Chapter 16
Beyond 3G Techniques of Orthogonal Frequency Division Multiplexing and Performance Analysis via Simulation

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ABSTRACT
As one of the techniques beyond 3G, because of the effective performance of high spectrum utilization and anti-fading for frequency selecting and adopted multi-carrier modulation technique that meets the requirement of the explosive traffic capacity, Orthogonal Frequency Division Multiplexing (OFDM) has carried great weight in wireless communications. This paper expounds OFDM technical characteristics and performs computer simulation on the OFDM system based on Inverse Fast Fourier Transform (IFFT) by means MATLAB. During the course of simulation, comparison between OFDM and traditional single-carrier technology is performed. The simulation results have great significance for research and applications in the field.

INTRODUCTION
OFDM is kind of both multi-carrier and multiplexing technique, which distributes a given channel into plurality of sub-channel. And each parallel transmitting sub-channel adopts single-carrier modulating. By this meaning, each sub-channel is flat relatively, and performs narrowband transmission. Signal bandwidth is less than related bandwidth, which eliminates interference between signal waveforms and improves frequency spectrum utilization because of signal orthogonality, frequency spectrum overlap (Ramasami, 2002).

DOI: 10.4018/978-1-4666-2645-4.ch016
OFDM discards the way using traditional band filter to distribute sub-carrier, and adopting frequency modulation meaning to select the signal waveforms that can keep orthogonality even while frequency spectrum aliasing. Therefore, OFDM is both modulating and multiplexing techniques.

For the traditional Frequency Division Multiplexing (FDM), guard band is used to avoid intercarrier interference (Figure 1), which induces frequency spectrum utilization. Whereas, OFDM system applies FFT technique into multi-carrier transmission system with orthogonal and aliasing frequency spectrum, so as to realize multiplex signal multiplexing and split conveniently. Here “orthogonal” indicates accurate mathematical relationship between carrier frequencies:

\[
\int_0^T \cos(2\pi mf_t) \cdot \cos(2\pi nf_t) dt = \begin{cases} 
T/2 & (m = n) \\
0 & (0 \neq m \neq n) 
\end{cases}
\quad (1)
\]

\[
\int_0^T \sin(2\pi mf_t) \cdot \sin(2\pi nf_t) dt = \begin{cases} 
T/2 & (m = n) \\
0 & (0 \neq m \neq n) 
\end{cases}
\]

\[
\int_0^T \cos(2\pi mf_t) \cdot \sin(2\pi nf_t) dt = \begin{cases} 
T/2 & (m = n) \\
0 & (0 \neq m \neq n) 
\end{cases}
\]

and an important advantage of OFDM technique is that modulation and demodulation can be performed by adopting IFFT/FFT, so as to reduce complexity for realizing the system.

**TECHNIQUE PRINCIPLE**

The essential technical principle is to divides one high speed data flow into plurality of low speed data flows. And the low-speed data flows are modulated by orthogonal frequency and transmit data simultaneously, thus wide band becomes narrow bands, and consequently, the problem of selective fading can be solved. In addition, if adding a delayed protection to generated OFDM signal, intersymbol interference can be figured out (Gong & Jia, 2002; IEEE Computer Society, 1999). The modulation principle in OFDM system is seen in Figure 2.

After the modulating of MQAM, MPSK or DPSK, etc., taking advantage of sub-carrier orthogonality, the original signal is demodulated. The principle is seen in Figure 3.

One OFDM symbol includes signals which are combined by multiple modulated sub-carriers, and each sub-carrier can be modulated by PSK or QAM symbol. If \( N \) indicates the number of sub-channel, \( T \) indicates OFDM symbol density, \( d_i \) (\( i=0, 1, 2, ..., N-1 \)) indicates data symbol distributed to each sub-channel, and \( f_i \) indicates the carrier frequency of the No. 0. \( \text{rect}(t)=1, \ |t|\leq T/2 \), the original OFDM symbol can be indicated as following:

\[
s(t) = \text{Re}\{\sum_{i=0}^{N-1} d_i \text{rect}(t - t_i - T / 2) \exp[j2\pi(f_c + i / T)(t - t_i)]\},
\]

\[
(2)
\]
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