



# Software Defined Radios - Architectures, Systems and Functions

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# Overview

- Software Defined Radio (SDR) technology has been proven in the commercial sector since the early 90's.
  - Today's rapid advancement in mobile telephone reliability and power management capabilities exemplifies the effectiveness of the SDR technology for the modern communications market.
- SDR technology offers potential to revolutionize satellite transponder technology by increasing science data through-put capability by at least an order of magnitude.
  - While the SDR is adaptive in nature and is "One-size-fits-all" by design, conventional transponders are built to a specific platform and must be redesigned for every new bus.
- The SDR uses a minimum amount of analog/Radio Frequency components to up/down-convert the RF signal to/from a digital format.
  - Once analog data is digitized, all processing is performed using hardware logic.
  - Typical SDR processes include; filtering, modulation, up/down converting and demodulation.
  - These innovations have reduced the cost of transceivers, a decrease in power requirements and a commensurate reduction in volume.
  - A additional pay-off is the increased flexibility of the SDR:
    - Allowing the same hardware to implement multiple transponder types by altering hardware logic – no change of analog hardware is required - all of which can be ultimately accomplished in orbit.

# Digital Signal Processing-101<sup>[1]</sup>

- Analog products detect signals such as sound, light, temperature or pressure and manipulate them.
  - Converters such as an Analog-to-Digital converter then take the real-world signal and turn it into the digital format of 1's and 0's.
    - This information can then be represented as discrete time, discrete frequency, or other discrete forms so that the information can be digitally processed.<sup>[2]</sup>
  - From here, the DSP takes over by capturing the digitized information and processing it.
  - It then feeds the digitized information back for use in the real world.
    - It does this in one of two ways, either digitally or in an analog format by going through a Digital-to-Analog converter. All of this occurs at very high speeds.

[1] Analog Devices

[2] All About Circuits, Technical Article



- DSP System has up to Four key components:
  - Computational Engine:
    - DSP requires mathematical operations on the incoming data in the form of calculations and manipulations. This can be accomplished by a Microprocessor or a Application Specific Integrated Circuit (ASIC) (e.g. Field Programmable Gate Array (FPGA, DSP Chip, etc.)
    - Processes by accessing the program, or task, from the Program Memory and the information stored in the Data Memory.
  - Data Memory:
    - This stores the incoming/outgoing data to be processed. This may or may not be required.
  - Program Memory:
    - This is where the DSP “steps” reside and is used to process or control data in a specified manner.
  - I/O:
    - There are multiple uses for the IO pins and is device dependent, such external ports, serial devices, timers, and simply to connect to the outside world to manage other aspects of the SDR.

# Real World to Digital World Comparisons

- For a practical example lets take a simple Low Pass Filter (LPF)
  - In the Analog world the LPF is comprised of Inductors, Capacitors and possibly Resistors
    - Each filter is designed within specific operating requirements and as such the component values are fixed. To change the filter, one would be required to physically change one or more components to realize new filter characteristics.
    - This could never be changed remotely (such as a satellite or airborne platform).
  - In the Digital world this is comprised of Flip-Flops, Adders, Subtractors, Multiply-and-Accumulate (MAC) sections of the FPGA or Processor software equivalents.
    - All filters are one size fits all – only the number of the components varies for any realizable filter.
    - This could easily be remotely changed or even changed on the fly as the mission requirements change.
      - For this reason alone, DSP receivers/transmitters are extremely flexible and much more simplistic in nature.

# DSP Applications and Uses

- There are numerous examples of how a digital signal processor can execute different algorithms which is dependent on the application.
  - Communications
  - Audio signal processing,
  - Audio and video compression – MP3, MPEG
  - Speech processing and recognition – iPhone's Siri, Hearing Aides
  - Digital image processing – Video Image Stabilization and Registration (VISAR)<sup>[3]</sup>
  - Radar/Sonar/Lidar applications
  - Biometrics

[3] <https://technology.nasa.gov/patent/TOP8-58>

# Commercial Off-The-Shelf (COTS) Software Defined Radios (SDR)

- By far the largest repository of DSP Products is the free and publicly available GNU-Radio ([www.gnuradio.org](http://www.gnuradio.org))
  - GNU Radio is a ***free & open-source software development toolkit*** that provides signal processing blocks to implement software radios. It can be used with readily-available low-cost external RF hardware to create software-defined radios, or without hardware in a simulation-like environment. It is widely used in hobbyist, academic and commercial environments to support both wireless communications research and real-world radio systems.<sup>[4]</sup>
  - The GNU Radio GUI is very similar in look at feel of the Analog Devices Labview Program.
- GNU Radio is compatible with USB Thumb-drive sized receiver/transmitters costing \$25 to multi-thousand dollar Top-Of-The-Line DSP engines.<sup>[5]</sup>

[4] [https://wiki.gnuradio.org/index.php/Main\\_Page#Which-license-does-GNU-Radio-use](https://wiki.gnuradio.org/index.php/Main_Page#Which-license-does-GNU-Radio-use)

[5] [https://en.wikipedia.org/wiki/List\\_of\\_software-defined\\_radios](https://en.wikipedia.org/wiki/List_of_software-defined_radios)



# So Why Should YOU care?

- With advancement in DSP and more specifically SDRs several orders of magnitude more data can be downlinked at very low cost (Bits/Watt)
  - “I don’t need more data” said no Scientist ever.
  - What used to take 25-50 watts and a large volume (1000 cm<sup>3</sup>) now fits in your pocket – aka Smart Phone.
  - The data rates for these SDRs (Smart Phones) is on the order of 100Mbps for the current 4G LTE mobile broadband and 1Gbps for pedestrians and stationary customers.<sup>[6]</sup>
  - These SDRs are extremely low cost and much smaller in volume compared to analog equivalent counterparts.

[6] <https://en.wikipedia.org/wiki/4G>



# So what does it take to get an SDR on a Balloon?<sup>[7]</sup>

- Spectrum licensing takes the longest amount of time for payload communications, often longer than building and testing the platform itself.
- Until 2011 The Federal Communications Commission (FCC) was content with allowing experimenters to use the Amateur Radio Satellite Service (UHF and above)
- Since 2012 the FCC has required platforms to get an experimental license to get the US in compliance with the rest of the world.
- There is a large number of CubeSat sized (10cm x 10cm x 10cm) communication systems that can easily be incorporated into a Balloon platform and at an extremely competitive cost. More information can be found here.<sup>[8]</sup>

[6] [https://www.klofas.com/papers/Klofas\\_Communications\\_Survey\\_2009-2012.pdf](https://www.klofas.com/papers/Klofas_Communications_Survey_2009-2012.pdf)

[8] <https://www.fcc.gov/document/guidance-obtaining-licenses-small-satellites>

