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Technologies for the Particular Propagation Characteristics in the 4-Level FSK Paging System

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Abstract

Particular propagation characteristics and the technologies for them in the 4-level FSK paging system are discussed by computer simulation and experiment. At first, the effect of time diversity technology is presented. The difference in BER improvement of three diversity reception methods are considered in the static and fading conditions. In the simulcast transmission which is usually adopted in paging system, the effect of the frequency offset transmission technology on the receiver sensitivity is also presented. The effectiveness of these technologies in the case of a direct conversion receiver with a digital demodulator is studied and clarified.

1.Introduction

The paging system is one of the most popular mobile communication systems. In terms of propagation, the paging receiver should receive several signals transmitted simultaneously from multiple base stations over a wide zone. Consequently, the dynamic range of the received signal power in the receiver must be very wide. And the several paths of propagation, from the unique transmitter and others, should be regarded as a multipath. In such a propagation environment, the paging receiver must be a quite small in structure, have low power consumption and have high sensitivity. Demand for the pager increased rapidly in recent years, with the number of subscribers exceeding 10,000,000 in Japan. Therefore, future plans were to raise the bit rate and turn binary FSK into 4-level FSK transmission in order to increase the number of subscribers and improve the grade of services. To realize this 4-level FSK paging receiver, we have proposed a receiver using a direct conversion configuration[1]. Using this receiver, two technologies are discussed in this paper. One is the time diversity technology[2][3] which is suitable for small equipment such as the paging receiver. The other is the frequency offset transmission technology[4][5][6].

In this paper, we will show the quantitative effects of these technologies on propagation characteristics such as time diversity and frequency offsets in simulcast transmission by computer simulation, and present experimental results using the direct conversion receiver.

2.Fundamental Parameters for 4-Level FSK Paging System

A new paging system (FLEX-TD) has been introduced in Japan. In this paging system, 4-level FSK is used for modulation and bit rate is flexibly variable for channel traffic. Table 1 shows some of the specifications of the FLEX-TD paging system[7][8]. In this paging system, time diversity transmission is used for maintaining the sensitivity of the receiver in the zone. The number of times of diversity transmission is variably set from 1 to 4 times according to the requirement of sensitivity improvement. Moreover, a bit interleave is used in this system for eliminating a burst error by fading. The interleaved block is 160msec for each bit rate. This interleave can eliminate the burst error below 10msec per interleaved block. Moreover, frequency offset transmission in the simulcast is used for improving the receiving probability in the border area, and a frequency offset below ±150Hz is specified.

3.Time Diversity Technology

In order to estimate the effects of time diversity technology, a computer simulation and experimental measurements are made in both a static environment and Rayleigh fading environment with 1Hz Doppler frequency.

Two methods are available for receiving repeatedly transmitted signals by time diversity[2]; one is called "Bit Combining Time Diversity (BC-TD)", the other is called "Code Word Combining Time Diversity (CWC-TD)". In this paging system, the codeword has 32 bits of data including BCH(31,21) and a parity bit. Figure 1 shows a block diagram of our simulation process in order to compare the sensitivity improvement of each TD method. In the BC-TD process, we use two methods. One is equal combining and the other is weighted combining which weights a signal to be combined by the received power given by RSSI (Received Signal Strength Indicator). These methods are denoted as follows,

$$S_{equal}(i) = \sum_{j=1}^{m} e_{ij} \cdots (1), \qquad S_{weighted}(i) = \sum_{j=1}^{m} w_{ij} \cdot e_{ij} \cdots (2)$$

where e_{ij} is each signal to be combined, or a demodulated signal, and w_{ij} is a weighting factor. Bit decision is made by using the above combined signal. The direct conversion receiver indicated in Figure 2 which we have proposed, is applied to the 4-level FSK demodulator in Figure 1.

Figure 3 shows a BER characteristic of 4-level FSK 6400bps in static environment. BER is after error correction. In this figure, data of equal combining, weighted combining of BC-TD and CWC-TD are plotted. BC-TD has a better improvement than CWC-TD in almost every region. But in the lower BER region, the CWC-TD has a better improvement. The reason for these features is supposed to result from the following. When C/N is below 9dB, the FM click noise is dominant compared to the FM gaussian noise. Therefore, once the FM click noise occurs, it will be difficult to recover the original data through combination with other diversity data even if these data has no click. CWC-TD, on the other hand, can eliminate any errors of the codeword if only one of the corresponding codewords, which are diversity transmitted, has either no errors or a few errors that are correctable. This is more effective when C/N is very high. Moreover, it is observed that the improvement of the weighted combining BC-TD is slightly better than that of the equal combining BC-TD in the case of static environment.

The BER characteristic of 4-level FSK 6400bps in Rayleigh fading environment with 1Hz Doppler frequency is shown in Figure 4. BC-TD with weighted combining has better improvement than CWC-TD, while BC-TD with equal combining has poor improvement. When the received power envelope falls with fading, the influence of the click noise becomes much greater in the case of equal combining, whereas the influence of the click noise is minimized in the case of weighted combining. This is because weighting factor w_{ij} becomes quite small due to RSSI as the received power envelope falls down.

Figure 5 shows the experimental results in static environment from an experimental receiver for FLEX-TD using the direct conversion configuration. This receiver uses CWC-TD. In this figure, the y-axis represents the success probability (Ps) when the receiver receives a message of 20 characters. Besides, the experimental results in fading environment with 1Hz Doppler frequency is shown in Figure 6. These results nearly agrees with that of simulated results.

The difference in the effects of the three time diversity methods have been clarified. BC-TD with weighted combining has the greatest improvement. To realize a BC-TD process, however, the problem exists that much more hardware, such as A/D converter and memory, is required than CWC-TD.

4.Simulcast Transmitting Frequency Offsets

In the simulcast transmission system, there is a critical area where each RF signal from several transmitters are overlapped. In the case of RF signals from two transmitters overlapping, and the carrier frequency of each RF signal (or FSK signal) being exactly same amplitude and opposite phase, these RF signals cancel each other and the received effective power is reduced. To improve this critical case, carrier frequency offset transmission technology is applied. We estimated the effect of frequency offset transmission technology in the 4-level FSK system by simulation and experiment.

Figure 7 shows a simulation model for simulcast by two transmitters. The attenuator and phase shifter at the transmitter(#2) create an RF signal power and phase difference between the two transmitters. The carrier frequency of each transmitter is shifted Δf_1 and Δf_2 respectively from the carrier frequency of f_c. The frequency offset Δf between transmitter(#1) and (#2) is denoted as $\Delta f = \Delta f_2 - \Delta f_1$.

Figure 8 shows the characteristics of frequency offset Δf versus BER when the RF signal power difference between the two transmitters is equal. The experimental results, obtained using the experimental receiver, are shown in Figure 9. From those results, we can determine an improvement of BER by frequency offset transmission. Two additional features are obtained. First, the larger the frequency offset Δf, the more the effect of improvement of BER and Ps is reduced. The reason for this is that the larger the frequency offset, the faster and deeper the fading caused by the frequency offset becomes. This fast and deep fading makes not burst errors but more random errors in the interleaved block, making it impossible to correct these errors in each codeword of the interleaved block. The second feature is that there are periodically peculiar points where the improvement of BER is very poor. The reason for this is considered as follows. In this paging system the received data bits are interleaved perpendicularly during the 160msec that corresponds to 32x32bits block in 6400bps. When the frequency offset Δf is set to the peculiar frequency, the fading interval caused by the frequency offset becomes $1/\Delta f$. When the interval $1/\Delta f$ corresponds to the multiple of the interleave period, the errors caused by the fading are concentrated for a specific codeword. To correct these errors in specific codeword by BCH correction becomes impossible. From the above results, the sensitivity of the receiver changes radically in response to the frequency offset. Therefore the RF carrier frequency of each base station should be set up with greater accuracy.

5.Conclusion

The effects of the two technologies for particular propagation characteristics in the 4-level FSK paging system were considered by computer simulation and experimental results using the direct conversion receiver with a digital demodulator. Similar to using the conventional heterodyne receiver, we confirmed the effects of the sensitivity improvement using that receiver. In the time diversity technology, the value of the difference of these effects was clarified between BC-TD and CWC-TD. In the frequency offset transmission technology in simulcast, we confirmed an improvement in frequency offset transmission and the relation between frequency offset and interleaved period.

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Table 1: Specifications of the FLEX-TD System

Modulation	4-FSK 6400bps/ 3200bps	2-FSK 3200bps/ 1600bps
Frequency Deviation	±1600Hz, ±4800Hz	±4800Hz
Error Correction	BCH(31,21) & 1 bit parity	
Interleave Block	32×32bits/ 32×16bits	32×16bits/ 32×8bits
Frequency Offset Transmission	≤±150Hz	

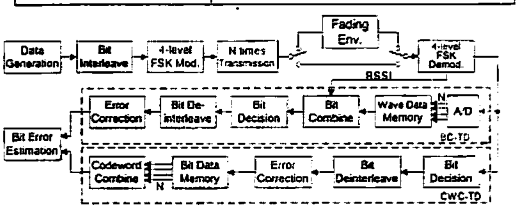

Figure 1: Block Diagram of the TD Simulation Process

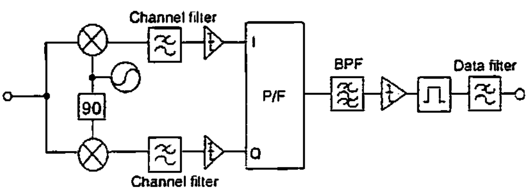

Figure 2: Direct Conversion Receiver for 4-level FSK

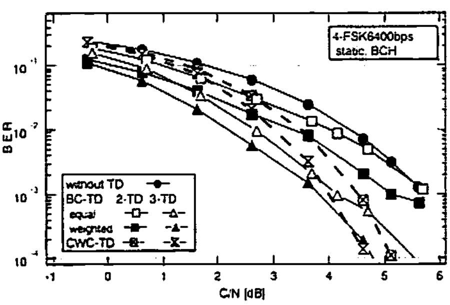

Figure 3: BER Improvement of TD (static)

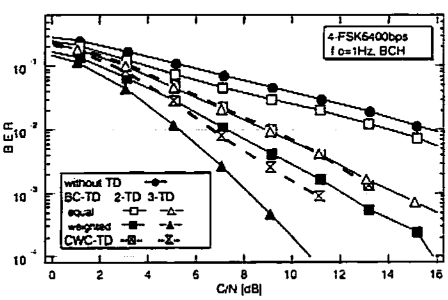

Figure 4: BER Improvement of TD(fD=1Hz)

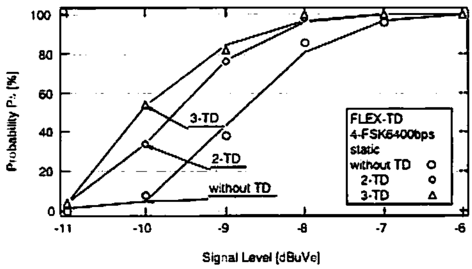

Figure 5: Experimental Results (static)

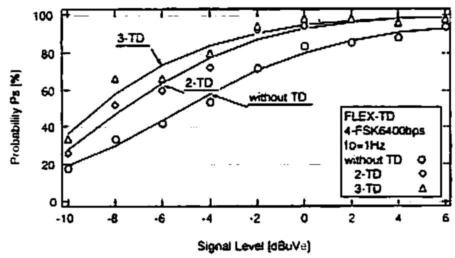

Figure 6: Experimental Results (fD=1Hz)

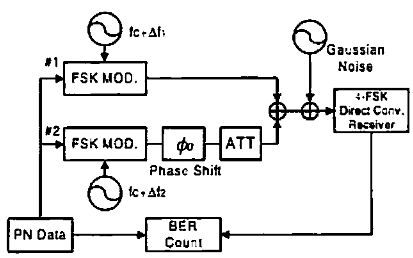

Figure 7: Simulation Model for Simulcast Transmission

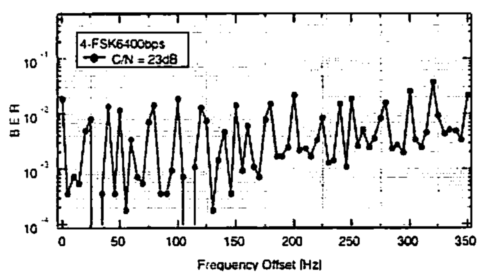

Figure 8: Frequency Offset vs.BER(simulation)

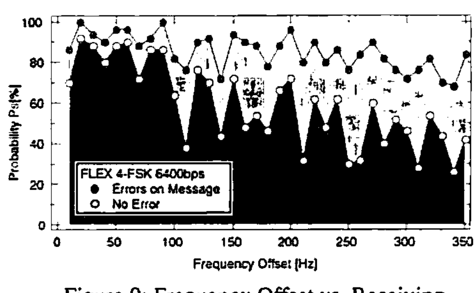

Figure 9: Frequency Offset vs. Receiving Probability(experimental results)