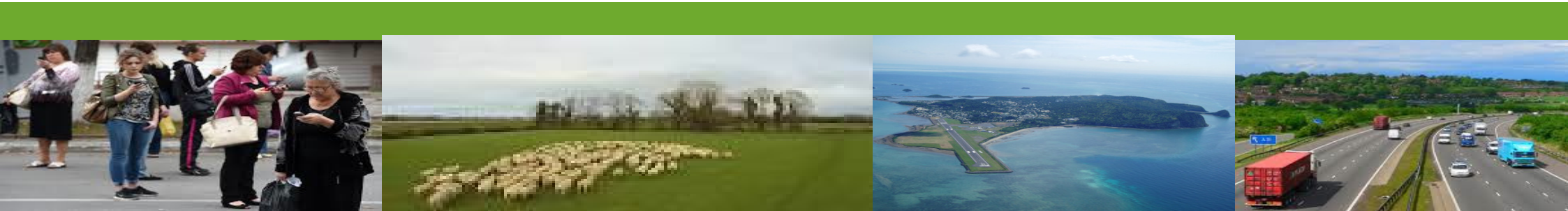




***Lime microsystems***

# What is “Digital Radio”

Danny Webster



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2. What are Radio Waves and Radio?
3. What is a Digital Radio?
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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 (Ceasar)
- Pony Express
- Flags and Semaphore
- Post
- Telegraphy and Morse Code 1830s
- **Symbol Alphabet of the channel**
  - Fire = “INVADERS!”
  - Response = Run away very fast!
  - No Fire = “Carry on as normal”
- **Packets of Information**
  - Before MicroSD Card was invented,
    - pigeons could not carry an entire Encyclopedia.
  - Messages needed to be split it into parts.
    - Internet and mobile radios use packets.
- **Speed and distance**
  - Messages take time to be transmitted.



## 2. What are Radio Waves?



# What are Radio Waves?

- **Electromagnetic waves.**
  - Same family as
    - InfraRed,
    - Visible Light,
    - Ultraviolet Light
    - X-Rays.
- **They have energy, speed and wavelength.**
- **Behave similar to light**
  - Reflection, Absorption, Refraction, Diffraction, Mirage.
- **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.**

# 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.
- CB Radios 1958
- RFID Tag 1980s
- Microwave oven 1980s
- Mobile (Radio) 1990s
- SatNav 1990s
- WiFi 1999 (Packet Based Radio)
- LimeSDR. 2016



# Radio Technology

- **Marconi – 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?



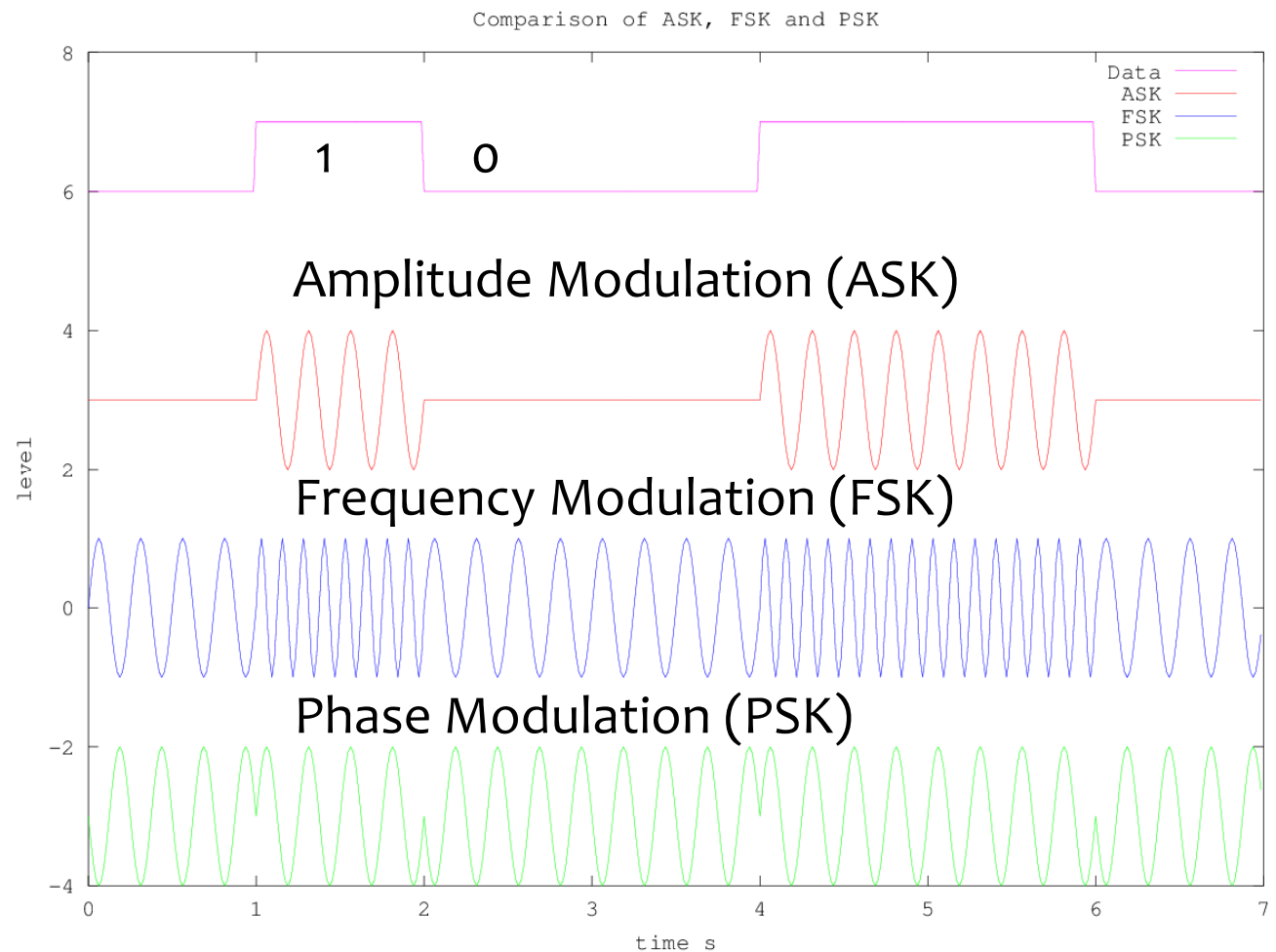
# What is digital Radio?

- **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.

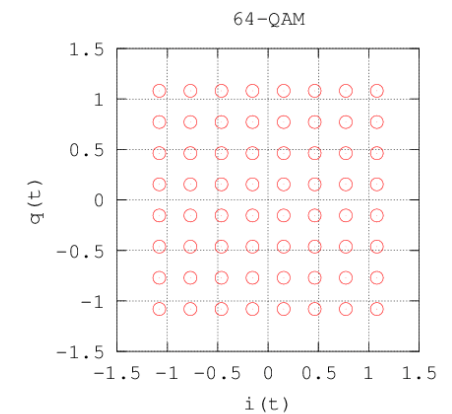
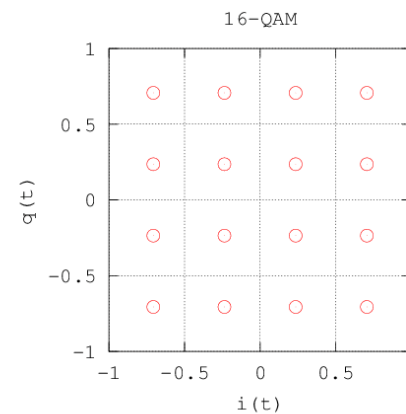
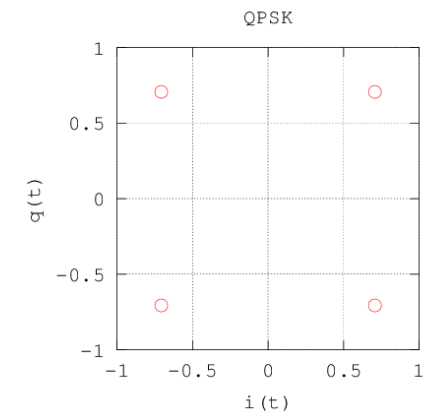
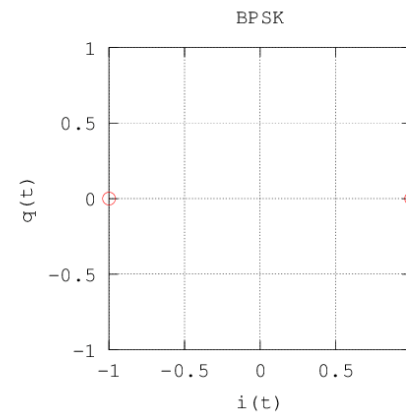


# AM vs PM vs FM

- **Coherent Detection**
    - Uses both phase and magnitude
  - **Amplitude Modulation**
    - Works with very simple incoherent receivers such as crystal set.
  - **Frequency Modulation**
    - Works with both simple incoherent discriminator based receiver, and coherent phase locked loop tracking based detector.
  - **Phase Modulation**
    - Coherent receiver only.
    - The Local Oscillator must be stable.
  - **LimeSDR can work 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.

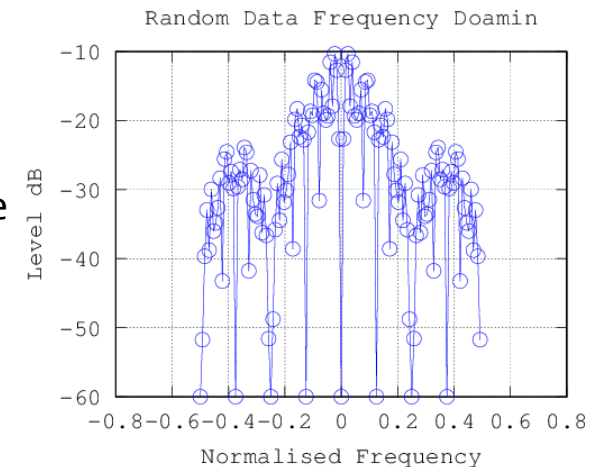
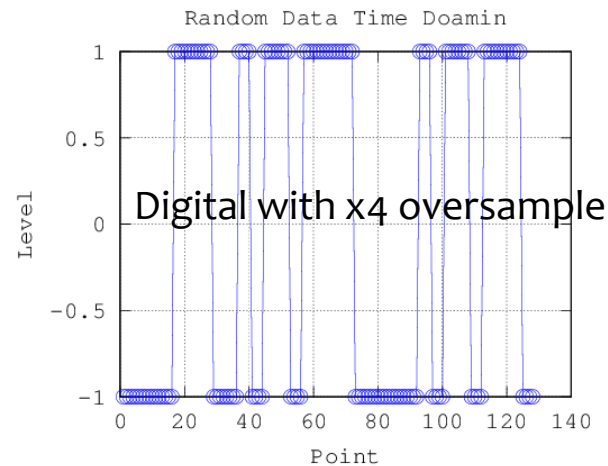
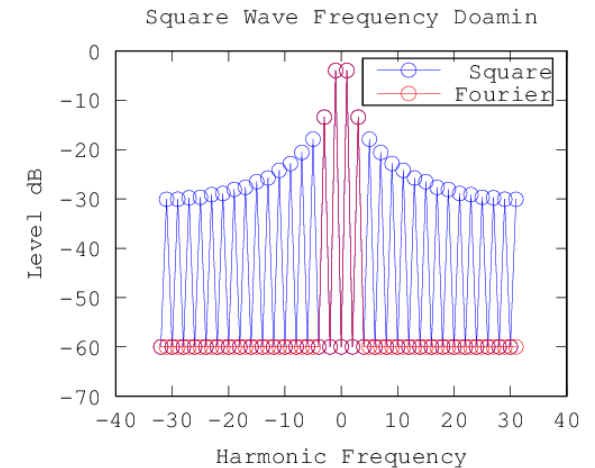
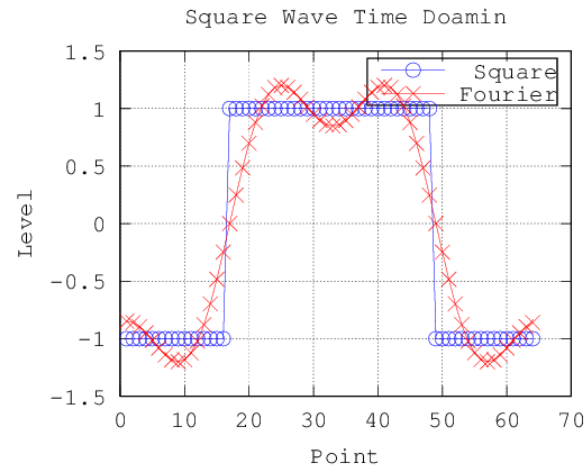
# Quaternary Amplitude Modulation (QAM)

- Widely used in modern digital radio.
- Both amplitude and phase is varied.
- 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**

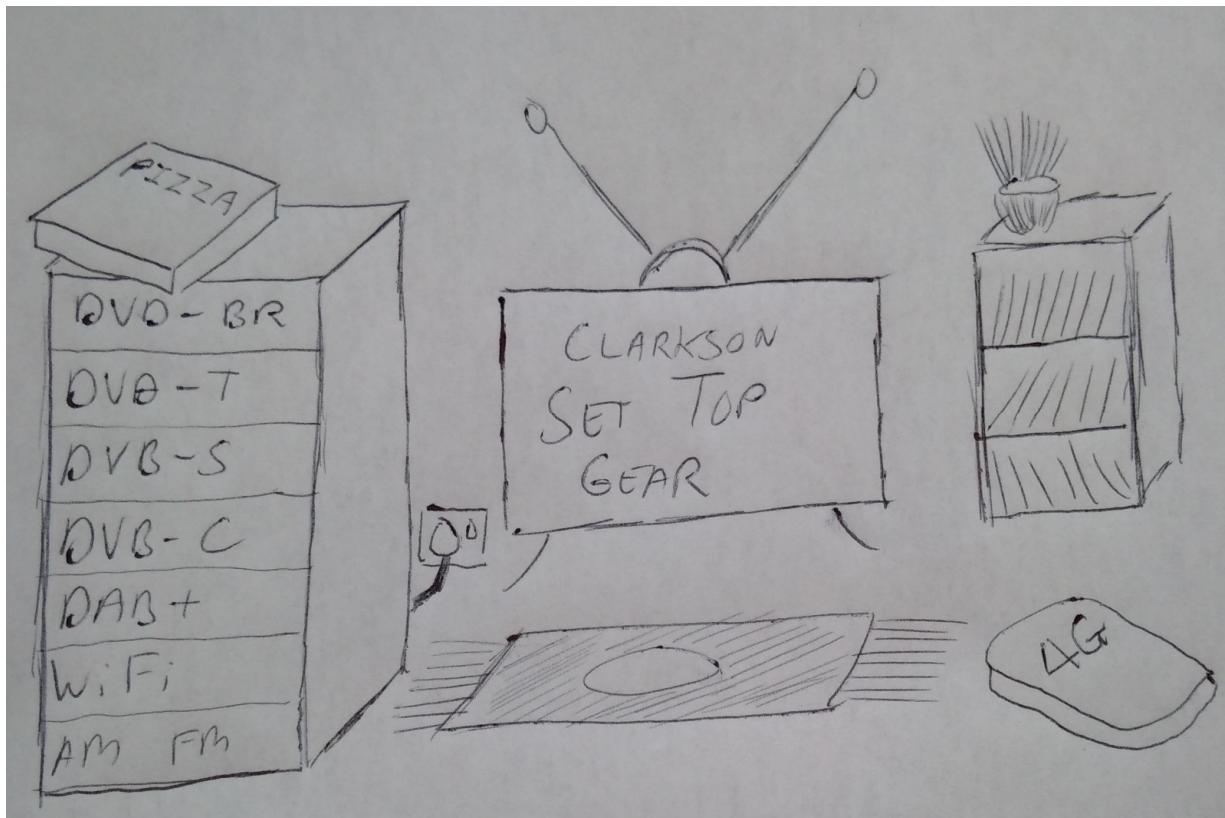
- A Radio whose behaviour can be dynamically redefined by software or firmware changes.
  - E.g. Has Microprocessors and FPGAs instead of hard wired parts.

- **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)

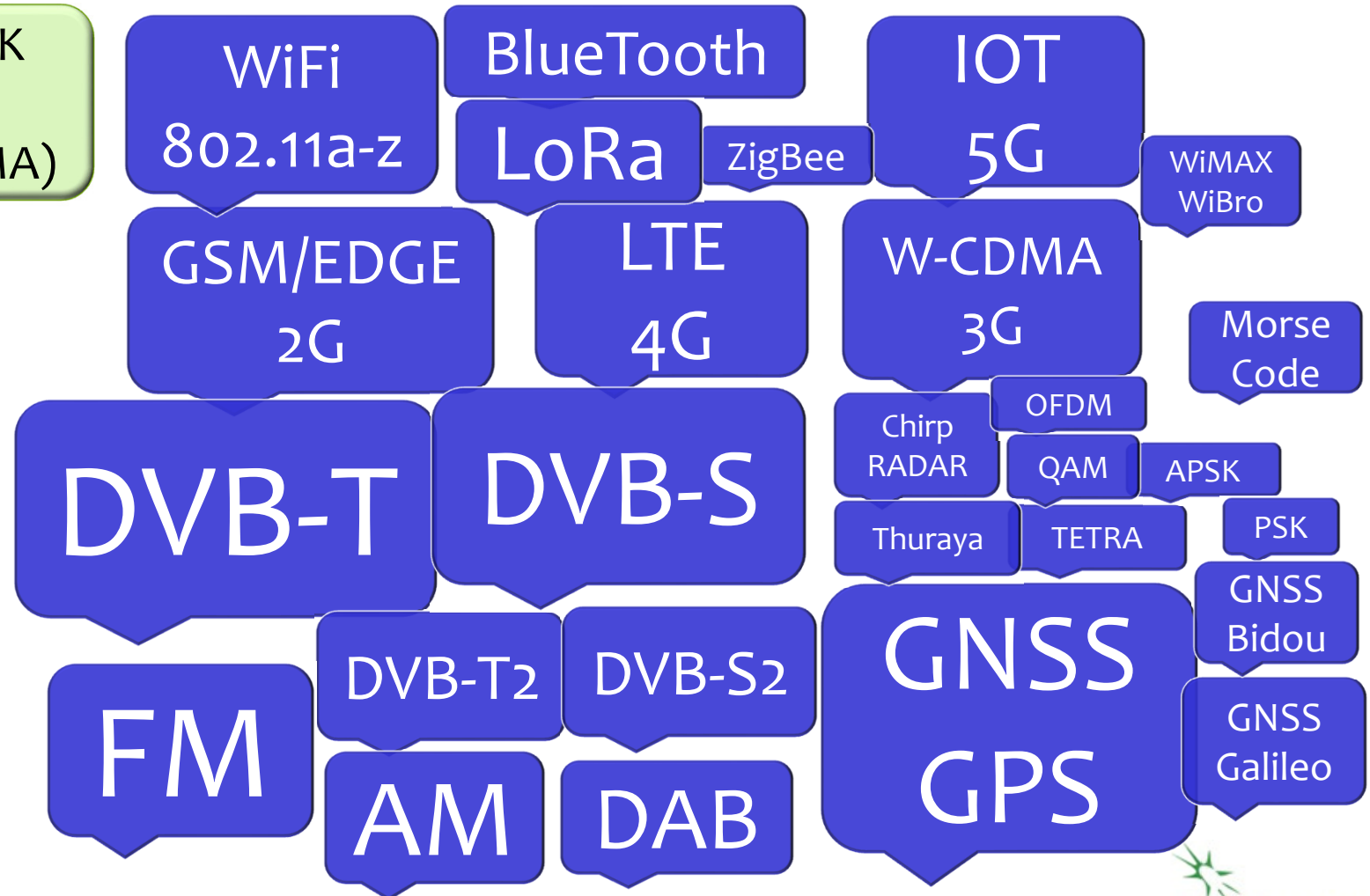


# SDR: Why do I need SDR? (Engineers)

<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

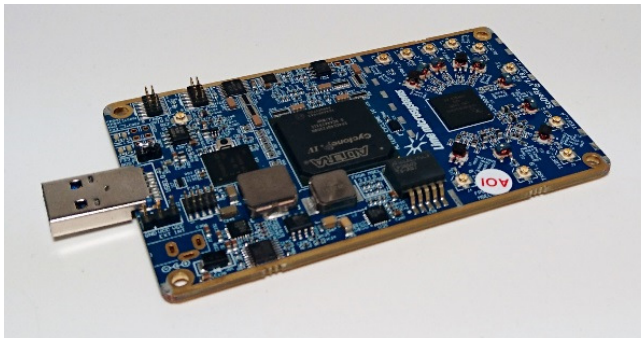
Optimal partitioning  
of the radio system  
leads to an easy to use  
low cost solution.

## 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