



What is “Digital Radio”

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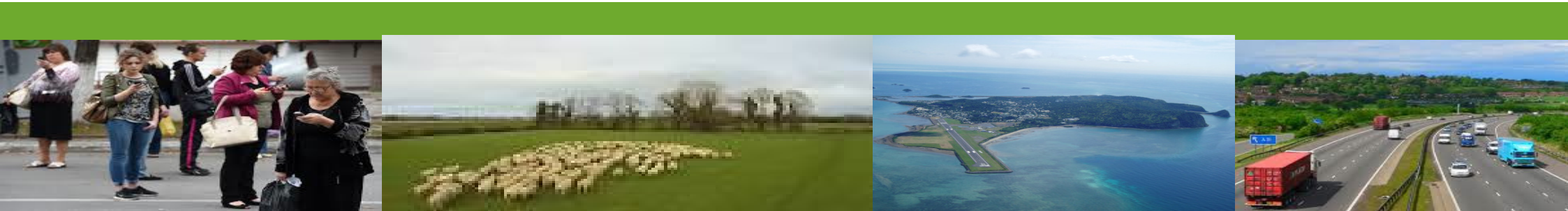


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1. What is communications?



Communications is ...

- **A message**
 - That contains information
- **Sent by**
 - a person or a machine
- **At**
 - a moment in time
- **To be received**
 - other people or machines
- **Usually requiring a response**
 - From the receiver
- **Other considerations**
 - Was it an accurate message
 - Was it sent by an authentic sender
 - Was it received by the intended receiver(s)
 - Was the message was correctly understood by the receiver.
 - Was privacy and secrecy violated.
- **With Radio communications there are no guarantees!**



Ancient forms of communications

- Bird songs
- Fire
- Smoke Signals
- Drums
- Carrier Pigeon (Cesar)
- Pony Express
- Flags and Semaphore
- Post
- Telegraphy and Morse Code 1830s
- Each channel has a **Symbol Alphabet**
 - “Fire” => “INVADERS!!!”
 - Response = Run away very fast!
 - “No Fire” = “Carry on as normal”
- **Packets of Information**
 - Before 2005 ...
 - Pigeons could not carry an entire Encyclopedia.
 - Then came along the MicroSD card!
 - Messages can be split it into parts.
 - Internet and mobile radios all use data packets.
- **Speed and distance**
 - Messages used to take time to be transmitted.
 - Wireless and optical comms are nearly instant.

2. What are Radio Waves?



What are Radio Waves?

- **Electromagnetic waves.**
 - Same family as
 - InfraRed,
 - Visible Light,
 - Ultraviolet Light
 - X-Rays.
- **Radiowaves have energy, speed and wavelength.**
- **Behave similar to light**
 - Reflection, Absorption, Refraction, Diffraction, Mirages.
- **Wavelength is often interpreted as frequency. (Cycles/Second – Hertz)**
- **Radiowaves cover a spectrum**
 - ELF (Submarines)
 - LF (Long Wave)
 - MF (AM, Medium Wave)
 - HF (Short Wave) 3-30MHz
 - VHF (FM and DAB) 30-300MHz
 - UHF (Television and Mobile Phones) 0.3-3GHz
 - SHF (Mobile Phones, Bluetooth, WiFi) 3-30GHz
 - Microwaves (Satellites and RADAR) 0.3-300GHz
 - ELF Milimeter Wave (Radar imaging) 30-300MHz
 - Terahertz (Experimental) >1THz
- **Lime SDR can transmit and receive over a wide range of radio frequencies in HF/VHF/UHF/SHF.**



Why Use Radio Waves For Communications?

- **Why use Radio Waves?**
 - Extremely Versatile.
 - Low cost, short, medium and long distance, real time communications.
 - Transmit sound, pictures, information and ideas.
 - Suitable for broadcasting
 - Suitable for personal communications.
 - land, sea, air and even space.

What is a Radio?

- **A device that can generate or receive radio waves, or even both.**
 - Transmitter. Generates radio waves.
 - Receiver. Receives radio waves.
 - Transceiver. Generates and receives radio waves.
- **The way we use and talk about Radio has changed significantly with time.**
 - Sending messages
 - Broadcasting Entertainment
 - Remote sensing
 - Personal Communications
 - Navigation
 - Cooking
 - Data Communications

- **Words for Radio.**

- Wireless Telegraphy 1895. (Morse)
- Crystal Set 1920s.
- British Broadcasting Corporation 1927.
- Television Set Mid 1930s.
- RADAR 1940s
- Wireless Set, Walkie Talkies 1940s.
- Transistor Radio. Late 1950s.
- Rig, CB Radios 1958
- RFID Tag 1980s
- Microwave (oven) 1980s
- Mobile (Radio) 1990s
- SatNav 1990s
- WiFi 1999 (Packet Based Radio)
- LimeSDR. 2016



Radio Technology

- **Marconi – Early Wireless Telegraphy**
 - Spark gap transmitter and monopole antenna.
 - Coherer detector. A switch that detected radio waves and lightening.
- **Early radios used Valves and point contact diodes.**
- **Gradually transistors and microchips replaced these early devices.**
- **LimeSDR uses advance microchips to provide a complex radio system in a small module.**

3. What is a Digital Radio?



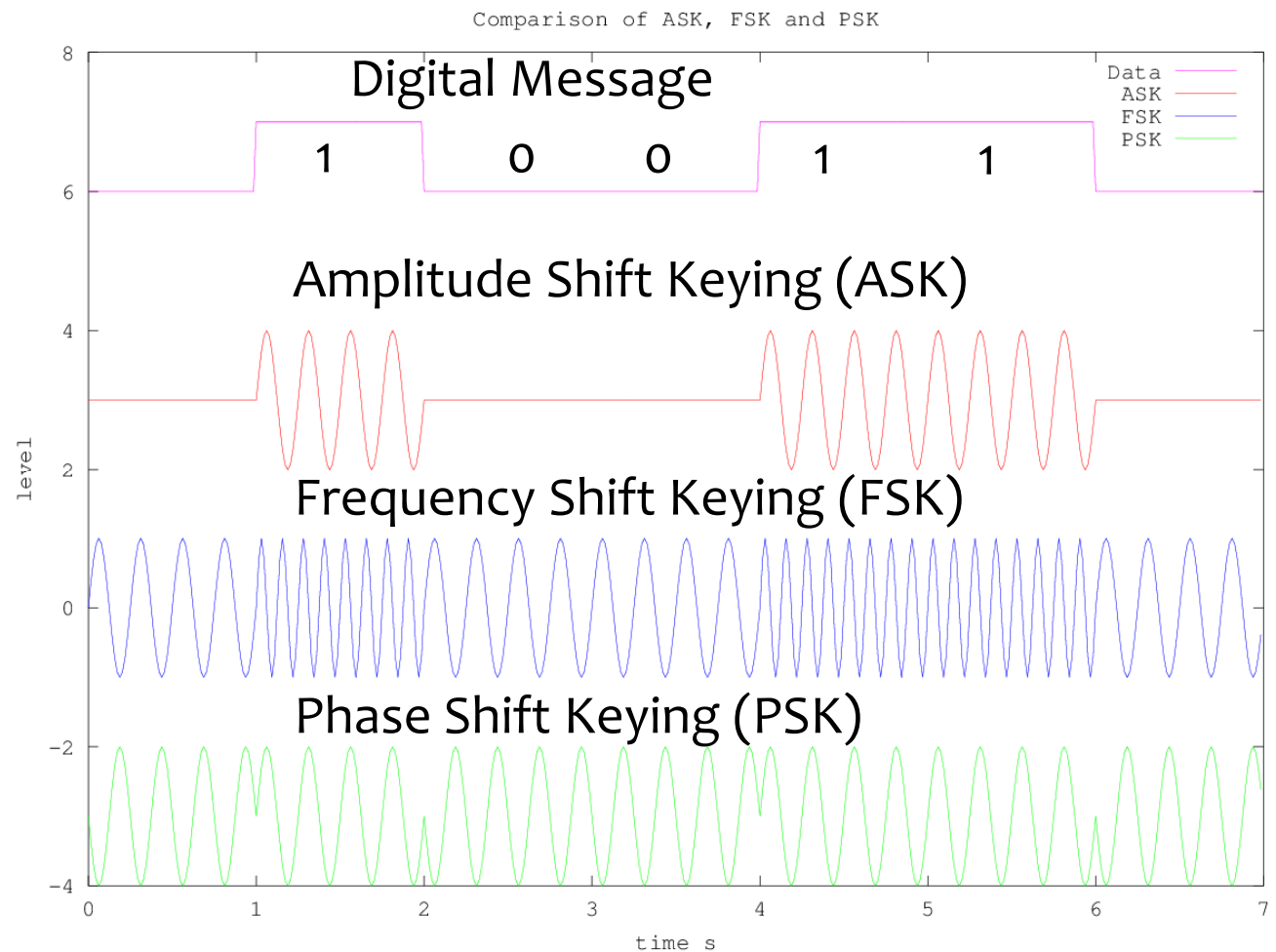
What is digital Radio?

- **Analogue Communication**

- Use directly amplified electrical signals from a sensor.
 - E.g. Microphone.
- Can use AM, FM and PM

- **Digital Communication**

- Describe the information to be sent by a sequence of pulses.
 - E.g Morse Code
 - SOS ... _ _ _ ...
- Can use ASK, FSK, and PSK
- Amplitude shift keying etc.

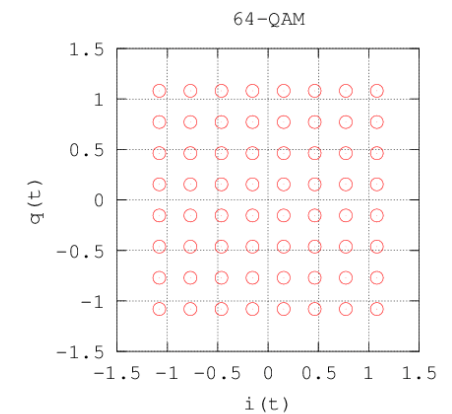
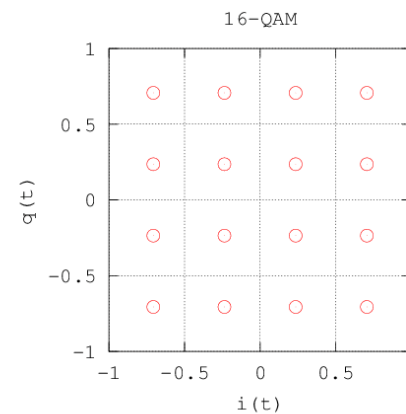
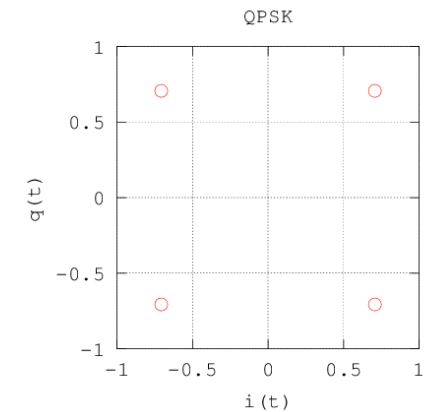
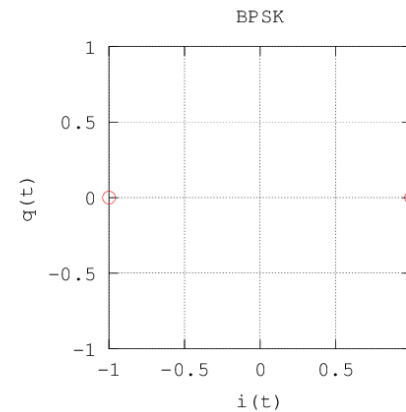


AM vs PM vs FM

- **Incoherent Detection**
 - Uses only amplitude or frequency of a signal
- **Coherent Detection**
 - Uses phase of the signal
- **Amplitude Modulation**
 - Simple incoherent receivers - crystal set.
- **Frequency Modulation**
 - Incoherent frequency discriminator
 - Coherent tracking phase locked loop
- **Phase Modulation**
 - Coherent receiver only.
 - The Local Oscillator must be stable.
- **LimeSDR works with all 3 types of modulation.**
- **Amplitude Modulation**
 - More vulnerable to noise and interference.
- **Frequency Modulation**
 - Tolerant to nonlinear limiting
 - Possible to trade increased bandwidth for better signal to noise ratio.
 - Simplest form of Spread Spectrum communication
- **Phase Modulation**
 - Very robust, tolerant to noise and nonlinear limiting amplifiers.

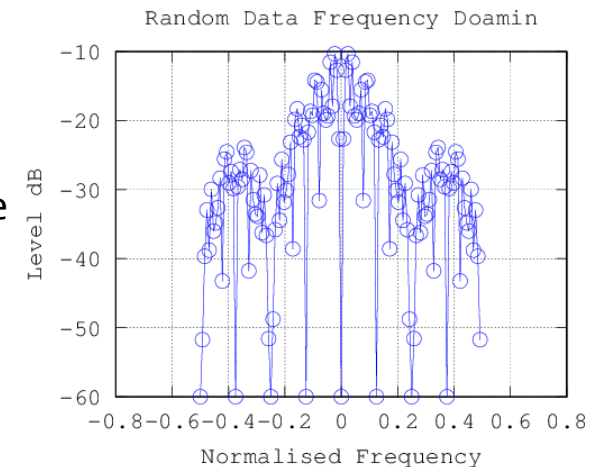
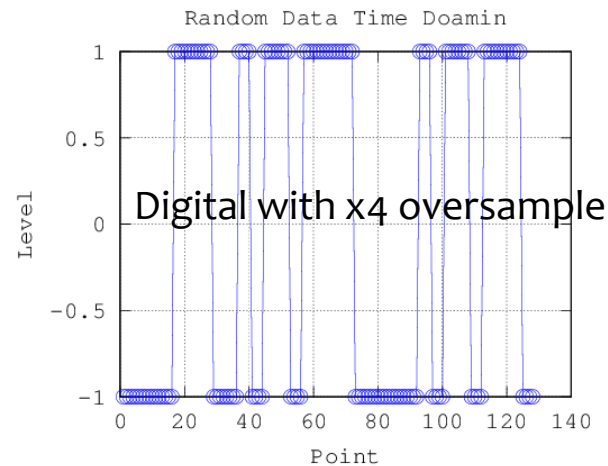
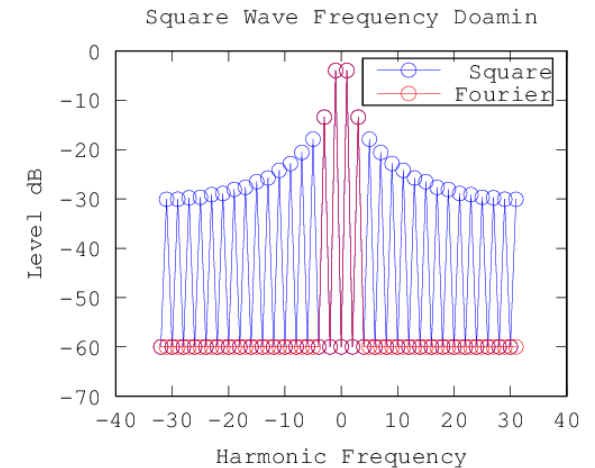
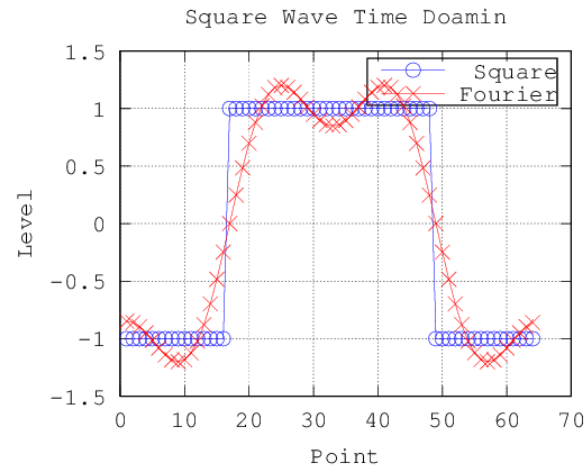
Quaternary Amplitude Modulation (QAM)

- Both amplitude and phase is varied.
- Widely used in modern digital radio.
- Alphabet of more than 2 symbols possible. E.g. 64-QAM
- Increased information content is exchanged for higher signal to noise requirements when using the same bandwidth.
 - Complex signal less robust
 - Shannon Hartley Theorem
- LimeSDR can work with QAM signals.



Digital Modulation and Bandwidth

- **Data changes with time.**
 - Looks like sequence of square waves.
- **Fourier Analysis**
 - Complex signals are made of harmonics.
 - Reducing harmonics lead to more gentle rise and fall behaviour.
- **Harmonics of random data**
 - Adjacent channel interference.
 - Must be filtered. (pulse shaping)



4. What is a Software Defined Radio?



What is software defined radio

- **Conceptual Definition**

- The ability to make a radio that can do something entirely new which it did not do in the factory.
 - E.g. Using a Realtek DVB-T dongle receiver for SAT-NAV.

- **Engineering Definition**

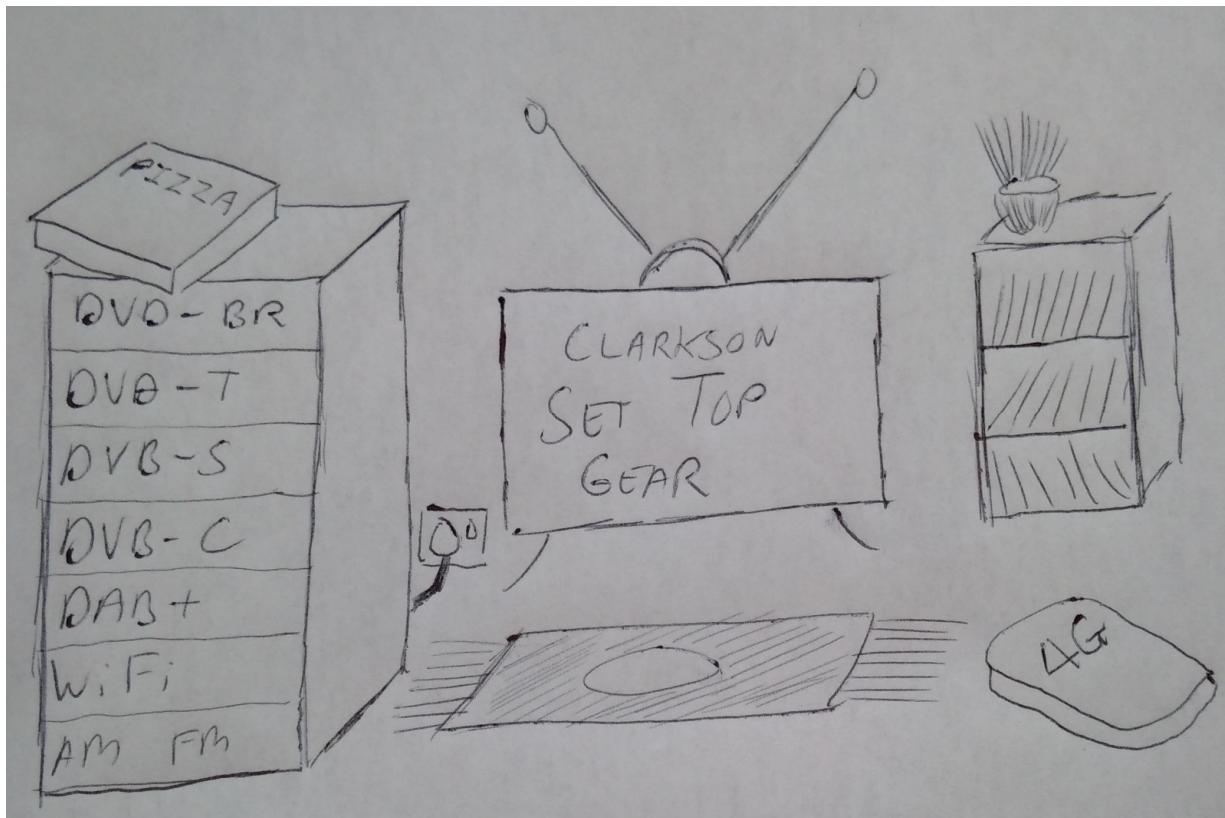
- A Radio whose behaviour can be dynamically redefined by software or firmware changes.
 - E.g. Has reprogrammable Microprocessors and FPGAs instead of hard wired parts.

- **Consumer Definition**

- Can I watch “Master Chef” live.
- Can I watch a youtube video of my cat.
- Can I use it as a “sat nav” down the motorway.



SDR: Why do I need SDR? (Consumer)

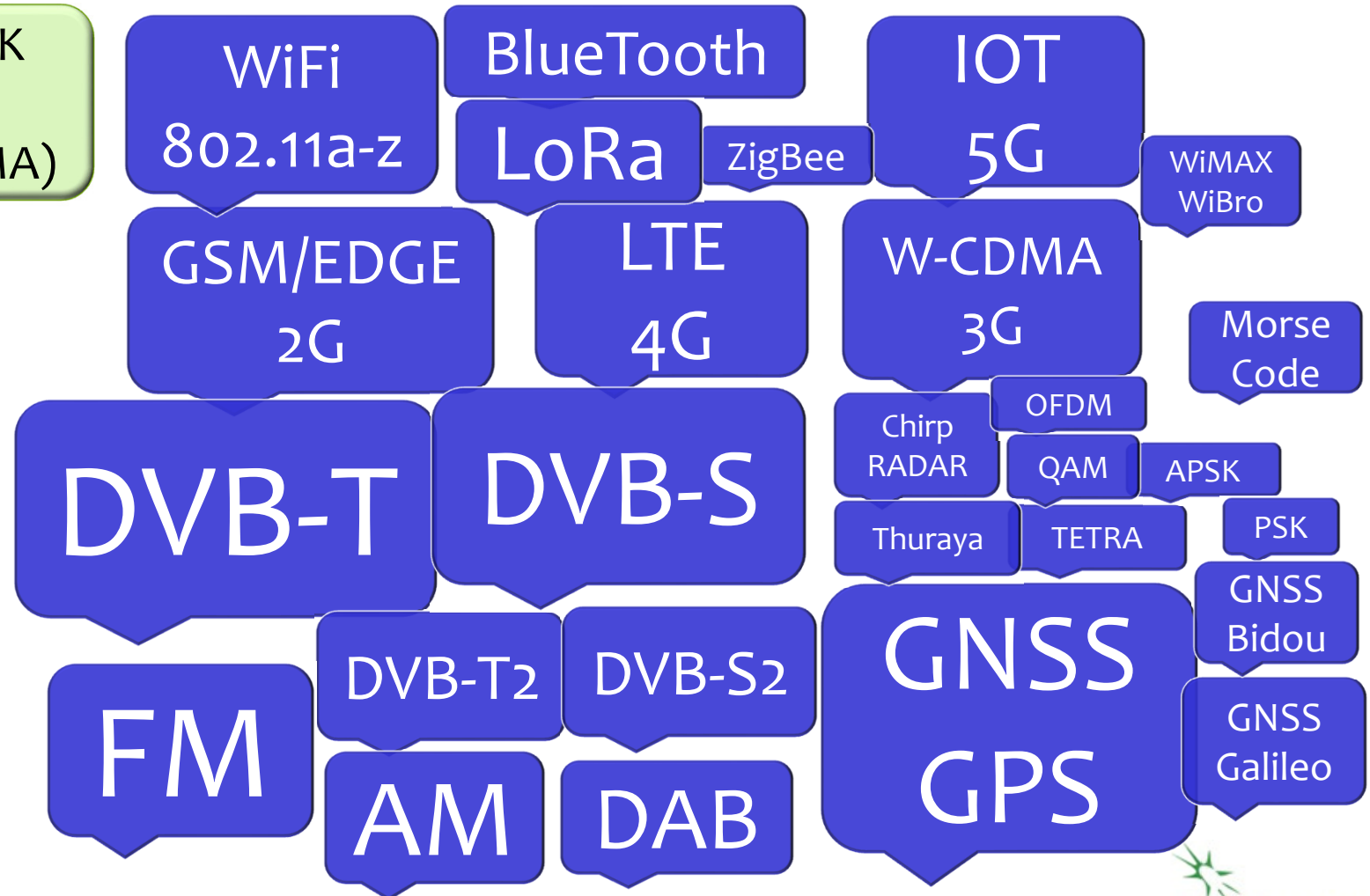


SDR: Why do I need SDR? (Engineers)

<1940s Morse AM FSK
1950s FM appeared
1978 Military GPS (CDMA)

Since 1991, an
explosion of Radio
Standards, many
are GMSK, CDMA
and OFDM based

We need SDR!!!



SDR – Partitioning for Low Cost

RF Parts

Antennas
SAW Filters
RF Switches
Power Amps

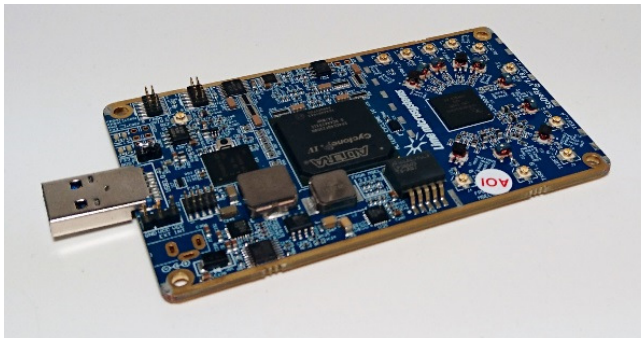
Optimal partitioning
of the radio system
leads to an easy to use
low cost solution.

TRX RFIC

RF and DSP
Field Programmable

FPGA

Data link and
Extra DSP



Open Source
Software/Apps

COMPUTER

Multicore
GHz Processor
And Memory

WiFi/Ethernet/
ADSL Network

PCIe
Link

USB3
Link