
Properties of Mobile Radio Propagation Above 400 MHz.
IEEE Trans. Vehic. Techn. 1974, pp. 143 - 159

/5/ D.C. Cox:
910 MHz Urban Mobile Radio Propagation:
Multipath Characteristics in New York City.
IEEE Trans. Com. 1973, pp. 1188 - 1193

/6/ W.C. Jakes, Jr.:
Microwave Mobile Communications,
John Wiley & Sons, New York 1974

/7/ H. Staras:
Diversity Receiption with Correlated Signals.
J. App. Phys., Vol 27, pp. 93 - 94 (1956)

/8/ L. Tschimpke:
Doctor-Thesis, Records 1977/78,
University of the German Armed Forces, Munich

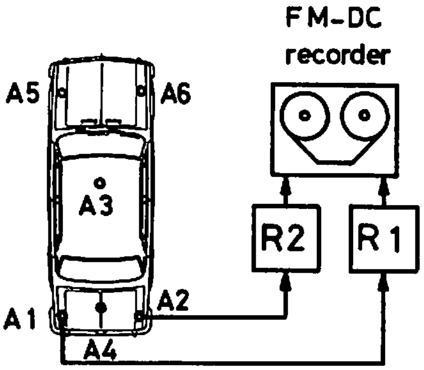

Fig. 1a: Measuring equipment. Ai = i^th^ antenna. R1,2 = receiver 1,2

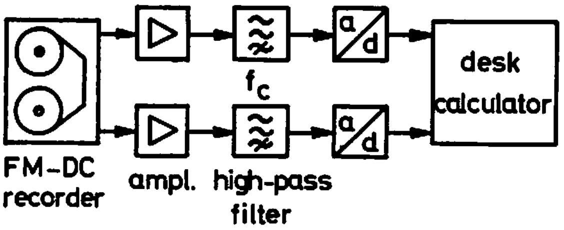

Fig.1b: Evaluation circuit

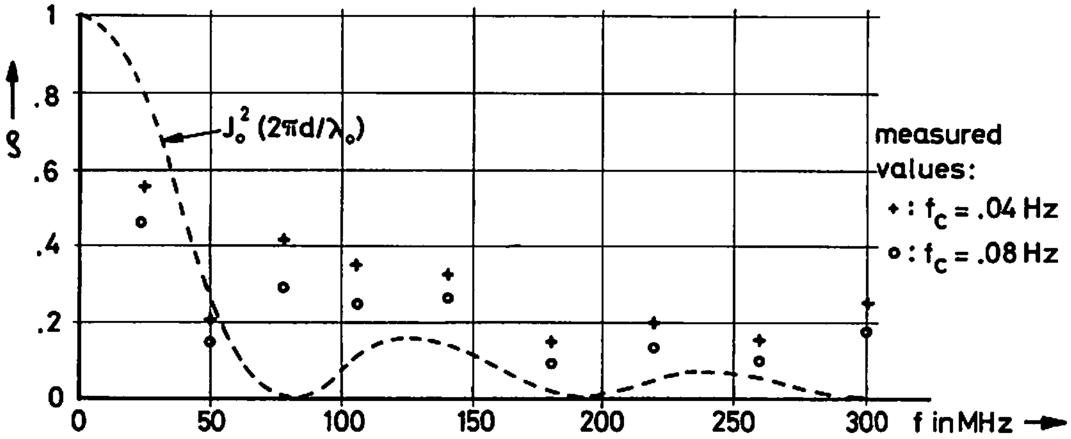

Fig. 2: Cross correlation between antennas 1 and 2. d = 137 cm

----- = theoretical dependence for plane ground

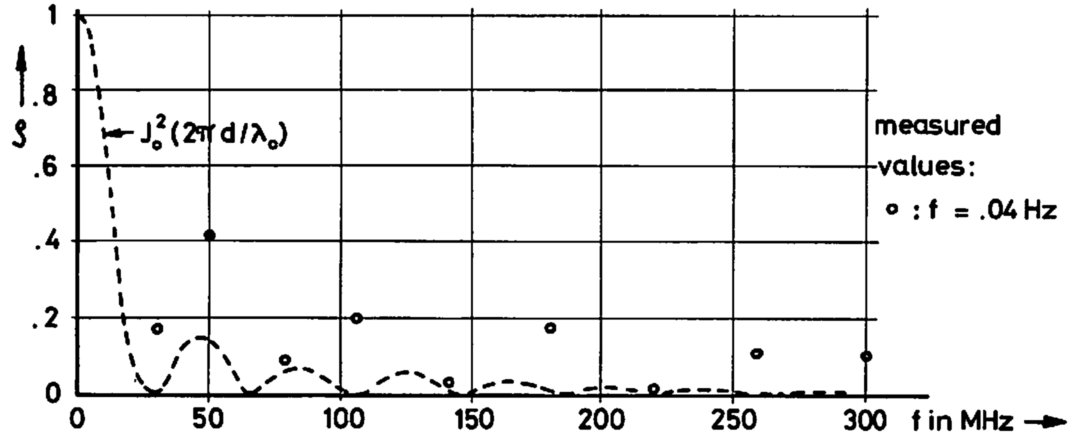

Fig. 3: Cross correlation between antennas 1 and 6. d = 397 cm