Faster-Than-Nyquist Transmission in SC-FDE System over Frequency Selective Channel with One Equalizer

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Abstract. When the Faster-than-Nyquis (FTN) signal transmits in the Single Carrier Frequency-Domain Equalization (SC-FDE) system over the multipath frequency selective channel, the Inter-Symbol Interferences (ISIs) will be induced by both FTN signaling and multipath channel. In this paper, we investigate the method to combat the induced ISIs together with one equalizer at the receiver. The simulation results demonstrate that acceptable BER system performance can be achieved with our proposed transceiver.

Keywords: Faster-than-Nyquist (FTN) · SC-FDE · Unique Word Inter-Symbol-Interference (ISI)

1 Introduction

The concept of FTN signaling was discovered by Mazo in 1970 [1]. He proved that increasing the rate of data transmitted of signal by 25% more than Nyquist rate in the AWGN channel, the minimum Euclidean distance does not reduce and the performance of transmission does not degrade [2].

In wireless communications, the transmitted signals normally go through multipath channel before reaching the receiver. Both FTN signaling and multipath frequency selective channel can induce ISIs in the transmission. To combat the both ISIs, Sygiura proposed a frequency-domain equalization (FDE) receiver structure in [3], which can operate in the context of FTN signaling transmission. Furthermore, an FTN transceiver without guard interval in the transmitter was used overlap FDE in [4] and demonstrated that the scheme can achieve higher transmission rate than that Nyquist without performance degradation.

In this paper, we investigate the FTN transmission in the SC-FDE system over the multipath frequency selective channel. The main contribution of this paper is that we propose a low-complexity receiver with one equalizer to combat the two induced ISIs together. The simulation results demonstrate that acceptable BER system performance can be achieved with our proposed transceiver.

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2 System Model

At the transmitter, the information bits are mapped to data symbols after modulation. Then the modulated data appended with a UW (Unique Word) to form a data block, passing through a FTN-shaping filter to get the FTN signal with transmission interval τT_s. The length of UW is set to be longer than the length of ISIs induced by both FTN signaling and multipath channel to eliminate inter-block interference (IBI). After that the SC-FDE blocks transmitted though the mobile radio channel. A multipath frequency selective channel with additive white Gaussian noise is considered in this paper. The receiver first removes the UW of the received signals, and utilizes the pilot for channel and FTN estimation. Then one MMSE equalizer in the frequency domain is applied on the received signals to combat the induced ISIs by FTN signaling and frequency selective channel. Finally, the equalized signals are demodulated to recover the original data (Fig. 1).

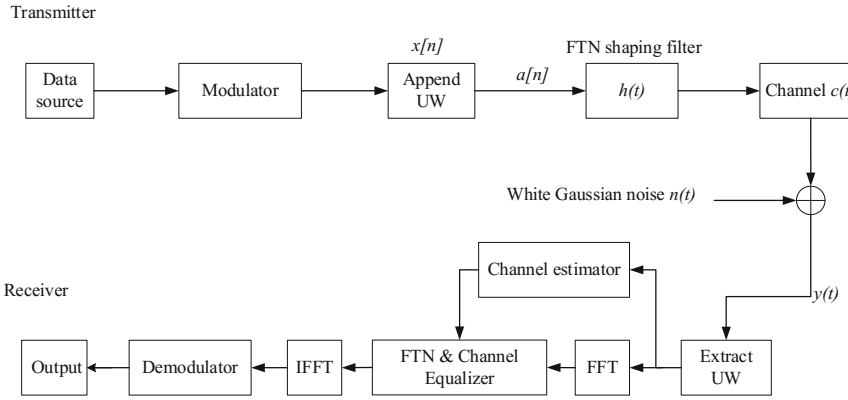

Fig. 1. System model of FTN transmission in SC-FDE system with one equalizer.

3 Simulation and Discussion

In this section we simulate the FTN transmission for SC-FDE system over multipath frequency selective channel. In the considered SC-FDE system, one transmitted frame is 1024 samples with 768 data symbols and 256 UW samples. The Zadoff-Chu sequences are used as the UW for channel estimation. For channel equalization at the SC-FDE receiver, the MMSE scheme is used. The symbol sampling rate is 1/τ10 M samples per second. In this simulation, we utilize the 3rd generation partnership project (3GPP) Pedestrian A channel with 4 dominant taps.

Figure 2 shows the BER (Bit Error Rate) performance of the SC-FDE system at different FTN rates using the designed frame structure under AWGN channel and multipath channel.

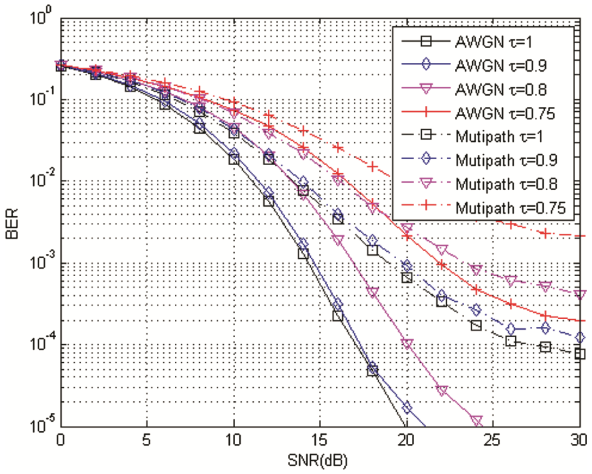

Fig. 2. BER performance of FTN transmission for SC-FDE with frame structure

We firstly compare the BER performance of FTNs transmission in AWGN channel with different value of τ. It can be observed that the BER perfomance of system becomes worse when decreasing the value of τ. In case of $\tau = 1$ and $\tau = 0.9$, the system error rate is up to 10^{-4} at SNR = 16 dB; for $\tau = 0.8$ SNR needs to be 20 dB to reach the same BER; when $\tau = 0.75$, the error rate is higher at high SNR.

Under the multipath channel, the ISIs are induced by both non-orthogonal FTN transmitter and multipath frequency selective channel, and we can see that at $\tau = 0.9$ and $\tau = 0.8$, the system BER can be almost up to 10^{-4} at SNR = 30 dB, which performs an acceptable for the information transmision; When $\tau = 0.75$, the BER performance can be only close to 10^{-3} at high SNR. In this case we need to consider the error correcting codes for improving the BER performance.

4 Conclusion

When combining FTN signaling with SC-FDE system over frequency selective channel, the FTN signaling and multipath frequency selective channel can both induce ISIs in the received signals. It is a promising approach these ISIs can be combatted by properly designed transceiver structure. With our designed frame structure using UW sequence, we can adopt one MMSE equalizer to combat both ISIs at the receiver. Such a low complexity transceiver can provide acceptable BER performance in a range of FTN signaling rate. The error correcting codes can be considered for further achieving better BER performance in certain SNR regime.

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References

1. Mazo, J.E.: Faster-than-Nyquist signaling. Bell Syst. Tech. J. **54**(8), 1451–1462 (1975)
2. Mazo, J.E., Landau, H.: On the minimum distance problem for faster-than-Nyquist signaling. IEEE Trans. Inf. Theor. **34**(6), 1420–2427 (1988)
3. Sugiura, S.: Frequency-domain equalization of faster-than-Nyquist signaling. IEEE Wirel. Commun. Lett. **2**(5), 555–558 (2013)
4. Fukumoto, H., Hayashi, K.: Overlap frequency domain equalization for faster-than-Nyquist signaling. Mathematics **4**, 1211–1218 (2015)