Modular Software Defined Radios

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Why

- Designed radio systems at:
  - SpaceX
  - Space Systems Loral
  - Planet Labs
- Frustrated with COTS solutions for comms
  - Or lack thereof

The Problem with Comms

- We want fast data links
- It's possible to go fast
- Custom one-off radio makes it expensive to go fast currently
- COTS radios haven't kept up with the smallsat revolution
  - FCC/ITU licensing hurdle

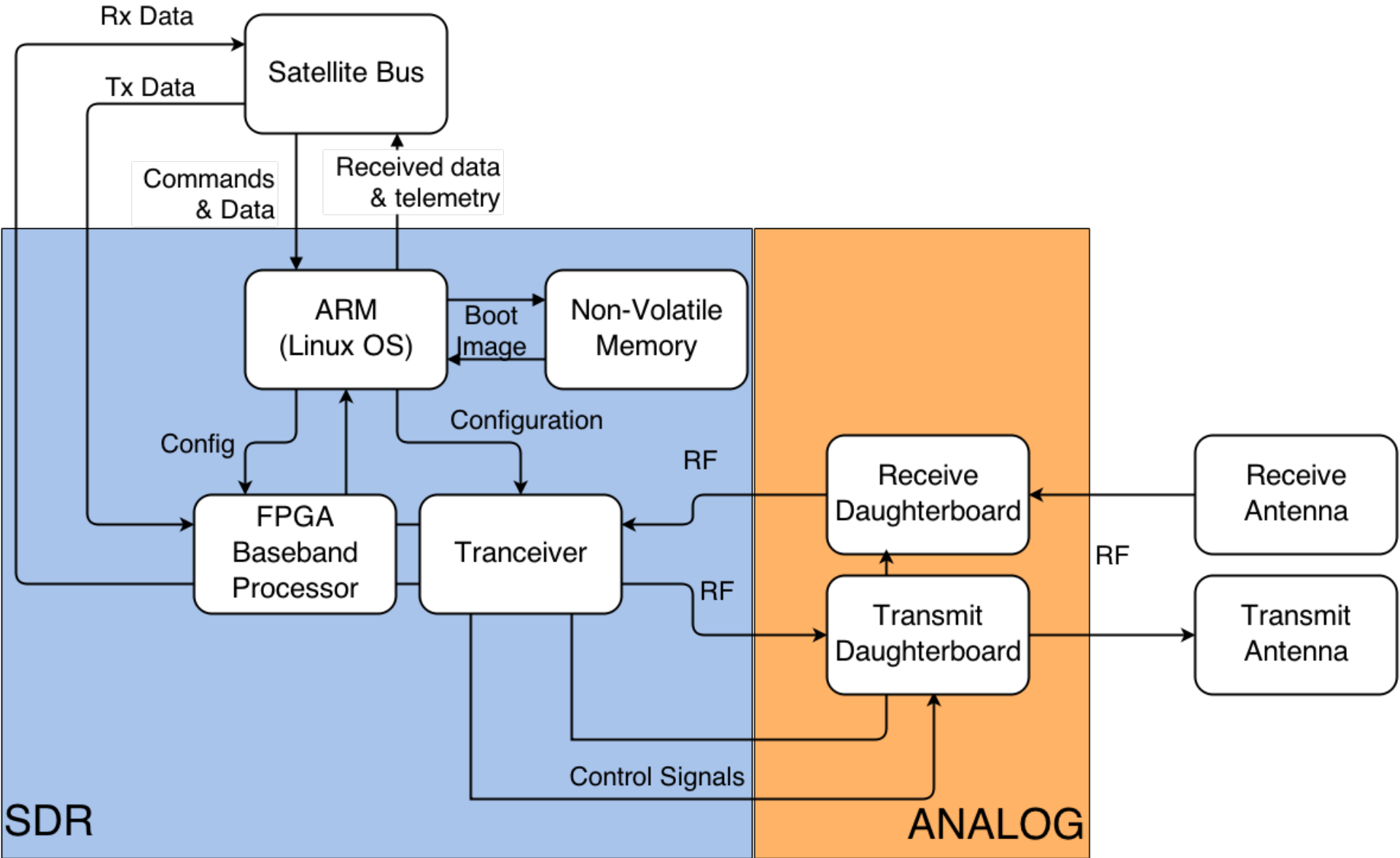
SDR VS Analog Synthesis

- Classical radio: RF is fully synthesized in analog components
- Software Defined Radio: RF is simulated in software.
- We have developed a hybrid approach which allows us to operate between VHF and Ku band with a single family of radios yet allows both high performance, and rapid design and reconfiguration.

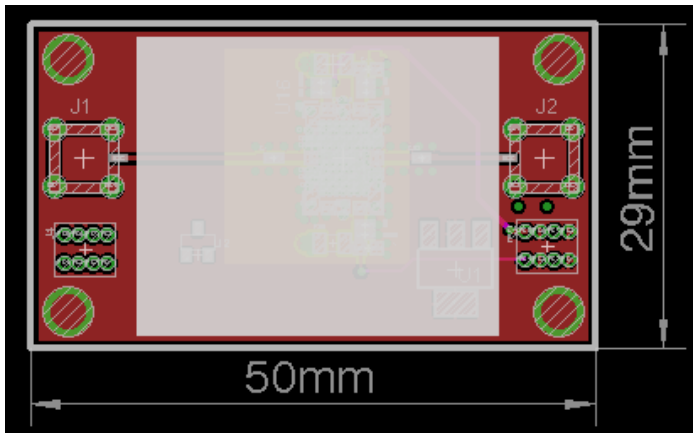
The Hybrid SDR Solution to Comms

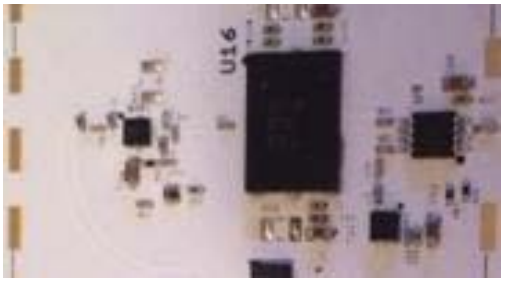
- Our hybrid hardware and software design for modular radio systems combines both the flexibility of software definition and the performance gains of specialized hardware.
- This enables flexible modulation and data rates at frequencies up to Ku band with only one family of radios.
- Low cost radios for most satellite groups

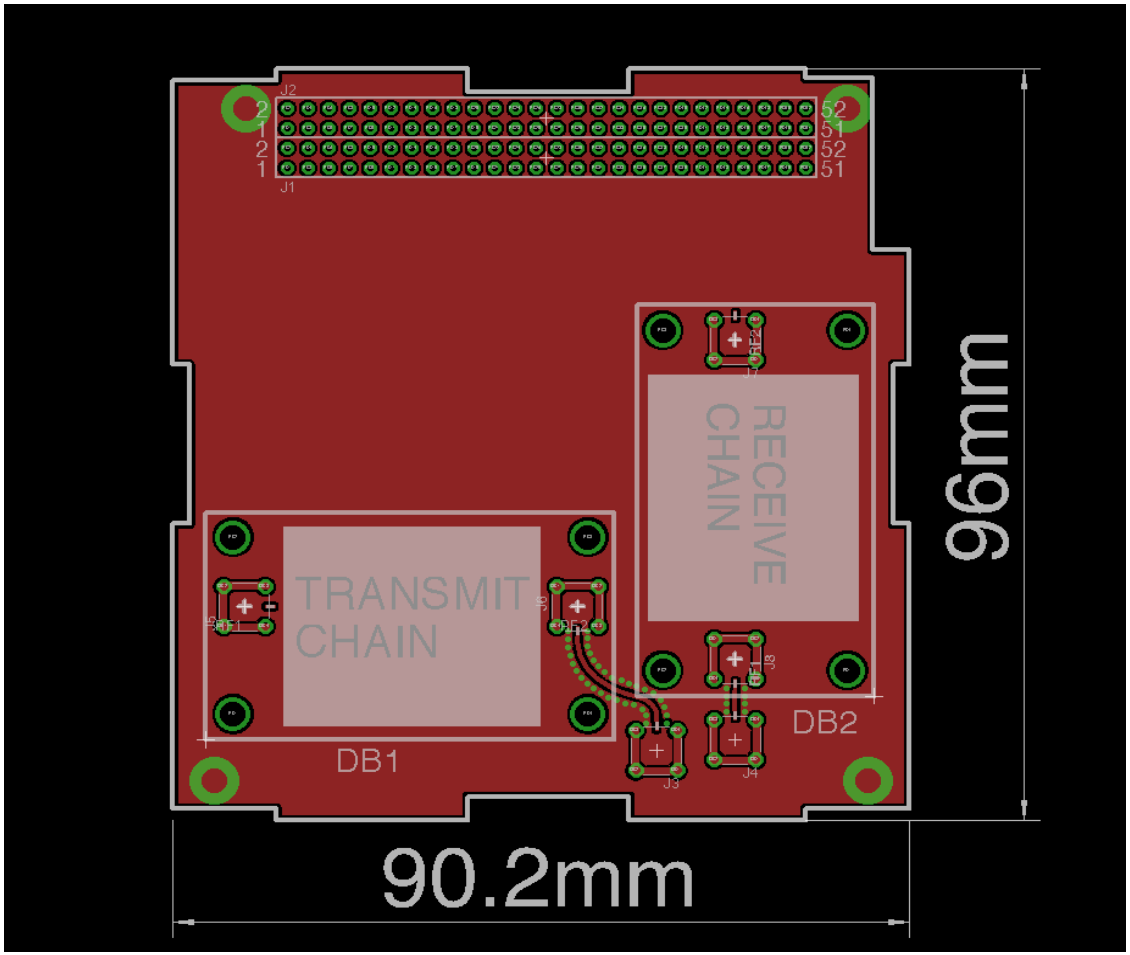
Block Diagram



Motherboard and Daughterboards







Basic Specs

- Full duplex radio
- Data Rates from 100 kbps (rate ½ reed solomon MSK) to over 200 Mbps (8-PSK)
- RF Frequencies between 71 MHz and 5900 MHz with motherboard
  - RF Frequencies between 5900 MHz and 12 GHz with upconverter daughterboard
- Output RF powers between 1-4 Watts

Case Study: FCC Allocation

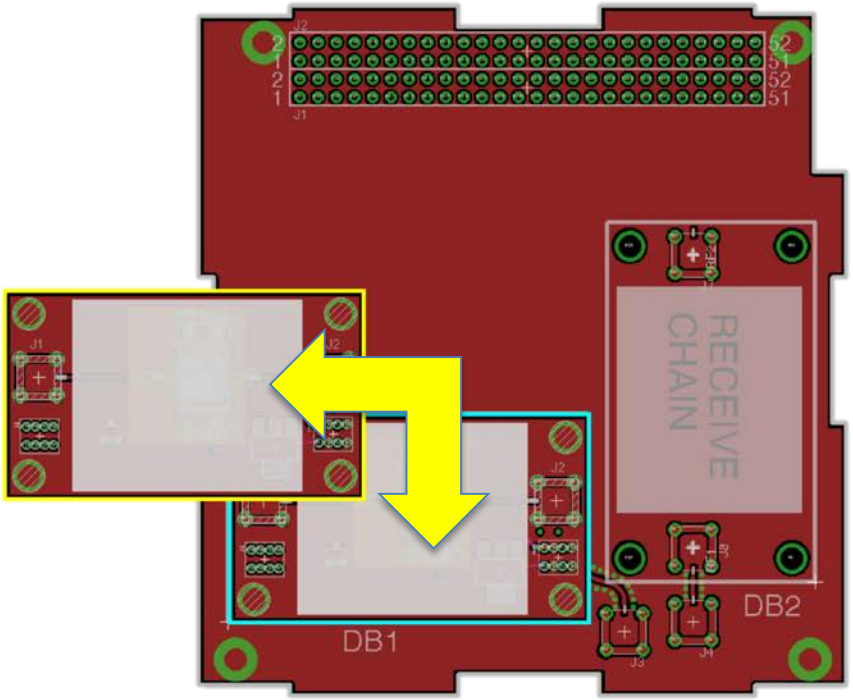
- The FCC/ITU allocate spectrum based on application
  - There are many tens of MHz of bandwidth scattered throughout S-band to Ka band for many applications
  - How do you design a spacecraft bus before you know exactly where the FCC will place you?
- Use SDR based transceiver
  - Develop your power system, software interface, mechanical structure
  - As a final steps, choose the upconverter, LNA and PA daughterboards once you know your spectral allocation

Case Study: FCC Allocation II

- Let's say you already have a business model based around communications but wish to move into earth observation
  - Your initial frequency allocation might be in Ku band for downlink, but you'll be moved into x-band for the new use
  - You already have an operations plan, mechanical design, and software suite using the Ku radio
    - Change costs money and time
  - Use the same SDR motherboard and change your RF frequency

Case Study: FCC Allocation II

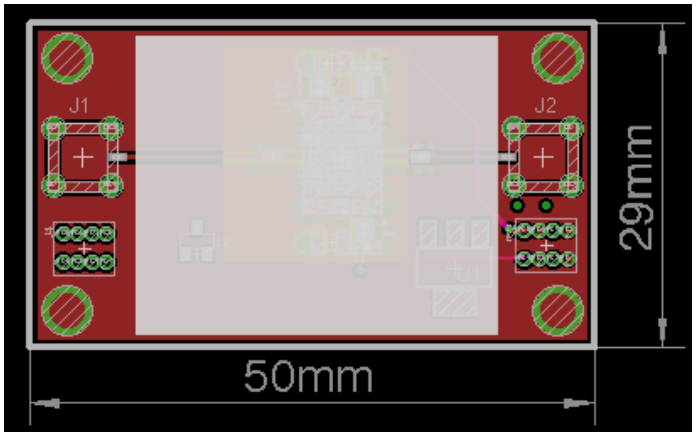
- Step 1: take out Ku band upconverter daughterboard
- Step 2: install X-band daughterboard
- Step 3: swap X/Ku antennas
- Step 4: Change the local oscillator frequency via UART command

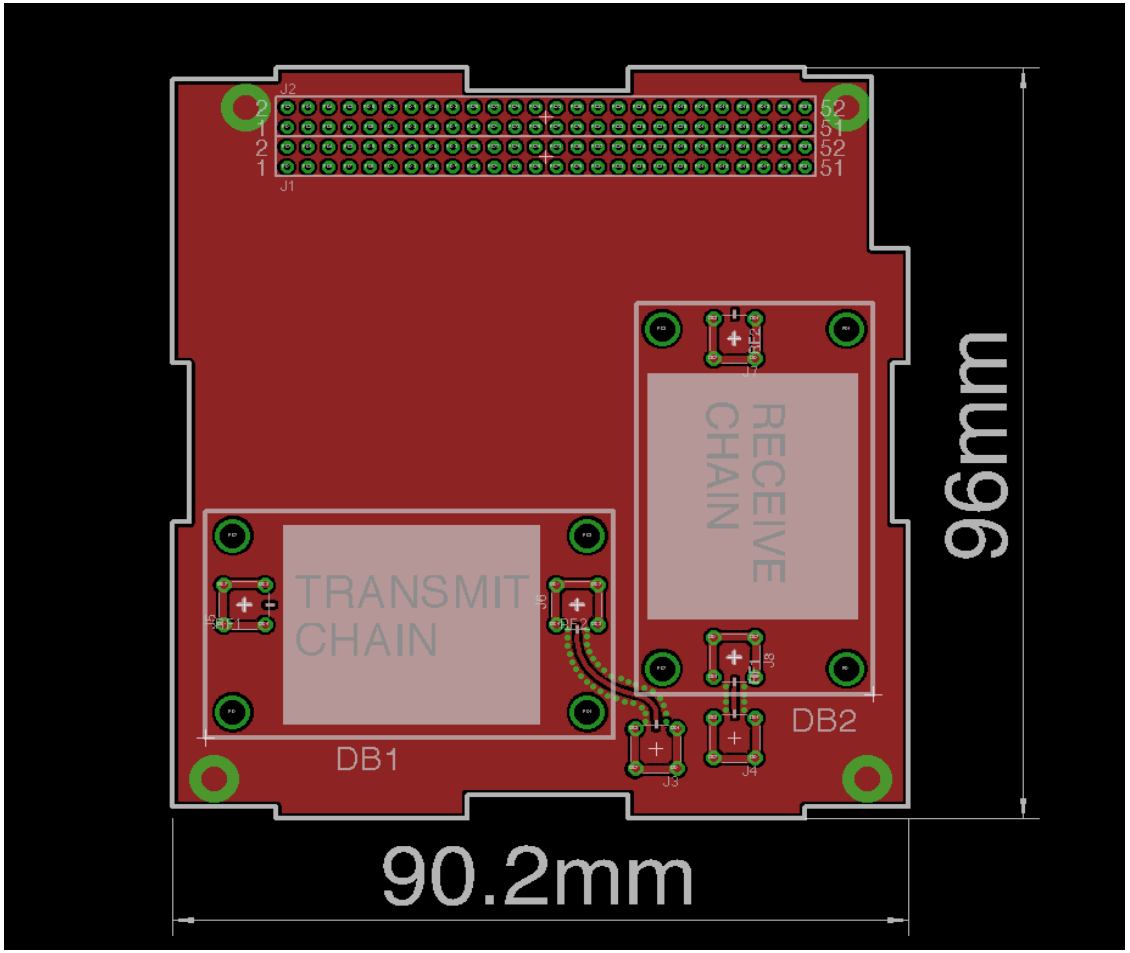


Case Study: Broadband

- Change FEC from DVB-S2 to DVB-S3
- Add mesh networking on next mission
- Switch between low speed beacon to high speed downlink
- Switch between low speed broadcast to large swaths to high speed duplex to a small cell
  - SDR + phased array

Mechanical


J1
J2
29mm
50mm


J2
J1
RECEIVE CHAIN
TRANSMIT CHAIN
DB1
DB2
96mm
90.2mm

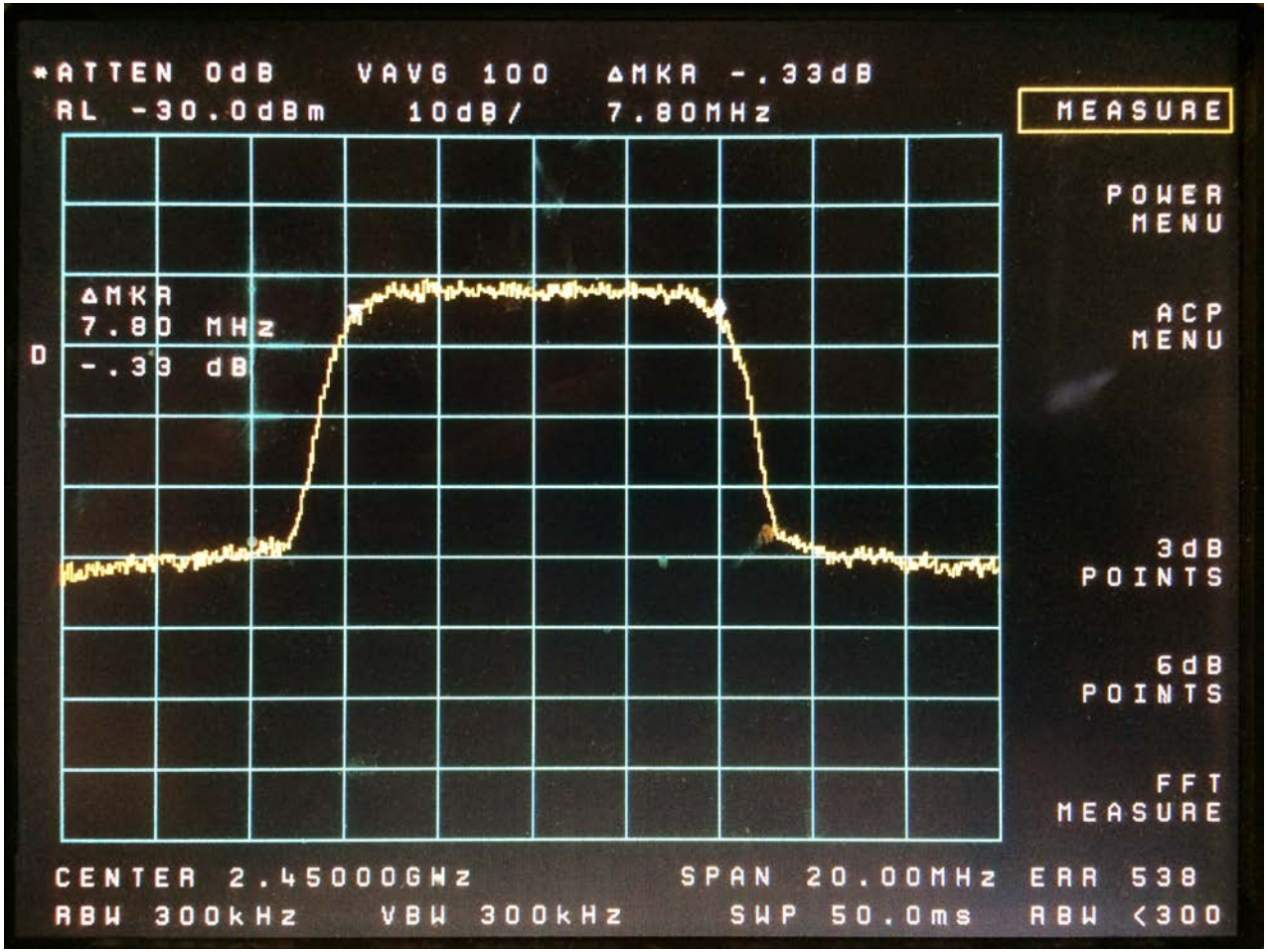
Mechanical

- Volume
  - Daughterboard to motherboard spacing is 9.05 mm
  - The SDR assembly is 90.2 mm X 96 mm X 13.8 mm including shielding, connectors, and daugherboard - motherboard spacing
  - The height of the overall assembly is increased by 4.6 mm over a custom single board assembly, which would consume only 9.25 mm
- Mass
  - The total mass of the SDR assembly is 97 grams
  - Each daughterboard contributes approximately 9.5 grams to the total weight of a radio assemlby
  - Assuming a launch cost of $4654/kg the extra weight of the daughterboards costs $88.43 during launch

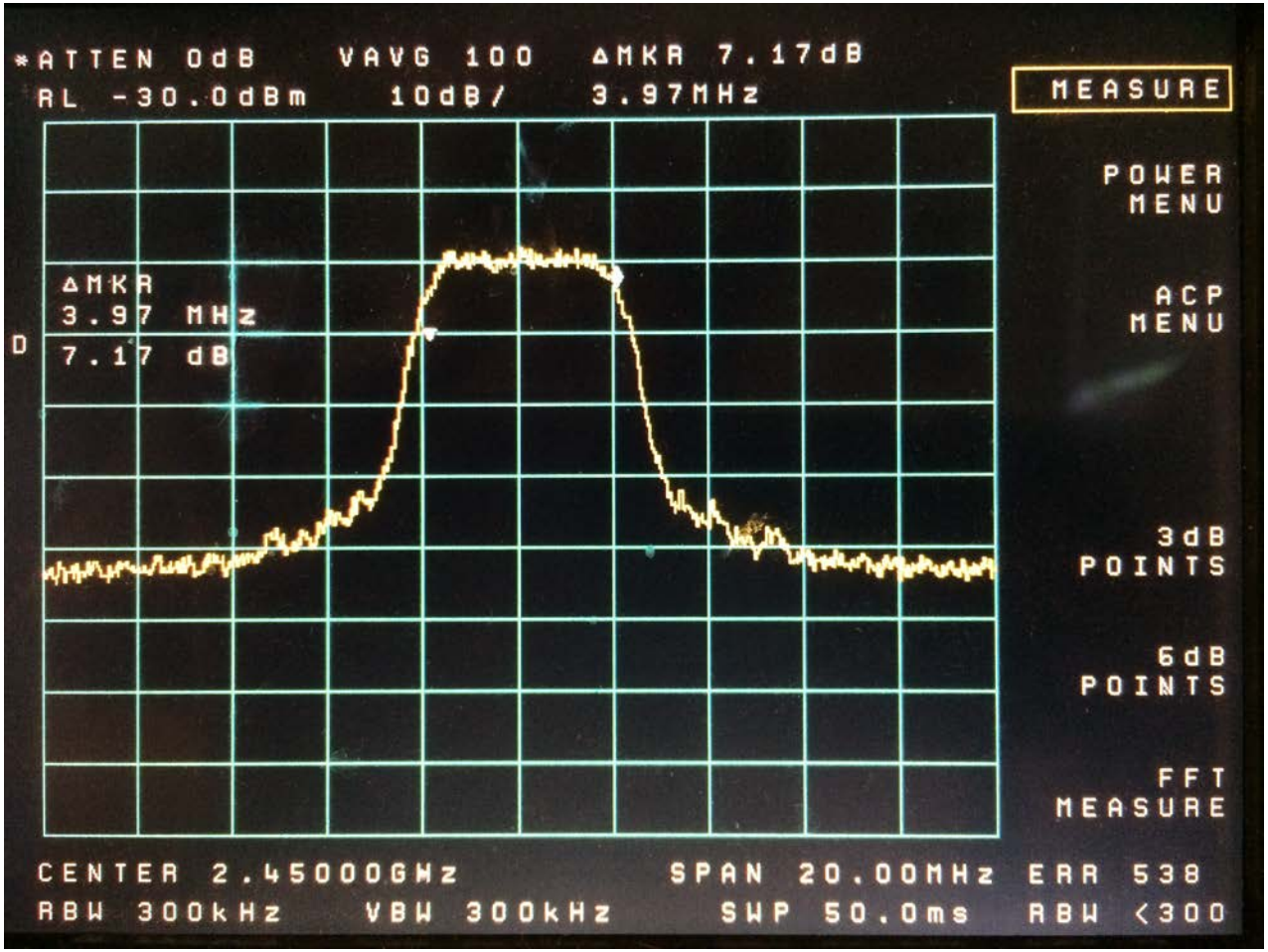
Results

- Changing the modulation scheme at S-band
- BPSK,QPSK, OQPSK, 8-PSK, 16-APSK
- 8QAM, 16QAM
- FSK, MSK, GMSK
- AM

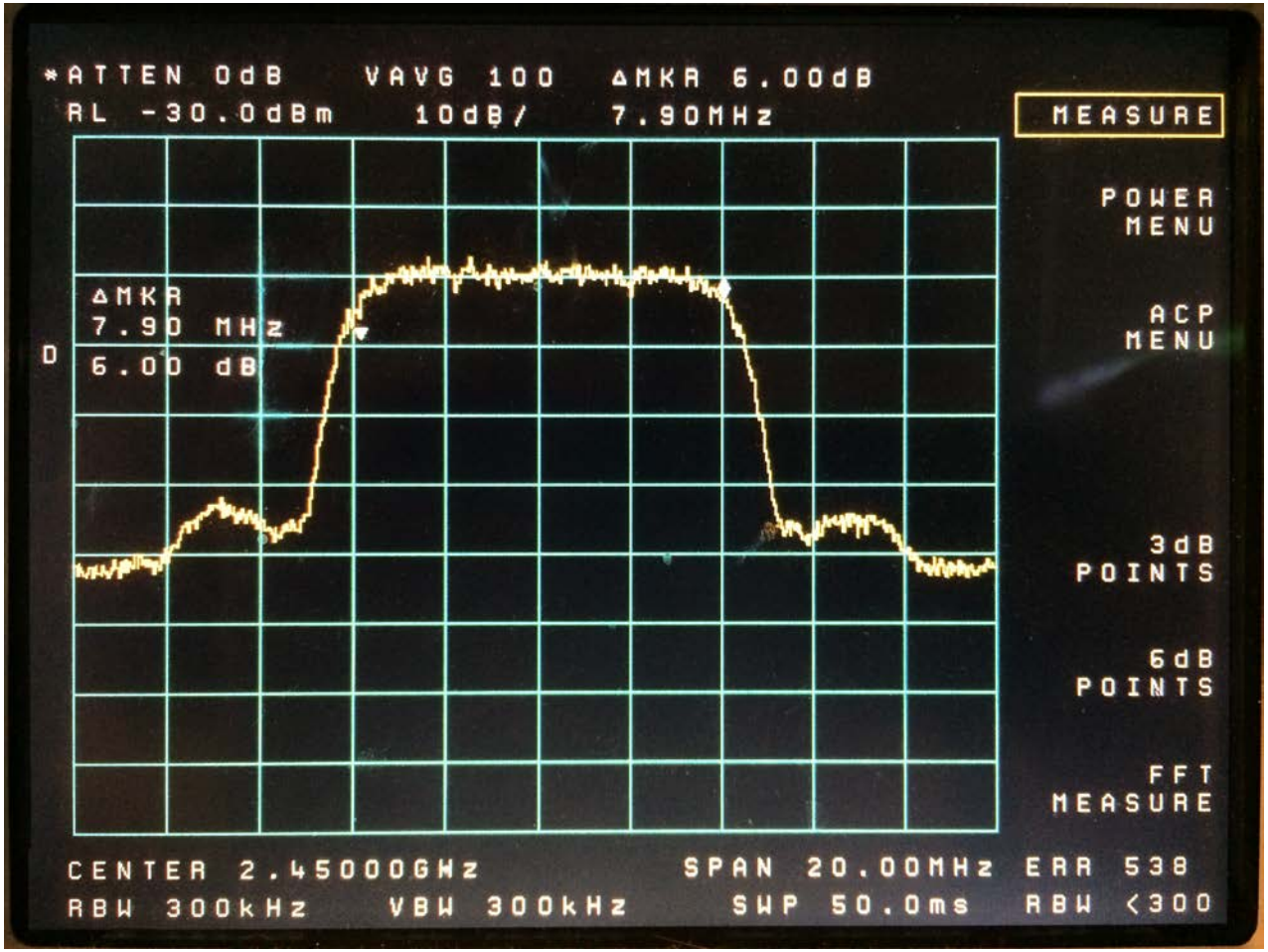
QPSK with FIR Filtering @ 2450 MHz 16 Mbps



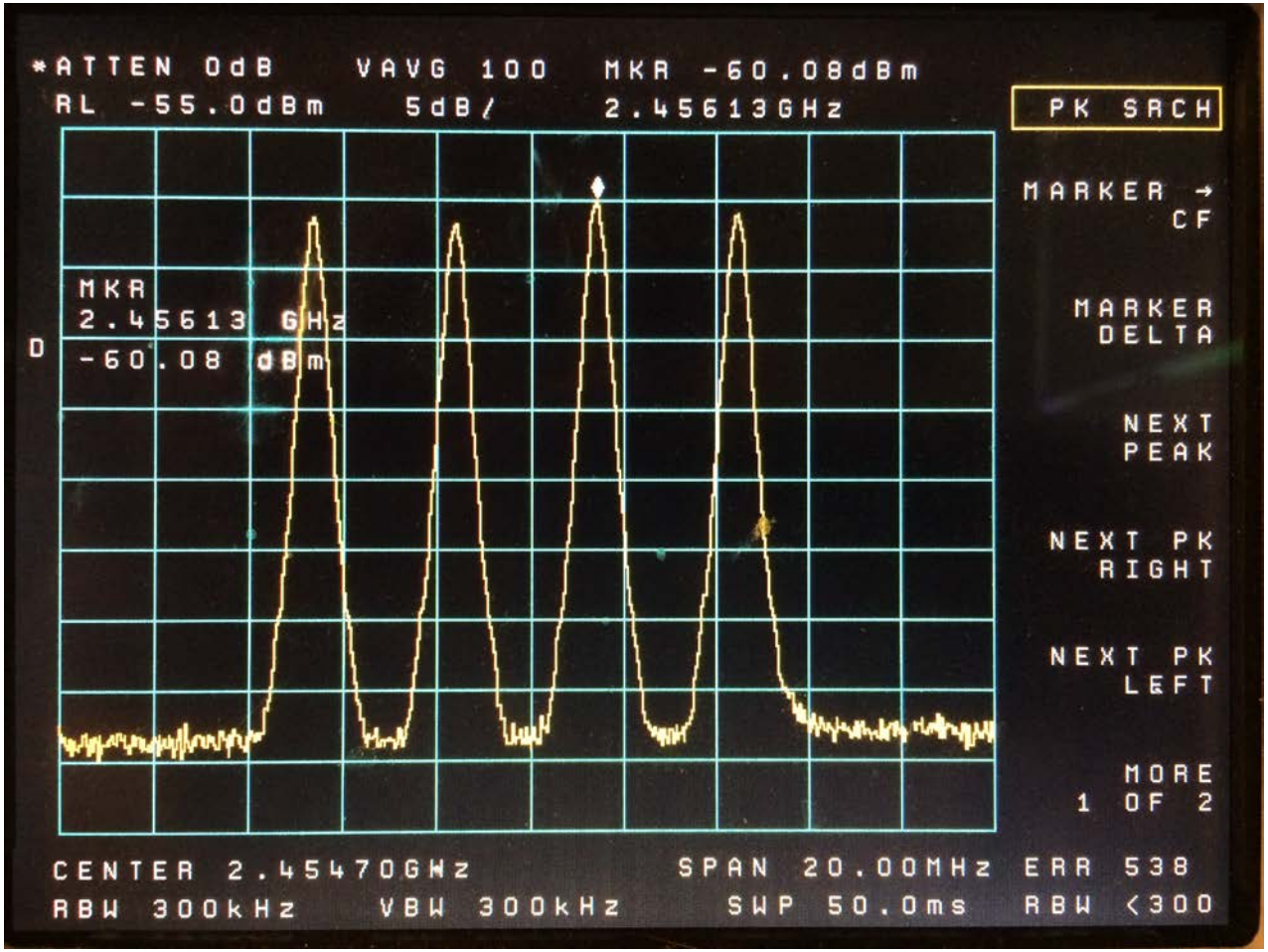
QAM-16 @ 2450 MHz, 16 Mbps



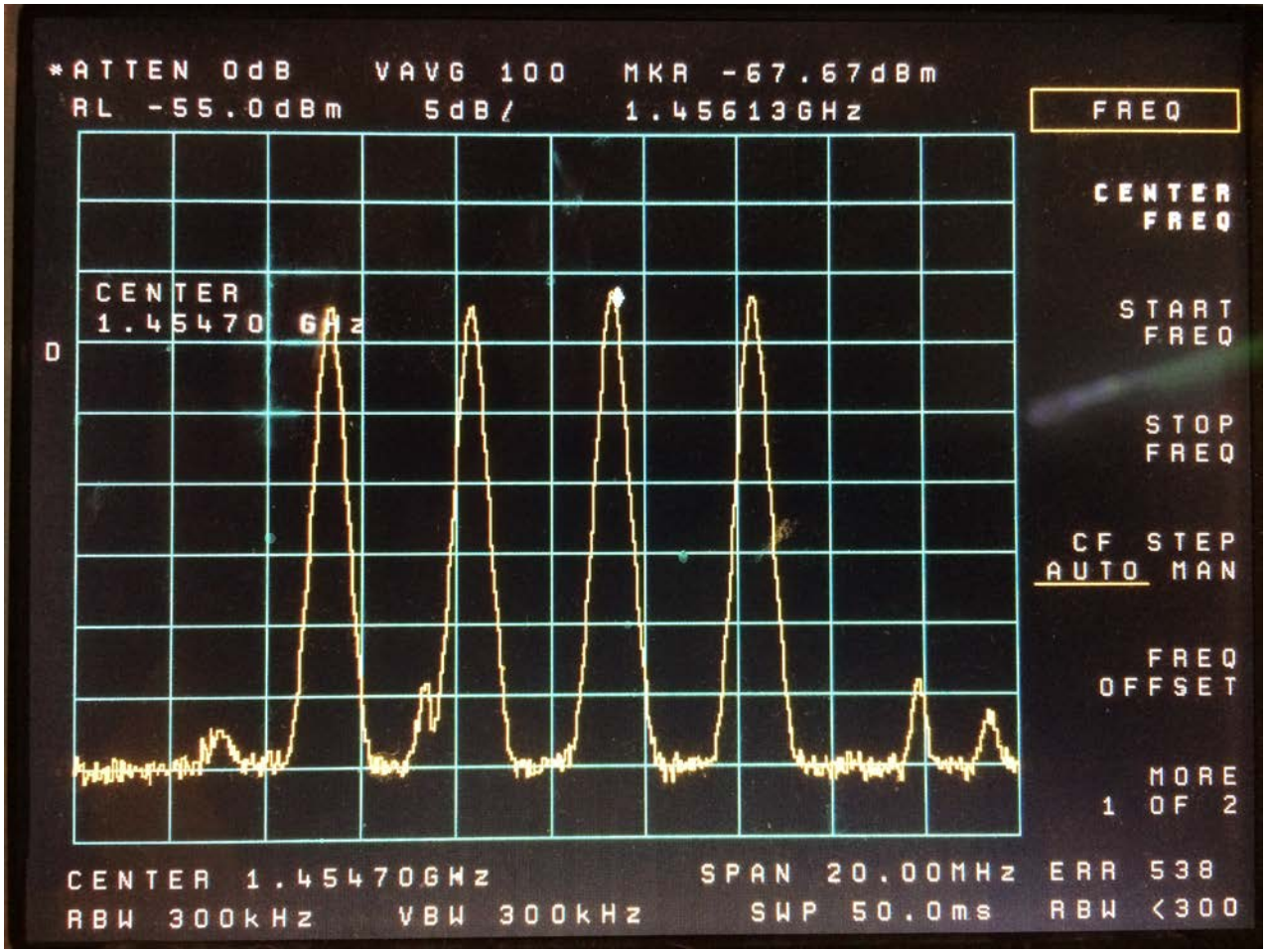
MSK @ 2450 MHz, 8 Mbps



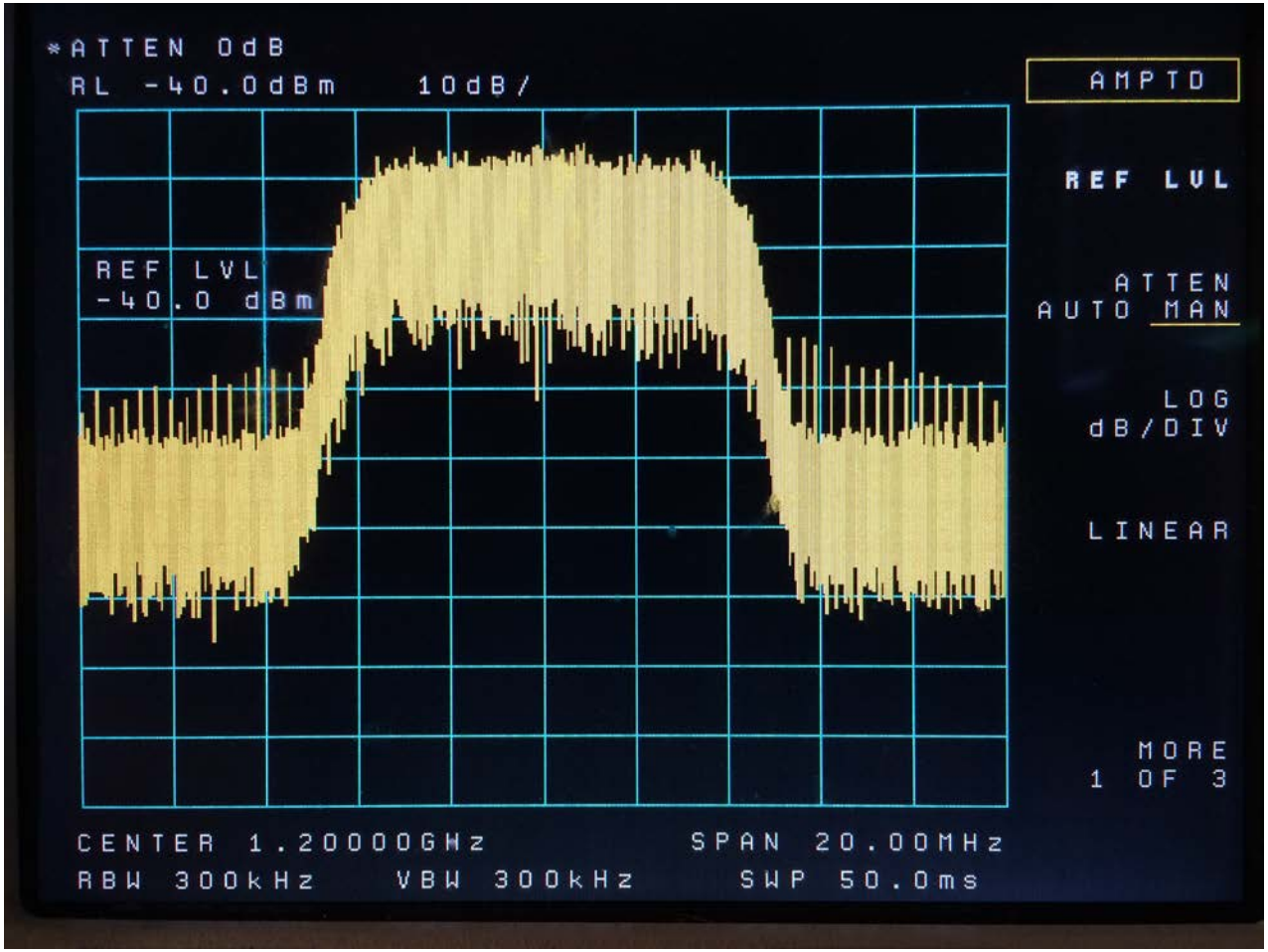
Four CW Tones @ 2450 MHz



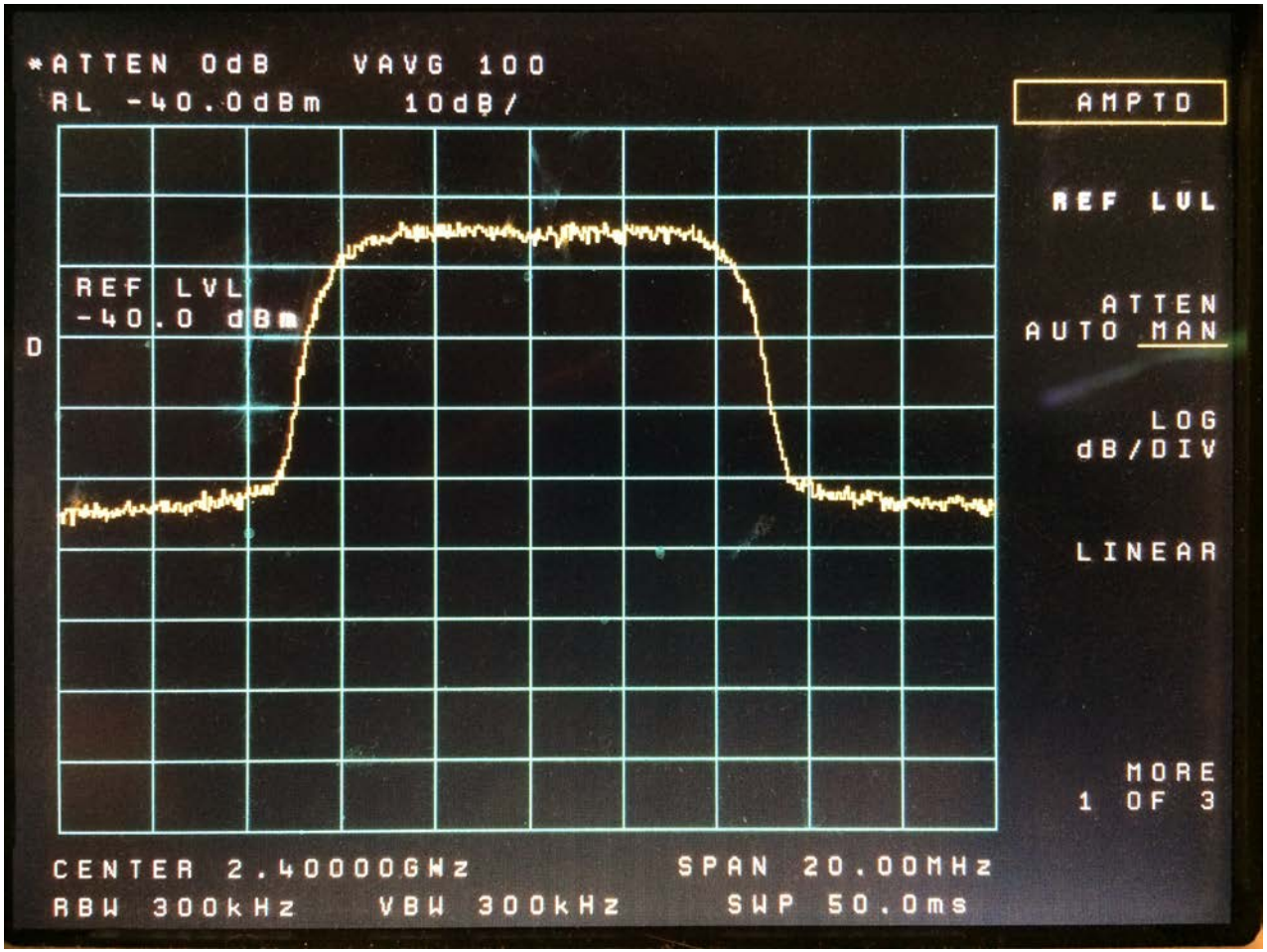
Four CW Tones @ 1450 MHz



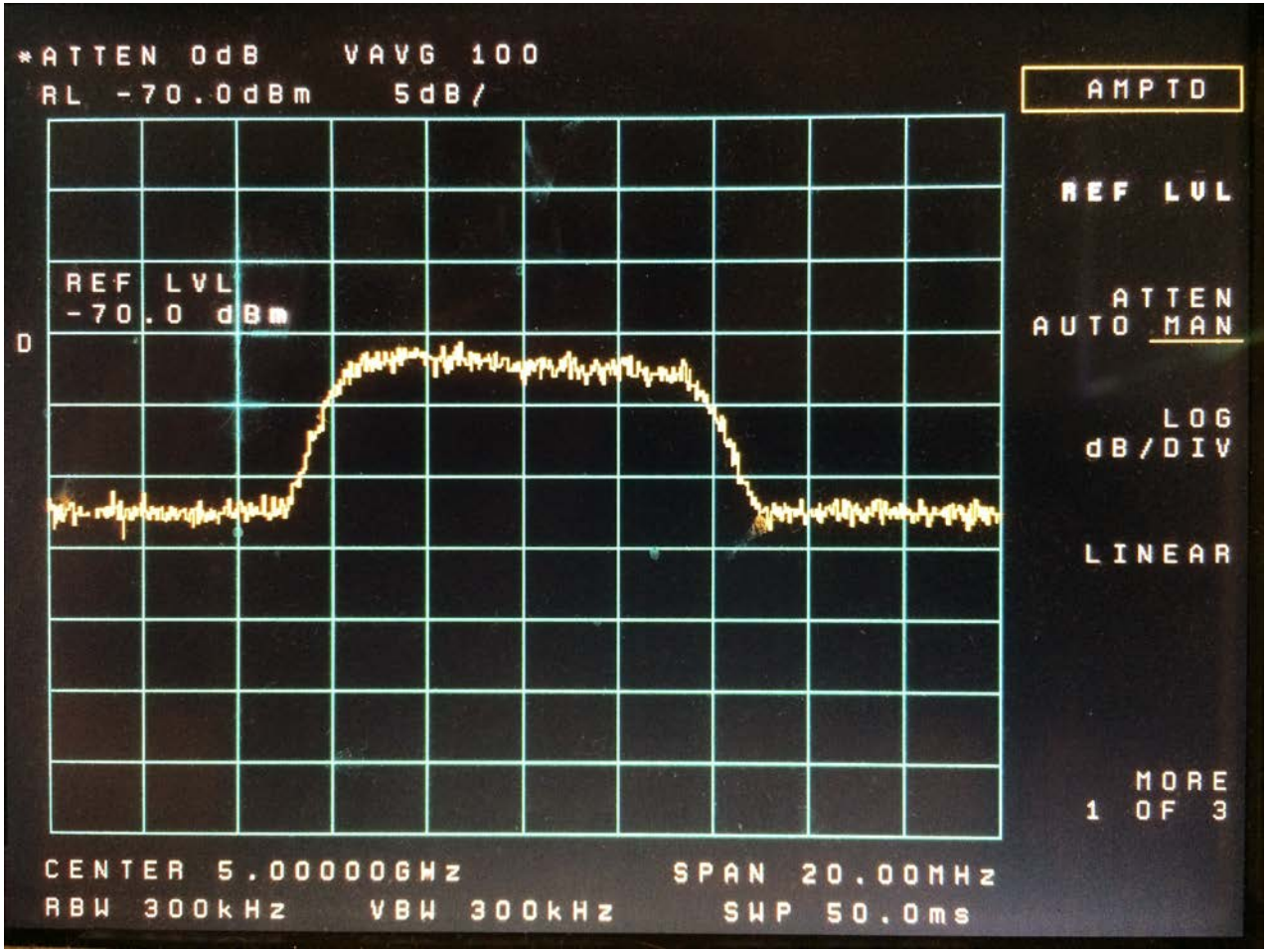
QPSK @ L-band 1200 MHz, 16 Mbps



QPSK @ S-band 2400 MHz, 16 Mbps



QPSK @ C-band 5000 MHz, 16 Mbps



Conclusions

- Data rates and frequencies adjustable from very low to very high
- Quick to swap for different use
- Daughterboard design makes it easy to prototype new applications
- Same design works for spacecraft and ground segment
- Software doesn’t have to change when RF changes

Thank You

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- Find me anytime this week for more information