ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING

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MULTICARRIER MODULATION

- Multipath propagation, time domain spreading of a signal, ISI occurs
- Frequency selective fading, distortion, signal detection becomes difficult
- MCM converts a frequency selective fading into flat fading channel
- Flat fading makes signal detection easier
- MCM easily removes ISI
- MCM transmits data over several carrier frequencies simultaneously
- Each sub-stream modulates different carrier frequency
- Parallel conversion lowers the data rate & bandwidth in each stream

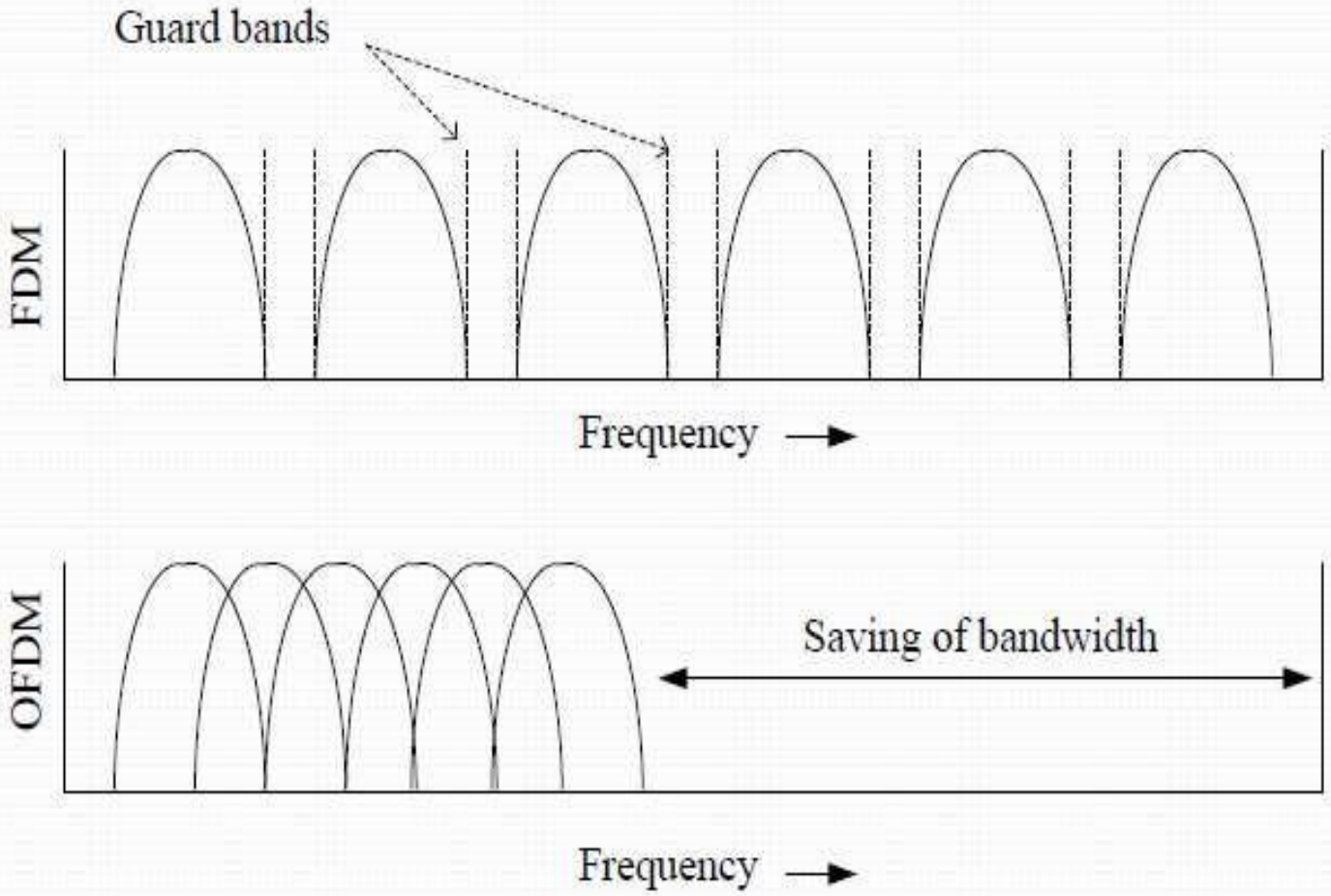
OPERATION OF MCM

- PSK or QAM modulationscheme is used
- Signals from each data stream are summed together to form the transmitted signal
- No change in original data rate & system bandwidth, but ISI is eliminated
- MCM needs larger bandwidth, spectrally inefficient
- Multiple carriers and multiple oscillators increases the BW
- OFDM is a special case of MCM, which addresses all the above issues

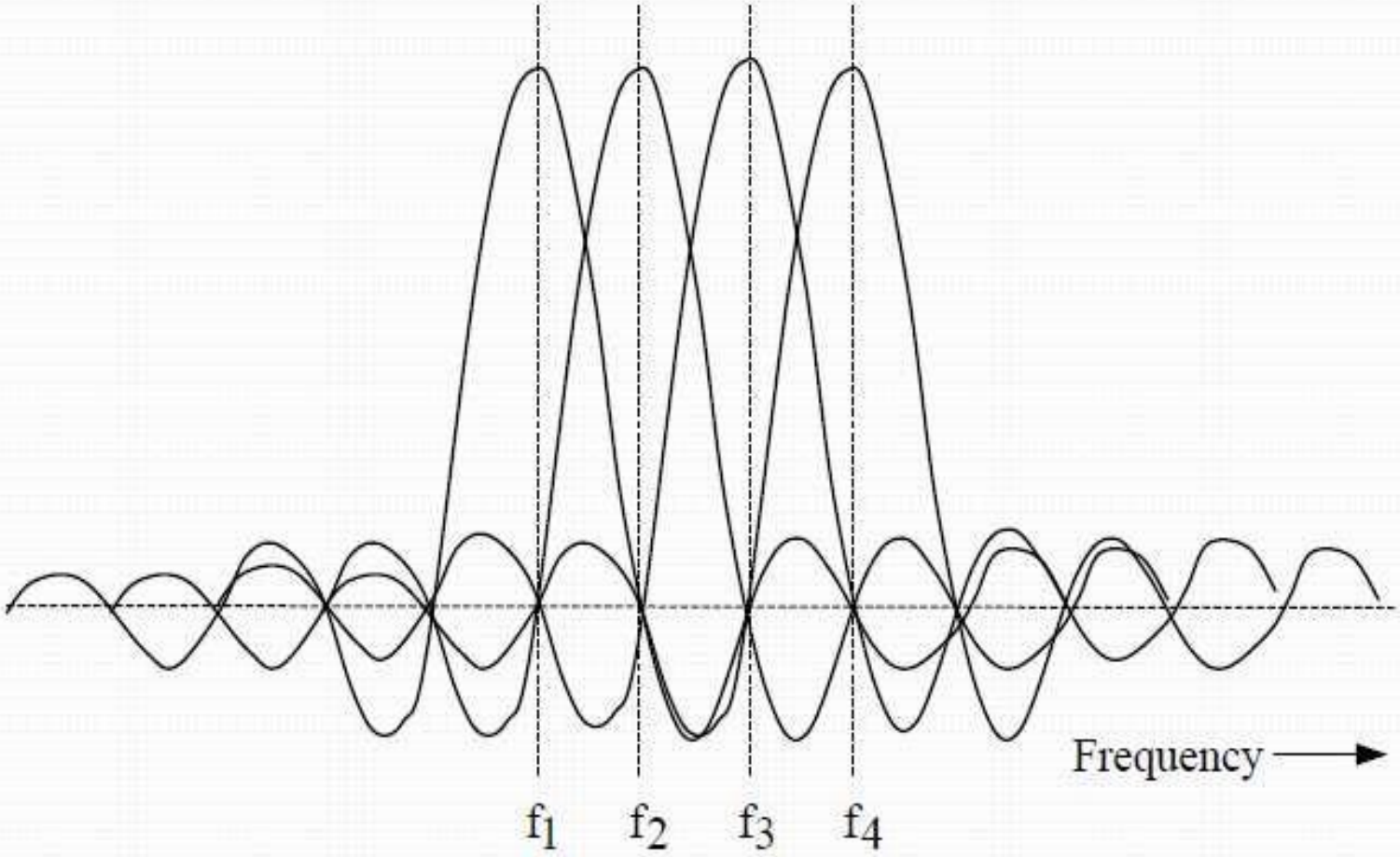
OFDM CONCEPT

- System bandwidth is divided into a set of parallel overlapping, yet orthogonal sub-bands independent to each other
- Data is first split into independent streams, which modulate different sub-carriers
- Then are multiplexed to create OFDM signal
- OFDM is a special case of FDM
- Significantly improves spectral efficiency
- Avoid the need for steep band pass filters
- Avoids the need of a bank of oscillators, since can be implanted digitally

FDM VS OFDM


Guard bands
FDM
Frequency
OFDM
Saving of bandwidth
Frequency

OFDM SIGNAL



OFDM ADVANTAGES

- Permits densely packed & overlapping sub-carriers
- Offers spectrally efficient transmissionscheme
- Can be digitally implemented using, fast & efficient signal processing
- Permits flexible use of spectrum
- Supports different modulation schemes based on channel conditions
- Almost completely avoids the need for an equalizer

OPERATION OF OFDM

Typically PSK or QAM modulations schemes are used

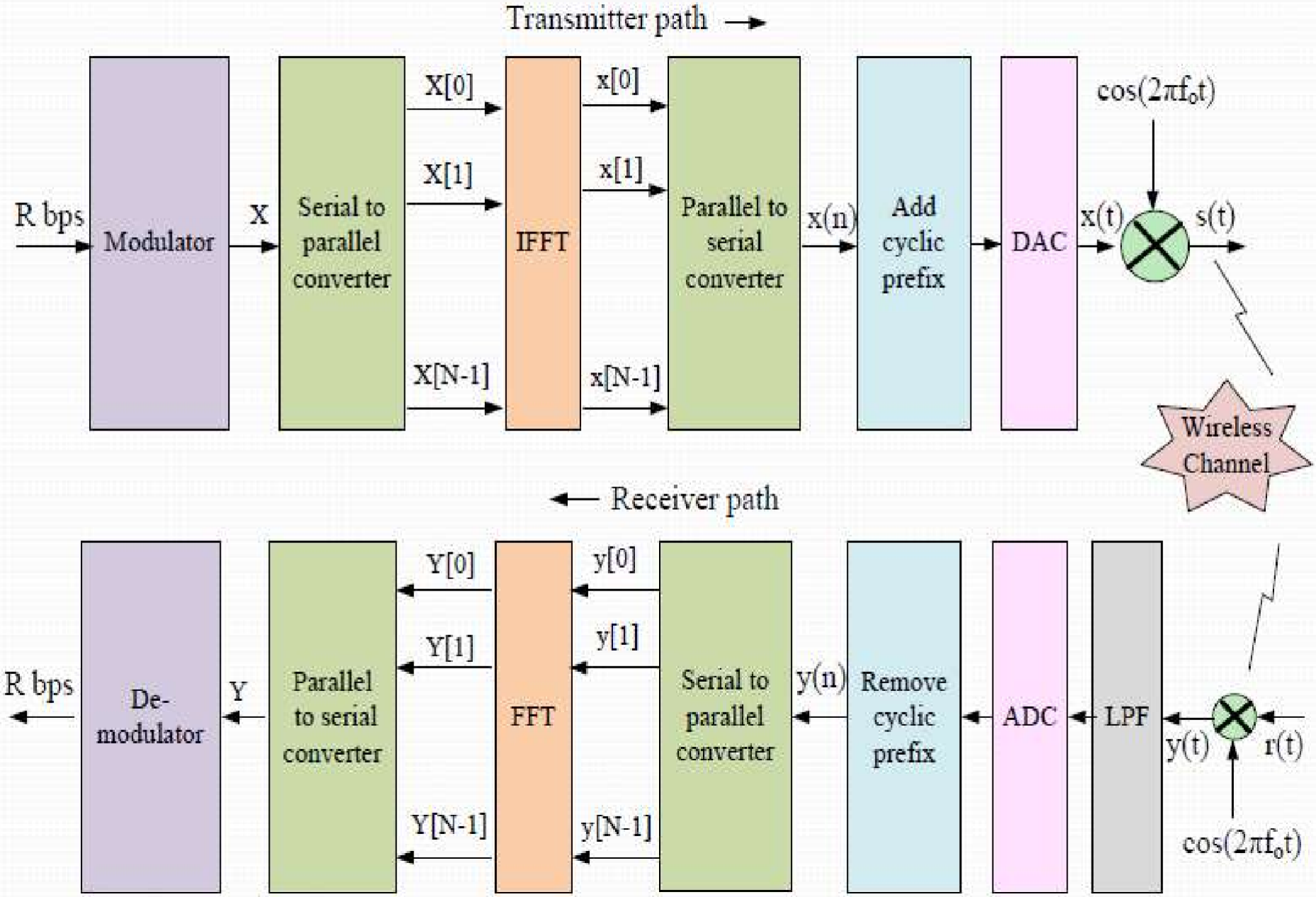
IFFT performs the transformation efficiently and ensures orthogonality of the sub carriers

Output of IFFT is

$$x[n] = \frac{1}{\sqrt{N}} \sum_{i=0}^{N-1} X[i] e^{j2\pi ni/N} \quad ,0 \le n \le N-1$$

- Number of computations are significantly reduced by IFFT
- IFFT needs that the number of sub-carriers be an integer to the power of 2
- Unused sub-carriers are set to zero
- Complexity of OFDM system is largely determined by IFFT points
- More IFFT points demands more power, but enhances resolution

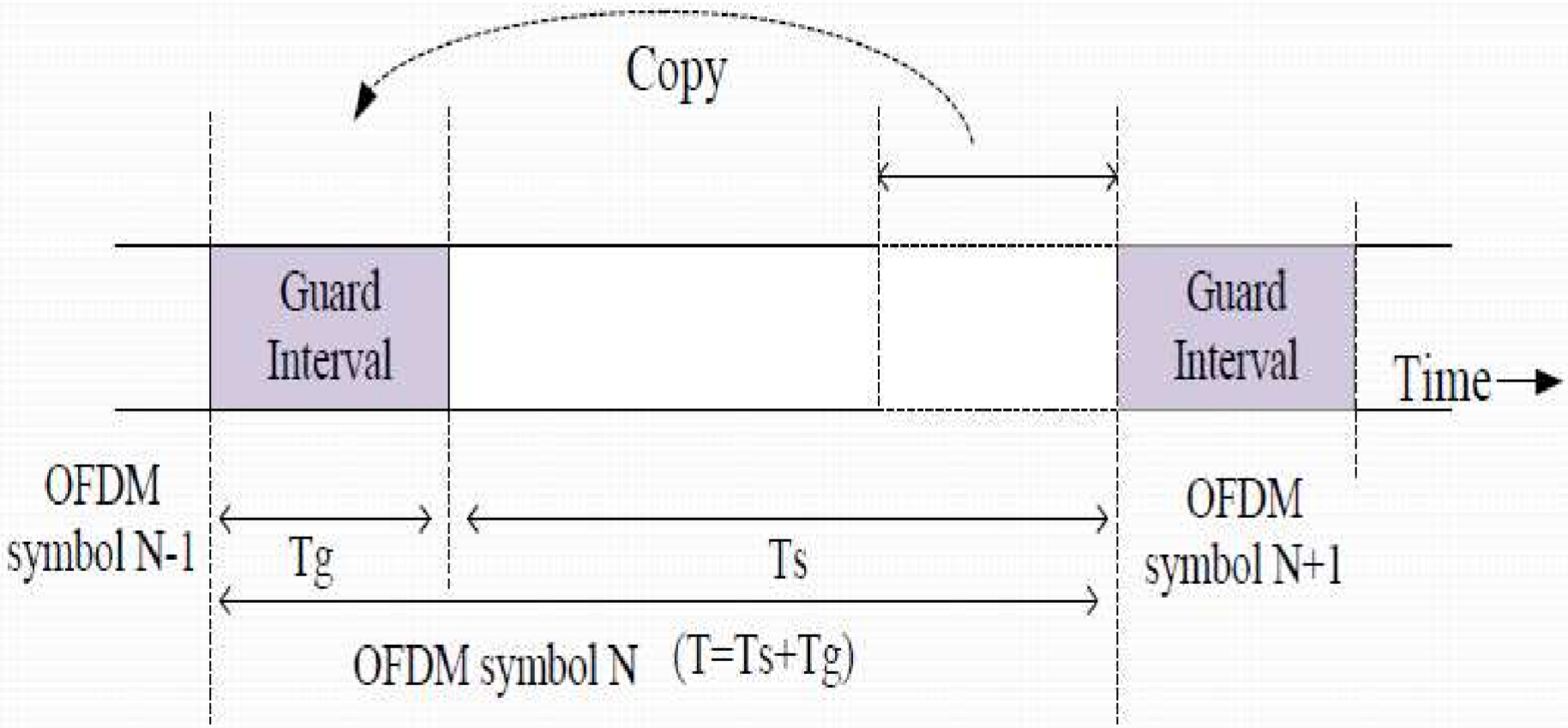
BLOCK DIAGRAM OF AN OFDM BASED SYSTEM



CYCLIC PREFIX

- Guard time between adjacent symbols is inserted to eliminate ISI
- No ISI will occurs, if guard time is larger than delay spread
- Guard time is a pure system overhead, contains no information
- CP is inserted in order to preserve orthogonality
- CP provides multipath immunity & synchronization tolerance
- CP increases required transmission bandwidth, hence lowersspectral efficiency
- Transmit power associated with CP is a waste

INSERTION OF CYCLIC PREFIX



OFDM DISADVANTAGES

HIGH PAPR

- A number of independently modulated sub-carriers result in **HIGH PAPR**
- Non-linear power amplifier, efficient, but cannot be used
- Causing performance degradation due to high distortion & out of band radiations
- High PAPR also increases complexity of ADC & DAC

FREQUENCY OFFSET

- Sub-carriers are very close and overlapping
- Even a small frequency offset will result in ISI
- Causes of frequency offset:
  - Frequency mismatch in local oscillators of transmitter & receiver
  - Doppler shift
  - Phase noise caused in the channel

TIMING OFFSET

- OFDM is slightly more tolerant to time offset, compared to frequency offset
- Causes lack of precision in symbol boundaries, resulting in ISI
- ISI occur only when time offset differs from CP duration
- Causes phase change & may also result in frequency offset

OFDM demands strict synchronization in frequency & time to preserve orthogonality

CONCLUSION

- Hence synchronization is necessary in OFDM because it minimizes performance degradation

- **Synchronization Methods**

  Several approaches to estimate jointly or individually, used iteratively or in one step

  1. Data aided method (pilot based)
  2. Non-data aided method (blind)
  3. Hybrid method

THANK YOU