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ORTHOGANAL FREQUENCY

 DIVISION MULTIPLEXING

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**INTRODUCTION**

**What is OFDM ?**

It is a process of splitting of higher data streams or channels into a number of lower data stream simultaneously. In simple terms, OFDM means spreading data over lots of narrowly spaced carrier. Each carrier is modulated with low speed data. OFDM provides frequency distribution of data .It is applied to both wired and wireless communication.

Orthogonal frequency-division multiplexing (OFDM) is a method of encoding digital data on multiple carrier frequencies. OFDM has developed into a popular scheme for [wideband](http://en.wikipedia.org/wiki/Wideband)[digital communication](http://en.wikipedia.org/wiki/Digital_communication), whether [wireless](http://en.wikipedia.org/wiki/Wireless) or over [copper](http://en.wikipedia.org/wiki/Copper) wires, used in applications such as digital television and audio broadcasting, [DSL](http://en.wikipedia.org/wiki/Digital_subscriber_line)[broadband internet access](http://en.wikipedia.org/wiki/Broadband_internet_access), wireless networks, and [4G](http://en.wikipedia.org/wiki/4G) mobile communications.

An OFDM modulation technique is used for transmitting large amount of digital data over a radio wave. OFDM work by splitting the radio signal into multiple smaller sub-signal that are then transmitted simultaneously at different frequencies to the receiver. OFDM reduces the amount of crosstalk in signal transmission. OFDM is a method of digital communication in which signal is split into several narrowband channel at different frequencies. OFDM is some like what conventional frequency division multiplexing (FDM).It is given priority of minimum interference.

A large number of closely spaced [orthogonal](http://en.wikipedia.org/wiki/Orthogonality#Communications)[sub-carrier signals](http://en.wikipedia.org/wiki/Subcarrier) are used to carry [data](http://en.wikipedia.org/wiki/Data) on several [parallel](http://en.wikipedia.org/wiki/Crosstalk_%28electronics%29) data streams or channels. Each sub-carrier is modulated with a conventional modulation scheme (such as [phase-shift keying](http://en.wikipedia.org/wiki/Phase-shift_keying)) at a low [symbol rate](http://en.wikipedia.org/wiki/Symbol_rate), maintaining total data rates similar to conventional *single-carrier* modulation schemes in the same bandwidth.

 The primary advantage of OFDM over single-carrier schemes is its ability to cope with severe [channel](http://en.wikipedia.org/wiki/Channel_%28communications%29) conditions. Channel [equalization](http://en.wikipedia.org/wiki/Equalization) is simplified because OFDM may be view as using many slowly modulated [narrowband](http://en.wikipedia.org/wiki/Narrowband) signals rather than one rapidly modulated [wideband](http://en.wikipedia.org/wiki/Wideband) signal. The low symbol rate makes the use of a [guard interval](http://en.wikipedia.org/wiki/Guard_interval) between symbols affordable, making it possible to eliminate [intersymbol interference](http://en.wikipedia.org/wiki/Intersymbol_interference) (ISI) and utilize echoes and time-spreading (on analogue TV these are visible as [ghosting](http://en.wikipedia.org/wiki/Ghosting_%28television%29) and blurring, respectively) to achieve a [diversity gain](http://en.wikipedia.org/wiki/Diversity_gain), i.e. a [signal-to-noise ratio](http://en.wikipedia.org/wiki/Signal-to-noise_ratio) improvement. This mechanism also facilitates the design of [single frequency networks](http://en.wikipedia.org/wiki/Single_frequency_network) (SFNs), where several adjacent transmitters send the same signal simultaneously at the same frequency, as the signals from multiple distant transmitters may be combined constructively, rather than interfering as would typically occur in a traditional single-carrier system.

**Types Of OFDM**

* C-OFDM (Coded-OFDM)
* V-OFDM (Vector-OFDM)
* W-OFDM (Wideband-OFDM)
* Flash- OFDM
* MIMO-OFDM (Multiple input, multiple output-OFDM)

**History**

* The idea which was proposed in mid 1960s, used parallel data transmission and FDM.
* In the 1960s, the OFDM technique was used in several high frequency military system.
* In 1971, Weinstein and Ebert applied the Discrete Fourier Transform (DFT) to parallel data transmission system as a part of Modulation and Demodulation process. They proposed time-limited MC transmission, which is what we call today.
* In 1980s, OFDM was studied for high-speed modem, digital mobile communication and high density recording.
* In 1985, Cimini first applied OFDM in mobile wireless communication.
* In the 1990s, OFDM was exploited for wideband data communication.
* Now OFDM technique has been adopted as the new European DAB standard, and HDTV standard.

**Characteristics and principles of operation**

**Orthogonality**

Conceptually, OFDM is a specialized FDM, the additional constraint being: all the carrier signals are orthogonal to each other.

In OFDM, the sub-carrier frequencies are chosen so that the sub-carriers are [orthogonal](http://en.wikipedia.org/wiki/Orthogonality#Communications) to each other, meaning that [cross-talk](http://en.wikipedia.org/wiki/Crosstalk_%28electronics%29) between the sub-channels is eliminated and inter-carrier guard bands are not required. This greatly simplifies the design of both the [transmitter](http://en.wikipedia.org/wiki/Transmitter) and the [receiver](http://en.wikipedia.org/wiki/Receiver_%28radio%29); unlike conventional [FDM](http://en.wikipedia.org/wiki/Frequency-division_multiplexing), a separate filter for each sub-channel is not required.

OFDM requires very accurate frequency synchronization between the receiver and the transmitter; with frequency deviation the sub-carriers will no longer be orthogonal, causing *inter-carrier interference* (ICI) (i.e., cross-talk between the sub-carriers). Frequency offsets are typically caused by mismatched transmitter and receiver oscillators, or by [Doppler shift](http://en.wikipedia.org/wiki/Doppler_shift) due to movement.

**Implementing OFDM Modulation**

OFDM modulation in a transmitter includes inverse fast fourier transform (IFFT) operation and cyclic prefix insertion. In an OFDM receiver, cyclic prefix is removed before the data is FFT for demodulation. The most computationally intensive operation of OFDM modulation is IFFT, and similarly, the core of OFDM demodulation is FFT. FFT is shared between multiple data path. To reduce logic usage, FFT module is often clocked much faster than rest of baseband module and reused. You can also share FFT module with other functional modules for channel estimation. However, such reuse depends on user-specific algorithms and may not be a general design consideration.

**Guard interval for elimination of intersymbol interference**

One key principle of OFDM is that since low symbol rate modulation schemes (i.e., where the symbols are relatively long compared to the [channel](http://en.wikipedia.org/wiki/Channel_%28communications%29) time characteristics) suffer less from [intersymbol interference](http://en.wikipedia.org/wiki/Intersymbol_interference) caused by [multipath propagation](http://en.wikipedia.org/wiki/Multipath_propagation), it is advantageous to transmit a number of low-rate streams in parallel instead of a single high-rate stream. Since the duration of each symbol is long, it is feasible to insert a [guard interval](http://en.wikipedia.org/wiki/Guard_interval) between the OFDM symbols, thus eliminating the intersymbol interference.

The guard interval also eliminates the need for a [pulse-shaping filter](http://en.wikipedia.org/wiki/Pulse-shaping_filter), and it reduces the sensitivity to time synchronization problems.

A simple example: If one sends a million symbols per second using conventional single-carrier modulation over a wireless channel, then the duration of each symbol would be one microsecond or less. This imposes severe constraints on synchronization and necessitates the removal of multipath interference. If the same million symbols per second are spread among one thousand sub-channels, the duration of each symbol can be longer by a factor of a thousand (i.e., one millisecond) for orthogonality with approximately the same bandwidth. Assume that a guard interval of 1/8 of the symbol length is inserted between each symbol. Intersymbol interference can be avoided if the multipath time-spreading (the time between the reception of the first and the last echo) is shorter than the guard interval (i.e., 125 microseconds). This corresponds to a maximum difference of 37.5 kilometers between the lengths of the paths.

**Idealized system model**

###  Transmitter



###  FIG: Transmitter

An OFDM carrier signal is the sum of a number of orthogonal sub-carriers, with [baseband](http://en.wikipedia.org/wiki/Baseband) data on each sub-carrier being independently modulated commonly using some type of [phase-shift keying](http://en.wikipedia.org/wiki/Phase-shift_keying) (PSK). This composite baseband signal is typically used to modulate a main [RF](http://en.wikipedia.org/wiki/Radio_frequency) carrier.

![\scriptstyle s[n]]()is a serial stream of binary digits. By [inverse multiplexing](http://en.wikipedia.org/wiki/Inverse_multiplexing), these are first demultiplexed into parallel streams, and each one mapped to a (possibly complex) symbol stream using some modulation constellation ([PSK](http://en.wikipedia.org/wiki/Phase-shift_keying)). Note that the constellations may be different, so some streams may carry a higher bit-rate than others.

An inverse [FFT](http://en.wikipedia.org/wiki/FFT) is computed on each set of symbols, giving a set of complex time-domain samples. These samples are then [quadrature](http://en.wikipedia.org/wiki/Quadrature_phase)-mixed to passband in the standard way. The real and imaginary components are first converted to the analogue domain using [digital-to-analogue converters](http://en.wikipedia.org/wiki/Digital-to-analogue_converter) (DACs); the analogue signals are then used to modulate [cosine](http://en.wikipedia.org/wiki/Cosine) and [sine](http://en.wikipedia.org/wiki/Sine) waves at the [carrier](http://en.wikipedia.org/wiki/Carrier_wave) frequency, , respectively. These signals are then summed to give the transmission signal,

**Receiver**



The receiver picks up the signal , which is then quadrature-mixed down to baseband using cosine and sine waves at the carrier frequency. This also creates signals centered on , so low-pass filters are used to reject these. The baseband signals are then sampled and digitised using [analog-to-digital converters](http://en.wikipedia.org/wiki/Analog-to-digital_converter) (ADCs), and a forward [FFT](http://en.wikipedia.org/wiki/FFT) is used to convert back to the frequency domain.

This returns parallel streams, each of which is converted to a binary stream using an appropriate symbol [detector](http://en.wikipedia.org/wiki/Detector_%28radio%29). These streams are then re-combined into a serial stream, ![\scriptstyle {\hat s}[n]](), which is an estimate of the original binary stream at the transmitter.

**Example of application**

**Cable**

* Assymetric digital subscriber line (ADSL).
* [Power line communication](http://en.wikipedia.org/wiki/Power_line_communication) (PLC).
* [ITU-T](http://en.wikipedia.org/wiki/ITU-T)[G.hn](http://en.wikipedia.org/wiki/G.hn)**,** a standard which provides high-speed local area networking of existing home wiring (power lines, phone lines and coaxial cable .

**Wireless**

* The [wireless LAN](http://en.wikipedia.org/wiki/Wireless_LAN) (WLAN) radio interfaces [IEEE 802.11a](http://en.wikipedia.org/wiki/IEEE_802.11a), [g](http://en.wikipedia.org/wiki/IEEE_802.11g-2003), [n](http://en.wikipedia.org/wiki/IEEE_802.11n-2009) and [HIPERLAN/2](http://en.wikipedia.org/wiki/HIPERLAN/2).
* It is used in 4G technology.
* Digital audio and video broadcasting.
* The wireless [personal area network](http://en.wikipedia.org/wiki/Personal_area_network) (PAN) [ultra-wideband](http://en.wikipedia.org/wiki/Ultra-wideband) (UWB) [IEEE 802.15.3a](http://en.wikipedia.org/wiki/IEEE_802.15.3a) implementation suggested by [WiMedia Alliance](http://en.wikipedia.org/wiki/WiMedia_Alliance).

**Advantages**

* High [spectral efficiency](http://en.wikipedia.org/wiki/Spectral_efficiency) as compared to other double [sideband](http://en.wikipedia.org/wiki/Sideband) modulation schemes, spread spectrum, etc.
* Can easily adapt to severe channel conditions without complex time-domain equalization.
* Robust against [intersymbol interference](http://en.wikipedia.org/wiki/Intersymbol_interference) (ISI) and fading caused by multipath propagation.
* Efficient implementation using [Fast Fourier Transform](http://en.wikipedia.org/wiki/Fast_Fourier_Transform) (FFT).
* Low sensitivity to time synchronization errors.
* Tuned sub-channel receiver filters are not required (unlike conventional [FDM](http://en.wikipedia.org/wiki/Frequency-division_multiplexing)).
* Facilitates [single frequency networks](http://en.wikipedia.org/wiki/Single_frequency_network) (SFNs); i.e., transmitter [micro diversity](http://en.wikipedia.org/wiki/Macrodiversity).
* Adaptively modifies modulation density.
* It has good signal reliability, more data transmission with fast speed.

**Disadvantages**

* Sensitive to high frequency phase noise.
* Sensitive to sampling clock offset.
* Sensitive to [Doppler shift](http://en.wikipedia.org/wiki/Doppler_effect) Sensitive to frequency synchronization problems.
* High [peak-to-average-power ratio](http://en.wikipedia.org/wiki/Crest_factor) (PAPR), requiring linear transmitter circuitry, which suffer from poor power efficiency.
* Loss of efficiency caused by [cyclic prefix](http://en.wikipedia.org/wiki/Cyclic_prefix)/[guard interval](http://en.wikipedia.org/wiki/Guard_interval). The double [sideband](http://en.wikipedia.org/wiki/Sideband) modulation of each sub-carrier causes lower [spectral efficiency](http://en.wikipedia.org/wiki/Spectral_efficiency) and higher transmitter power requirements for equivalent coverage as compared to [VSB](http://en.wikipedia.org/wiki/8VSB).

**CONCLUSION**

* In simulation OFDM is used over an AWGN channel.
* In hardware comparison OFDM has lower potential.
* It OFDM produce low hardware complexity.
* It is a suitable modulation techniques for high performance wireless telecommunication.

REFERENCE

* <http://en.wikipedia.org/wiki/Orthogonal_frequency-division_multiplexing>.