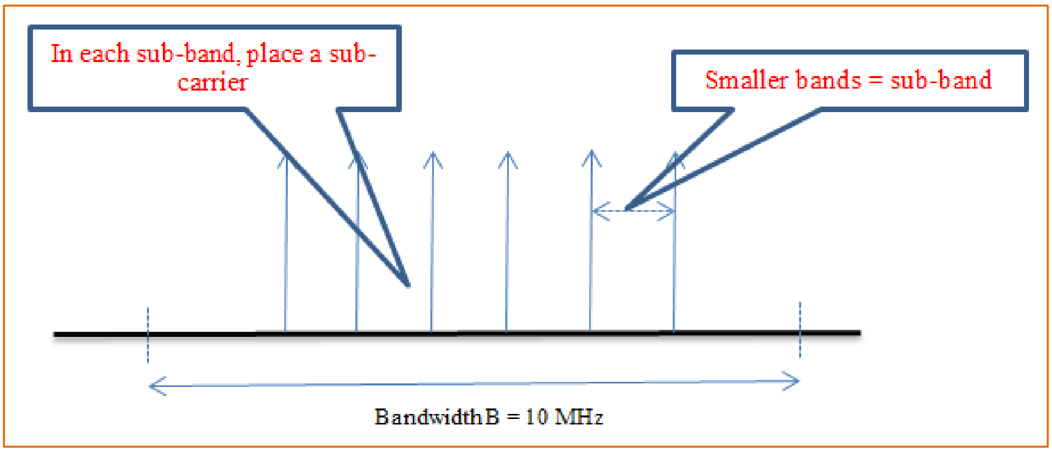
OFDM: Orthogonal Frequency Division Multiplexing

OFDM = Orthogonal FDM = Orthogonal Frequency Division Multiplexing

OFDM is a combination of modulation and multiplexing. Multiplexing generally refers to independent signals produced by different sources.

OFDM = Multi-carrier communication = multi-carrier modulation technique

The channel is split into number of sub-channels. The important property here is any two sub-channels are orthogonal to each other. Now each sub-channel transmits a part of the original information. Every channel gives some bandwidth. So this available bandwidth is divided into N sub-bandwidth, representing N sub-carriers.



Let B = Bandwidth of channel = 10 MHz
N = Number of sub-carriers or sub-bands = 1000
Bandwidth of each channel = B/N = 10 MHz/1000
= 10 KHz

Such a system with multiple sub-bands and multiple subcarriers is termed as Multi Carrier Modulated (MCM) system. This is basis or precursor for OFDM. This enables smooth transmission and reception in a broadband wireless communication system.

The basic principle of OFDM is to split a high-rate data stream into a number of lower rate streams that are transmitted at a time over number of sub-carriers. So, OFDM converts high speed data bits into parallel low speed data flows. As a consequence of having many sub-channels, OFDM eliminates the problem of fading that occurs in multi-path propagation of radio signals.

OFDM uses large number of closely spaced orthogonal sub-carriers. Each carrier is modulated with a conventional modulation scheme such as QAM.

OFDM Basic principle

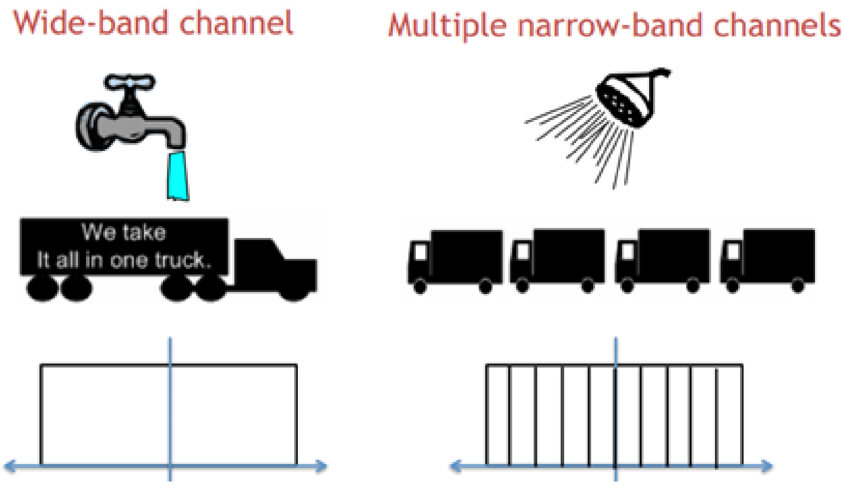
- Split high symbol rate data stream into N lower rate streams
- Transmit N lower rate data streams using N sub-carriers
- N sub-carriers must be mutually orthogonal. Any sub-carrier must be orthogonal to all other sub-carriers.

Orthogonal Frequency Division Multiplexing (OFDM), is a form of multicarrier transmission, in which a high-rate data stream is transmitted in a parallel manner over a number of low-rate orthogonal subcarriers. By using multicarrier modulation, bits are overlayed on many carriers at the same time.

Real-life analogy of OFDM concept

OFDM is a special case of Frequency Division Multiplexing (FDM). As an analogy, FDM signal is like water flow out of a faucet and OFDM signal is like a shower. In a faucet all the water comes in one big stream and cannot be divided. OFDM shower is made up of a lot of little streams.

Consider the analogy of making a shipment via a truck. We have two options, hire a big truck or a bunch of smaller trucks. Bothe methods carry the exact same amount of data. But in case of accident, only ¼ of data on the OFDM trucking will suffer.



Here in above figure, four smaller trucks represent four sub-carriers in OFDM system and these sub-carriers must be orthogonal to each other. In case of FDM (wide-band channel) data will be transported using entire bandwidth. In OFDM multiple narrow-bands are used and each carry part of data stream.

ORTHOGONALITY

The main concept in OFDM is orthogonality of the sub-carriers. Note that all the subcarriers used are either sine waves or cosine waves. OFDM transmission depends on orthogonality principle. If two vectors are orthogonal (angle between them = 90), then they are orthogonal. Note that Amharic and English are orthogonal. This means if one person is talking in Amharic and other is using English in same room, they do not interfere each other. We can easily separate interference caused at the receiver because there is no relationship between Amharic and English.

One real life example of interference is: two people talking at the same time. Consider transmitting 2 signals using same frequency. There will be interference between these two signals if they are not orthogonal. Orthogonality means both signal is having phase difference of 90 degrees. So, they will not interfere with each other.

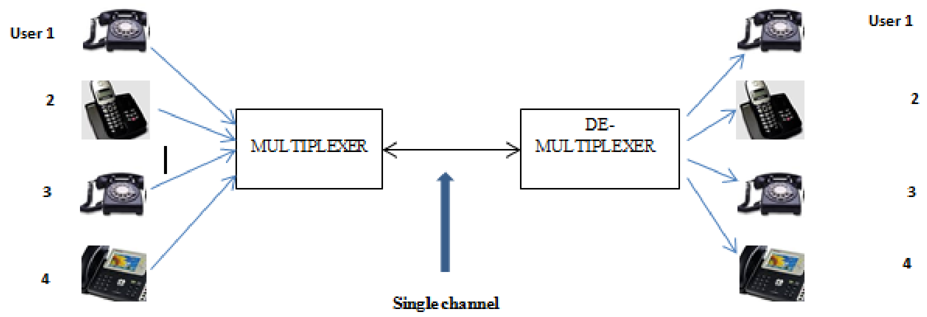
sin x and cos x are orthogonal to each other due to 90-degree phase difference between them. Orthogonal signals do not interfere. Two signals to be orthogonal, they have to have a phase shift of 90 degrees. Note that orthogonal signals are used extensively in communication industry. And orthogonal channels are designed to save BW.

This orthogonal idea is key to understanding OFDM. The orthogonality allows simultaneous transmission of lot of sub-carriers without interference from each other.

OFDM is based on the idea of frequency-division multiplexing (FDM).

Multiplexing is a technique, which allows many users to share a single communication channel (wire, cable, radio link, fiber optic cable, satellite) simultaneously. So, a number of information sources share the same communication channel. Information transmitted can be either voice (telephone signals) or data (computer signal, images, video etc). well-known application of multiplexing is telephone communication system.

Below figure illustrates the technique of multiplexing 4 users' data.



FDM extends the concept of single carrier modulation by using multiple sub-carriers within the same single channel. The total data rate to be sent in the channel is divided between the various sub-carriers. Note that the data neither have to be divided evenly among sub-carriers, nor from the same information source. Each chunk of data can use different modulation technique.

The use of orthogonal subcarriers would allow the subcarriers spectra to overlap, thus increasing the spectral efficiency. As long as orthogonality is maintained, there is no problem in recovering individual subcarrier's signals despite their overlapping spectrums.

OFDM = Multi-carrier communication = multi-carrier modulation technique

Carrier**: A**s the name suggests, its job is to carry the input signal from one place to other. Carrier is a **HF** signal. Sine or cosine wave are used as carrier in modulation techniques such as AM, FM, ASK, FSK, PSK, QPSK, QAM etc. Real-life examples of ***carrier*** signal: **Bus**, **Train**, **Airplane** etc.

In single - carrier communication system, data are transported over only one carrier. A single carrier system modulates information onto one carrier. Carrier is a sinusoidal wave. Information is baseband signal. Modulation can be AM, FM, PM in analog communication system.

For digital systems, information is in the form of bits, or collection of bits called symbols. These bits or symbols are modulated onto the carrier. Different kind of digital modulation techniques are: ASK, FSK, PSK, QPSK, QAM etc.

In **multi – carrier** communication system, input data are distributed among several carriers and simultaneously transmitted. If we use multiple carriers to transport input data, it is called as multi-carrier modulation scheme. OFDM is an example of using this technique. Note that multi-carrier modulation techniques are used in **fourth generation (4G)** communication systems.

The **OFDM** is a **multi-carrier modulation** in which carriers are **spaced** by a multiple of **1/*T***, where ***T* is the bit duration** and it is characterized by an **overlap of the spectrum** of the signals transmitted on different carriers.

The signal (OFDM signal) transmitted on the channel is a summation of a **huge number of sinusoidal carriers.** In OFDM, these carriers are known as sub-carriers. Each sub-carrier can be modulated by any kind of digital modulation techniques such as ASK, FSK, PSK, QPSK, QAM etc.

For high data rate transmissions, we use higher bandwidths. So, the duration of 1-bit becomes smaller. This leads to many problems and loss of information and information recovery is difficult at the receiver.

Also, as bandwidth used by the single carrier system increases, interference from other continuous signal sources becomes greater.

MULTICARRIER

The channel bandwidth is divided into many small sub-bands which are used for transmission of data in parallel. Ideally each sub-band is small enough to reduce fading and hence no ISI (Inter Symbol Interference).

OFDM Applications

OFDM is present in

- WiFi (Wireless Fidelity) = wireless LAN. WLAN implies Wireless LAN. It is what we have in our laptop.
- WiMax (Worldwide Interoperability for Microwave Access). WiMAX stands for Worldwide Interoperability for Microwave Access. This is metropolitan area networking (MAN) that provides internet to your home, office or car.
- LTE (Long Term Evaluation) = 4th generation wireless cellular standard
- DAB (Digital Audio Broadcasting)
- DVB (Digital Video Broadcasting) TV systems
- DVB-H – Multimedia to Handheld
- PLC (Power Line Communication)

- OFDM is successfully used for HF radio applications and chosen as the standard for digital audio broadcasting (DAB) and digital terrestrial TV broadcasting in Europe and high-speed wireless local areas networks (wireless LAN).