Performance of Several MMFSK Systems Using Limiters for High Frequency Power-Line Communications

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ABSTRACT

This paper presents BER performance of several FH/M-ary multilevel FSK (MMFSK) and OFDM (MC-SS type) systems using limiters, and compares their properties in an AWGN channel and in a high frequency power-line. The proposed MMFSK systems are modified by using a parallel system and a multi-tone combination system. As a limiter, a soft clipper is adopted. High frequency power-line models terminated by matched and opened impedance are employed. As a result of computer simulation, in the same data rate, it is shown that the BER performance of several MMFSK systems are superior to that of OFDM systems using almost the same bandwidth of MMFSK both in an AWGN channel and in a high frequency power line.

Key words - power line communication, high frequency, FH, MMFSK, OFDM, limiter

1. INTRODUCTION

Frequency hopping/M-ary multilevel FSK system (MMFSK) [1][2] is a modified version of multilevel FSK [3] in which to increase the information transmission rate plural numbers of hopping patterns are used instead of single hopping pattern. The feature of MMFSK system is that the amplitude (or envelope) of transmitting signal takes constant value. Then, the modulation schemes will be suited to power-line signal transmission because of their robustness to impulsive noise disturbances. While, orthogonal frequency division multiplexing systems (OFDM) have been also discussed for power-line communications [4][5]. In OFDM systems, dynamic range of the signal amplitude becomes large. However, in power-line communications, large fluctuation of signal level, large distortion of waveform and large impulsive noise should be taken into account. To cope with these factors, a limiter will be necessary in these systems. When the limiter is adopted at the receiver, the nonlinear distortion by saturation of signal amplitude arises in OFDM systems, on the other hand, the distortion can be made small in the MMFSK systems. The effect of limiters on BER performance has been studied in an additive white Gaussian noise (AWGN) environment and in a low frequency (10-450[kHz]) power-line [7][8]. When the MMFSK systems are applied to high data rate transmission on high frequency (2-30[MHz]) power line, several ideas and modifications will be necessary.

In this paper, first, we present the models of a basic MMFSK, an MMFSK multi-tone combination system which adopts the combination of several frequency tones instead of a frequency tone per chip [9], and parallel connection of several MMFSK systems. Second, we present a model of high
2. SYSTEM MODEL

2.1 MMFSK

Figure 1 shows a transmitter model of a basic MMFSK modulation system. In this system (N+H)-bit data can be transmitted at the same time in one symbol duration. The binary input data stream of (N+H)-bit is first divided into two parts of N and H-bit data. Then N-bit data are translated to one of \(2^N\) code words by ordinary rule of N-ary signaling, as shown in Fig.2(a), where L means the number of chips in a symbol for frequency hopping. Again, H-bit data are translated to one of \(2^H\) hopping patterns, as shown in Fig.2(b). By these operations we obtain a hopping pattern transmitted by MMFSK as shown in Fig.2(c), where \(n\) corresponds to the number of frequency slots used.

Figure 3 shows a receiver model of MMFSK system. First, the received signal is filtered through a band-path filter (BPF) of the whole system bandwidth. Second, a conventional non-coherent detection for each frequency slot operates. Next, the value for each frequency slot is evaluated by a soft decision [8]. The soft decision method preserves the detected analog value for each frequency slot. These operations are repeated \(L\) times. By these evaluations, an \(n \times L\) map will be filled with the detected analog values in the receiver. This map is reversely cyclic-shifted (subtraction (mod n)) according to the \(h\) hopping patterns. Then, \(h\) patterns of \((n \times L)\)-map are produced, and all the \(L\)-chip rows of \(n\) levels for all the \(h\) patterns are separately added. Finally, a level (a frequency slot num-
3. MODEL OF HIGH FREQUENCY POWER-LINE [10]

Figure 8 shows a model of high frequency (2-30[MHz]) power-line of VVF cable. The VVF cable is constructed of two wires of ø1.6mm. The branched cable of A, B, C and D are connected in order from the transmitter (Tx) side, and these configurations are defined as 1-branch, 2-branch,..., 4-branch system, respectively. When there is no branch, it is defined as 0-branch system. The terminals of cables A, B, C, D and the receiver (Rx) have two kind of conditions, i.e., opened and matched by 91[Ω]. Figure 9 shows the characteristics of 4-branch system. For the matched terminals, the amplitude is almost flat and the phase is linear, however, for the opened terminals, the characteristic becomes coarse.

4. SIMULATION RESULTS

Tables 1 and 2 show the specifications of simulations for several MMFSK and OFDM systems. These systems are numbered (1), (2), (3) and (4) as follows.

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Fig.8 Model of high frequency power-line.

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Fig.9 Characteristics of high frequency power line model.
4.1. Comparison of P/MMFSK(1) and OFDM (4Mbps)(3)

Figures 10 and 11 show BER performances of parallel MMFSK (1) and OFDM (4Mbps) (3) in an AWGN channel. Data rate 4 [Mbps] is common. Both systems are degraded by the limiter. However, the influence by the limiter and the required Eb/No in parallel MMFSK system (1) are less than that in the OFDM system (3). For example, at BER=10^-3, the limiter of infinite threshold level, the required Eb/No of systems (1) and (3) are 6.0 and 9.2, respectively. For the limiter of threshold level 1.0, the required Eb/No of systems (1) and (3) become 7.5 and 18.0, respectively. The reason is that the dynamic range of the transmitting signal of the parallel MMFSK system is smaller than that of OFDM.

4.2. Comparison of P/MMFSK Multi-Tone Combination(2) and OFDM (8Mbps)(4)

Figures 12 and 13 show BER performances of parallel MMFSK multi-tone combination (2) and OFDM (8Mbps) (4) in an AWGN channel. Data rate 8 [Mbps] is common. The similar manner of the previous systems (1) and (3) is shown. For example, at BER=10^-3, in the limiter of threshold level infinite, the required Eb/No of systems (2) and (4) are 7.5 and 9.5, respectively. Then, in the limiter of threshold level 1.0, the required Eb/No of system (2) becomes 10.5, however, for the system (4), BER=10^-3 can not be achieved in Eb/No=20[dB].
5. CONCLUSIONS

In this paper, we have presented the BER performance of several MMFSK systems using limiters for high frequency power line communications in comparison with OFDM systems.
Using limiters, the BER of several MMFSK systems has been superior to that of OFDM (MC-SS type) systems both in an AWGN channel and in a high frequency power line. However, for a high frequency power line with opened terminals, the degradation of BER of all systems becomes large. Therefore, additional improvement will be necessary for further studies.

REFERENCES