DIRECTIVITY DIVERSITY FOR HIGH-SPEED DIGITAL LAND MOBILE RADIO

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I. INTRODUCTION

In order to realize a highly efficient, multi-function digital mobile radio system, digital signal should be transmitted with high bit rate. However, unacceptably high error rates are produced by frequency-selective Rayleigh fading in land mobile radio channels [1]. The directivity diversity technique is considered to be one of the most effective techniques for mitigating the effect of time delay spread [2], [3]. This paper presents the field test results on transmission performance of a 128 kbps MSK discriminator detection with 2- and 4-branch directivity diversity.

II. EXPERIMENTAL TEST SYSTEM

The 128 kbps MSK signal transmission was performed from the base site to the measuring vehicle. The carrier frequency and RF output power of the transmitter were 920 MHz and 20 W, respectively. A 511 bit PN sequence was used as the test pattern. A corner reflector antenna having 3 dB down beamwidth of 46 degrees and a gain of 10.7 dB in the beam center was used as the base site transmitting antenna. The height of the antenna was approximately 80 m above sea level.

Fig. 1 shows a block diagram of the field test system installed in the measuring vehicle. The directivity diversity antenna was constructed with two 180-degree and four 90-degree corner reflector antennas for 2- and 4-branch diversity, respectively. These antennas were placed on a ground plate which was set on the roof of the measuring vehicle. The height of the ground plate was approximately 3 m. A quarter-wavelength monopole antenna was also mounted as the reference antenna. Postdetection selection combining was used for 2-branch diversity reception. In the 4-branch diversity reception, 2-branch switched diversity with a specified threshold level was used at first for each receiver, and then postdetection selection combining was applied for both receivers.

The measured items in the field test were; 1) instantaneous amplitude of the received signal for each branch and diversity, 2) average value of received signal strength, 3) number of errors with and without diversity, 4) vehicular speed, and 5) time. The experiments were performed in Yokosuka City. There are many small hills in this area. Therefore the measuring vehicle often traveled up and down relative to the base site.

III. RESULTS

A. *Fundamental Performance*

Fig.2 shows an example of measurement results on the instantaneous amplitude fluctuation of the received signal. The fluctuation of the back side directivity antenna was smaller than that of the front side antenna. Fig.3 shows the cumulative probability distribution of the instantaneous amplitude obtained in a representative 100 m section. Although many results agree with a Rayleigh-distribution, some follow an Io-distribution. One of these curves corresponds to the results shown in Fig.2. These results suggest that it is possible to receive only a direct wave by using directivity antennas.

The measured correlation coefficients between two-branch directivity antennas were lower than 0.5. Although many measured average receiving power differences between directivity antennas were small, some measured results were 6 to 10 dB. This is because the measuring vehicle is sometimes in line-of-sight from the base site at a crossing of streets, so the receiving level of the base site side's directivity antenna becomes high. However, these differences are not considered the cause of serious degradation in diversity reception.

B. Multipath Delay Spread

Before the signal transmission experiments, time delay spreads were measured by a multipath propagation analyzer using the spread spectrum technique [4]. Maximum resolution time is 0.648 usec, and measuring window size for time delay is 10 usec. Fig.4 shows an example of measurement results for 4-branch directivity antennas. These time delay spreads were measured when the measuring vehicle ran on streets perpendicular to the base site antenna's main beam. It can be seen that time delay spread is a few usec. It is also found that the first reflected wave level in picture (c) is 10 dB lower than that in picture (d). This means that a directivity antenna is useful for separating the direct wave from reflected waves.

C. BER Performance

Measured average bit error rate (BER) characteristics are placed against average carrier to noise power ratio (CNR) obtained with 2-branch directivity diversity in Fig.6, and 4-branch in Fig.7. In order to show the improvements more clearly, the BER performance with 2-branch space diversity is shown in Fig.5. The following points are illustrated in these figures.

(1) The improvement difference between 2-branch space diversity and 2-branch directivity diversity is small. Compared to the case without diversity, the average BER is reduced only 1/4 to 1/10 at CNR = 30 dB.

(2) For the specified average BER of 1×10^{-3}, the diversity gain of 4-branch directivity diversity is approximately 17.5 dB. The value is 6.5 dB larger than that of 2-branch directivity diversity.

(3) The so-called irreducible error caused by the time delay spread is reduced remarkably by using 4-branch directivity diversity. The value is one tenth smaller than that of 2-branch directivity diversity. If the threshold level of switched diversity is adaptively changed according to the receiving level, the irreducible error can be reduced more effectively.

IV. CONCLUSIONS

The improvements obtainable from directivity diversity have been experimentally investigated in the frequency-selective Rayleigh fading environment. The results of the field test have shown that directivity diversity is useful for mitigating the effect of time delay spread. Although the average BER can be lowered less than 1×10^{-4} by using 4-branch directivity diversity, it is not sufficient for highly reliable data transmission systems. Adaptive automatic equalization and forward error correction techniques are also expected to be effective for this purpose.

REFERENCES

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[4] H.Omori et al., "Field test of multipath propagation analyzer using spread spectrum system at 920 MHz", *Papers of Tech. Group IECE Japan* (in Japanese), TGAP80-124, Feb.1980.

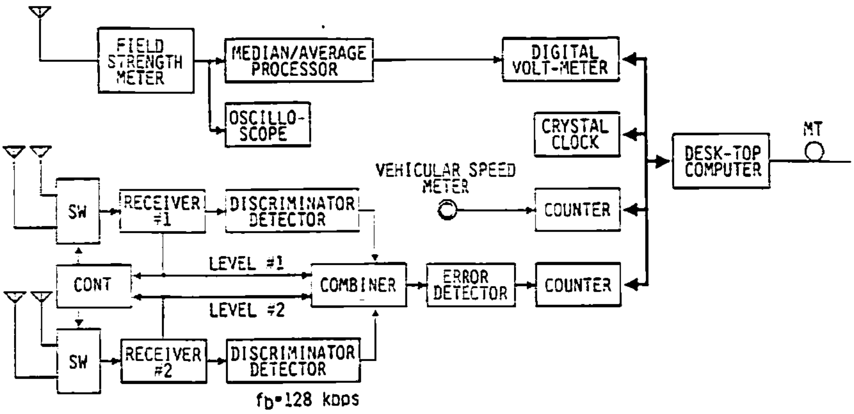


Fig.1 Experimental setup installed in measuring vehicle

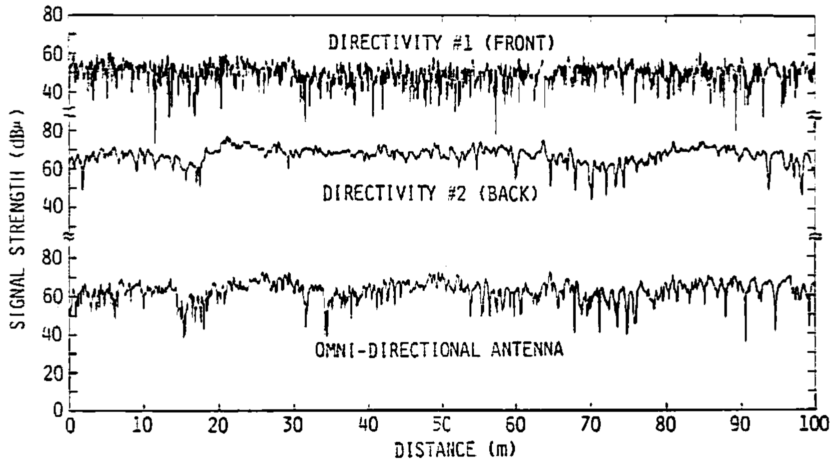
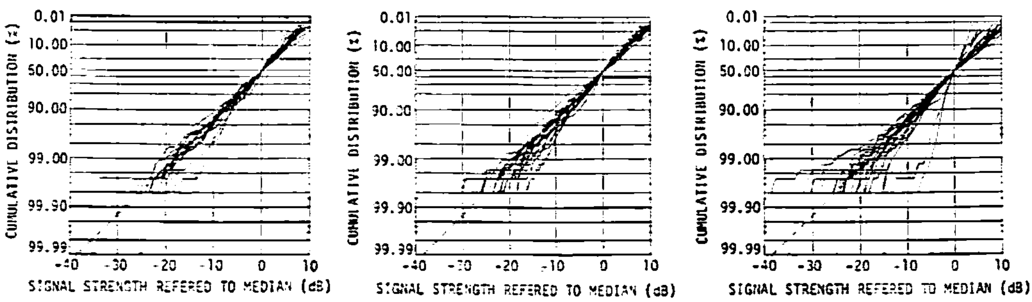
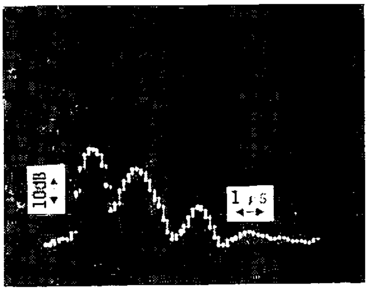


Fig.2 Instantaneous amplitude fluctuation of the received signal

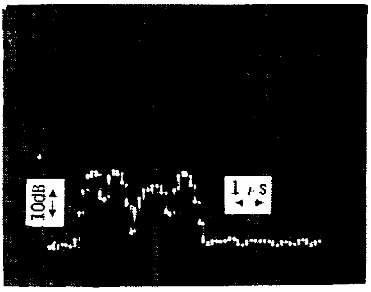


(a) omni-directional antenna (b) directivity #1 (front) (c) directivity #3 (back)

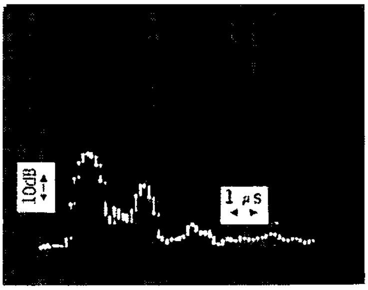
Fig.3 Cumulative probability distribution of the instantaneous amplitude obtained in 100 m sections



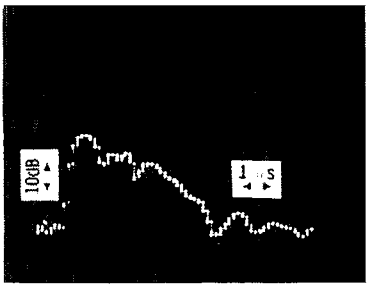
(a) directivity #1 (front)



(b) directivity #2 (back)



(c) directivity #3 (left)



(d) directivity #4 (right)

Fig.4 Measured time delay spread for 4-branch directivity antennas

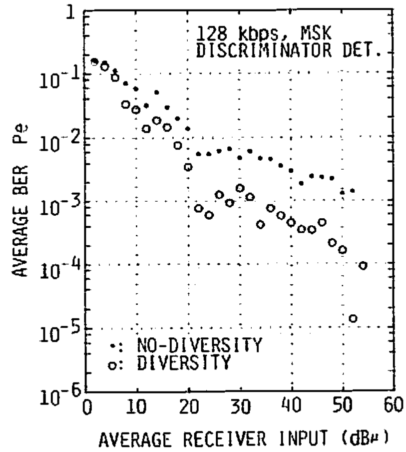


Fig.5 Effect of 2-branch space diversity

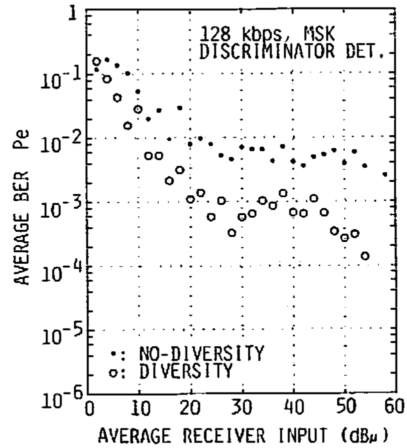


Fig.6 Effect of 2-branch directivity diversity

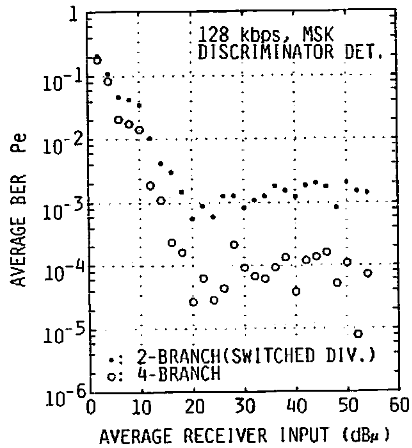


Fig.7 Effect of 4-branch directivity diversity