DIVERSITY IMPROVEMENT IN FH-MFSK LAND MOBILE RADIO

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1. Introduction

Diversity effect is one of the major features of spread spectrum techniques. Among which, frequency diversity in the FH (Frequency Hopping) technique is considered much helpful to reduce the influence of fading[1]. That is realized by hopping over a sufficiently wide bandwidth in selective fading channels accompanied by appropriate coding and decoding techniques. Recently, this frequency diversity effect has become regarded as one of the most important factors for the design of FH mobile radio systems with high spectral efficiency[2]. However, few experimental investigations on the mobile FH systems have been reported yet.

An advanced spread spectrum mobile radio equipment (SSFH2: Spread Spectrum Frequency Hopping) has been developed, for the purpose of conducting field tests including the multiple access communications. FH-MFSK (Frequency-Hopping-Multilevel-FSK) modulation, Reed-Solomon coding and soft decision decoding are applied. This development is based on the results of theoretical analyses and laboratory experiments carried out for several years by using a prototype FH-BFSK (Frequency-Hopping-Binary-FSK) equipment [3]. Field tests as well as laboratory experiments have been performed, and the results show that these techniques have a remarkable effect against fading and noise.

The outline of the equipment and its BER (Bit Error Rate) performance in fading channels are described.

2. Frequency hopping mobile radio equipment

2.1 System parameters and block diagram

Table 1 shows the system parameters, and Fig.1 shows the block diagram. Simplex (Press-to-talk) operation is applied and the addresses (hopping patterns) for transmission and reception can be selected independently. Usually, a fixed address is assigned in receiving mode for each equipment, and random access is feasible by sending the address of the desired receiver.

Binary data sequence, such as digitized voice, is converted every 6 bits to a matrix of 8 frequencies and 7 time-slots as shown in Fig.2(b). Then the center frequency of the matrix is changed according to the hopping pattern at intervals of one time-slot. This frequency hopping offers the advantages of anti-jamming, frequency diversity and asynchronous multiple access.

The detector and decoder are shown in Fig.3. The received hopping signal is converted to 8-ary FSK signal by mixing the synchronized hopping local signal. These 8 frequencies corresponding to the octal Reed-Solomon code are separated by a parallel bank of 8 filters, and the output of each envelope detector is quantized to 8 bits. These bits are stored in the 8×7 matrix in the decoder, and information bits are obtained by maximum-likelihood decision on the matrix. The diversity combining is implemented in the process of summing up seven elements in the matrix, which correspond to a seven-symbol code word.

2.2 BER performances

Fig.4 shows the BER performances of the SSFH2 equipment. Lines are the results obtained in laboratory experiments by using the fading simulator[3].

They are the BER performances with Gaussian noise, in a flat and a selective Rayleigh fading channel. The coherence bandwidth of the selective fading channel is 500kHz. The performance of conventional binary FSK in a Rayleigh fading channel is also shown. The performance in the selective fading channel is greatly improved as compared with the case of flat fading. This is owing to the increase in coding gain by the frequency diversity effect (randomization of errors [4]) . For instance, the improvement is 17dB at the BER of 10^{-3}.

The BER performance in an actual urban area is also shown in Fig.4. The results are classified into 5 groups according to the vehicle velocity. A base station was set up at Radio Research Laboratories (Koganei City, Tokyo), and the mobile station ran along Loop 8, in urban area of Suginami-ku, 12 km away and out of sight from the base station. An omni-directional antenna is used at both stations, and the signal is transmitted from the mobile station at a power of 5W. The BER is measured every 5 seconds.

Although slightly dispersed, the BER performance equals or exceeds that in the case of selective fading in the laboratory, which denotes that the frequency diversity effect is practically useful. Further, irreducible errors which often encountered on digital transmission in mobile radio communication[5] do not appear, and the BER performance is independent of the vehicle velocity.

In this area, the envelope of the received signal is Rayleigh-distributed within the distance covered in 5 seconds, and the multipath delay profiles, which are measured in the way similar to Cox's[6] by the direct sequence spread spectrum signal, show that delayed components more than 1 μs usually exist. Thus the fading channel in this area will be regarded as a frequency selective Rayleigh fading. Further discussions on the relation between the BER performances and the propagation characteristics will be given later.

As mentioned above, the SSFH2 equipment shows a good performance in an actual mobile radio channel as well as in a laboratory. Further field tests for multiple-access communication will be performed in the near future.

3. Conclusion

Experiments on the FH mobile radio equipment with Reed-Solomon coding and soft decision decoding have been performed. The result shows that the reduction of bit errors by the frequency diversity effect is remarkable, for instance 17dB improvement in BER of 10^{-3} in the laboratory experiment by using the fading simulator. That is similar to the field test in urban area, and in addition, irreducible errors which often encountered on digital transmission in mobile radio communication do not appear. Thus it is experimentally verified that the FH-MFSK and appropriate coding techniques are significantly tolerable to fading in urban area.

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References

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Table 1. System parameters of SSFH2 equipment.

Voice coding	Adaptive delta modulation (with compander)	
Data rate	19.2kbps	
Hopping rate	22.4khps	
Spread bandwidth	10MHz	
Center frequency	775MHz	
Modulation	FH-MFSK (8-ary FSK)	
Detection	Noncoherent detection	
Hopping pattern	Reed-Solomon code(511 time slots)	
Error correction	Octal Reed-Solomon code	
Frequency synthesizer	Phase settling time	Less than 0.2μs
	Spurious	Less than -65dB
Initial acquisition	Sliding correlation (using preamble)	
Tracking	Modified delay lock loop	
Other functions	Measurement of bit error rate	
	Frame synchronized operation among equipments (wired)	

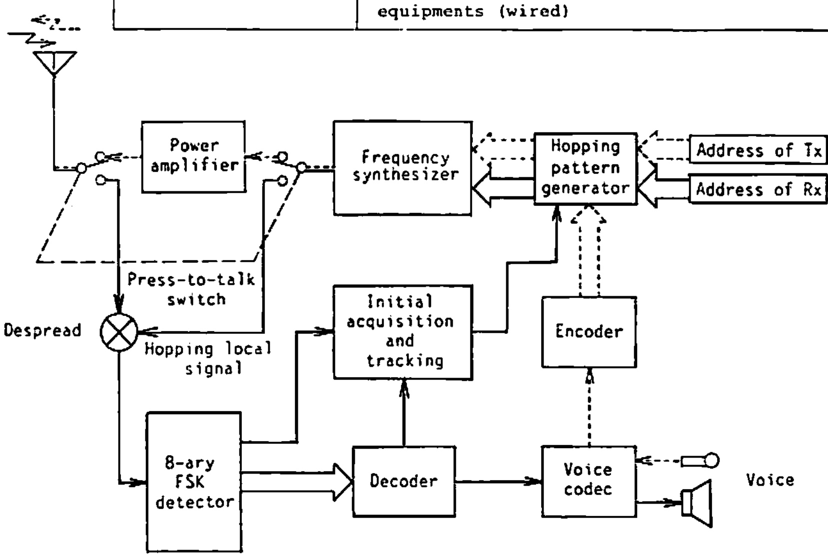

Fig.1. Block diagram of SSFH2 equipment.

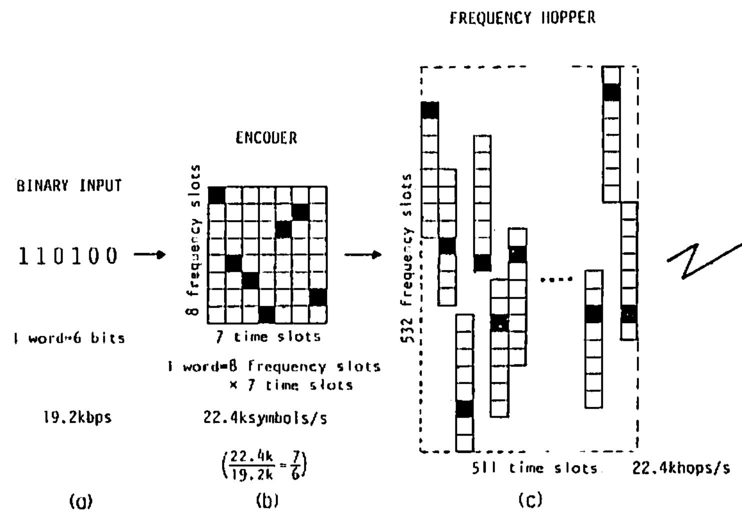

Fig.2. Signal processing in the transmitter.

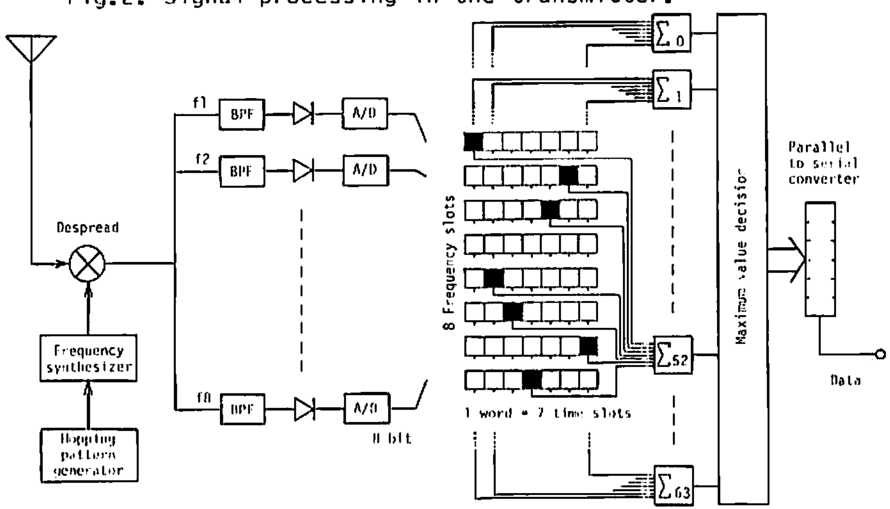

Fig.3. Detector and decoder in SSFH2 equipment.

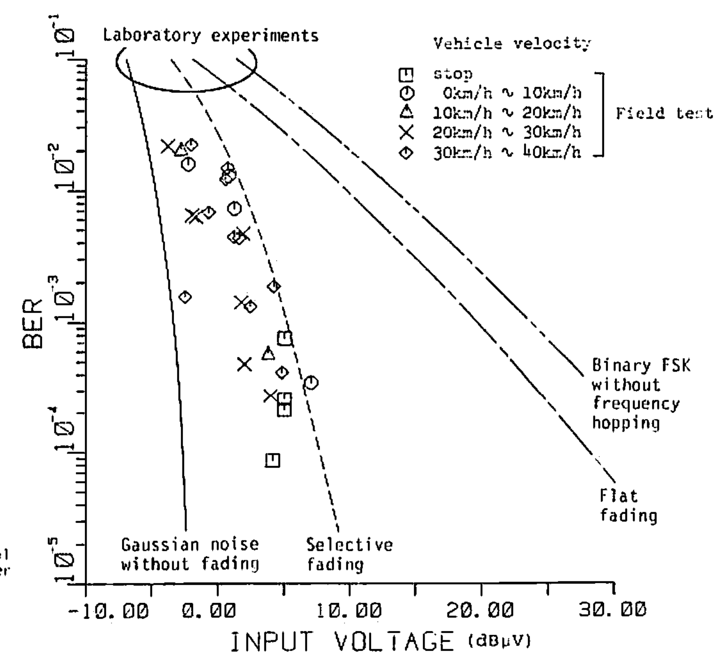

Fig.4. BER performances of SSFH2 equipment.