MODULE 1
MODULATION AND OFDM

Modulation

- Modulation is the process of modifying one signal based on another.
- used mostly in the transmission of data from one point to another.

Analog Modulation

- In analog modulation ,the modulated (message) signal is continuous both in amplitude and time.
- In this modulation,the transmission of data in analog format and output also analog in nature.
- In analog modulation,any value between maximum and minimum is valid.
- Analog modulation is more preferable than digital in Case of transmission of data, a voice signal can directly transmitted through analog.
- It is more sensitive to noise.
- Implementation of analog modulation is cheaper.
- It gives less accurate results.

Digital Modulation

- In digital modulation,the modulated(message) signal is discrete both in time and amplitude.
- Transmission of the data in digital format in terms of 1’s and 0’s and output also digital in nature.
- In digital modulation only 2 values, one value is 0 and another is 1 and remaining values are considered as noise and are rejected.
- In case of transmission of any signal digital modulation is less preferable.
- Less sensitive to noise , ease of multiplexing.
- Digital modulation implementation is costly than analog.
- It Produces more accurate output than analog.

Analog transmisssion of Digital data

- For digital modulation, digital data (0 and 1) is translated into an analog signal (baseband signal).
- **Digital modulation is required if digital data has to be transmitted over a medium that only allows for analog transmission.**
- In wireless networks, digital transmission of digital data cannot be used. Here, the binary bit-stream has to be translated into an analog signal first.
- The three basic methods for this translation are **amplitude shift keying (ASK)**, **frequency shift keying (FSK)**, and **phase shift keying (PSK)**.

Need of modulation in wireless medium

- Apart from the translation of digital data into analog signals, wireless transmission requires an additional modulation, an **analog modulation** that shifts the center frequency of the baseband signal generated by the digital modulation up to the radio carrier.

- Baseband signal cannot be directly transmitted in a wireless system.

  - **Antennas**: an antenna must be the order of magnitude of the signal's wavelength in size to be effective.

  - **Frequency division multiplexing**: Using only baseband transmission, FDM could not be applied.

  - **Medium characteristics**: Path-loss, penetration of obstacles, reflection, scattering, and diffraction – all the effects depend heavily on the wavelength of the signal.

Modulation in Transmitter and Receiver

Figure 2.21
Modulation in a transmitter

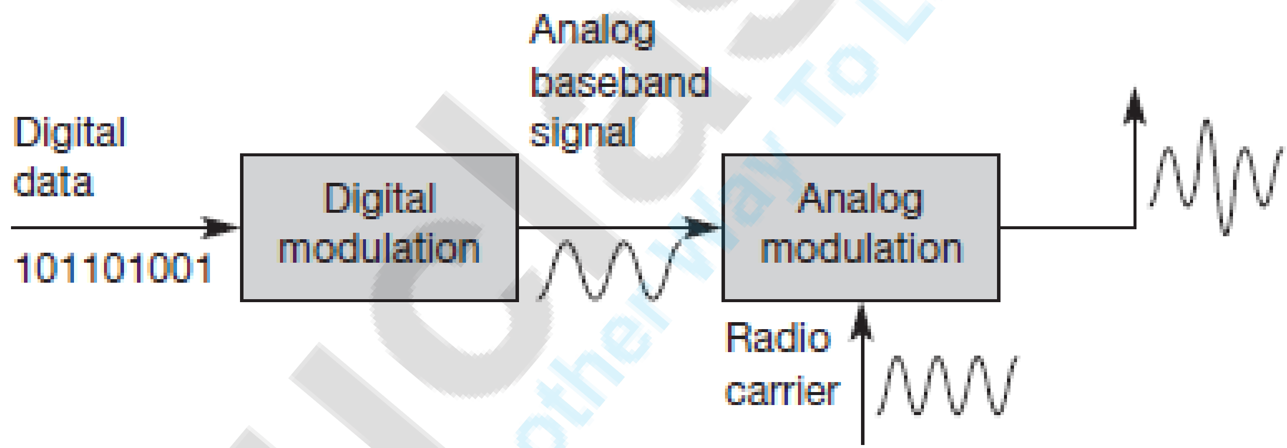
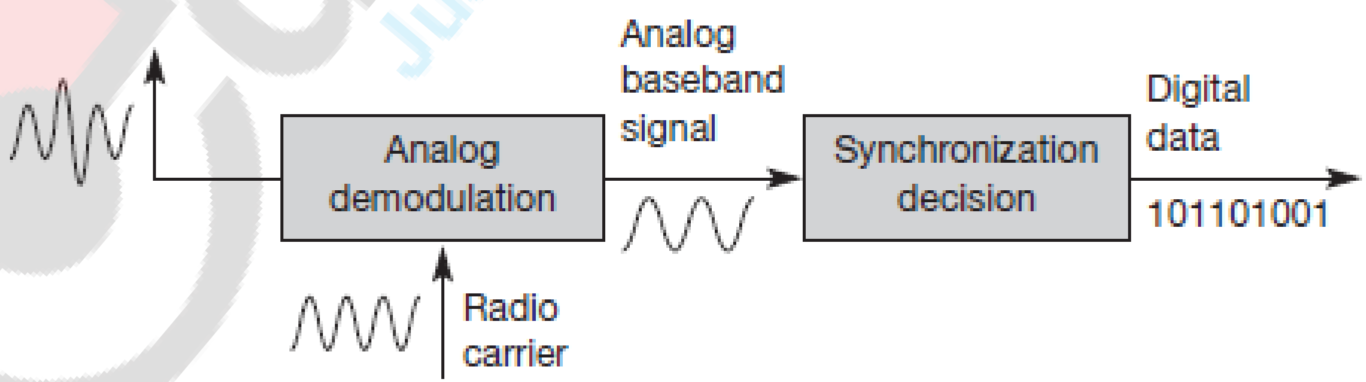


Figure 2.22
Demodulation and data reconstruction in a receiver



- **Analog modulation schemes**:
  - Amplitude modulation.
  - Frquency modulation.
  - Phase modulation.
- **Digital modulation schemes**:
  - Amplitude shift keying.
  - Frequency shift keying
  - Phase shift keying.

The digital modulation scheme differ in many issues,

- **spectral efficiency -** how efficiently the modulation scheme utilizes the available frequency spectrum.
- **power efficiency-** how much power is needed to transfer bits – which is very important for portable devices that are battery dependent.
- **robustness** to multi-path propagation, noise and interference.

Amplitude shift keying (ASK)

- The two binary values, 1 and 0, are represented by two different Amplitudes.
- This simple scheme only requires **low bandwidth**, but is very **susceptible to interference**.
- Effects like multi-path propagation, noise, or path loss heavily influence the amplitude.
- In a wireless environment, a constant amplitude cannot be guaranteed, so ASK is typically not used for wireless radio transmission.
- ASK can be applied to wireless infra red transmission, using a directed beam or diffuse light.

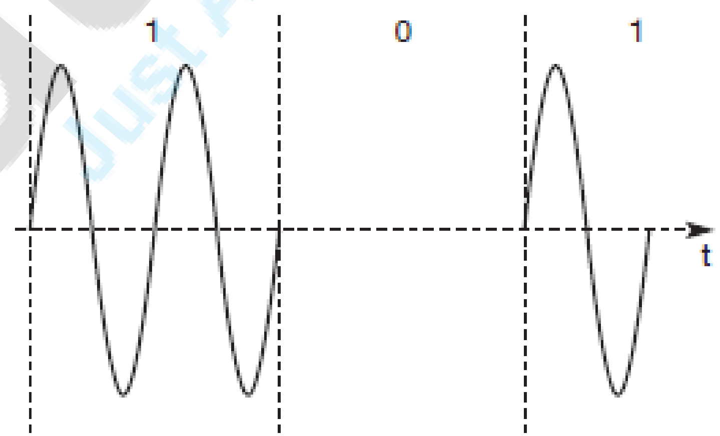


Figure 2.23
Amplitude shift keying (ASK)

Frequency shift keying (FSK)

- A modulation scheme often used for wireless transmission.
- The simplest form: **binary FSK (BFSK)**, assigns one frequency f1 to the binary 1 and another frequency f2 to the Binary 0.
- switch between the oscillators, one with the frequency f1 and the other with f2, depending on the input.
- To avoid sudden changes in phase, special frequency modulators with **continuous phase modulation**, **(CPM)** can be used.
- Sudden changes in phase cause high frequencies, which is an undesired side-effect.
- A simple way to implement **demodulation** is by using **two bandpass filters**, one for f1 the other for f2. A **comparator** can then compare the signal levels of the filter outputs to decide which of them is stronger.
- FSK needs a **larger bandwidth** compared to ASK but is much **less susceptible to errors.**

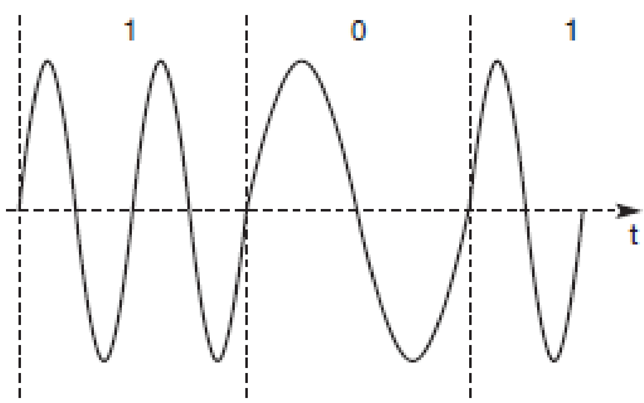


Figure 2.24
Frequency shift keying (FSK)

Phase shift keying (PSK)

- uses shifts in the phase of a signal to represent data.
- shifting the phase by 180° each time the value of data changes- **binary PSK (BPSK)**.
- A simple implementation of a BPSK modulator could multiply a **frequency f with +1 if the binary data is 1** and with **–1 if the binary data is 0**.
- To receive the signal correctly, the receiver must **synchronize in frequency and phase** with the transmitter. This can be done using a **phase lock loop (PLL)**.
- Compared to FSK, PSK is more **resistant to interference**, but receiver and transmitter are also more **complex**.

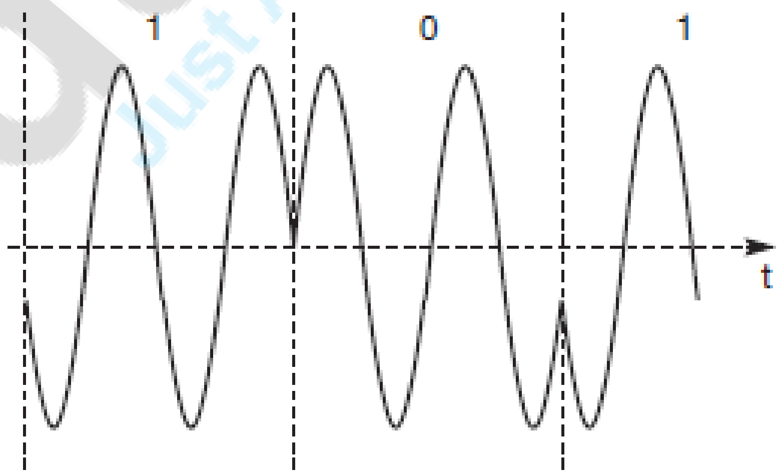
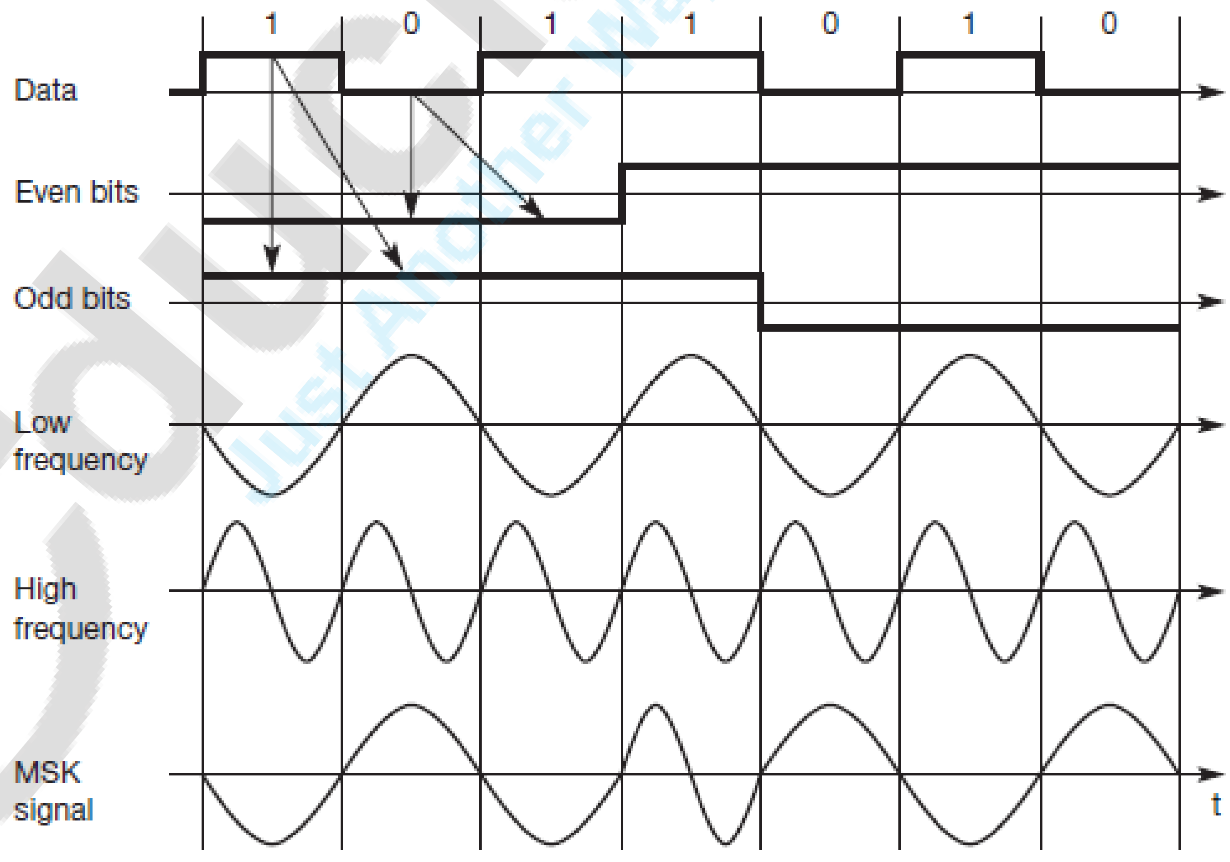


Figure 2.25
Phase shift keying (PSK)

Advanced frequency shift keying

- A famous FSK scheme used in many wireless systems is **minimum shift keying (MSK)**.
- MSK is basically **BFSK without abrupt phase changes**, i.e., it belongs to CPM schemes.
- In a first step, **data bits are separated into even and odd bits**, the duration of each bit being doubled. The scheme also uses two frequencies: f1, the lower frequency, and f2, the higher frequency, with f2 = 2f1.

Figure 2.26
Minimum shift keying (MSK)



- According to the following scheme, the lower or higher frequency is chosen (either inverted or non-inverted) to generate the MSK signal.
- if the even and the odd bit are both 0, then the higher frequency f2 is inverted.
- if the even bit is 1, the odd bit 0, then the lower frequency f1 is inverted.
- if the even bit is 0 and the odd bit is 1, f1 is taken without changing the phase.
- if both bits are 1 then the original f2 is taken.

- A high frequency is always chosen if even and odd bits are equal. The signal is inverted if the odd bit equals 0. This scheme avoids all phase shifts in the resulting MSK signal.
- Adding a **Gaussian lowpass filter to the MSK** scheme results in **Gaussian MSK (GMSK)**, which is the digital modulation scheme for many European wireless standards.
- The filter **reduces the large spectrum needed by MSK**.

Advanced phase shift keying

Quadrature PSK:

- higher bit rates can be achieved for the same bandwidth by **coding two bits into one phase shift.**
- phase shift can always be relative to a **reference signal**.
- If this scheme is used, a phase shift of 0 means that the signal is in phase with the reference signal.
- A QPSK signal will then exhibit a phase shift of 45° for the data 11, 135° for 10, 225° for 00, and 315° for 01 – with all phase shifts being relative to the reference signal.

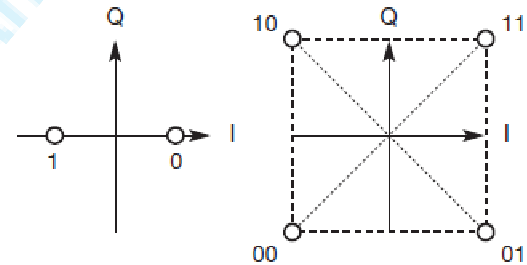


Figure 2.27
BPSK and QPSK in the phase domain

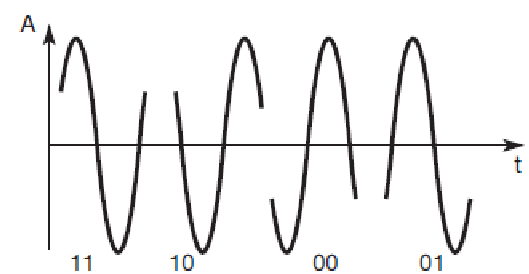


Figure 2.28
QPSK in the time domain

Differential QPSK (DQPSK):

- The phase shift is not relative to a reference signal but to the phase of the previous two bits.
- In this case, the receiver does not need the reference signal but only compares two signals to reconstruct data.
- quadrature amplitude modulation (QAM): PSK+ASK.

Orthogonality of signals

- 2 vectors are orthogonal if they are perpendicular to each other. i. e. the dot product of the two vectors is zero.
- Orthogonality of a signal is a measure of two things:
  - The correlation of a signal waveform with a copy of itself. (AUTO-CORRELATION)
  - The correlation of a signal waveform with ANOTHER signal waveform (CROSS-CORRELATION).
- To evaluate either correlation, one **multiplies one waveform with time-shifted versions of the other signal**/the copy and takes the integral of the product. The more the signals/copy overlap or align, the higher is the magnitude of the correlation.
- Good AUTO-CORRELATION at zero delay .

Orthogonal Frequency Division Multiplexing (OFDM)

Multi-carrier modulation(MCM):

- good ISI (Inter-Symbol interference) mitigation property.
- higher bit rates are more vulnerable to ISI. OFDM splits the high bit rate stream into many lower bit rate streams.
- each stream being sent using an independent carrier frequency.

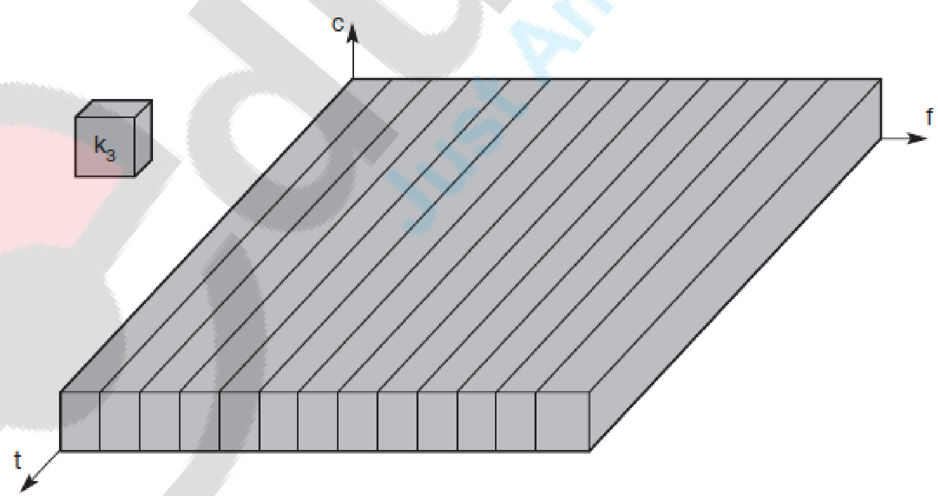
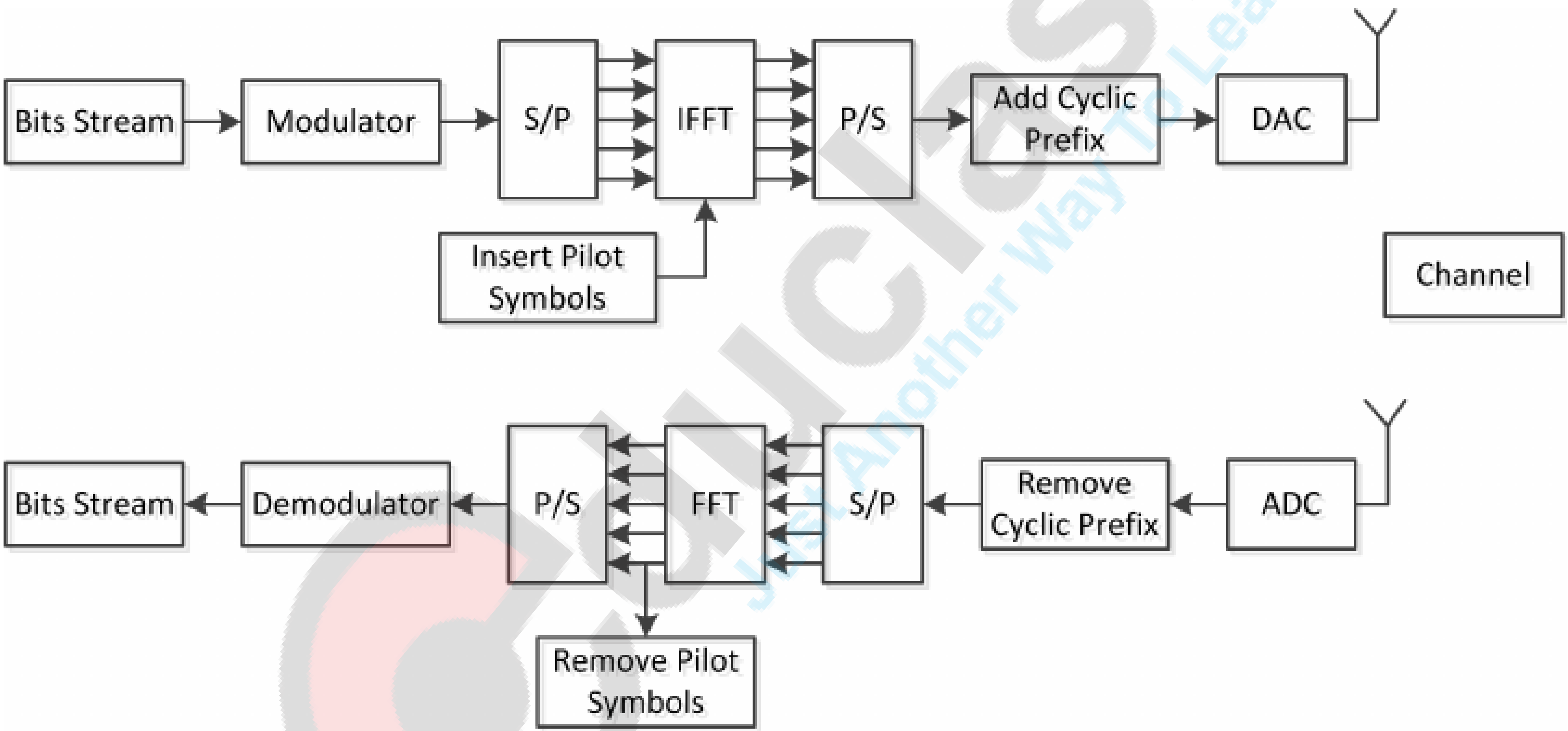


Figure 2.30
Parallel data transmission on several subcarriers with lower rate

OFDM Block Diagram



References

Mobile Communications, Second Edition, Jochen Schiller, Pearson Education- Chapter 2.