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An Arduino Controlled 35 MHz to 4.4 GHz Signal Generator

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Project Objectives

- Experiment with ADF4351 eval boards to determine suitability for
  - Local oscillators
    - Lock to station 10 MHz reference
    - Direct or multiplied for the higher bands
      - e.g., 752 MHz, 1152 MHz, 2160 MHz, 3312 MHz, 5616 MHz (2808 x 2), 10224 MHz (3408 x 3)
  - Beacons
- Use the Arduino Uno to control the ADF4351
- Try the LCD Keypad Shield on the Arduino Uno

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ADF4351

APPLICATIONS

Wireless infrastructure (W-CDMA, TD-SCDMA, WiMAX, GSM, PCS, DCS, DECT)
Test equipment
Wireless LANs, CATV equipment
Clock generation

FUNCTIONAL BLOCK DIAGRAM

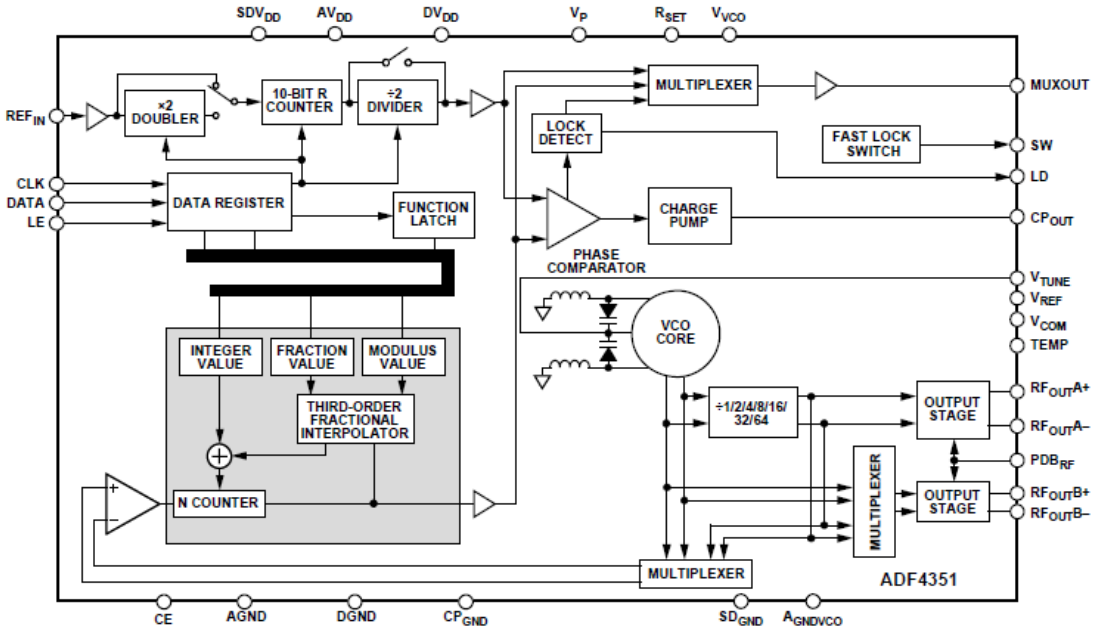

Figure 1.

ADF4351 Features

Output frequency range: 35 MHz to 4400 MHz
Fractional-N synthesizer and integer-N synthesizer
Low phase noise VCO
Programmable divide-by-1/-2/-4/-8/-16/-32/-64 output
Typical jitter: 0.3 ps rms
Typical EVM at 2.1 GHz: 0.4%
Power supply: 3.0 V to 3.6 V
Logic compatibility: 1.8 V
Programmable dual-modulus prescaler of 4/5 or 8/9
Programmable output power level
RF output mute function
3-wire serial interface
Analog and digital lock detect
Switched bandwidth fast lock mode
Cycle slip reduction

ADF4351

- VCO runs from 2.2 to 4.4 GHz
  - Programmable RF Output divider: 1, 2, 4, 8, 16, 32, or 64
  - Gets range down to 34.375 MHz
- Output frequency programmable to 10 KHz resolution
- Up to to 250 MHz reference input
- Differential RF output
  - Terminate opposite polarity if using single-ended
  - Two pairs of outputs
- Output power can be set to one of four levels
  - 4 dBm, -1 dBm, +2 dBm, +5 dBm
- Need to program 6 32-bit registers to use

Phase Noise Performance

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TYPICAL PERFORMANCE CHARACTERISTICS

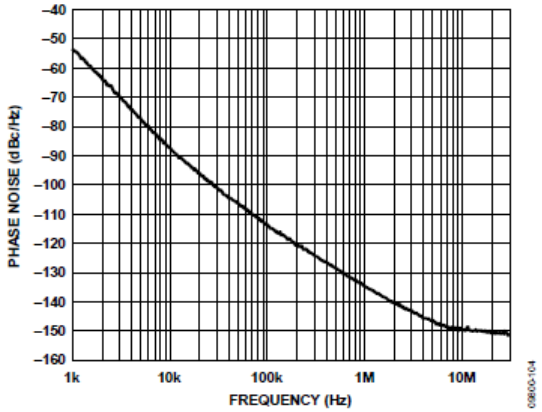

Figure 4. Open-Loop VCO Phase Noise, 2.2 GHz

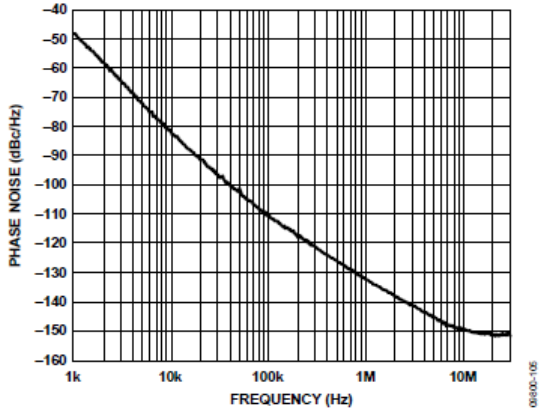

Figure 5. Open-Loop VCO Phase Noise, 3.3 GHz

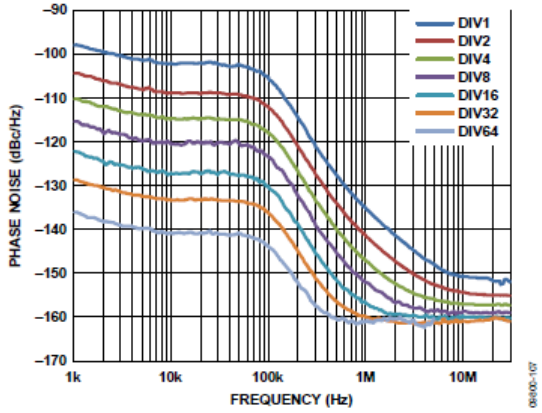

Figure 7. Closed-Loop Phase Noise, Fundamental VCO and Dividers, VCO = 2.2 GHz, PFD = 25 MHz, Loop Filter Bandwidth = 63 kHz

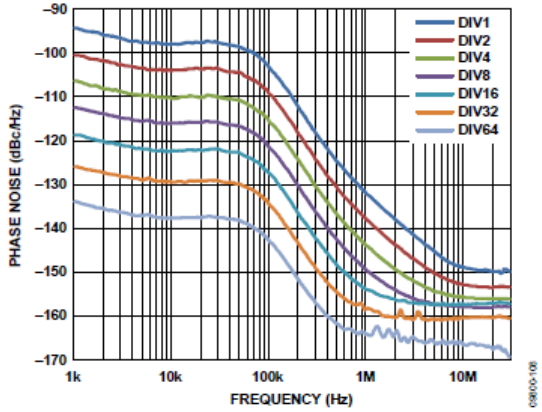

Figure 8. Closed-Loop Phase Noise, Fundamental VCO and Dividers,

Phase Noise Performance (2)

Figure 5. Open-Loop VCO Phase Noise, 3.3 GHz

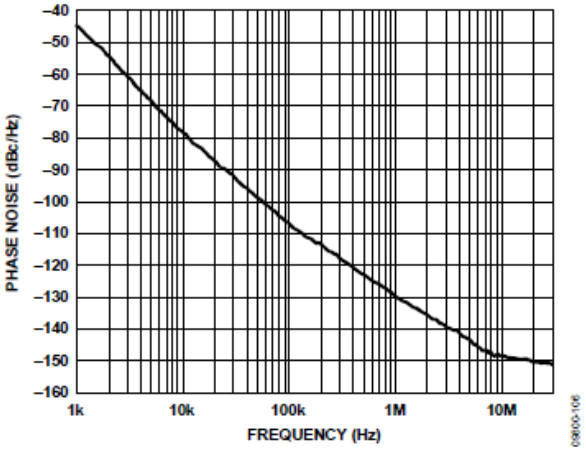

Figure 6. Open-Loop VCO Phase Noise, 4.4 GHz

Figure 8. Closed-Loop Phase Noise, Fundamental VCO and Dividers, VCO = 3.3 GHz, PFD = 25 MHz, Loop Filter Bandwidth = 63 kHz

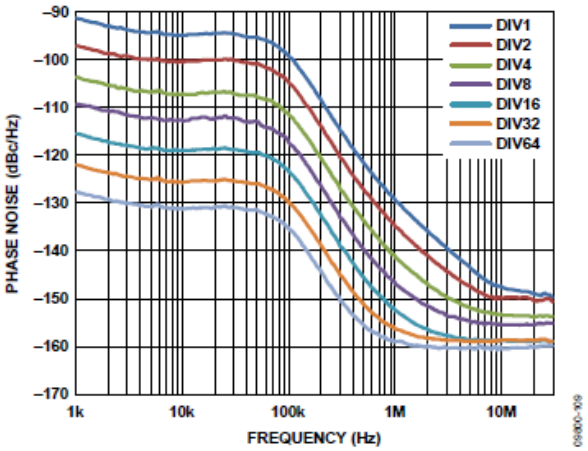

Figure 9. Closed-Loop Phase Noise, Fundamental VCO and Dividers, VCO = 4.4 GHz, PFD = 25 MHz, Loop Filter Bandwidth = 63 kHz

Data Sheet Spur Performance

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ADF4351 Data Sheet

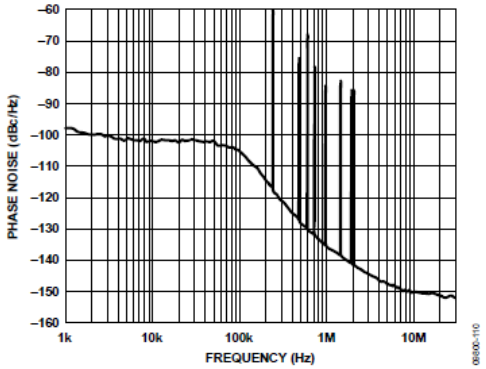


Figure 10. Fractional-N Spur Performance, Low Noise Mode, W-CDMA Band; RF_{OUT} = 2111.28 MHz, REF_{IN} = 122.88 MHz, PFD = 30.72 MHz, Output Divide-by-2 Selected; Loop Filter Bandwidth = 60 kHz, Channel Spacing = 240 kHz; RMS Phase Error = 0.21°, RMS Jitter = 0.27 ps, EVM = 0.37%

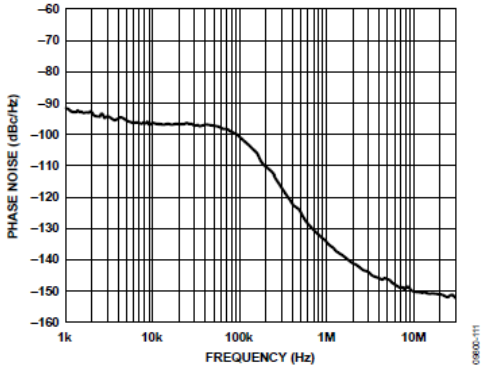


Figure 11. Fractional-N Spur Performance, Low Spur Mode, W-CDMA Band; RF_{OUT} = 2111.28 MHz, REF_{IN} = 122.88 MHz, PFD = 30.72 MHz, Output Divide-by-2 Selected; Loop Filter Bandwidth = 60 kHz, Channel Spacing = 240 kHz; RMS Phase Error = 0.37°, RMS Jitter = 0.49 ps, EVM = 0.64%

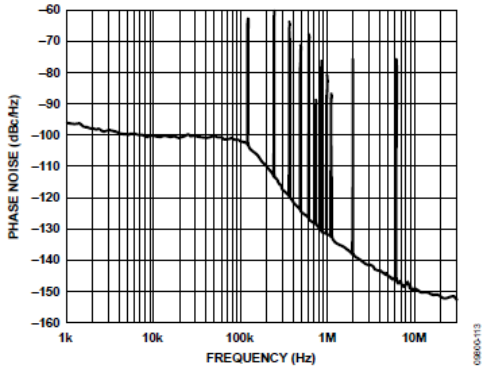


Figure 13. Fractional-N Spur Performance, Low Noise Mode, LTE Band; RF_{OUT} = 2646.96 MHz, REF_{IN} = 122.88 MHz, PFD = 30.72 MHz; Loop Filter Bandwidth = 60 kHz, Channel Spacing = 240 kHz; Phase Word = 9, RMS Phase Error = 0.28°, RMS Jitter = 0.29 ps, EVM = 0.49%

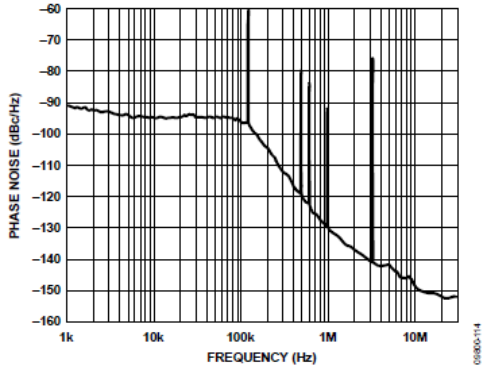
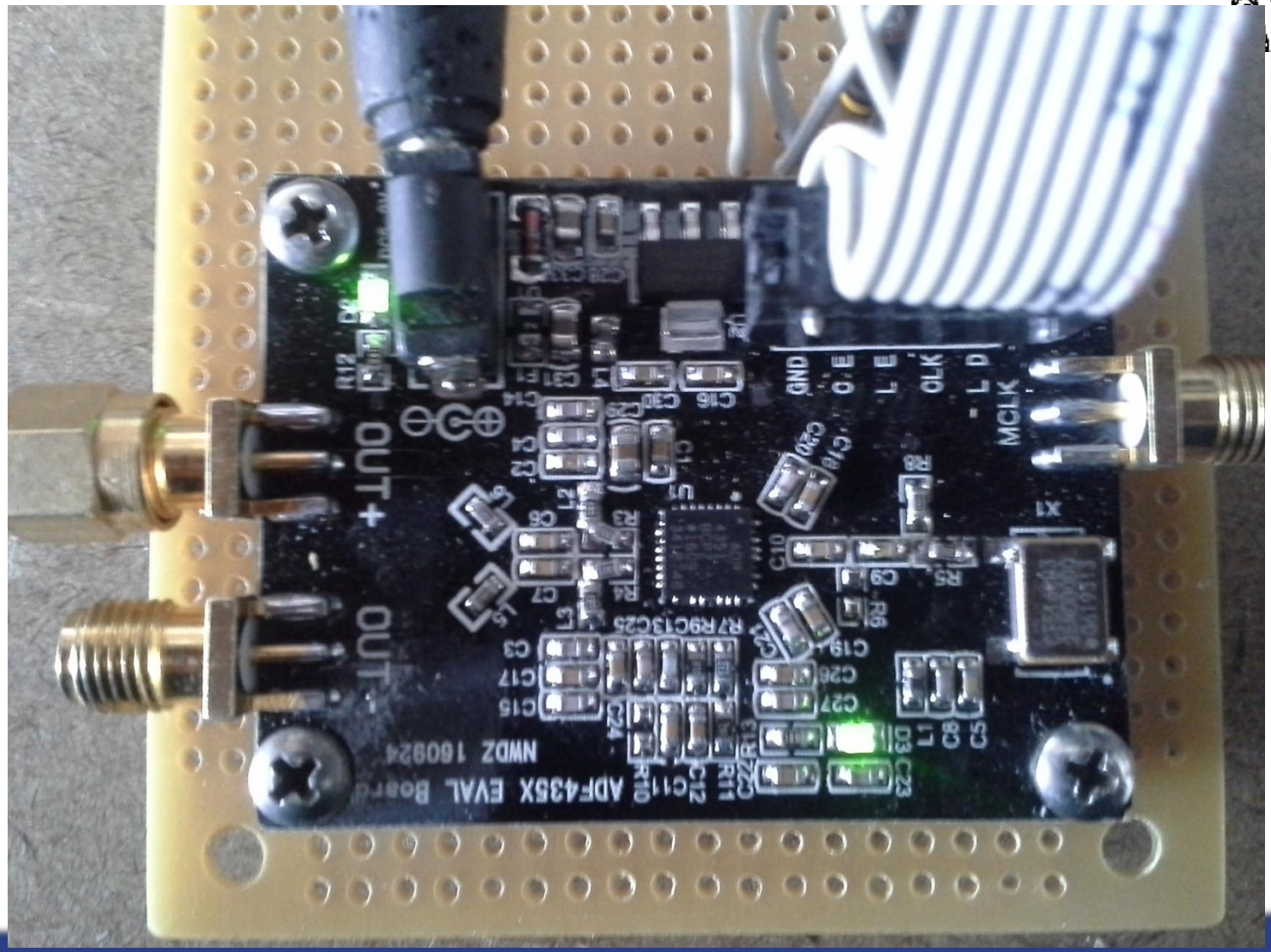


Figure 14. Fractional-N Spur Performance, Low Spur Mode, LTE Band; RF_{OUT} = 2646.96 MHz, REF_{IN} = 122.88 MHz, PFD = 30.72 MHz; Loop Filter Bandwidth = 60 kHz, Channel Spacing = 240 kHz; RMS Phase Error = 0.56°, RMS Jitter = 0.59 ps, EVM = 0.98%

Chinese ADF4351 Eval Board



Chinese ADF4351 Eval Board

- Can be found for $25-$30 including shipping on eBay
- 5-9 VDC input power via 1.1 mm barrel power plug
- Serial Peripheral Interface (SPI) and lock signals brought out to a 10-pin header on the board
- On-board 25 MHz crystal reference feeds the ADF4351 and a SMA connector
  - Remove 0 Ohm resistor R5 to use external reference
- Two LEDs
  - Power
  - Lock
- 3.3V Logic Signals (Caution: requires level shifters when interfacing to the Arduino Uno!)

Interface Between the Aruino Uno and the ADF3451 Eval Board

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ADF4351 Signal	Arduino Function	Arduino Pin*	Direction	Level Shift Required
ADF Data	MOSI	11	To ADF4351	Yes
ADF Clock	SCK	13	To ADF4351	Yes
ADF LE	Select	3	To ADF4351	Yes
Muxout	Lock Detect	2	From ADF4351	No
+5VDC				
GND				

Interface via the LCD Button Shield and Interface Board
*Per F1CJN software

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Arduino LCD Button Shield

- Plugs directly into the Arduino Uno
- ~$7.50 for two from China including shipping

Arduino Uno Board

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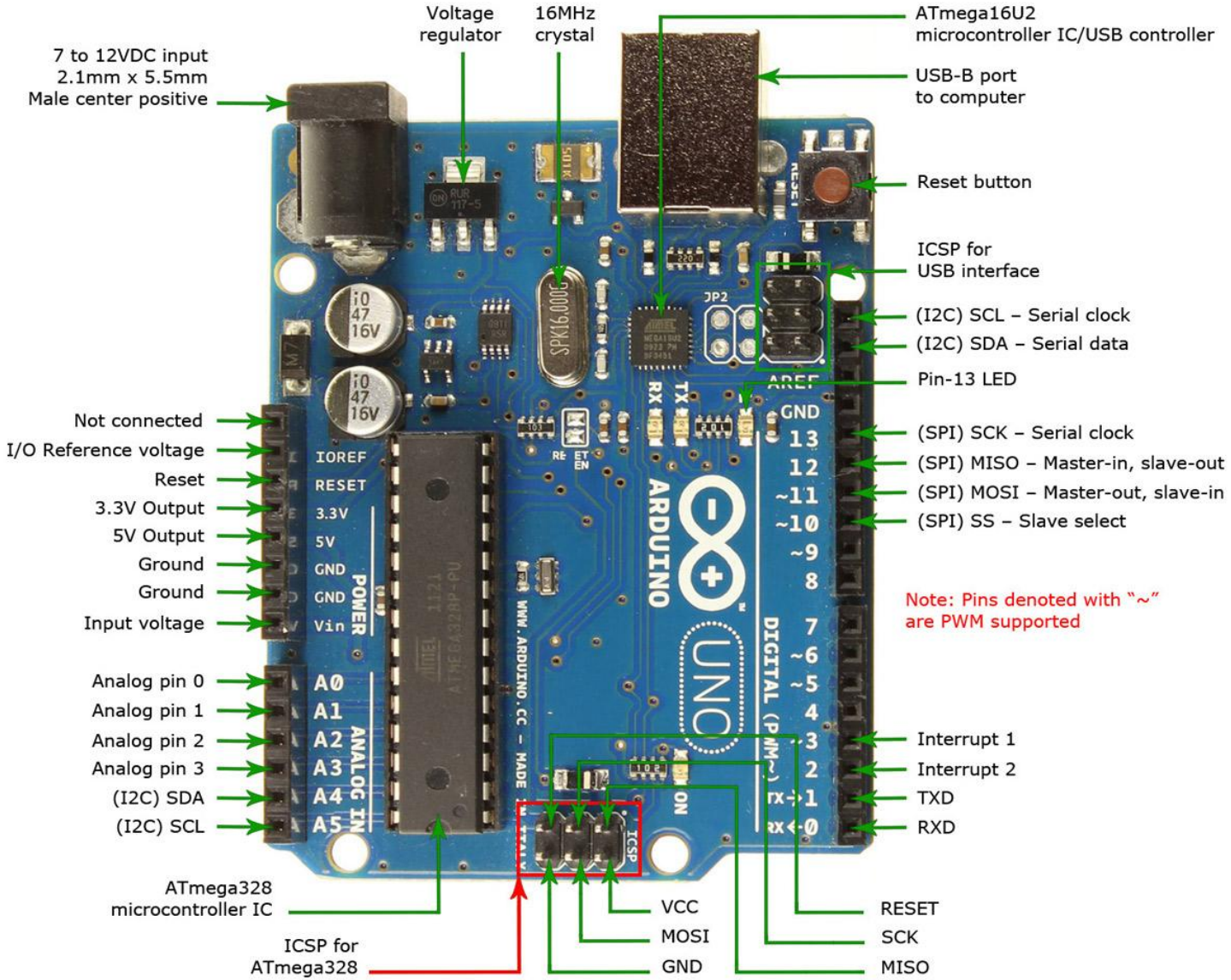

Atmel ATMega328P

- High Performance, Low Power Atmel® AVR® 8-Bit Microcontroller Family
- Advanced RISC Architecture
  - 131 Powerful Instructions – Most Single Clock Cycle Execution
  - 32 x 8 General Purpose Working Registers
  - Fully Static Operation
  - Up to 20 MIPS Throughput at 20MHz
  - On-chip 2-cycle Multiplier

ATMega328P Memory

- 32KBytes of In-System Self-Programmable Flash program memory
- 1KBytes EEPROM
- 2KBytes Internal SRAM
- Write/Erase Cycles: 10,000 Flash/100,000 EEPROM
- Data retention: 20 years at 85C/100 years at 25 C
- Optional Boot Code Section with Independent Lock Bits
  - In-System Programming by On-chip Boot Program
  - True Read-While-Write Operation
- Programming Lock for Software Security

ATMega328P Peripheral Features

- Two 8-bit Timer/Counters with Separate Prescaler and Compare Mode
- One 16-bit Timer/Counter with Separate Prescaler, Compare Mode, and Capture Mode
- Real Time Counter with Separate Oscillator
- Six PWM Channels
- 8-channel 10-bit ADC in TQFP and QFN/MLF package
- Temperature Measurement
- 6-channel 10-bit ADC in PDIP Package
- Temperature Measurement
- Programmable Serial USART
- Master/Slave SPI Serial Interface
- Byte-oriented 2-wire Serial Interface (Philips I2C compatible)
- Programmable Watchdog Timer with Separate On-chip Oscillator
- On-chip Analog Comparator
- Interrupt and Wake-up on Pin Change

Software Development for the Arduino

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- Open source Integrated Development Environment (IDE)
  - https://www.arduino.cc/en/Main/Software
- Programming language is like C++
- Many subroutines for hardware available
  - LCD Display, Keypad, SPI bus, ……
- Long list of examples included with IDE
- Lots of open source code
  - E.g., Arduino Uno makes a nice beacon keyer

F1CJN Software

- Alain Fort, F1CJN wrote software for controlling the ADF4351
- Code compiles and loads on the Arduino Uno and available at
  - http://f6kbf.free.fr/html/ADF4351%20and%20Arduino_Fr_Gb.htm (thanks to WW2R and W5LUA)

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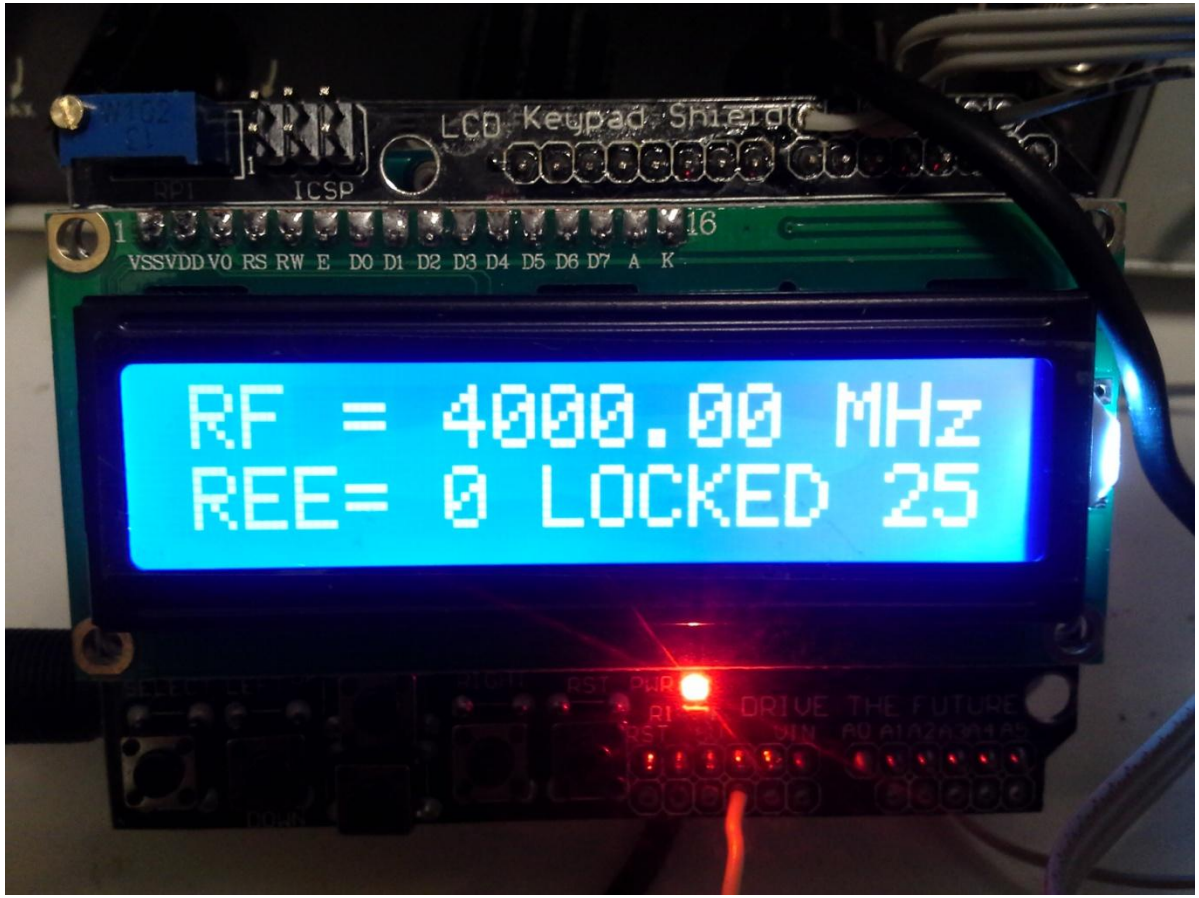
SW Human Interface

- Left, Right, Up, and Down buttons to move between fields
- Frequency Selectable in 10 kHz steps
- Select 10 MHz or 25 MHz reference
- Store up to 20 frequencies in EEPROM



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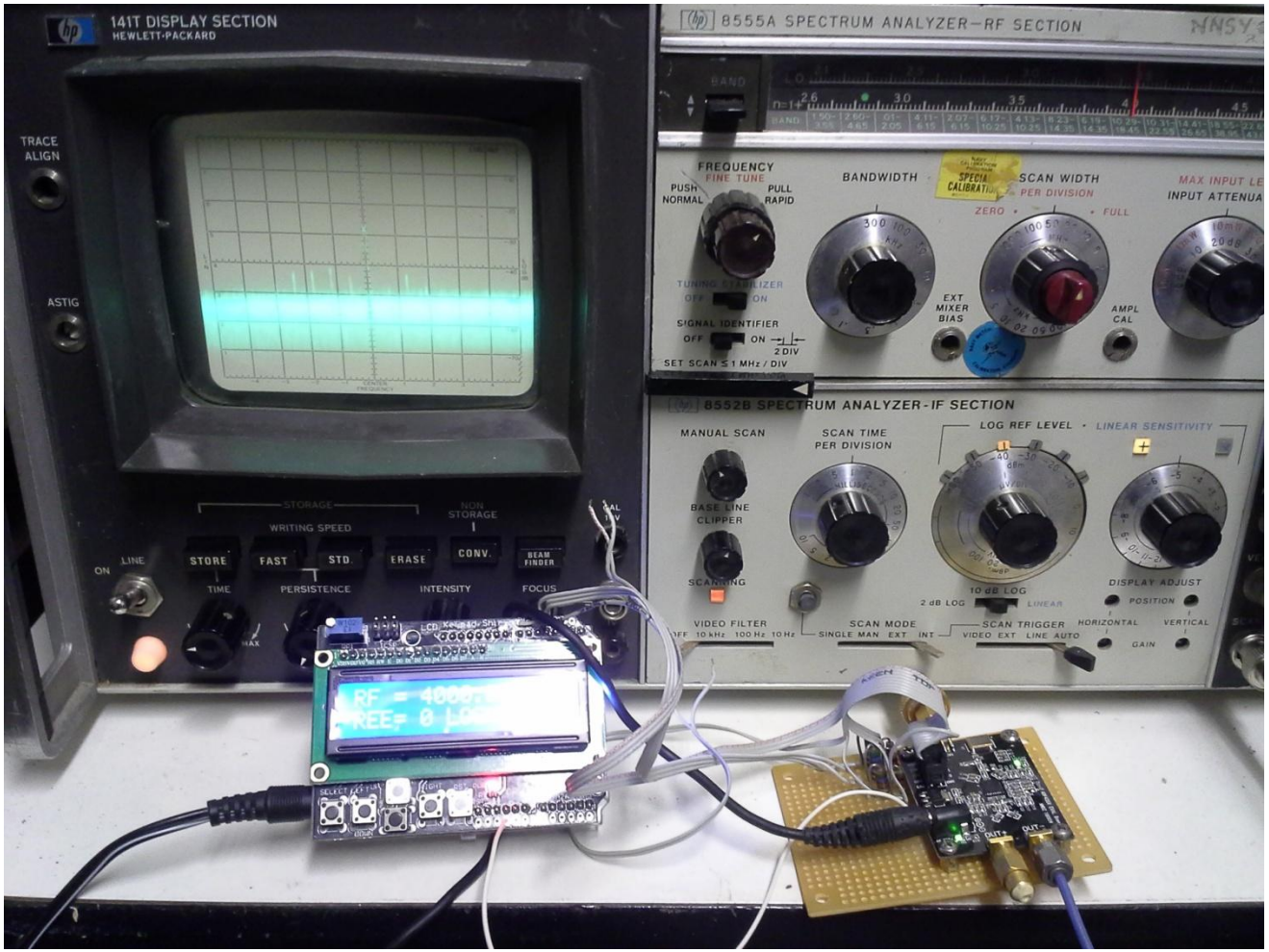
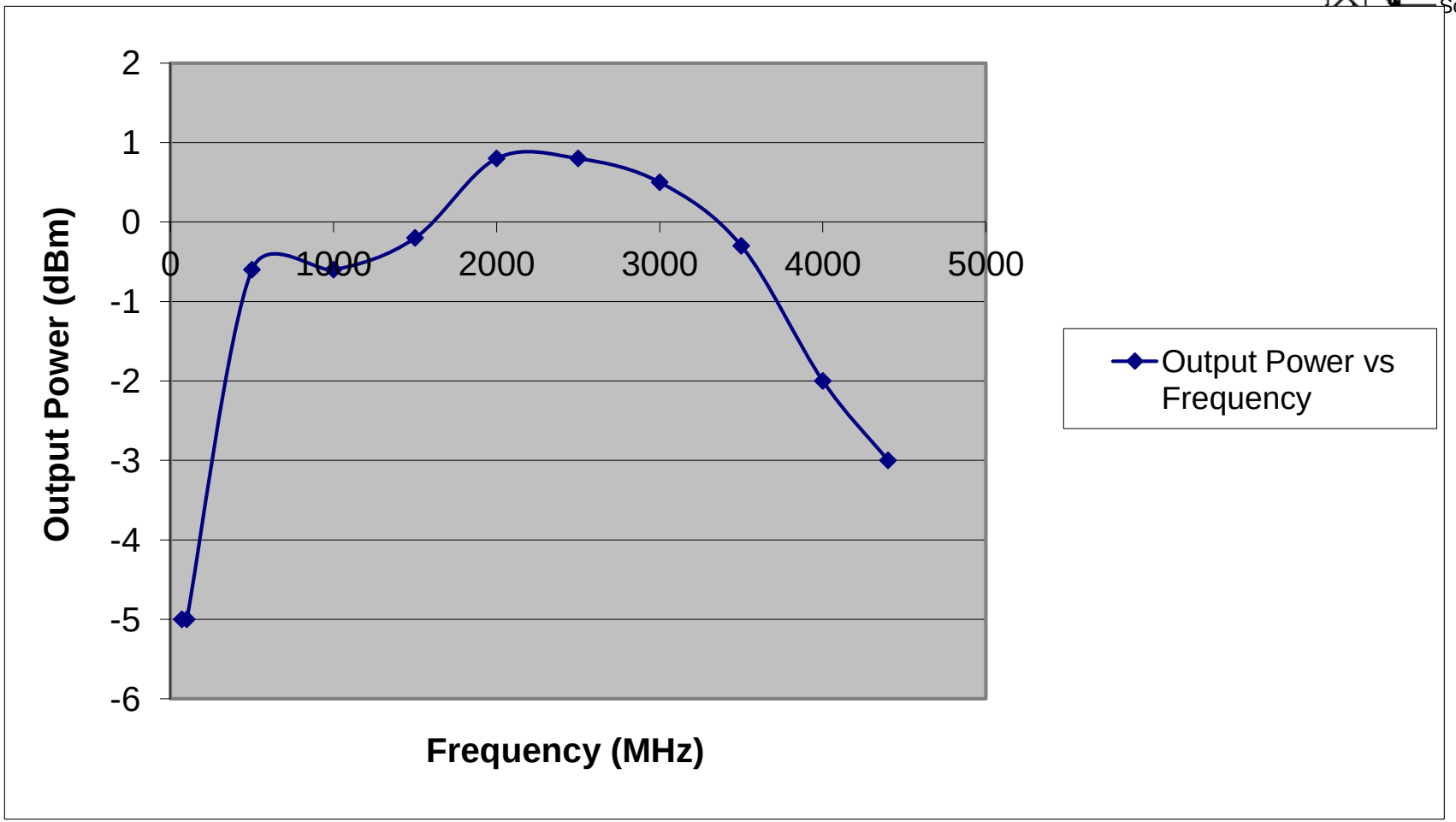
Very Preliminary Test Results



Measured Output Power*



*Single ended with other polarity terminated

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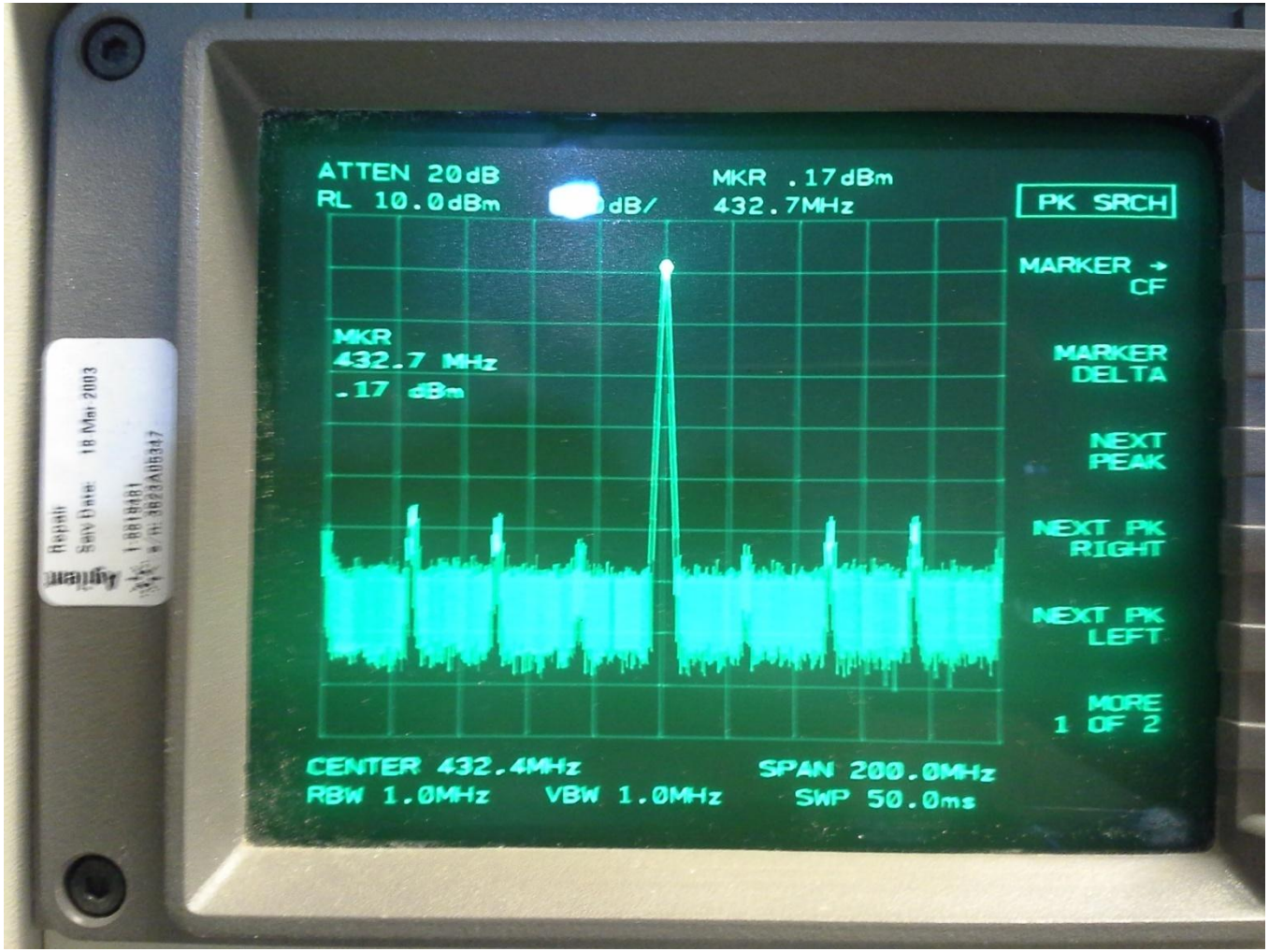
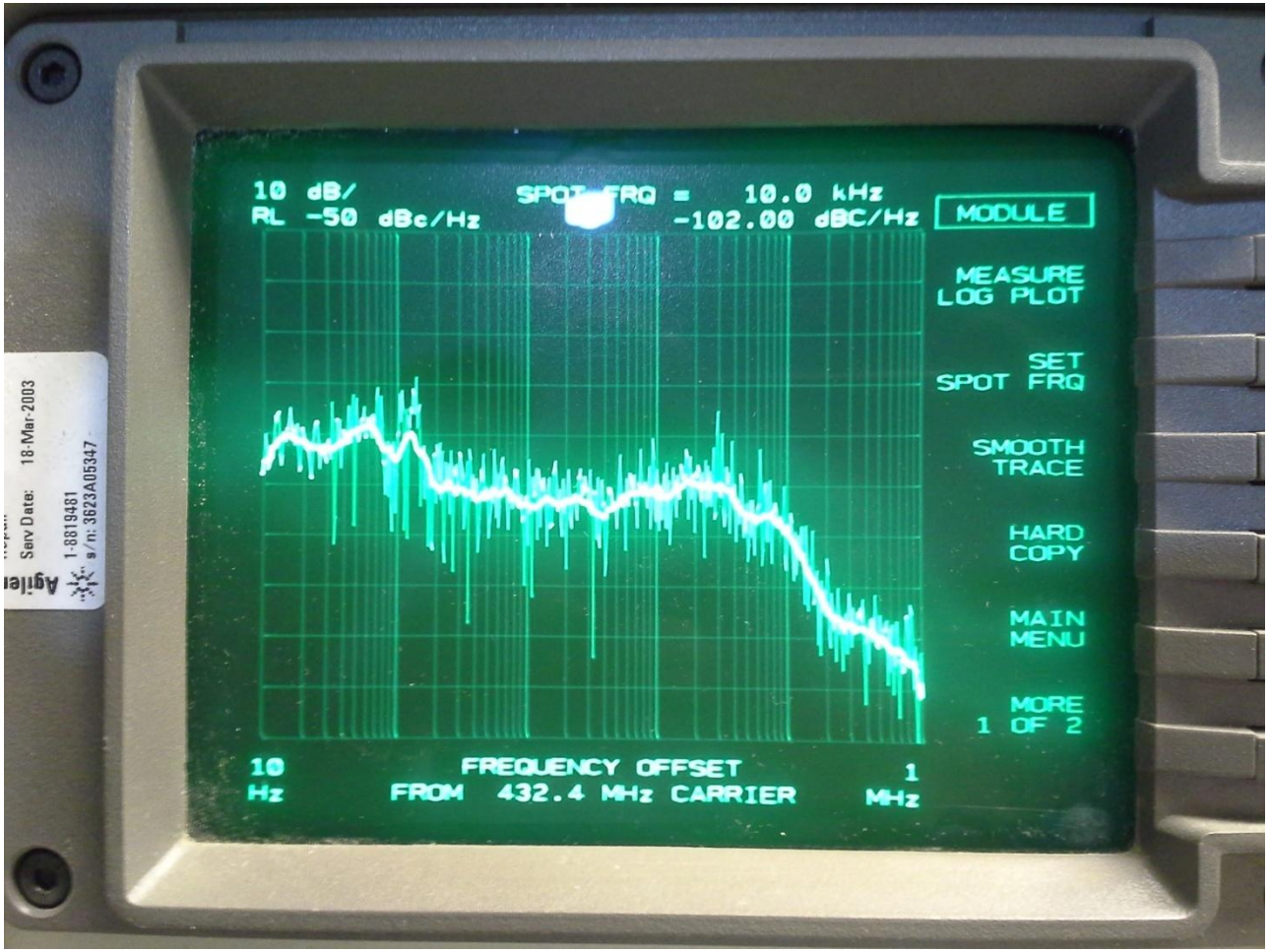
Spectrum: 432.280 MHz



Phase Noise: 432.380 MHz



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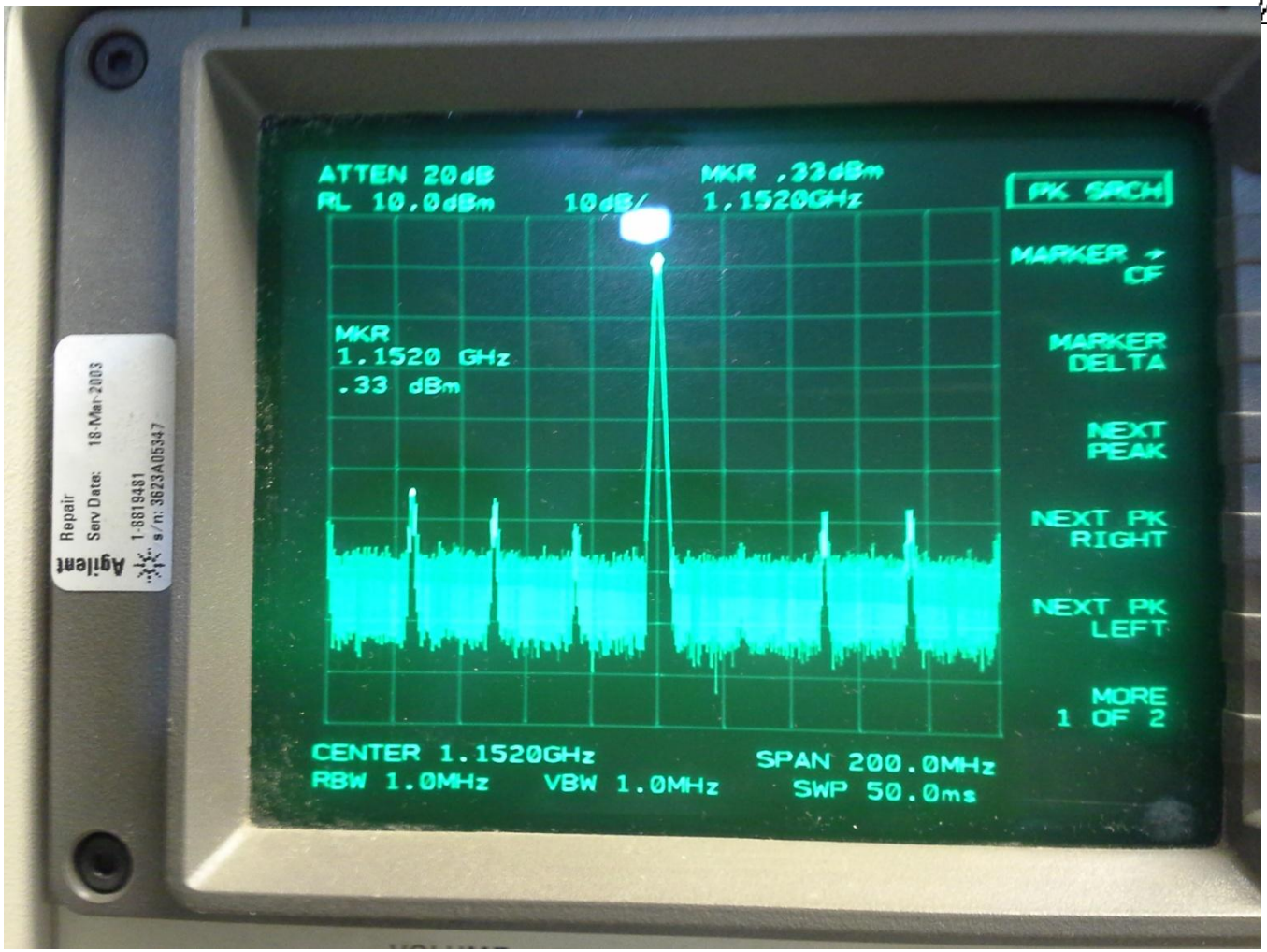
Spectrum: 1152 MHz

Spur are multiples of on-board 25 MHz reference



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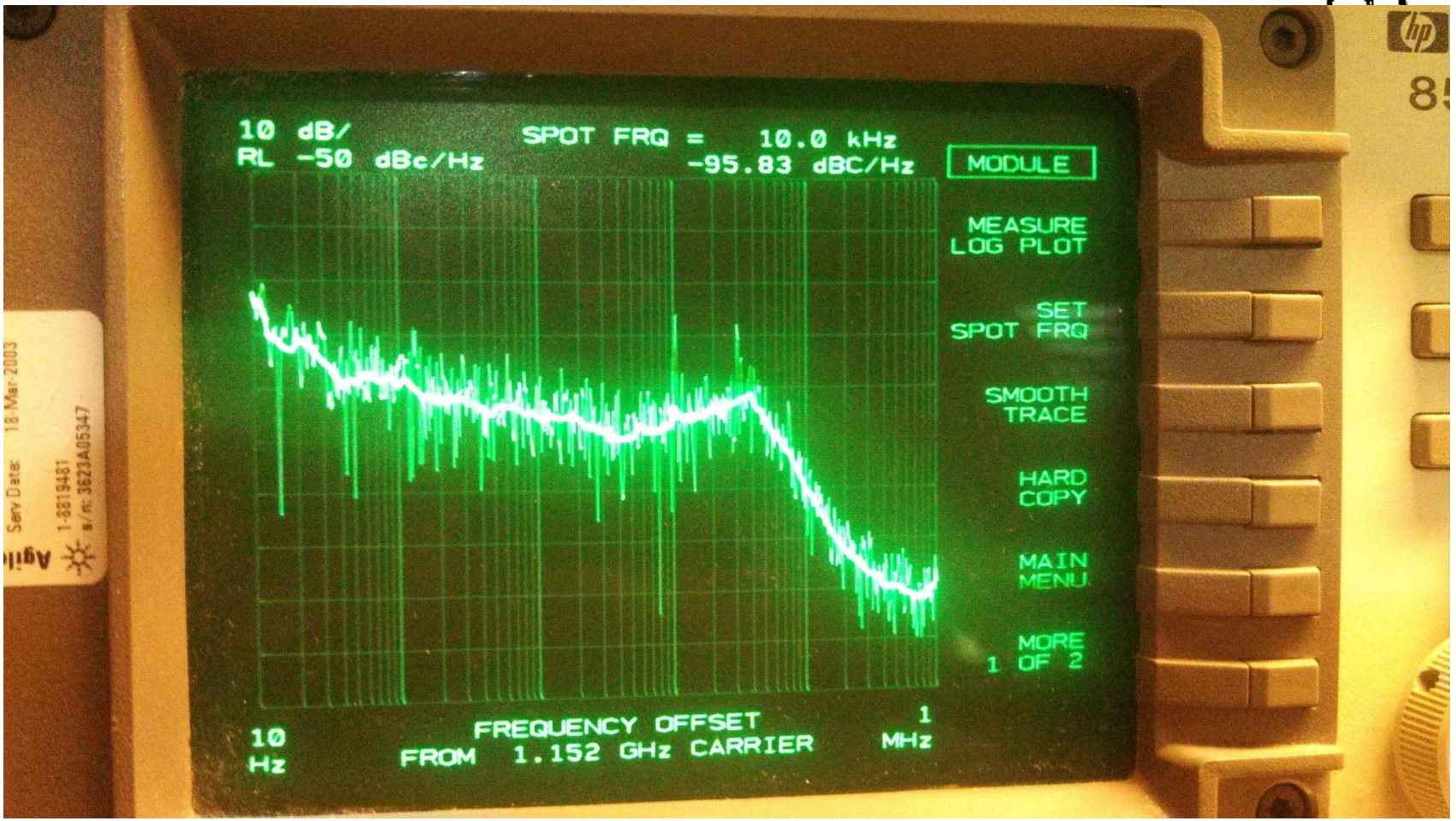
Phase Noise: 1152 MHz



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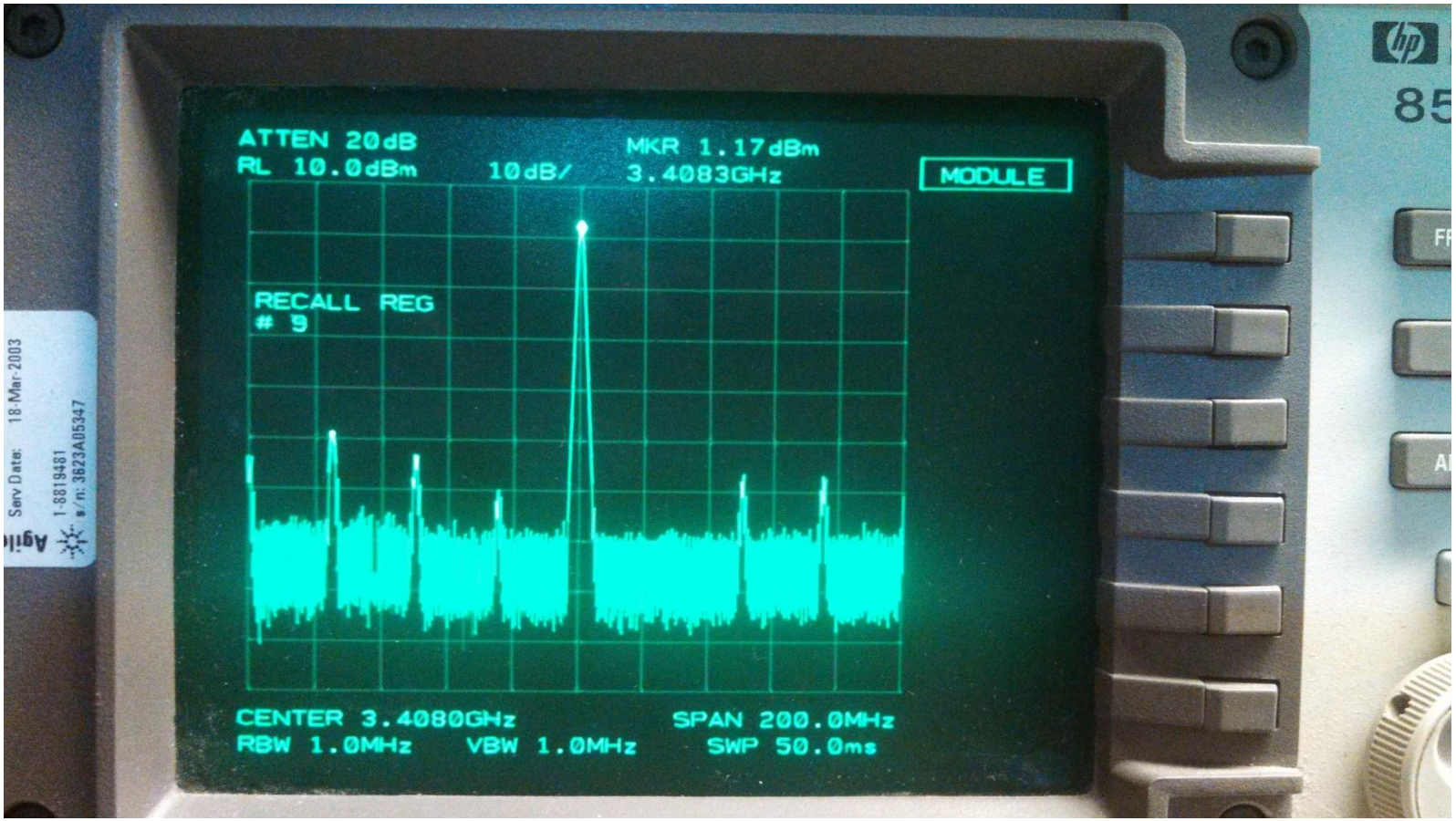
Spectrum: 3408 MHz



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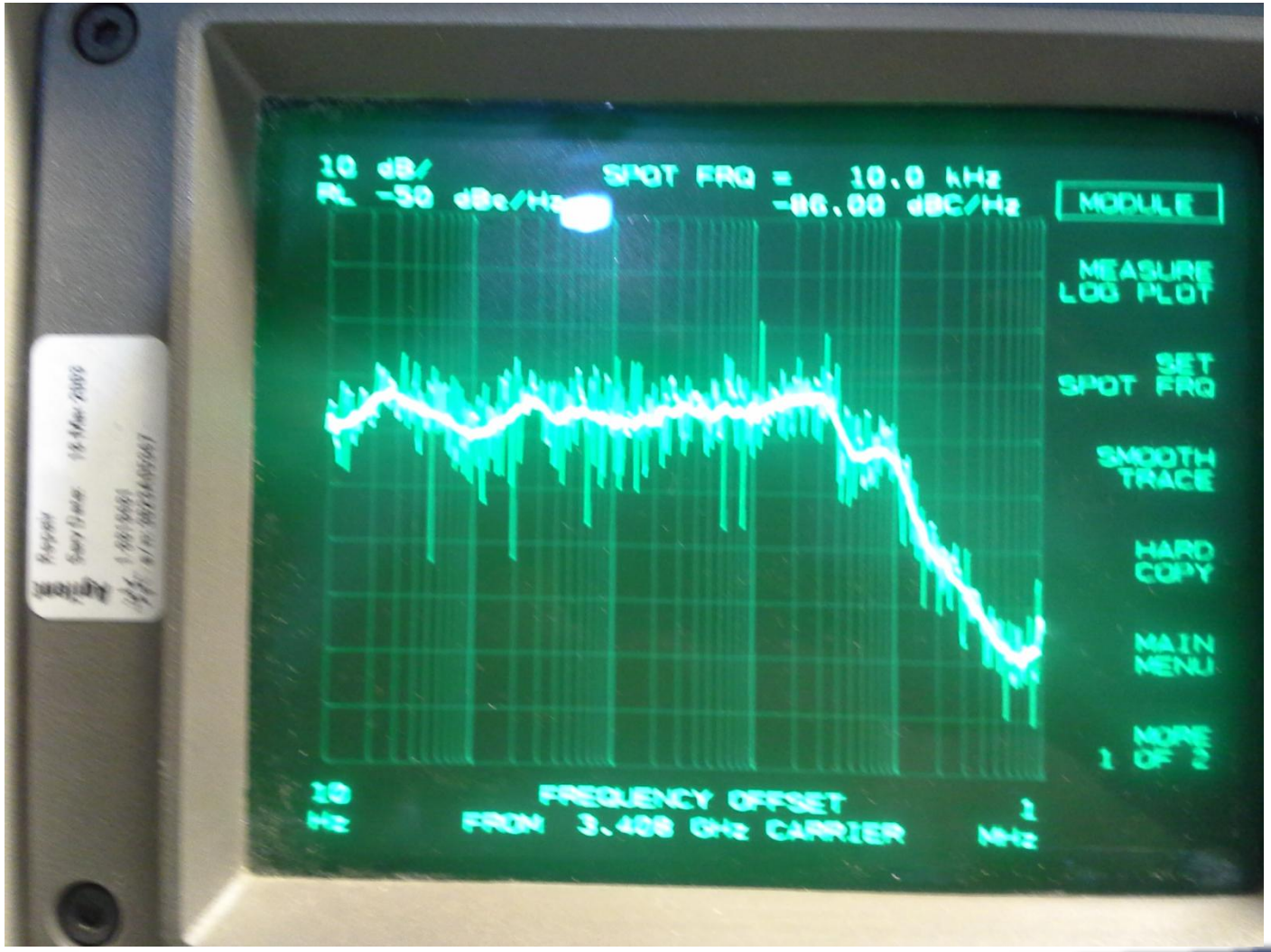
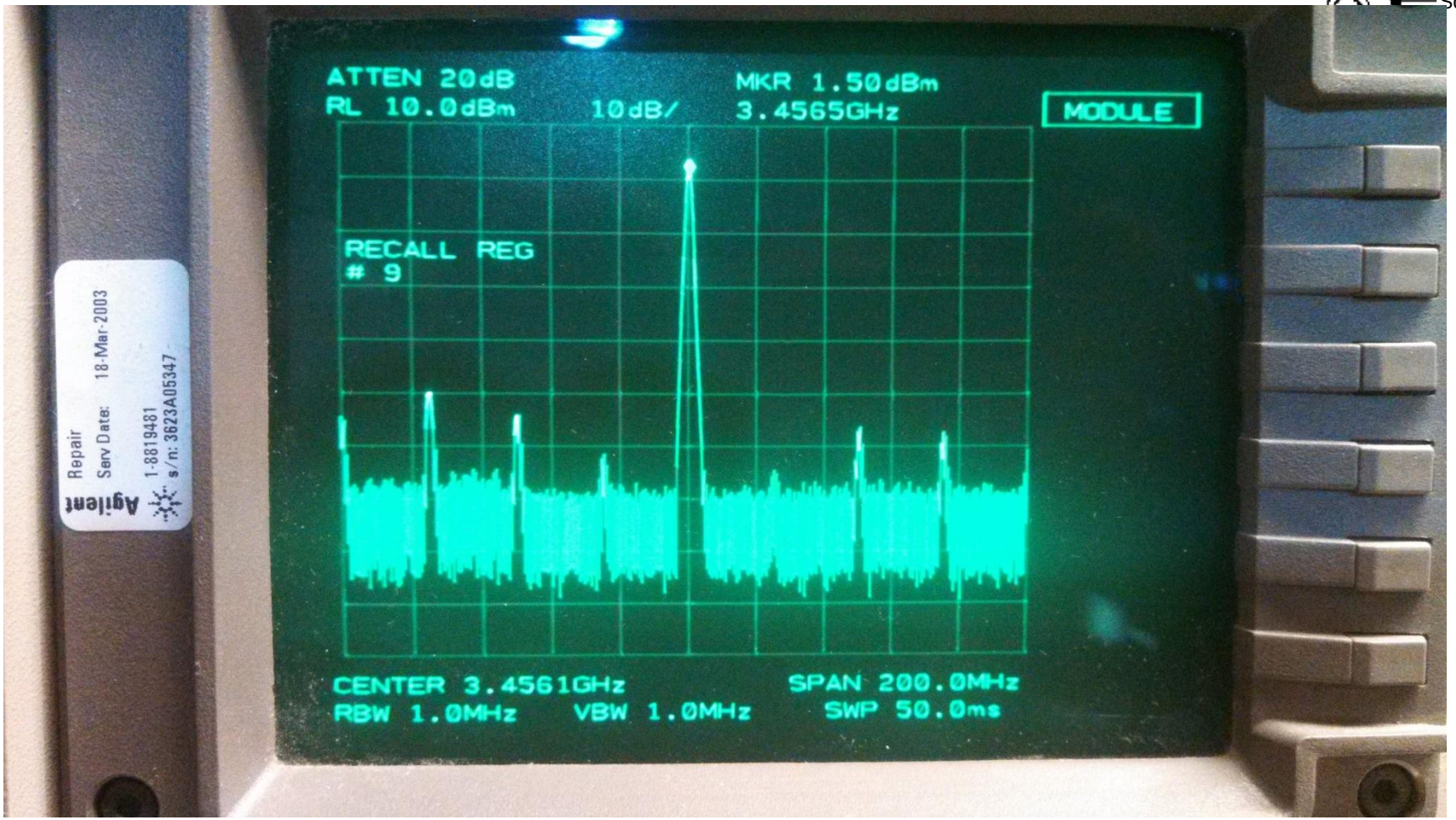
Phase Noise: 3408 MHz



Spectrum: 3456 MHz



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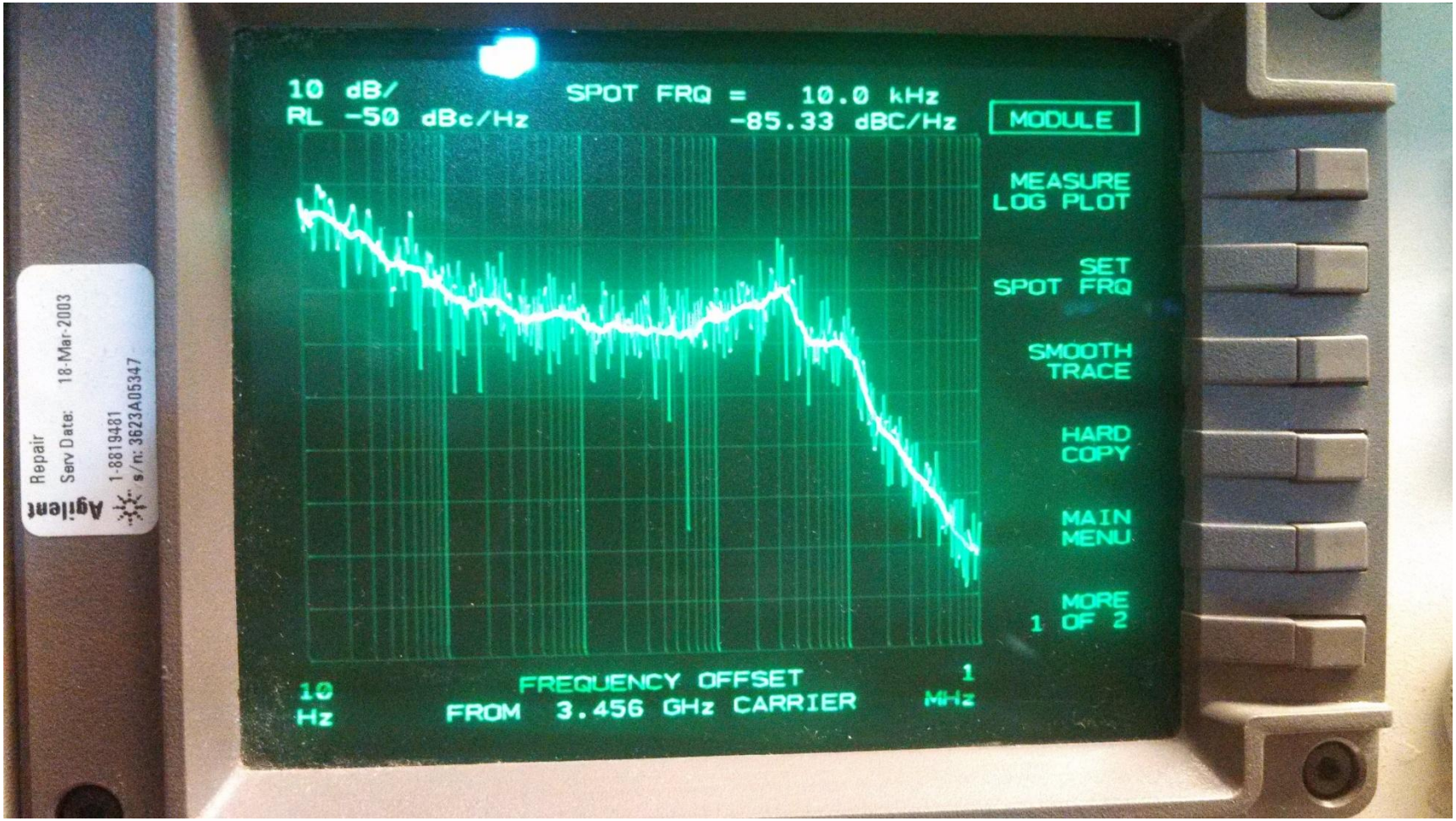
Phase Noise: 3456 MHz



Plans

- Connect to station 10 MHz reference and test
  - Verified that ADF4351 locks to external 10 MHz reference
- Reverse engineer how the ADF4351 is being set up with F1CJN code
- Experiment with ADF4351 settings
  - Data sheet notes controls to optimize performance for a single frequency or narrow bandwidth
  - Try low spur vs. low phase noise modes
  - Look for “sweet spots”
- Try a balun on the output
- Look at how the Orion version performs
  - Purported to be cleaner output due to better PCB layout than Chinese boards
  - Different interface
- Research means of retaining load with power removed

Initial Conclusions

- On-board 25 MHz reference useful for testing but likely noisier than a good 10 MHz reference
  - Mine measured low by 366 Hz
  - Output spectrum with 10 MHz reference yet to be measured
- Amplification needed to bring signal up to nominal mixer input level of +7 dBm

Initial Conclusions

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- Overall, these ADF4351 eval boards look like a good starting point for microwave LOs and Beacons
  - Use filters, multipliers, and amplifiers as needed to get spectrum and power level needed
  - Wide frequency range
  - Inexpensive