METEORCOMM LLC

ITCR 1.0 STI-CO Wayside and Base Station Intermod Final Report

Document Revision: 1.0
Document Number: 00002522-A

This work was funded in whole or in part by the Federal Railroad Administration, US Department of Transportation under U.S. Government Grant FR-TEC-0003-11-01-00, and is therefore subject to the following license: The Government is granted for itself and others acting on its behalf a paid-up, nonexclusive, irrevocable worldwide license in this work to reproduce, prepare derivative works, distribute copies to the public, and perform publicly and display publicly, by or behalf of the Government. All other rights are reserved by the copyright owner.

Document Number: 00002522- A

Revision history

Revision	Date	Summary of Changes
1.0	10/24/2011	First release FRA

Table of Contents

Table of Figures

1. Project Detail

Contract Number	FR-TEC-0003-11-01-00
Phase	1
Work Breakdown Number	
Dates of Survey	July 15th to July 28th, 2011
Locations	1) BNSF Control Point (CP) Boeing, Seattle, WA 47.512701 N, 122.286982 W 2) BNSF Control Point (CP) Rhodes, Seattle, WA 47 30.923' N, 122 17.298' W 3) BNSF Control Point (CP) Titlow, Tacoma, WA 47.243971 N, 122.555637 W 4) BNSF FED Site 47 31' 48.99" N, 122 17' 43.78" W 5) BNSF Auburn Base Station, Auburn, WA, 47.30314 N, Long 122.231 W
Test Engineer	Ramon Abelleyro

2. Executive Summary

This is the initial effort to determine if intermodulation products/interference could affect the PTC 220 MHz band at or near several wayside and base station sites.

A few BNSF sites where PTC 220 MHz radio systems will be installed in the future were selected by MCC:

- BNSF CP Boeing and BNSF CP Rhodes, signal sites with multiple track circuits, switch control equipment, and CTC system.
- BNSF CP Titlow, signal site with multiple track circuits, switch control equipment, and CTC system. Interconnected through a 160 MHz ARES radio.
- BNSF FED Site with Dragging Equipment Detectors and 45 MHz, 100 watts digital radio.
- BNSF Auburn Base Station, co-located and sharing tower with two cellular telephone companies. Many different types of antennas on the tower, and various types of fixed communications systems share the BNSF bungalow with three 160 MHz radios: dispatch on main line Tacoma – Seattle; local yard and dispatch on branch to Stampede Pass, and one ARES radio for signals.

Several instruments were used to monitor the PTC 220 MHz band while equipment in each site was operated, track switches opened and closed, and base station 160 MHz and other radios transmitted. No significant evidence of intermodulation/interference was detected on any of the sites. Additional testing for longer periods of time at some sites is planned to acquire more information to complete this effort.

3. Testing Detail

It was necessary to secure cooperation from several BNSF employees to assist in providing access to sites, opening bungalows and describing equipment in and around each site. Everyone approached at BNSF provided valuable support and assisted in every way they could, without their help it would have not been possible to undertake this effort.

Testing commenced with Control Points Boeing and Rhodes, continued with CP Titlow and Auburn Base Station, and also included an FED Site in Seattle immediately north from Rhodes.

Several separate visits were made on different days to each site, the first to survey the site and equipment, another visit to carry out initial testing, and other visits to verify some of the testing results after evaluating them, sometimes using different instruments from those used in the previous visit. The Auburn Base Station required most visits than any other site, due to the complexity of the multiple radio systems located in the base station.

On CP Boeing, CP Rhodes and CP Titlow, arrangements were made to have present BNSF signal technicians request permission from the Main Line Dispatcher to momentarily take over control of each site and operate locally the track switches and signal equipment while measurements were being taken. Upon arriving at each site the inside and outside antennas were assembled and placed, and the test instruments readied to take measurements in the equipment room and outside the bungalow.

A variable amount of time would elapse until the Dispatcher could grant the signals technician control of the site, there had to be no trains operating in the area. Since all three sites are on main line, the amount of time varied as did the period of time allowed by the Dispatcher to operate the site locally. The time granted to operate locally a site varied between ten and fifteen minutes. All active system testing had to be carried out during that short interval of time.

The FED Site in Seattle had no signals systems, only Fault Detection Equipment and a powerful 100 watts 45 MHz digital radio. Several dragging equipment detection devices were installed on the tracks next to the FED Site. A 220 MHz mag mount antenna on an SUV was used for testing. This site was of great interest due to the location of a UP base station only thirty feet away. The UP Base Station had several mobile radio antennas that appeared to operate in the 160, 220, 450 and 800/900 MHz bands.

A powerful 45 MHz radio in the FED site could interact with the radios in the UP base station to generate intermodulation products across a broad portion of spectrum. Measurements were limited to monitoring the 45 MHz and 220 MHz bands. Continuous traffic was detected in the 45 MHz band, probably due to a SCADA system continuously polling all waysides, including this site. Transmissions on 45 MHz were observed using an Agilent N6841A RF Sensor.

These emissions were extremely short and beyond the typical capture range of conventional portable spectrum analyzers such as the Agilent N9912A or Anritsu S412A. More measurements will be taken over an extended period of time returning to this FED site and using an Agilent N6841A RF Sensor to monitor the PTC 220 MHz band for a longer period of time.

The Auburn Base Station is a complex radio site with two telephone companies sharing the tower and many antennas of various types installed at different levels. There are three bungalows with BNSF equipment located in the larger building in the center.

On the tower there appear to be antennas that are no longer used or connected, and the type of structure appears to be prone to generate intermodulation. Several portions of spectrum were swept looking for evidence of intermodulation products. Initial observations for a limited amount of time did not provide evidence of intermodulation. More testing for an extended period of time is planned.

Measurements in Auburn were taken inside the bungalow, with an omnidirectional 220 MHz antenna, and at several places approximately 50 feet outside the bungalow, using an omnidirectional 220 MHz antenna on a magnetic mount on top of an SUV vehicle. Outside measurements were also taken approximately 450 yards away from the base of the tower, with the mag mount 220 MHz antenna.

In Auburn it was not possible to carry out Basic Electrical Verification (Antenna Parameters), Antenna Isolation Test (isolation between antennas) or Active Intermodulation tests. The two 160 MHz Dispatch radios and one 160 MHz ARES radio in Auburn are in continuous use for train operations and could not be taken off-line for physical testing of the antenna systems. The only testing that could be done was to ask a BNSF Radio Technician to operate the PTT of these three base station radios during brief periods of time, while there was no traffic in the channel. This was informal testing not recorded as measurements.

From experience gained in the Auburn Base Station, a new method will be used to monitor intermodulation/interference products in other base stations. An SUV equipped with an Agilent RF Sensor and 220 MHz mag mount antenna will park outside a base station and collect information on the 220 MHz band for a period of a few hours. Active channels in each base station will be monitored and whenever they transmit, the 220 MHz band will be observed for evidence of Intermodulation/ Interference products generated by the active channels transmitting in the base station.

A list of BNSF base stations and active radio channels at each of the base stations in the Northwest is being compiled. A few of these base stations, including Auburn, will be selected to observe the PTC 220 MHz band for periods of a few hours at each base station. This process will not require any radios at a base station to be taken off-line, and will permit the observation, monitoring and recording of certain events in the PTC 220 MHz band for longer periods of time.

Since the main purpose of this effort is to identify and capture intermodulation/interference products, measurements were made with three separate spectrum analyzers on different bands or portions of RF spectrum around the PTC 220 MHz band. No specific frequencies were targeted for capture, it was more important to find any intermodulation products that could be interfering with the PTC 220 MHz band.

Measurements were made and recorded as spectrum screen shots, which have been included in each of the five appendices: Appendix A to Appendix E, one for each site surveyed. It was necessary to break down many graphic files with screen shots and pictures into five attachments to keep file sizes to a size that could be sent electronically without exceeding the maximum size limits of many mail servers.

All testing results were extremely valuable. Signals, CTC and ARES radio systems have multiple types of signal equipment, including relays for DC track circuits, modulated/coded audio frequency track circuits, interlocking equipment, and electromechanical equipment to operate track switches. This equipment has the potential to interfere with any radio frequency system installed and operating in the same site.

Base stations such as Auburn, with a large number of radio equipment and antennas from BNSF and other tenants sharing the site, also present a substantial risk of intermodulation/interference to the PTC 220 MHz band. Testing has not yet been completed, even though initial measurements did not find evidence of intermodulation/interference, additional testing will have to be carried out over longer periods of time at Auburn and a few other base station sites.

In retrospect, a concern that remains after testing five sites is that perhaps not sufficient time might have been allocated to the observation process, it is not possible to “pass” or “fail” a site based only a on a brief period of observation and spectrum data capture. Planned testing of more base stations and the FED Site in Seattle next to a UP base station will provide a stronger basis on how long spectrum observations and monitoring should take in order to obtain a reliable perspective.

4. Equipment List

Three different spectrum analyzers were used and compared, two of them are portable RF Analyzers from Agilent and Anritsu, and one is an N6841A RF Sensor from Agilent designed for use by US government agencies. The performance of the N6841A Agilent RF Sensor was far superior to the other two portable instruments, details are provided after the Equipment list below. The Agilent RF Sensor will be the reference instrument for all future testing in this program.

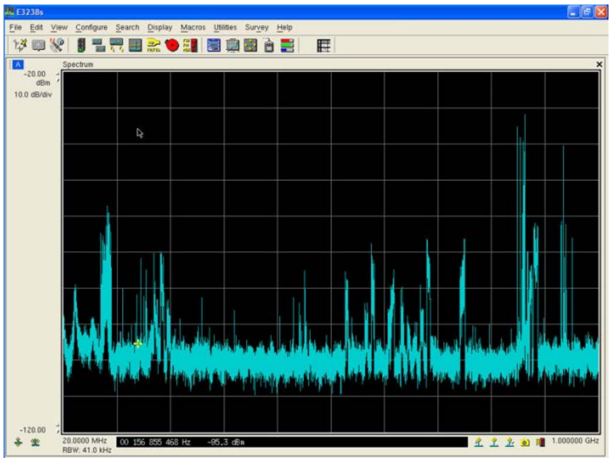
The Agilent N6841A RF Sensor will have to be configured to identify, separate, capture and record RF signals of interest, such as intermodulation/interference. Different “triggers” will have to be configured in the lab and in the field to recognize and separate signals of interest from the rest of the RF data captured. This RF Sensor captures and displays a very large amount of signal information. This makes it difficult to discern signals of interest from an intense background of other non-meaningful signals.

For the comparison of three spectrum analyzers on next page, the instruments settings used had similar BW parameters: 30 KHz RBW and VBW for S412A and N9912A, and 41 KHz BW for N6841A.

5. Instruments and Equipment Used

- Agilent N6841A RF Sensor and N6820E Software Suite, first civilian application for Agilent Everett's developed product for use by US Government agencies. Operated from a Panasonic CF-30 notebook PC.
- Anritsu S412E LMR Master, multi-function field portable RF Analyzer including Spectrum Analyzer, Network Analyzer, Power Meter, Cable and Antenna Fault detector, Vector Voltmeter, and Interference Analyzer.
- Agilent N9912A Field Fox, multi-function field portable RF Analyzer including Spectrum Analyzer, Network Analyzer, Power Meter, Cable and Antenna Fault detector, Vector Voltmeter, and Interference Analyzer.
- Panasonic CF-30 Thoughbook notebook PC – To control and operate Agilent N6841A RF Sensor.
- Bird 4304A, single element portable wattmeter, 25-1000 MHz, 5 to 500 W.
- Fluke 117 True RMS digital multimeter.
- STI-CO filters 160 MHz and 220 MHz band pass.
- STI-CO filters, multi-band, 150, 450, 800 MHz.
- STI-CO Discone multiband antennas 100 MHz - 1,500 MHz.
- STI-CO band specific antennas on mag mounts.
- STI-CO made coax cables cut to multiples of a wavelength for 160 and 220 MHz testing.
- Assortment of new RF connector adaptors to hook up different equipment and antenna connectors.
- Mini-Circuits precision attenuators.

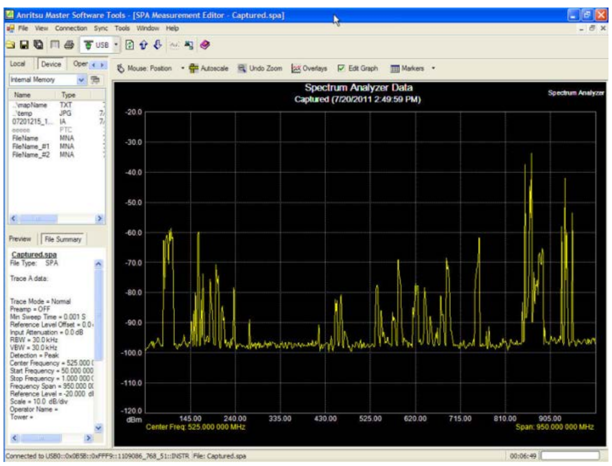
Figure 1: Spectrum from 20/50 MHz to 1000 MHz at BNSF Auburn base station - 60 feet west from base of tower



Agilent N6841A RF Sensor operated from Panasonic CF-30

Highest Performance

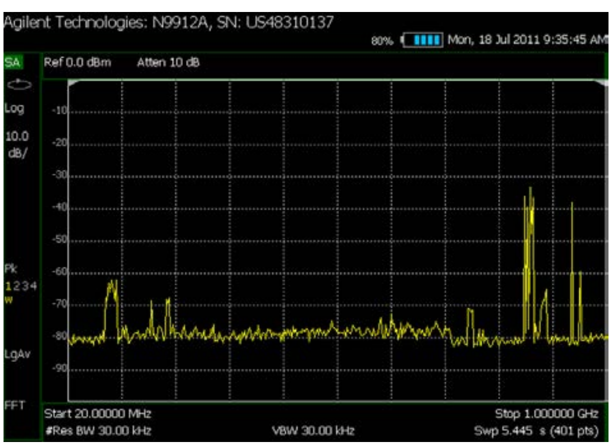
- Sharpest screen display with best details
- 500,000 points resolution, can be zoomed in
- Fraction of a second to sweep 1,000 MHZ
- Up to 1,000 times faster than most Spectrum Analyzers
- Captures, displays and logs extremely short signals
- No-gap analysis of up to 20 MHZ spectrum
- Operation from 20 MHz to 6 Gigahertz
- Automatically stores all signals captured
- Automatically recognizes 30+ D/A modulations
- Rugged stand-alone enclosure for field use
- Can be remotely operated by PC via TCP/IP links
- Precise transmitter geolocation using 4 RF Sensors
- 12 V DC or 120 V AC operation, 15 watts



Anritsu S412E LMR Master Spectrum Analyzer

Good Performance

- Screen display with good details
- Less than 1,000 points resolution
- Several seconds to sweep 1,000 MHZ
- Not able to display extremely short signals
- Operation from 20 MHz to 6 Gigahertz
- Can store screen shots in PC via USB cable
- Good portable instrument enclosure, not rugged
- Cannot be remotely or locally operated from PC
- Can be used for quick spectrum evaluation
- Built-in battery for up to 4 hours field operation

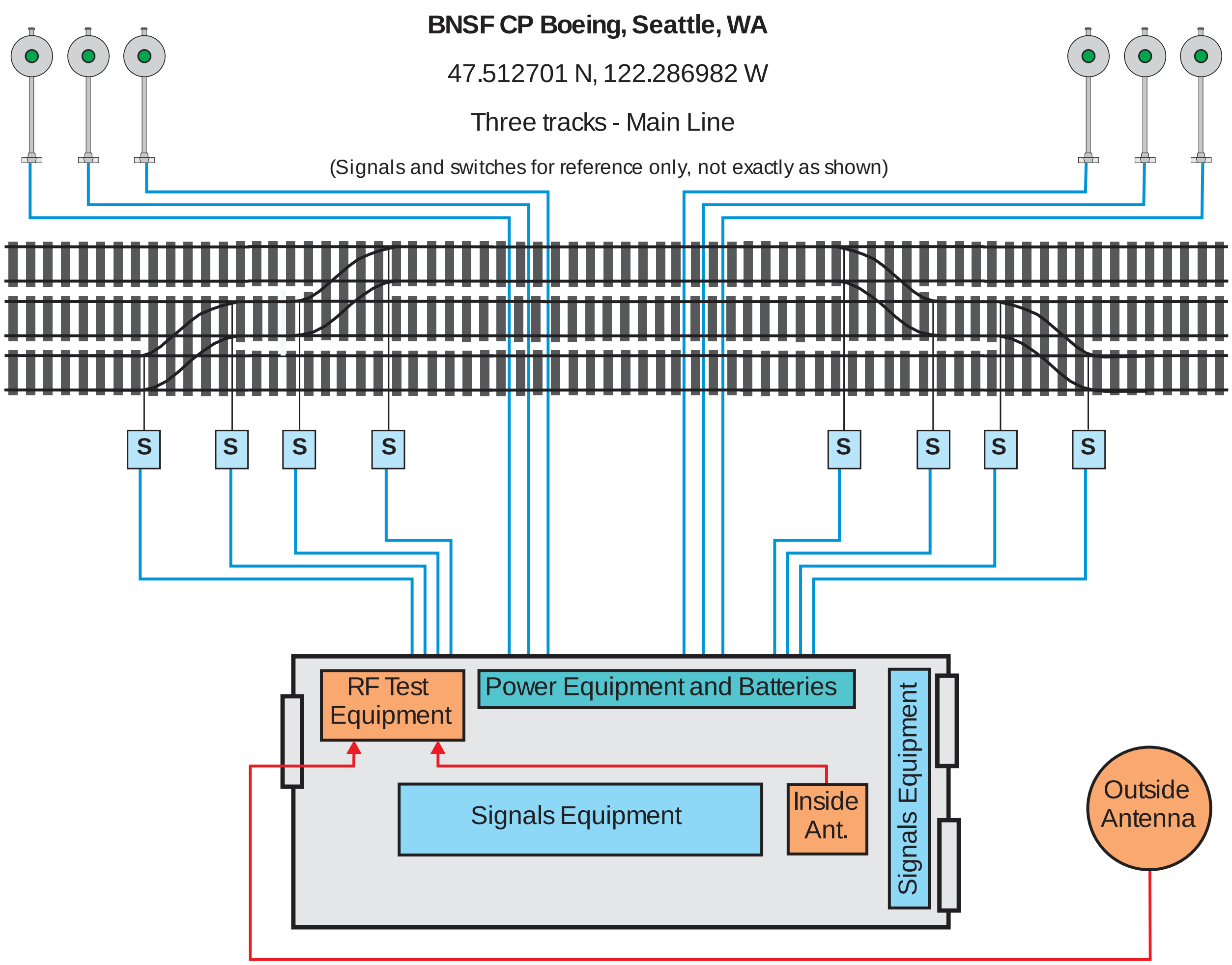


Agilent N9912A Field Fox Spectrum Analyzer

Lowest Performance

- Screen display with poor details
- 400 points resolution
- Longer than 5 seconds to sweep 1,000 MHZ
- Not able to display extremely short signals
- Not able to display many signals across spectrum
- Operation from 20 MHz to 6 Gigahertz
- Can store screen shots in PC via USB cable
- Good portable instrument enclosure, not rugged
- Cannot be remotely or locally operated from PC
- Cannot be used for quick spectrum evaluation
- Built in battery for up to 4 hours field operation

Figure 2: Site survey BNSF CP Boeing

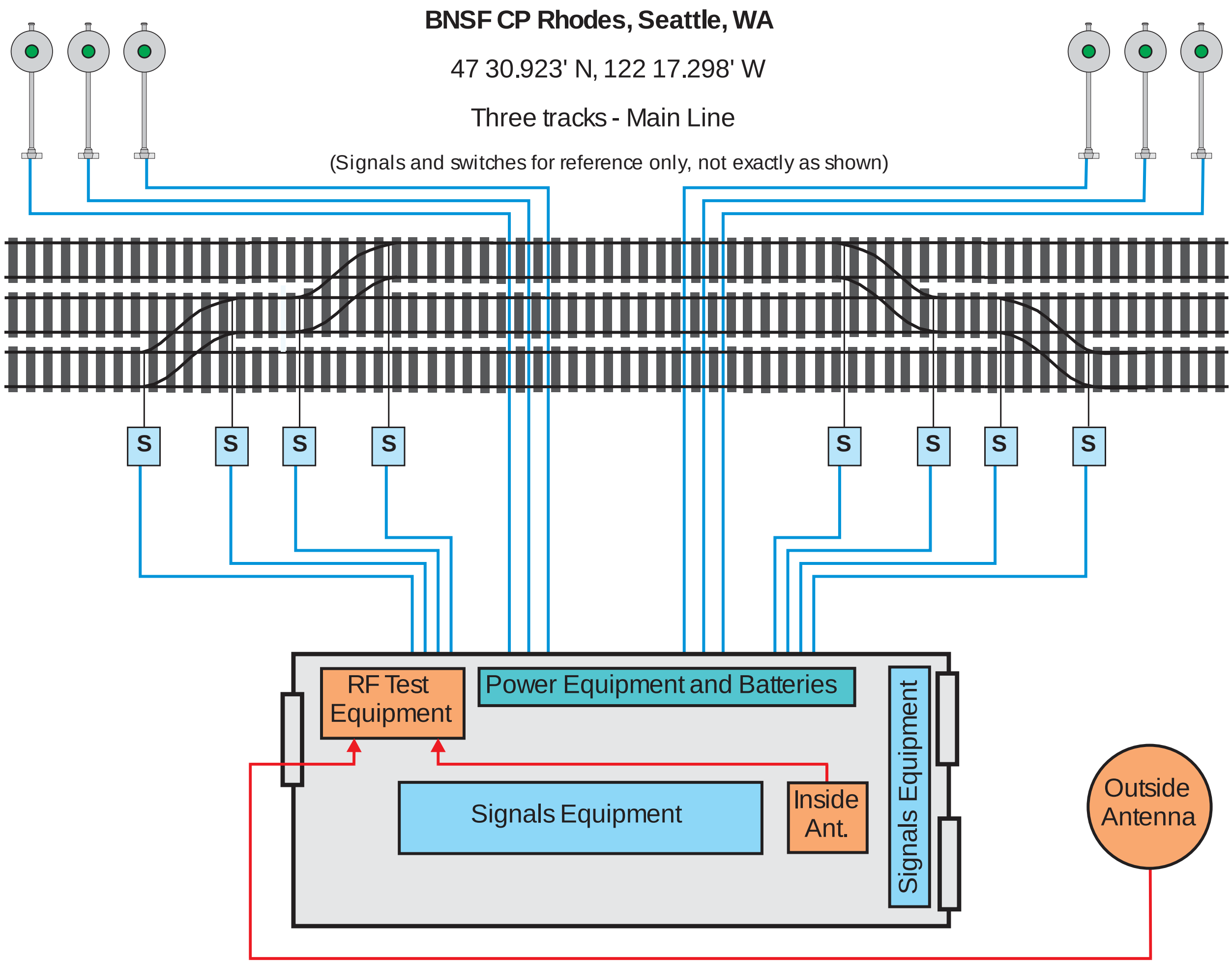


CP Boeing is connected by fiber optic cables. It contains various types of signals equipment including DC track relays and CTC equipment. No RF equipment or antennas now, PTC radios installation is planned.

The metal bungalow is well constructed and maintained. There are no obvious intermodulation/interference generation sources such as rusty fences, towers or metal surfaces. Signals equipment on the tracks, such as switches also appear to be well installed and maintained.

Appendix A: BNSF CP Boeing, Seattle provides several pictures of the site with more details, and also includes spectrum analyzer screens captured as pictures when measurements were taken.

Figure 3: Site survey BNSF CP Rhodes

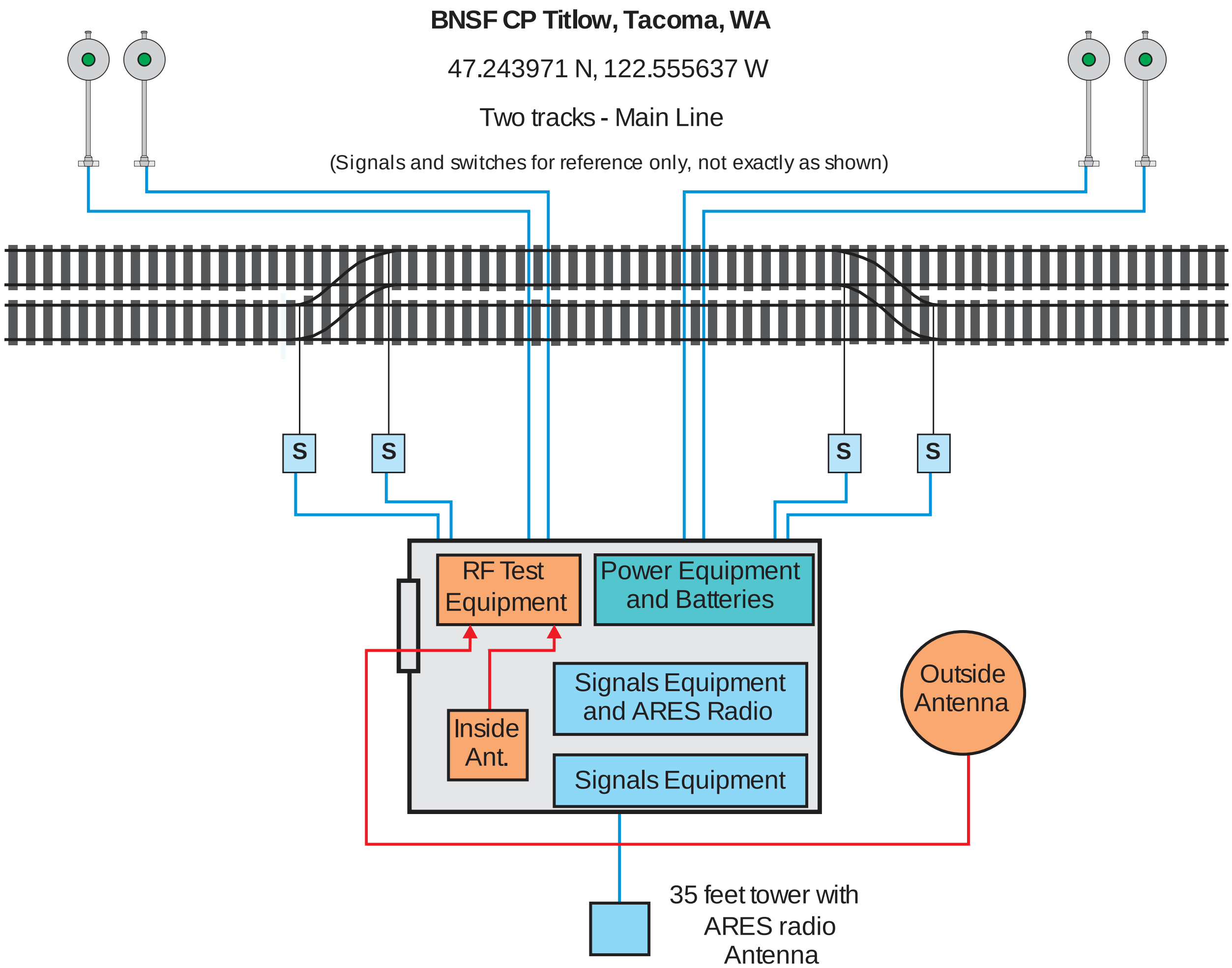


CP Rhodes is connected by fiber optic cables. It contains various types of signals equipment including DC track relays and CTC equipment. No RF equipment or antennas now, PTC radios installation is planned.

The metal bungalow is well constructed and maintained. There are no obvious intermodulation/interference generation sources such as rusty fences, towers or metal surfaces. Signals equipment on the tracks, such as switches also appear to be well installed and maintained.

Appendix B: BNSF CP Rhodes, Seattle, WA provides several pictures of the site with more details, and also includes spectrum analyzer screens captured as pictures when measurements were taken.

Figure 4: Site survey BNSF CP Titlow

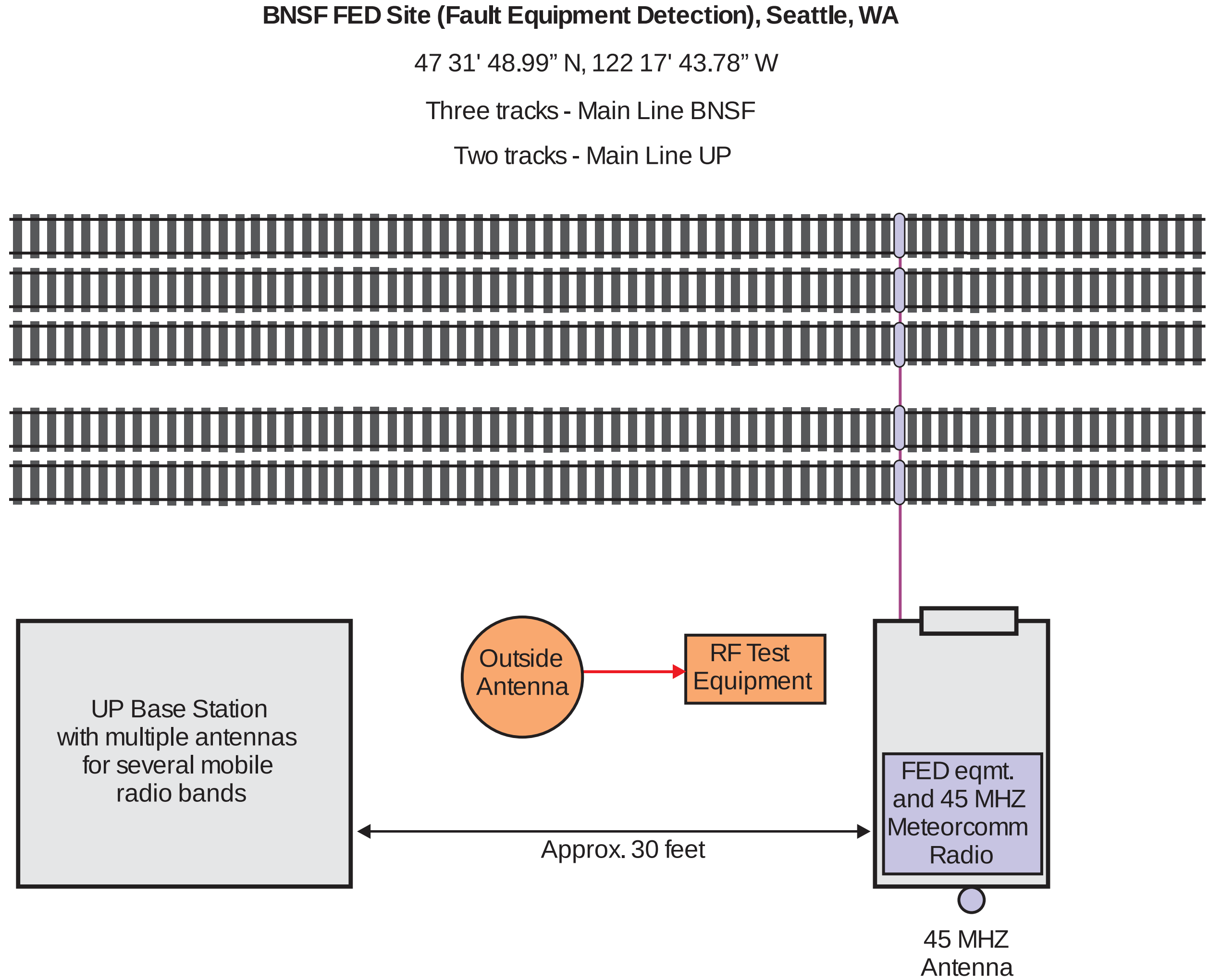


CP Titlow is connected by a 160 MHz ARES radio. It contains various types of signals equipment including DC track relays and CTC equipment. Only an ARES radio antenna now, PTC radios installation is planned.

The metal bungalow is well constructed and maintained. There are no obvious intermodulation/interference generation sources such as rusty fences, towers or metal surfaces. Signals equipment on the tracks, such as switches also appear to be well installed and maintained.

Appendix C: BNSF CP Titlow, Tacoma, WA provides several pictures of the site with more details, and also includes spectrum analyzer screens captured as pictures when measurements were taken.

Figure 5: Site survey BNSF FED site

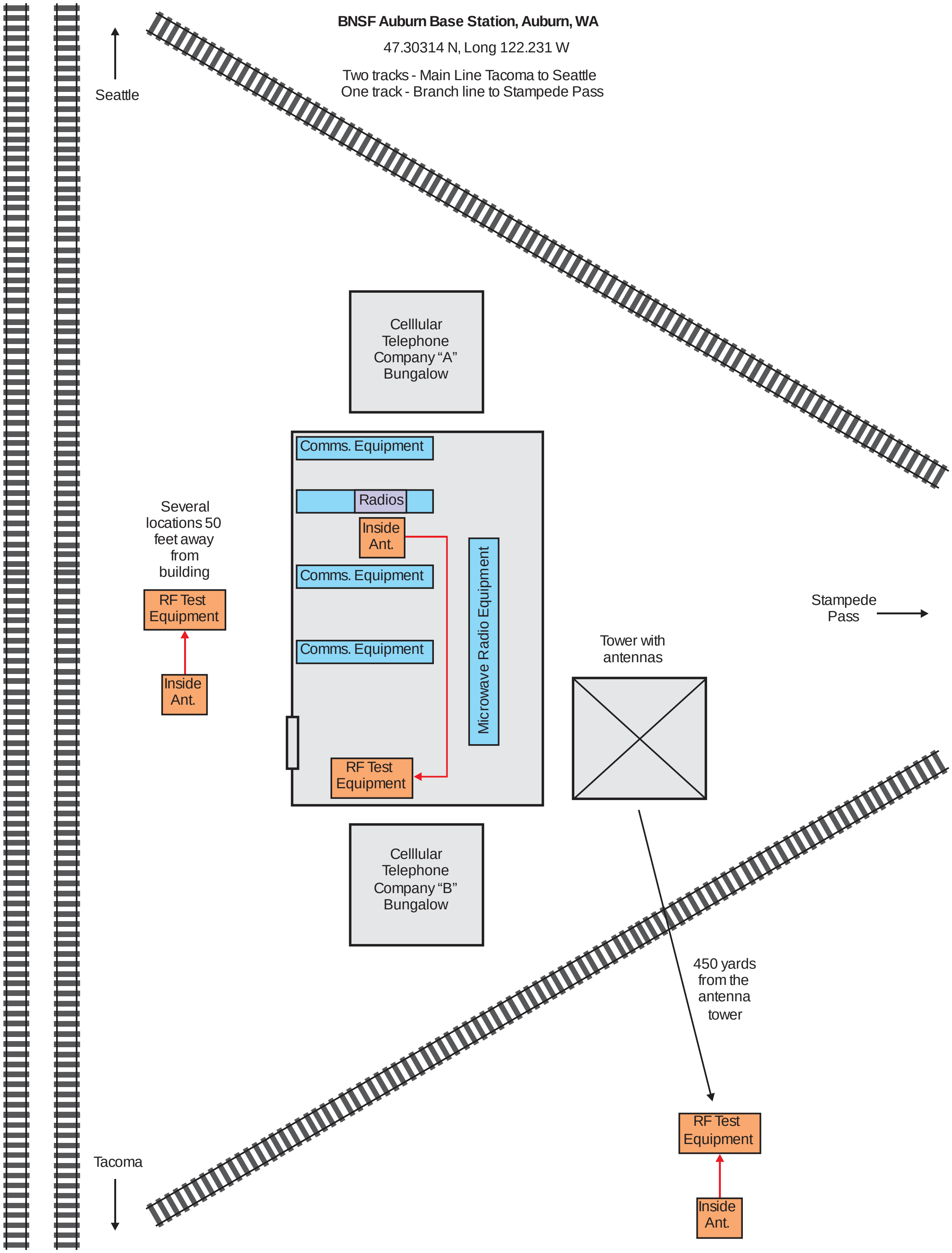


The BNSF FED site is connected by a 45 MHz Meteorcomm radio. It contains FED and radio equipment. Only a 45 MHz radio antenna now, PTC radios installation is planned.

The metal bungalow is somewhat old and not as well maintained as the three signal only sites previously surveyed. There is a UP base station metal bungalow with multiple mobile radio antennas for different bands, there are some metal areas that might contribute to generate intermodulation/interference. The highest intermodulation risk factor lies with the multiple band radios and antennas in the UP bungalow. FED equipment on the tracks appear to be well installed and maintained.

Appendix D: BNSF FED Site, Seattle, WA provides several pictures of the site with more details. Screen shots were not possible to capture due the extremely short type of signals detected, more testing is planned at this site.

Figure 6: Site survey BNSF Auburn Base Station site



The BNSF base station site in Auburn is connected by multiple links that include microwave radios. It contains various types of microwave and mobile radio communications systems and equipment.

There are numerous antennas that appear to operate in bands from low VHF to 5 or 6 GHz, including omnidirectional, folded dipoles, yagis and dishes of various types and sizes. Also, there are several metal structures around the bungalows and building, fences and other potential sources that might contribute to generate intermodulation products.

It was not possible to discern from the ground which antenna on the tower belonged to whom. BNSF and two telephone companies share the site, with each telephone company having its own bungalow.

The BNSF equipment room is a brick building, well built and maintained. Inside the building are many metal trays, cable runs and other metal parts that have been well installed and maintained. There are no obvious intermodulation/interference generation sources.

Three 160 MHz base station Kenwood 35 watts radios are installed on a 19-inch rack, directly under an ARES radio also mounted on a 19-inch rack frame. Only two of these three radios are used.

Measurements inside the Auburn base station were taken with an omnidirectional antenna placed between the three 160 MHz Kenwood base station radios and the ARES radio directly above.

Measurements outside the Auburn Base Station building were taken using a 220 MHz antenna on a magnetic mount placed in the center of the roof on an SUV. These measurements were taken about 60 feet from the base of the tower, and at 450 away from the tower.

Appendix E: BNSF Auburn Base Station, Auburn, WA provides several pictures of the site with more details, and also includes spectrum analyzer screens captured as pictures when measurements were taken. There are two spectrum analyzer screen shots for every measurement, one captured with an Anritsu S412E portable RF analyzer, and one captured with an Agilent N6841A RF Sensor controlled by a Panasonic CF-30 rugged notebook PC.

6. Conclusions

Initial measurements did not provide evidence of intermodulation/interference products in any of the five sites tested.

In some sites such as CP Boeing, CP Rhodes and CP Titlow there appears to be low risk that intermodulation/interference sources could pose a problem in the PTC 220 MHz band in the future.

In sites such as FED Seattle there is high risk that there could be intermodulation issues affecting the PTC 220 MHz band in the future. Reasons include:

- Very powerful digital transmitter in 45 MHz reaching antennas and radio equipment in several bands, and also reaching rusty patches on the surface of a UP base station located 30 feet away.
- Multiple radio transmitters in several bands in the UP base station reaching 45 MHz antenna and radio equipment in FED site, as well as reaching rusty patches in their own metal bungalow.

In sites such as Auburn Base Station there is high risk that there could be intermodulation issues affecting the PTC 220 MHz band in the future. Reasons include:

- Large number of antennas and radio systems not necessarily coordinated between three users.
- Metal structures that might not be well bonded and/or painted, and might have loose parts.
- Antennas and RF parts/cables/components that are no longer connected to a radio.
- Multiple radio systems transmitting with high power in frequencies below 1 GHz.

7. Action Items

- Configure Agilent N6841A RF Sensor to trigger on desired signals of interest to observe activity of intermodulation/interference products on 220 MHz band, identifying, displaying, recognizing modulation type and recording every signal of interest, even if it would be extremely short.
- Repeat measurements in Auburn Base Station and a few other selected base stations using a different method, observing traffic on active channels at each base station and monitoring the effect of those transmissions on the PTC 220 MHz band during a period of a few hours.
- Repeat measurements at the FED Seattle site using a similar method: Identify every local active channel in the FED site and UP Base Station, and then observing the effect of traffic on these channels on the PTC 220 MHz band during a period of a few hours.

Appendix A: BNSF CP Boeing, Seattle

Figure 7: BNSF CP Boeing exterior view with Discone broadband antenna

Figure 8: BNSF CP Boeing interior view with DC track circuit relays

Figure 9: BNSF CP Boeing interior view with Agilent N9912 Field Fox and N6840 RF Sensor

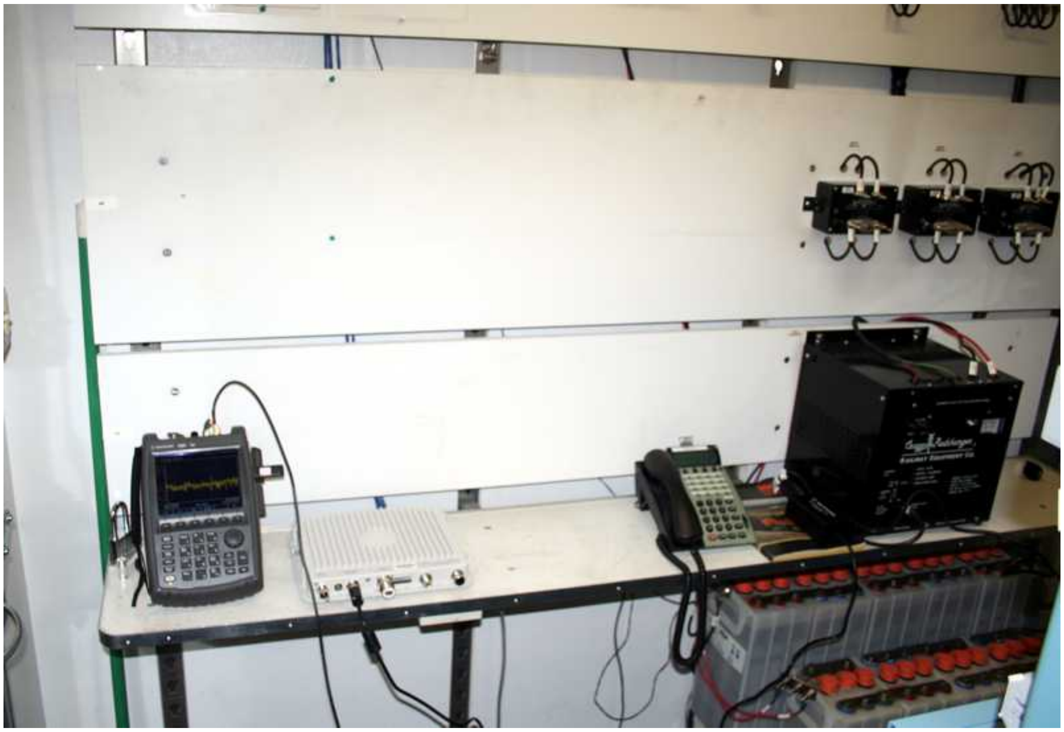


Figure 10: BNSF CP Boeing interior view with 220 MHz antenna and metal ground plane

Figure 11: BNSF CP Boeing 215 to 225 MHz band outside with Discone Antenna no CTC activity

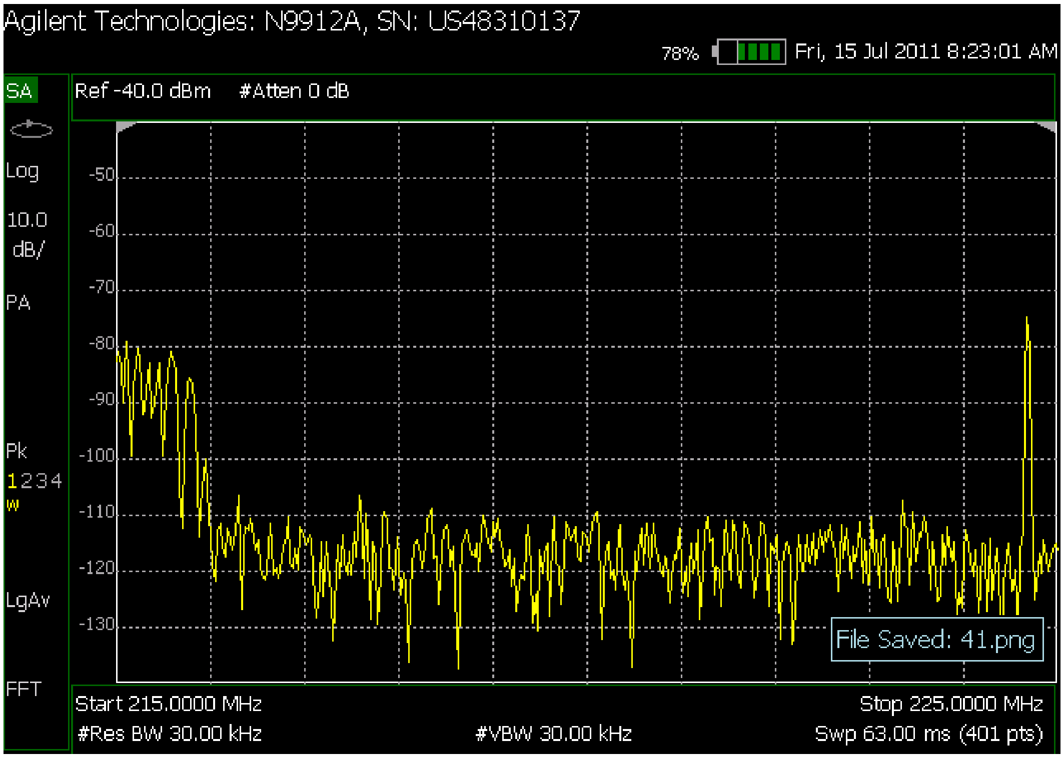


Figure 12: BNSF CP Boeing 215 to 225 MHz band - Outside with Discone Antenna with CTC activity

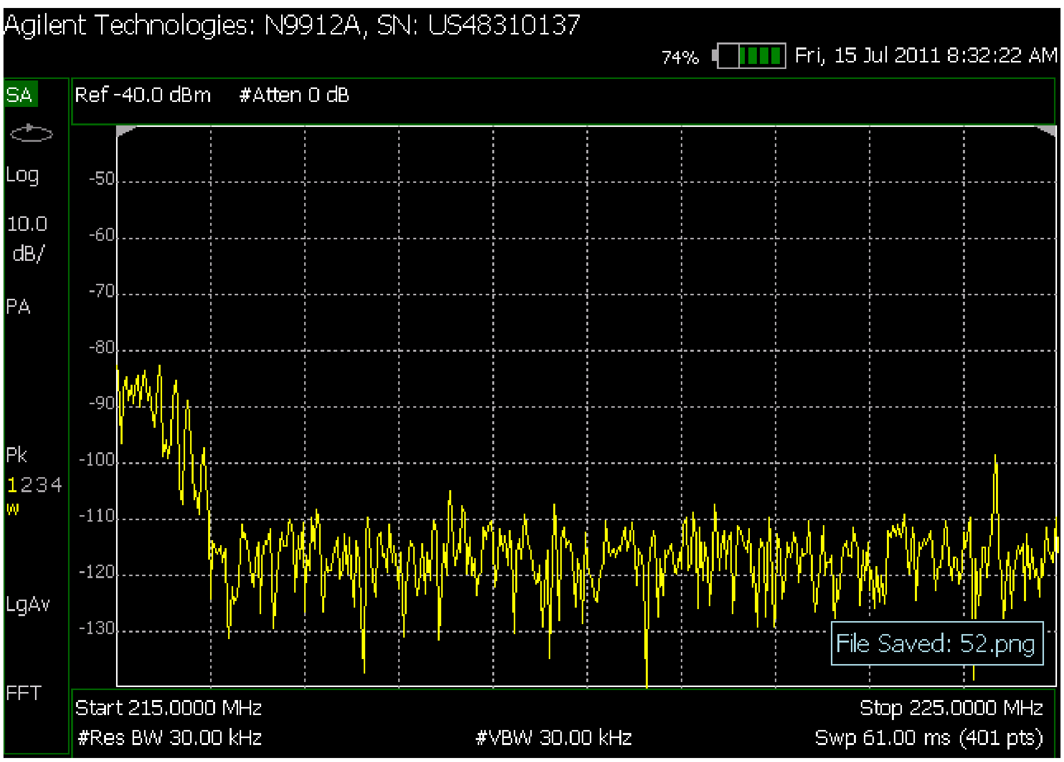


Figure 13: BNSF CP Boeing 200 to 250 MHz band outside with Discone Antenna no CTC activity

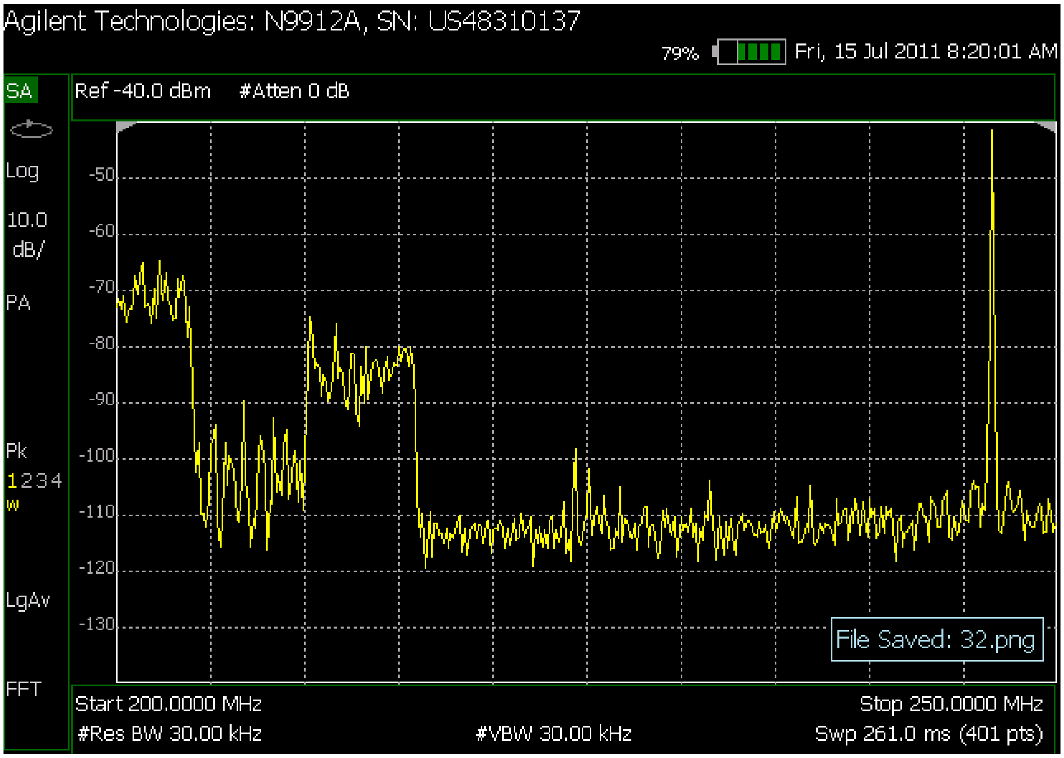


Figure 14: BNSF CP Boeing 200 to 250 MHz band outside with Discone Antenna with CTC activity

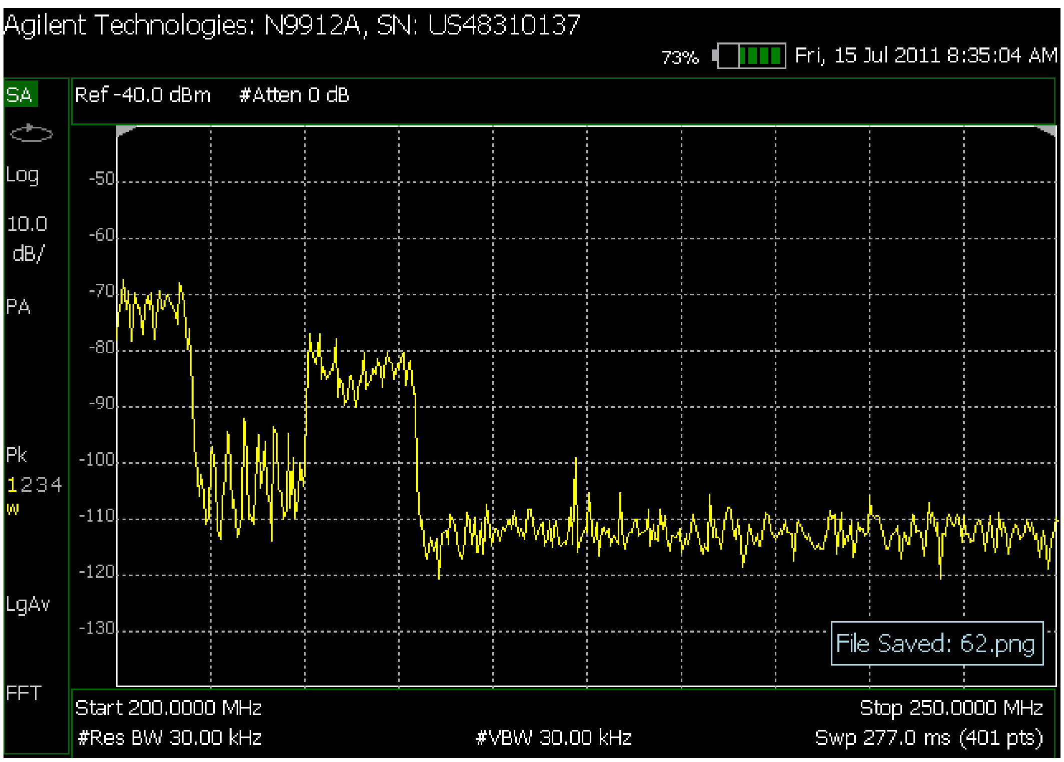


Figure 15: BNSF CP Boeing 100 to 600 MHz band - Outside with Discone Antenna with CTC activity

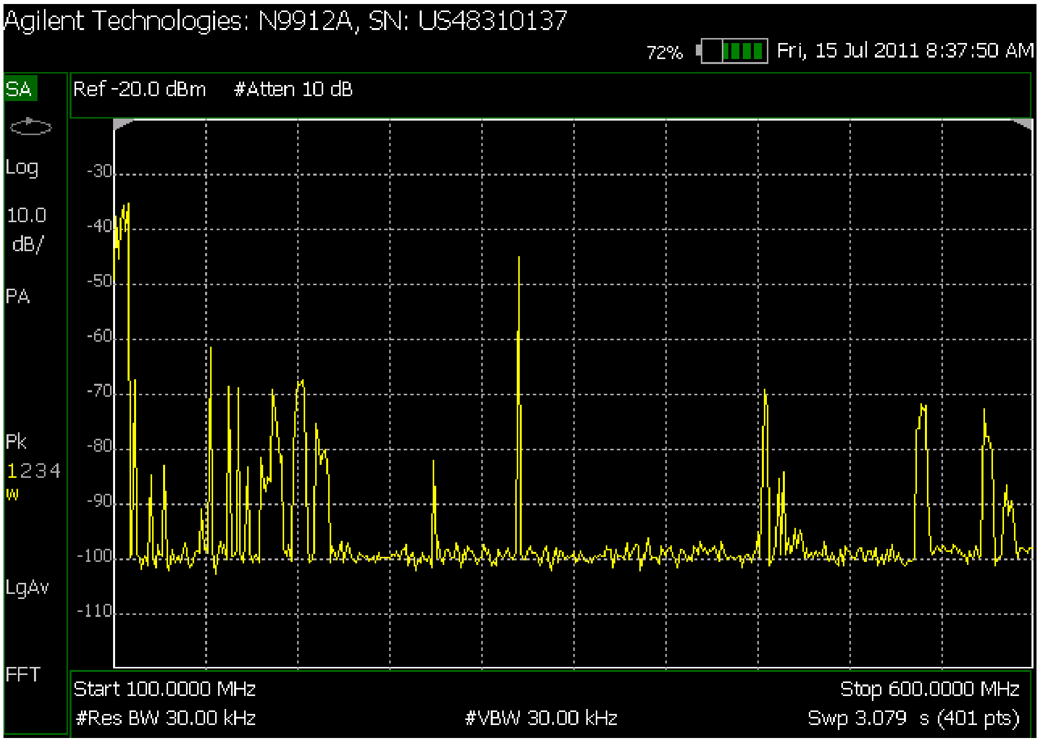


Figure 16: BNSF CP Boeing 215 to 225 MHz band inside with 220 MHz Antenna with CTC activity

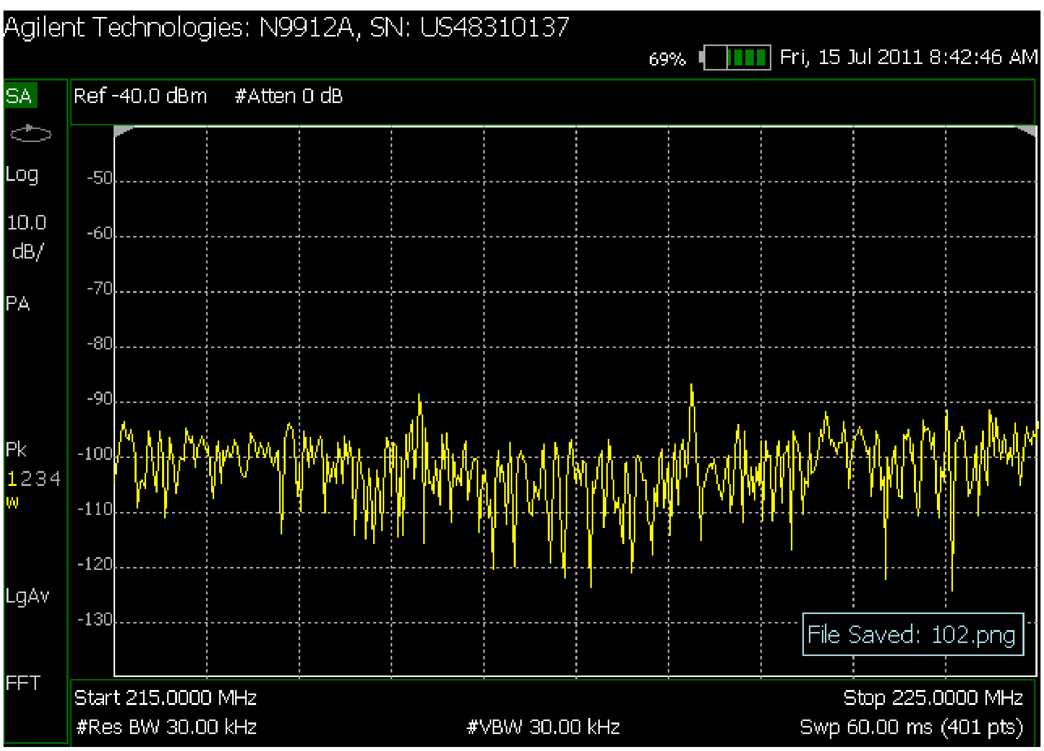


Figure 17: BNSF CP Boeing 200 to 250 MHz band inside with 220 MHz Antenna with CTC activity

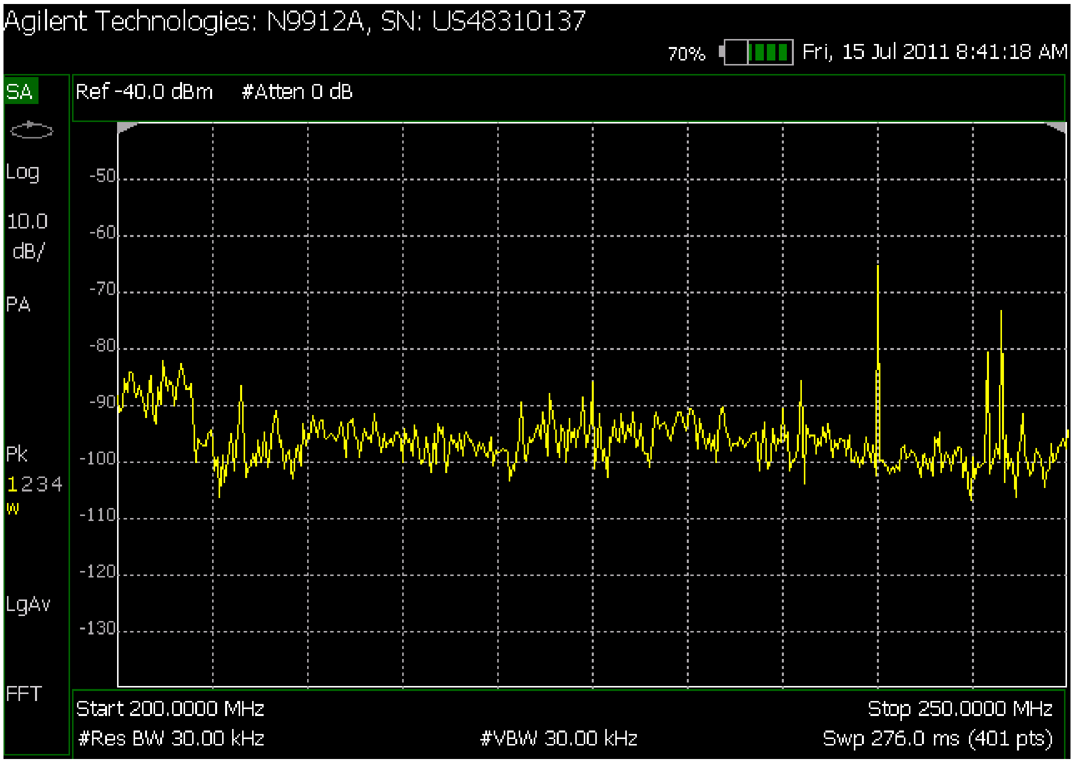
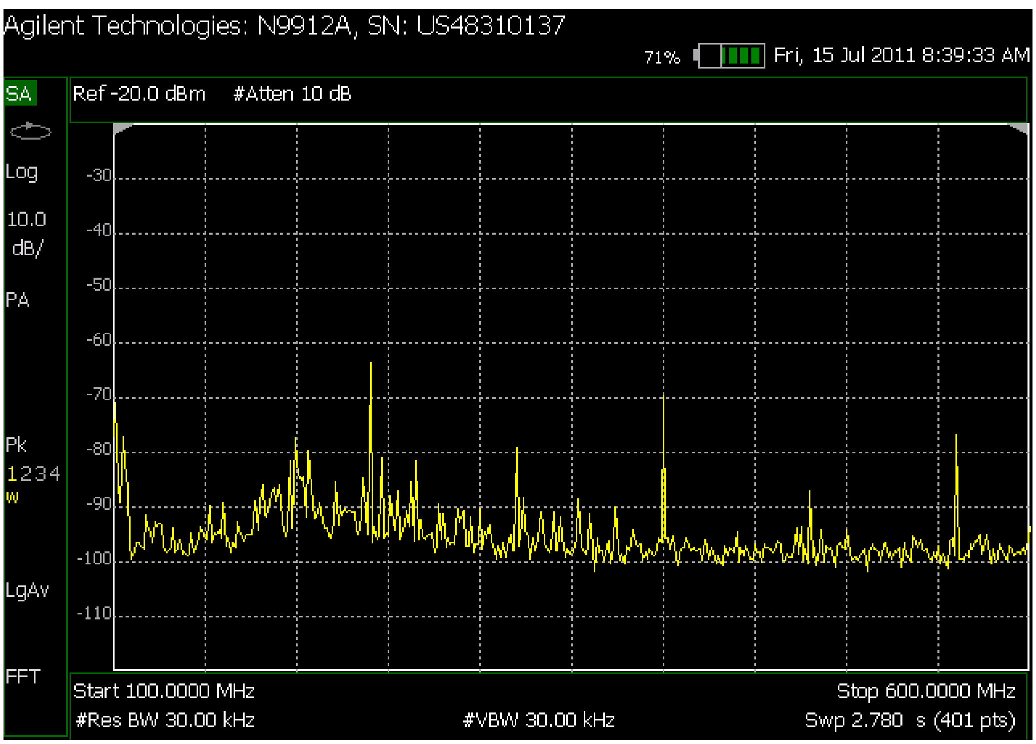


Figure 18: BNSF CP Boeing 100 to 600 MHz band inside with 220 MHz Antenna with CTC activity



Appendix B: BNSF CP Rhodes, Seattle, WA

Figure 19: BNSF CP Rhodes exterior view

CP Rhodes interior views similar to Appendix A: BNSF CP Boeing, Seattle.

Figure 20: BNSF CP Rhodes 215 to 225 MHz band outside with Discone Antenna with CTC activity

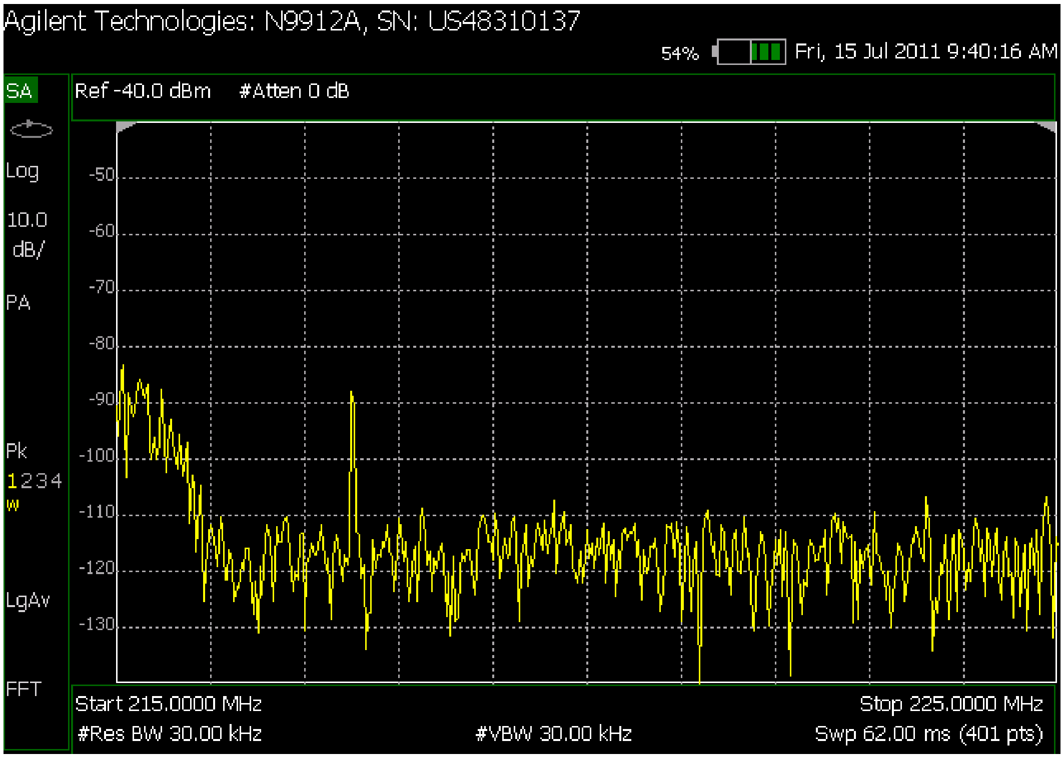


Figure 21: BNSF CP Rhodes 200 to 250 MHz band outside with Discone Antenna with CTC activity

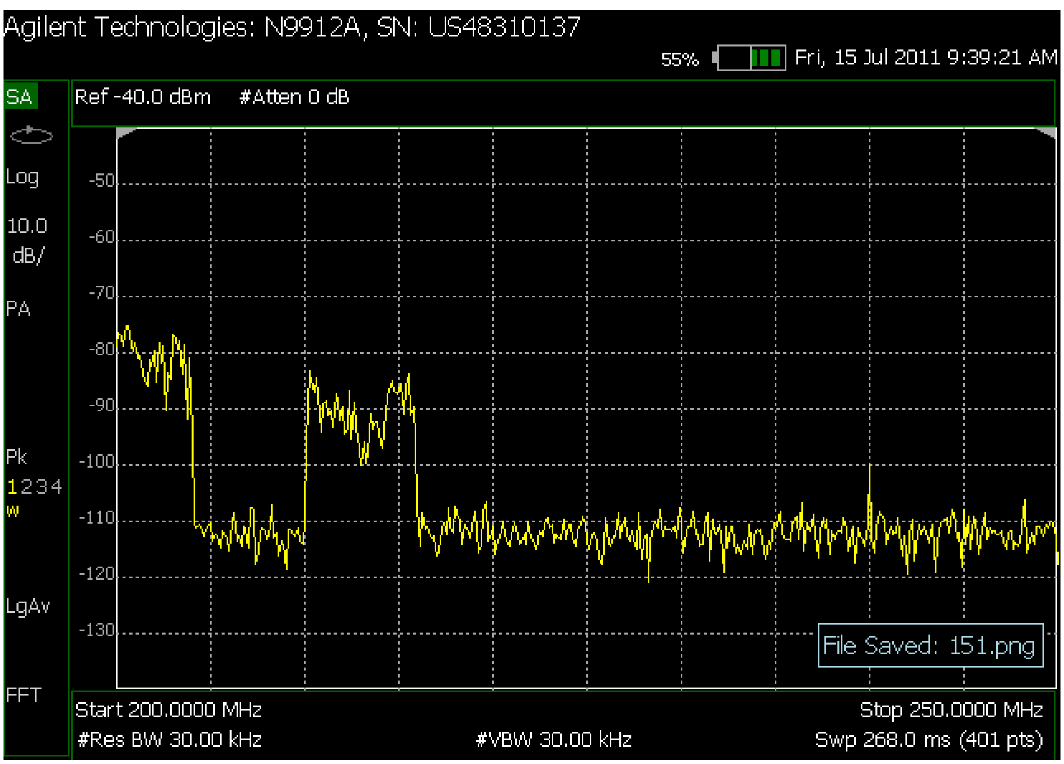


Figure 22: BNSF CP Rhodes 100 to 600 MHz band outside with Discone Antenna with CTC activity

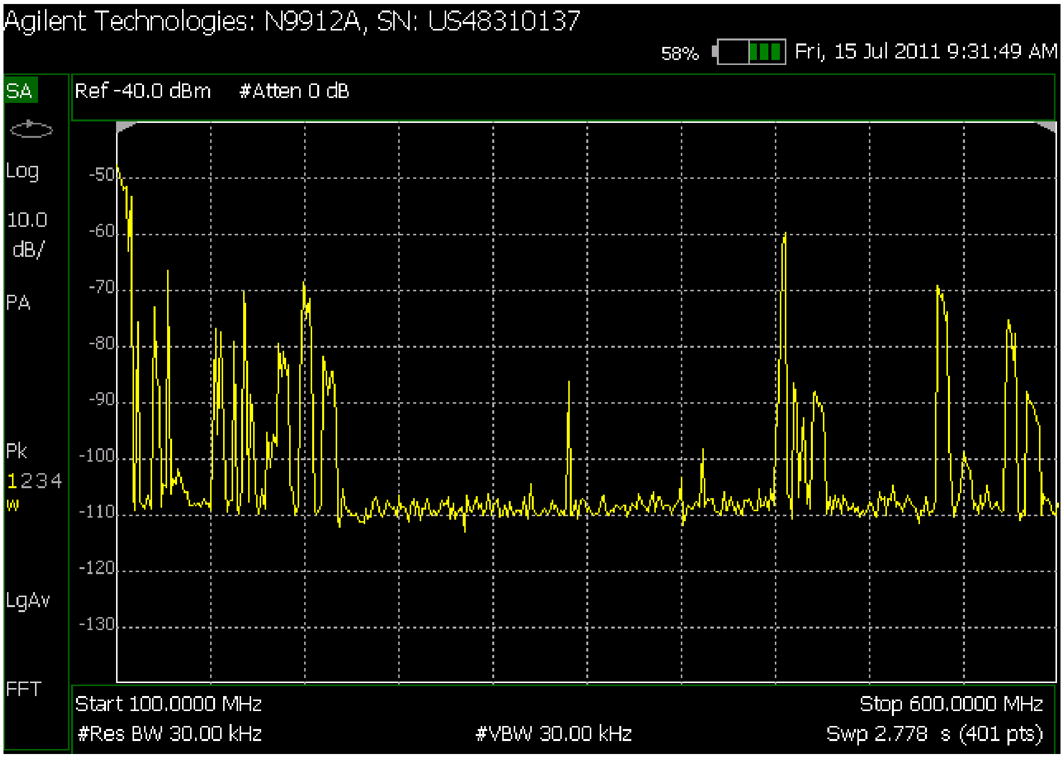


Figure 23: BNSF CP Rhodes 215 to 225 MHz band inside with 220 MHz Antenna with CTC activity

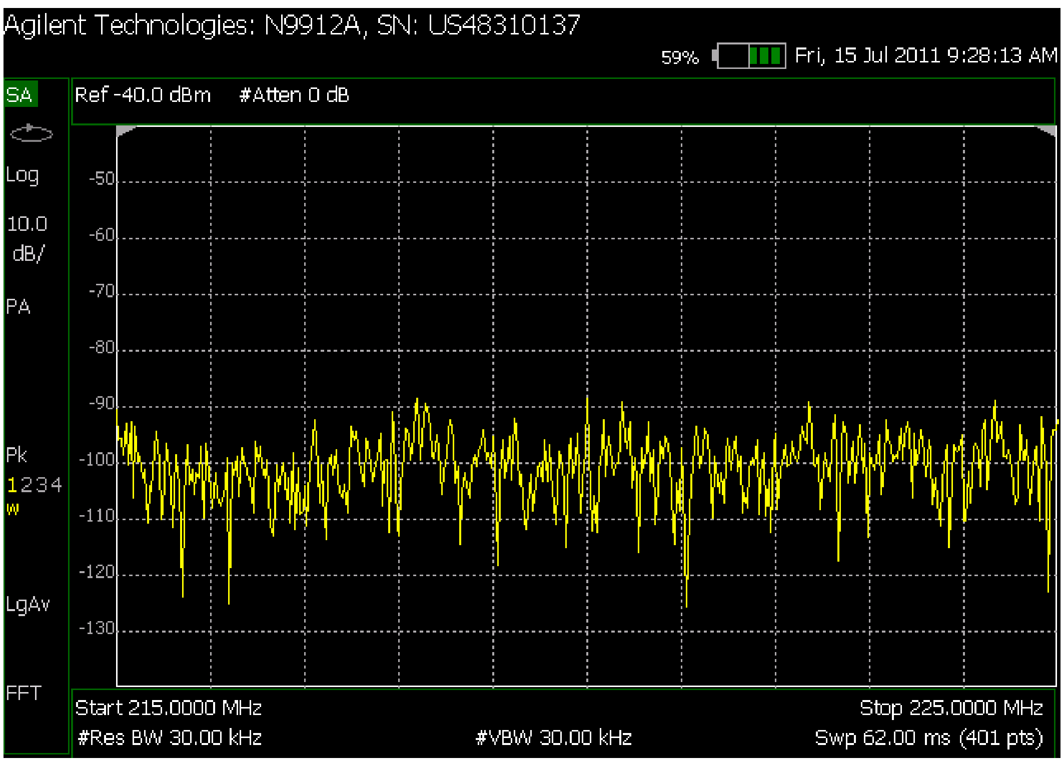


Figure 24: BNSF CP Rhodes 200 to 250 MHz band inside with 220 MHz Antenna with CTC activity

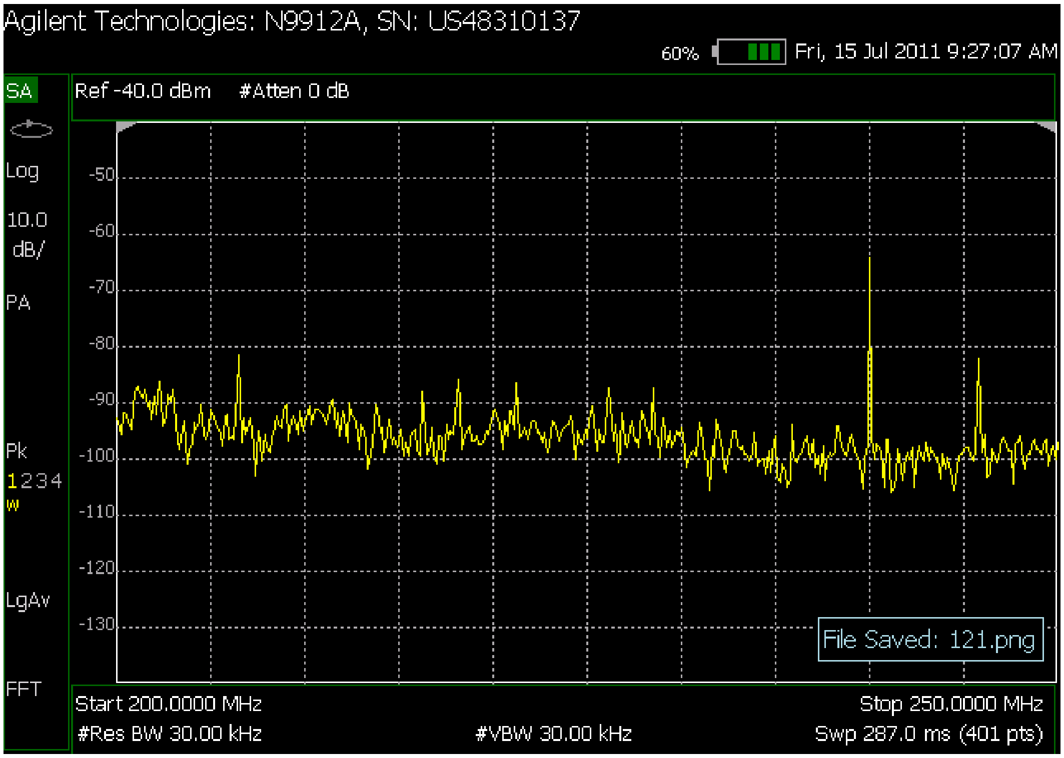
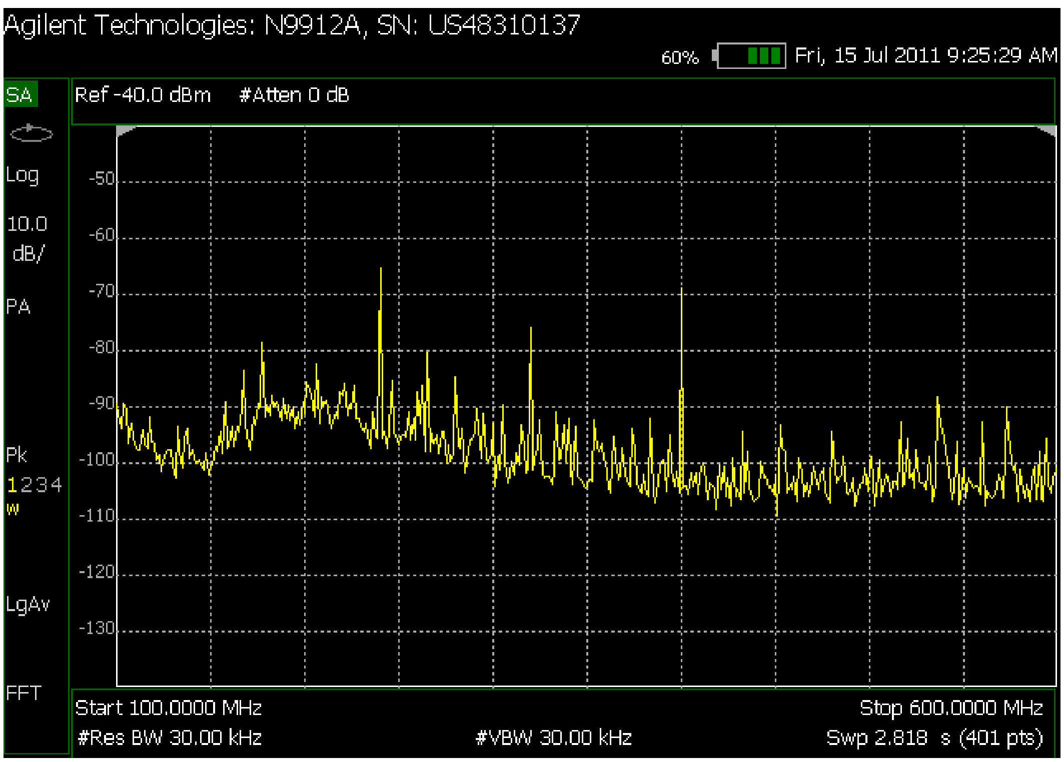


Figure 25: BNSF CP Rhodes 100 to 600 MHz band inside with 220 MHz Antenna with CTC activity



Appendix C: BNSF CP Titlow, Tacoma, WA

Figure 26: BNSF CP Titlow exterior view with Discone broadband antenna

Figure 27: BNSF CP Titlow view of 35' swing-down antenna mast for 160 MHz ARES radio

Figure 28: BNSF CP Titlow interior view with DC track circuit relay rack

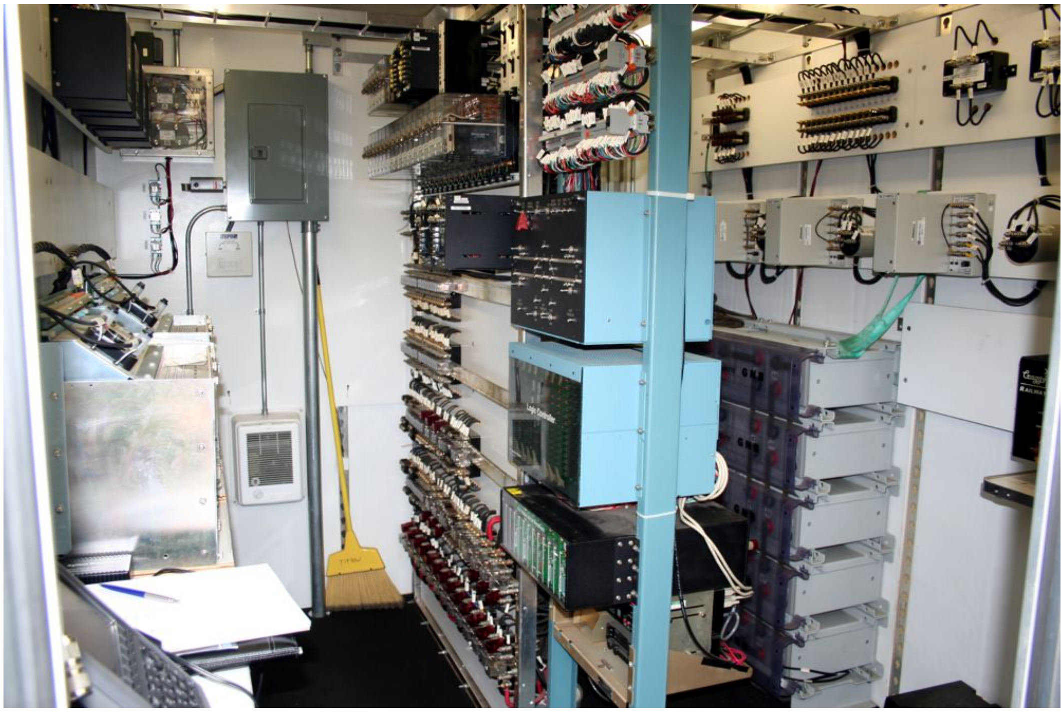


Figure 29: BNSF CP Titlow interior view with audio frequency track circuit equipment

Figure 30: BNSF CP Titlow interior view with Agilent N9912A Field Fox RF analyzer

Figure 31: BNSF CP Titlow interior view with 220 MHz antenna and metal ground plane

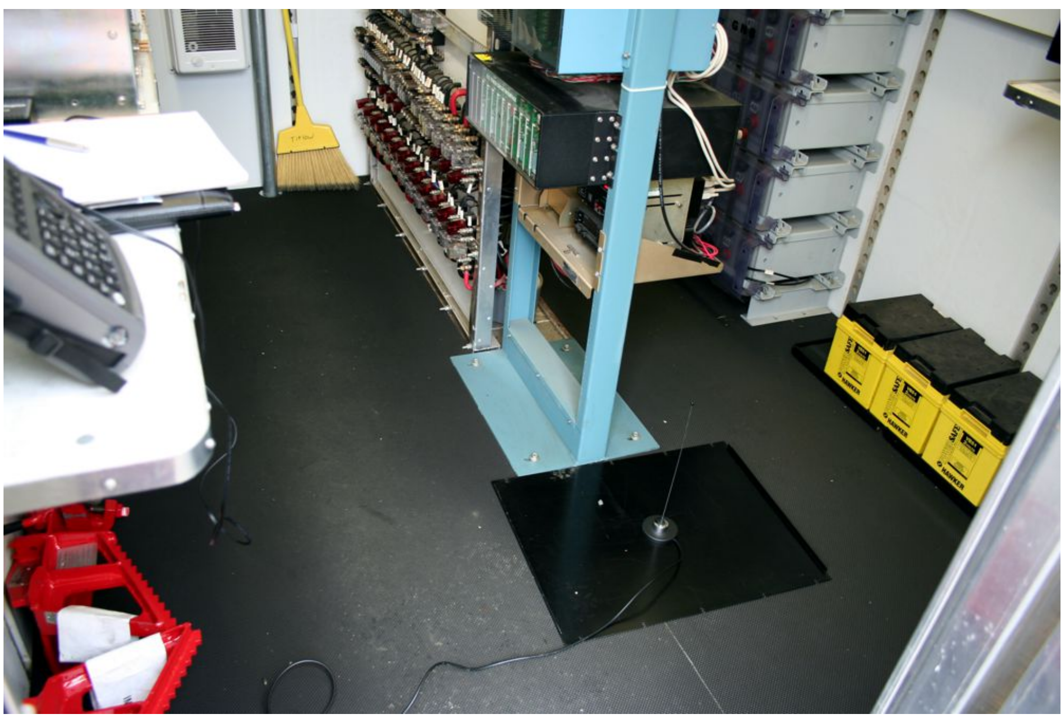


Figure 32: BNSF CP Titlow 215 to 225 MHz band outside with Discone Antenna no CTC activity

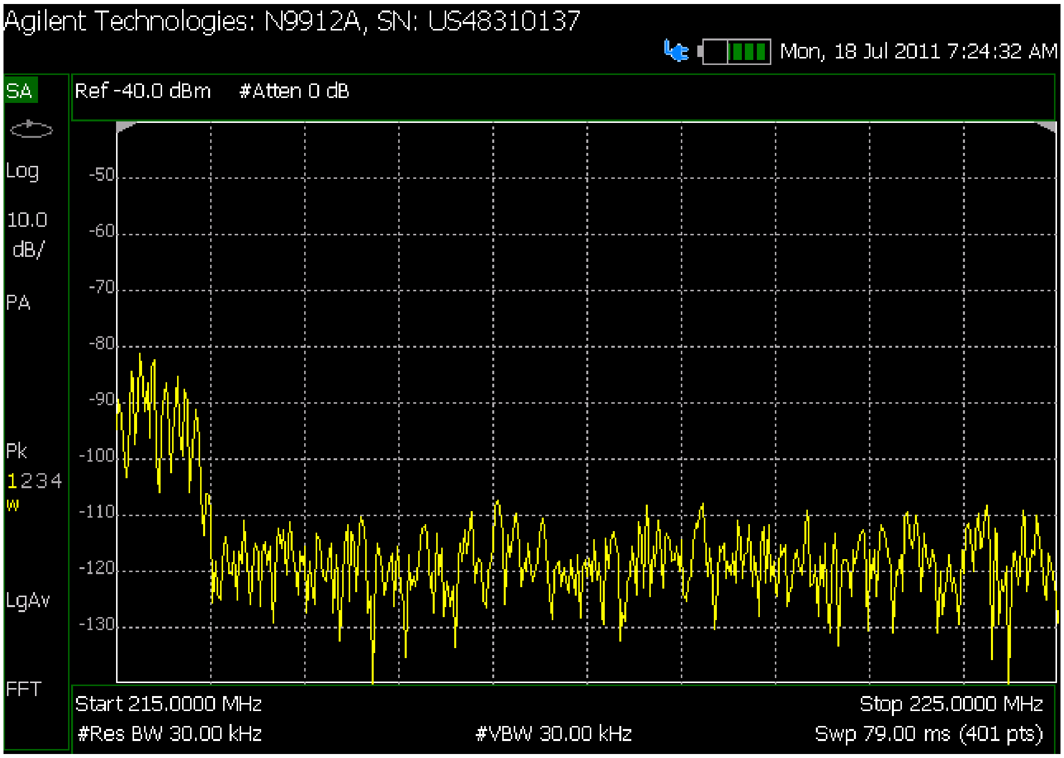


Figure 33: BNSF CP Titlow 215 to 225 MHz band outside with Discone Antenna with CTC activity

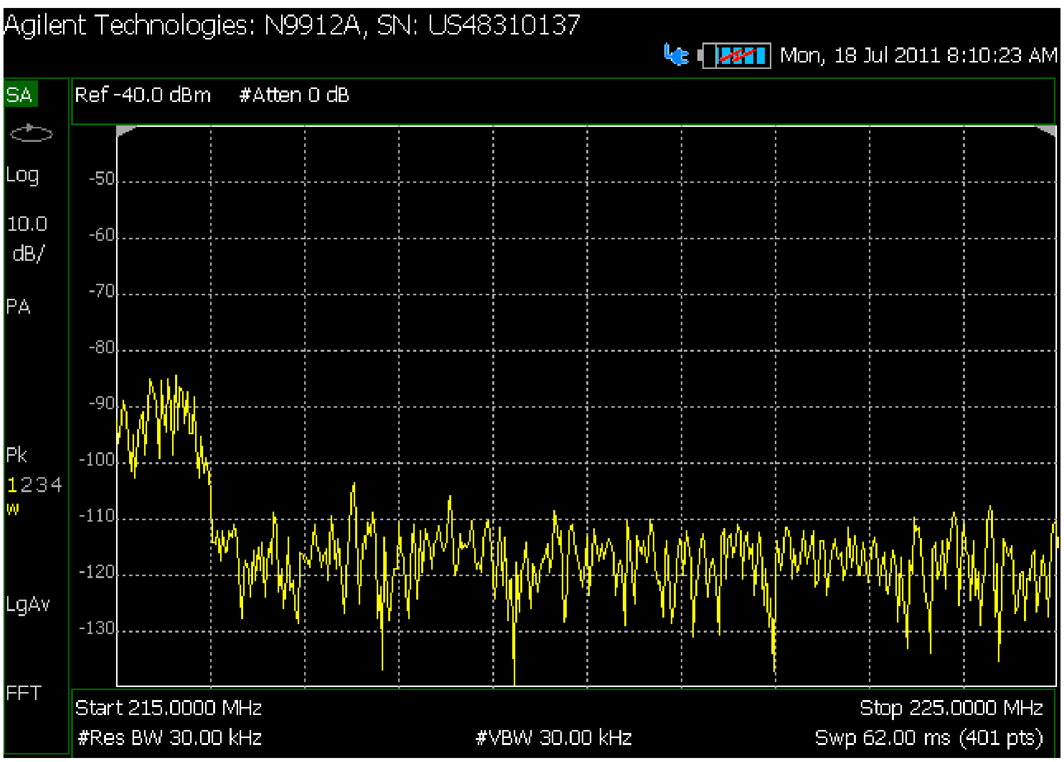


Figure 34: BNSF CP Titlow 215 to 225 MHz band inside with 220 MHz Antenna no CTC activity

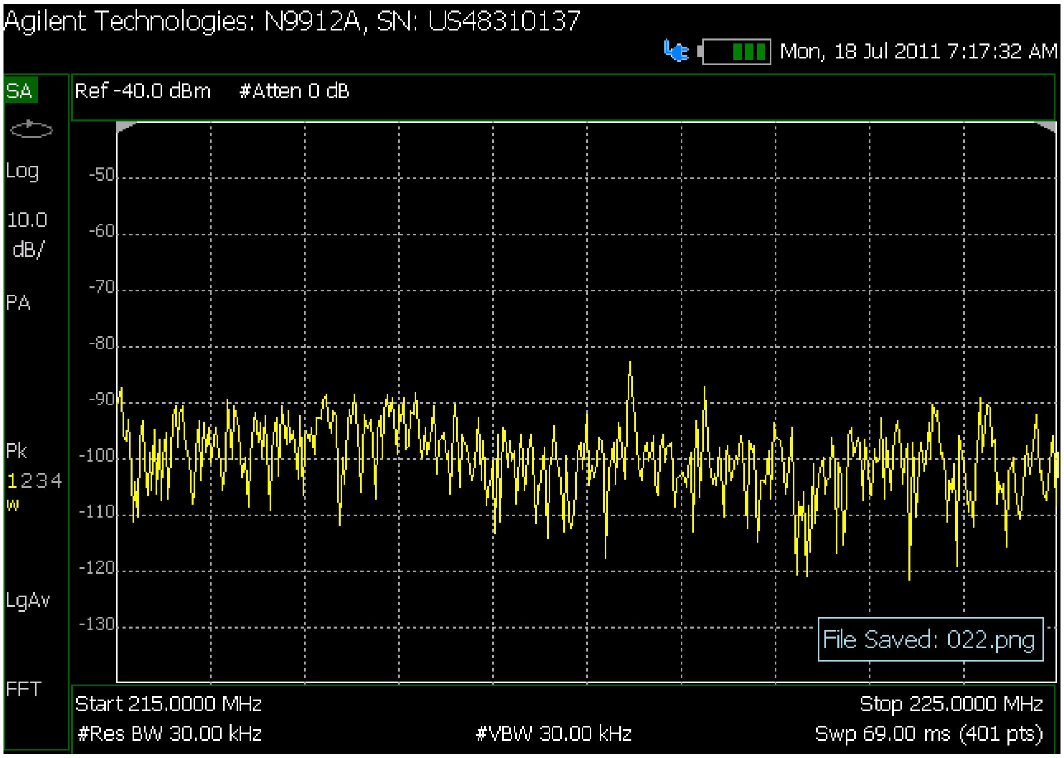
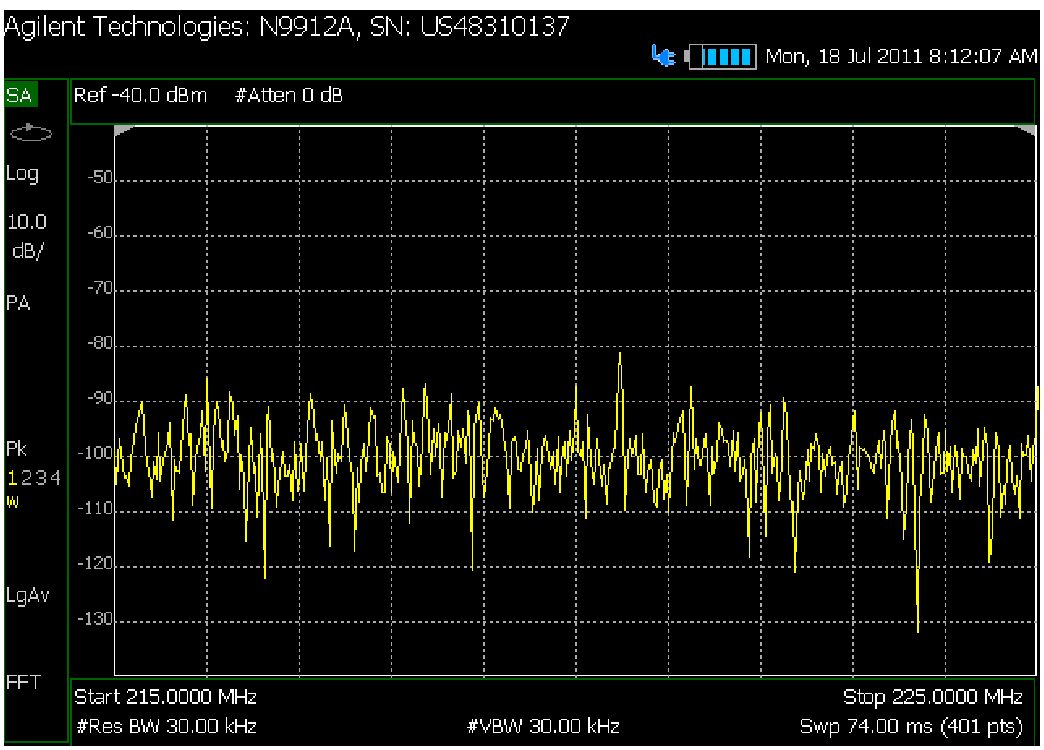


Figure 35: BNSF CP Titlow 215 to 225 MHz band inside with 220 MHz Antenna with CTC activity



Appendix D: BNSF FED Site, Seattle, WA

Figure 36: BNSF FED site, Seattle exterior view

Figure 37: BNSF FED site, Seattle, left, UP Base Station site, right

Figure 38: BNSF FED site, Seattle, right, UP Base Station site, left

Figure 39: BNSF FED site, Seattle, view of UP Base Station antennas

Appendix E: BNSF Auburn Base Station, Auburn, WA

Figure 40: BNSF Auburn Base Station exterior view

Figure 41: BNSF Auburn Base Station closer exterior view

Figure 42: BNSF Auburn Base Station antenna tower top view

Figure 43: BNSF Auburn Base Station antennas mounted on side of tower

Figure 44: BNSF Auburn Base Station antennas mounted on top of tower

Figure 45: BNSF Auburn BS three base station radios, bottom center - ARES radio, top center

Figure 46: BNSF Auburn BS rear view of three base station radios, bottom center

Figure 47: BNSF Auburn Base Station microwave equipment

Figure 48: BNSF Auburn Base Station 20 to 1000 MHz Anritsu S412E

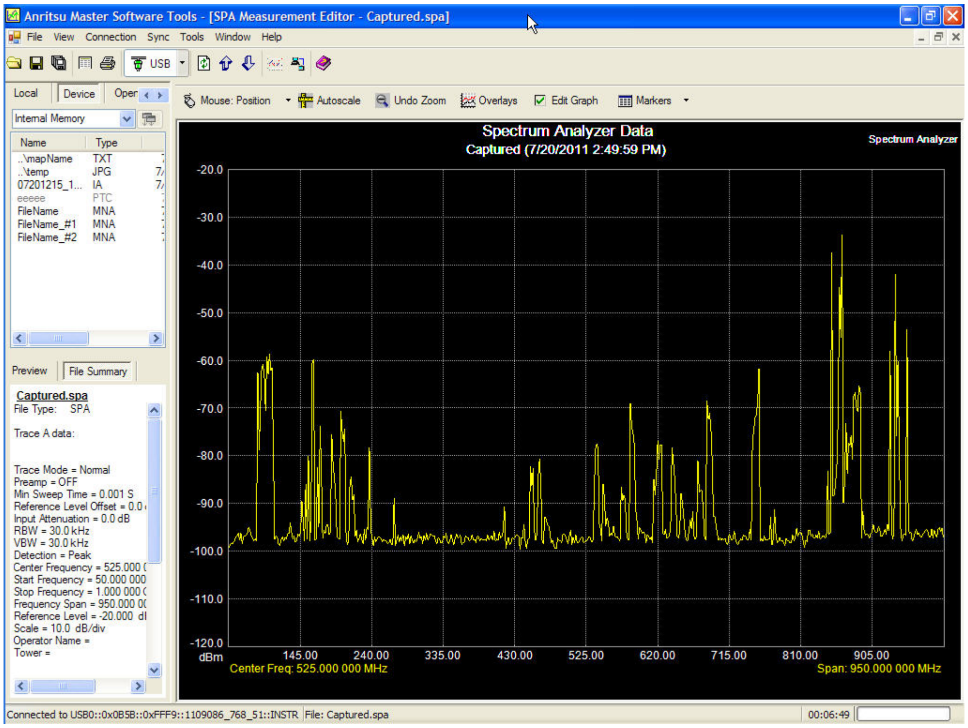


Figure 49: BNSF Auburn Base Station 20 to 1000 MHz Agilent N6841A

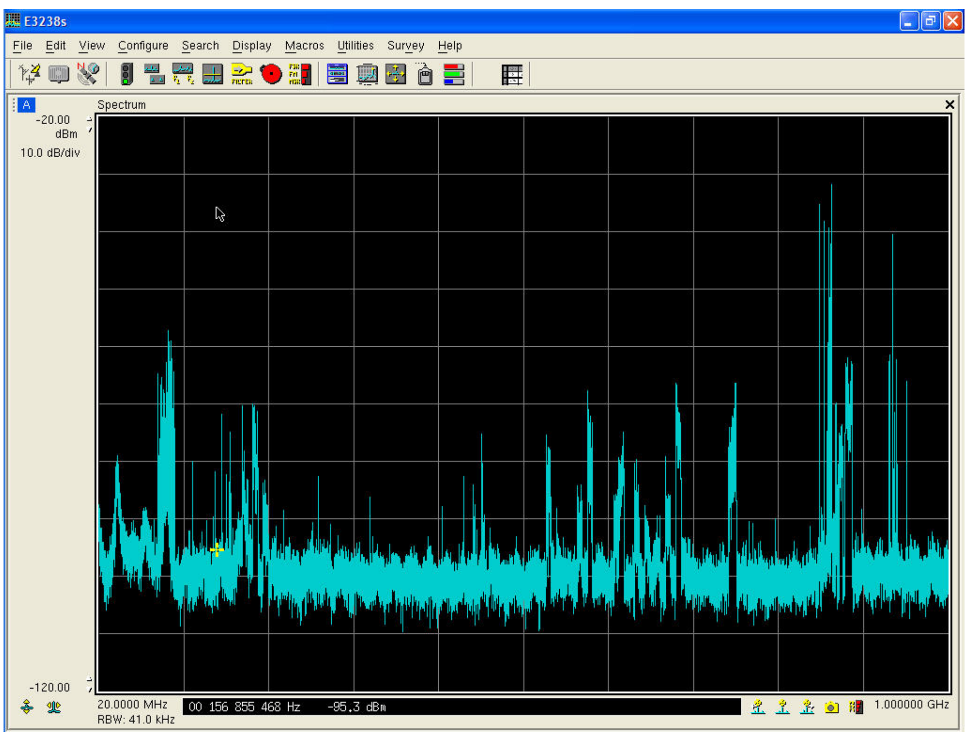


Figure 50: BNSF Auburn Base Station 20 to 60 MHz Anritsu S412E

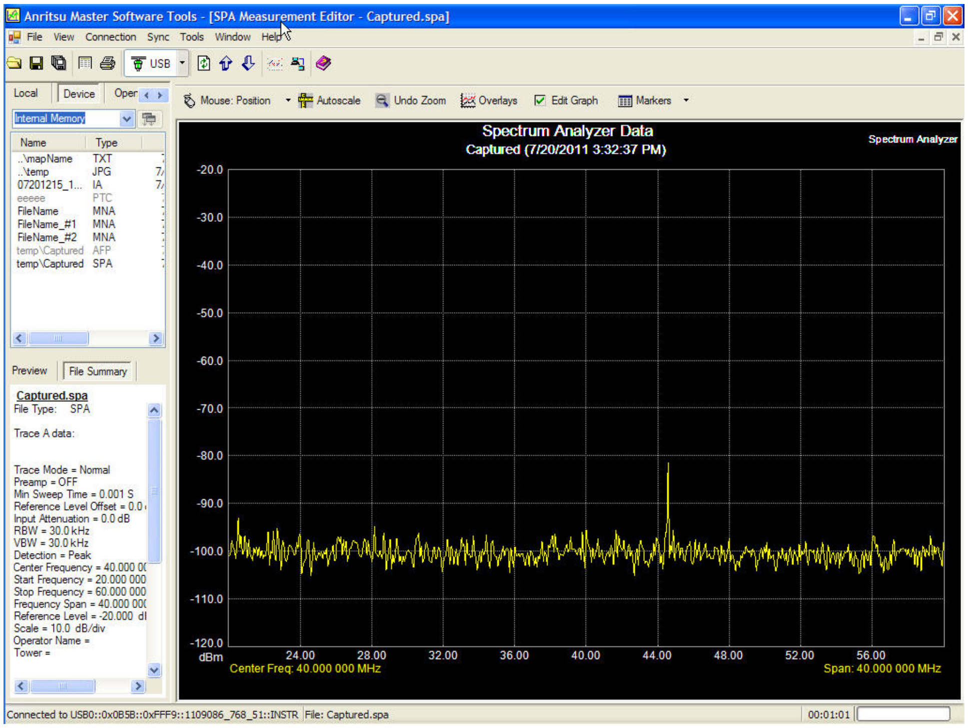


Figure 51: BNSF Auburn Base Station 20 to 60 MHz Agilent N6841A

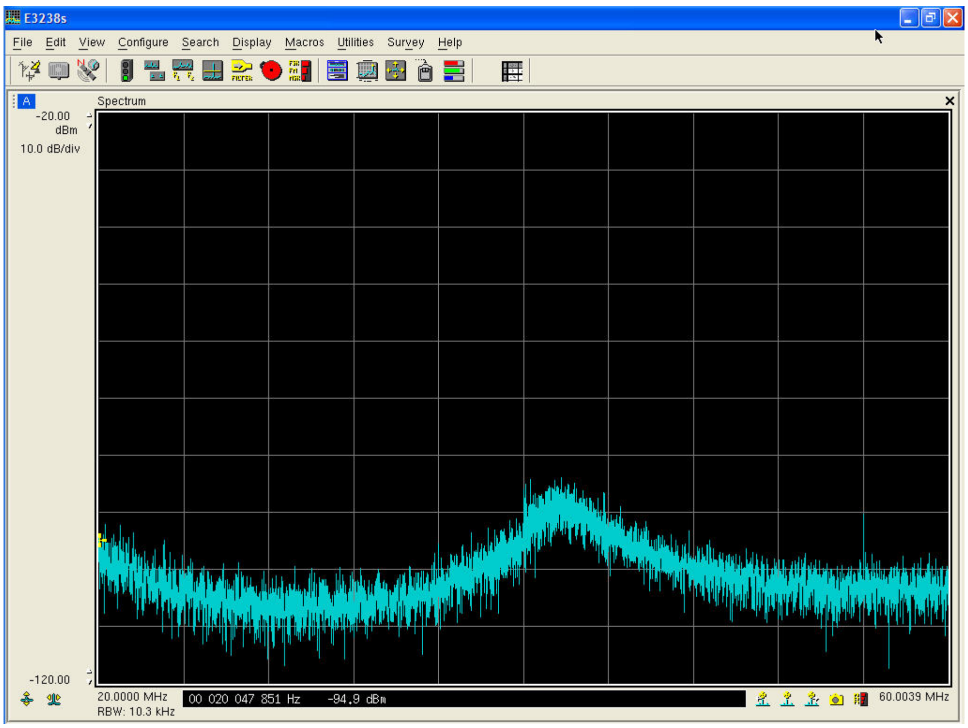


Figure 52: BNSF Auburn Base Station 50 to 110 MHz Anritsu S412E

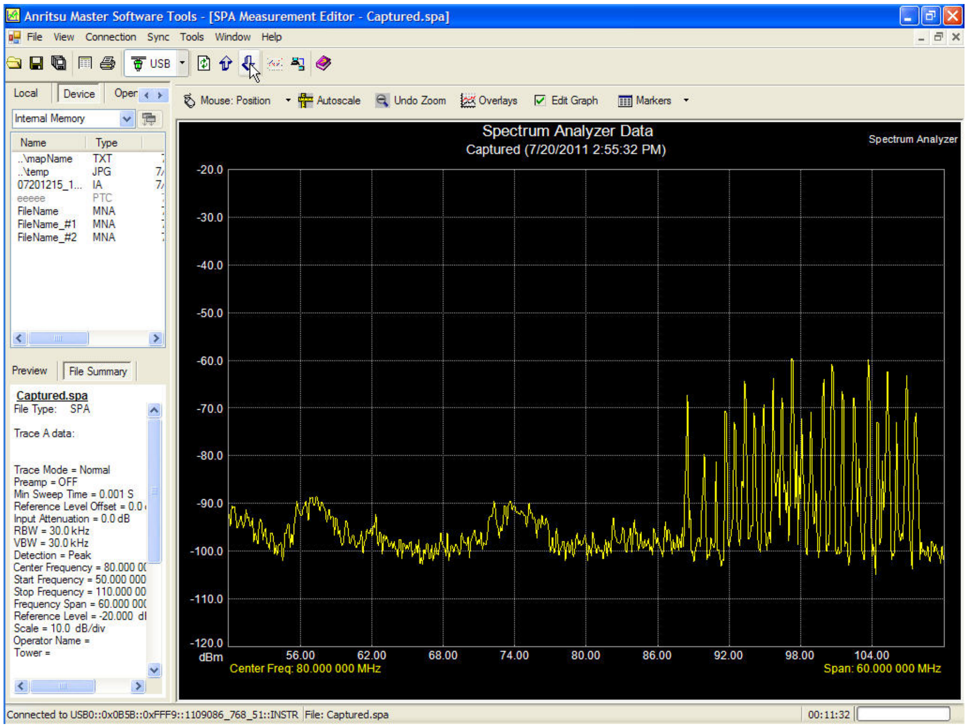


Figure 53: BNSF Auburn Base Station 50 to 110 MHz Agilent N6841A

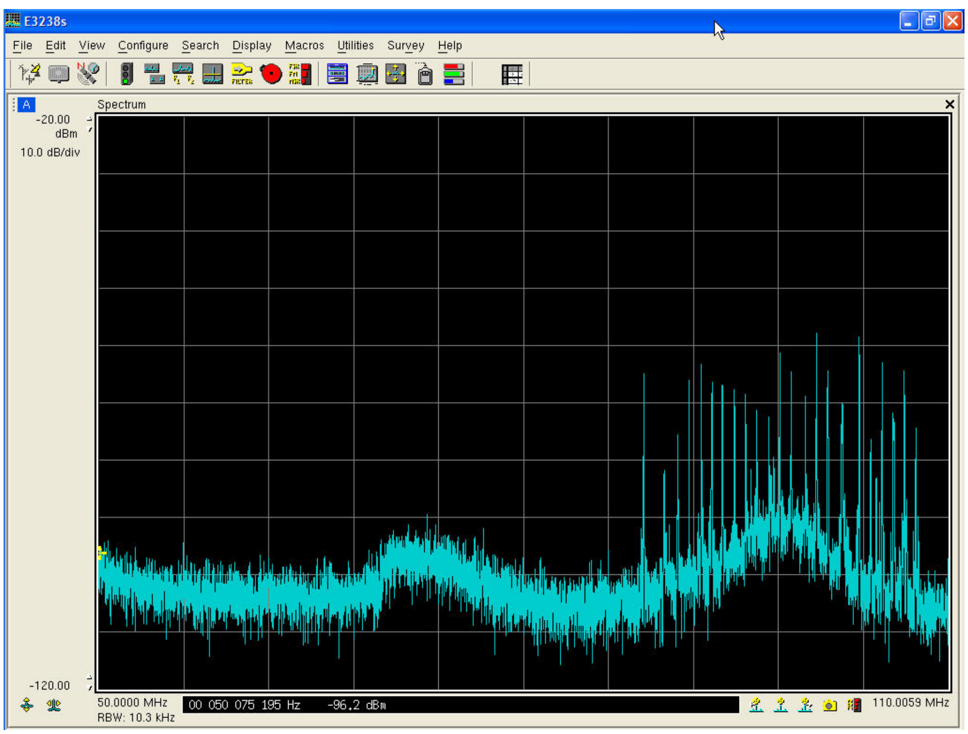


Figure 54: BNSF Auburn Base Station 86 to 110 MHz Anritsu S412E

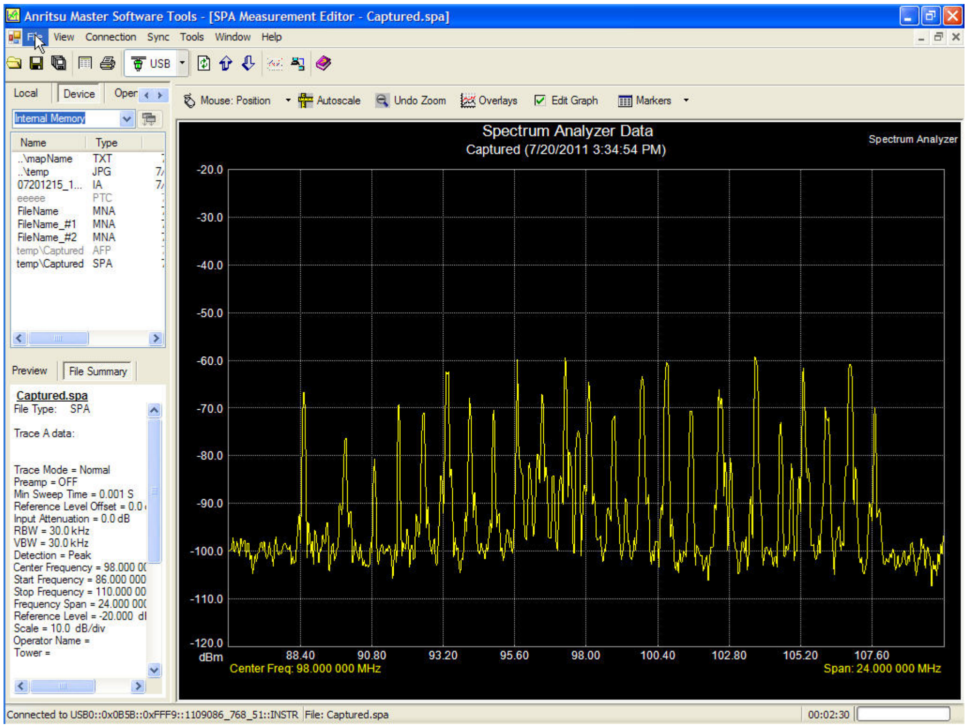


Figure 55: BNSF Auburn Base Station 86 to 110 MHz Agilent N6841A

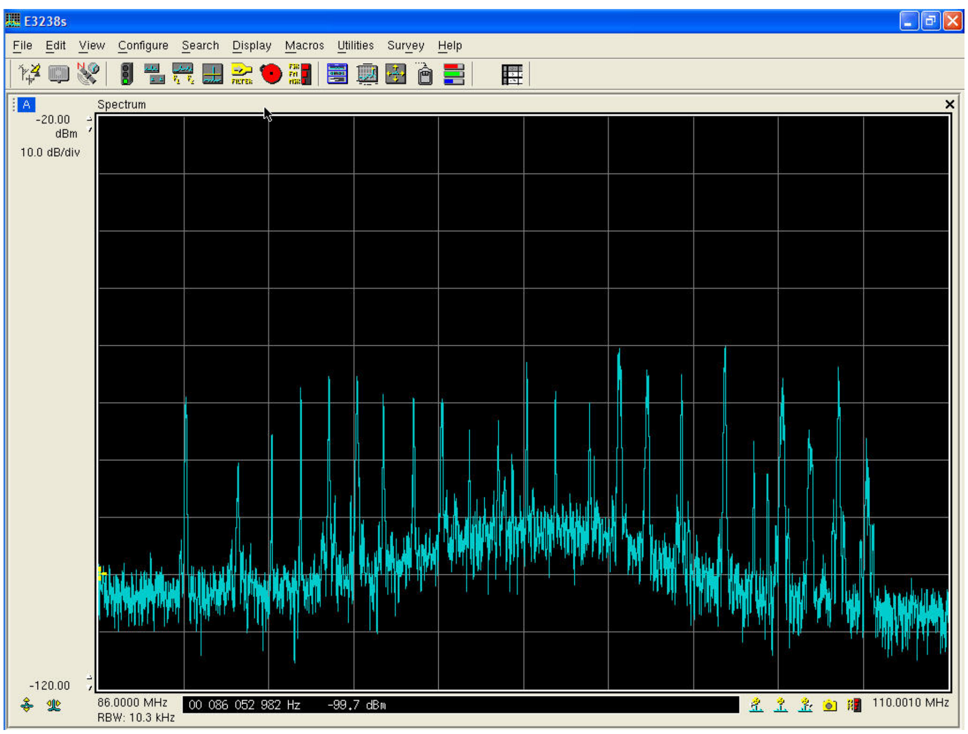


Figure 56: BNSF Auburn Base Station 100 to 200 MHz Anritsu S412E

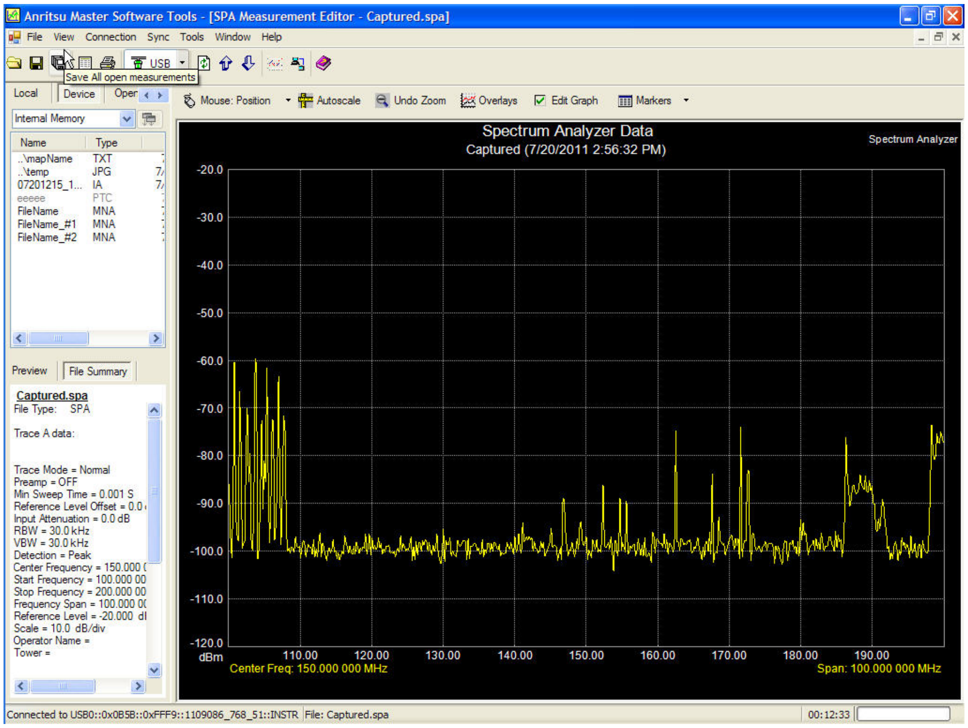


Figure 57: BNSF Auburn Base Station 100 to 200 MHz Agilent N6841A

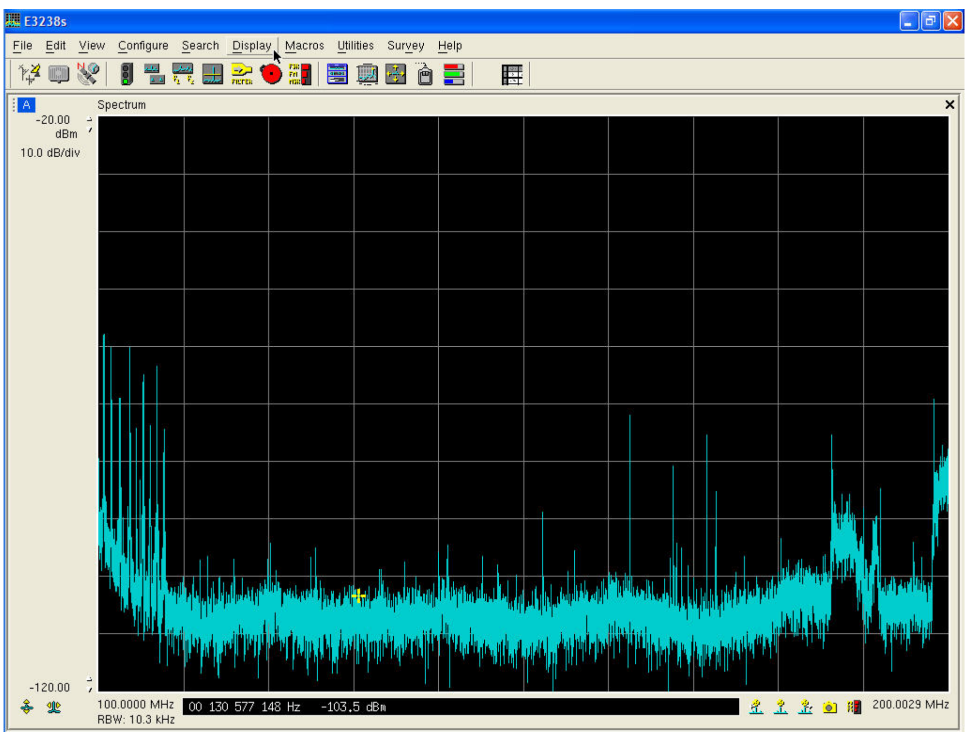


Figure 58: BNSF Auburn Base Station 138 to 172 MHz Anritsu S412E

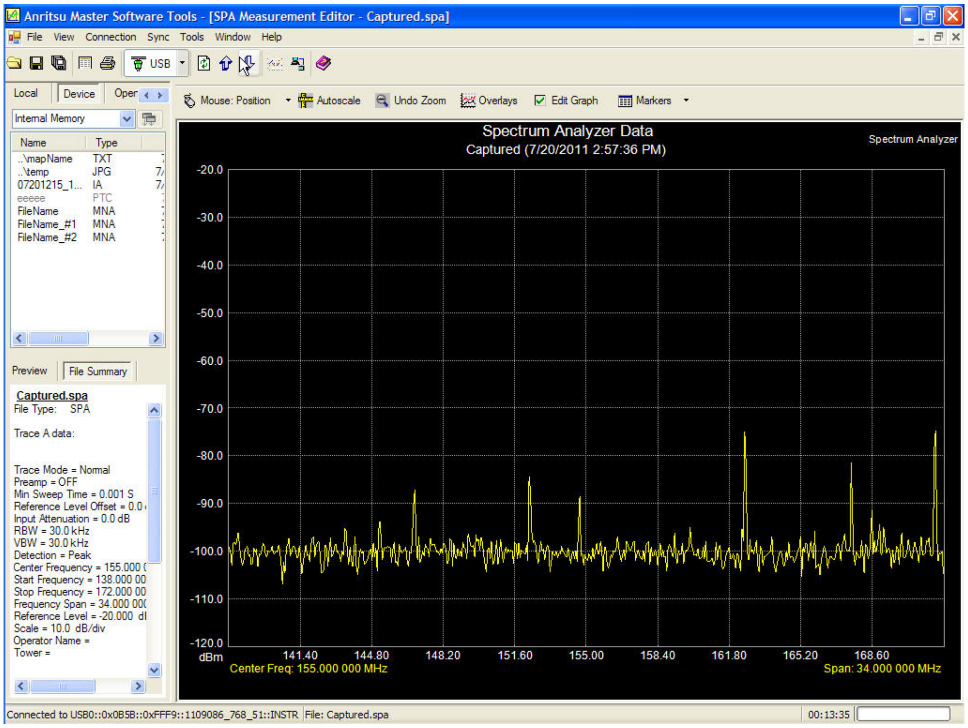


Figure 59: BNSF Auburn Base Station 138 to 172 MHz Agilent N6841A

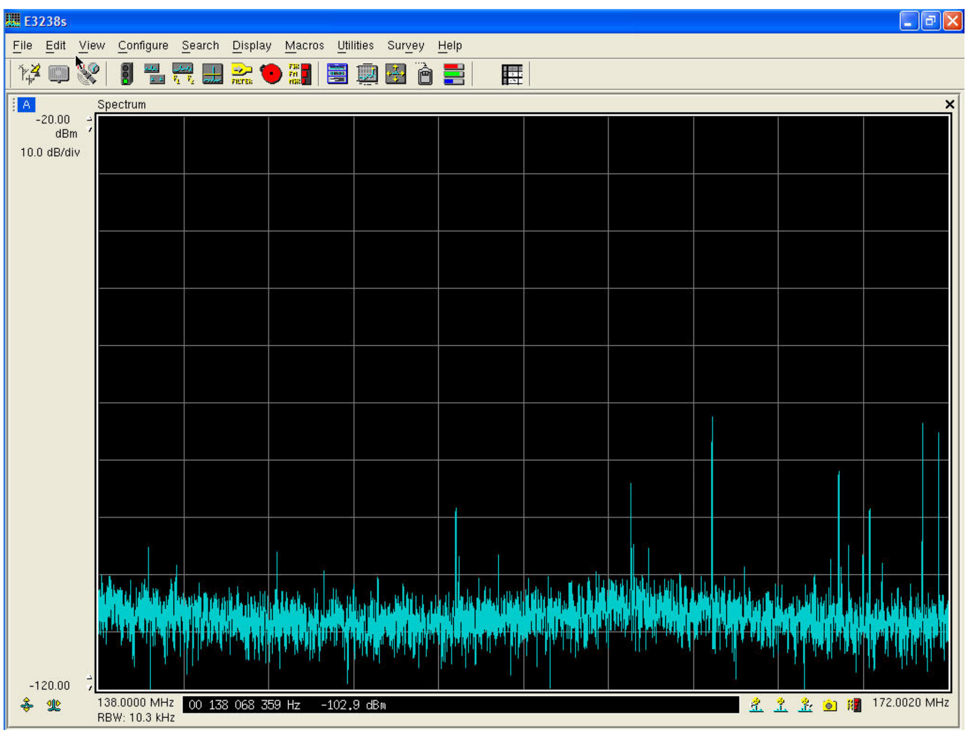


Figure 60: BNSF Auburn Base Station 138 to 230 MHz Anritsu S412E

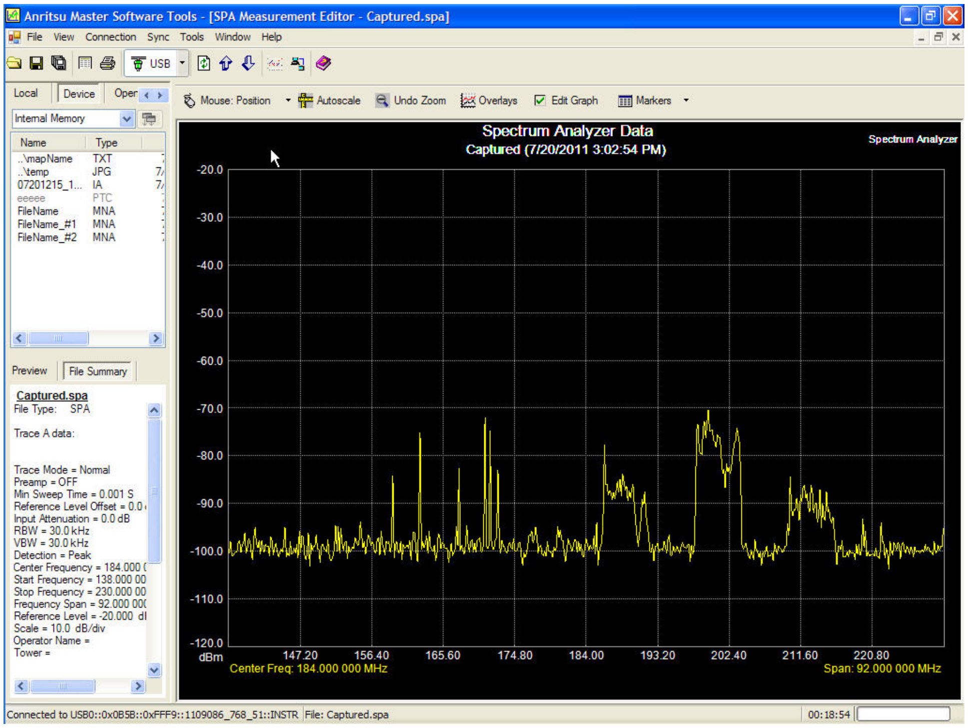


Figure 61: BNSF Auburn Base Station 138 to 230 MHz Agilent N6841A

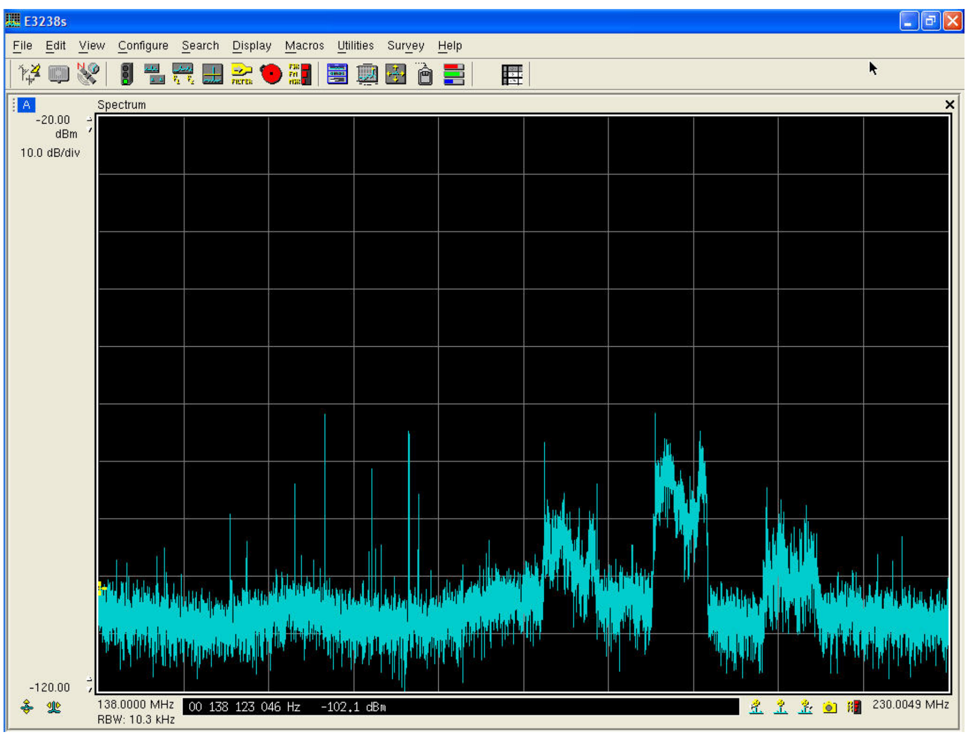


Figure 62: BNSF Auburn Base Station 150 to 170 MHz Anritsu S412E

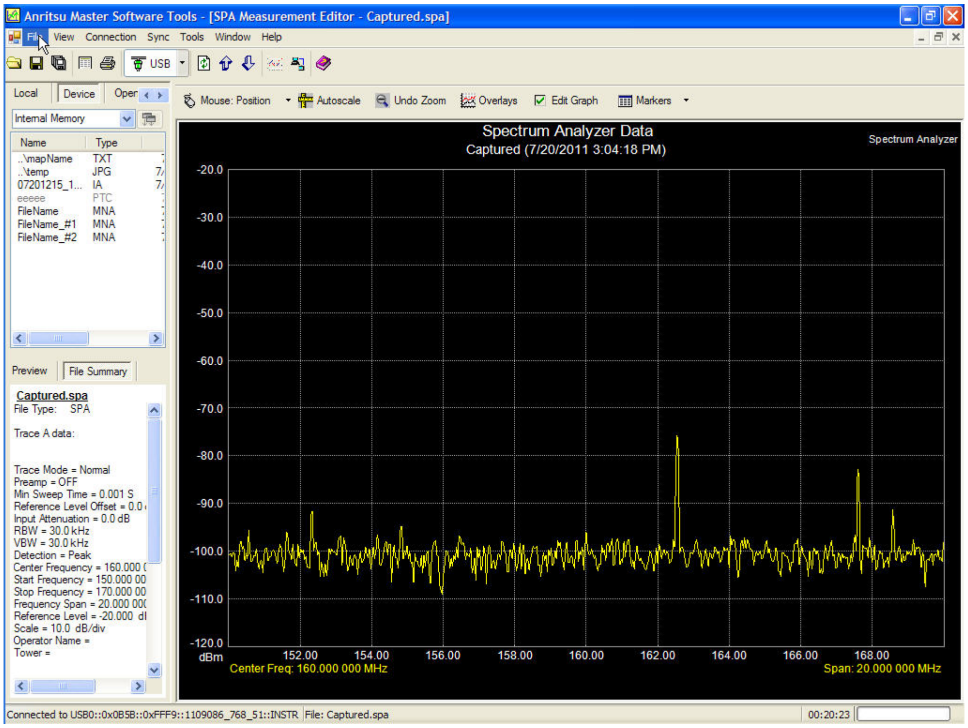


Figure 63: BNSF Auburn Base Station 150 to 170 MHz Agilent N6841A

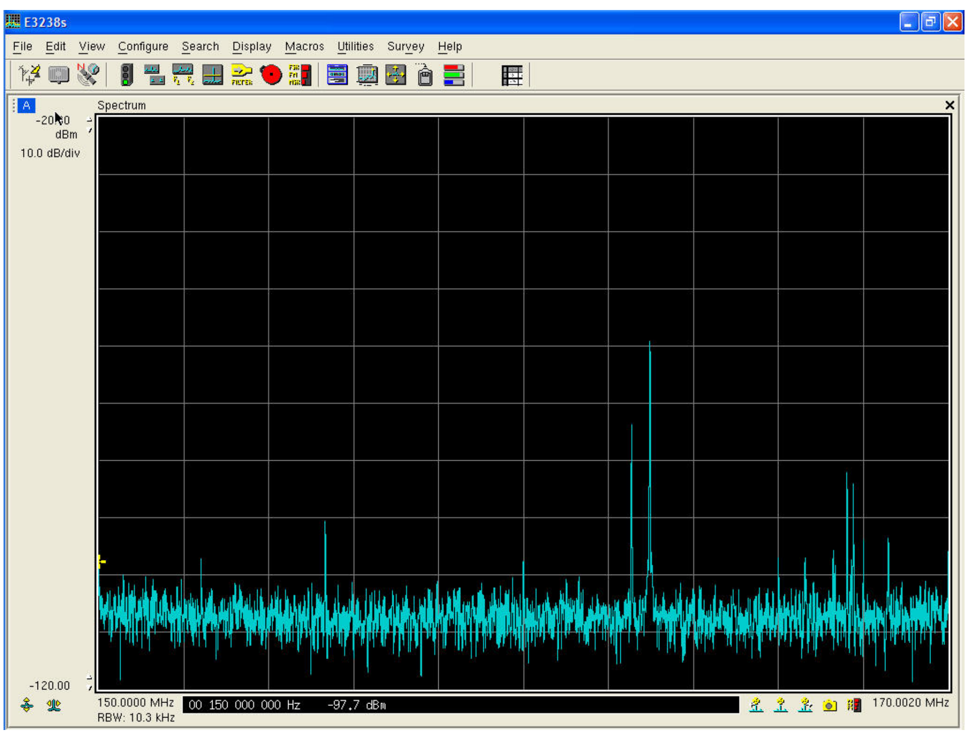


Figure 64: BNSF Auburn Base Station 208 to 228 MHz Anritsu S412E

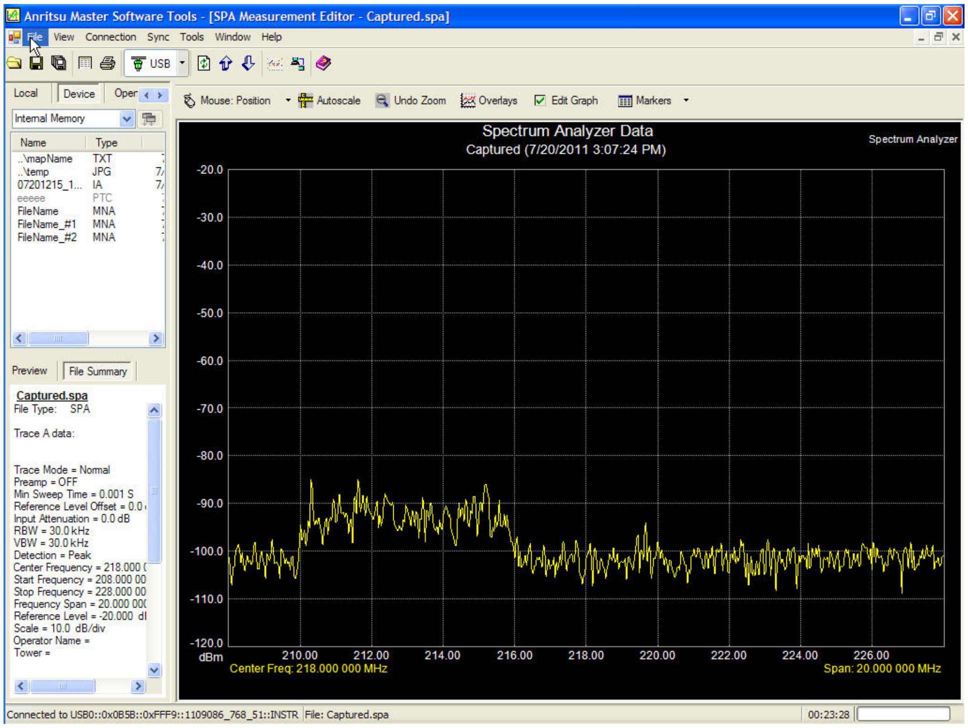


Figure 65: BNSF Auburn Base Station 208 to 228 MHz Agilent N6841A

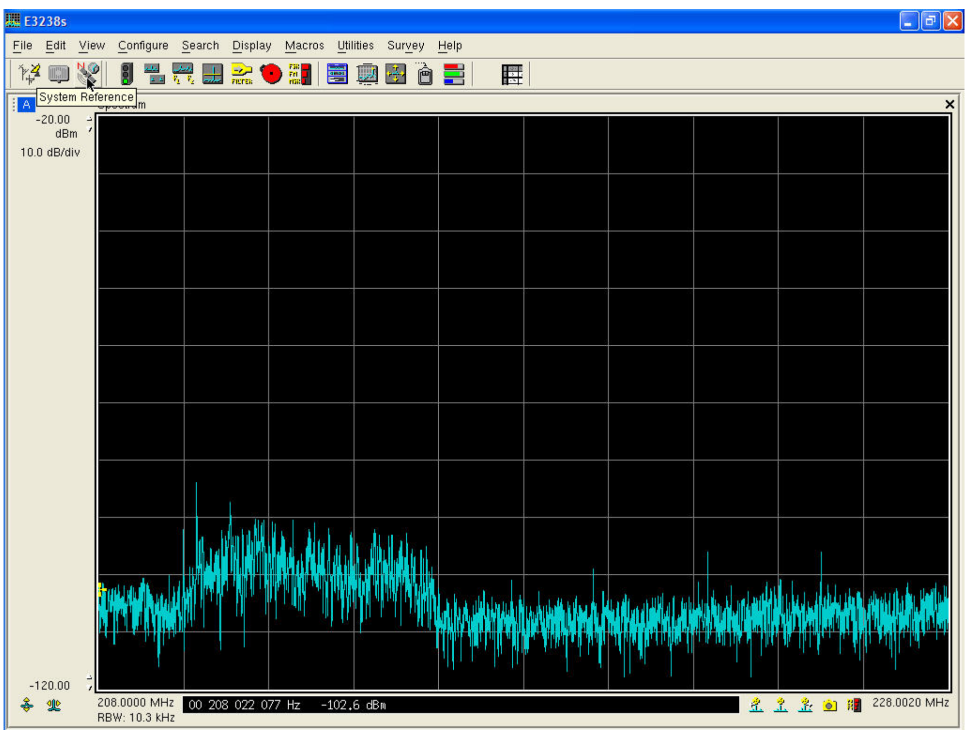


Figure 66: BNSF Auburn Base Station 215 to 225 MHz Anritsu S412E

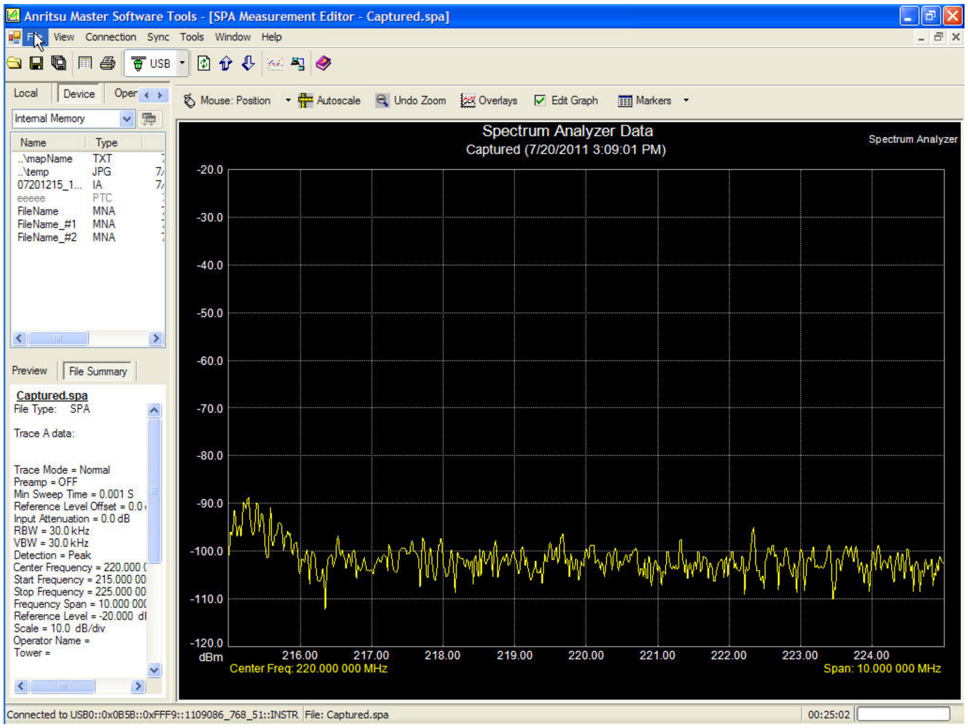
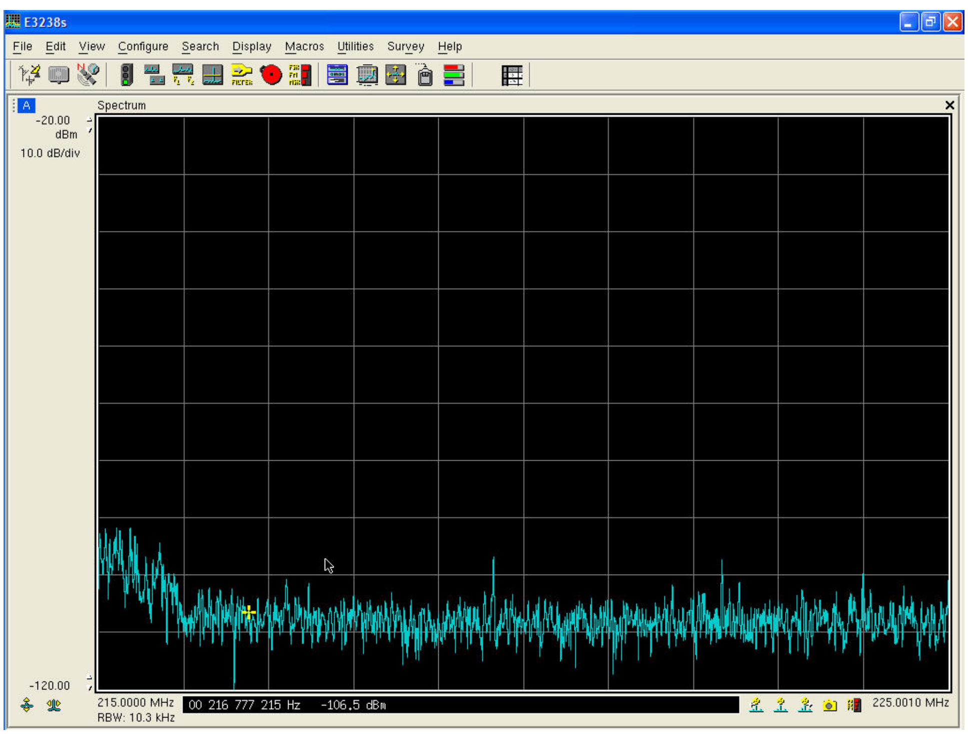


Figure 67: BNSF Auburn Base Station 215 to 225 MHz Agilent N6841A



DCN 00002522-A

Figure 68: BNSF Auburn Base Station 380 to 450 MHz Anritsu S412E

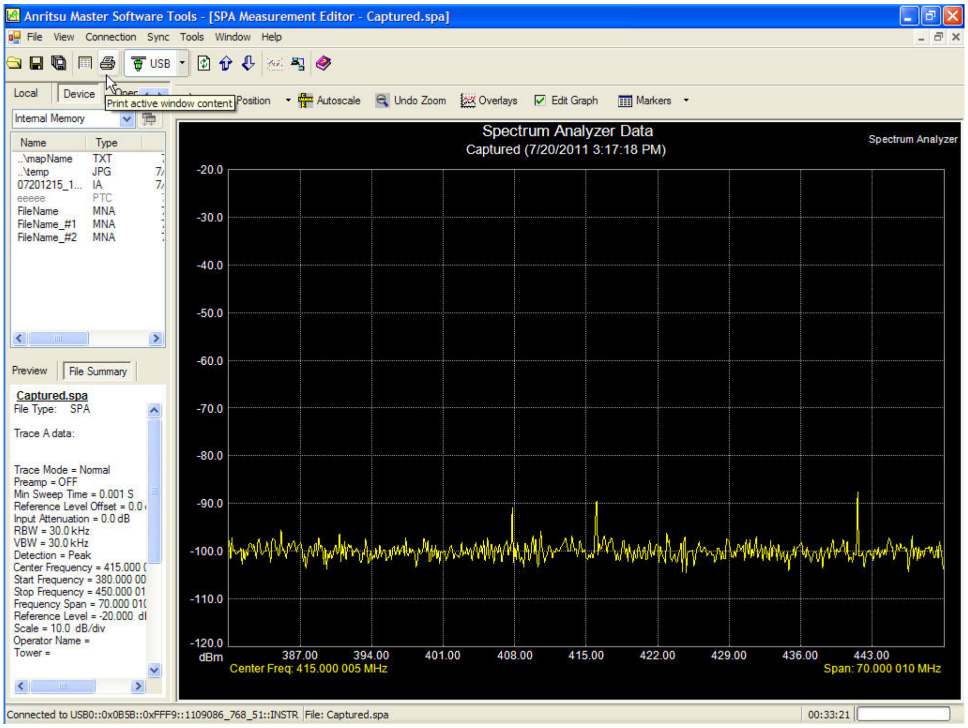


Figure 69: BNSF Auburn Base Station 380 to 450 MHz Agilent N6841A

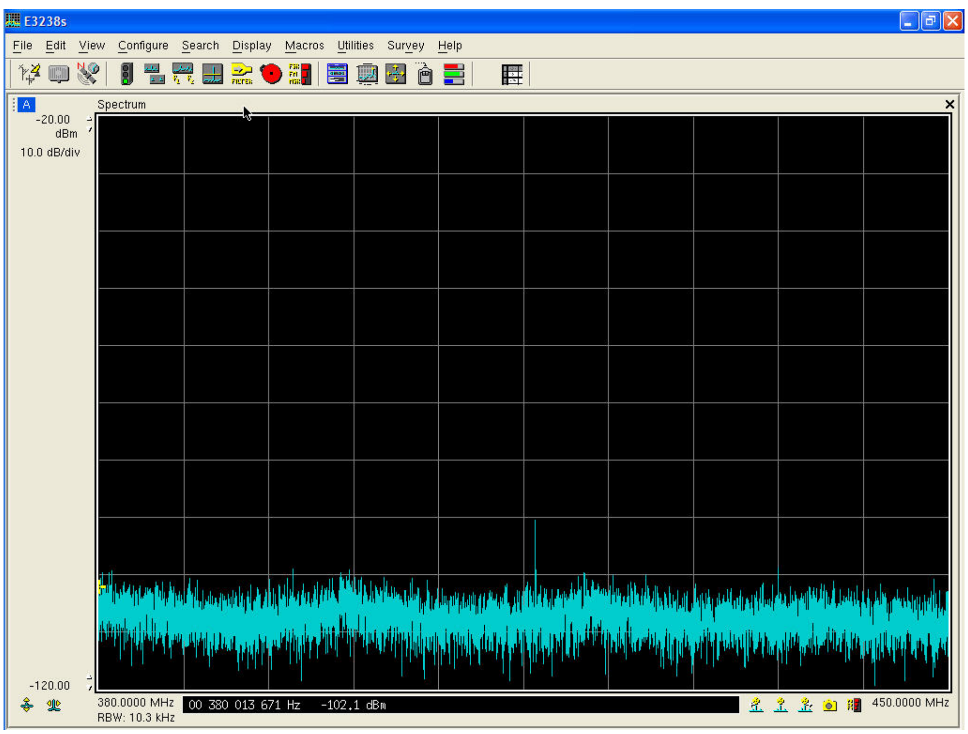


Figure 70: BNSF Auburn Base Station 450 to 470 MHz Anritsu S412E

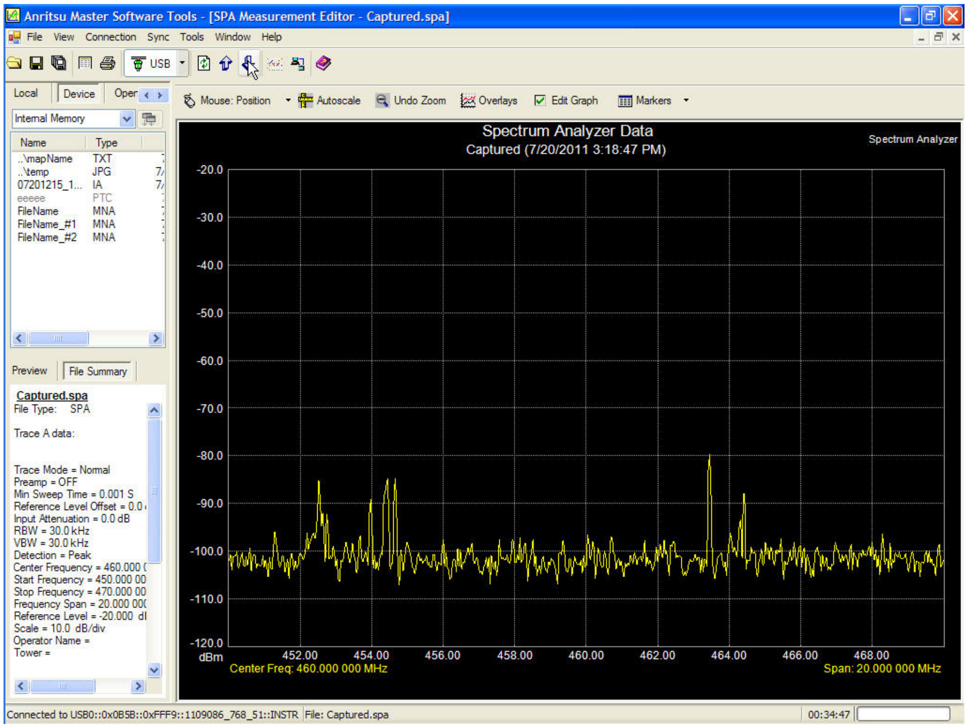
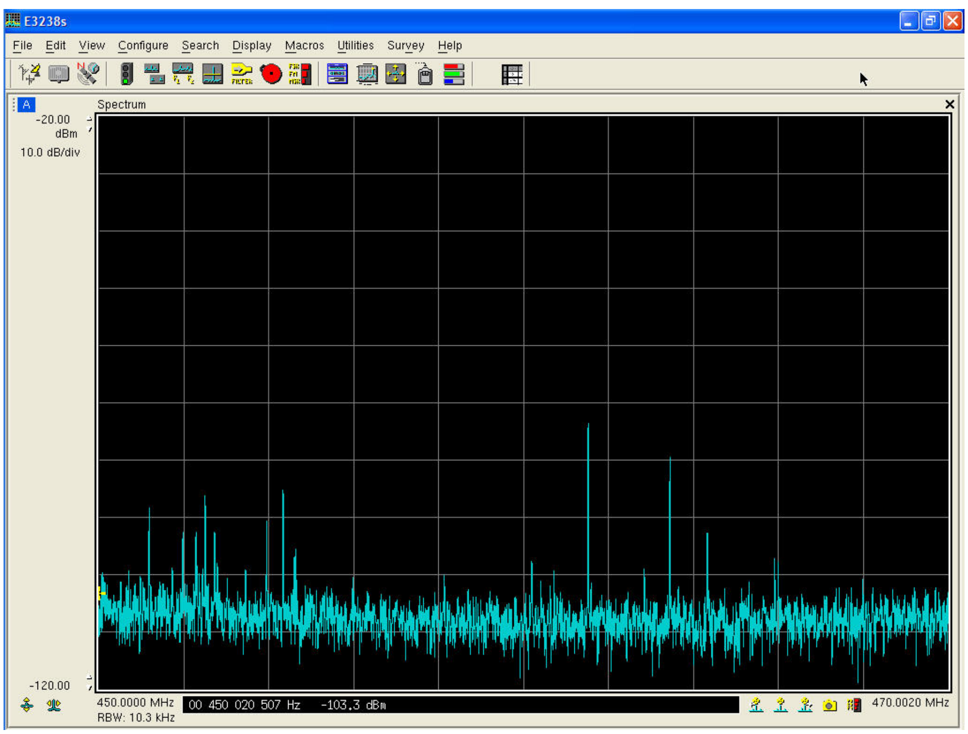


Figure 71: BNSF Auburn Base Station 450 to 470 MHz Agilent N6841A



DCN 00002522-A

Figure 72: BNSF Auburn Base Station 450 to 520 MHz Anritsu S412E

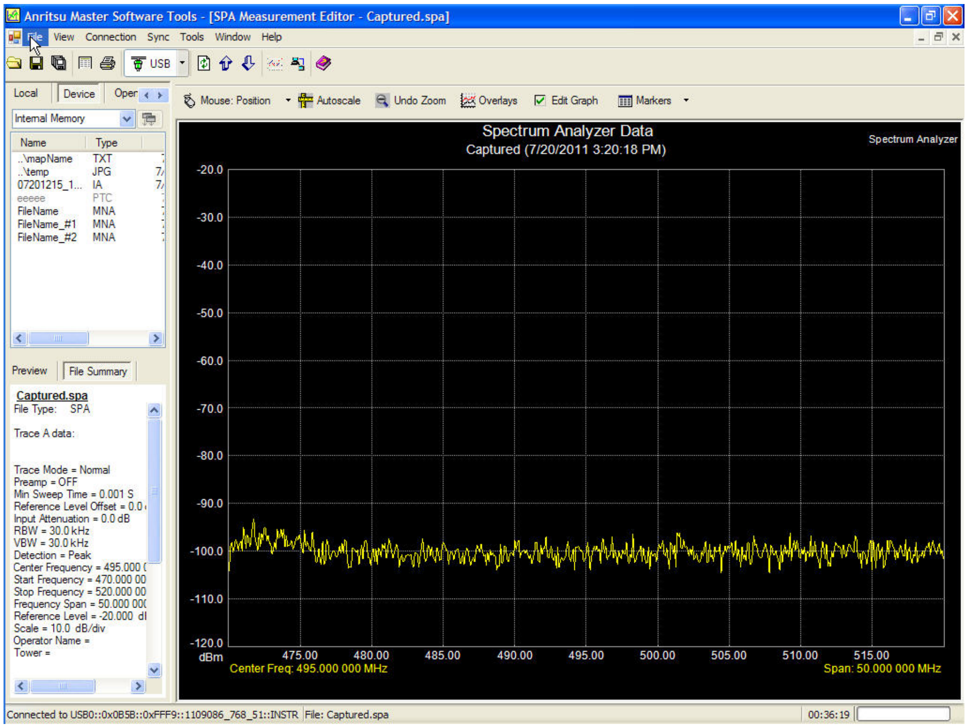


Figure 73: BNSF Auburn Base Station 450 to 520 MHz Agilent N6841A

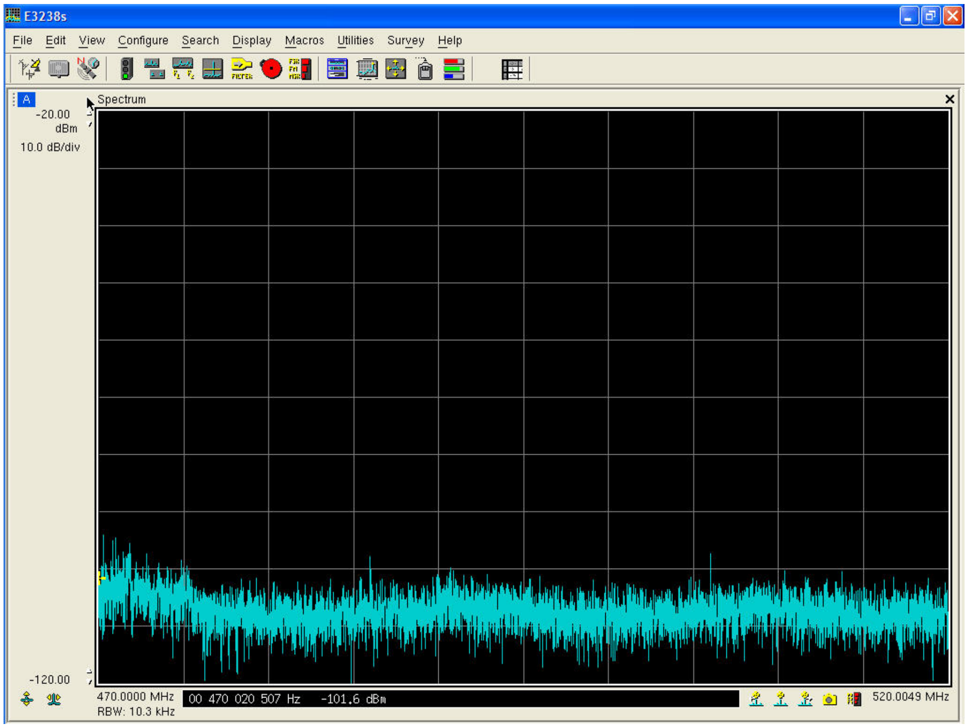


Figure 74: BNSF Auburn Base Station 700 to 800 MHz Anritsu S412E

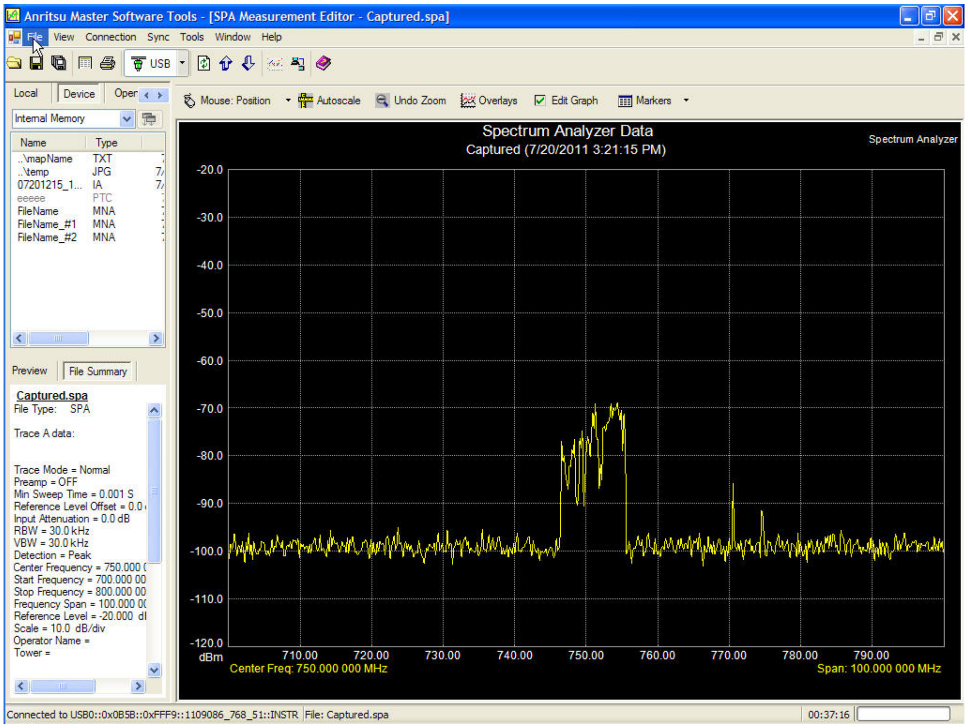


Figure 75: BNSF Auburn Base Station 700 to 800 MHz Agilent N6841A

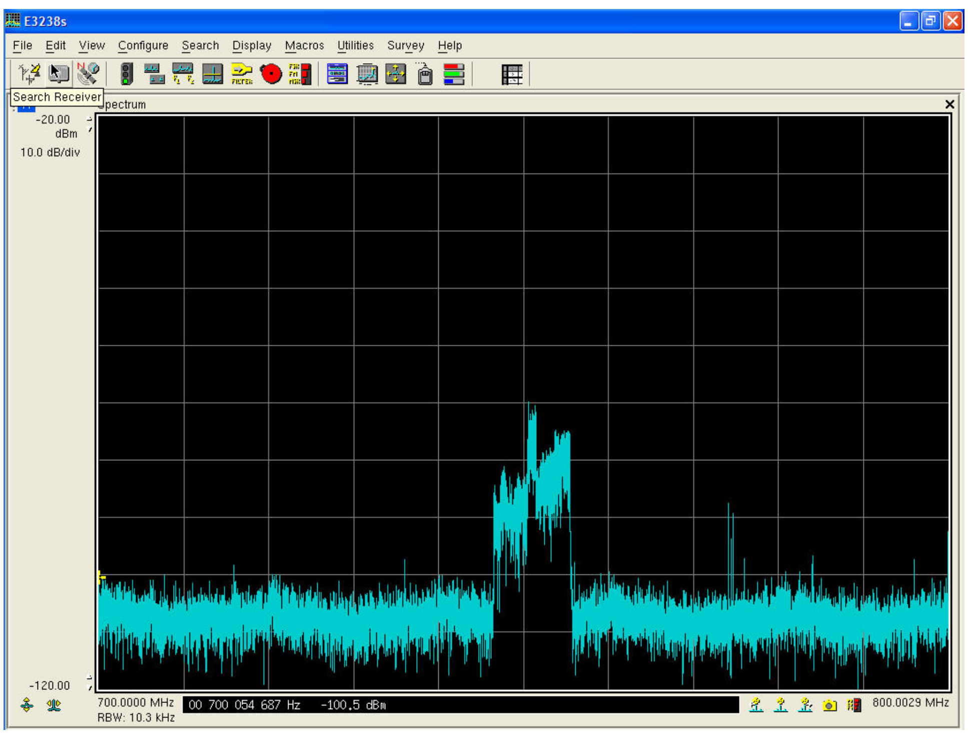


Figure 76: BNSF Auburn Base Station 800 to 860 MHz Anritsu S412E

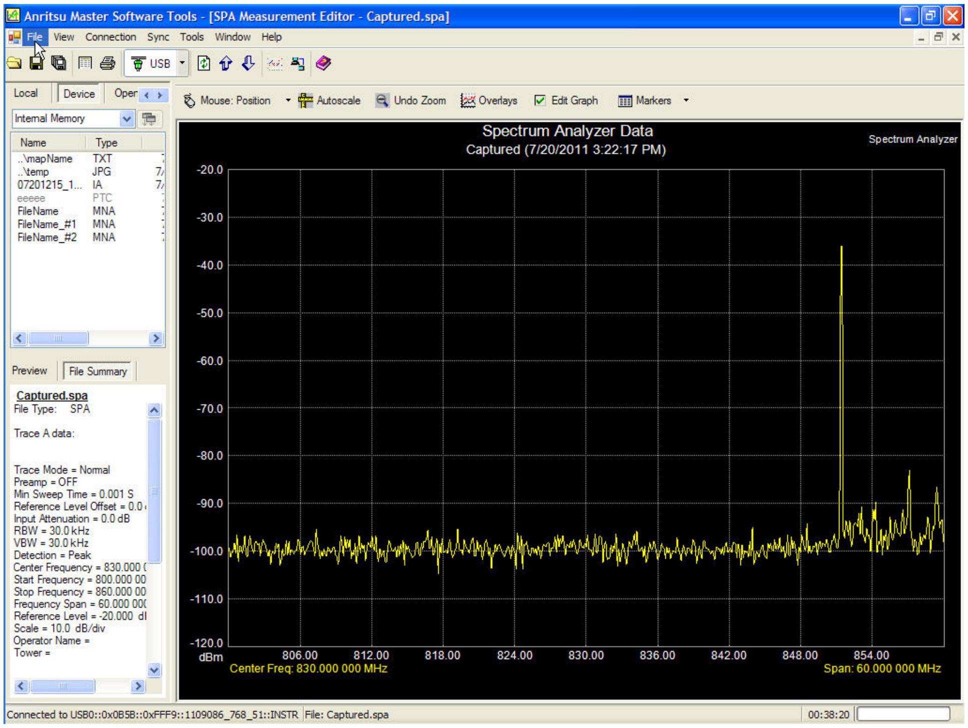


Figure 77: BNSF Auburn Base Station 700 to 800 MHz Agilent N6841A

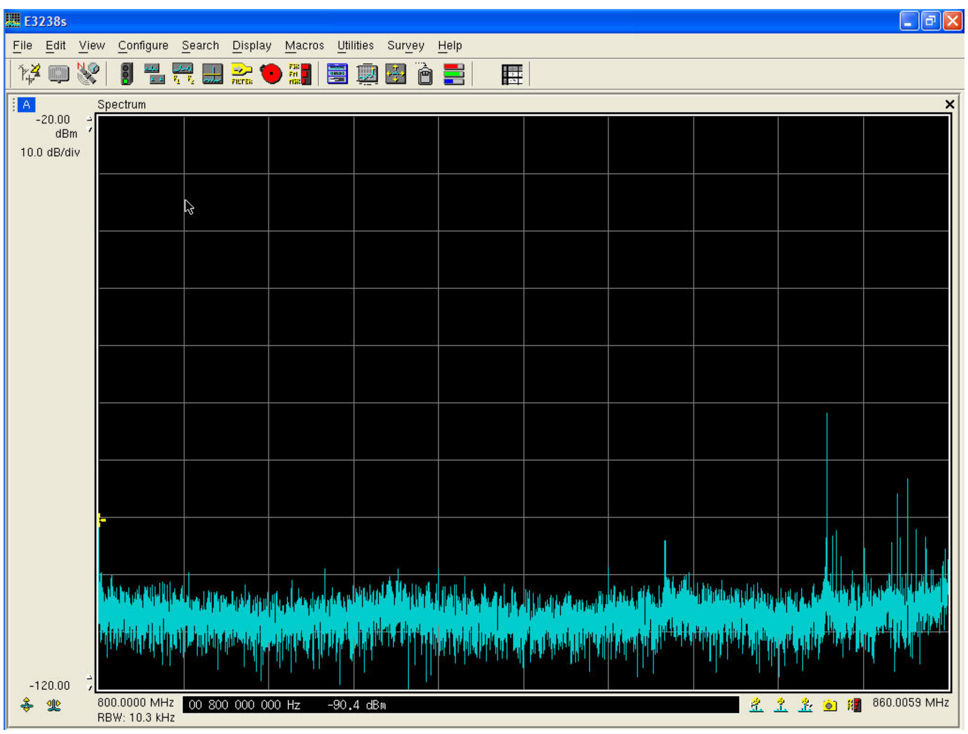


Figure 78: BNSF Auburn Base Station 850 to 900 MHz Anritsu S412E

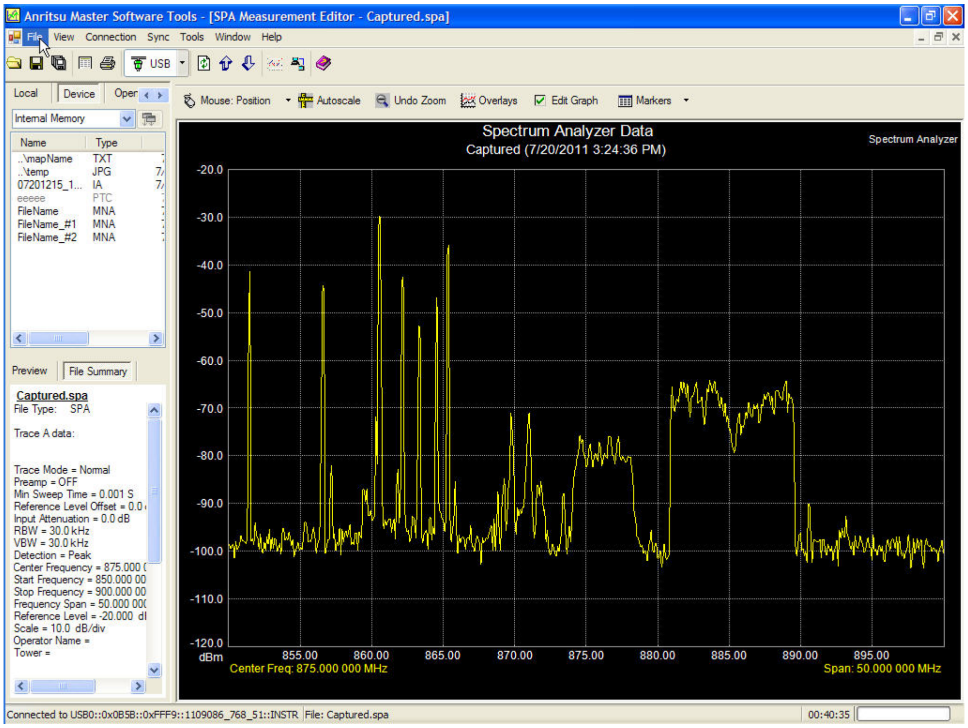
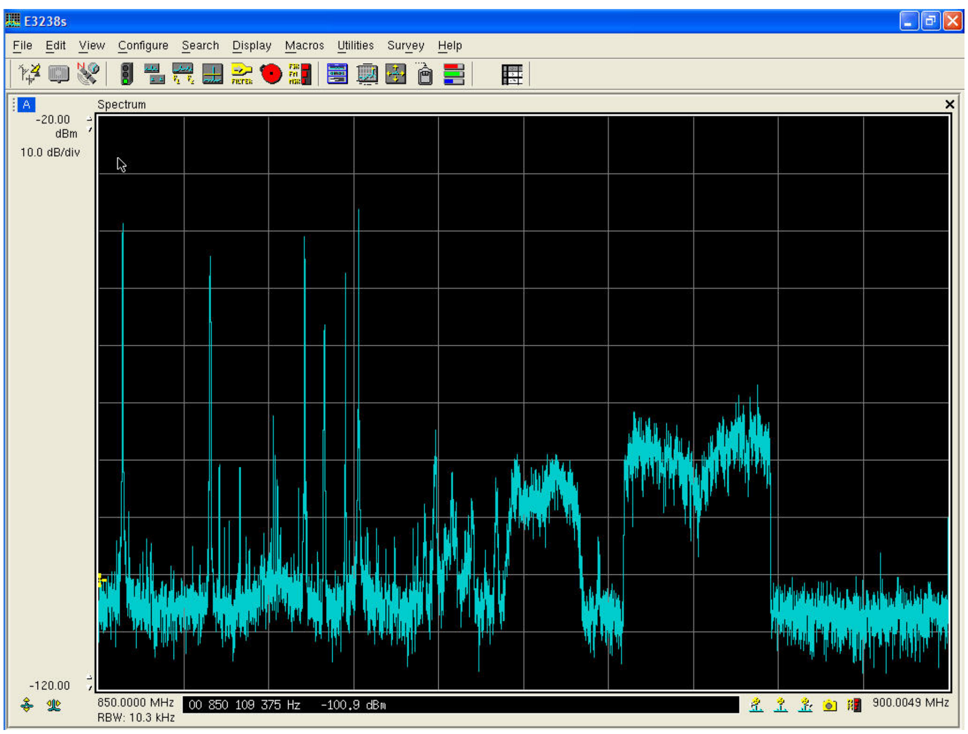


Figure 79: BNSF Auburn Base Station 850 to 900 MHz Agilent N6841A



DCN 00002522-A

Figure 80: BNSF Auburn Base Station 850 to 950 MHz Anritsu S412E

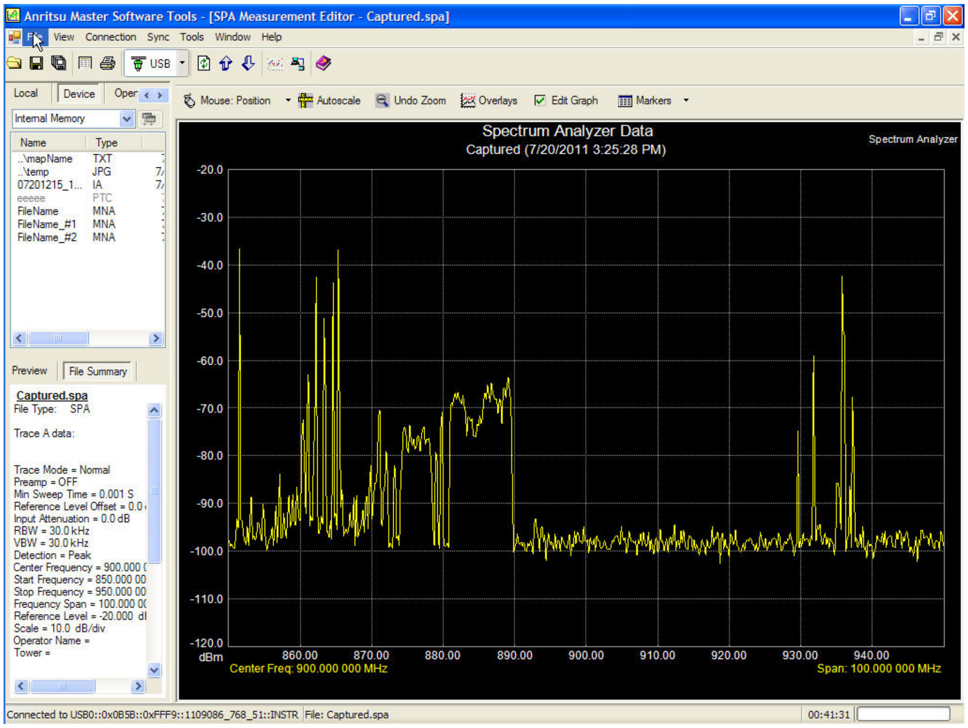


Figure 81: BNSF Auburn Base Station 850 to 950 MHz Agilent N6841A

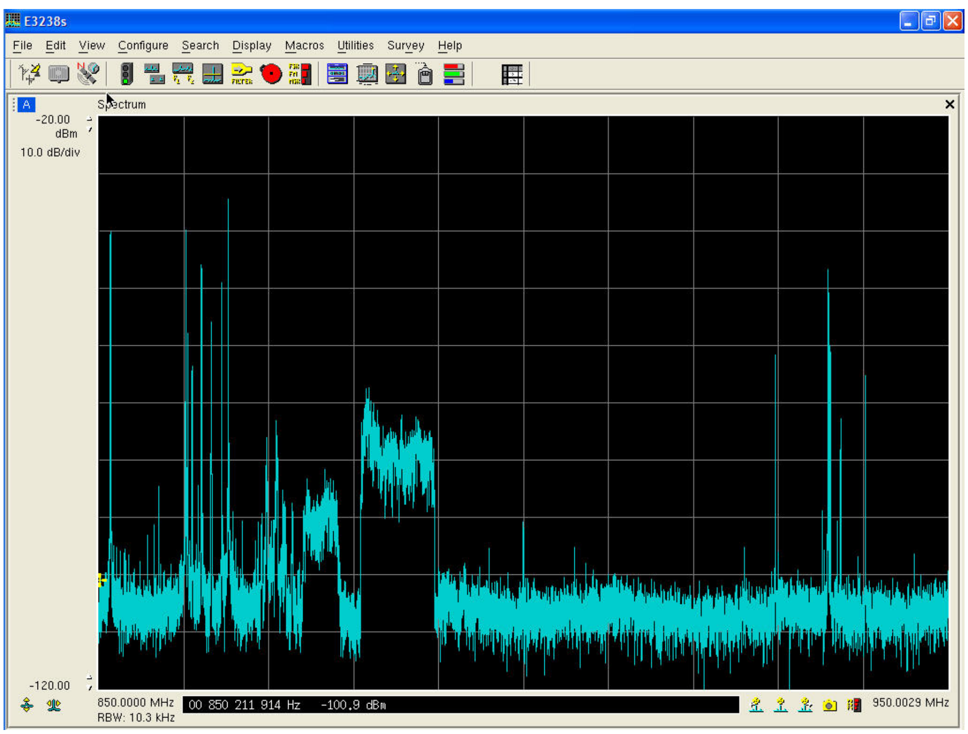


Figure 82: BNSF Auburn Base Station Spectrogram 208 to 228 MHz Anritsu S412E

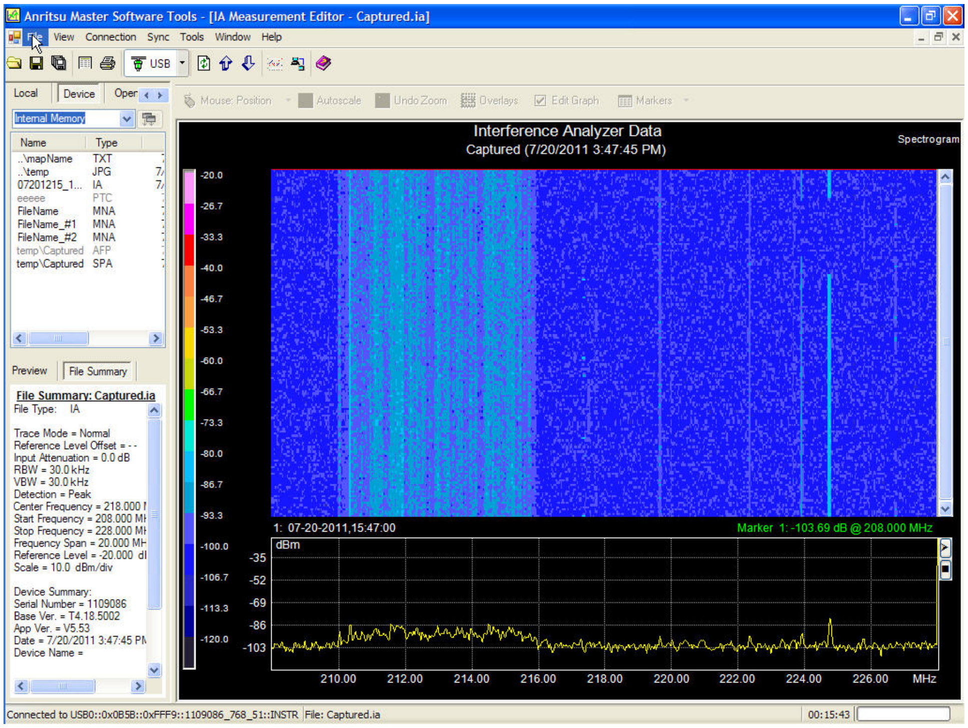


Figure 83: BNSF Auburn Base Station Spectrogram 208 to 228 MHz Agilent N6841A

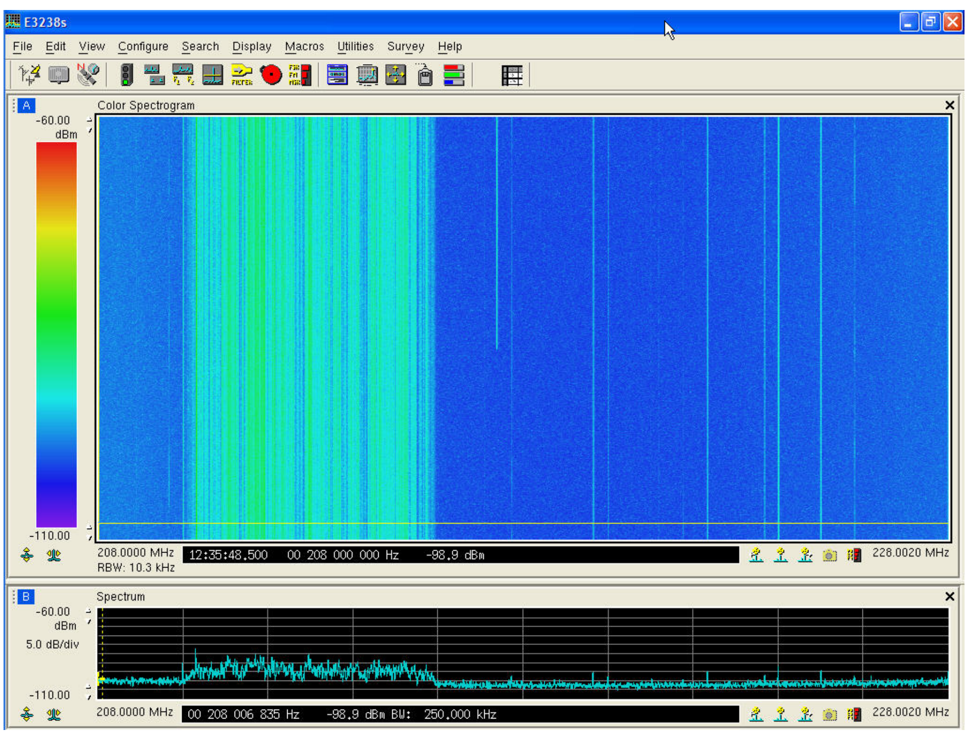


Figure 84: BNSF Auburn Base Station Spectrogram 850 to 900 MHz Anritsu S412E

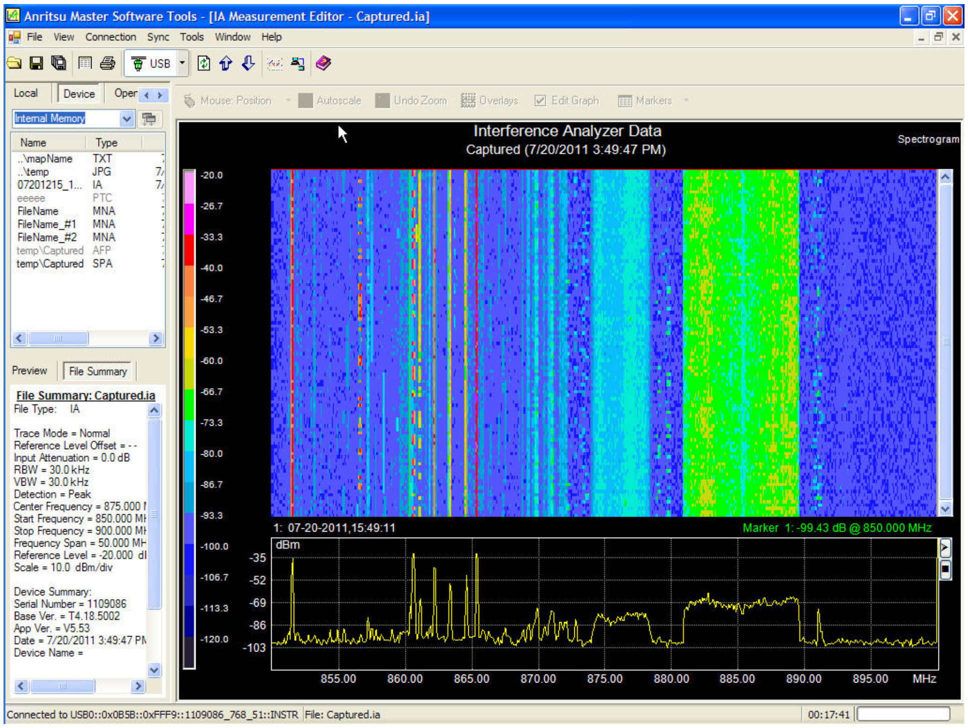


Figure 85: BNSF Auburn Base Station Spectrogram 850 to 900 MHz Agilent N6841A

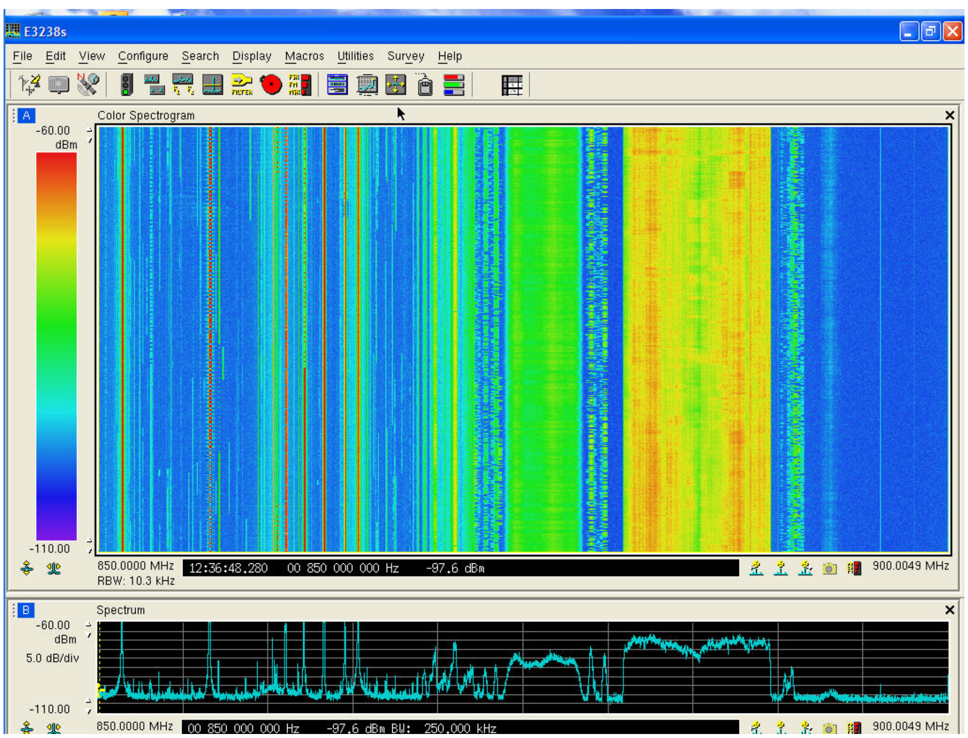


Figure 86: BNSF Auburn Base Station inside 220 MHz spectrum when 160 MHz radios transmit