Anju et al. International Journal of Recent Research Aspects ISSN: 2349-7688, Vol. 2, Issue 4, December 2015, pp. 164-168

Orthogonal Frequency Division Multiplexing

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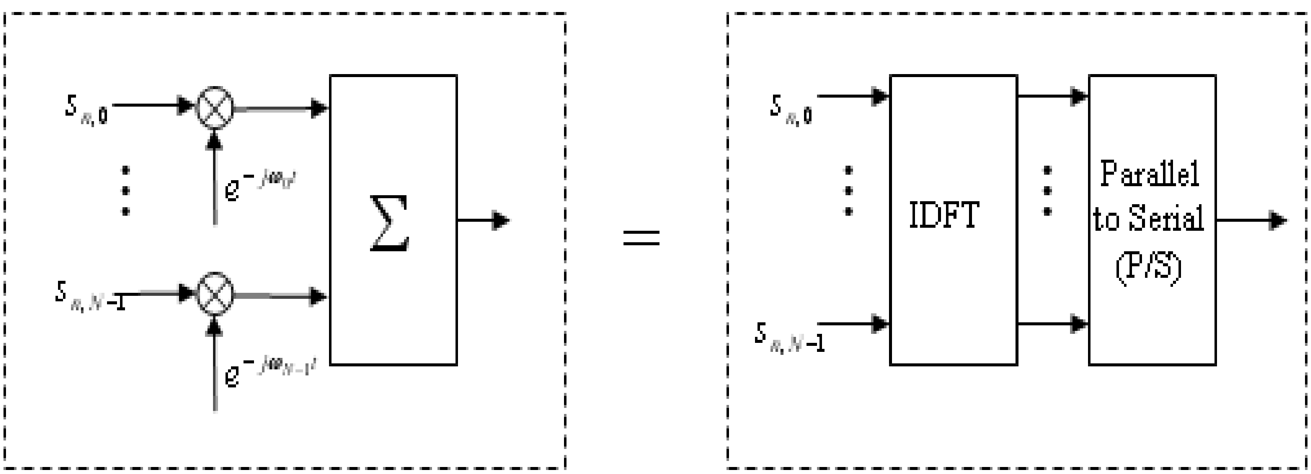
Abstract: OFDM was introduced in the 1950s but was first implemented in the 1960s. It was originally developed from the multi-carrier modulation techniques used in high frequency military radios. A patent for OFDM was granted in the 1970s. However, when OFDM was first introduced, it was not very popular because of the cost and complexity of large arrays of sinusoidal generators and coherence demodulators. The actual widespread use of OFDM started after the inverse discrete Fourier transform (IDFT) and discrete Fourier transform (IDFT) made the OFDM implementation possible without the use of large number of sinusoidal generators.

Orthogonal frequency division multiplexing (OFDM) is a form of digital modulation used in a wide array of communications systems. This paper will explain what OFDM is, why it's important, where it's used, and what test instrumentation is required to maintain it. Perhaps we should first explain what is so special about OFDM. Orthogonal frequency division multiplexing (OF'DM) is one of the most promising solution for obtaining light *data* rate t in frequency selective falling radio channels [I]. Advances in VLSl technologies have led to new interest in this technique for transmitting information through overlapping carriers.

Keywords: Orthogonal Frequency Division Multiplexing (OFDM)

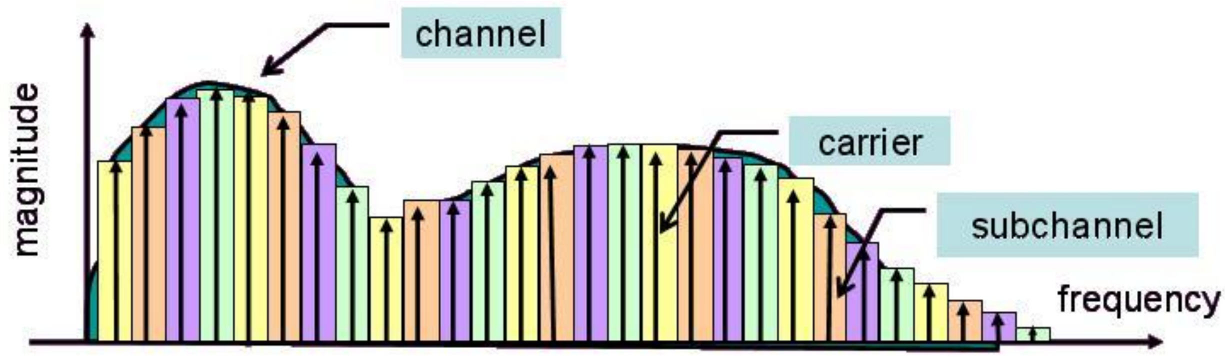
I. INTRODUCTION

Main idea: split data stream into N parallel streams of reduced data rate and transmit each on a separate subcarrier. When the subcarriers have appropriate spacing to satisfy orthogonality, their spectra will overlap. OFDM modulation is equivalent to the IDFT:



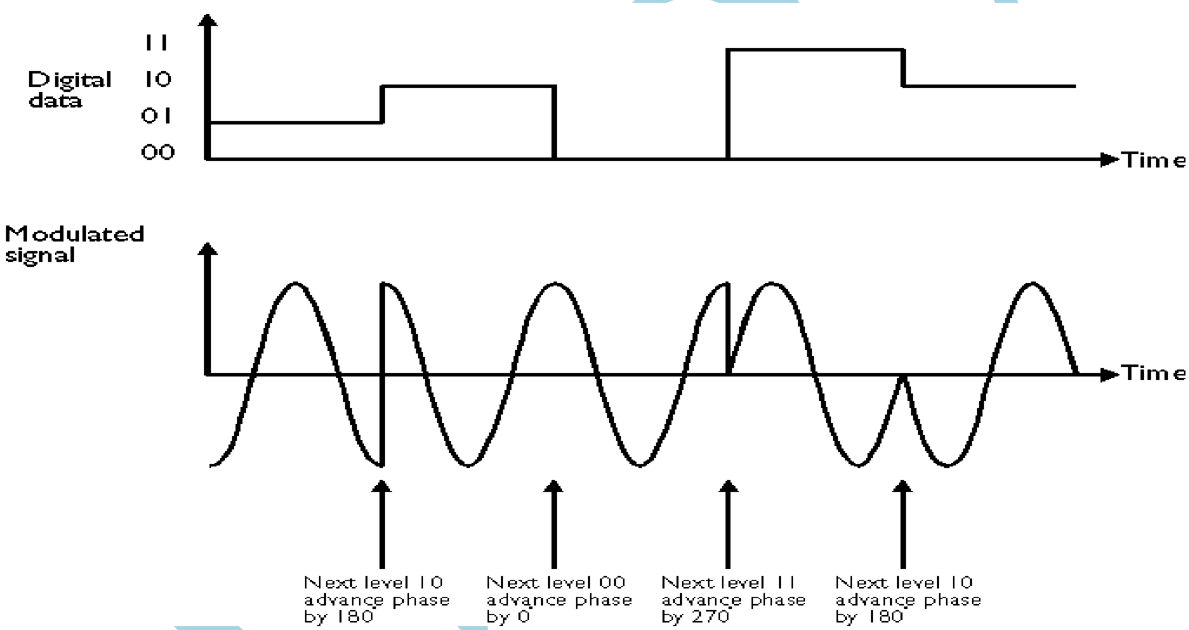
OFDM - What is it?

- Method of Digital Communication that breaks a large bandwidth into small subcarriers using the Inverse Fast Fourier Transform (IFFT).
- Removes Intersymbol Interference (ISI) by having subcarrier frequency be integer multiples of the symbol rate.
- By dividing total bandwidth into independent subchannels, multiple access is achieved by distributing subchannels between users.
- Allows for higher data rates by allocating power and subchannels to users through Adaptive Modulation.



OFDM Mechanism

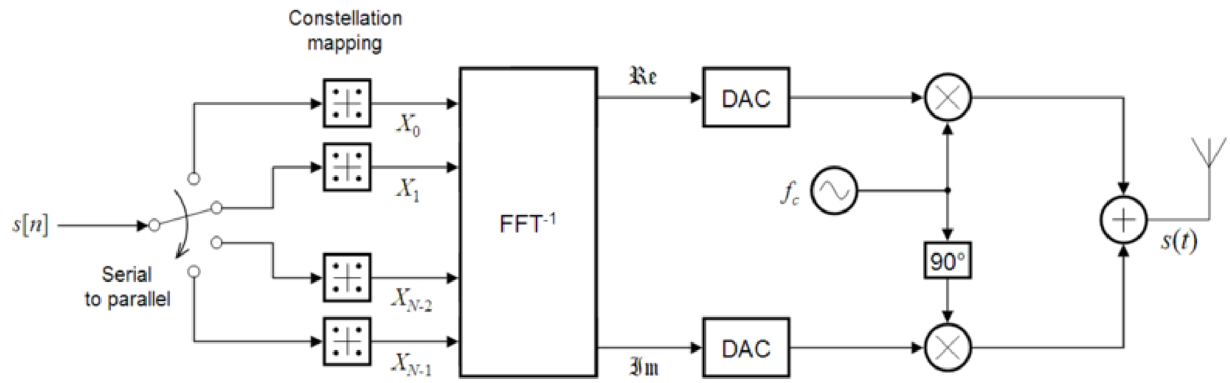
- Parallel Data Streams
- The available frequency spectrum is divided into several sub-channels
- low-rate bit stream is transmitted over one sub-channel by modulating a sub-carrier using a standard modulation scheme, for example 4-QAM
- Multiple Carriers are combined through the Fourier Series
- Computed by Inverse Fast Fourier transform



4-QAM modulation

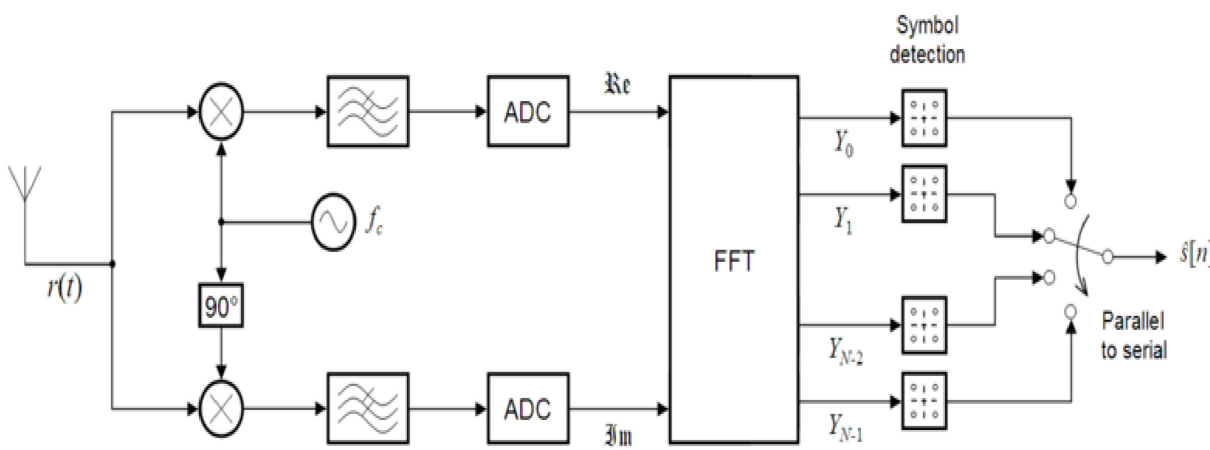
➢ **OFDM Transmitter**

An OFDM carrier signal is the sum of a number of orthogonal sub-carriers, with base band data on each sub-carrier being independently modulated commonly using some type of quadrateral amplitude modulation (QAM) or phase-shift keying (PSK).

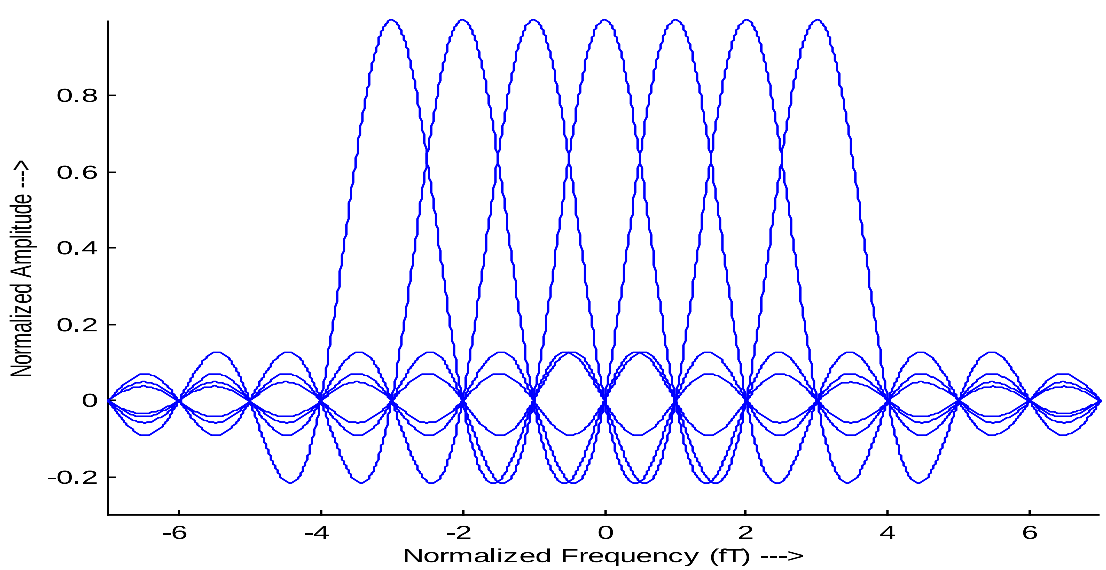


II. OFDM RECEIVER

The receiver picks up the signal r(t), which is then quadrature-mixed down to baseband using cosine and sine waves at the carrier frequency. This returns N parallel streams, each of which is converted to a binary stream using an appropriate symbol detector. These streams are then re-combined into a serial stream, which is an estimate of the original binary stream at the transmitter.



III. OFDM SPECTRUM



- Spectra of Individual Sub-Carriers.
- Sub-Carrier Spacing = 1/(Symbol Duration)
- Slow-Roll off avoided using Raised Cosine (RC) Windowing.

Variation of OFDM

- MIMO-OFDM
- VOFDM (Vector OFDM)
- WOFDM - Wideband OFDM
- Flash OFDM - Flarion (Lucent/Bell Labs spinoff)

IV. DIFFERENT TYPES OF MULTIPLEXING

- **FDM frequency division multiplexing**
  (FDM) is a technology that transmits multiple signals simultaneously over a single transmission path.
- **TDM (synchronous)**
  Time-division multiplexing (TDM) is a method of putting multiple data streams in a single signal by separating the signal into many segments, each having a very short duration.
- **Wavelength-Division Multiplexing (WDM)**
  Technology which multiplexes multiple optical carrier signals on a single optical fibre by using different wavelengths (colours) of laser light to carry different signals.

OFDM Applications

- Digital Video Broadcasting
- Digital Audio Broadcasting
- ADSL
- Wireless LANs
- OFDMA -Multiple Accesses.

OFDM ADVANTAGES

- OFDM is spectrally efficient
- IFFT/FFT operation ensures that sub-carriers do not interfere with each other.
- OFDM has an inherent robustness against narrowband interference.
- Narrowband interference will affect at most a couple
- Of sub channels.
- Information from the affected sub channels can be
- erased and recovered via the forward error
- Correction (FEC) codes.
- Equalization is very simple compared to Single-Carrier systems
- OFDM has excellent robustness in multi-path environments.
- Cyclic prefix preserves orthogonality between sub-Carriers.
- Cyclic prefix allows the receiver to capture multi-path energy more efficiently.
- Ability to comply with world-wide regulations:
- Bands and tones can be dynamically turned on/off to comply with changing regulations.
- Coexistence with current and future systems:
- Bands and tones can be dynamically turned on/off for enhanced coexistence with the other devices.

OFDM DRAWBACKS

- High sensitivity inter-channel interference, ICI
- OFDM is sensitive to frequency, clock and phase offset
- The OFDM time-domain signal has a relatively large peak-to-average ratio
- tends to reduce the power efficiency of the RF amplifier
- non-linear amplification destroys the orthogonality of the OFDM signal and introduced out-of-band radiation

V. CONCLUSION

OFDM and Adaptive Modulation allow for increased performance in a time-varying channel complicated communications system between three software applications on two different processors. One way to transmit this high data rate information is to employ well known conventional single-carrier systems. Since the transmission bandwidth is much larger than the coherence bandwidth of the channel, highly complex equalizers are needed at the receiver for accurately recovering the transmitted information. Multi-carrier techniques can solve this problem significantly. Root-finding and Linear methods handle allocations with clear tradeoffs

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