Ascent Ground and Satellite Demonstration

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Big Picture Goals

- Place more capable satellites into higher orbits
- Utilize software defined radios
- A programmable transponder that supports multiple linear and non-linear (FM) conversations simultaneously
- Digital modulation support
- Multi-users SHARING the Output Power
- Downlink assumed to be in X band (10.45 GHz), or greater
- Real time Doppler compensation

Current Focus Goals

- C-Band Uplink, X-Band Downlink (five and dime)
- Provide Frequency/Time Locking Capability for the Ground Station
- Utilize SDR technology to maximize flexibility to Experiment and Modify Operation
- Optimize Satellite architecture to minimize Ground Station costs
- Provide for maximum Power Weighting @Output for the downlink to prevent satellite capture
- UHF/VHF/L-Band/S-Band/HF optional Uplinks
- Provide a Digital Downlink of Satellite Data
- Provide a Digital Downlink of ID, Time stamp, Location (ala GPS/Grid Square) and uploaded TLE
- Provide for a DVB-S2 Input & Output when available
- Build in Redundant paths where feasible
- Provide multiple Digital Downlink paths
- Provide multiple Voice Downlink paths with different modulation types
- Provide a Multi-channel In- Single Channel out for contact Initiation and/or emergency channel
- Provide a controlled Ham Band Scanner Survey Downlink Capability

General Approach

- **Build and Demonstrate an example Ground and Satellite system that gives the user a sense of what a modern satellite system might look and feel like**
- **Concentrate on the system, not the implementation**
    - ***Talk to me about GNU Radio flow graphs at the demonstration area***
- **Incorporate the latest technology that is available and cost effective**
- **Use hardware and software that is identical or mimics planned future systems**
- **Make the communication architecture programmable to facilitate experimentation and optimization**
- **Use COTS SDR(s) likely to be used to facilitate early launch opportunities**

Demonstration Approach

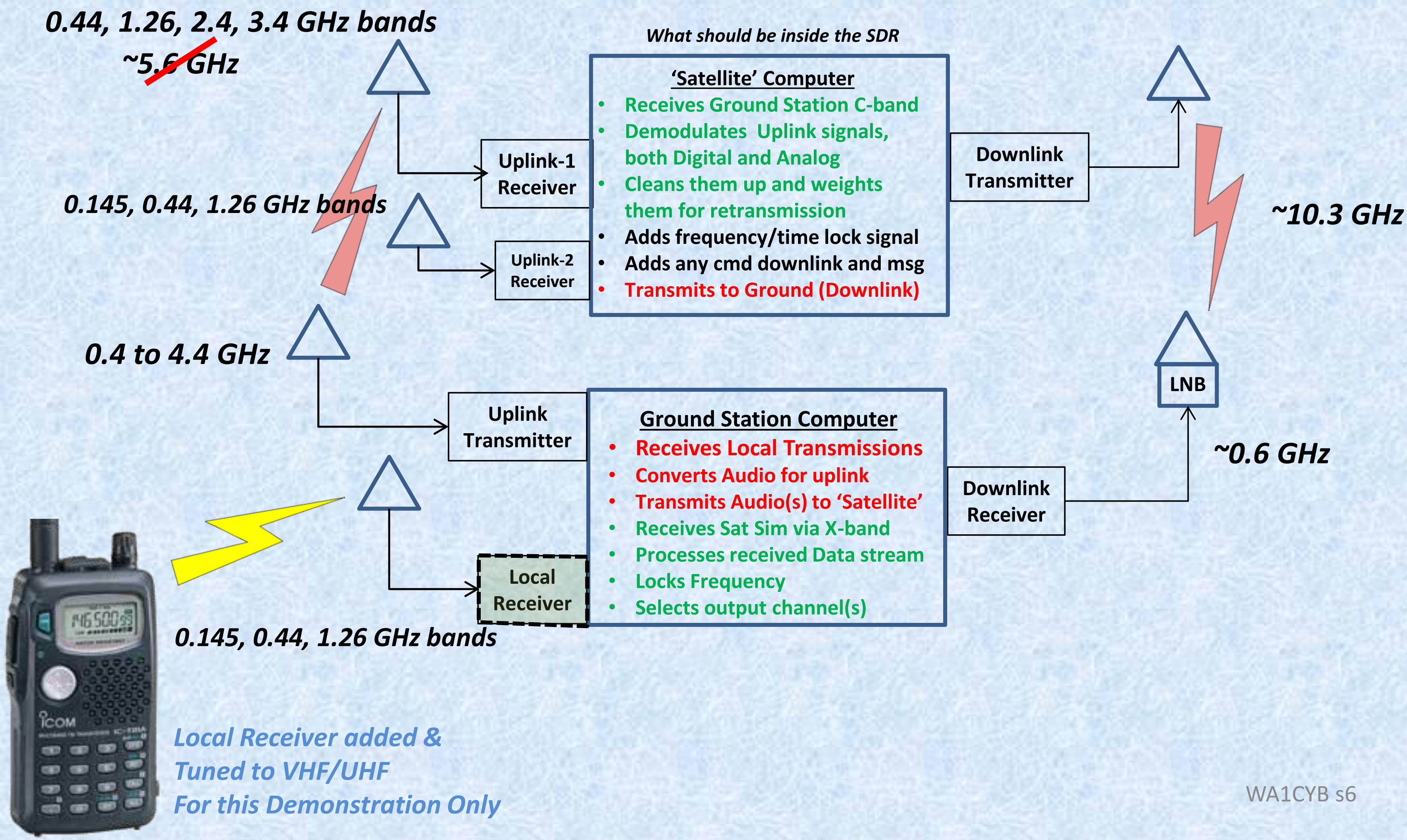
Satellite Demo:

- **Use *available* ETTUS SDR (N210) instead of the E310 or B205 that is desired.**
- **Use a laptop running GNU Radio software with UBUNTU Linux**
  - ***GNU Radio SW is loaded internally in the E310 version, but we needed a display***
- **Use a cheap RTL-SDR as the second satellite receiver**

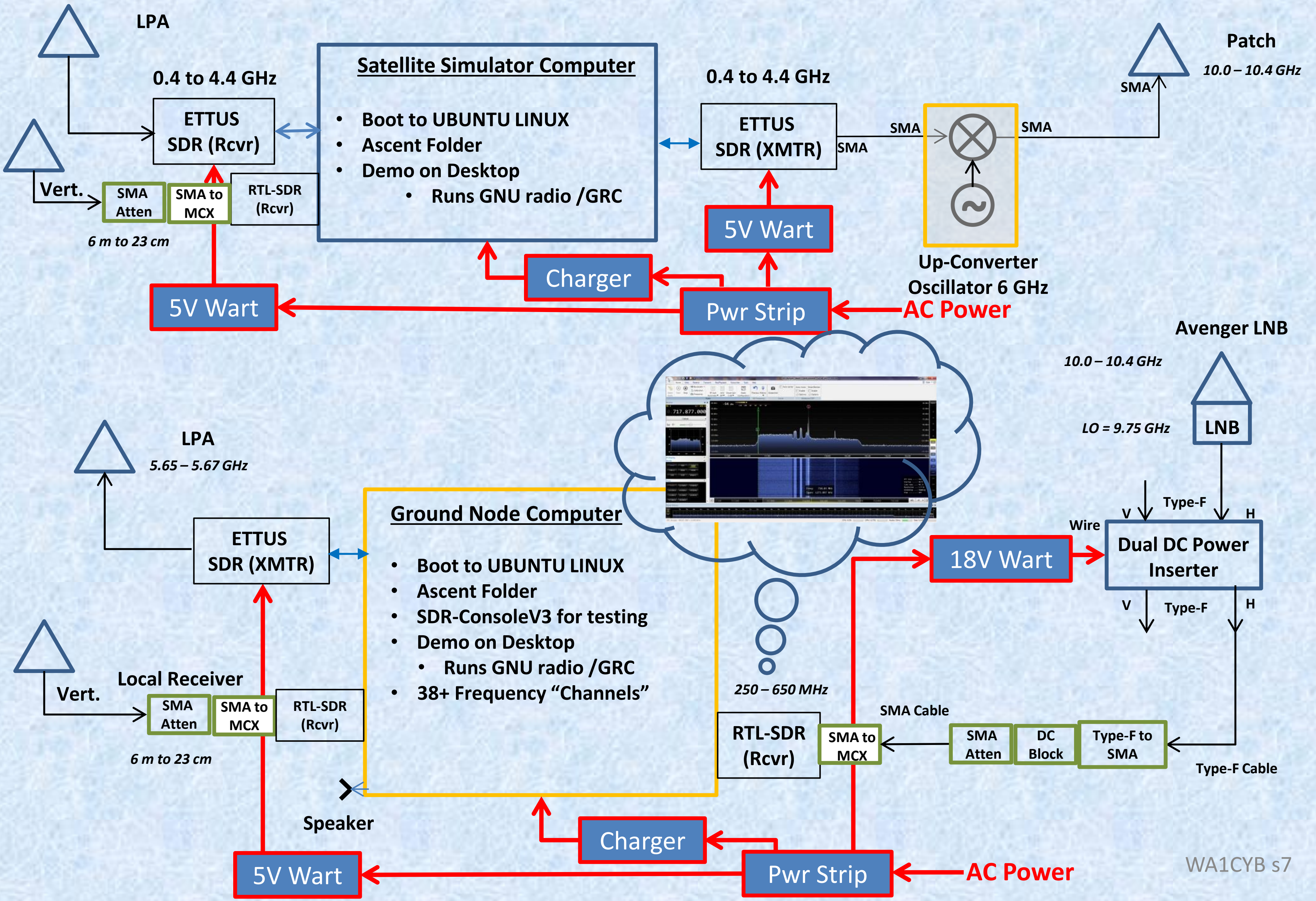
Ground Station Demo:

- **Use *available* ETTUS SDR (N210) instead of the E310 or B205 that is desired.**
- **Use a laptop running GNU Radio software with UBUNTU Linux**
  - ***GNU Radio SW is loaded internally in the E310 version, but we needed a display***
- **Use a cheap RTL-SDR as the local receiver in place of a microphone input**

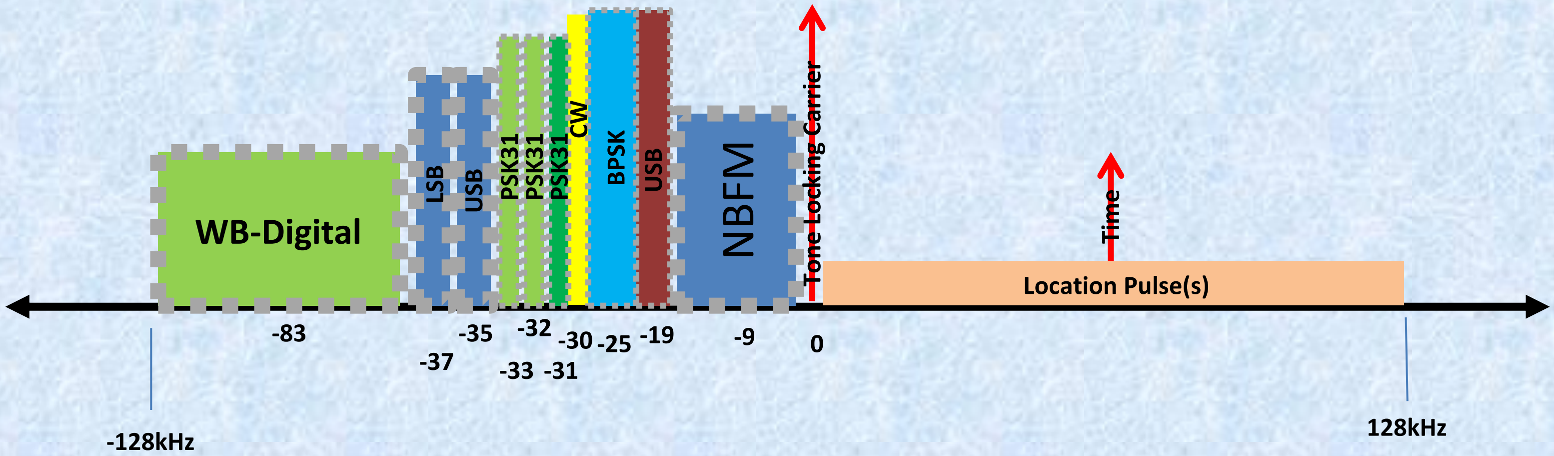
Ascent Demonstration- AMSAT Symposium



3U Satellite Demo Connection Diagram (Commo)



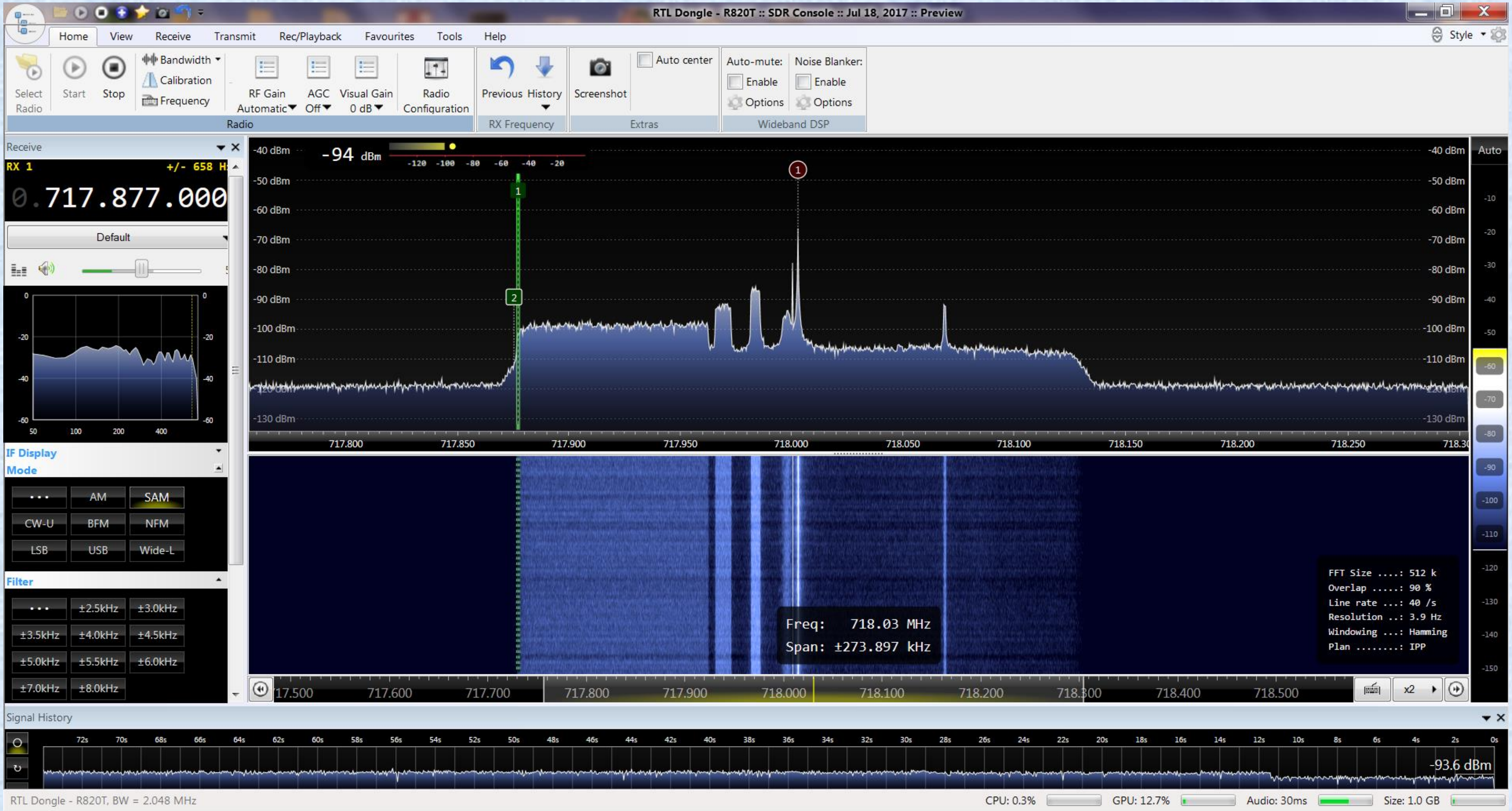
Example Downlink Frequency Band Plan
Arbitrary Peak Weighting



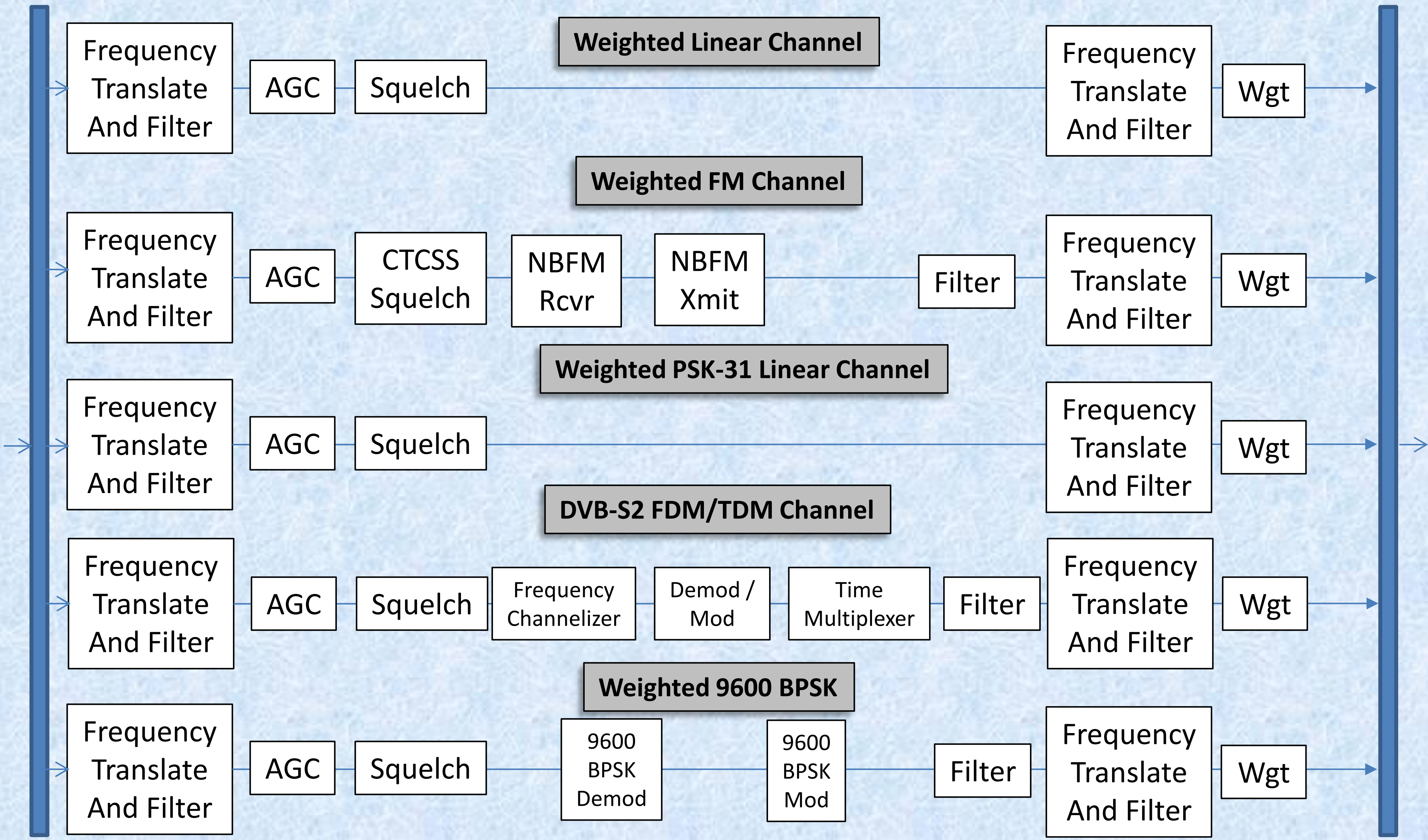
1. Tone Locking Carrier: Enables Ground Lock of Spectrum when Doppler is present
2. NBFM: Voice Channel(s) Translated from a Low Band
3. USB: Combined Multi-channel In Initiate contact and/or emergency channel down
4. BPSK: ID, Telemetry and data stream from satellite
5. CW: CW Bandwidth(s) Translated from a Low Band
6. PSK31-3: Satellite broadcast of ID, Time stamp, Location (ala GPS) and TLE
7. PSK31-2: Chat Channel #2
8. PSK31-1: Chat Channel #1
9. USB: Channel #3
10. LSB : Channel #4
11. Wide Band Digital: Channel #5
12. Location Pulse(s): Enables Precise Ranging/Location

As Seen at Avenger LNB Output

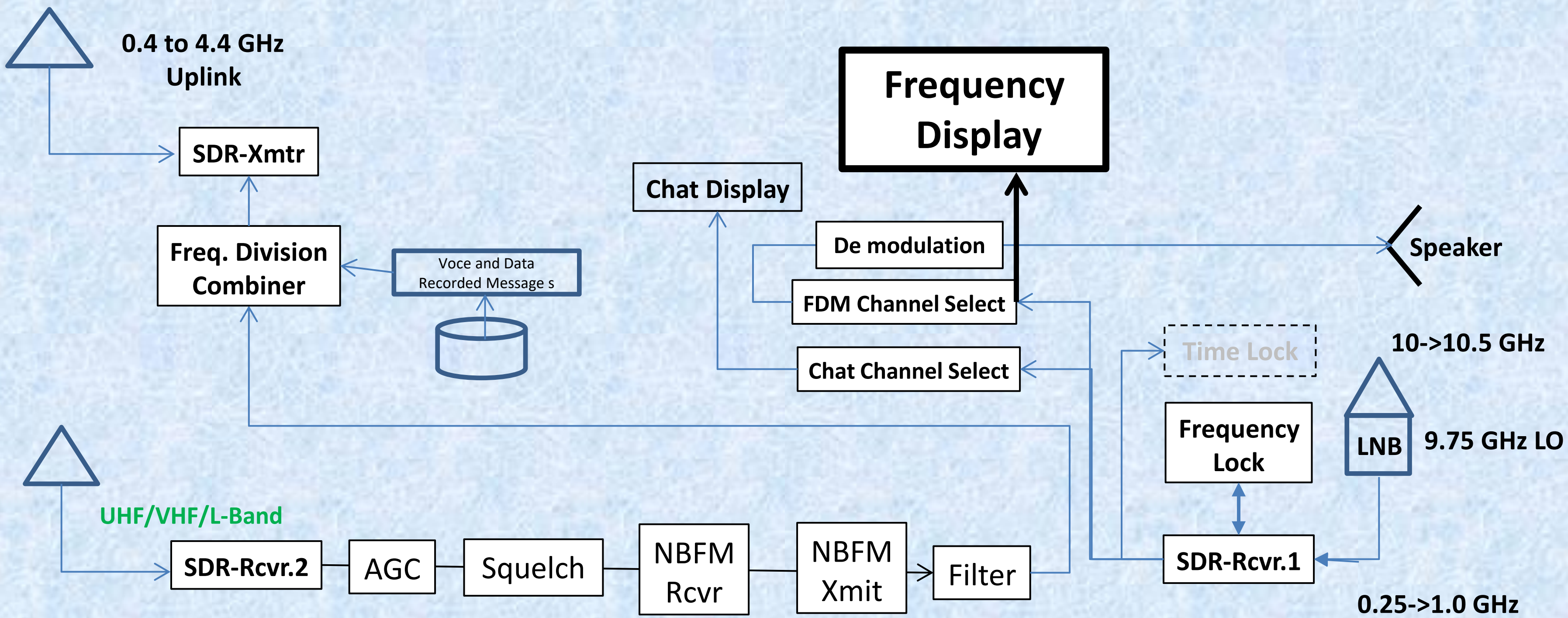
(Noise in at 5.5 GHz, Few channels enabled, Sat Out at 10.45 GHz)



Example Channel Breakdowns



Demo Ground Station



Local Receiver

Tuned to a ham band

RTL: freq. <1300 MHz

Amateur Radio Science Experiment Possibilities

- 2nd receiver can be tasked to do other functions
- Conduct an Amateur Frequency Survey (multi-bands)
- Examine propagation via WSPR and WJT modes
- Upper atmosphere scattering
- Urban noise sources versus frequency etc.
- Multiple frequency inputs on different bands with common output band channel (Cross band input) for emergency use. “Hoot and Holler” Conference call
- Shared Aperture Antenna Steering
- Automatic logging of satellite users/peak signal level /vs satellite location
- Very weak satellite transmitter power beacon experiments (no power amplifier, straight SDR power)
- Even more satellite input frequency receivers (1 chip for each 2 frequency bands)
- Harmonic beacons for frequencies above x-band…… endless possibilities!

~5 Minutes to Transfer 1 Complete Set of Measurements Using 1 Output Channel

		Bits	Bits	Bits
Total Points		**32 bit Xfer min.**	**16 bit Xfer min.**	**8 bit Xfer min.**
94,510	***points***	3,024,896	1,512,736	756,656
		~UNCOMPRESSED Downlink Times		
		seconds	seconds	seconds
	Rate	**Time to Xfer**	**Time to Xfer**	**Time to Xfer**
	1200	2,521	1,261	631
	9600	315	158	79
	24000	126	63	32
	48000	63	32	16

Go See the Demonstration!

- The Following slides show in a series of 5 test builds what the satellite could do
- If you want to build your own system, start with the simplest linear satellite (sat_test_1)
- Git-hub site has all the sat_test flow diagrams
- Helpful Notes contained in the flow graphs

Sat-test_1.grc
- **Linear repeater +/- 128 kHz w/ single agc and squelch**
- **CW tone at the output center frequency , f_{0out}**
- **ID (cw) at f_{0out} – 30.5 kHz**
- **Pseudo Doppler available (As if in LEO or higher orbit)**

Sat-test_2.grc
- **Sat_test_1.grc capability plus**
- **Added nbfm channel at receive center frequency, f_{0in}**
- **Added nbfm output at f_{0out}-9 kHz**
- **Squelch shown set low, Noise in nbfm Channel only**
- **Audio enabled for demo purposes**

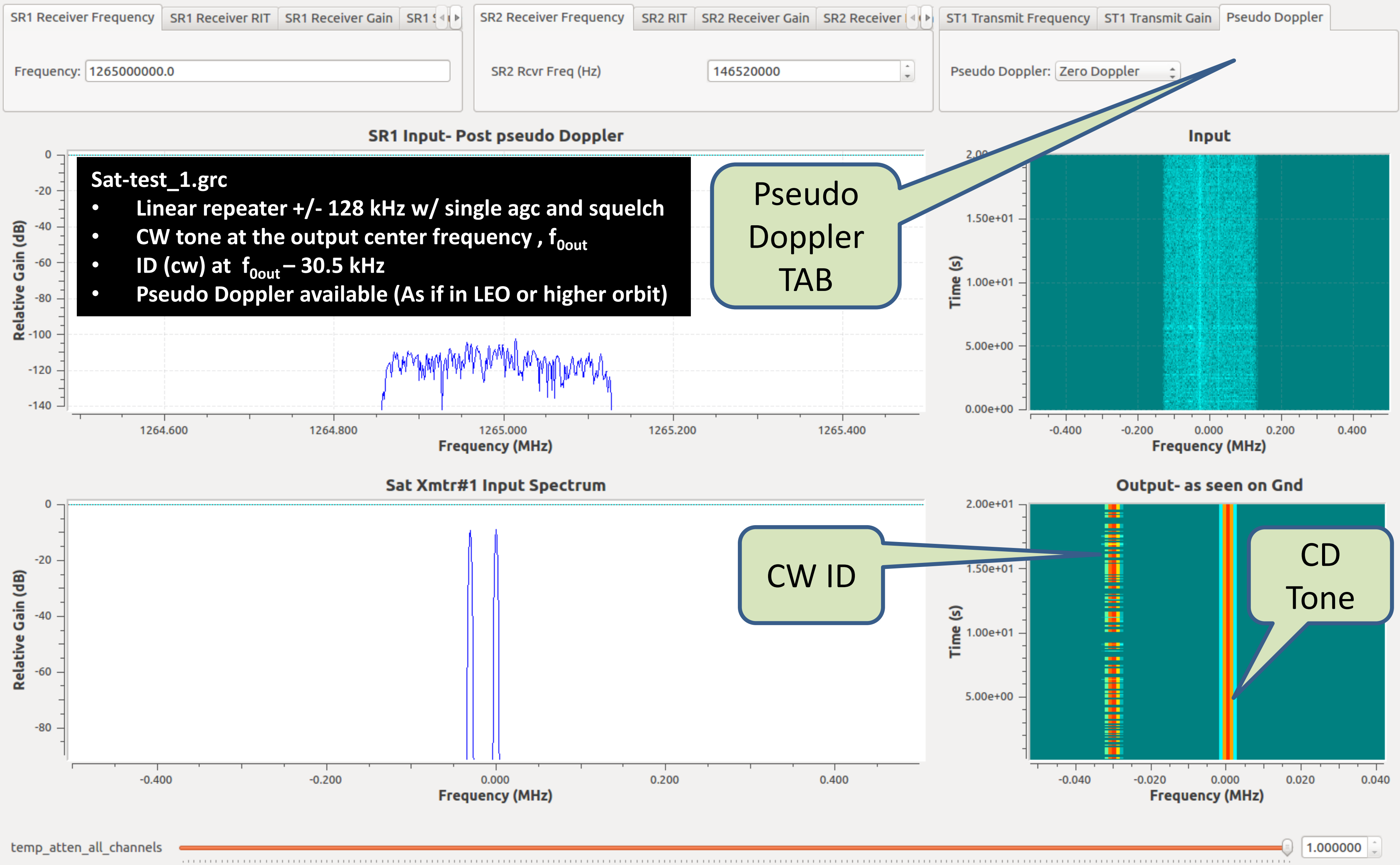
Sat-test_3.grc
- **Sat_test_2.grc capability plus**
- **Shifted 128kHz of input to f_{0in}-62.5 kHz**

Sat-test_4_r3.grc
- **Sat_test_3.grc capability plus**
- **250 kHz noise shifted up 12.5 kHz and attenuated 100 dB**
- **Added 32 (30 useable) linear channels (1.95 kHz bw)**
  - **Output 30 channels at f_{0out}-125 kHz to f_{0out}-62.5 kHz**
- **Added 8 input channels (7 useable) linear channels (7.81 kHz bw)**
  - **Lower edge if the bank at f_{0out}-13kHz, upper edge at f_{0out}-59 kHz**
- **Note that cw ID is also placed in the lower part of the 3rd filter from nbfm**
- **Second receiver (SR2) enabled**
- **Linear output of SR2 placed in the 1st filter from nbfm**

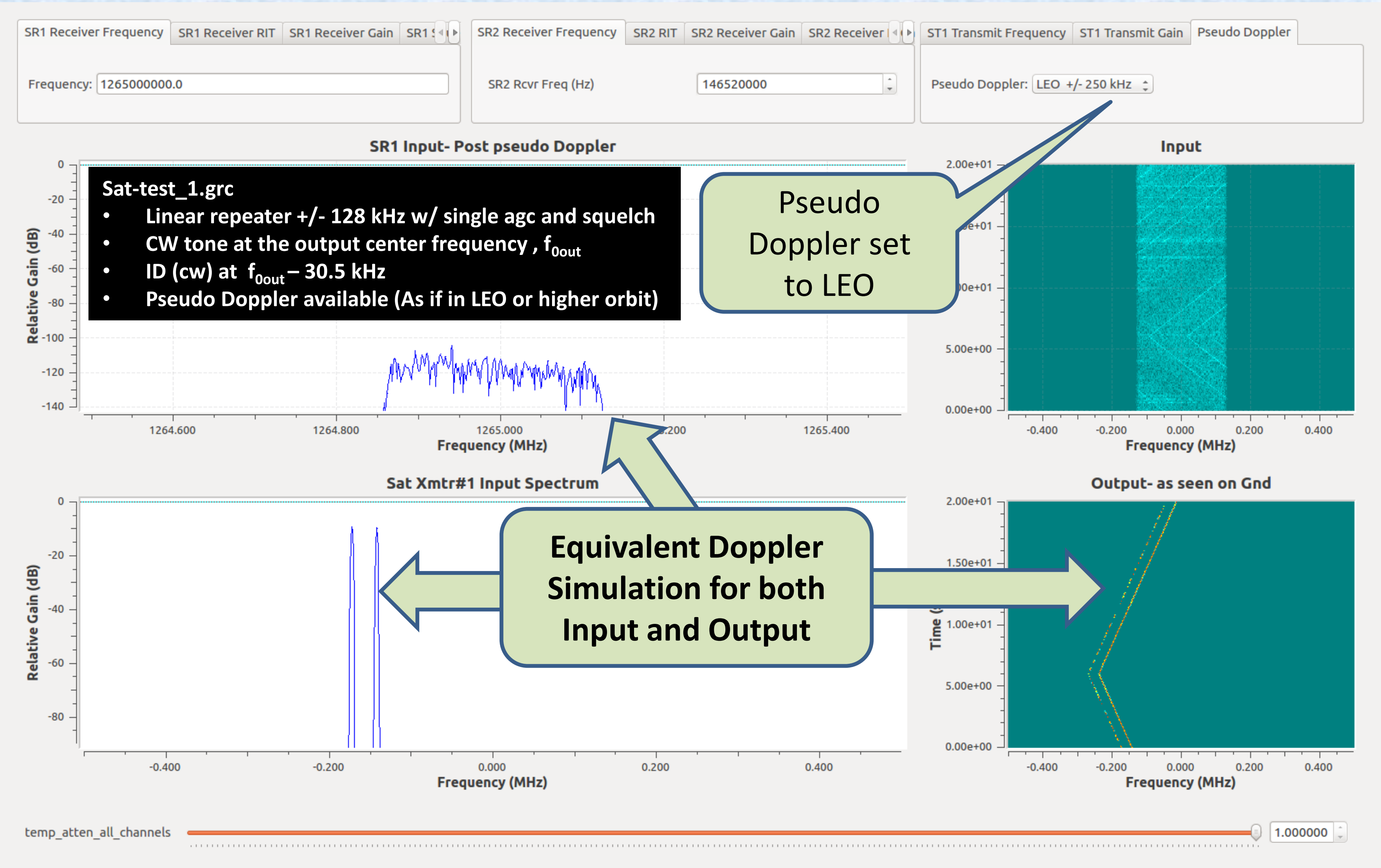
Sat-test_5.grc
- **Sat_test_4_r3.grc capability plus**
- **Adjusted nbfm bw on receive**
- **Added three psk31 transmit streams, 1kHz apart , each with ID text**
  - **Three placed in 4th 7.81 kHz linear channel at ~f_{0out}-40 kHz**
  - **Placed another psk31 stream on a reduced output upper stream**
    - **Output frequency just under f_{0out}-125 kHz**
- **Maxes out current external computer resource used for development**

https://github.com/WA1CYB/satellite_ground_emulator/tree/master/Ascent/Concept%20Demo%20System

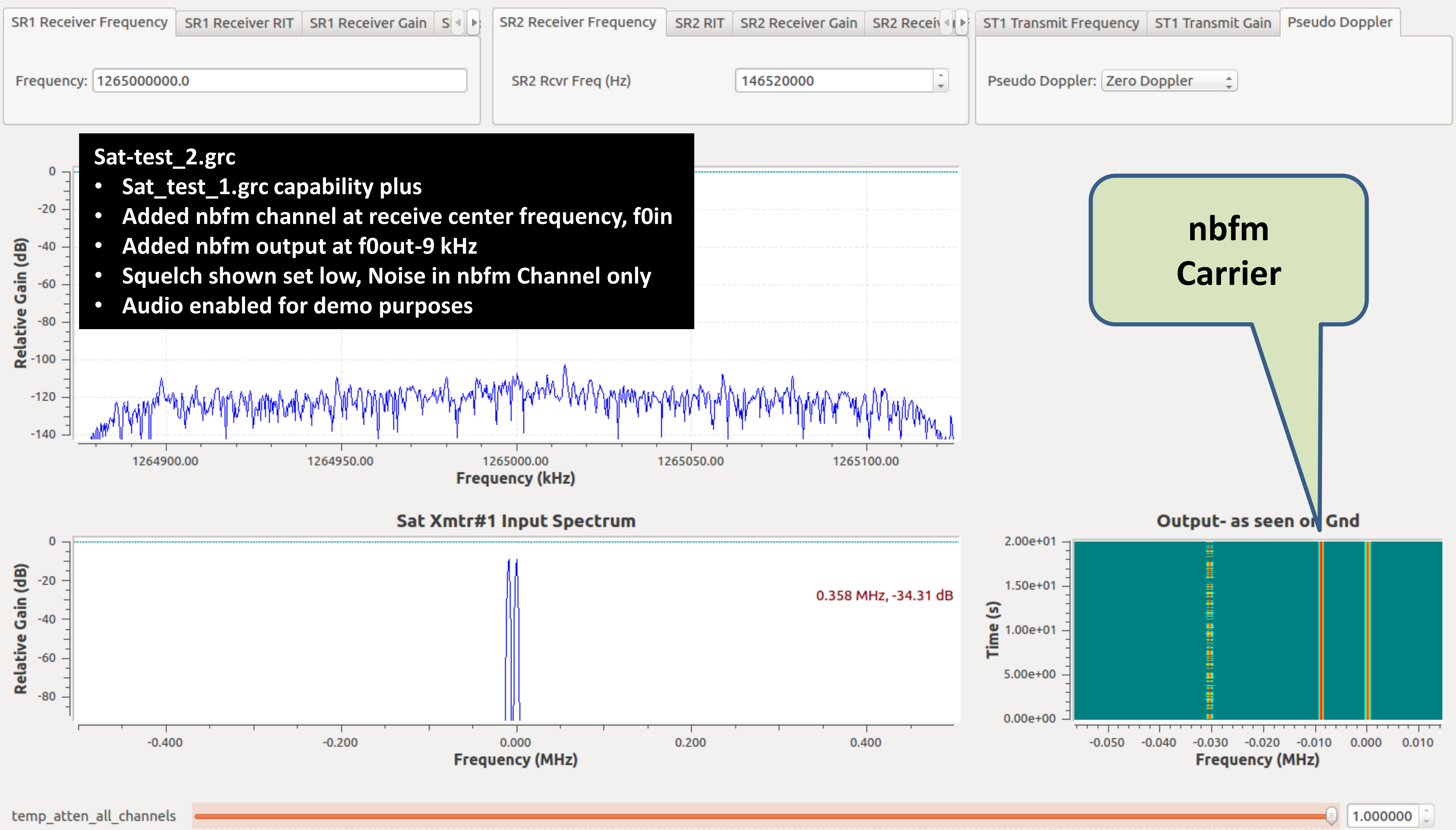
sat_test_1_0.png



sat_test_1_1.png



sat_test_2_0.png



Sat-test_2.grc

- Sat_test_1.grc capability plus
- Added nbfm channel at receive center frequency, f0in
- Added nbfm output at f0out-9 kHz
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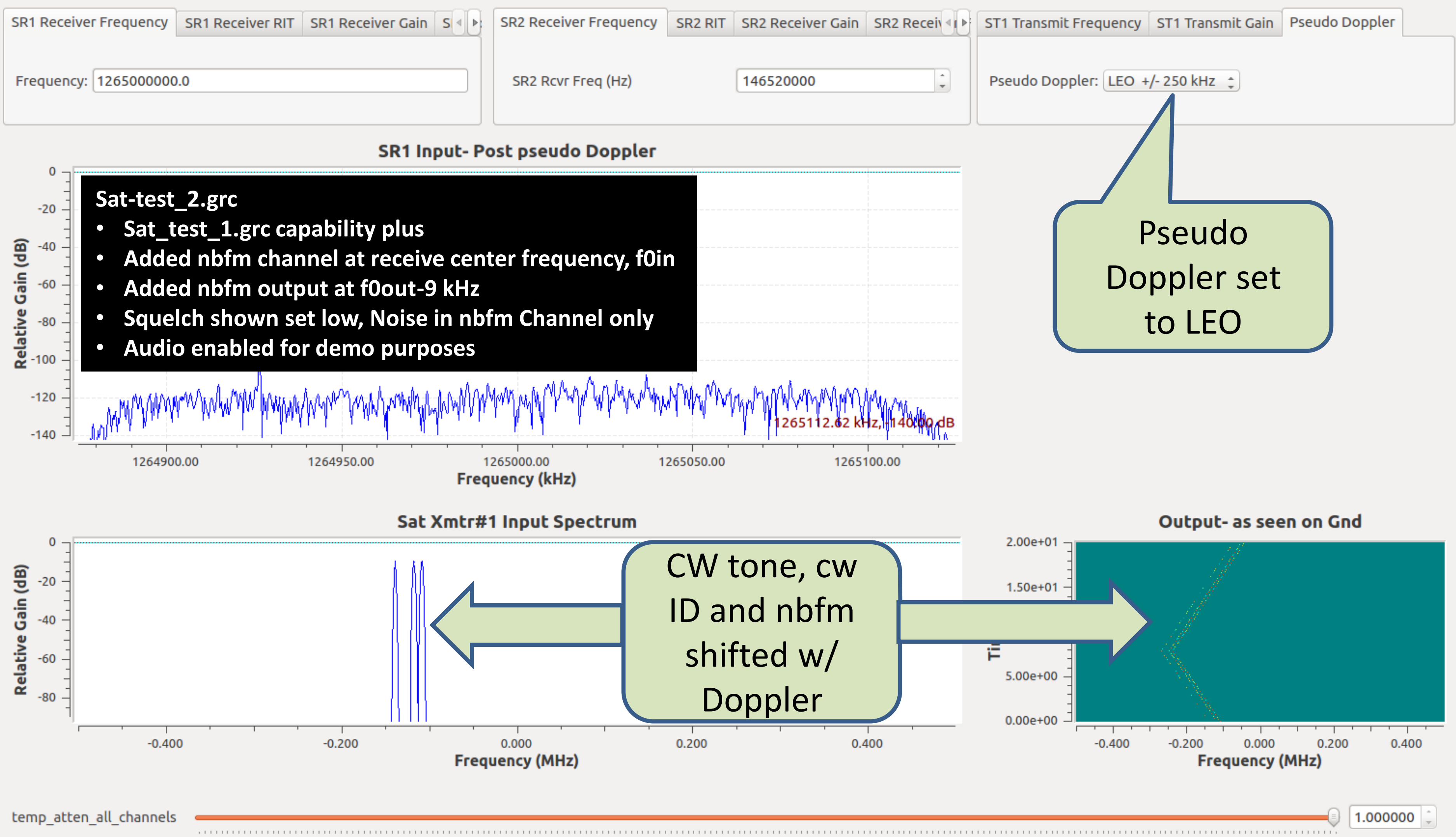
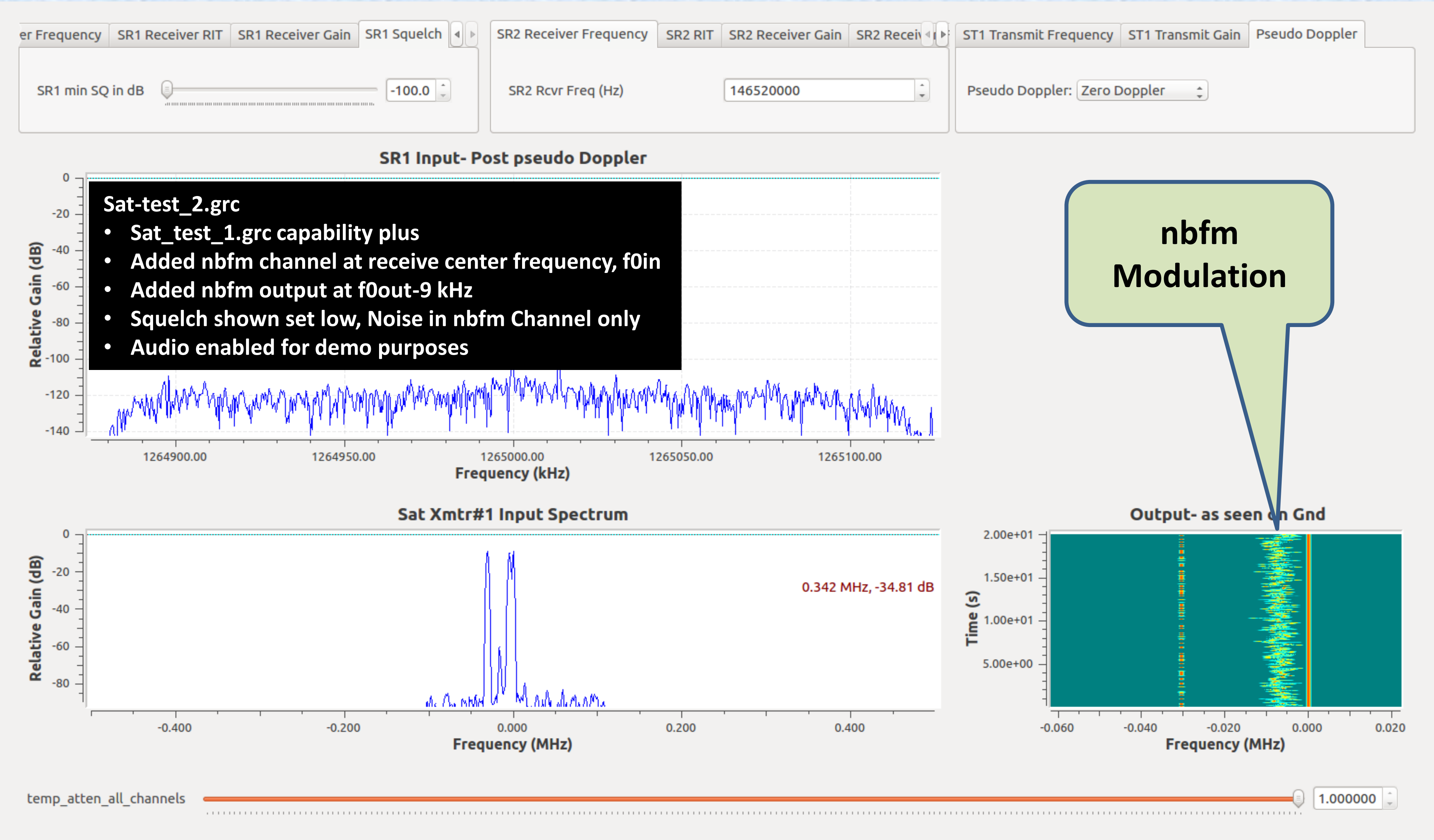
- Audio enabled for demo purposes

sat_test_2_1.png



sat_test_2_2.png



Sat-test_2.grc

- Sat_test_1.grc capability plus
- Added nbfm channel at receive center frequency, f0in
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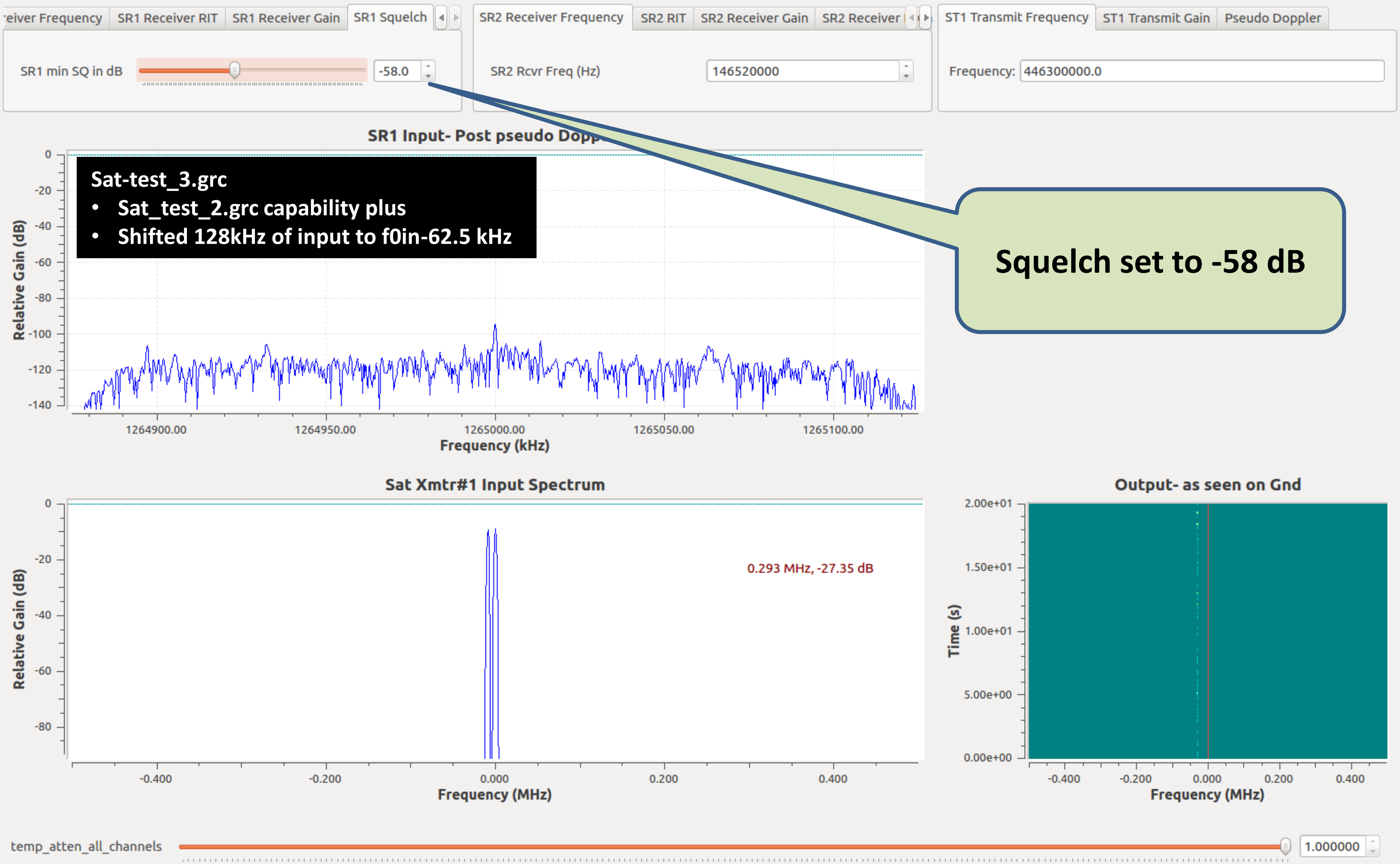
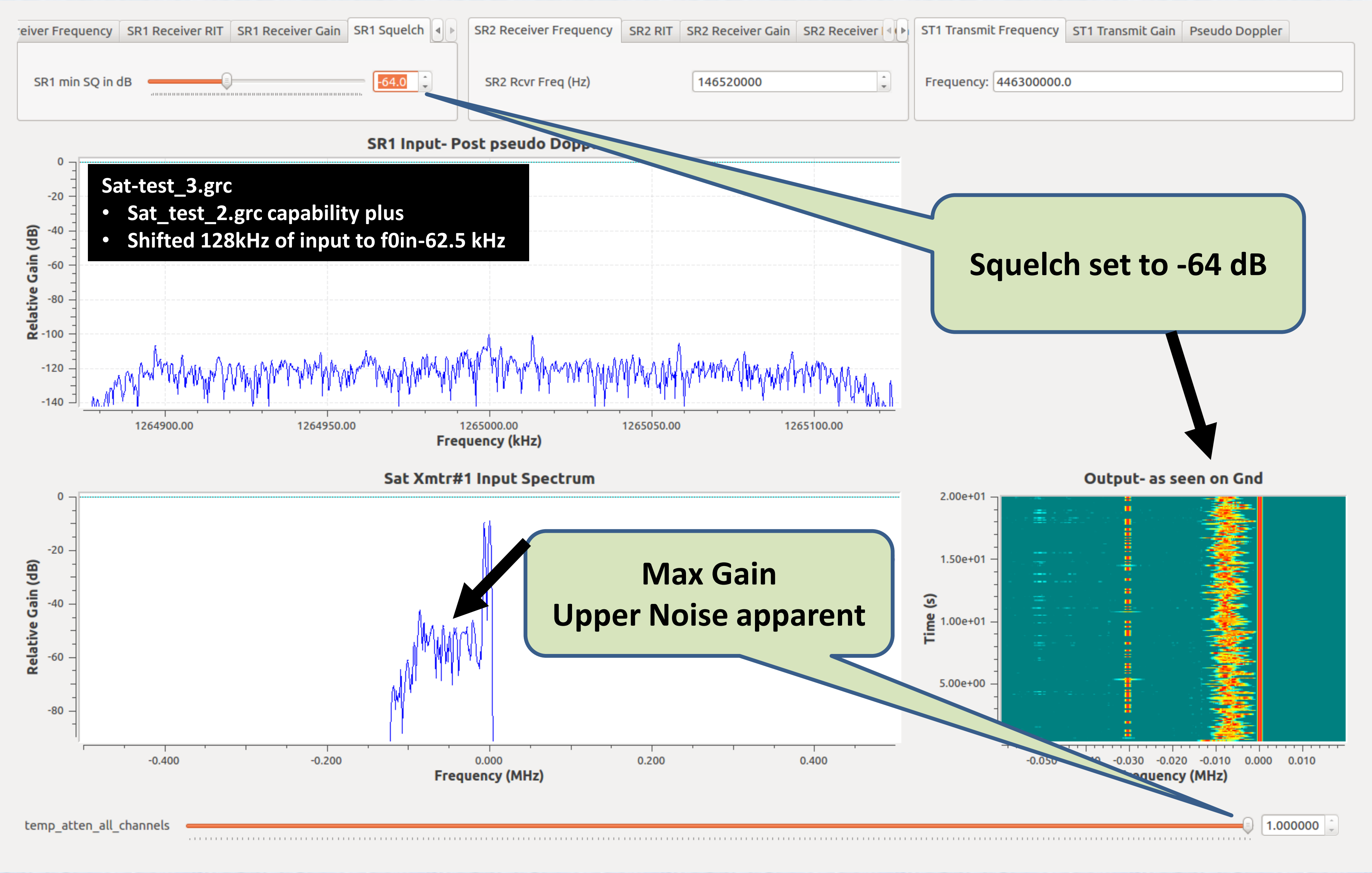
nbfm Modulation

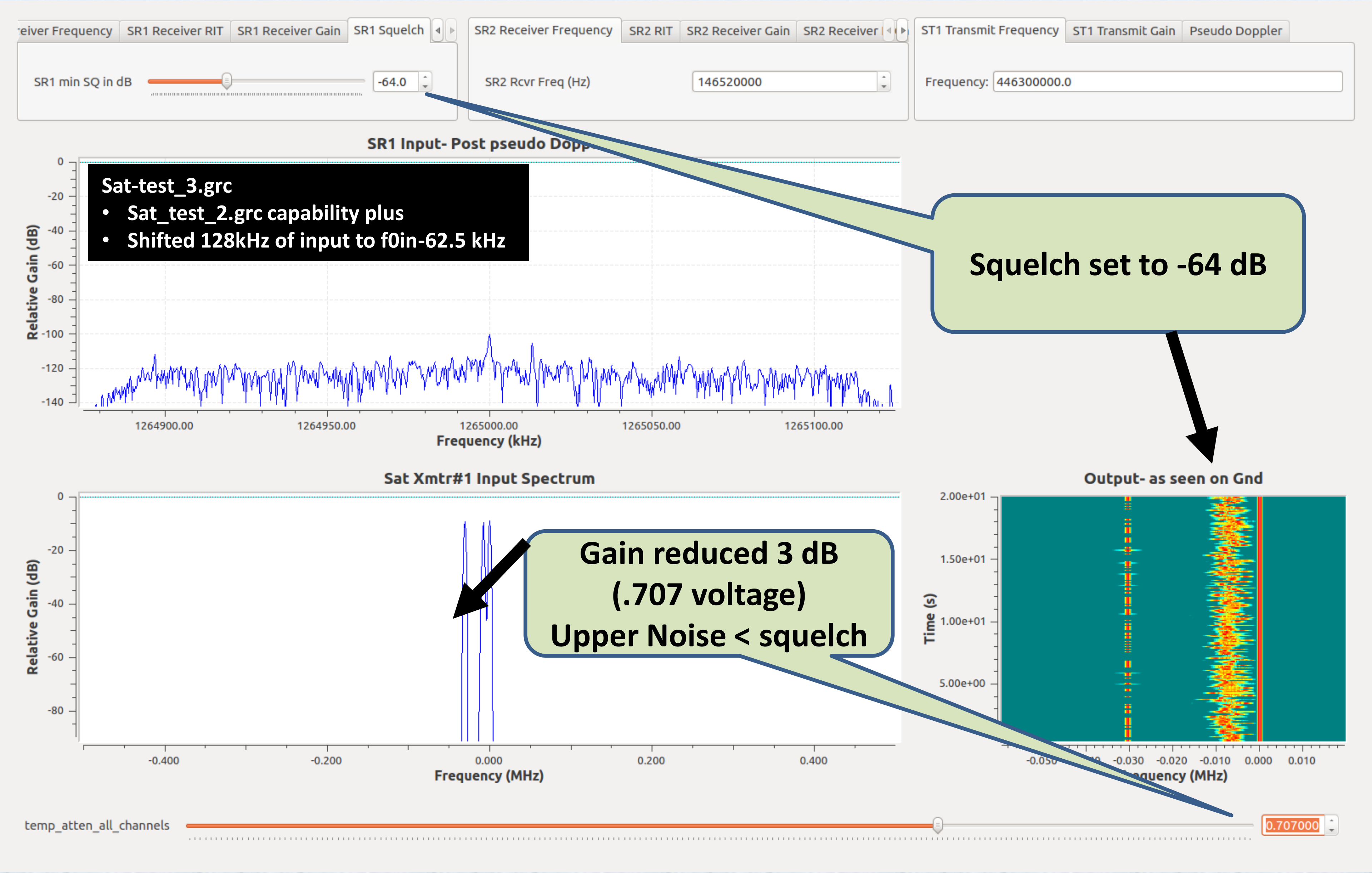
sat_test_3_0.png



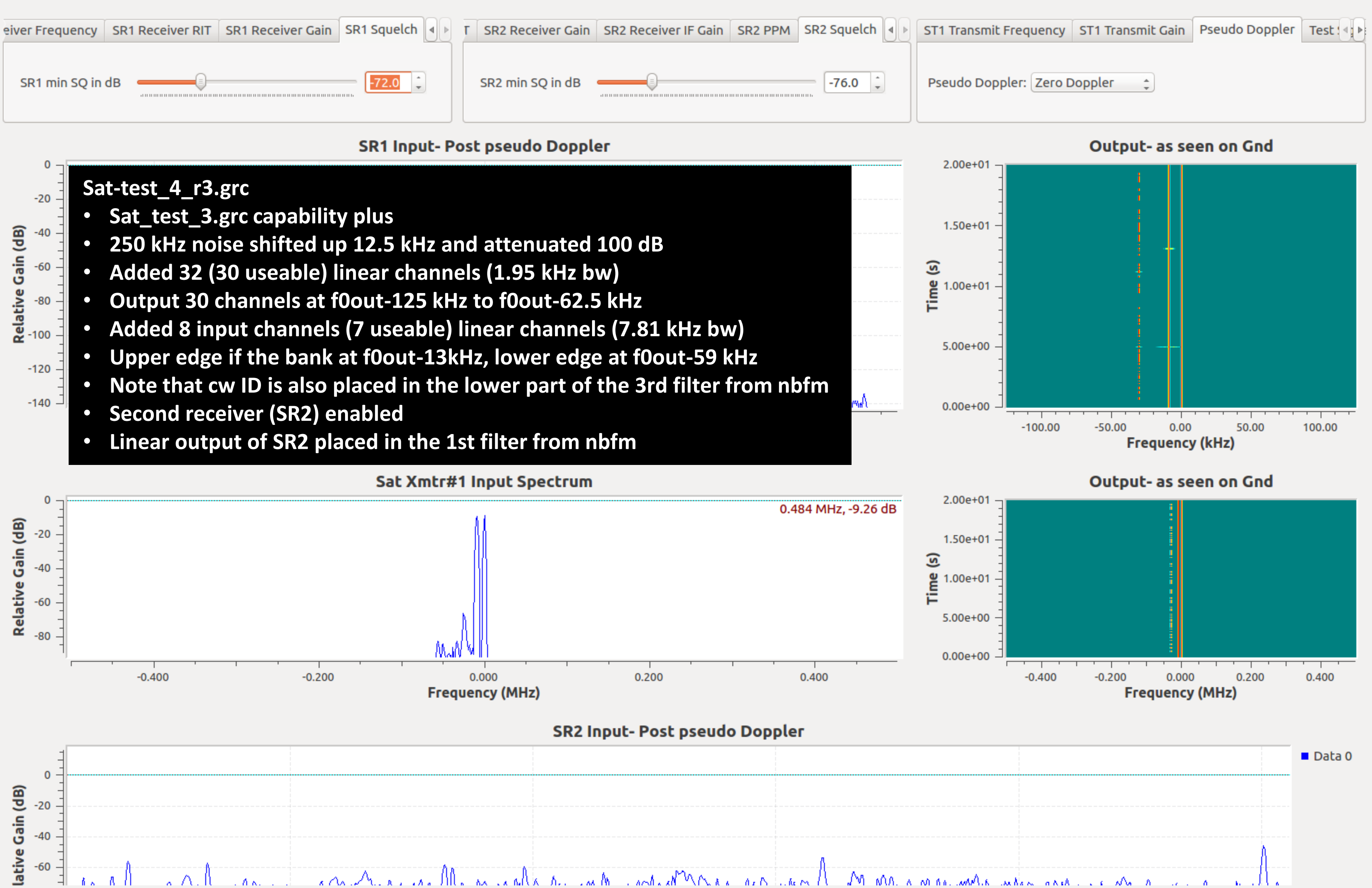
sat_test_3_1.png



sat_test_3_2.png



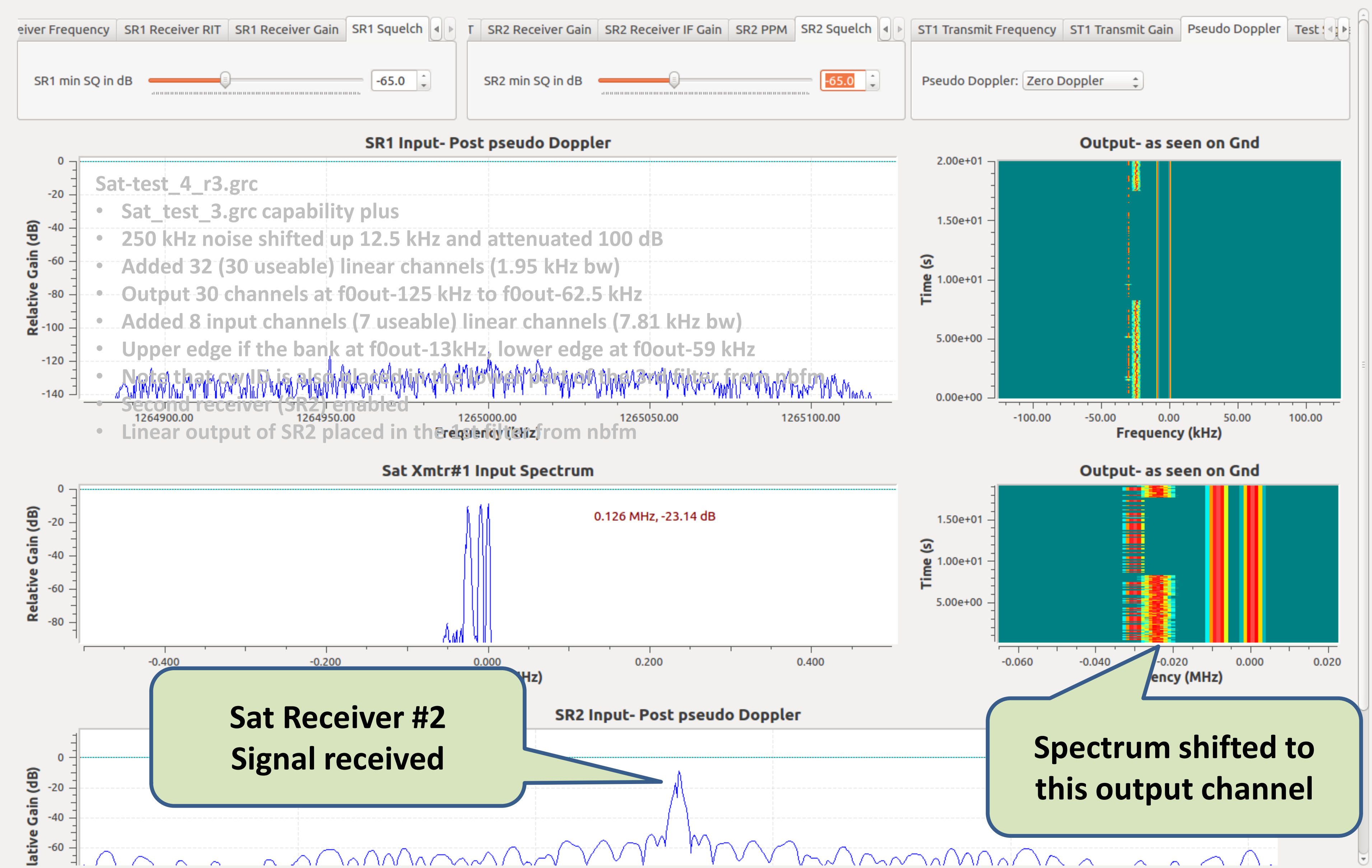
sat_test_4_0.png



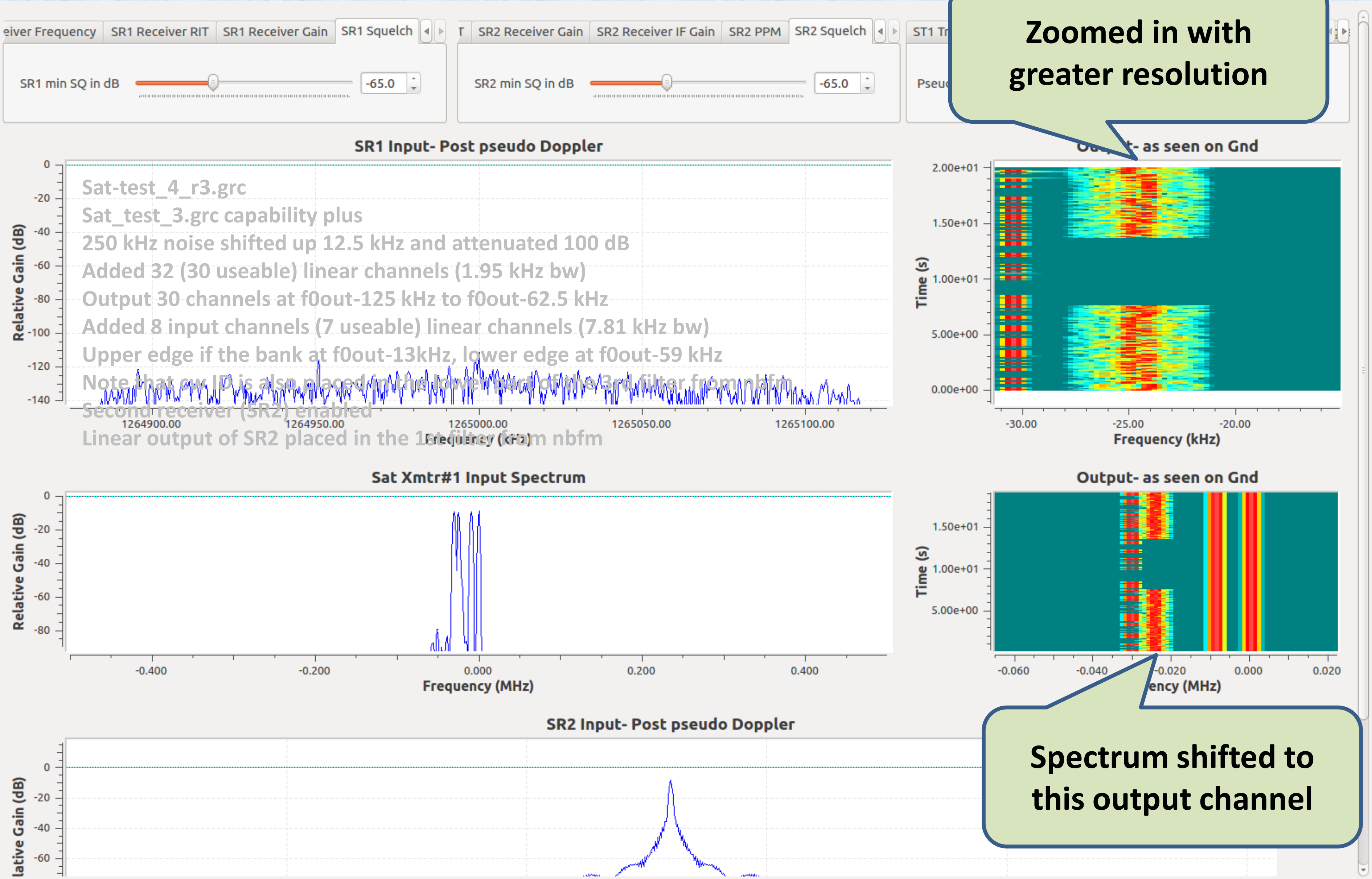
Sat-test_4_r3.grc

- Sat_test_3.grc capability plus
- 250 kHz noise shifted up 12.5 kHz and attenuated 100 dB
- Added 32 (30 useable) linear channels (1.95 kHz bw)
- Output 30 channels at f0out-125 kHz to f0out-62.5 kHz
- Added 8 input channels (7 useable) linear channels (7.81 kHz bw)
- Upper edge if the bank at f0out-13kHz, lower edge at f0out-59 kHz
- Note that cw ID is also placed in the lower part of the 3rd filter from nbfm
- Second receiver (SR2) enabled
- Linear output of SR2 placed in the 1st filter from nbfm

sat_test_4_2.png



sat_test_4_3.png



Sat-test_4_r3.grc

Sat_test_3.grc capability plus

250 kHz noise shifted up 12.5 kHz and attenuated 100 dB

Added 32 (30 useable) linear channels (1.95 kHz bw)

Output 30 channels at f0out-125 kHz to f0out-62.5 kHz

Added 8 input channels (7 useable) linear channels (7.81 kHz bw)

Upper edge if the bank at f0out-13kHz, lower edge at f0out-59 kHz

Note that cw ID is also placed in the lower band of the 3rd filter from nbfm

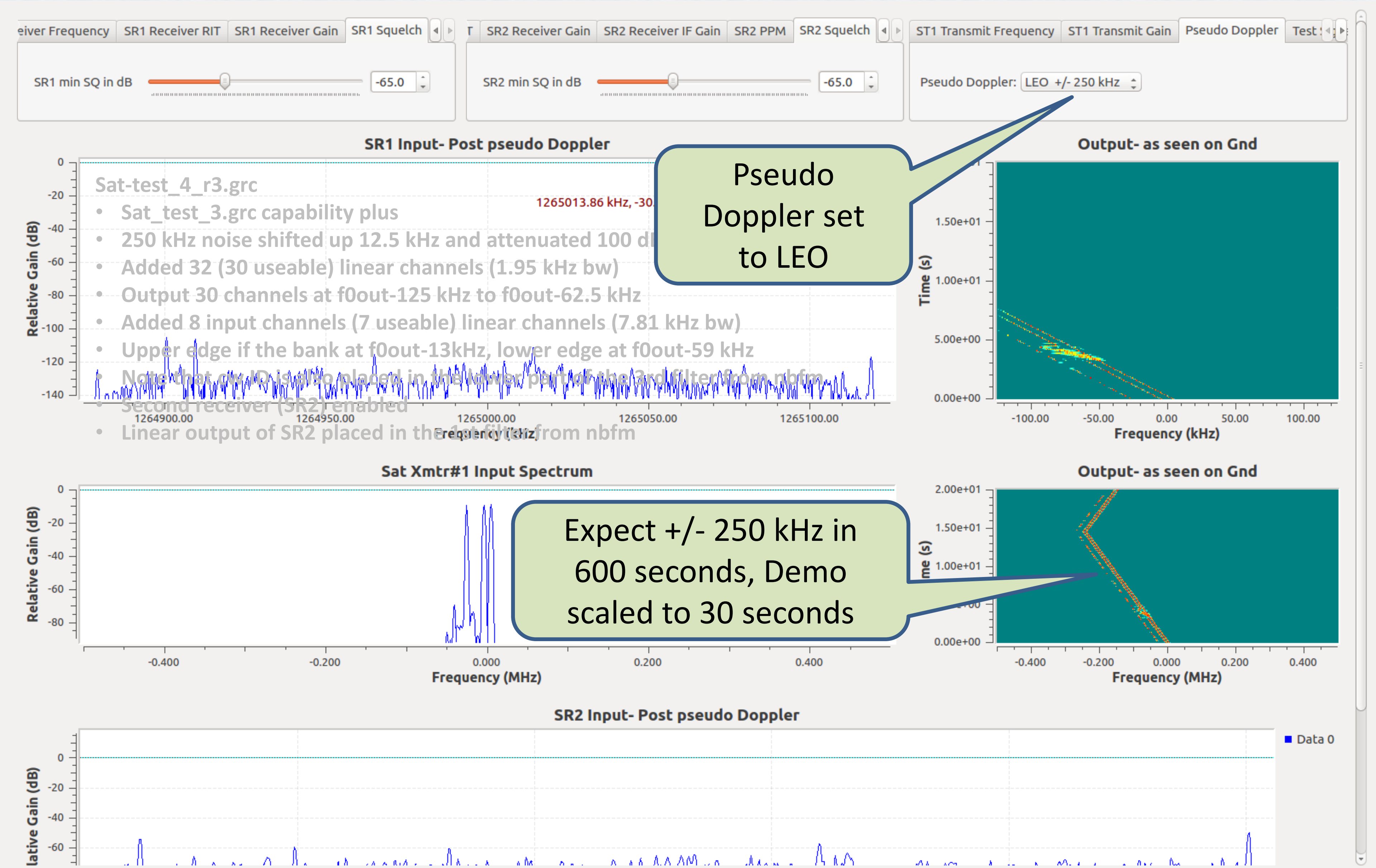
Second receiver (SR2) enabled

Linear output of SR2 placed in the 1st filter from nbfm

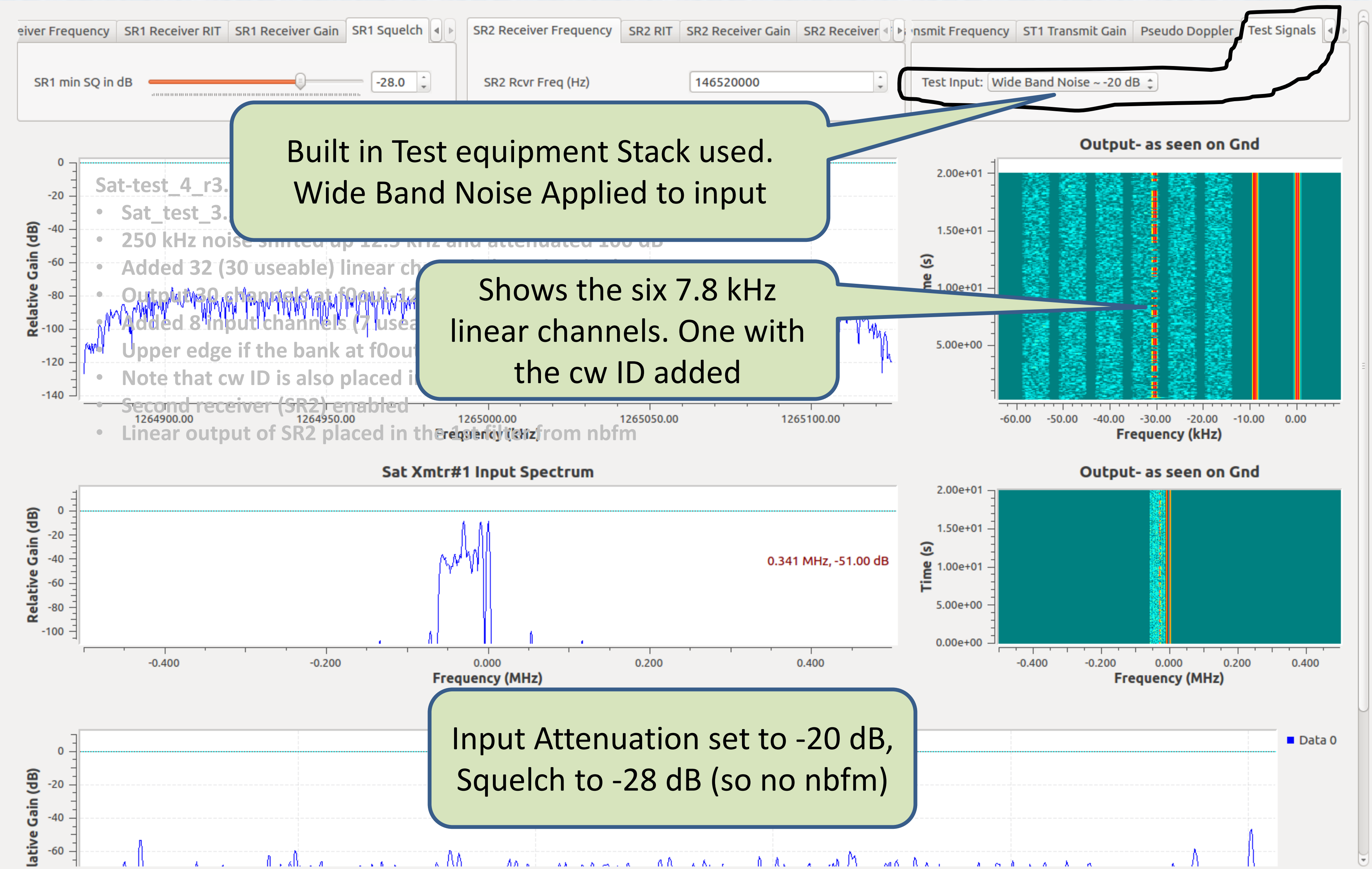
Zoomed in with greater resolution

Spectrum shifted to this output channel

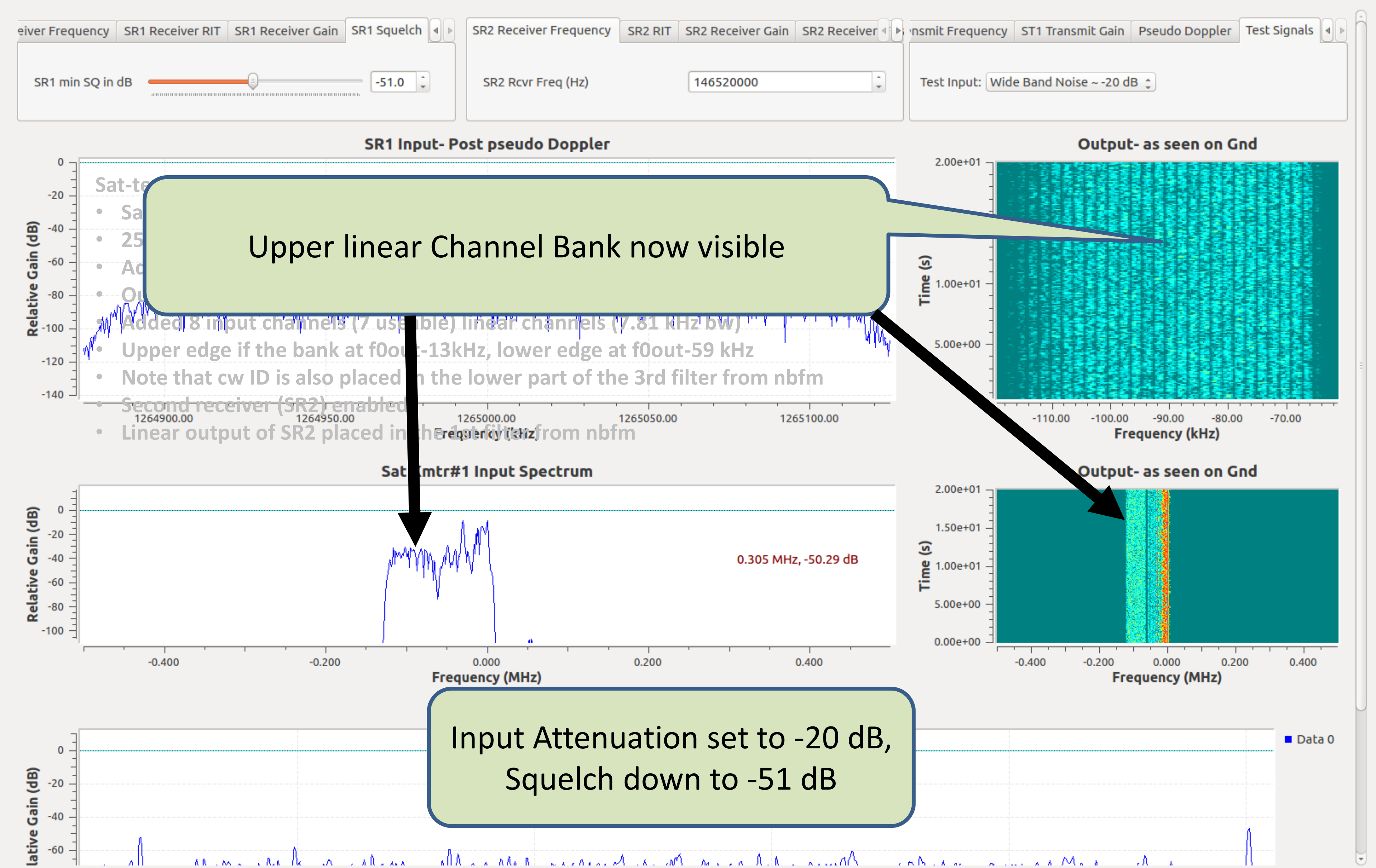
sat_test_4_4.png



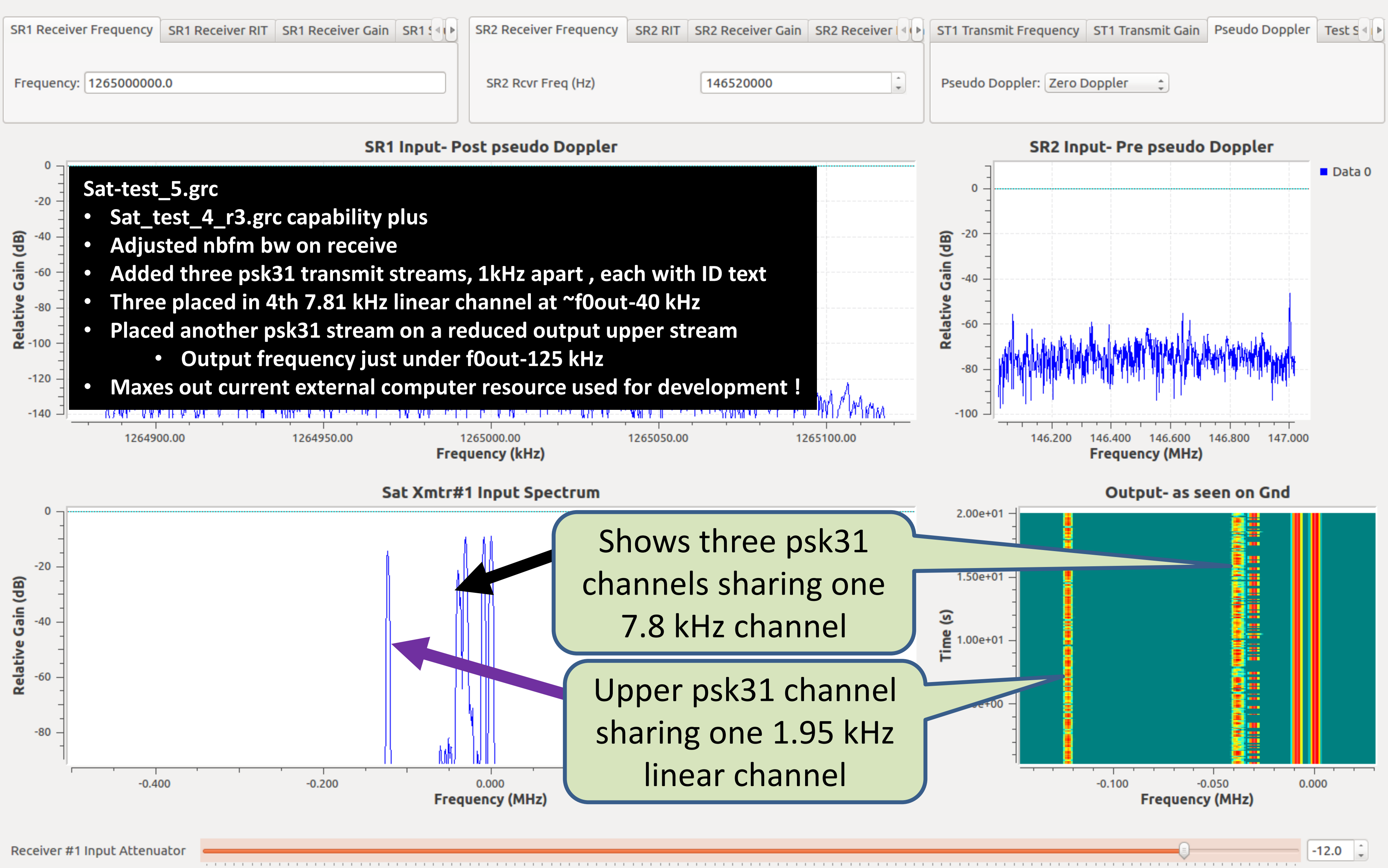
sat_test_4_6.png



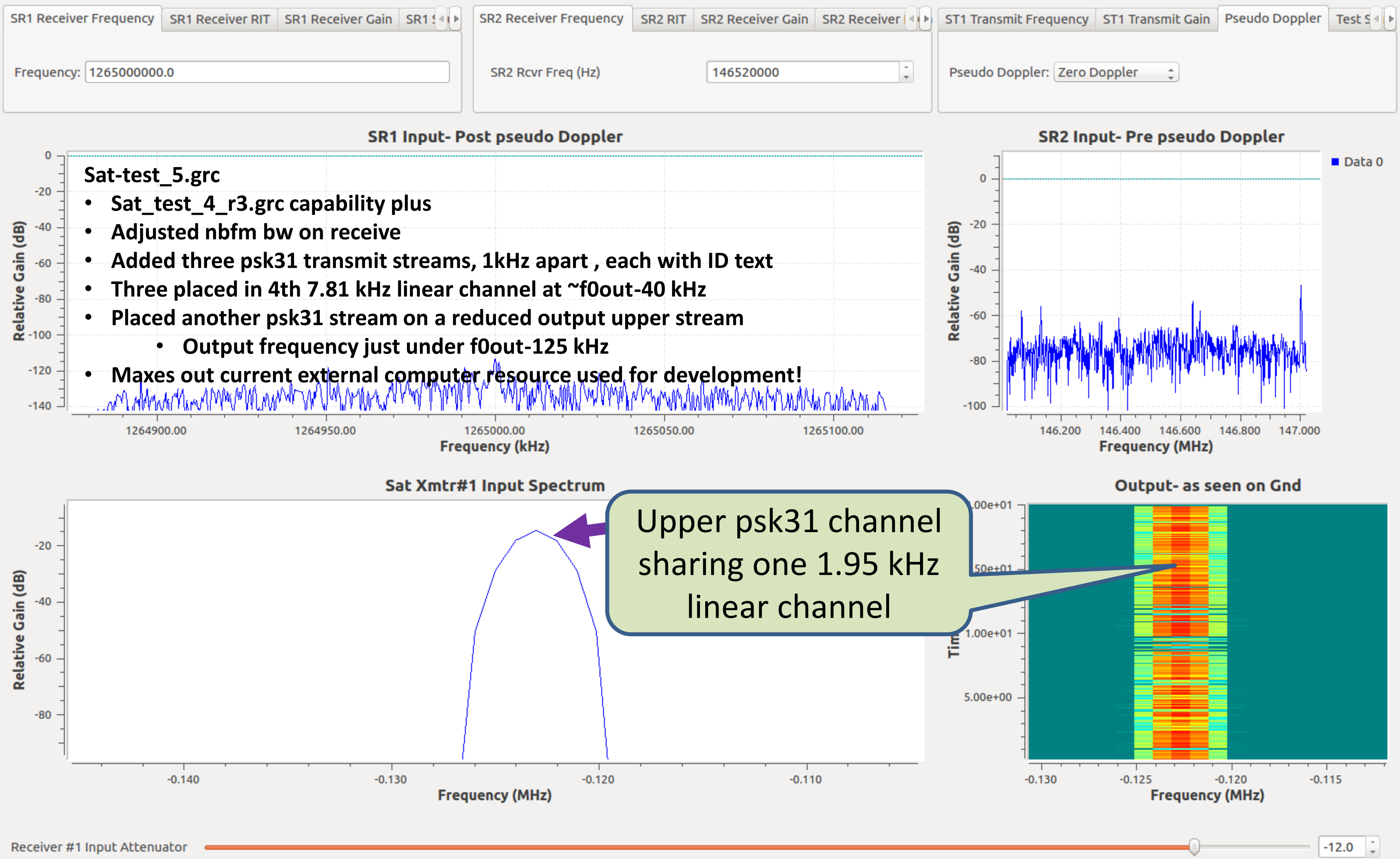
sat_test_4_7.png



sat_test_5_0.png



sat test 5 1.png



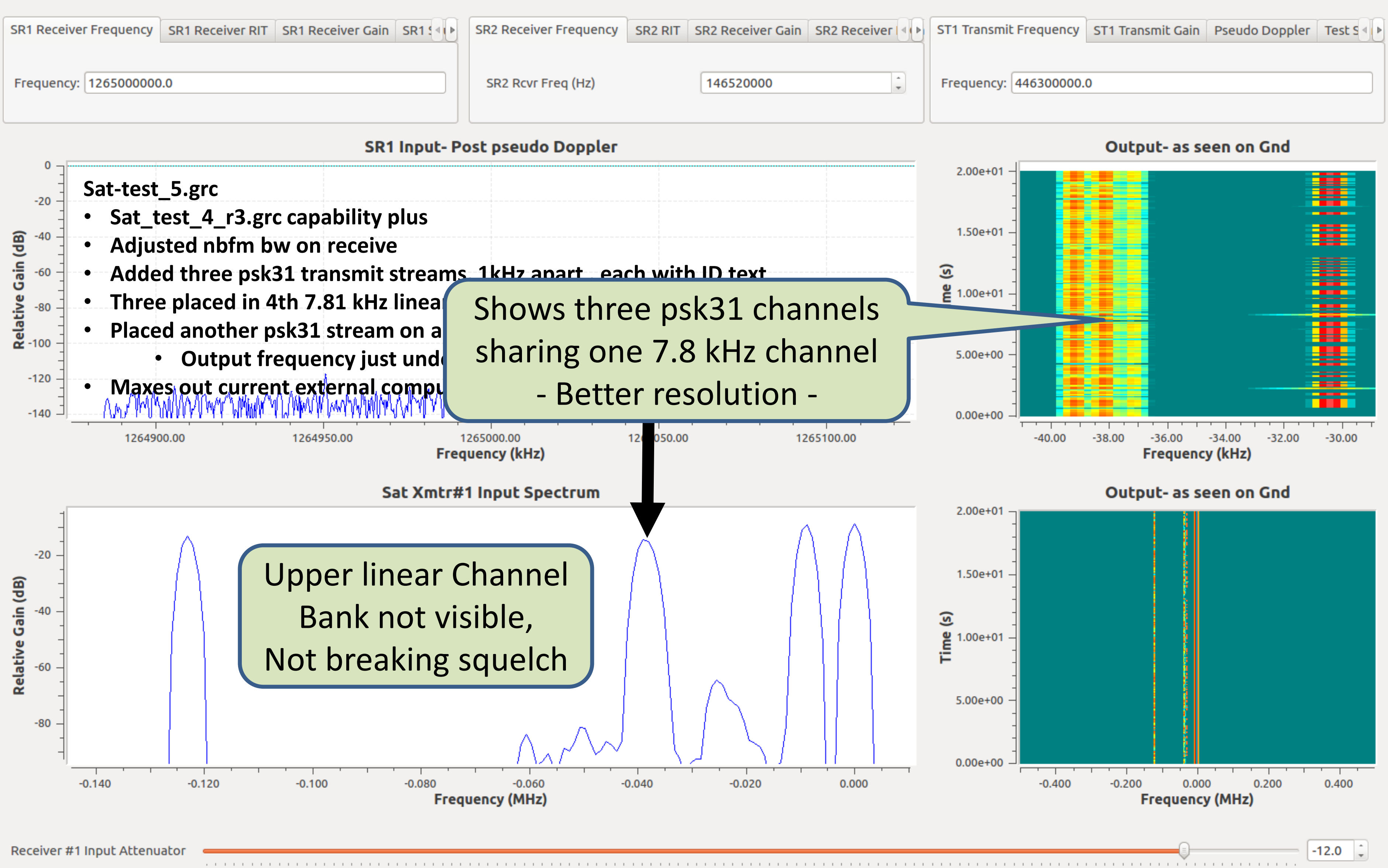
Sat-test_5.grc

- Sat_test_4_r3.grc capability plus
- Adjusted nbfm bw on receive
- Added three psk31 transmit streams, 1kHz apart , each with ID text
- Three placed in 4th 7.81 kHz linear channel at ~f0out-40 kHz
- Placed another psk31 stream on a reduced output upper stream
  - Output frequency just under f0out-125 kHz
- Maxes out current external computer resource used for development!

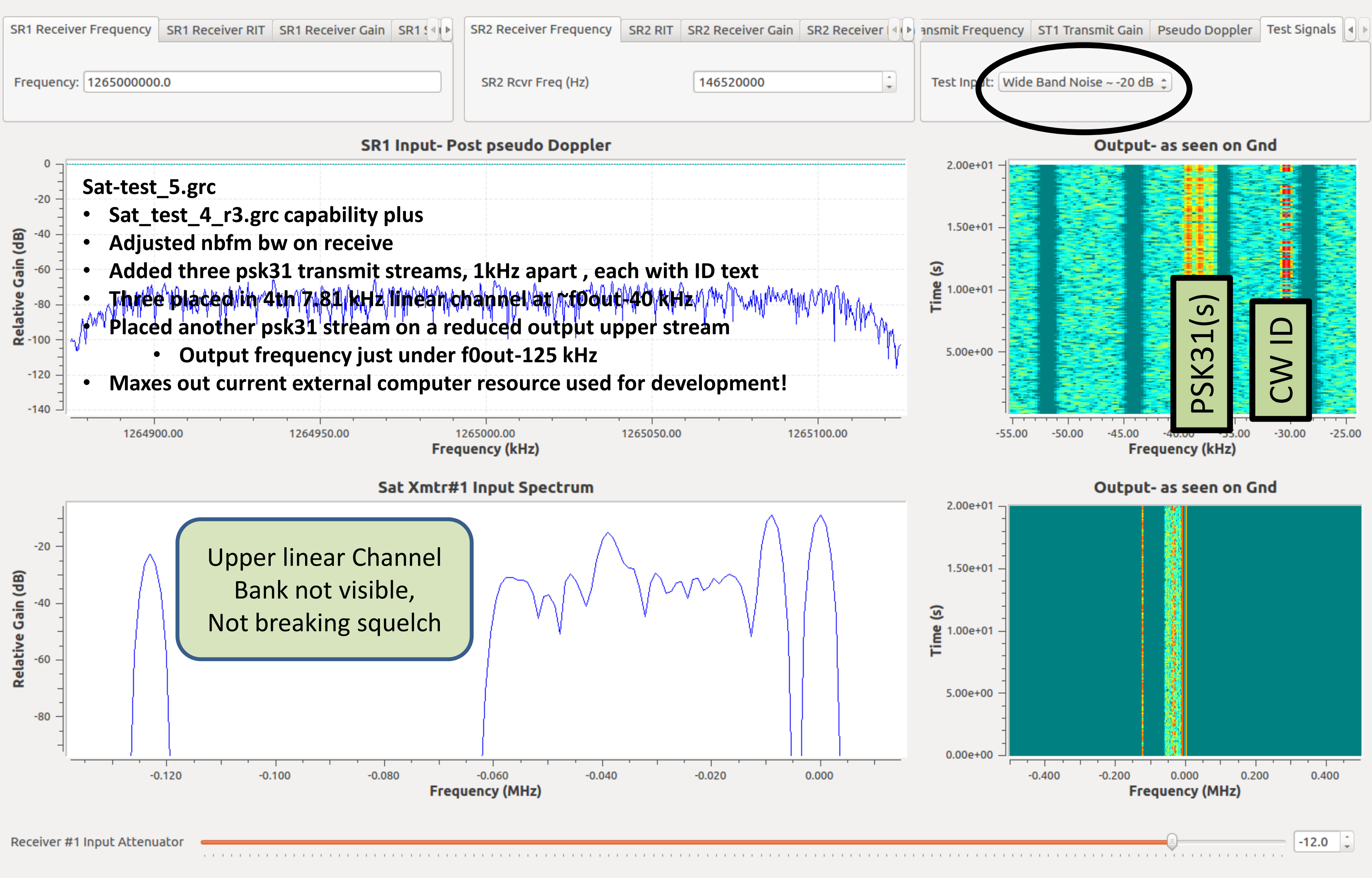
Upper psk31 channel sharing one 1.95 kHz linear channel

dB

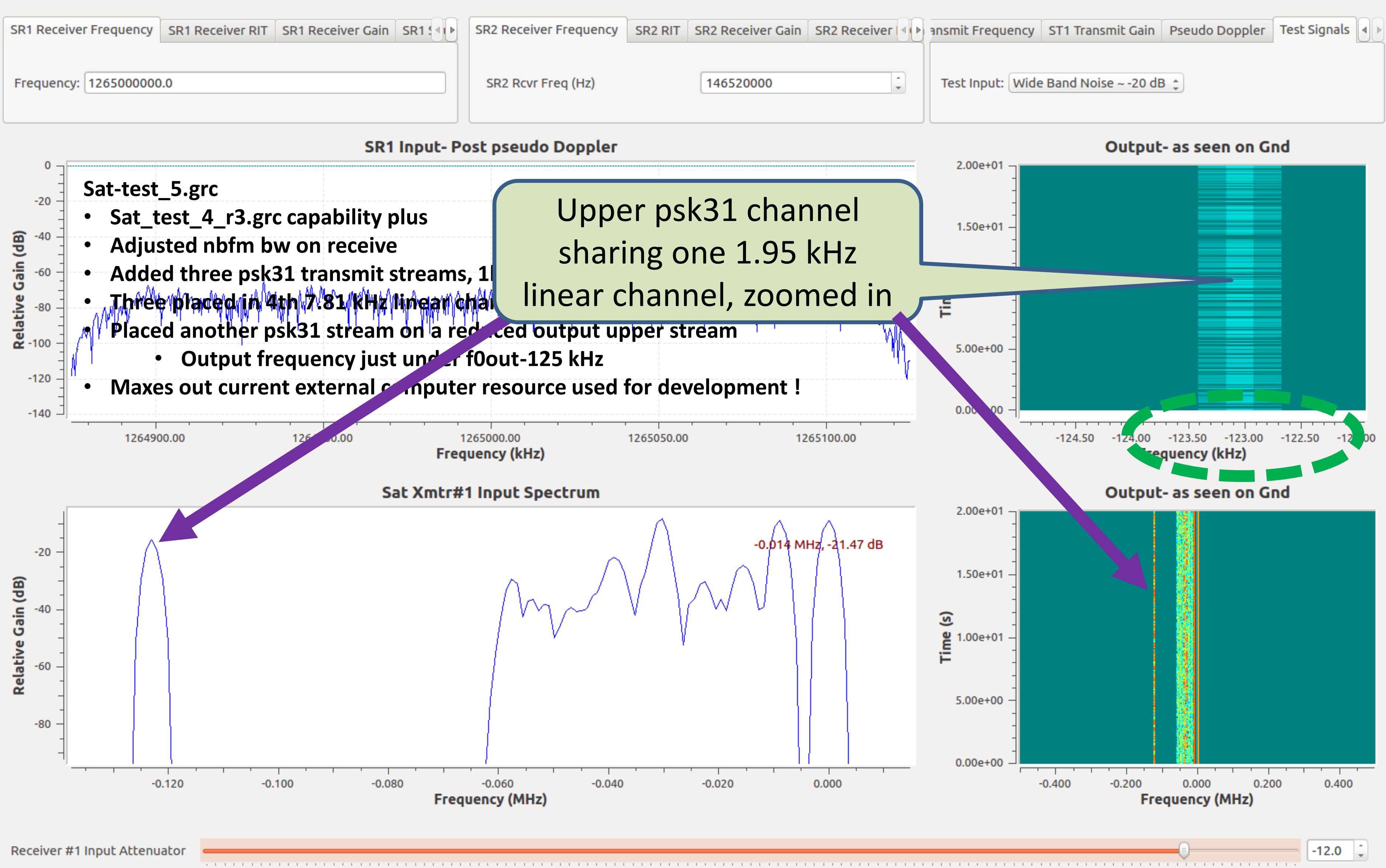
sat_test_5_2.png



sat_test_5_3.png



sat_test_5_4.png

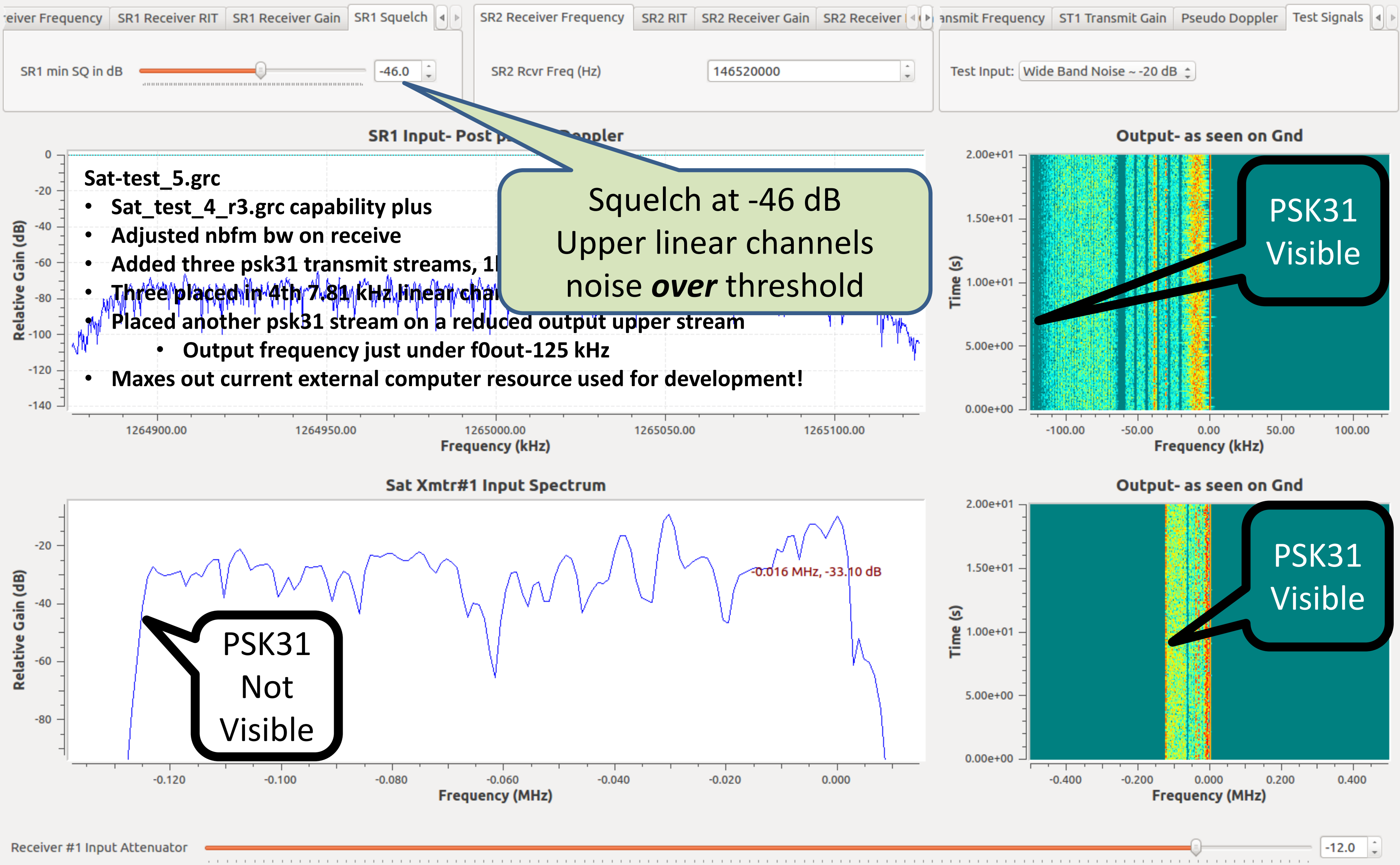


Sat-test_5.grc

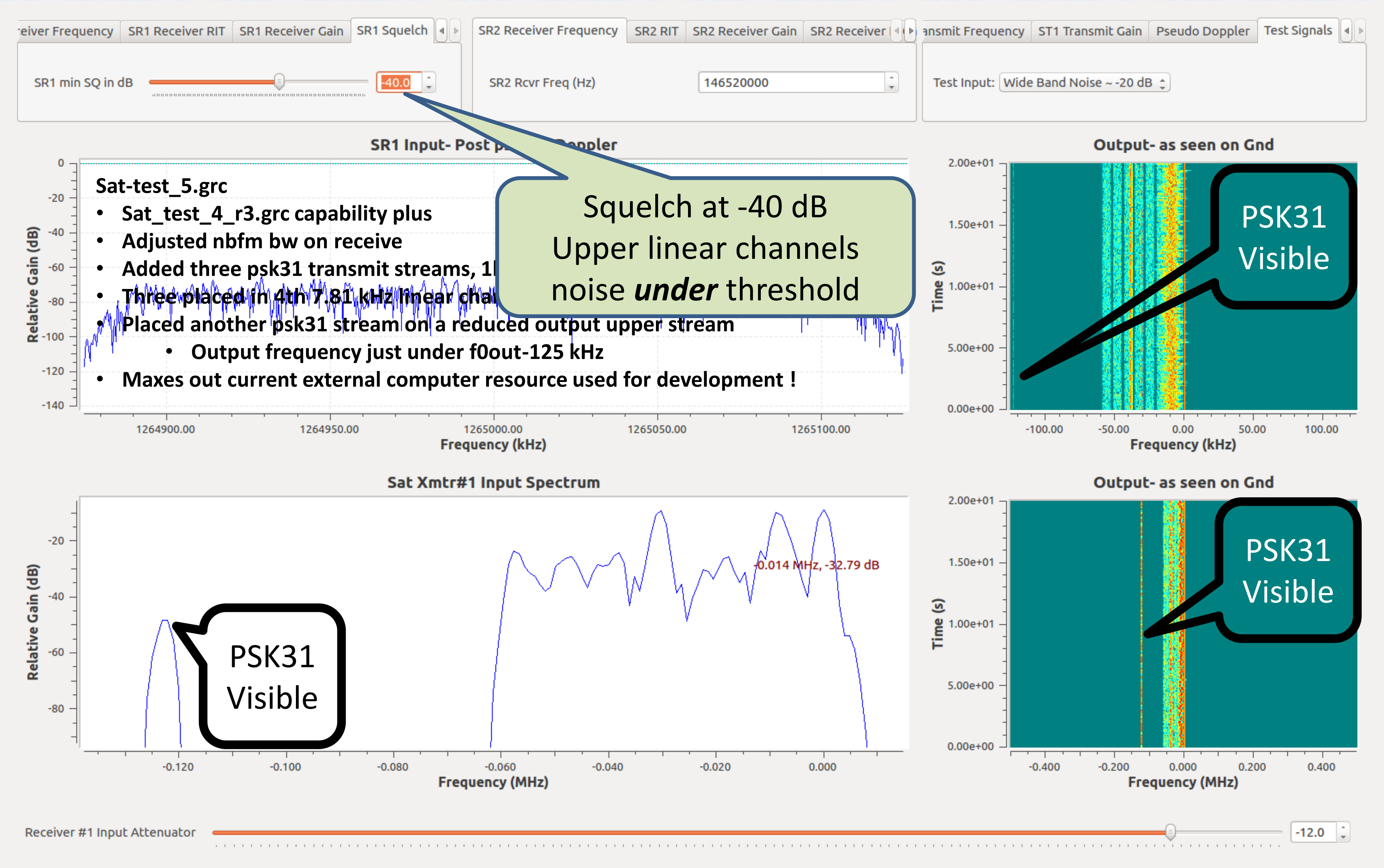
- Sat_test_4_r3.grc capability plus
- Adjusted nbfm bw on receive
- Added three psk31 transmit streams, 1l
- Three placed in 4th 7.81 kHz linear chai
- Placed another psk31 stream on a reduced output upper stream
  - Output frequency just under f0out-125 kHz
- Maxes out current external computer resource used for development !

Upper psk31 channel sharing one 1.95 kHz linear channel, zoomed in

sat_test_5_5.png



sat_test_5_6.png



Go See the Demonstration!

Operational Procedure- rev A

	Operation of the Ground Station
1	Warm up receiver and LNB
2	Run Frequency Calibration using ATSC pilots (Resulting error between 500 and 650MHz is less than 100 Hz
3	Turn GS receiver on SDR w/ LNB), input offset if needed
4	Turn GS C-band transmitter at known frequency and look for 2nd Harmonic in GS receiver SDR w/ LNB)
5	Measure Offset error and save, This is the LNB error + transmitter error + corrected SDR receiver error (GS error). Restart if required
6	Wait for Satellite, monitor beacon frequency range
7	After CW/Range beacon is visible, Center manually on the display. This is the GS error+ Satellite error + Doppler + Satellite frequency error
8	Subtract the GS error in step 5 from the measured frequency in step 7. This is the Satellite error + Doppler + Satellite frequency error
9	Turn on the Satellite error + Doppler + Satellite frequency error lock circuit
10	All receiver channels should be locked to the satellite and track it within +/-250Khz (LEO X-band)
11	Transmit with selected offset (channel) on a unused channel
12	Verify receiver picks up transmitter on frequency translation to X-Band.
13	Antenna Rotation Control not demonstrated (this time)
	Operation of the Satellite Station
1	Warm up SDRs (Receiver and Transmitter)
2	Bypass command structure and turn on system manually
3	Enable CW/Range Beacon
4	Enable C-band receiver Band
5	Enable Transmitter
	System Operation Verification
1	Use HT to talk to ground station on Channel zero
2	Verify reception on Channel zero on the Ground Station at X-band