TIME DIVERSITY EFFECT OF SSP-FSK SIGNALS IN MOBILE RADIO SYSTEMS

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Abstract

The Separated-Split-Phase (SSP) coding method, a very attractive coding method for control data transmission in mobile radio systems, is described. Many experimental results show that the SSP coding method is sufficiently effective for rejecting d.c. wander problem and obtaining time diversity effects.

I .Introduction

Split-Phase-coded Frequency Shift Keying (SP-FSK) and subcarrier FSK are very common techniques for control data transmissions in mobile radio systems. These coding-modulation schemes give a favorable d.c. cut-off in discriminated output necessary for eliminating frequency drift and obtaining simplicity in circuit construction. The coding rate of the SP is a half of NRZ, while SP coding has the advantage of d.c. balance and ease of bit synchronization.

In the SSP coding method, redundancy is utilized not only for d.c. balance but also for time diversity. Time diversity [1] is one of the most promising techniques for improving the quality of land mobile radio signals degraded by rapid and deep fading.

In Section II, the principle of SSP coding is outlined and the characteristics of the baseband power spectrum is discussed. In Section III, Bit-Error-Rate (BER) characteristics are clarified by laboratory experiments and field experiments. The BER characteristics of a case using space diversity, employing postdetection selection combining [2], are also clarified by the experiments.

II .Principle

The SP and SSP coded signal formats are shown in Fig.1. For SP coding, the polarity of the first half of T and that of the second half are reversed. The SP coded waveform has no d.c.component, and has zero-crossing points at the center of every T, which are useful for retiming.

For SSP coding, the first half and the second half are arranged with $(n+1/2)T$ sec separation. Using SSP coding, the BER characteristics can be improved by selecting .the decision result for the first or second half, depending on which has been received with more signal power than the other.

The baseband power spectrum of the SSP coded signals, $w(f)$, can be described such that

$$\frac{w(f)}{T}=\left[\frac{\sin(\pi fT)}{\pi fT}\sin\{\pi(n+1/2)fT\}\right]^2 .$$

The power spectra in the case where the separation $n=0$, 1, 4 and 8 are plotted in Fig.2. The SSP where $n=0$ is the SP. Although the component near d.c. increase as n advances, the d.c. components for each n are zero.

III .Experiments

The block diagram and major parameters for the experimental test system for SSP-FSK signal transmissions are shown in Fig.3 and Table I . In the experiment, the diversity [2] and narrowband transmission techniques [3] to be employed in NTT's next High-capacity

Land Mobile Communication System [4] are adopted. In the laboratory experiments, multipath propagation between the transmitter and receiver is replaced by a Rayleigh fading simulator. The test course for the field experiments is shown in Fig.4. The test area where many buildings stand close together is chosen as presenting typical multipath fading areas. The SSP-FSK signals are transmitted from the mobile station. Two antennas with about 5λ separation for diversity reception are set up at the base station. In the base station, the number of bit-errors, median signal values at the receiver input and fading pitches are processed at intervals of 10 minutes, and the average BER, classified according to median signal value and fading pitch, is obtained.

The results of the laboratory experiments for maximum Doppler frequency $f_D=40$Hz, equivalent to about a 50km/h vehicle speed with a radio frequency of 900MHz, are shown in Fig.5. The theoretical results, obtained by convolution of the BER characteristic under static condition and the probability density function for two- or four- branch diversity with the correlation coefficient, are also plotted in Fig.5. The difference between the BER characteristics of the SP and those of the SSP expresses the time diversity effect. Without space diversity, the median signal value required to obtain a BER of 10^{-3} can be reduced 10dB by time diversity effects. With space diversity, the time diversity effect is 6dB. Using both two-branch space diversity and two-branch time diversity, a diversity effect of 18dB is obtained for four-branch diversity.

The relation between the separation n and the time diversity effect with space diversity is shown in Fig.6. As n became smaller, the correlation coefficient of the received signal envelope increases, and the time diversity effect decreases.

The measured BERs in the field experiments are shown in Fig.7. The time diversity effect for a BER of 10^{-3} without space diversity and with space diversity are 8dB and 4dB, respectively. Both the time and space diversity effects are smaller than that of laboratory experiments, because the correlation coefficient for space diversity is 0-0.5, and because the average BER is obtained from the average value of several measurements for $f_D \geqq 20$Hz.

IV.Conclusion

The SSP coding method, in which redundancy is utilized for d.c. balance and time diversity, is proposed. Experimental results show that the time diversity effect for BER of 10^{-3} is 10dB. With space diversity, an 6dB effect is obtained.

Acknowledgment

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Reference

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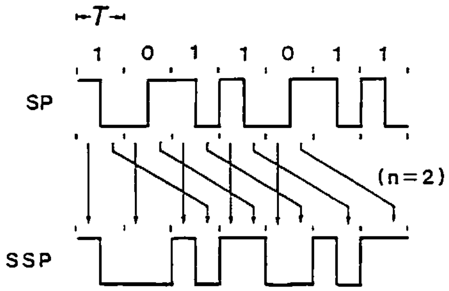

Fig.1 SP and SSP coded signal formats

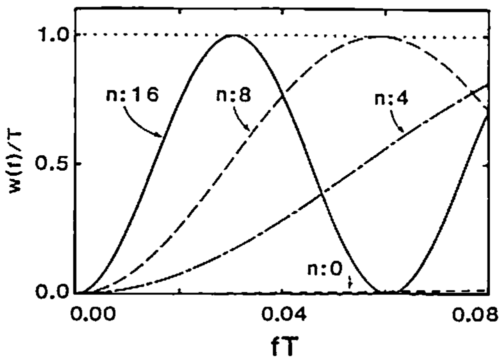

Fig.2 Baseband power spectrum

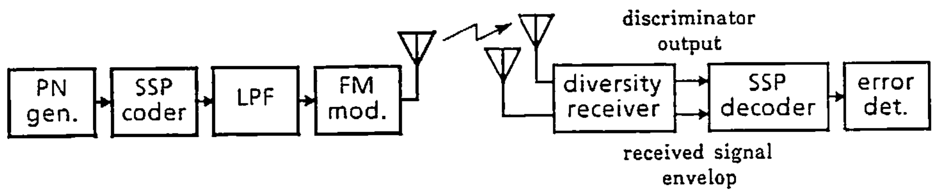

Fig.3 Block diagram for the experimental test system

Table I Major parameters for the experiments

Item	Features
Radio frequency	920MHz
IF band width	8kHz
Signaling bit rate	2400bps
Coding-Modulation	SSP-FSK
Baseband BbT	0.75
Frequency deviation	2.4kHz
Detection	Limiter-Discriminator
Diversity	Two-branch Postdetection selection

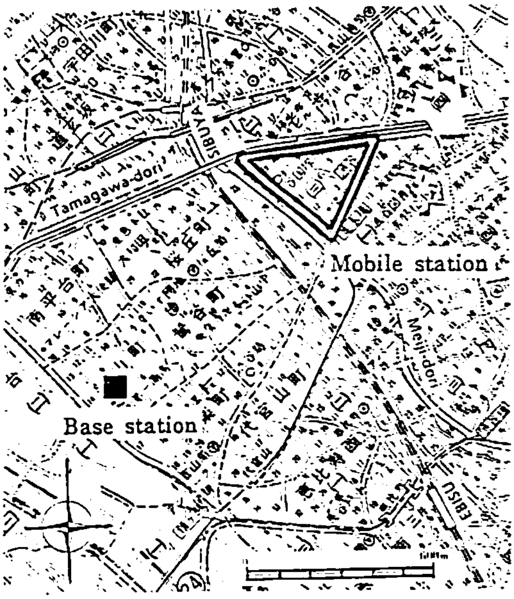

Fig.4 Test course for field experiments

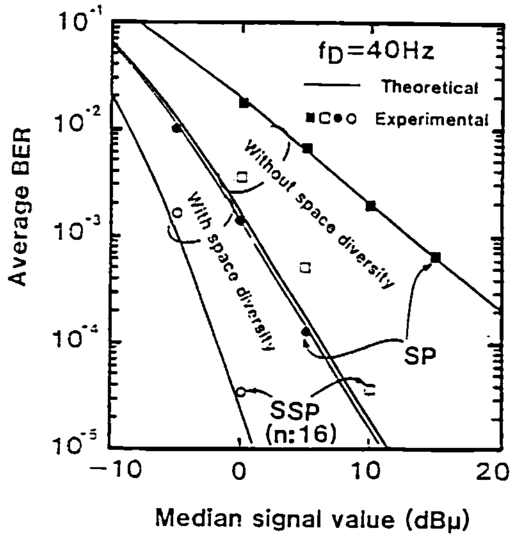

Fig.5 Average BER versus median signal value

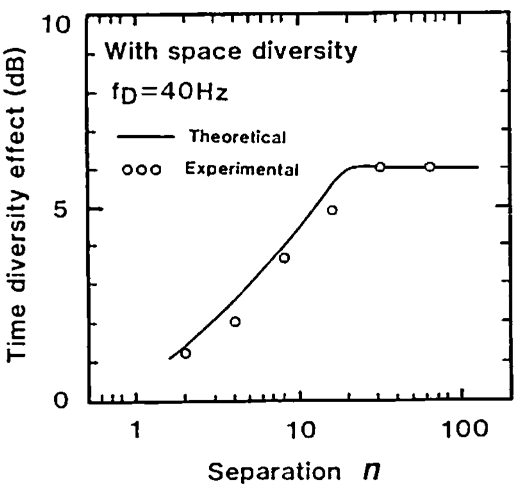

Fig.6 Time diversity effect versus separation n

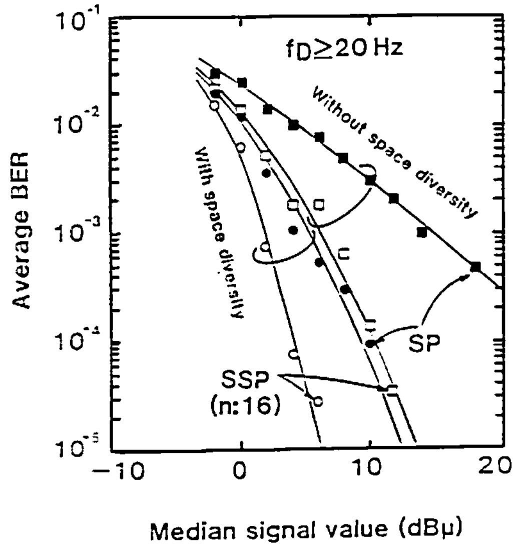

Fig.7 Average BER versus median signal value (field experiment)