Ham Radio: The Best 1,000 Hobbies you can Undertake

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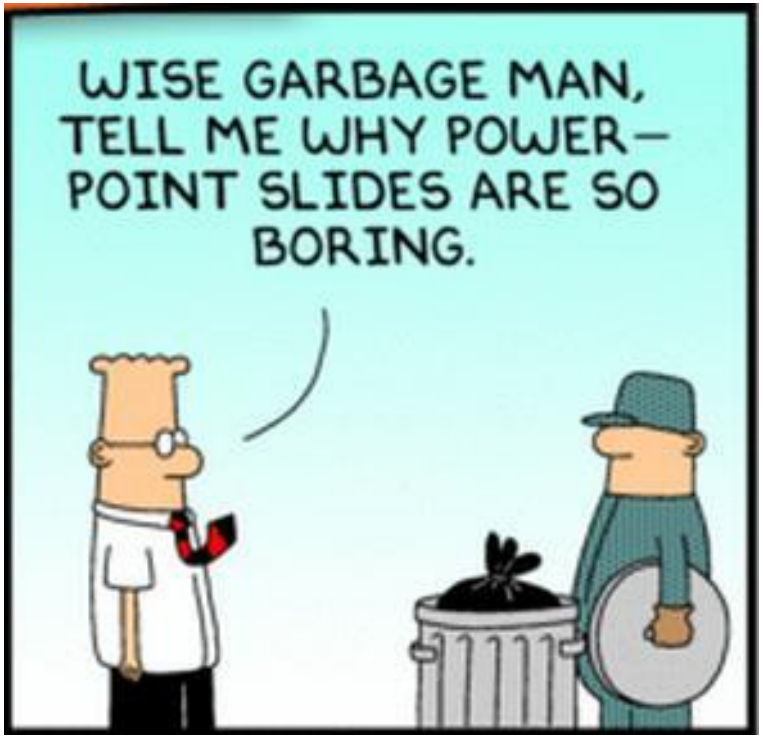
ARRL / TAPR DCC – St. Louis, MO.

Outline

- What is Ham Radio?
  - Can anyone really answer that question?
  - Why do you want to be a ham?
- Life Long Learning (and Technology)
  - What technologies do we use in Ham Radio?
    - Silicon, Firmware, Software, Maker, SDR, Internet, Cloud
  - Where are (some of them) headed?
  - How will it impact you? Our hobby?
- Ham Radio is a big playground.
  - Get your hands dirty

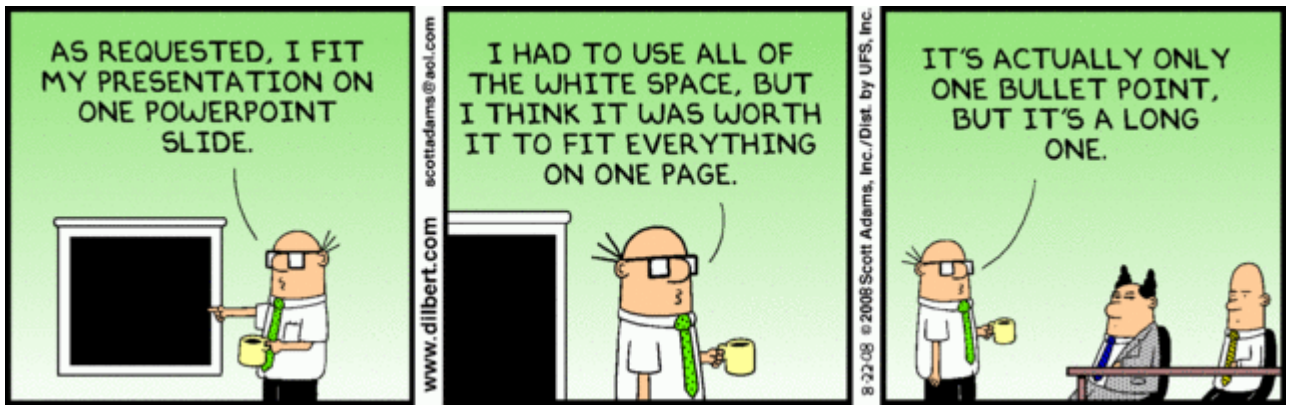

WISE GARBAGE MAN, TELL ME WHY POWER-POINT SLIDES ARE SO BORING.

What is Ham Radio?

- Depends on your perspective.
  - Public Service.
  - Field Day, Contesting, DXing.
  - CW, SSB, Rag Chewing.
  - Antique Radios.
  - The list could go on forever.
- It’s 1,000 hobbies rolled into one.
- For many folks in this room:
  - It’s probably about technology.
    - Equipment, Software, Antennas, Physics, Science.
  - It’s about learning, knowledge, and teaching.
- Let’s look forward a bit.

Key Technologies

- Our future amateur operational & experimental capability is dependent on three key technologies:
  - Silicon
    - The foundation of modern electronics.
  - Computation
    - The ability to process information.
  - Data Networking
    - The ability to move (and store) information.


AS REQUESTED, I FIT MY PRESENTATION ON ONE POWERPOINT SLIDE.
I HAD TO USE ALL OF THE WHITE SPACE, BUT I THINK IT WAS WORTH IT TO FIT EVERYTHING ON ONE PAGE.
IT'S ACTUALLY ONLY ONE BULLET POINT, BUT IT'S A LONG ONE.
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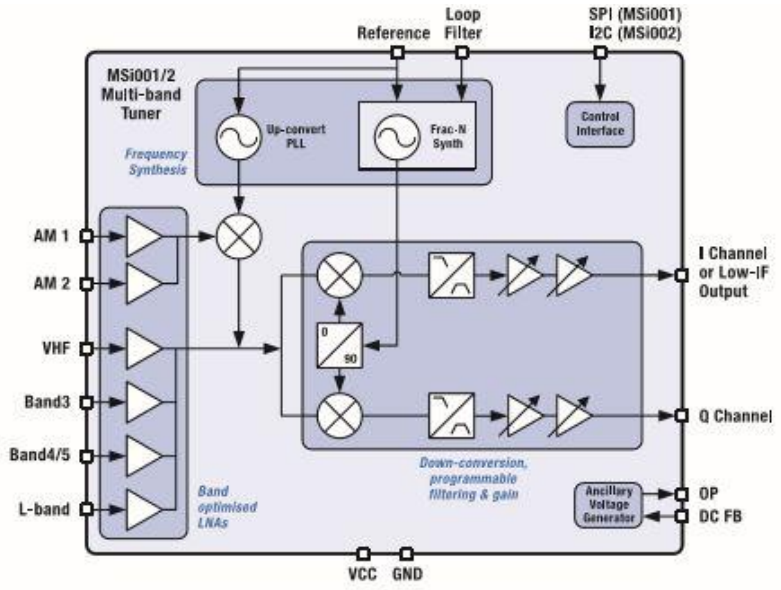
Silicon

- Many recent advances dependent on Silicon.
  - Especially: CPU, GPU, FPGA, RAM, FLASH, Ethernet
- Reduction in Silicon geometry:
  - Reduces Cost per transistor.
  - Reduces Power dissipation per transistor.
    - Power-per-unit-area still increasing
  - Increases Switching speed of a transistor.
  - Permits system-on-chip (SOC) due to *phenomenal* transistor count per die.
- However:
  - Features are smaller than optical wavelength.
    - Photo-lithography: Ultra-Violet, phase-masks, Extreme Ultra-Violet.
    - 7 & 10 nm devices may need 90 masks, ~$15m mask set.
      - High fixed-cost. Concern for low- & medium- production volume devices.
  - It's getting difficult to turn off a transistor.
    - The channel is short, electric field can't pinch off.
      - High-dielectric constant gate insulator, Fin-FET, Gate-All-Around FET
    - Gate oxide approaching 5 atoms thickness.
      - Quantum tunneling of gate charge into the channel.
  - CPU clock rate Power-Dissipation-limited last ~10 years.

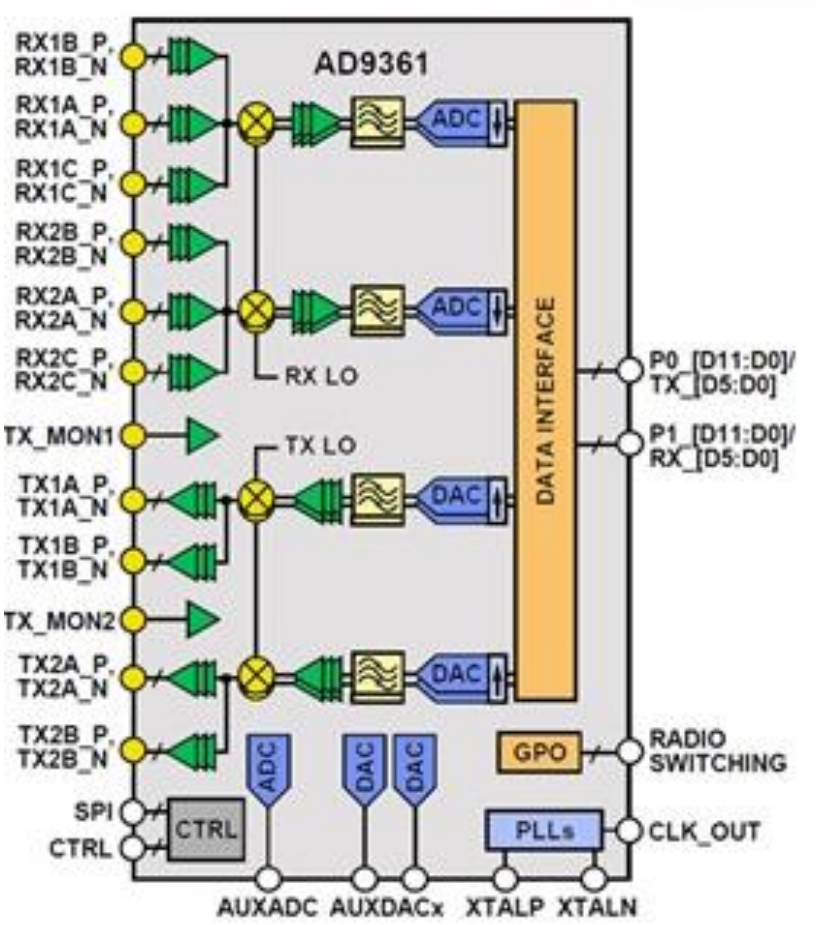
New CMOS Silicon

- Integrated RF/Mixer + LO synthesizer chips becoming available.
  - Analog Devices, Lime Micro, Mirics to name a few.
- Provide range of input frequencies.
  - Mirics: 150 KHz – 2 GHz. [used in SDRPlay]
  - Analog Devices: 100 MHz – 6 GHz [used in Ettus SDR radios]
  - Lime Micro: up to 12 GHz (multi chip solution).
- Some paired with dual ADC + DSP + Host interface chip (USB typical).
- Some provide AGC, typically not for SSB.

Mirics MSi001



Analog Devices AD9361

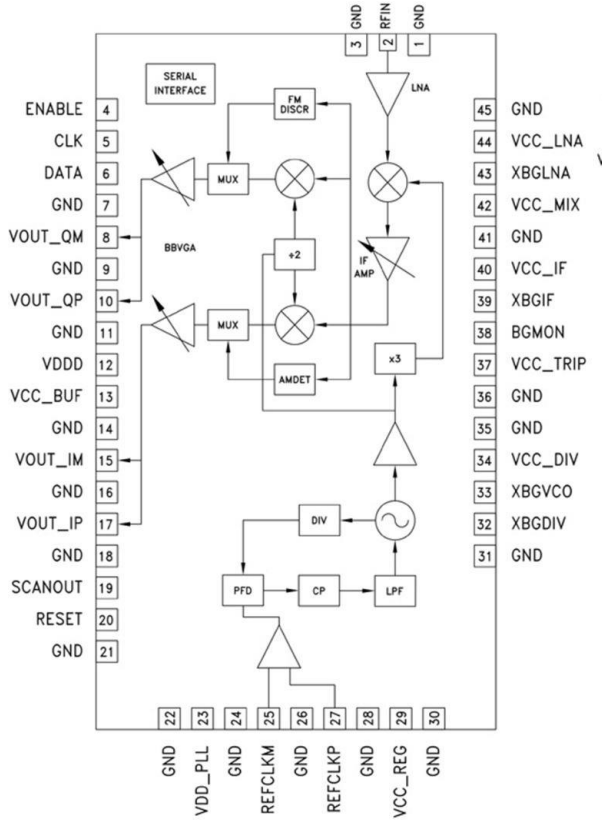


- Single Chip 70 MHz – 6 GHz.
- 2 Rx + 2 Tx (2x2 MIMO)
- 12-bit ADCs and DACs
- Channel BW: 200 KHz to 56 MHz
- Includes LNAs, LO Synthesizer, and RF AGC.

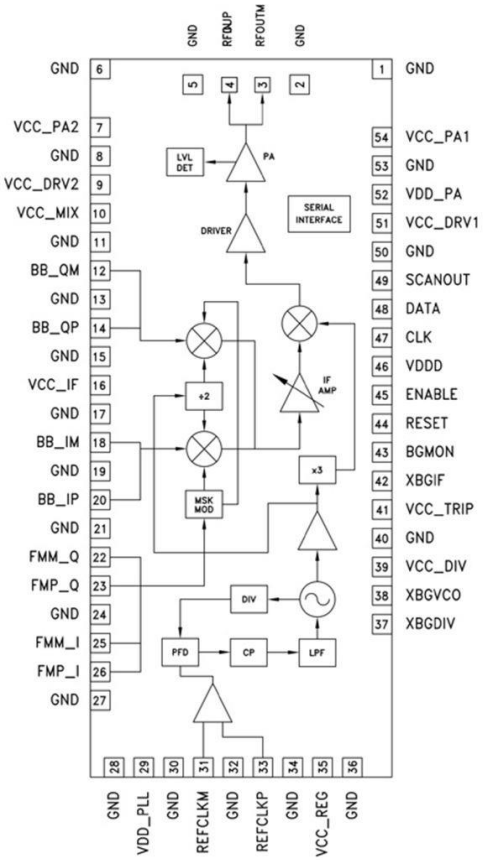
Ettus B210 USRP

60+ GHz SDR Chipsets

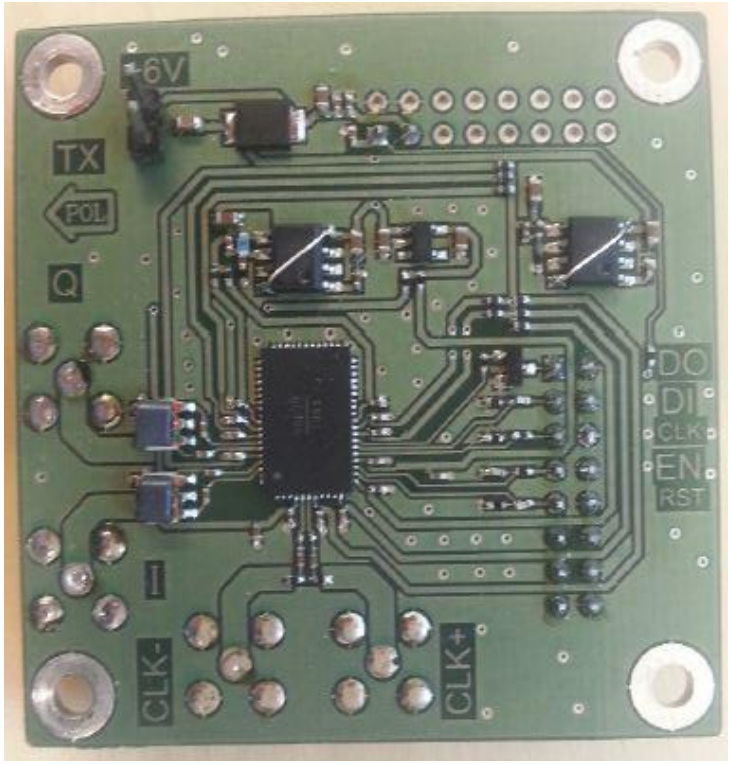
- Growing interest in millimeter wave for 5G. Chipsets for 60-80 GHz available.
- Open source Gnuradio / Hittite drivers: Per Zetterberg.



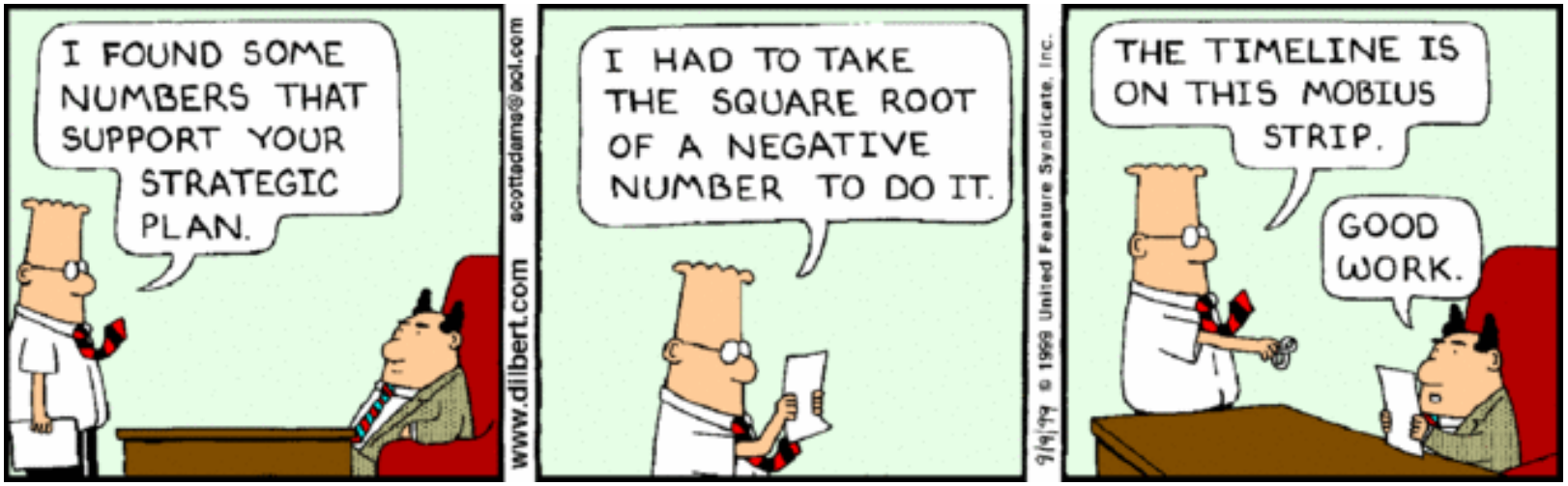
HMC6001 Rx



HMC6000 Tx



60 GHz Transmitter board.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I HAD TO TAKE THE SQUARE ROOT OF A NEGATIVE NUMBER TO DO IT.
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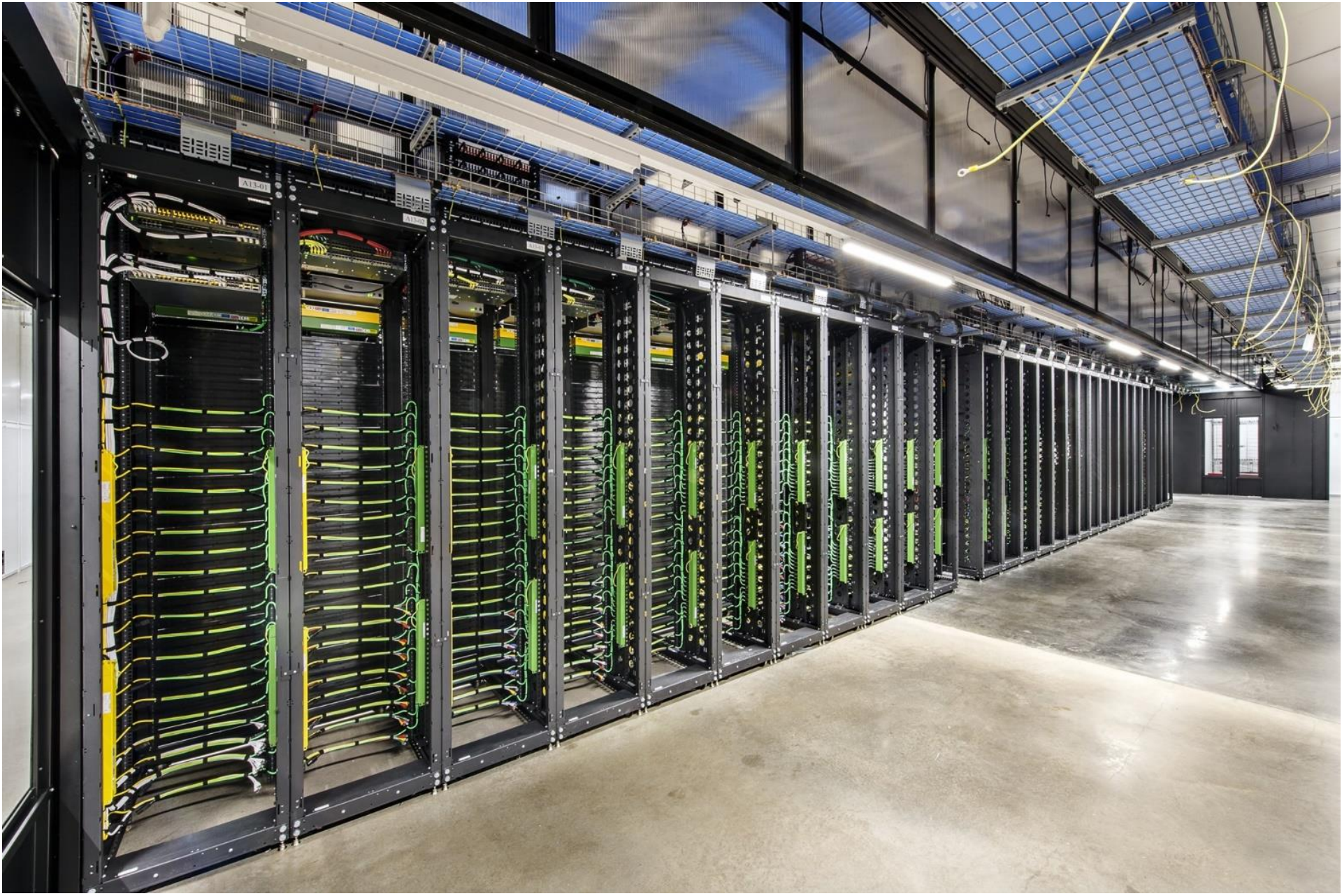
THE TIMELINE IS ON THIS MOBIUS STRIP.
GOOD WORK.

Computer System Enhancements

- As experimenters, we need faster computer *systems*.
  - Can no longer get there via CPU speed.
  - Computer gamers driving Consumer bleeding-edge.
- Alternate approaches:
  - Speed up memory access
    - Larger on-die cache. 15 Mb on some devices.
    - Massive DRAM: servers now up to 1.5 TB
    - PCIe SSD replace mechanical hard drive (AHCI → NVME).
  - Parallel computing
    - 2017: Consumer CPUs increasing to ~10 cores / 20 threads.
    - Xeon / Epyc devices in 20~36 core range.
    - 2-4 Xeon devices per server.
  - GPU computation: 10,000 cores now feasible.
  - FPGA co-processing: Customized to the problem.
- I/O electrical signals soon becoming a bottleneck.
  - Multi-level signaling, active pre- and post- equalization
    - NRZ → PAM4: 25 Gsym/sec = 50 Gb/s per lane.
  - The reach is a couple inches on PC board.
  - 400GE = 25G PAM4 x 8 for 2~3 meter reach on twin-axial cable.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A13-02

What is a Data Center?

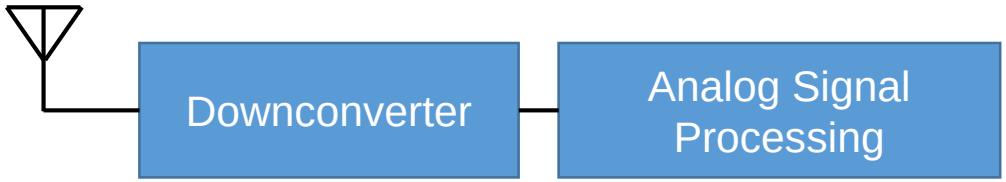
- Cluster of 50,000~80,000 server blades.
  - Standardized HW, SW Virtualization.
- Makes networked parallelism affordable on an on-demand basis.
  - $0.015 ~ $2.00 per CPU hour depending on resources.
- CPU (increasingly also GPU) does almost any function
  - Datacom processing (NFV)
  - Application functions and services
  - Data analysis, search, filter/map/reduce, etc.
  - Signal processing.
- Massively interconnected Ethernet
  - High speed Ethernet switching, low cost copper and fiber.
  - 10 GE now leaking into high-end Consumer products.
- Computer System technology is driven by the data center.
  - Technology leaks into consumer products after several years.


YOU'RE PRETTY NEW TO CLOUD STORAGE, AREN'T YOU?
LYNCH

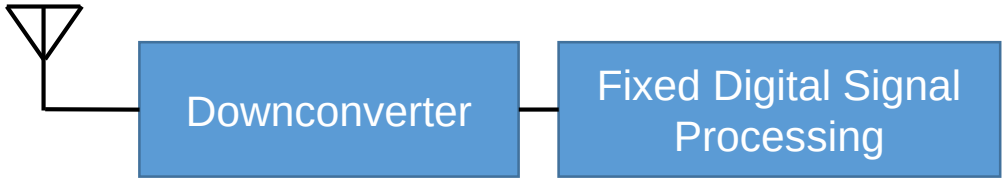
Software Defined Radio

- For many, it's simply a different implementation of the same old radio.
  - Some new features enabled: adaptive pre-distortion, wideband noise mitigation, etc.
- What could SDR otherwise do?
- Form the basis of growing low-cost test equipment implementations.
  - Spectrum Analyzer, Network Analyzer.
  - Change FPGA image → Oscilloscope, Bode Analyzer.
  - RFI Test Set and signature analysis. Networked coherent localization.
- Capture wide spectral bands, transient capture.
  - Save to disk, or make available on the internet.
    - Post-contest sponsor verification.
    - Web-based SDR reception.
- Emergent silicon → Low-cost all-mode VHF, UHF, Microwave radios.
  - High performance point-to-point data links.
  - Radar-like applications with increasing resolution, excellent sensitivity.
- Citizen Science
  - Eclipse analysis, ionospheric sounding, sensor fusion.

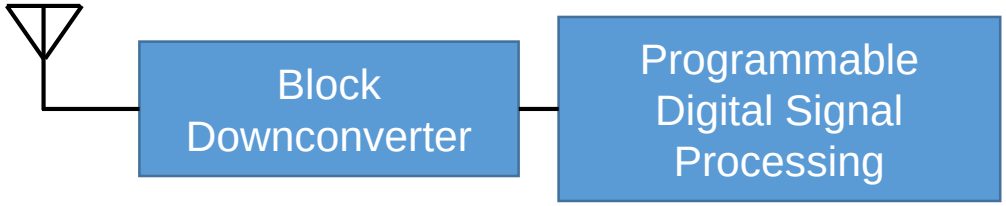
Evolution of Mobile Radio



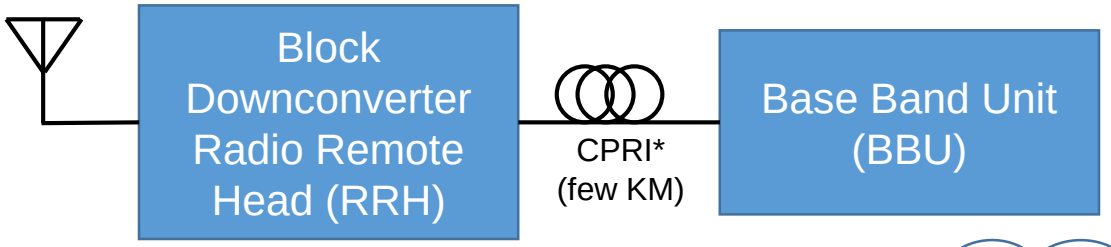
Analog Radio



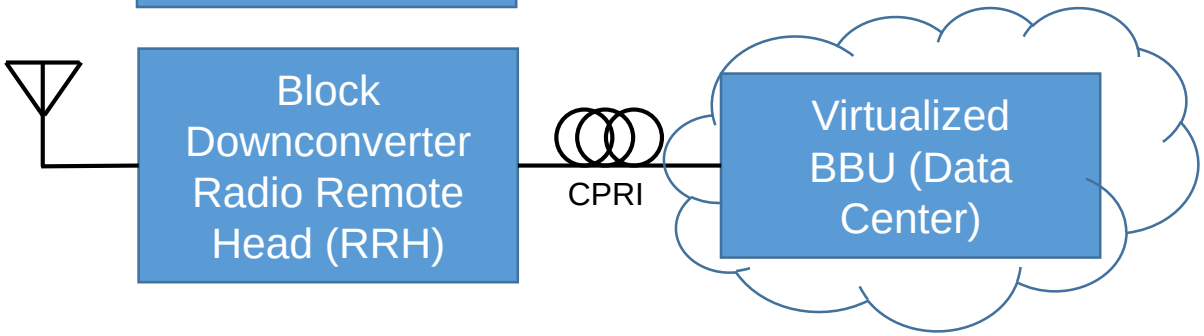
Digital Radio



Software Defined Radio (Multichannel)



CRAN – Centralized Radio Access Network (Dedicated HW/FW/SW Processing Unit)



Cloud RAN – Cloud Radio Access Network (General Purpose Virtualized Processing)

* Common Public Radio Interface

Lessons from Mobile Evolution

- FPGAs made programmable DSP (and thus SDR) initially possible.
- Separation of the processing from the radio head makes the RF small, lower power, remotable.
- Virtualization of baseband processing uses general purpose CPU and GPU in a data center.
  - Eliminating dedicated hardware.
  - Supporting massive number of radio channels and antennas.
  - Providing flexibility, easy to change.
  - Chaining functions, coupling to the internet.

Ham Radio example of the Evolution

- FPGA makes the second generation of SDR much more performant.
- Local general purpose CPU (and GPU) can process baseband information.
  - New capability: advanced signal processing
  - New capability: wideband spectral recording and analysis.
- Condensation and chaining of information onto the web (e.g. WSPR spots).
  - New capability: propagation analysis.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Connections (James Burke, BBC)

- 1978 (UK) 1979 (USA) TV Series.
- Self-motivated ($) individuals invent (seemingly) unrelated technologies.
- These form a web of interconnected technologies that lead to new inventions that no one anticipates.

Conjecture:

Consumer Computing and Networking advances +

Open-source HW, FW, and SW make discovery and sharing vastly easier.

= Much more rapid solutions that can’t be easily anticipated.

"If you don't read the newspaper, you're uninformed.

If you read the newspaper, you're mis-informed"

-- Mark Twain

- Your personal experience, experiments, projects, and measurements are more valuable to true understanding.
- Build, Experiment, Publish.

- Invent Ham Radio hobby # 1001


THAT CONCLUDES MY TWO-HOUR PRESENTATION. ANY QUESTIONS?
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DID YOU INTEND THE PRESENTATION TO BE INCOMPREHENSIBLE, OR DO YOU HAVE SOME SORT OF RARE "POWERPOINT" DISABILITY?
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ARE THERE ANY QUESTIONS ABOUT THE CONTENT?
THERE WAS CONTENT?