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ADEQUATE MOBILE RADIO ANTENNA

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1. Introduction

Land mobile radio communication systems have been developed rapidly. Wave propagation on a mobile radio in urban areas has already investigated[1] and many useful results have been obtained, but investigation about the relation between signal propagation and antenna radiation pattern has been insufficient. Monopole antenna or dipole antenna, whose radiation patterns were ominidirectional in the horizontal plane, have been mounted on many mobile units. When these antennas are used in randomly-disturbed electromagnetic field, it cannot be assured that they are most useful and most adequate.

Therefore, a statistical model[2],[3] is applied to the electric field in urban areas. Then, the relations between the radiation pattern of an antenna mounted on a mobile unit, and the probability that a receiver is able to get signals above its noise level are studied theoretically. Theoretical analysis has already been accomplished and reported[4] by the authors.

The analysis results are summarized as follows:

(1) The antenna with adequate radiation pattern in horizontal plane can reduce the probability that it's output becomes below receiver's noise level.

(2) The antenna which has a narrower angle between the main beam direction and the horizontal plane and a sharp beam in the vertical plane can reduce the probability that it's output becomes below receiver's noise level.

(3) Mobile radio communication quality, using the above directional antenna, is higher than when using conventional antennas.

The purpose of this paper is to confirm the theoretical considerations by several experiments. While driving a car on which a directional antenna is mounted, received levels are recorded and a computer processing is made on these data.

The experimental results indicate that the antenna mounted on a mobile unit is not always required to have an ominidirectional radiation pattern in the horizontal plane. Instead, an antenna which has a narrower angle between the main beam direction and the horizontal plane and a sharp beam in the vertical plane is more useful and more profitable for mobile radio use.

More detailed explanation will be described in the following sections.

2. Experiment

2-1 Measuring Method

A blockdiagram of this experimental setup is shown in Fig. 1. An aluminum ground plate 1.5 m x 1.5 m is mounted on the top of the mobile unit and a receiving antenna is located in the center of the ground plate. The receiving signals from the antenna are connected to receiver's input port by a cable. Then, the detected signals are recorded on magnetic tape by a data recorder. Analog signals, which are the output of the data recorder, are converted to digital data by an A/D converter. These data are dealt with and analyzed by a computer. Signal strength measurements are made while driving the car at 12 km/hr on two orthogonal paths, as shown in Fig. 2.

The paths are surrounded by buildings. Therefore, they are regarded as being out of line of sight from the transmitter's point.

It can be considered that the obtained data in these experiments are regarded as normal examples in urban areas.

2-2 Antenna

When the receiving antenna is used in randomly-disturbed electric fields to research received signal characteristics, it must have various directional patterns. The two-element dipole antenna shown in Fig. 3 is used to receive signals, because directional patterns of this antenna can be changed by antenna spacing and phase.

The vertically stacked dipole antenna is also used to receive signals, because it has sharper beamwidth in vertical plane than a monopole antenna's beamwidth.

Radiation patterns of the antennas, which are located in the center of the ground plane, are measured in free space. The measured patterns are shown in Fig. 4. The main beam directions in the vertical plane are about 20° ∿ 40° above the horizontal plane.

3. Results

Table 1 shows the average signal strength for each antenna output at the two paths. It indicates that the two-element dipole antenna, with spacing λ (at the receiving frequency) and fed in phase, has a larger average signal strength than a monopole antenna. The vertically-stacked dipole antenna also has larger average signal strength than a monopole antenna. An antenna which has large average signal strength has a sharp beam in the vertical plane and has a main beam direction near the horizontal plane.

Figure 5 shows the probability density distribution for antenna output levels. The received levels are normalized by the monopole antenna average signal strength. These distributions resemble the Rayleigh density distribution, with a little difference in low relative signal levels. When an antenna having large average signal strength is used, the probability that its received signal becomes below a given level is less than the same probability for a monopole antenna. For example, the probability that signals received by antenna with spacing λ and fed in phase become below the -20 dB relative level is 0.13 percent. The probability that signals received by vertically-stacked antenna is also 0.2 percent and the probability that signals received by monopole antenna is 0.32 percent. Therefore, at -20 dB relative level, the probability that signals received by antenna with spacing λ and fed in phase is improved 60 percent over the probability for signals received by the monopole antenna.

Table 2 shows the expected number of crossings, which are normalized by the monopole antenna's level crossings, at a given level per second in driving path B. The expected number of crossings at the receiver's threshold level can be reduced by using an antenna which has high average signal strength.

Table 3 shows the expected average duration of fades below the given level. The average duration of fades for the antenna with spacing λ and fed in phase is 0.81 relative to the monopole antenna's average duration of fades at a level of -20 dB below the monopole antenna average signal strength in driving path B. Therefore, the average duration of fades for an antenna with spacing λ and fed in phase is improved 19 percent over the average duration of fades for the monopole antenna.

4. Conclusion

Experiments were made in disturbed electric fields. For mobile radio communication, it is necessary that the received average signal level be higher, that the number of crossings at the receiver's threshold level be smaller and that the duration of fades at the receiver's threshold level be shorter. Therefore, it is understood experimentally that the antenna having a narrower angle between the main beam direction and the horizontal plane and a sharp beam in vertical plane is more suitable for mobile radio than a conventional monopole antenna.

As the experimental results shows similar tendency to the theoretical ones, the theoretical considerations are confirmed by the experiments.

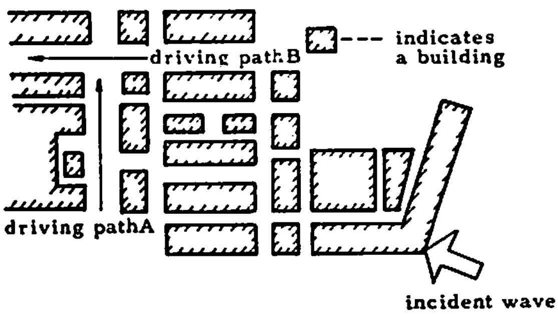
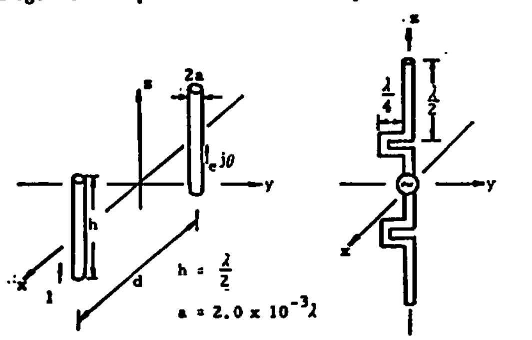


Fig. 2. Experimental site map.



(a) two element array antenna

(b) vertically stacked dipole antenna

Fig. 3. Antenna used for experiments

5. References

(1) W. C. Y. Lee: "The elevation angle of mobile signal arrival", IEEE Trans., COM-21, Nov., 1973.

(2) E. N. Gilbert: "Energy reception for mobile radio", Bell Syst. Tech. J. Vol.44, pp.1779-1803, Oct. 1965.

(3) W. C. Y. Lee: "Statistical analysis of the level crossings and duration of fades of the signal from an energy density mobile radio antenna", Bell syst. Tech. J., Vol.46, Feb. 1967.

(4) H. Iwasaki, Y. Mikuni and K. Nagai: "Statistical analysis of received signals from a directional antenna for mobile radio communication in urban areas", IECEJ, Ap-76-100, pp.25-30, Feb. 1976.

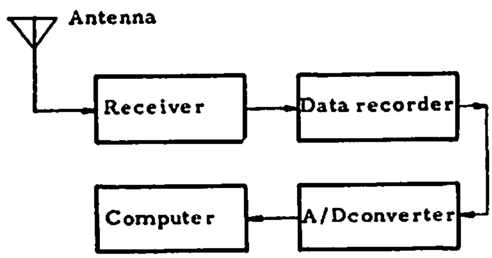
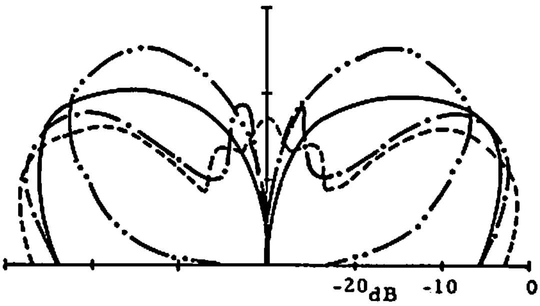


Fig. 1. Experiment method blockdiagram

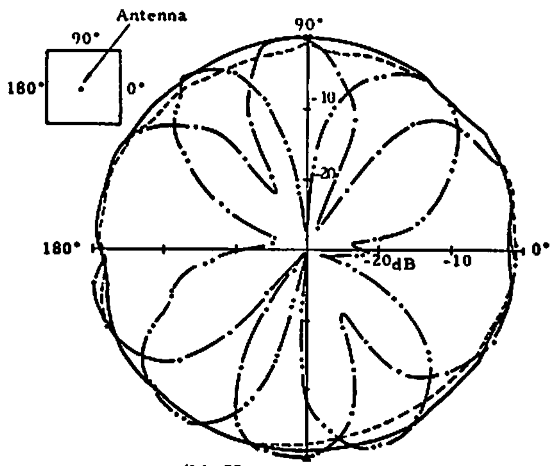
Antenna	Driving Path A		Driving Path B	
	Theoretical	Experimental	Theoretical	Experimental
Antenna with spacing λ, fed in phase	1.095	1.020	1.095	1.088
Vertically stacked dipole antenna	1.73	1.012	1.73	1.025
Monopole antenna	1.0	1.0	1.0	1.0
Antenna with spacing λ, fed out of phase	0.88	0.998	0.88	0.912

Table 1. Average signal strength values for each antenna.



(a) Vertical plane

- ——— monopole antenna
- – – – vertically stacked dipole antenna
- —·—·— antenna with spacing λ and fed in phase
- —··—··— antenna with spacing λ and fed out of phase



(b) Horizontal plane

Fig. 4 Radiation patterns Antenna is located in the center of the ground plate.

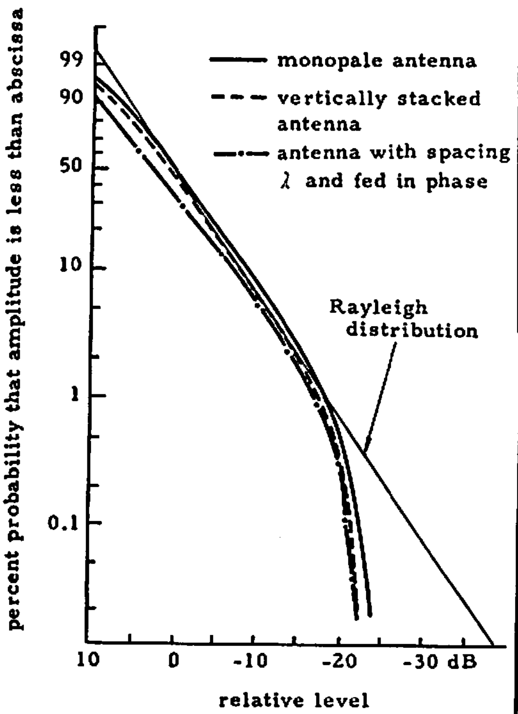


Fig. 5. Probability that received signal from an antenna become below a given level in driving path B.

Relative level / Antenna	-10 dB		-20 dB	
	Theoretical	Experimental	Theoretical	Experimental
Antenna with spacing λ, fed in phase	0.96	0.7	0.88	0.71
Vertically stacked dipole antenna	0.8	0.82	0.77	0.71
Monopole antenna	1.0	1.0	1.0	1.0
Antenna with spacing λ, fed out of phase	1.05	1.43	1.06	1.29

Table 2. Comparison of electric field level crossing rates for several antennas in driving path B.

Relative level / Antenna	-10 dB		-20 dB	
	Theoretical	Experimental	Theoretical	Experimental
Antenna with spacing λ, fed in phase	0.99	0.96	0.95	0.81
Vertically stacked dipole antenna	0.78	0.85	0.76	1.0
Monopole antenna	1.0	1.0	1.0	1.0
Antenna with spacing λ, fed out of phase	1.1	1.01	1.07	1.3

Table 3. Comparison fades duration in electric field for several antenna in driving path B.