5G WIRELESS TECHNOLOGIES

Radio systems. Parameters. Modulations

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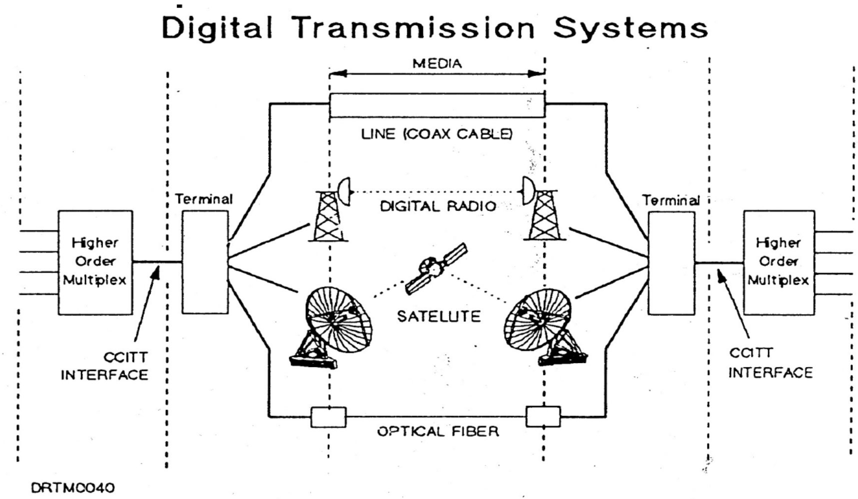
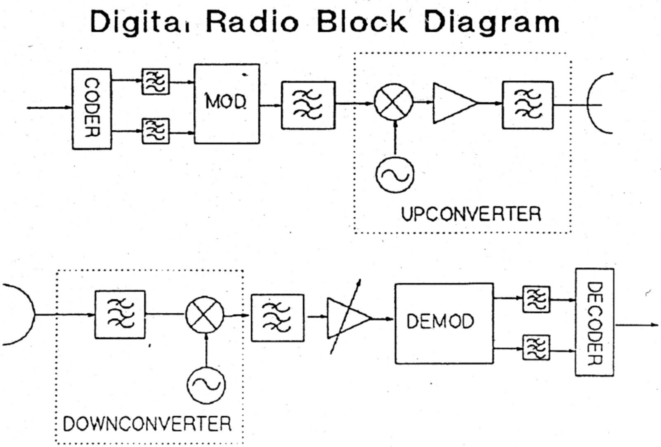
Structure of the data transmission system



Transmitter and receiver



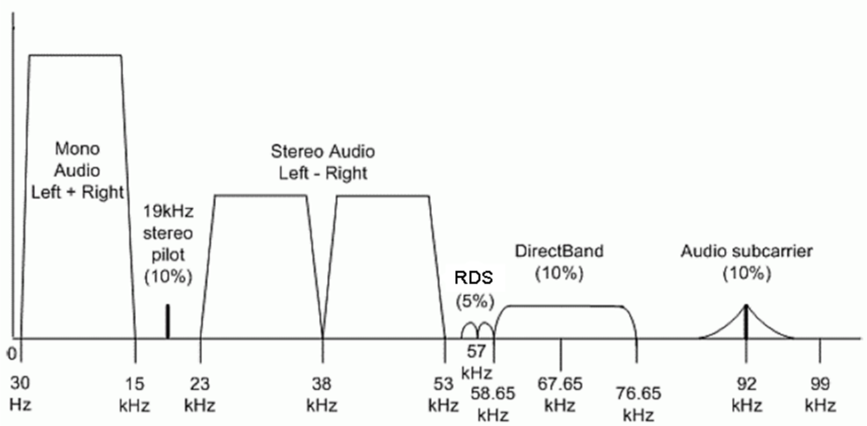
Requierements for a transmission system

- Ensure the signal transmission from the source to the user without disrotion;
- Compensate distortions in the channel:
  - baseband;
  - radio channel for modulated signals.

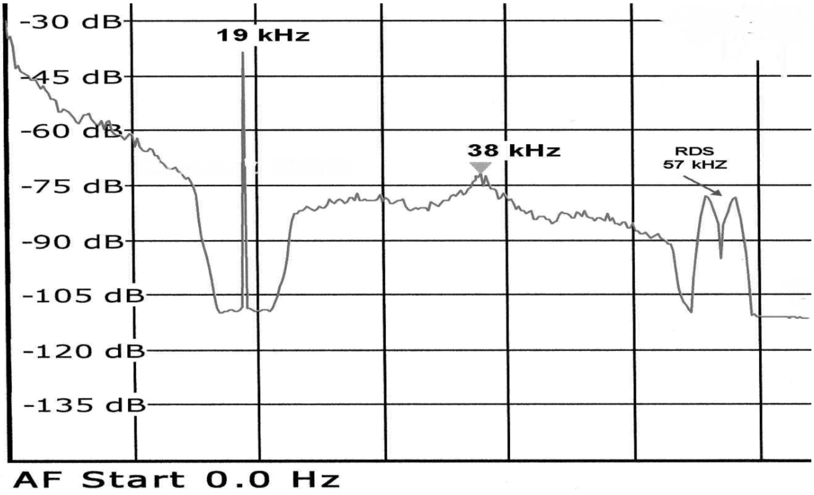
Example — audio signal transmission

Type of the signal	f_{min}, Hz	f_{max}, Hz
Phone (voice) signal	300	3400
AM band signal	50	10000
FM band signal	30	15000

Example — complex stereo signal



Example — Latvian SWH radio signal

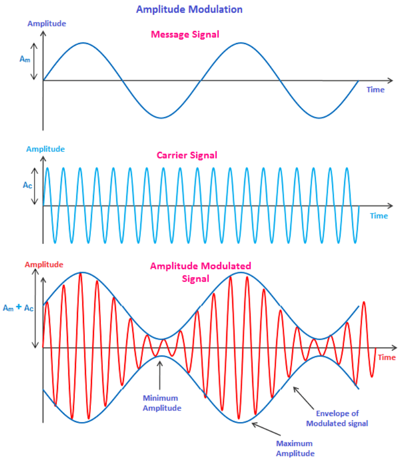


Amplitude modulation

$$s_{AM}(t) = [S_m + a \cdot s(t)] \cos(2\pi f_0 t + \varphi_0).$$

$$\Delta f = 2 f_{max},$$

where f_{max} is highest frequency in the spectrum of the modulating signal

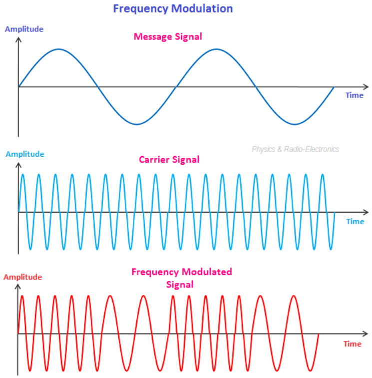


Frequency modulation

$$s_{FM}(t) = S_m \cos\left(2\pi f_0 t + 2\pi f_{dev} \int_0^t s(t)\mathrm{d}t + \varphi_0\right).$$

$$\Delta f = 2(f_{dev} + f_{max}),$$

where f_{max} is highest frequency in the spectrum of the modulating signal and f_{dev} is frequency deviation.



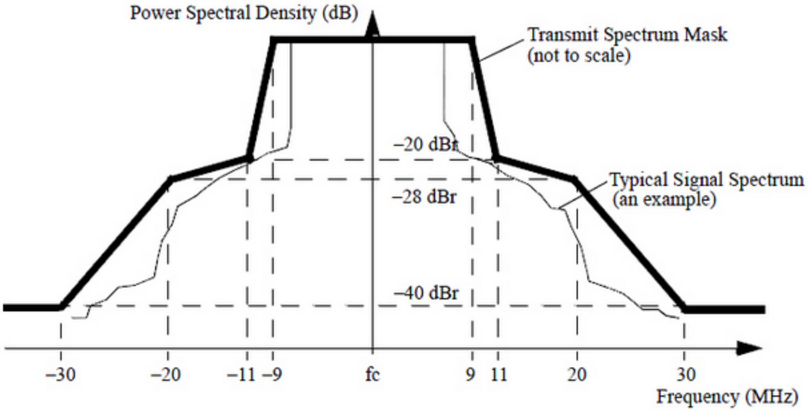
Passband of the channel

Type of the channel	f_{min}, Hz	f_{max}, Hz
Phone (voice) signal	0	4000
AM band signal	50	10000
FM band signal	30	15000

Passband of the radio-frequency channel

Type of the channel	f_{max}, kHz	Δf, kHz
Radiophone	4	8
AM band signal	10	20
FM band signal	57	265

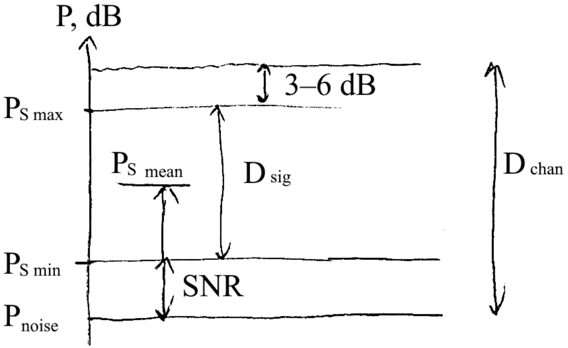
Spectral mask



Dynamic range

The dynamic range of the signal D_{sig} should be narrower than the one of the channel D_{chan}.

The typical dynamic range of the human voice — 40dB.
The dynamic range of the symphonic orchestra — 70dB.

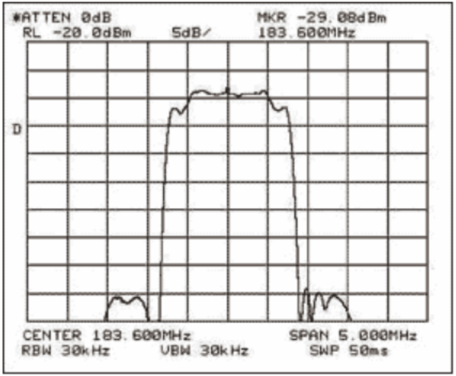


Methods of the signal selection

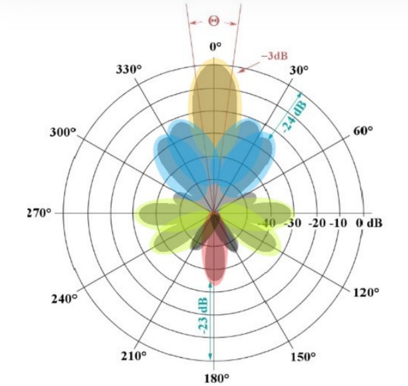
1. By frequency.
2. By time — TDMA.
3. By code — 3G.
4. By direction.
5. By polarization.
6. By level.

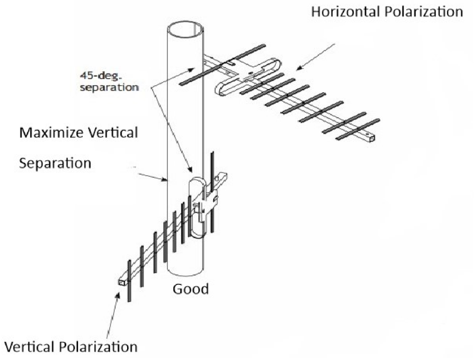
Selection by frequency

- Each transmitter-receiver pair operates on the dedicated carrier frequency.
- Uplink and downlink frequencies may be different.
- Channel separation by LC resonant circuit or more complex filter.



Selection by direction and polarization

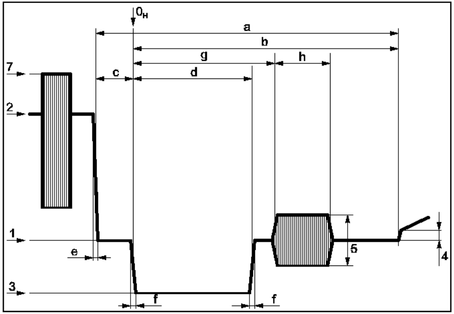




Selection by level

Line synchronization pulses in the PAL system TV signal are separated by level.

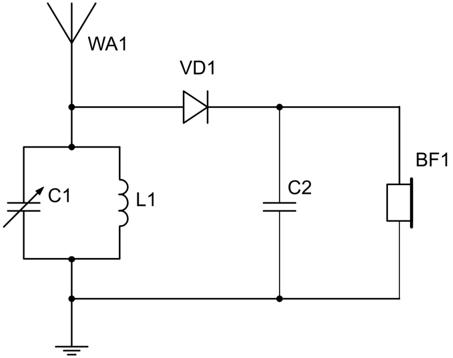
Line Synchronizing Signal



Detector receiver

In literature, commonly known as crystal receiver. Why?

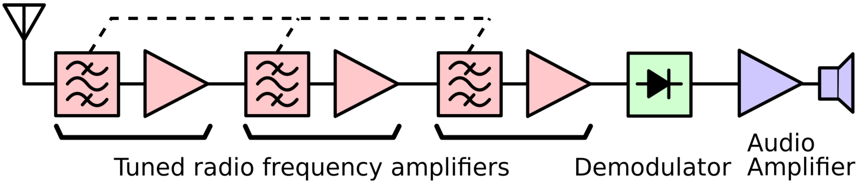
1. Which types of modulations it is able to receive?
2. Which types of siganl selection methods it uses?



Tuned receiver

In Latvian literature, known as tiešās pastiprināšanas uztvērējs.

- Main drawback of the crystal receiver?
- Why radio frequency amplifier is necessary?
- Why baseband amplifier is necessary?



Tuned receiver drawbacks

The band width is carrier frequency dependent.

If $Q = 100$,

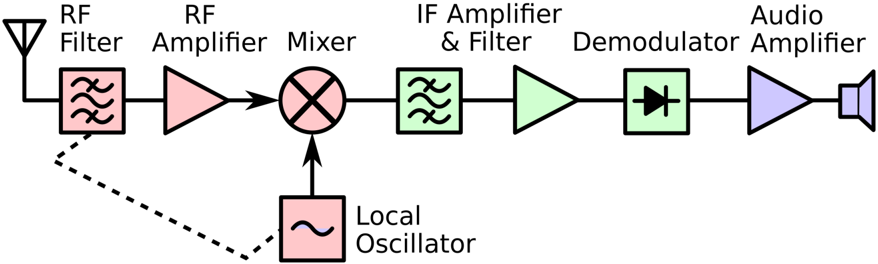
f_0	$2\Delta f$
100 kHz	1 kHz
1 MHz	10 kHz
10 MHz	100 kHz
100 MHz	1 MHz

The gain is also frequency dependent:

$$G = a\sqrt{\frac{Y_{21}}{Y_{12}}}, \text{ where } Y_{12} = \omega C.$$

$$\text{So, } G \propto \frac{1}{\sqrt{\omega}}.$$

Superheterodyne receiver I



Superheterodyne receiver II

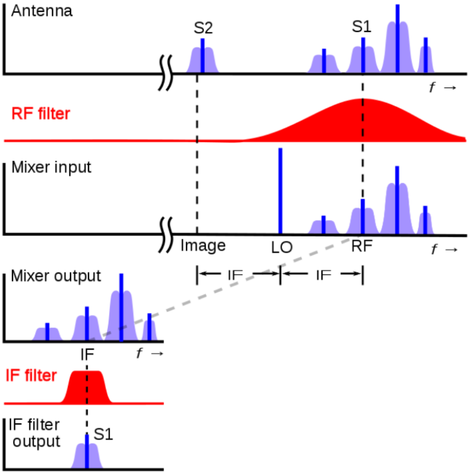
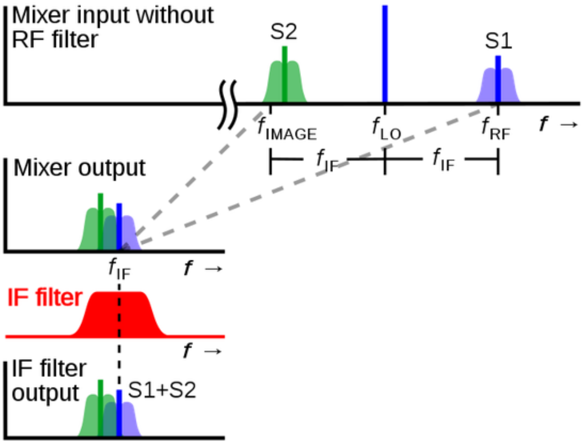
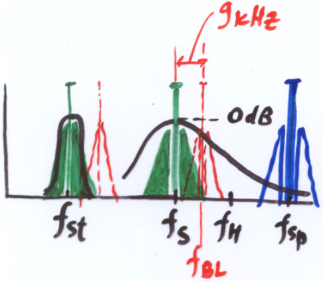


Image frequency

- Main drawback of the superheterodyne receiver is problems with image frequency.
- Possible spectrum inversion.



Example



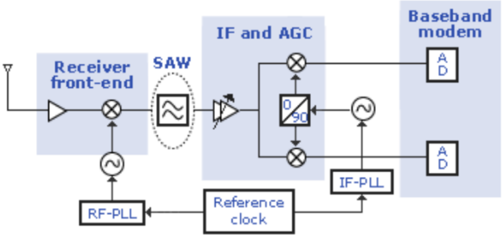
$$f_{st} = 465\,\text{kHz}\quad,\quad Q = 50$$

$$f_s = \underline{500\,\text{kHz}}$$

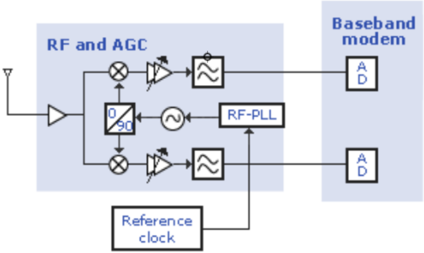
$$f_{sp} = 500 + 2 \times 465 = \underline{1430\,\text{kHz}}$$

$$f_{BL} = 500 + 9 = \underline{509\,\text{kHz}}$$

Direct conversion receiver



(a) An example of typical heterodyne receivers



- Which type of modulation is assumed to be processed by each receiver?

Evolution of radio receivers

1. Crystal receiver.
2. Tuned frequency receiver.
3. Superheterodyne receiver.
4. Direct conversion receiver.
5. SDR.

Radio parameters

1. Bands, modulations and intermediate frequencies.
2. Sensitivity.
3. Selectivity parameters.
4. Dynamic range.
5. Automatic gain control (AGC) capabilities.
6. Output power.
7. etc.

Selectivity

1. Adjacent channel.
2. Image frequency.
3. Forward channel (IF).
4. Other possible channels.

Shows how much interfering signal is suppressed compared with a receiving signal.

Sensitivity

1. Shows the receiver's ability to process weak signals.
2. Can be measured at different input voltage levels with antenna equivalent.
3. Input and output sensitivity.
4. Limit of the sensitivity.

Shows how much interfering signal is suppressed compared with a receiving signal.

Noise in the system

$$h_{ex} = \frac{P_{s,ex}}{P_{n,ex}} = \frac{\bar{V}^2_{s,ex}}{\bar{V}^2_{n,ex}} = \frac{\bar{V}^2_{s,in}K_p}{\bar{V}^2_{n,in}K_p}$$

$$V_{s,in} = \sqrt{h_{ex}\bar{V}^2_{n,in}}$$

$$\bar{V}^2_{n,in} = 4k_B T \Delta f R_g$$

So, $V_{s,in} = \sqrt{h_{ex} 4k_B T \Delta f R_g}$.
Typical requirement: 20dB or BER 10^{-6}.