Lecture 11
Implementation aspects

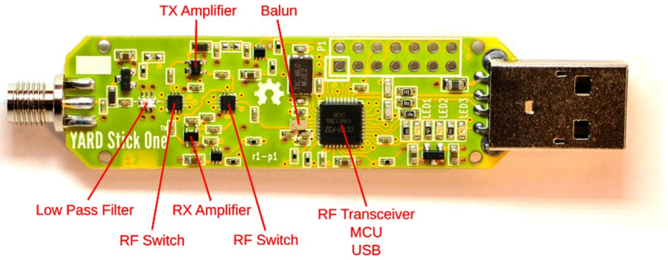

Figure: greatscottgadgets.com

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Project

- Study one existing or proposed link
  - If choosing a standard, also choose an application example.
- Write a description of it, including
  - Technical details on speed, modulation, equalisation, antennas etc.
  - Link budget, both numerical and graphical
    - Use well motivated assumptions where no data can be found.
  - 2-4 pages.
- Deadline: 25 May 2018
- Format: pdf
- Email: ajn@eit.lth.se, with subject:"EITN75 report"
- Make sure report itself includes all necessary info, including participants names.
- Reports will be run through Urkund.

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Ideas

- Sattellite links, such as Sattelite TV, INMARSAT, GPS, Irridium,
- Space probes such as Mars probes, including rovers, New Horizons (Pluto), Pioneer, Voyager, Cassini etc.
- DAB-radio, Terrestial digital TV,
- Domestic system: *GSM, 4G, 5G*, Blutetooth, Bluetooth LE, WiFi, *LORA*, WiMax,
- Medical applications: MICS, Bluetoth LE
- *Submarine communication*

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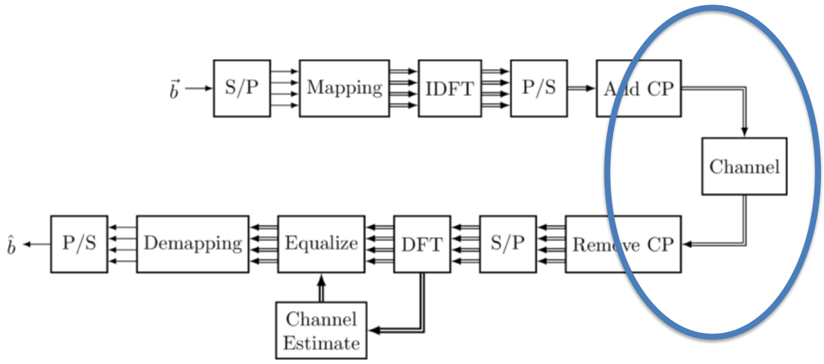
Hardware

- Moving theory to practice



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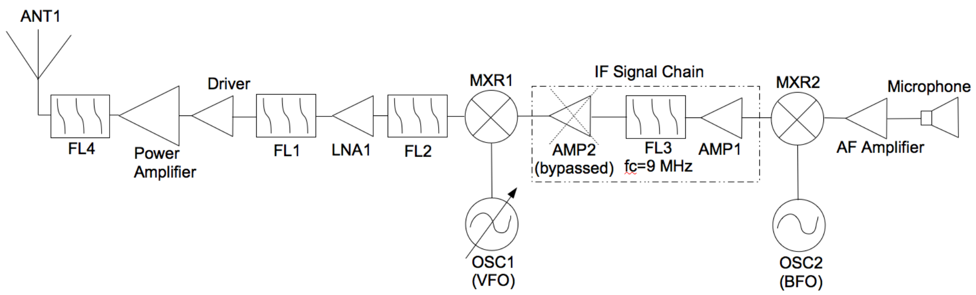
http://dspillustrations.com/pages/posts/misc/python-ofdm-example.html

Transmitter



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Transmitter

- Modulate signal
- Move signal in frequency
- Amplify signal

- Modulator
- Oscillators
  - XO
  - VCO
  - PLL
- Mixer
- Filter
- PA

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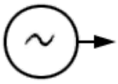
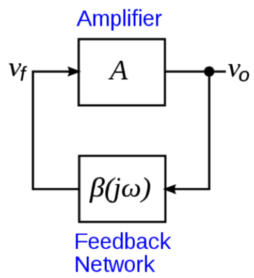
Oscillator

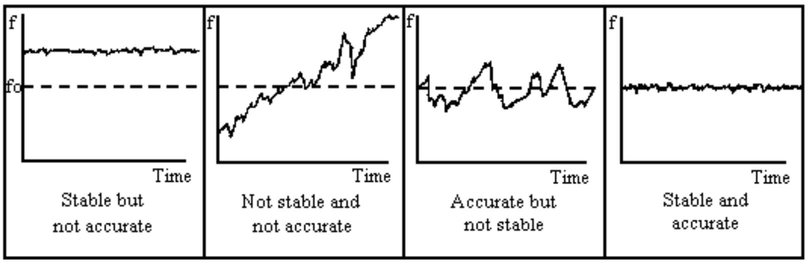
- Postive feedback
  - Amplifier
  - Filter
- Filter can be
  - RC
    - Varactor diode
  - Ceramic
  - Crystal
  - Dielectric
  - Atomic resonance (Atomic clock)





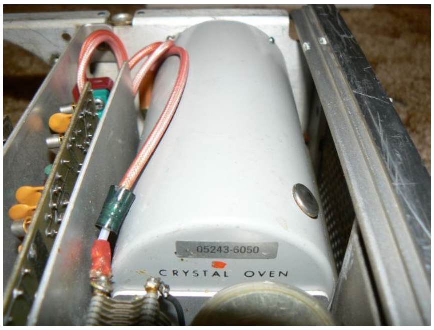
Frequency vs. time

- NIST



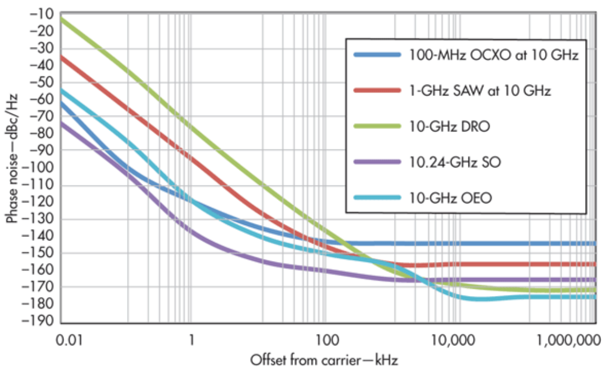
Oscillator errors

- Pushing
  - Dependence on votage supply
- Pulling
  - Dependence on load
- Temperature
  - TCXO, OCXO
- Aging
- Vibration
  - Microphonics



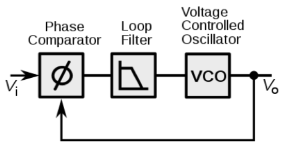
Phase Noise

- Oven-controlled Xtal Oscillator
- Surface Acoustic Wave
- Direlectric resonator Oscillator
- Sapphire oscillator
- Opto-Electric Oscillator



Phase Locked Loop (PLL)

- Closed-loop control system working on the phase of the output.
- Locks one signal to another in phase (hence the name)
- By introducing mixing in the design, new frequencies can be generated.
- Today digitally implemented at low cost and high fidelity.



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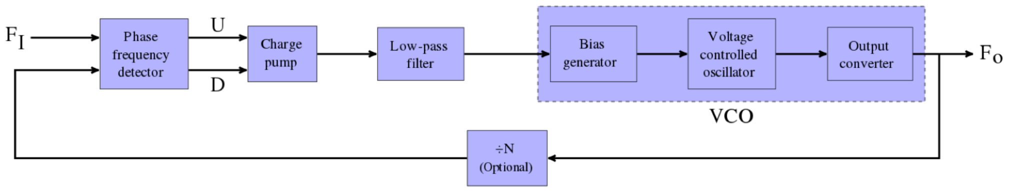
Digital PLL



- Fout = Fi*N
- Add divider on reference frequency
  - Fout=Fref/M*N
- Add option N/N+1 on main divider
  - Fout=Fref/M*(N+K/F)
  - F is the cycle length, K is the number of (N+1) divisions.

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Simple transmitter

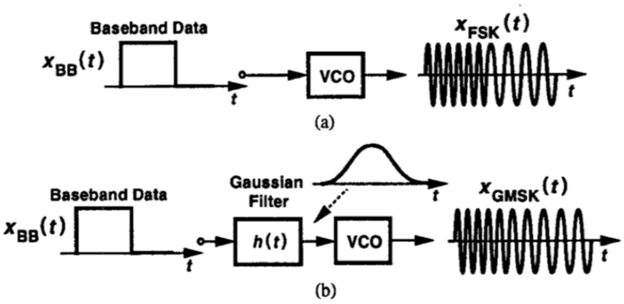


Fig. 1. Generation of (a) FSK and (b) GMSK signals.

http://www.seas.ucla.edu/brweb/papers/Conferences/RCICC99.pdf

QPSK-transmitter

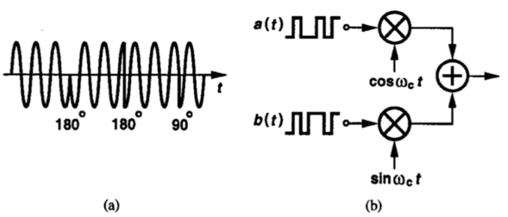


Fig. 2. (a) QPSK waveform, (b) generation of QPSK signal from baseband streams.

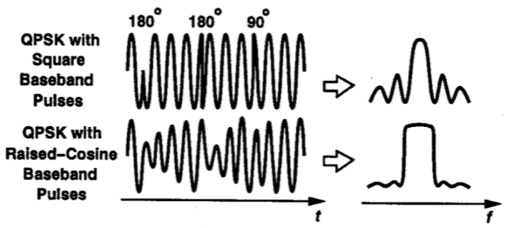


Fig. 4. Variation of envelope with raised-cosine baseband pulses.

$$sin\left(\theta + \frac{\pi}{2}\right) = cos(\theta)$$

$$a \sin x + b \cos x = c \sin(x + \varphi)$$

$$c = \sqrt{a^2 + b^2}$$

$$\varphi = \text{atan2}(b, a)$$

Pulse shaping in the digital domain

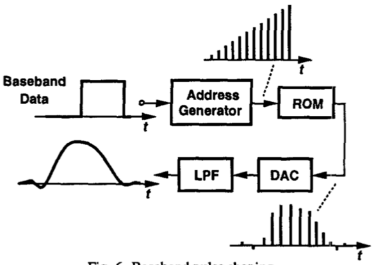


Fig. 6. Baseband pulse shaping.

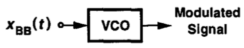


Fig. 7. Baseband/RF interface in for nonlinear modulation.

Direct conversion transmitter

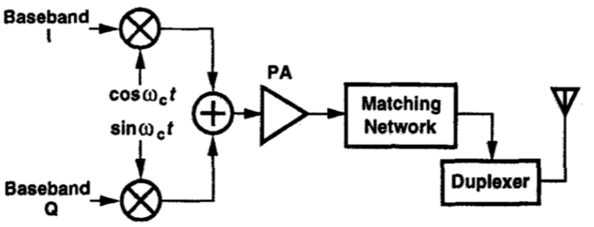


Fig. 16. Direct-conversion transmitter.

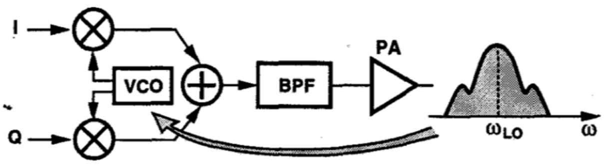


Fig. 17. LO pulling by PA.

LO injection pulling

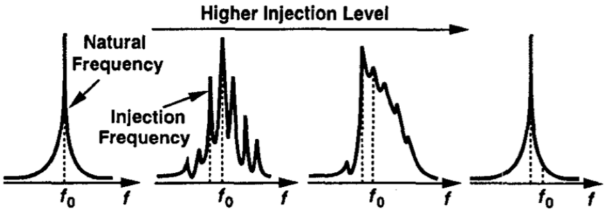


Fig. 18. Injection pulling as the magnitude of the injected noise increases.

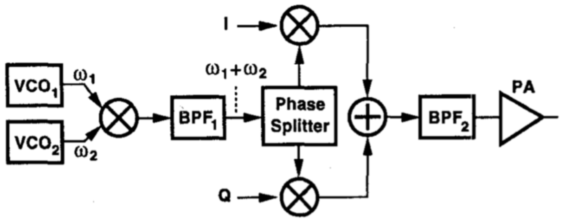
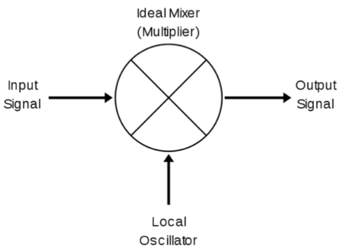
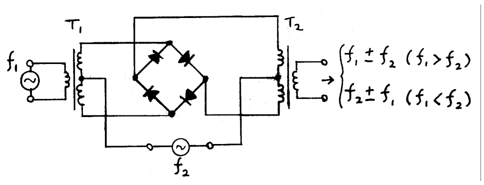


Fig. 19. Direct-conversion transmitter with offset LO.

Mixers



$f_1 \otimes f_2 \rightarrow (f_1 + f_2),(f_1 - f_2)$



I/Q-mixer (Gilbert cells)

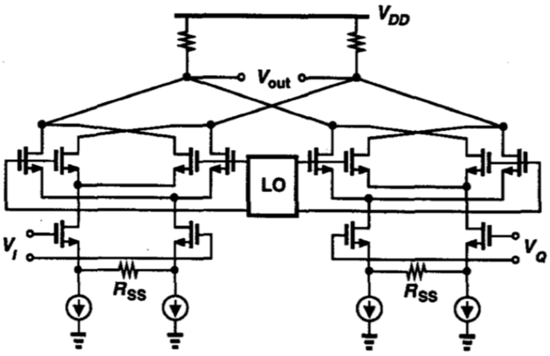
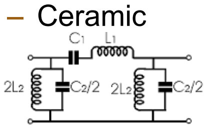


Fig. 25. I/Q upconverter using Gilbert cells.

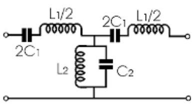
- Note:
  - Balanced inputs
  - Balanced outputs

Filters

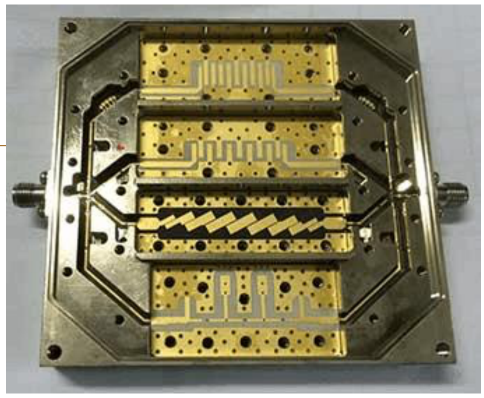
- Typically made of coupled resonators
- RC
- Waveguide
- Cavity
  - Ceramic

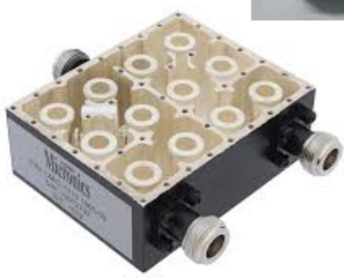


Pi section filter



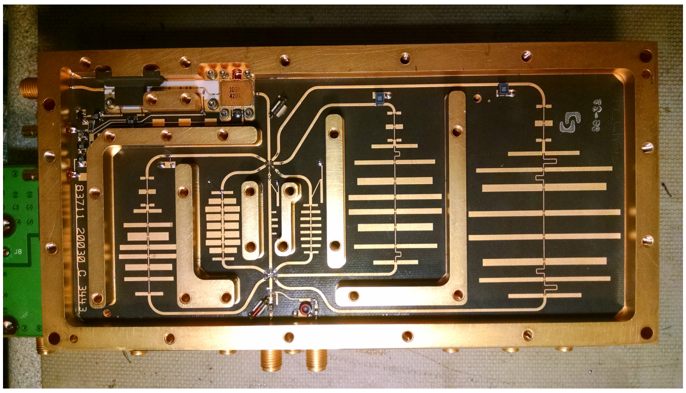
T section filter

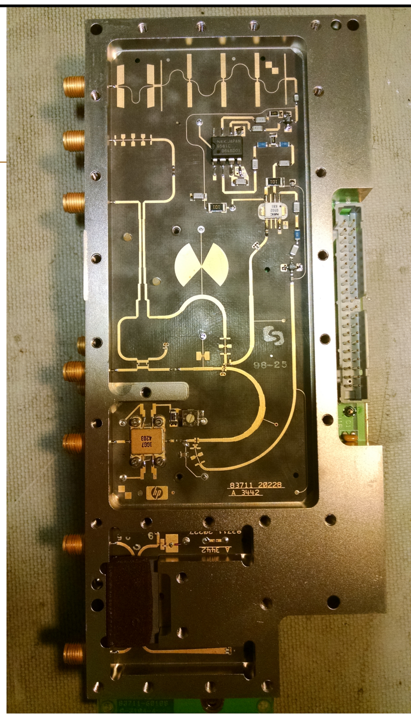




20 GHz synthesizer filters

- HP83732B





Power Amplifier

- High absolute output power
- Often low gain
  - Needs pre-amplifier (driver)
- Differnt types, depending on
  - Frequency (Hz)
  - Power (W, dBm)
  - Efficiency (%)
  - Price (€$)
  - Size (mm, m, g, kg)
  - Etc.
- Different topologies, depending on
  - Linearity
  - Efficiency
  - Pushing
  - Pulling
  - Noise
  - Etc.

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Perfect amplifier

- Measure of linearity of amplifier.

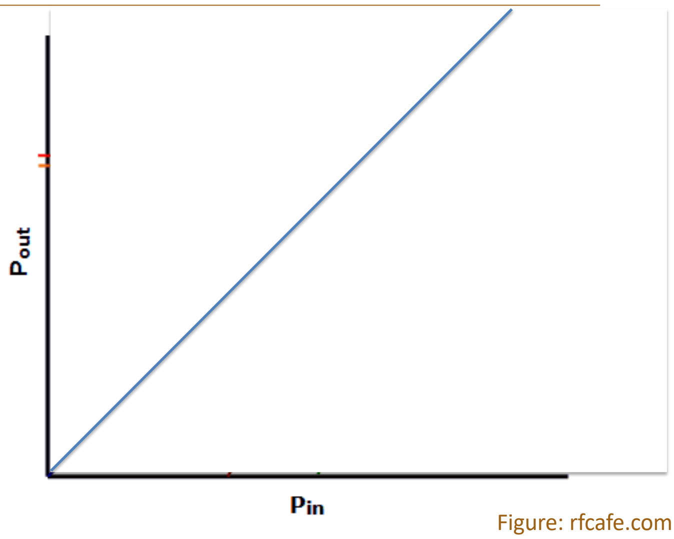


Figure: rfcafe.com

1dB Compression level, Intercept point

- Measure of linearity of amplifier.

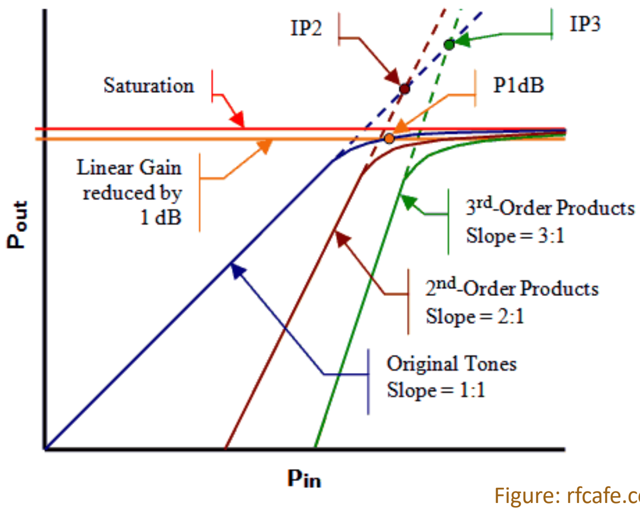
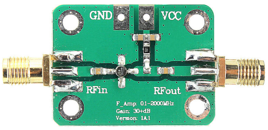
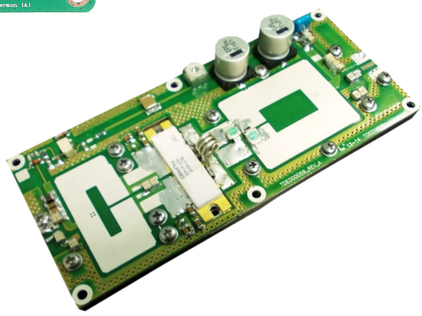


Figure: rfcafe.com

Solid state

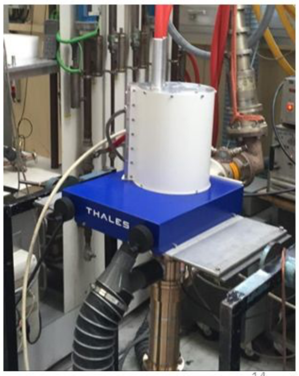




Spoke power sources

- 400 kW tetrode-based solution
- Two complete stations to Uppsala University FREIA facility (Proof of concept)
- FAT of tube recently (Thonon)

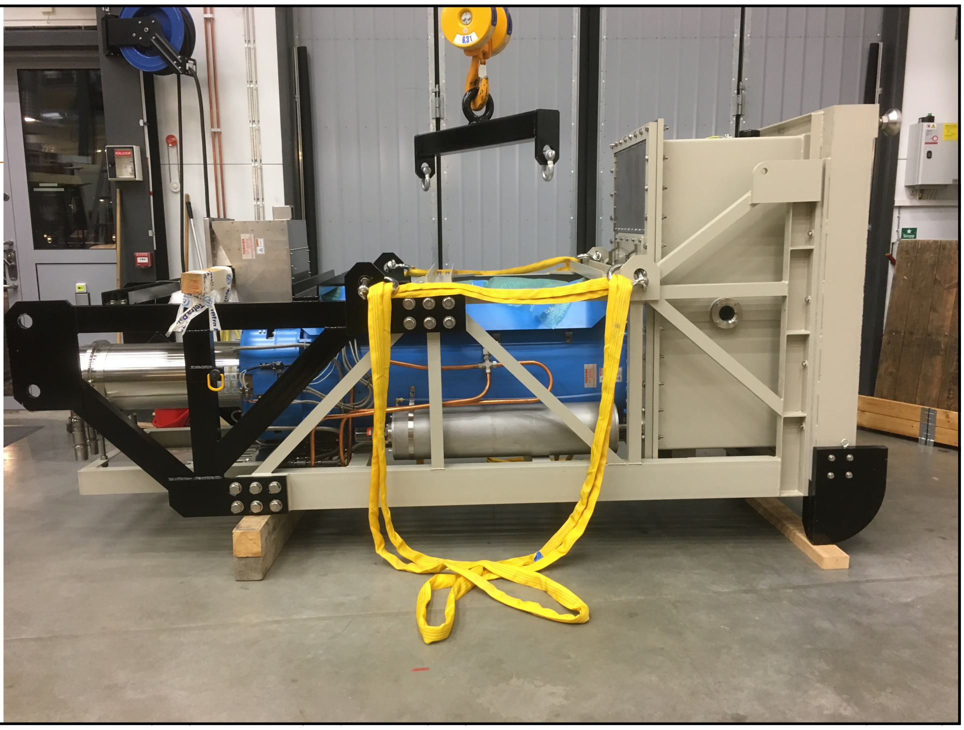
Results	
Peak power	200 kW
Efficiency	66%
Gain	15 dB
Duty	4.6%



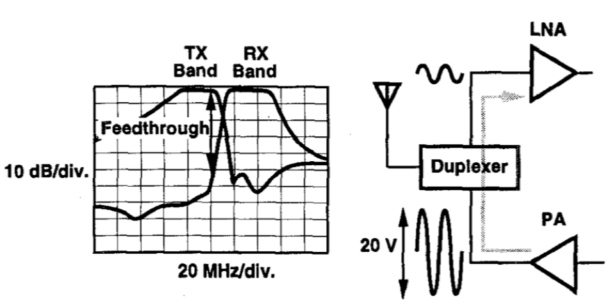
Klystron

- 1.5 MW
- 700 MHz
- Pulsed
- Duty Cycle 4%

- Power supply
- 110 kV
- 25 A (ca.)



Duplex filter, Antenna switch



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Antenna switch timing

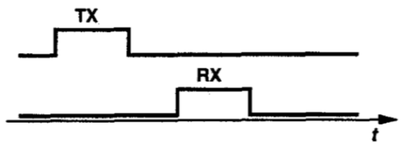
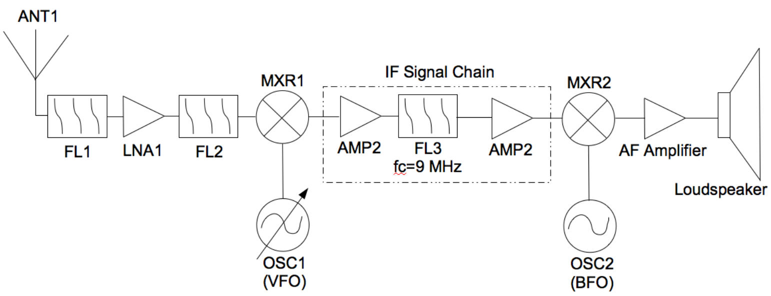


Fig. 12. Time offset between TX and RX time slots in a TDMA system.

Reciever



Reciever

- Simple
- Super Heterodyne
- Double Super Heterodyne
- Homodyne
- Digital Homodyne / direct conversion
- Direct sampling

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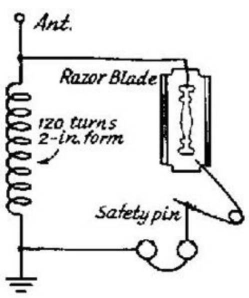
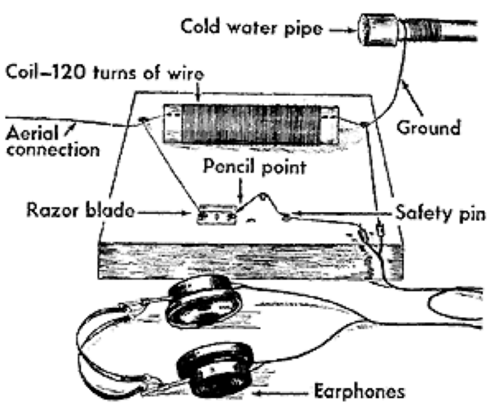
Simplest: Foxhole radio

- AM-reception



Fox Hole Radio



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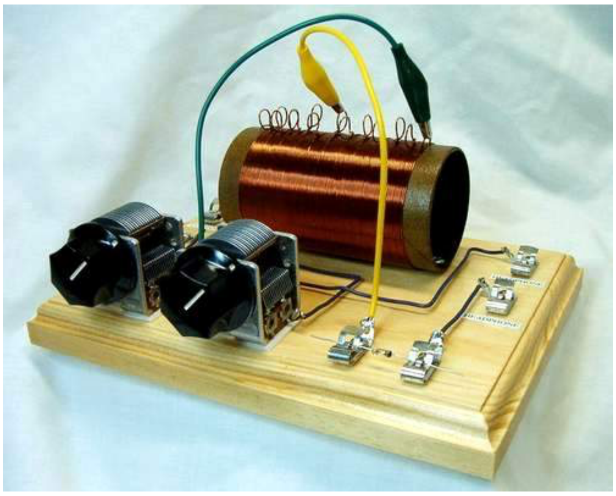
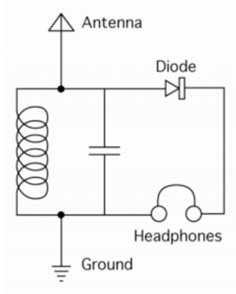
My first radio!

- (Similar,
  mine is lost…)





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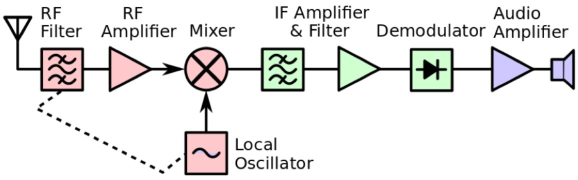
Superheterodyne

- Filter
- LNA
- Mixer
- Demodulator



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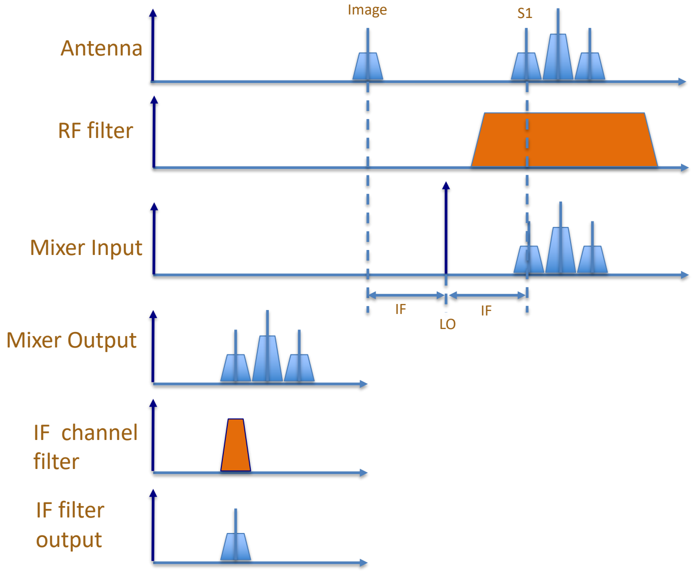
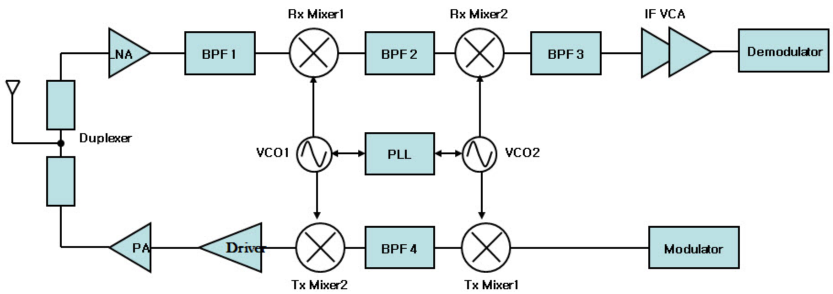
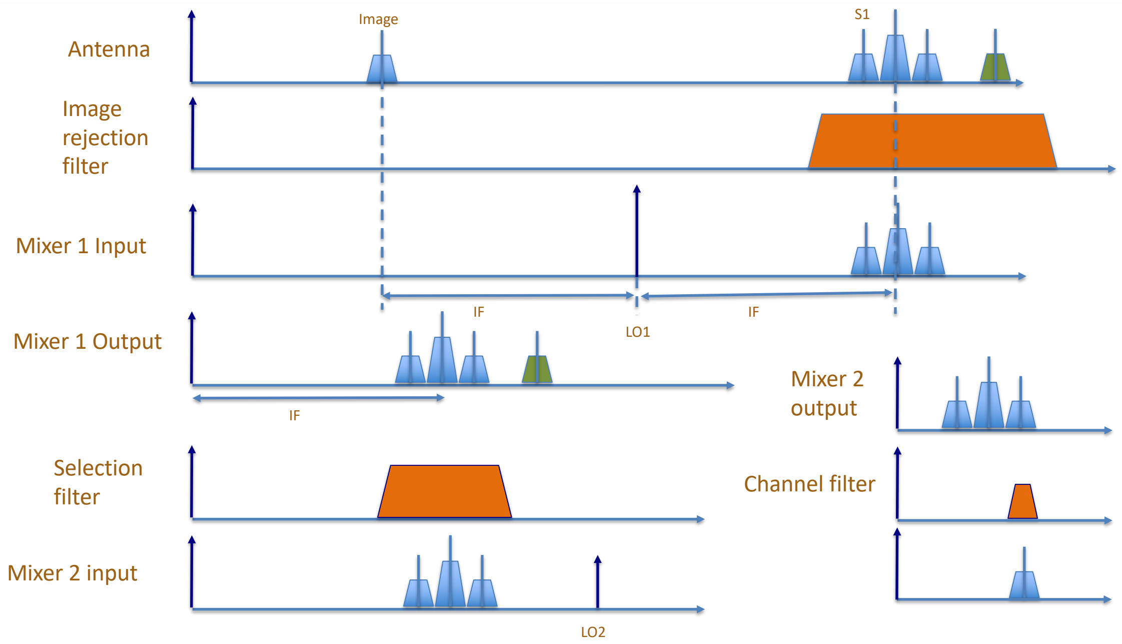
Superheterodyne

$$Q = \frac{f_r}{BW}$$



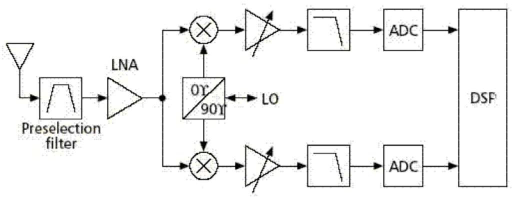
Double Super Heterodyne





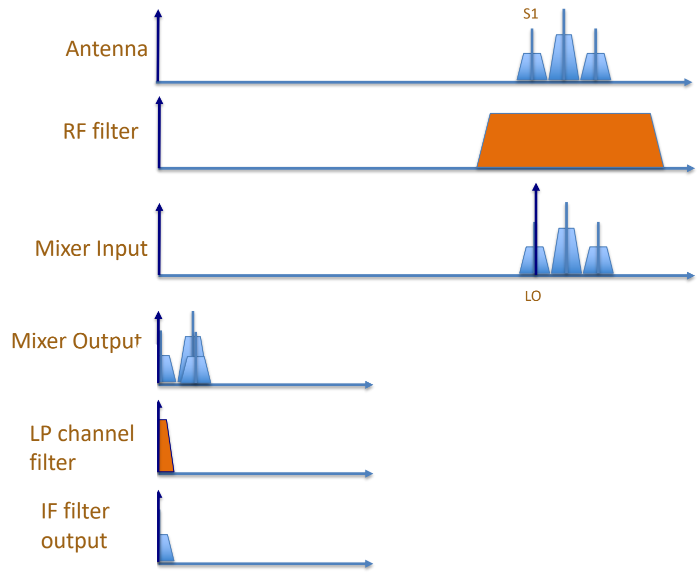
Homodyne

- Direct conversion
- Zero-IF
- Synchrodyne
- (Very low IF)



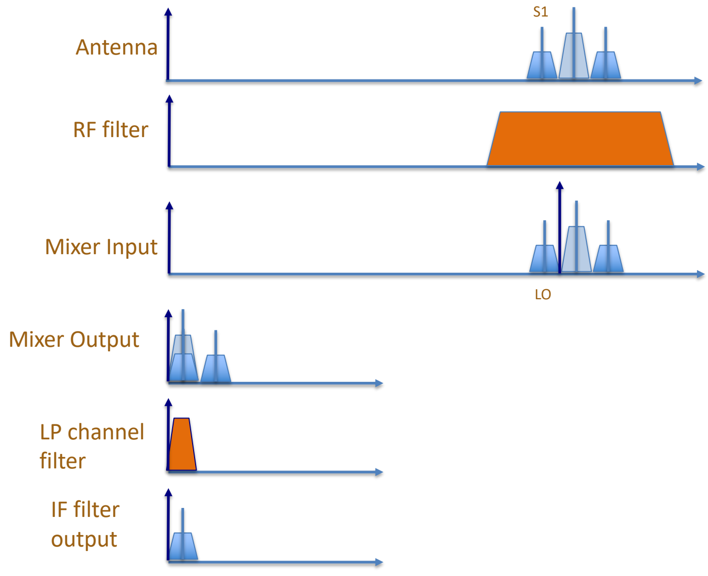
Homodyne

$f_{LO} = f_{channel}$



Very-low IF

$f_{LO} = f_{channel} \pm \frac{1}{2} Channel\ Bandwidth$



Digital technology

- Moving border inside the digital domain
  - AD/DA
  - Subsampling
  - FPGA/Signal processor

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AD/DA

- Sampling speed
  - Input bandwidth
- Resolution in number of bits
  - True number of bits (ENOB, resolution)
- Timing jitter

www.maximintegrated.com/en/design/tools/calculators/product-design/data-conversion.cfm

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AD9267

- 16 bit
- 250 MSPS

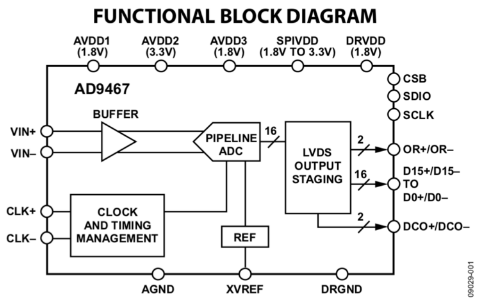
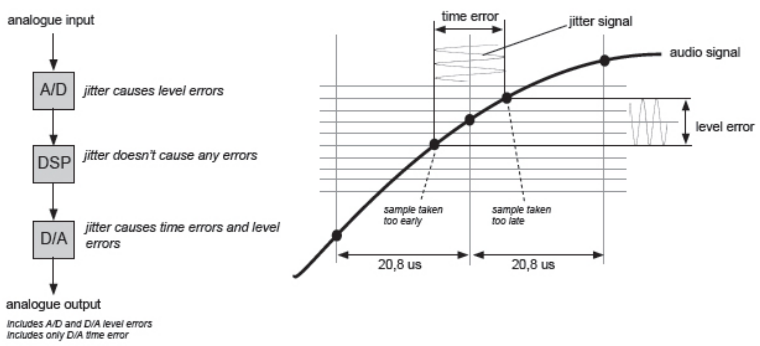


Figure 1.

- Input bandwidth: 900 MHz
- At f_{in}=300MHZ, SNR is specified to 74 dB, which equals 12 bits.
  - No data is goven above 300 MHz.

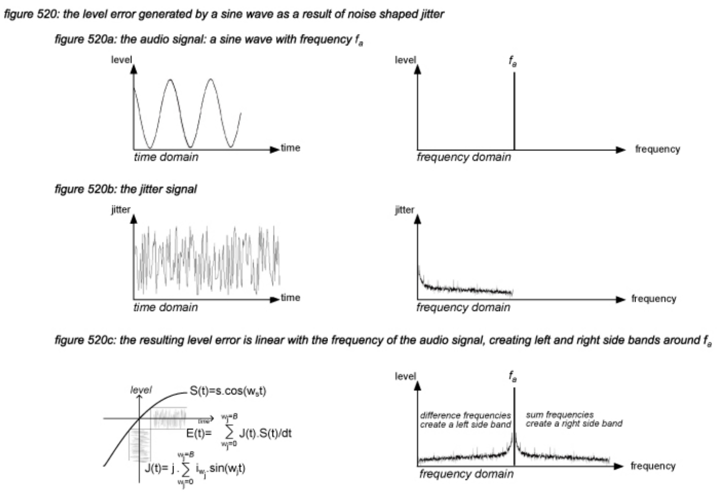
Timing jitter

figure 519: the result of jitter: DA time errors and AD & DA level errors



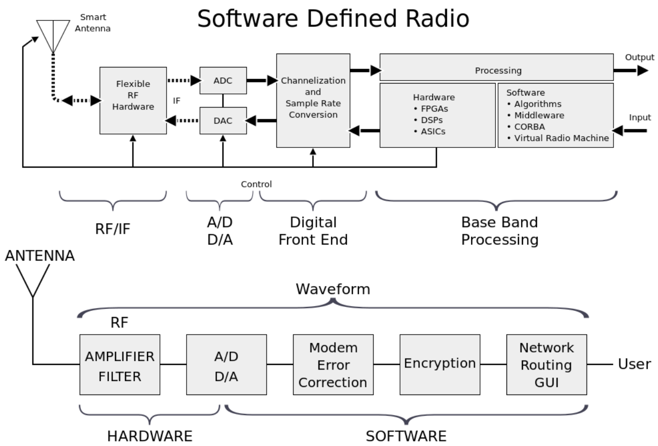
www.yamahaproaudio.com/europe/en_gb/training_support/selftraining/audio_quality/chapter5/10_jitter/

Jitter = noise = sidebands



Software radio - SDR

- Wikipedia picture



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