Lecture 13

SDR, Cognitive radio, mesh networks, source coding

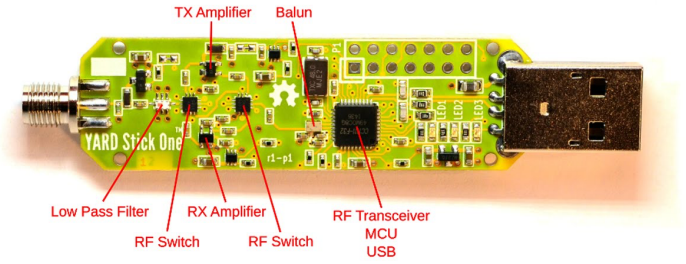

Figure: greatscottgadgets.com

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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

AD9267

- 16 bit
- 250 MSPS

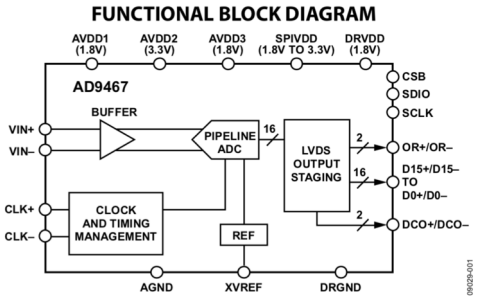
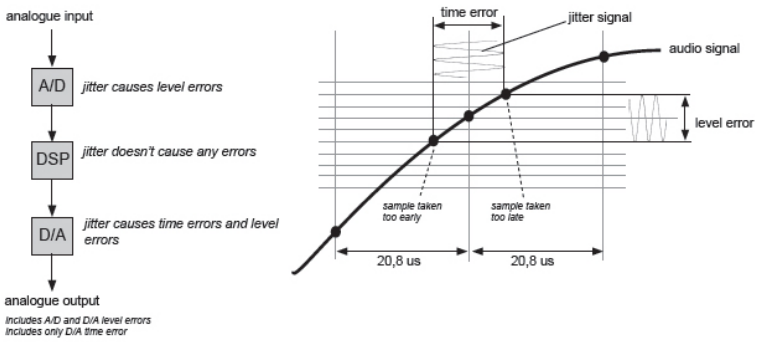


Figure 1.

- 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

figure 520: the level error generated by a sine wave as a result of noise shaped jitter

figure 520a: the audio signal: a sine wave with frequency f_a

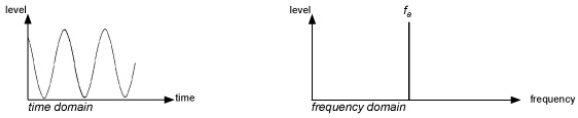


figure 520b: the jitter signal

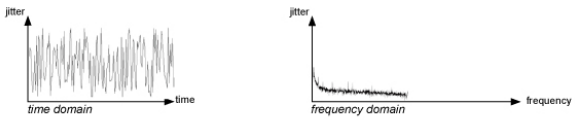
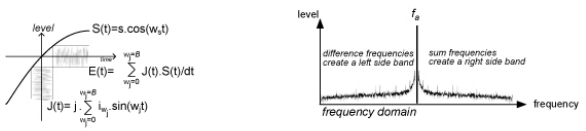


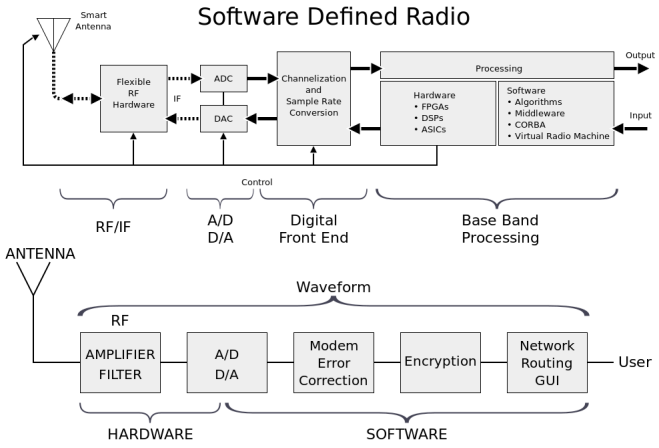
figure 520c: the resulting level error is linear with the frequency of the audio signal, creating left and right side bands around f_a



Software radio - SDR

GNU Radio
the gnu software radio

- Wikipedia picture



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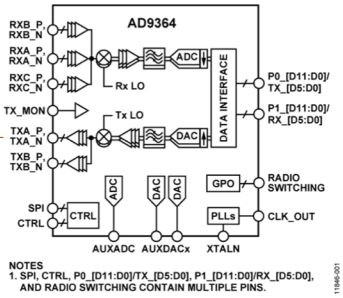
AD9364

- RF 1 × 1 transceiver with integrated 12-bit DACs and ADCs
- Band: 70 MHz to 6.0 GHz
- Supports TDD and FDD operation
- Tunable channel bandwidth: <200 kHz to 56 MHz
- Dual receivers: 6 differential or 12 single-ended inputs
- Superior receiver sensitivity with a noise figure < 2.5 dB
- RX gain control
- Real-time monitor and control signals for manual gain
- Independent automatic gain control
- See data sheet for additional features



Ca. 140 EUR/pc

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USRP
Ettus research, now National Instruments

- 15.700 SEK
- 8 000 SEK

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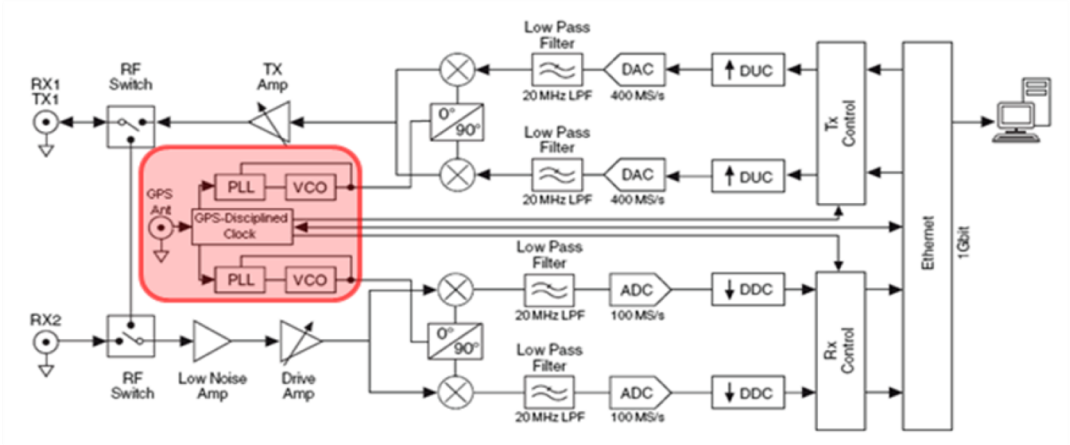
USRP 239x



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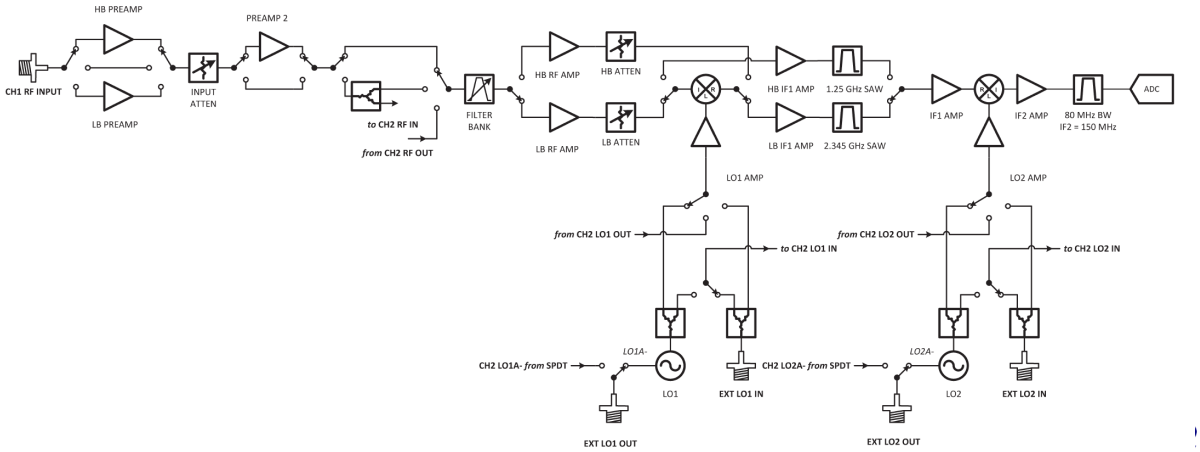
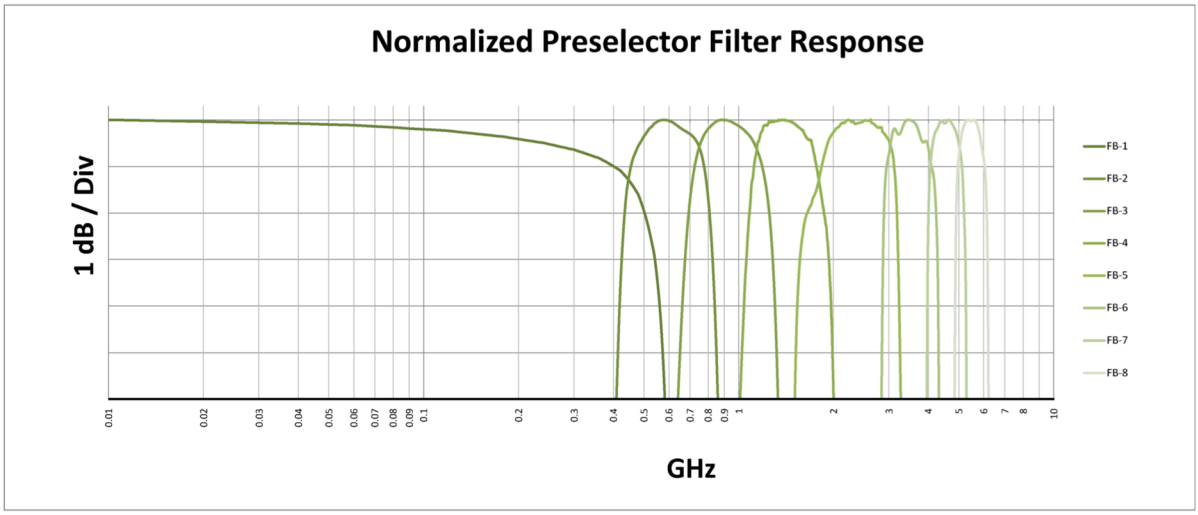
But still needs RF-hardware





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Frequency	Noise Figure[3] (dB)
10 MHz – 3 GHz	< 5
3 GHz – 5 GHz	< 4
5 GHz – 6 GHz	< 8

Frequency	Image Rejection[3] (dBc)
500 MHz – 6 GHz	-70

Phase Noise (dBc/Hz)			
Frequency Offset	0.9 GHz	2.4 GHz	5.8 GHz
10 kHz	-88	-86	-82
100 kHz	-105	-107	-103
1 MHz	-124	-127	-127

Third Order Intercept (dBm)			
Frequency	Full Scale = - 45 dBm	Full Scale = - 30 dBm	Full Scale = - 20 dBm
10 MHz - 1.8 GHz	-8	-2	16
1.8 GHz - 3 GHz	-10	-1	14
3 GHz - 6 GHz	-13	-1	12

Frequency	Non-Input Related (Residual) Spurs[2, 3] (dBm)
10 MHz – 3 GHz	< -95
3.2 GHz	-92
4.8 GHz	-98
5.4 GHz	-98

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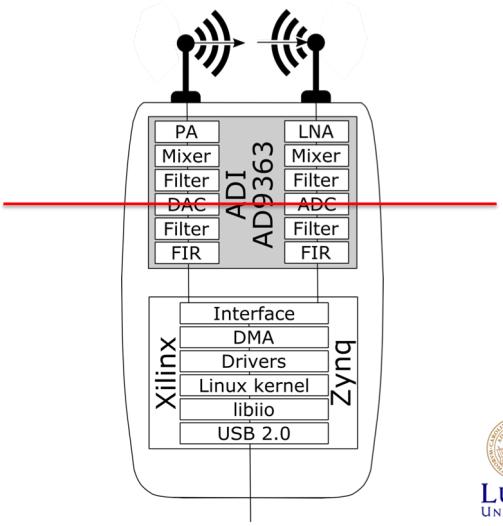
Analog Devices

- RF coverage from 325 MHz to 3.8 GHz
- Up to 20 MHz of instantaneous bandwidth
- Flexible rate, 12-bit ADC and DAC
- 150 USD



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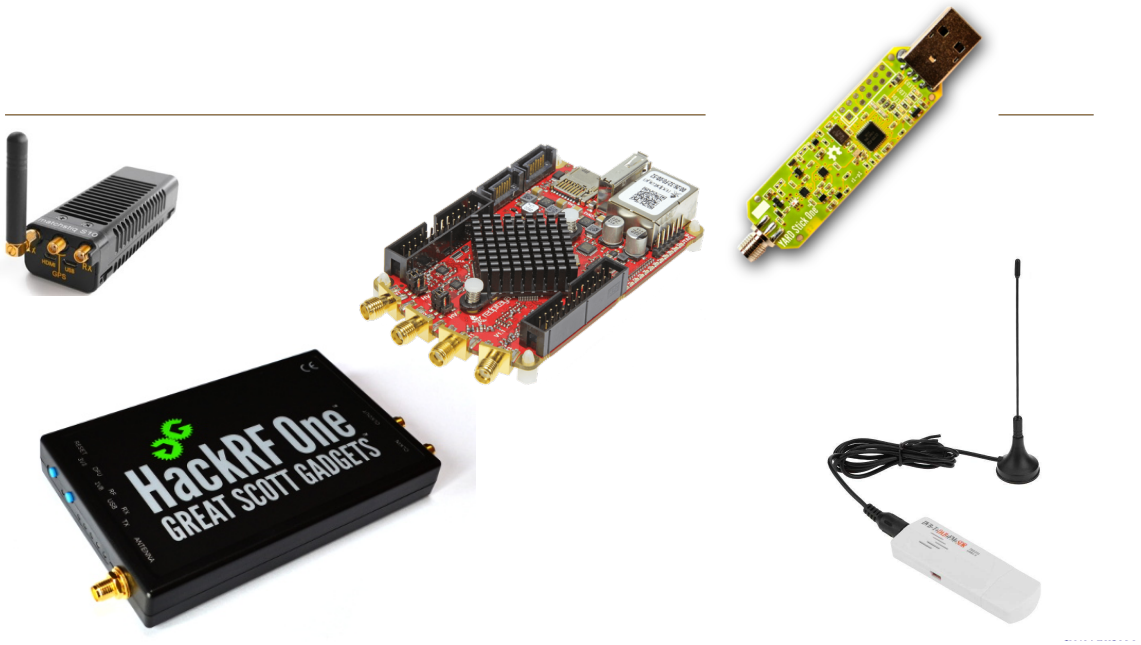
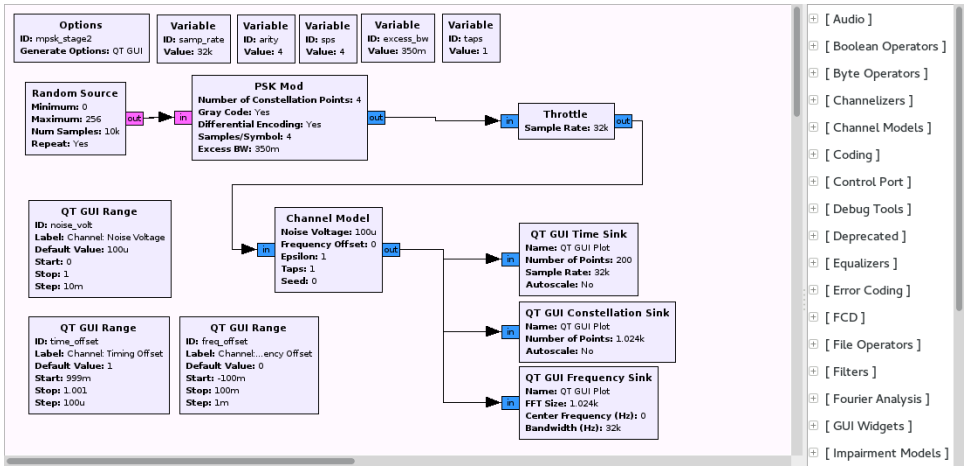


GNU radio

GNU Radio
THE FREE & OPEN SOFTWARE RADIO ECOSYSTEM



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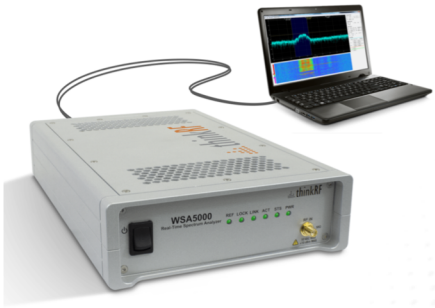
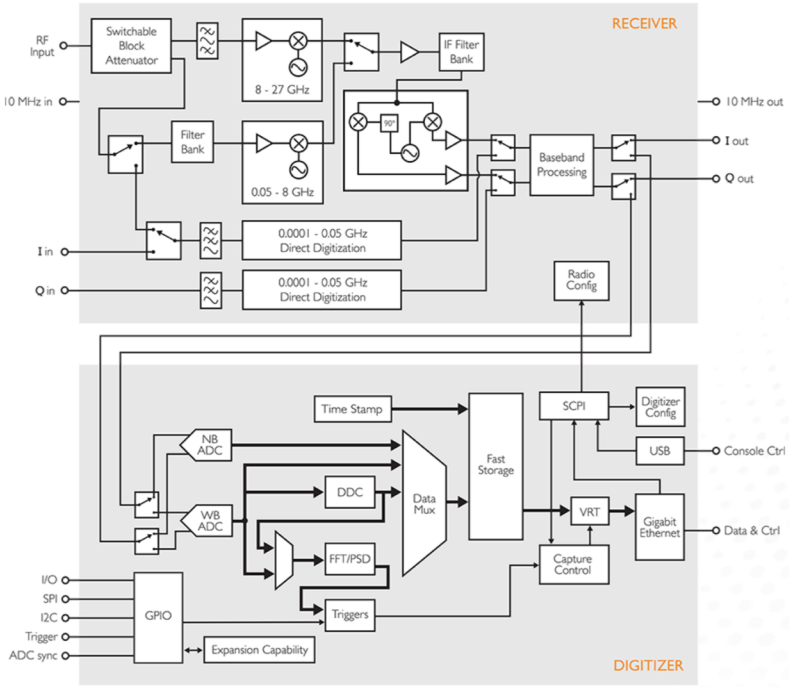
WSA5000

100 kHz to 27 GHz
BW 100 MHz
SFDR 100 dBc

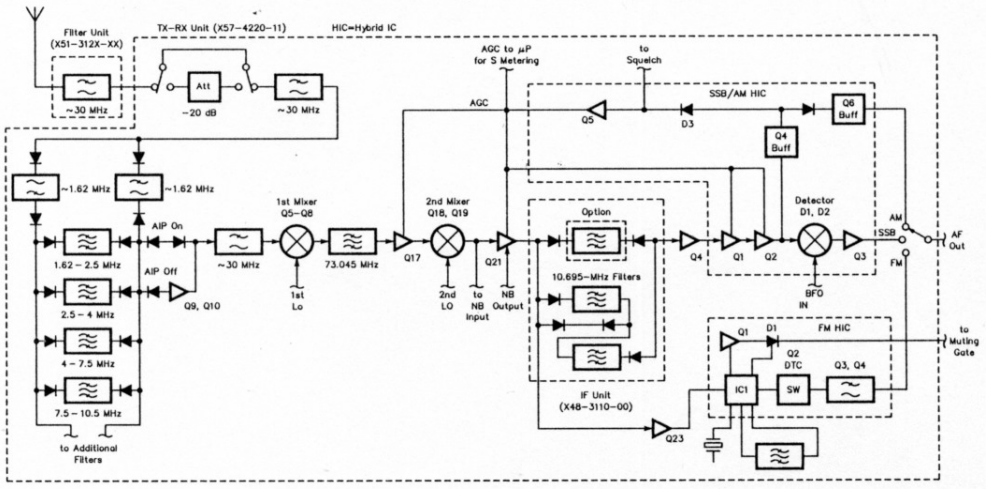


”…applications such as signals intelligence/electronic intelligence (SIGINT/ELINT), technical surveillance countermeasures (TSCM), and regulatory monitoring.”

www.thinkrf.com/real-time-spectrum-analyzers/



Kenwood TS-50



Some things is not solved by SDR:

- Antennas
  - Hard to combine size, efficiency, bandwidth and directivity.

Cognitive radio

- ”A Cognitive Radio (CR) is an intelligent radio that can be programmed and configured dynamically. Its transceiver is designed to use the best wireless channels in its vicinity. Such a radio automatically detects available channels in wireless spectrum, then accordingly changes its transmission or reception parameters to allow more concurrent wireless communications in a given spectrum band at one location. This process is a form of dynamic spectrum management.”

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www.netmanias.com/en/post/blog/10813/5g-new-radio/cognitive-radio-the-new-5g-radio

Cognitive radio

- Two versions
  - Full cognitive radio – Mitola radio
    - » Adapts all parameters to the needs and environment
  - Spectrum sensing cognitive radio
    - » Adapts frequency, bandwidth and time.
- Sometimes UWB is included in the concept.

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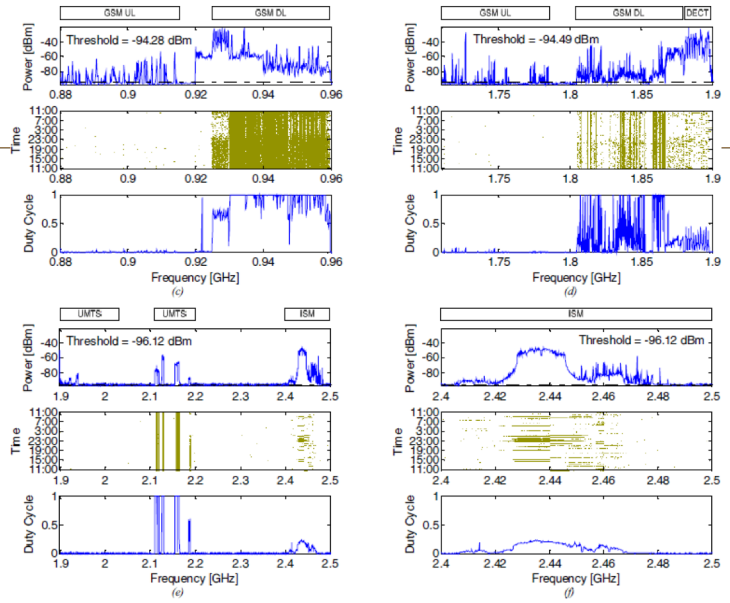
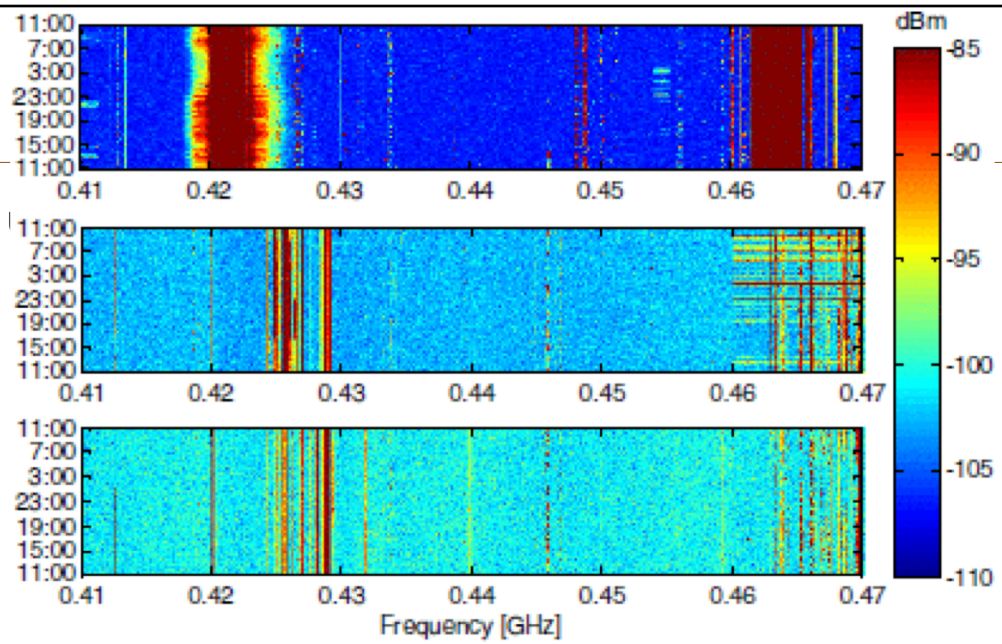
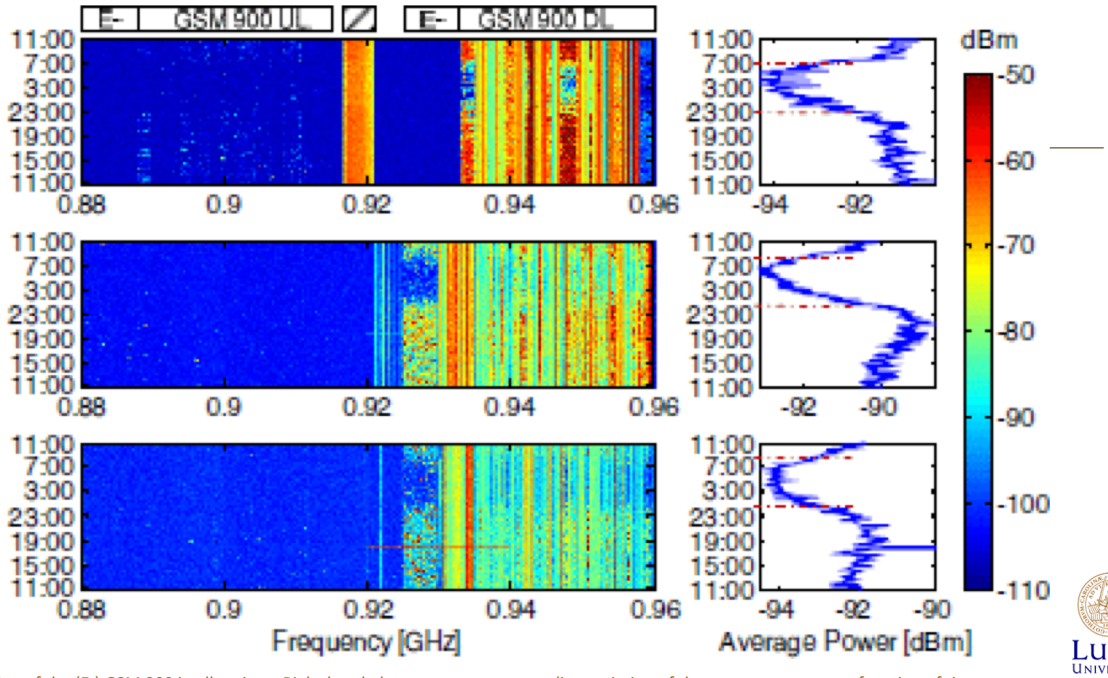


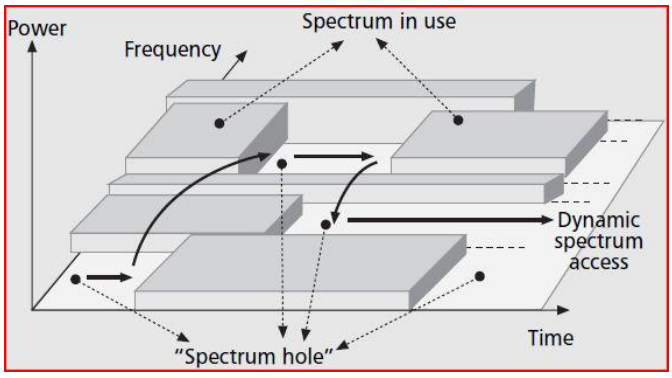
Survey on spectrum utilization in Europe: Measurements, analyses and observations



Usage of the 400 MHz band in Brno, Paris and Paris.



Utilization of the (E-) GSM 900 in all regions. Right-hand plots present corresponding variation of the average power as a function of time.



Essentially RF-spectrum Frogger

- Single player is easy (relativly)
- Multiple players gets hard
  - Game theory
  - Collaboration
  - Supervision

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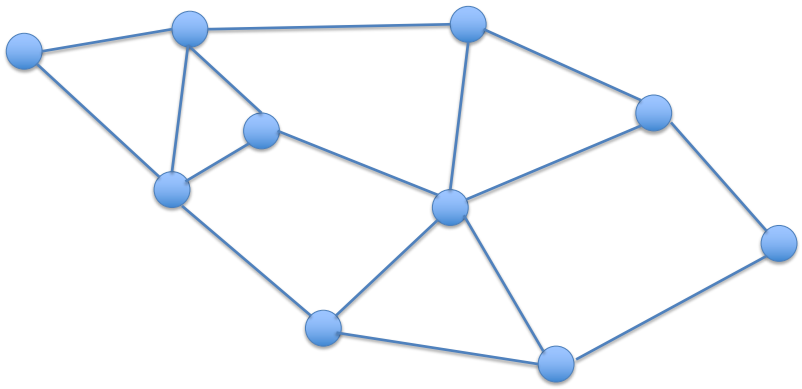
Relaying, multi-hop, Cooperative communication



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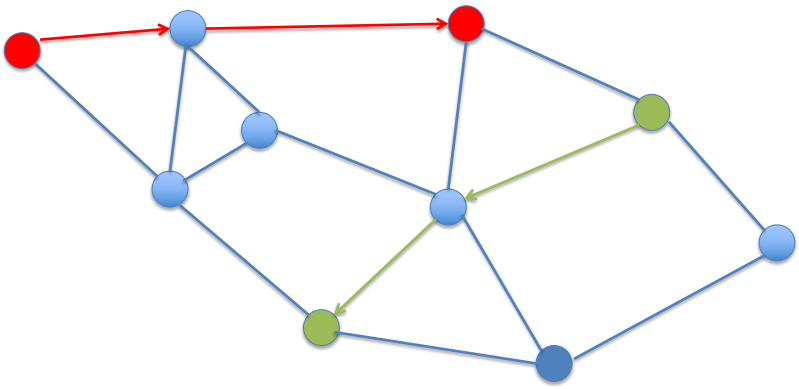
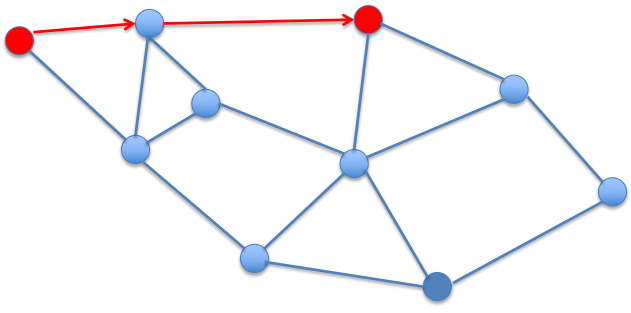
Relaying



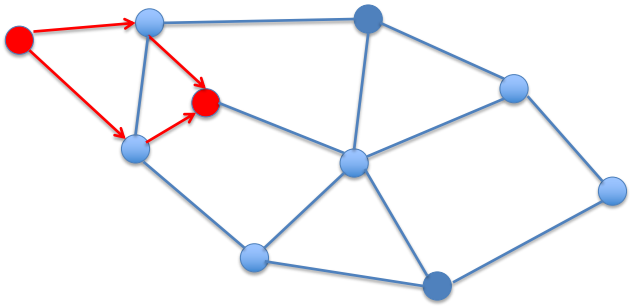
Relaying

- Amplify-and-forward
- Decode-and-forward
- Compress-and-forward



Relaying

- Parallell relays
- Different strategies
  - Full Channel information
  - Partial channel information
  - No channel information



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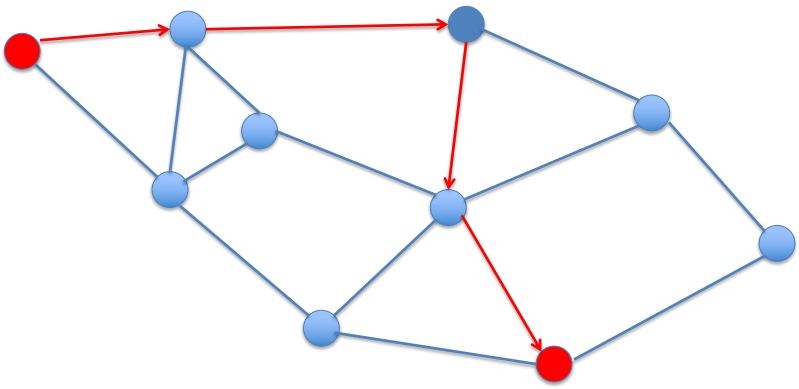
Multi-hop



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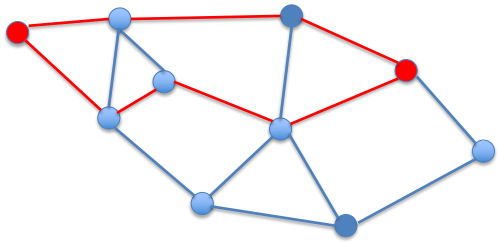
Cooperative communication

- Full central ownership

Vs.

- ”Egoistic” nodes



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Mesh network application

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Source coding

- Source coding **removes** redundancy from the information to be transmitted.
  - Similar to compression.
- Channel coding **adds** redundancy to the information to be transmitted.
- Both steps are useful, as there is a difference in the type of redundancy that is most effective.

Source coding

- Different coding algorithms, and standards, for different types of signals
  - Speech
  - Music
  - Pictures
  - Movies
  - Measured signals
  - etc.

Speech coding

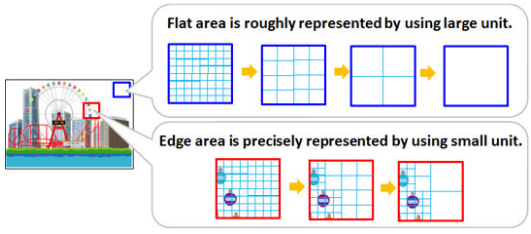
Many standards available, such as.

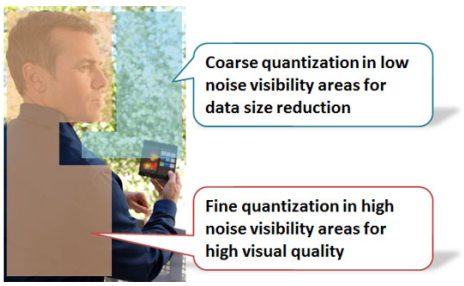
- Wide-band speech coding
  - AMR-WB for WCDMA networks
  - VMR-WB for CDMA2000 networks
  - G.722, G.722.1, Speex, IP-MR and others for VoIP and videoconferencing
- Narrow-band speech coding
  - FNBDT for military applications
  - SMV for CDMA networks
  - Full Rate, Half Rate, EFR, AMR for GSM networks
  - G.723.1, G.726, G.728, G.729, iLBC for VoIP or videoconferencing

Ref: Wikipedia

Video coding

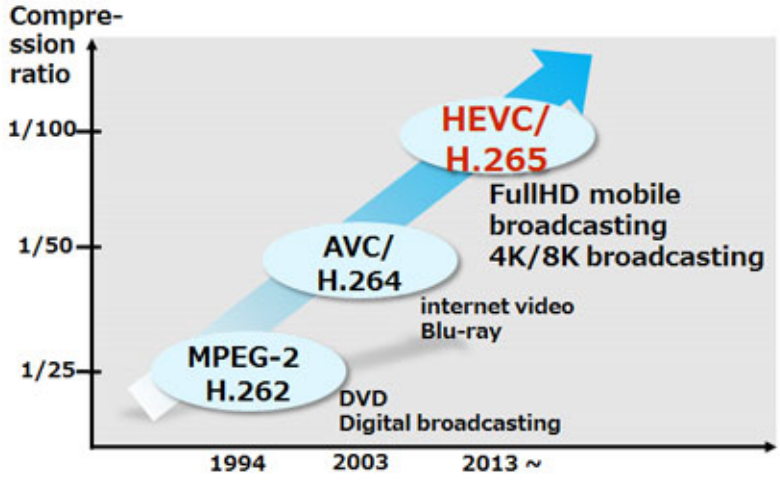
- Many standards available here also.





www.nec.com/en/global/rd/research/cl/hevc/index.html

Video coding development



www.nec.com/en/global/rd/research/cl/hevc/index.html

Wireless system design

- Problem: Move information (data) from point A to B.
- Examples of design questions:
  - What kind of information? (Quality of Service)
  - What type of signal? (source coding)
  - How much, how fast? (Bandwidth)
  - Environment? (Carrier frequency, RF bandwidth, modulation, equalisation)
  - What type of application? (Cost, complexity)
    - » Channel coding, interlieaving,
  - How far? (TX Power, antennas, RX Noise Factor)

Example of a real world complication

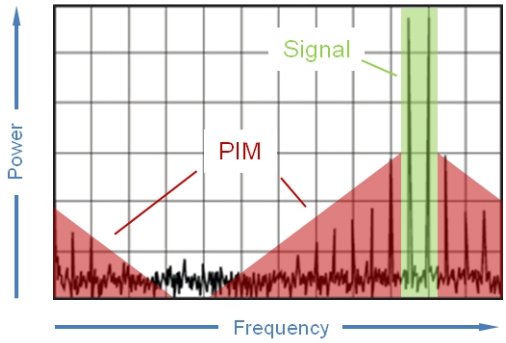
Passive Intermodulation

- $f_{intermod} = \pm j f_1 \cdot \pm k f_2$
- $j, k \in \mathbb{N}$
- Most problematic:

$$2f_1 - f_2$$
$$-f_1 + 2f_2$$

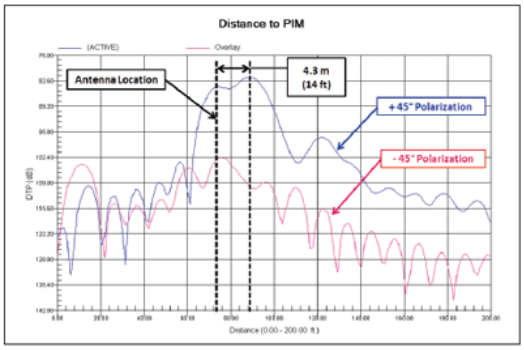
▲ Figure 1. Rooftop antenna installation

Network Disturbance by
Passive Intermodulation (PIM)

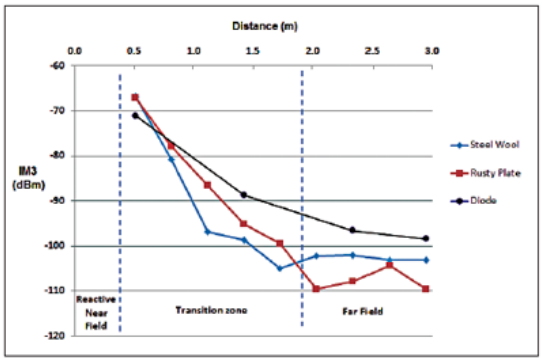


http://www.wavelengthsmagazine.com/issue26/mitigating-passive-intermodulation.html

Passive Intermodulation (PIM)



▲ Figure 6. Overlay of +45° and -45° Distance-to-PIM™ plots



▲ Figure 4. PIM vs. Distance for objects placed in front of an antenna

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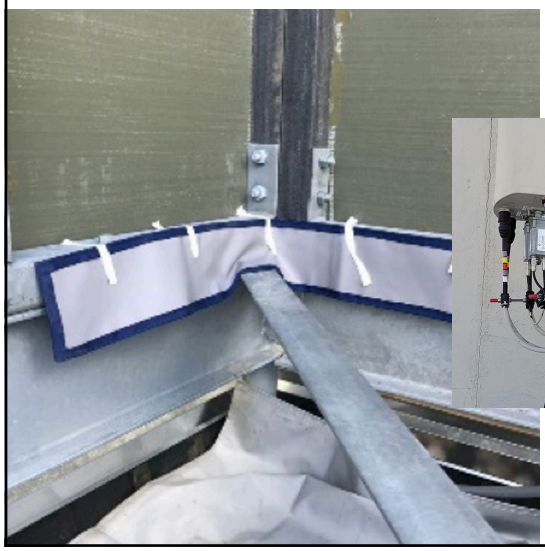
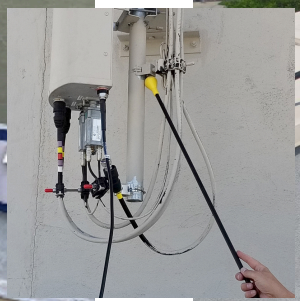
PIM





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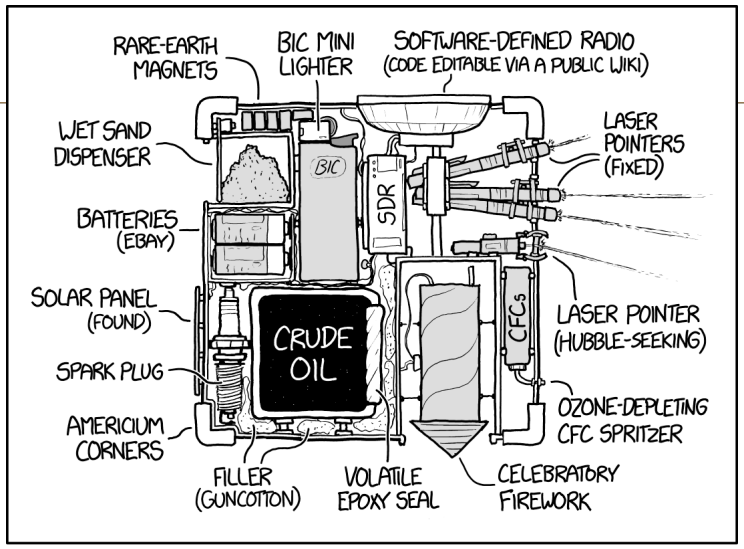

MY CUBESAT PROPOSAL WAS THE FIRST TO BE REJECTED FOR VIOLATING EVERY DESIGN AND SAFETY REQUIREMENT SIMULTANEOUSLY.

www.xkcd.com/1992

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