GENERALIZED OFDM WITH FREQUENCY-DOMAIN EQUALIZATION IN A FREQUENCY SELECTIVE RAYLEIGH FADING CHANNEL

Haris GACANIN, Shinsuke TAKAOKA and Fumiyuki ADACHI

Department of Electrical and Communication Engineering, Graduate School of Engineering, Tohoku University

I. INTRODUCTION

Orthogonal frequency-division multiplexing (OFDM) [1] is one of the promising techniques for very high-speed data transmissions in a severe frequency-selective fading channel [2]. However, since OFDM uses a numerous number of narrowband orthogonal subcarriers to transmit data in parallel, the problem of high peak-to-average power ratio (PAPR) arise. To alleviate the PAPR problem, a novel technique called generalized OFDM (GOFDM) is presented, in which OFDM symbols with less number of subcarriers are serially concatenated. Frequency-domain equalization (FDE) is applied to eliminate the intersymbol and inter-subcarrier interference. This paper evaluates the BER performance of generalized OFDM.

II. PERFORMANCE OF GENERALIZED OFDM

Figure 1 illustrates the transmitter/receiver structure for the GOFDM system. A sequence of N_s data symbols $\{d(i);\ i=0\sim N_s-1\}$ is to be transmitted during an FFT time window. $\{d(i)\}$ is transformed into a sequence of K blocks of N_m data symbols each. The GOFDM signal $\{s^k(t)\}$ is a serial concatenation of K OFDM signals having N_m subcarriers, i.e., $N_m=N_s/K$. The GOFDM signal can be expressed using the equivalent lowpass representation as

$$s(t)=\sum_{k=0}^{K-1}s^k(t-kN_m)u(t-kN_m)\ , \quad (1)$$

where $s^k(t)$ is the k-th OFDM signal having N_m subcarriers given by

$$s^k(t)=\sqrt{\frac{2E_c}{T_c}}\sum_{i=0}^{N_m-1}d^k(i)\exp\left[j2\pi t\frac{i}{N_m}\right]\ . \quad (2)$$

In Eq. (2), E_c and T_c respectively represent the signal energy per FFT sample and sample period, $\{d^k(i);\ i=0\sim N_m-1,\ k=0\sim K-1\}\}$, where $d^k(i)=d(kN_m+i)$, is the k-th block data sequence, and $u(t)=1(0)$ for $t=0\sim N_m-1$ (otherwise). Then, the last part of N_g samples is inserted as a cyclic prefix at the guard interval (GI). The GI-inserted GOFDM signal of N_s samples is transmitted over the frequency-selective fading channel.

At the receiver, after removing the GI, N_s-point FFT and FDE are applied to the received GOFDM signal. The frequency-domain signal $\{\hat{R}(n); n=0\sim N_s-1\}$ after FDE is transformed, by applying N_s-point IFFT, back into the time-domain signal $\hat{r}(t)$:

$$\hat{r}(t)=\frac{1}{N_s}\sum_{n=0}^{N_s-1}\hat{R}(n)\exp\left[j2\pi t\frac{n}{N_s}\right]=\sum_{k=0}^{K-1}\hat{r}^k(t-kN_m)u(t-kN_m) \quad (3)$$

for $t=0\sim N_s-1$, where $\hat{r}^k(t)$ is the k-th OFDM signal having N_m subcarriers. Then, N_m-point FFT is applied to $\tilde{r}^k(t)$ to obtain:

$$\hat{d}^k(i)=\sum_{t=0}^{N_m-1}\hat{r}^k(t)\exp\left[-j2\pi i\frac{t}{N_m}\right] \quad (4)$$

for $i=0\sim N_m-1$ and $k=0\sim K-1$, which is the decision variable for data symbol $d(kN_m+i)$. A special case of GOFDM is the conventional OFDM system and another is the single carrier (SC) system. For computer simulation, we assume $N_s=256$, $N_g=32$, MMSE-FDE and a frequency-selective fading channel with L-path exponential power delay profile (decay factor β of 0, 2, 4, 10 dB). Figure 2 shows how the BER performance of GOFDM system changes from OFDM (K=1) to SC (K=256). It can be seen that the BER performance of the GOFDM system lies between conventional OFDM (as upper bound) and SC system (as lower bound).

III. CONCLUSIONS

The GOFDM can be controlled by a simple parameter K and found to bridge between the conventional OFDM and SC systems. As K increases (or approaching the SC system), the PAPR reduces and performance improves as well. However, application of channel coding and various resource allocation techniques may give different result. This will be discussed in forthcoming papers.

REFERENCES

[1] Richard Van Nee and Ramjee Prasad, *OFDM for Wireless Multimedia Communications*, Artech House, 2000.

[2] J.G.Proakis, *Digital Communications*, McGraw-Hill, 3rd Ed., 1995.

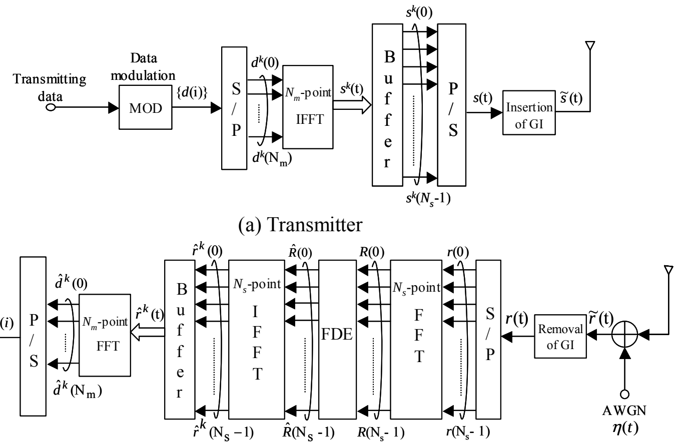

Fig. 1. GOFDM transmitter/receiver structure.

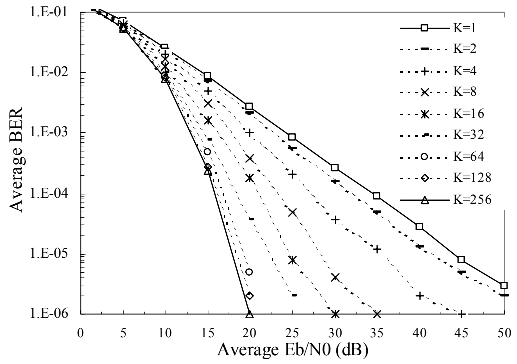

Fig. 2. BER performance.