Remarks on Modulation

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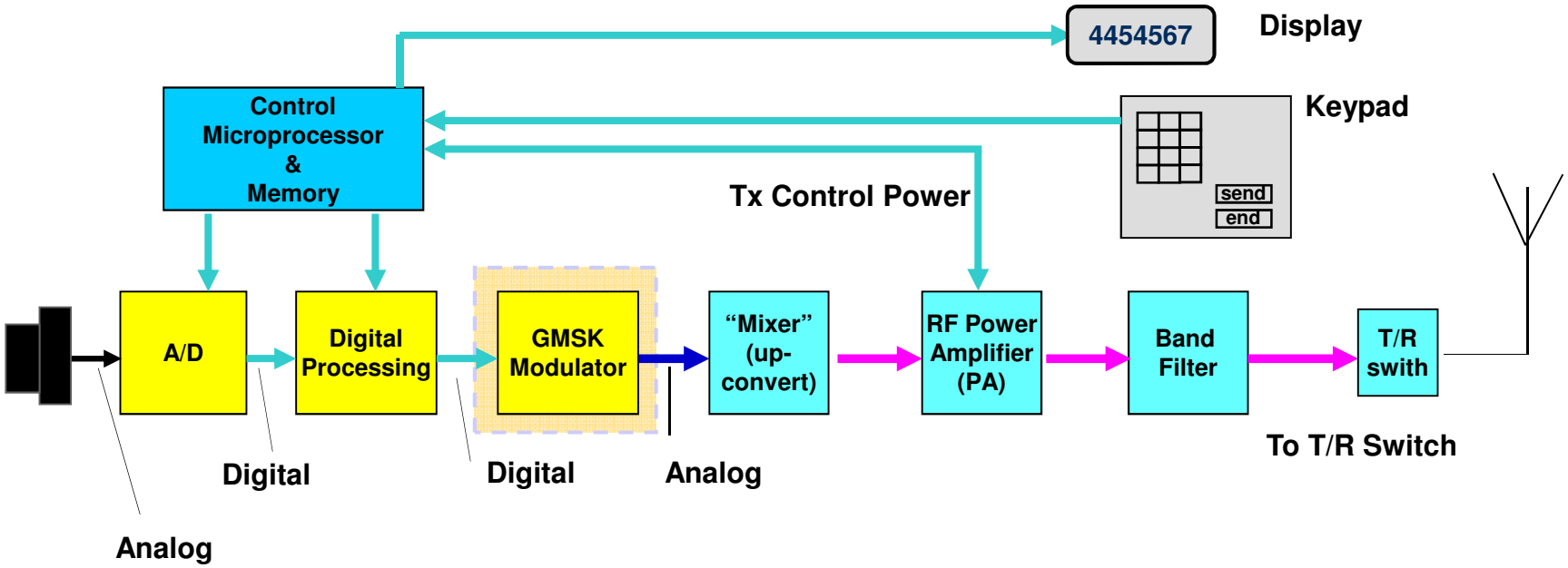
Topics for the special Projetcs

1. Half rate
2. Adaptive Multi Rate
3. Viterbi Algorithm
4. Timing advance
5. Service classification
6. Alloha
7. ISI
8. Equalization
9. Reed Solomon Codes
10. Doppler
11. GPRS Basics
12. EDGE Basics

Modular block diagram (Transmitter)



Base band analog waveform

Base band digital waveform

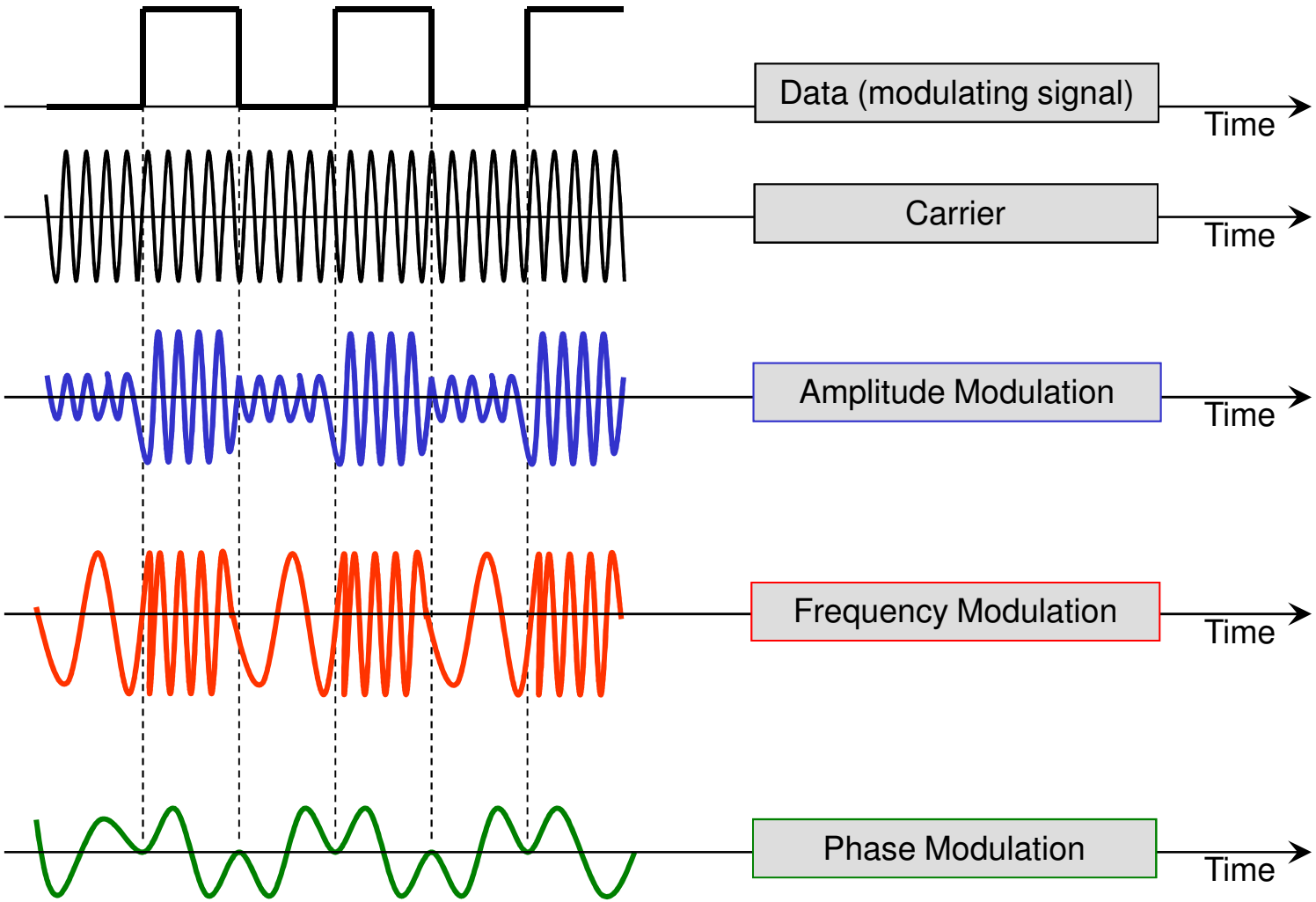
Intermediate Frequency signal

RF wave form

Modulation

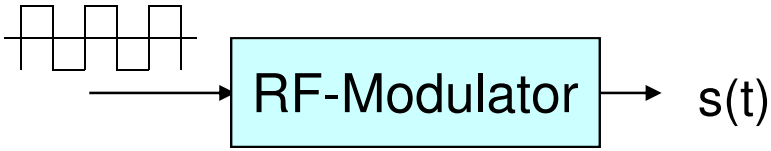
- Modulation: process of facilitating the transfer of information over a medium (converting information so that it can be successfully sent over a medium).
- How: vary a parameter of a sinusoid to represent the information which is to be sent (use a digital bit stream to vary the signal's amplitude, phase, or frequency).
- Why: To change the signal's bandwidth so it can be transmitted on a limited-bandwidth communication channel (like a telephone line or a cable TV channel) without too much distortion.

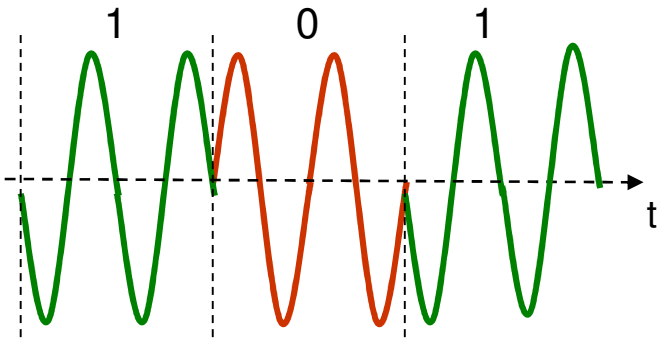
Digital modulation



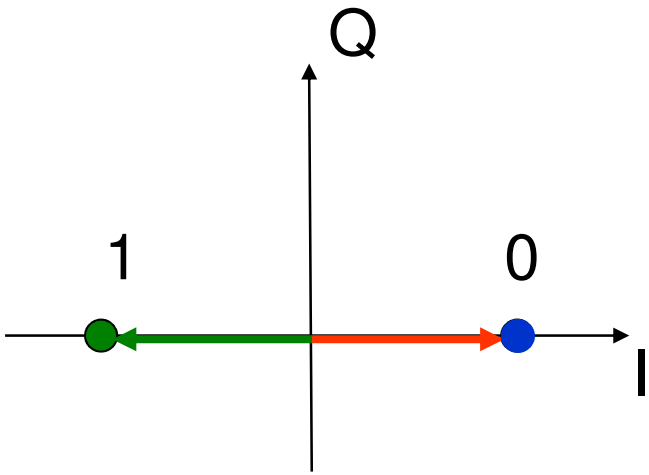
Phase shift (180^0 in this case) to indicate data change

Binary Phase Shift Keying (BPSK)





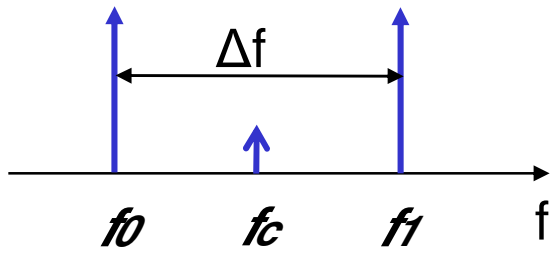
2 possible values for the signal phase

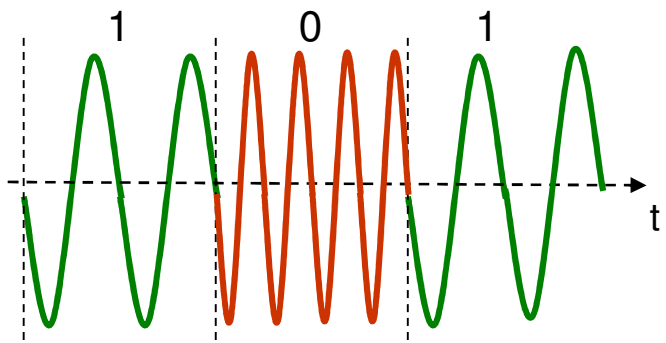


One signal vector represents one bit

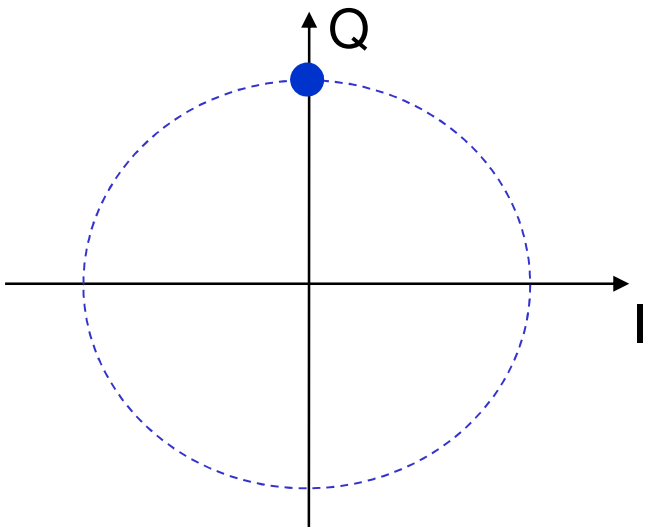
Binary Frequency Shift Keying (BFSK)

- Logical “0” is transmitted as signal at frequency f_0
- Logical “1” is transmitted as signal at frequency f_1
- Nominal carrier frequency is mid-way between these two values





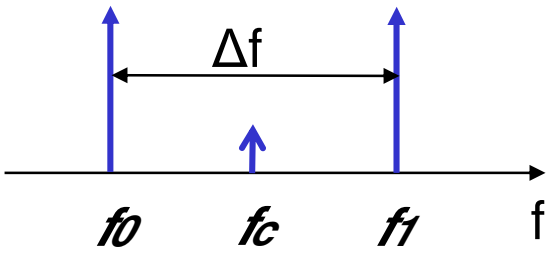
2 possible values for the signal frequency

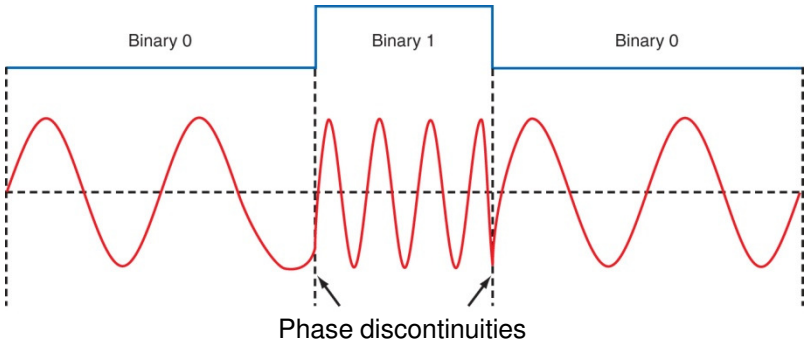


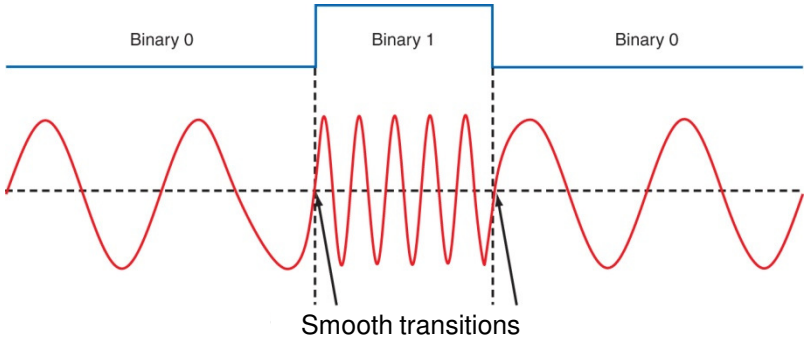
One signal vector represents one bit

Binary Frequency Shift Keying (BFSK)

- Bandwidth needed for FSK depends on the distance between the carrier frequencies (Δf).
- For arbitrary frequency distance (Δf) the FSK signal will have a step phase change at the transition between bits.
- Binary data consisting of sharp transitions between "one" and "zero" states potentially creates signals that have sidebands.
- This creates problems for many radio communications systems, as any sidebands outside the allowed bandwidth cause interference to adjacent channels.
- However, Δf can be chosen so the FSK signal has continuous phase across bit boundaries.





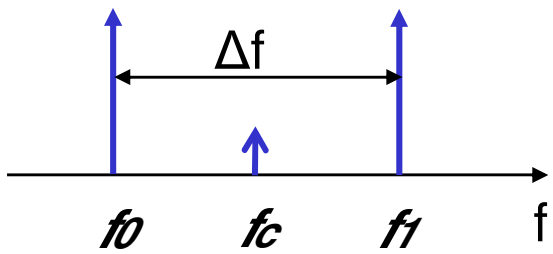


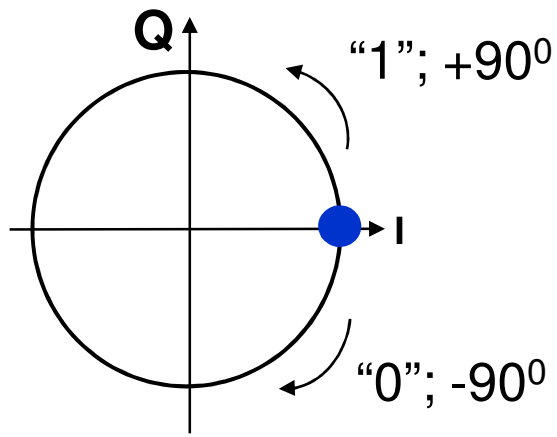
MSK

- Minimum shift keying (MSK) is a special type of continuous phase-frequency shift keying (CPFSK) with h=0.5. A modulation index of 0.5 corresponds to the minimum frequency spacing that allows two FSK signals to be coherently orthogonal, and the name minimum shift keying implies the minimum frequency separation (i.e. bandwidth) that allows orthogonal detection.

Minimum Shift Keying (MSK)

- What is minimum shift keying (MSK)?
  - MSK is binary FSK with ***minimum frequency separation (shift)*** to maintain orthogonality, and ***phase continuity*** at data transition instants.
  - Phase ramps up through 90 degrees for a binary one, and down 90 degrees for a binary zero.
  - Is a constant envelop modulation scheme.

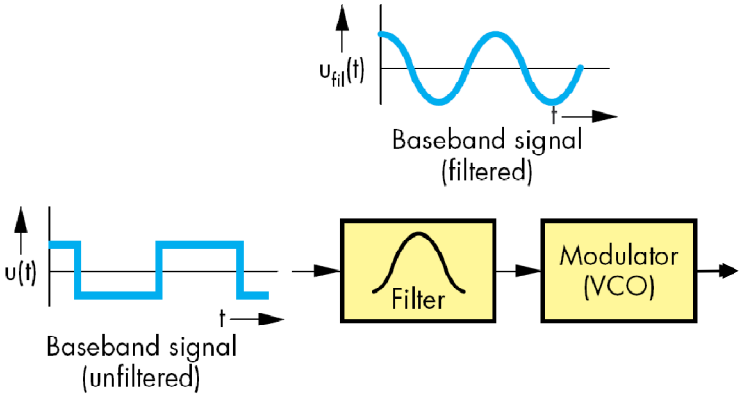


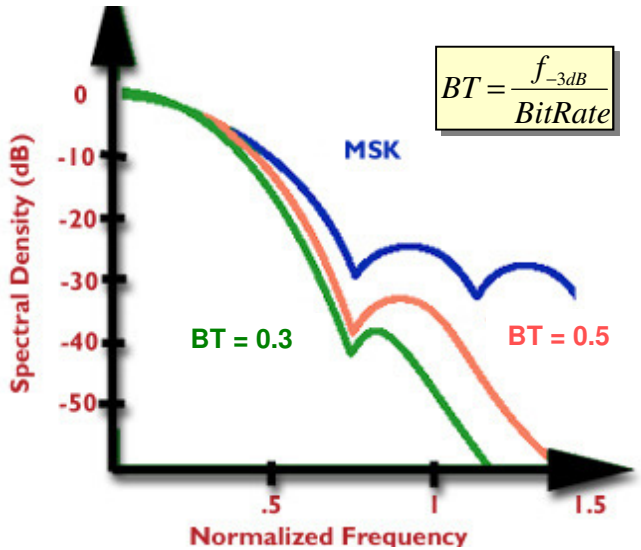


- Why MSK?
  - Continuous phase at bit transitions.
  - Better bandwidth efficiency.
  - Simpler receivers.

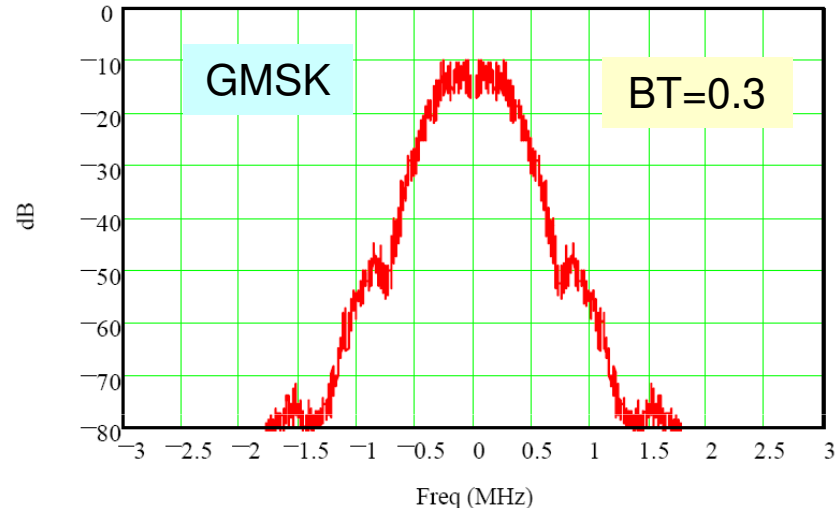
GMSK properties

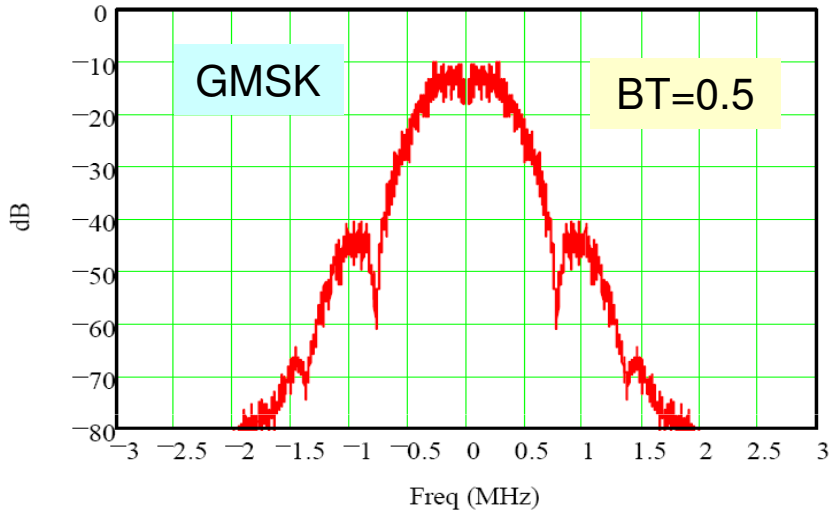
- A filter with Gaussian impulse response can be used as pre-filtering of the symbols prior to the continuous phase modulation. Its purpose is to control the modulated signal bandwidth.
- The result is: Improved spectral efficiency & reduced main lobe over MSK.
- The Gaussian filter is characterized by its BT product (bandwidth-time product):
  - Describes the amount the symbols overlap.
  - B is the filter's –3 dB bandwidth.
  - T is the symbol period = 1/fsymbol rate.
  - The lower the BT product, the narrower the modulation bandwidth and the higher the inter-symbol interference.
  - BT = 0.3 for GSM networks (good spectral efficiency at the expense of some inter-symbol interference (ISI).
- GMSK allows efficient class C non-linear amplifiers to be used

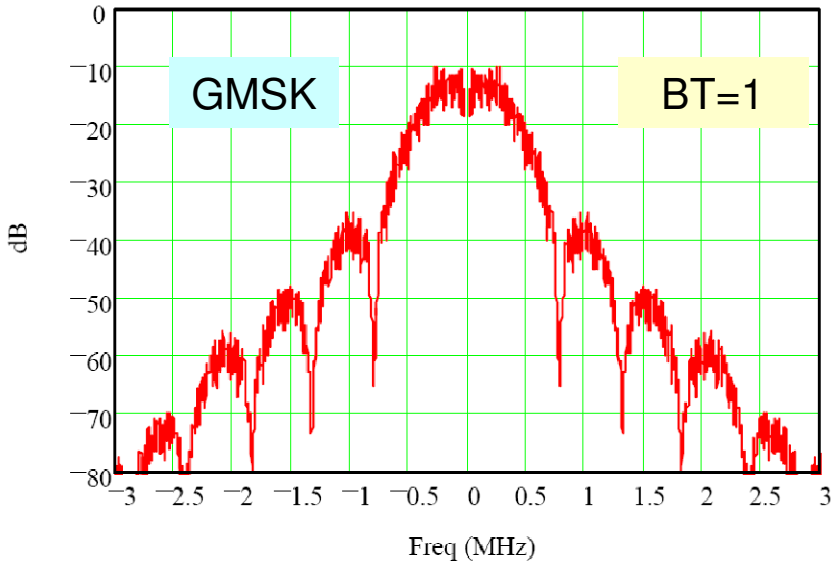


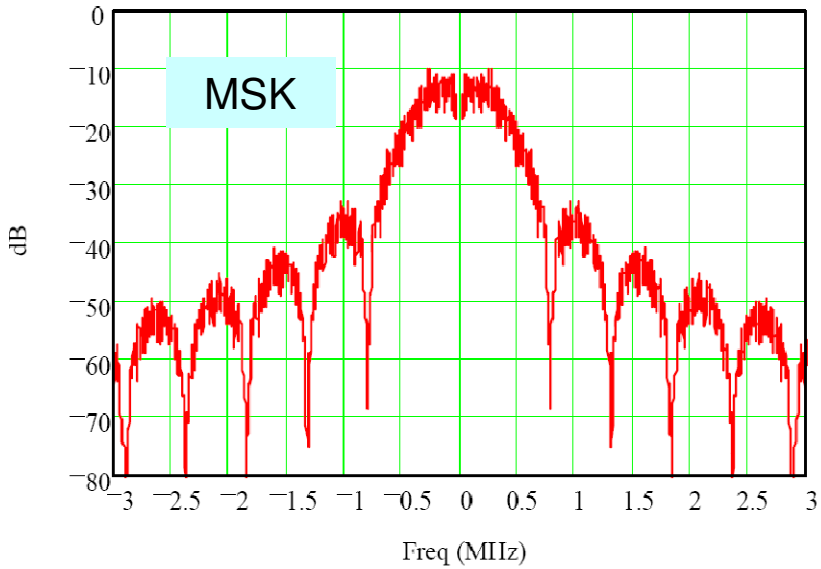


Signal spectra for GMSK and MSK

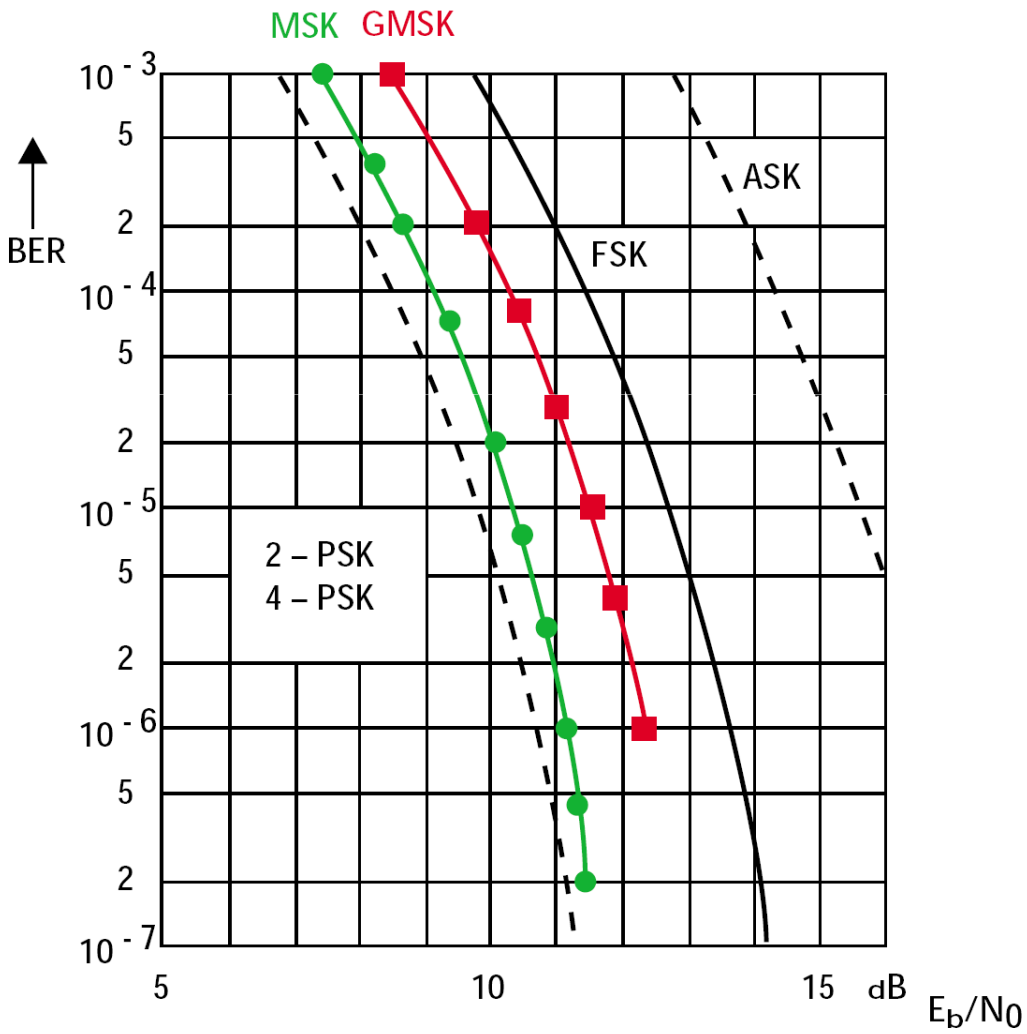








Performance of different modulation schemes



Summary – Modulation

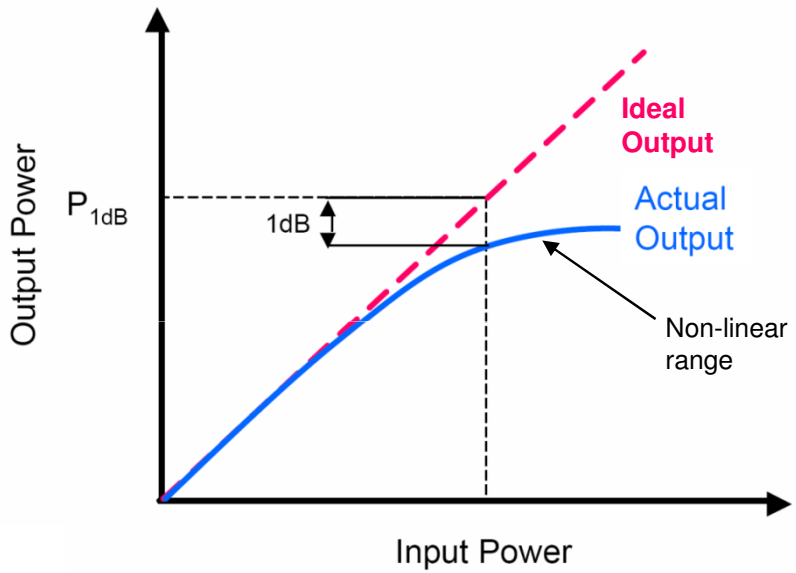
- **GSM Modulation: Gaussian Minimum Shift Keying**

- **Characteristics:**
  - **Reduced side lobes**
  - **Usage of non-linear power amplifiers**
  - **Optimized battery life**

Remarks on Amplifiers

Power amplifier characteristics

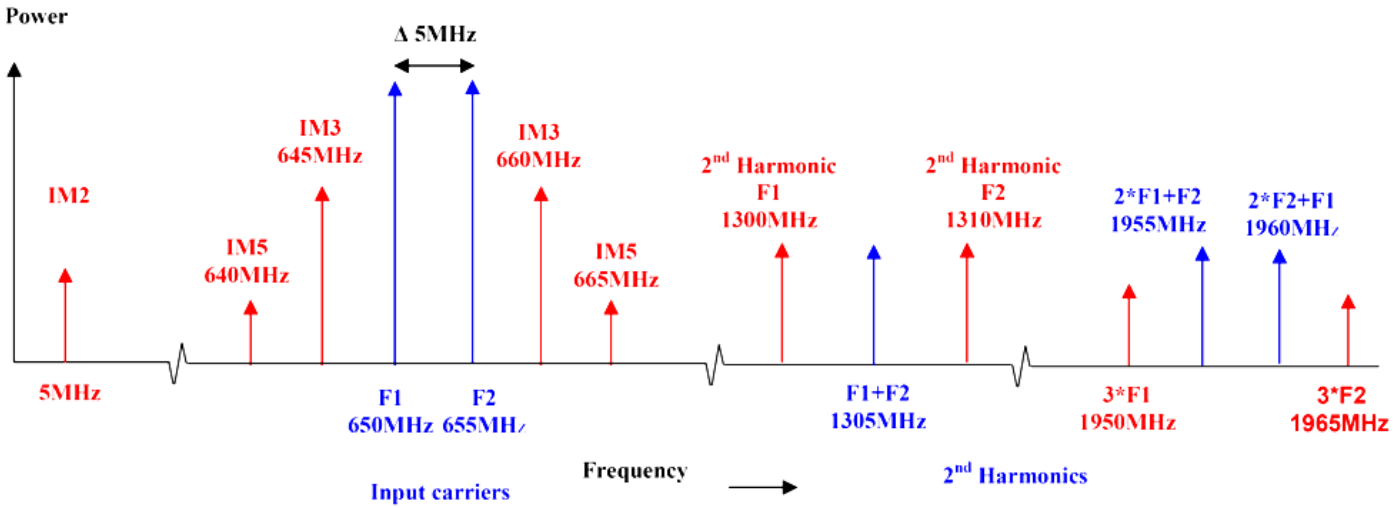
- Linearity
  - Active RF devices are ultimately non-linear in operation. When driven with a large enough RF signal the device will generate undesirable spurious signals.
  - How much spurious generated by the device is dependant on the linearity of the device.
- 1dB Compression Point
  - A measure for the linearity of the device.
  - Starting at a certain input power, we notice that the output power compresses, or saturates.
  - The output power when the amplifier has compressed 1dB is called the 1 dB compression point (P_{1dB} of) the amplifier.
- The peak-to-average power ratio should be small in order to stay in the linear region
- Operation in the nonlinear region
  - consumes more power if nonlinearity is compensated
  - shapes the spectrum if nonlinearity is not compensated



The point at which the power gain is down 1 dB from the ideal is referred to as the 1 dB compression point.

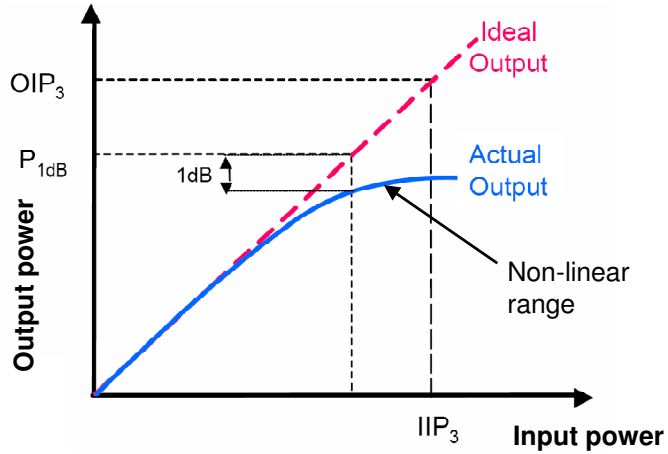
Inter-modulation Products

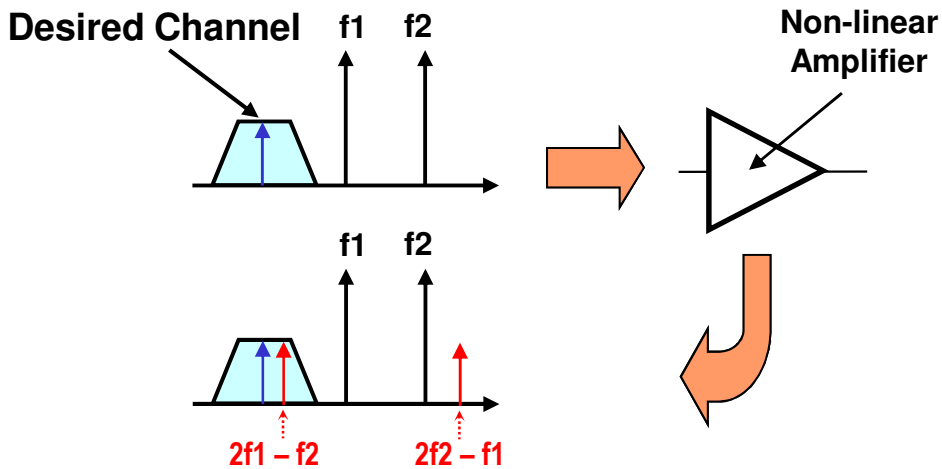
- Higher order intermodulation products are signals with frequencies adjacent to the input frequencies.
- Intermodulation occurs due to the non-linearity of the amplifier.
- For example if we apply two frequencies 650MHz & 655MHz (i.e. spaced by 5MHz) to an amplifier, then there will be 'sidebands' or inter-modulation products at multiples of 5MHz.
  - 5MHz below 650MHz and 5MHz above the 655MHz carrier will be the 3rd Order intermodulation products (IM3) at 645MHz and 660MHz.
  - 5MHz below the IM3 at 645MHz and 5MHz above the IM3 at 660MHz will the IM5 products.
- These products can be a problem as they may fall within the passband of the system and cannot be filtered out.



spurious that can be produced when an amplifier is driven into nonlinearity

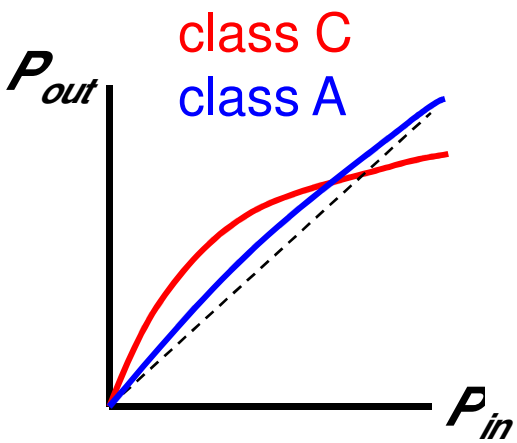
Intermodulation distortion





- Higher order intermodulation products are signals with frequencies adjacent to the input frequencies.
- Intermodulation occurs due to the non-linearity of the amplifier.
- Examples: A receiver attempting to listen to a channel at 902 MHz in the presence of two adjacent signals (originating from other users) may be jammed by third order products.
- With GMSK PA can be operated highly in compression (non-linear range)
- 8-PSK needs linear range - otherwise too much signal distortions

Amplifier classification



Class A amplifiers:

- Linear, i.e. pulse shape is preserved
- Energy loss is very high (efficiency is at best 50%)

Class C amplifiers:

- Non-linear, significant adjacent channel interference.
- The efficiency very high, reaching 75%.

- **Amplifier Efficiency:** the ratio of RF output power to input power (% DC power converted to radiated signal; important for battery life).
- There is always a trade-off between amplifier efficiency and linearity.

- With GMSK, amplifiers can be operated highly in compression (non-linear range).
- 8-PSK needs linear range - otherwise too much signal distortions.

Amplifiers and wireless systems

- Efficiency in the handset power amplifier (PA) is key to maximizing battery life.
- Amplifiers are typically most efficient when they operate close to their saturation level.
- Therefore, mobile-station amplifiers should ideally be designed so that the average power level of the signal is as close as possible to this saturation level.
- This works well for second generation (2G) modulation formats, such as offset-quadrature-phase-shift keying (OQPSK) or Gaussian minimum- shift keying (GMSK), which provides good prevent ion of compression of the signal and interference with the adjacent frequency channels .
- In 3G spread-spectrum based systems, the handset can transmit multiple channels at different amplitude levels. Modulation schemes such as OQPSK or GMSK are no longer suitable, creating a need for a modulation format or a spreading technique that can accommodate multiple channels at different power levels while producing signals with low peak-to-average power ratios.
- Hybrid-phase-shift keying (HPSK), also known as orthogonal-complex quadrature phase-shift keying (OCQPSK), has been proposed as the spreading technique for WCDMA and cdma2000.

Hybrid-phase-shift keying (HPSK)