METEORCOMM LLC

STI-CO

BNSF 5018
(C44-9W - GE)
Locomotive Noise Test Battery Report

CONTRACT NUMBER FR-TEC-0003-11-01-00

Document Number: 00002456-A

Table of Contents

Project Detail:

Contract Number	FR-TEC-0003-11-01-00
Dates of Survey	December 5th to 16th, 2011
Locations	BNSF Delta Facility Everett WA
	47.99965 N LAT,-122.186202 W LON, elev. 31 ft
Test Engineers	Ramon Abelleyro, Derek Edmondson, Chris Goetz

The testing location for this locomotive was in Everett WA at the BNSF Delta rail yard. The locomotive was located on a siding near the entrance to the yard and was stationary throughout the testing period.

BNSF Delta Locomotive Yard
Figure 1

BNSF Delta Yard Testing Location
Figure 2

Locomotive under test BNSF 5018
General Electric C44-9W
Figure 3

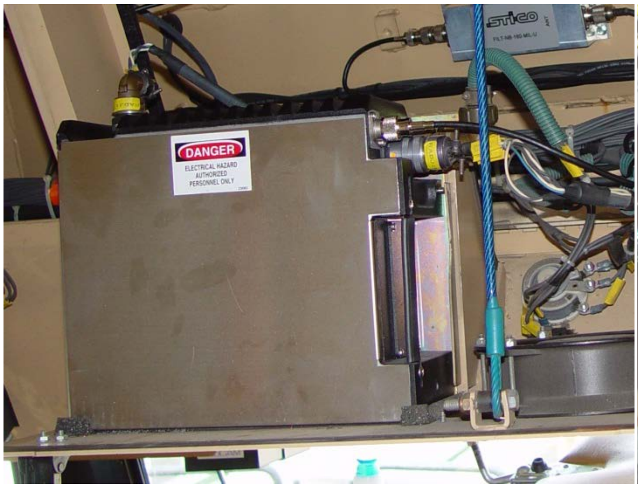
STI-CO HDLP-MB-PLLG25-BN Installed
Figure 4

The locomotive was outfitted with a General Electric “COMM handler” antenna system that includes a VHF, 3 UHF, CEL, and GPS elements and the STI-CO PTC antenna array part number HDLP-MB-PLLG25-BN which included PTC 220, CEL A, CEL B GPS and WIFI antennas.

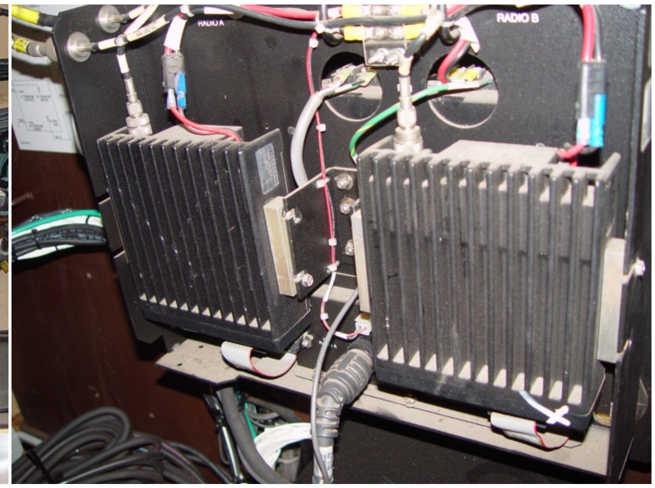
GE Comm. Handler
Figure 5

STI-CO HDLP-MB-PLLG25-BN
Antenna Array
Figure 6

The radio systems included AAR Voice, distributed power radio assembly, a UHF HOT/EOT system as well as the YARD download radio which was out of service. The PTC System was partially installed, but did not present any issues with proceeding with the test battery.



AAR Voice Radio
Figure 7

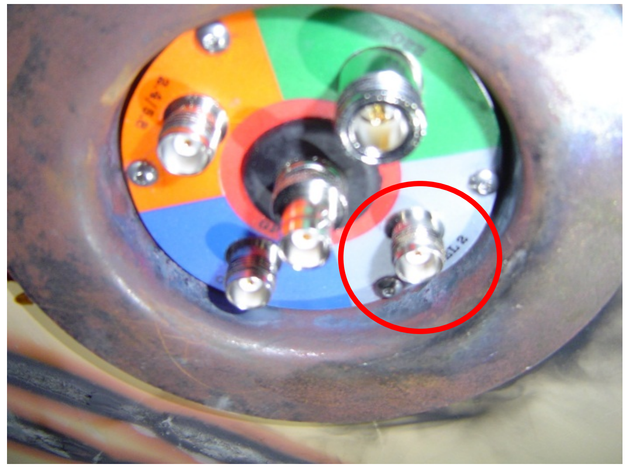


Distributed Power Radio Assembly
Figure 8

HOT/EOT Transmitter
Figure 9

Yard Radio
Figure 10

Un-Terminated Cables
Figure 11



Damaged TNC Connector
Figure 12

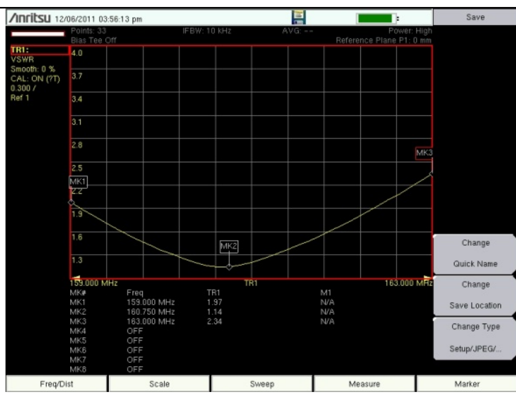
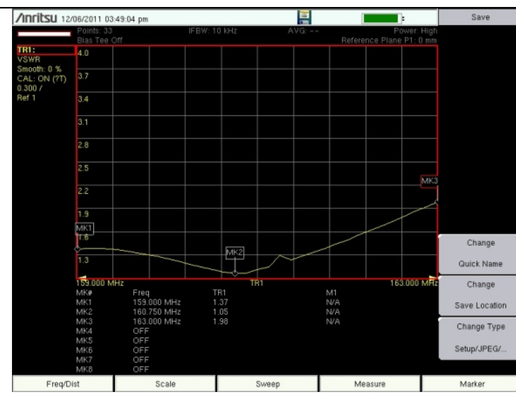
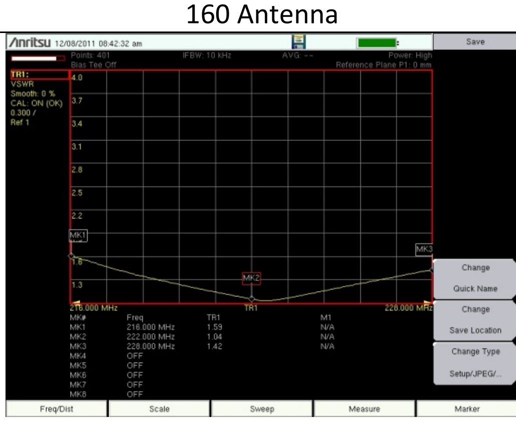
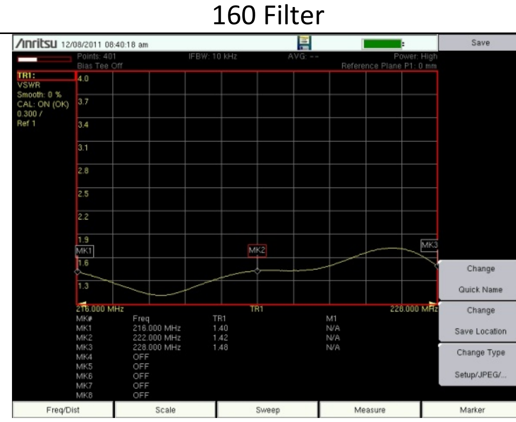
Some minor operational readiness issues were noted in the form of missing connectors on the cellular data cables from the antennas. The connectors were installed and testing continued without incident. A damaged TNC connector was documented on the engineer side array and was most likely damaged during installation. The connector was repaired in place.

VSWR Test

This test is designed to collect VSWR data in several formats for use in locomotive noise and intermodulation reporting. The test involved collecting voltage standing wave ratio and return loss data in the following formats; VSWR, S1P scatter parameters, comma separated values, and a portable network graphics. It is important to know if the antenna system is properly matched to the transceiver equipment as this can be a source of intermodulation and/or standing waves in the RF system. The first set of data was collected at the RF port located closest to each antenna element in the locomotive radio frequency system to give an accurate picture of antenna matching. A second set of data recorded the VSWR at the end of the transmission line cable that connects to the radio transceiver antenna connector, including any installed filtering to show what the full system response is that is presented to the transceiver. This measurement includes all system losses.

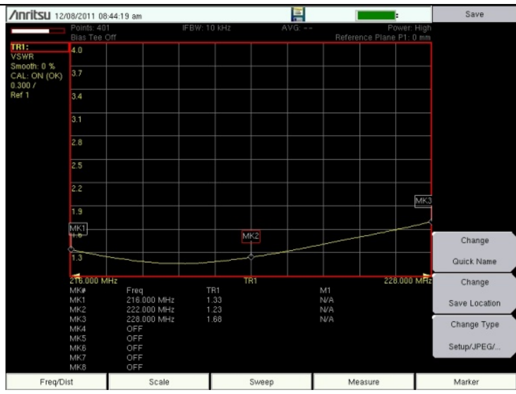
This test helps to characterize the band pass parameters of the antenna. The information is useful in determining how much the antenna element contributes to filtering out of band energy as well as whether or not the antenna is functioning correctly. The results from the VSWR testing indicated all antennas and associated components were functioning properly. The full data from this testing has been presented in Appendix A. Data recorded from the locomotive is presented in Table A below.

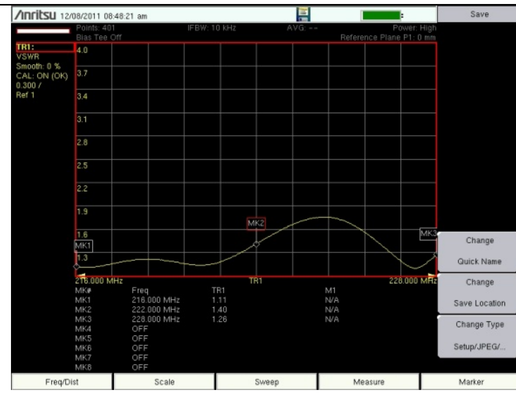
TABLE A VSWR Plots

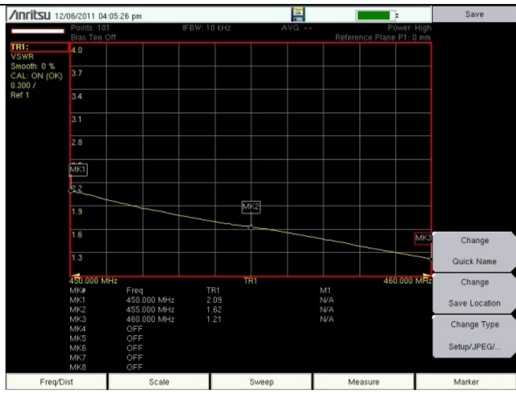
 160 Antenna	 160 Filter
 220 PTC ENG Antenna	 220 PTC ENG Filter

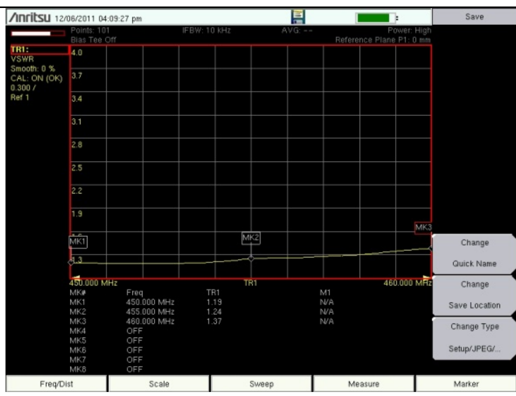
DCN 00002456-A

TABLE A VSWR Plots

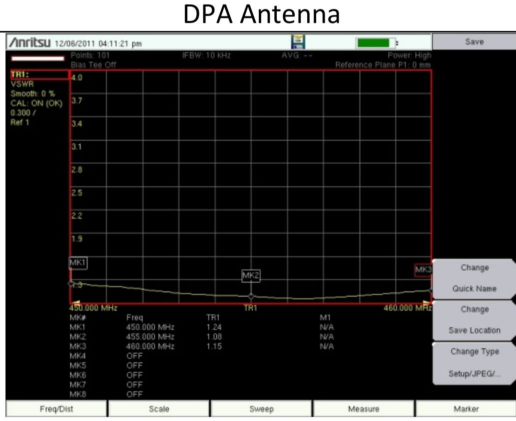

220 PTC CND Antenna


220 PTC CND Filter


HOT Antenna


DPA Antenna


DPA Cable


DPB Antenna

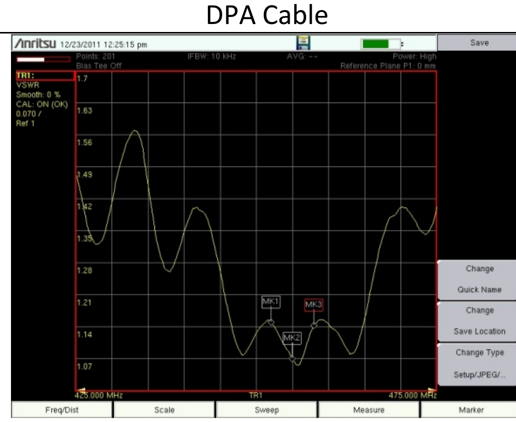
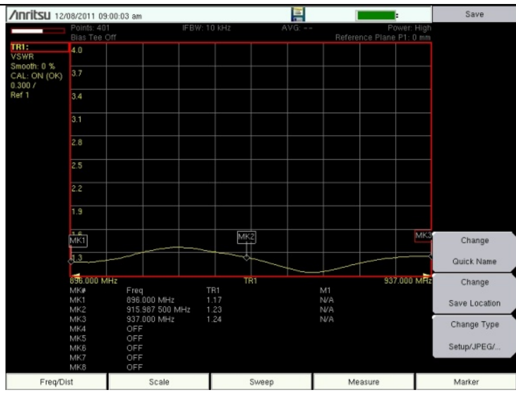
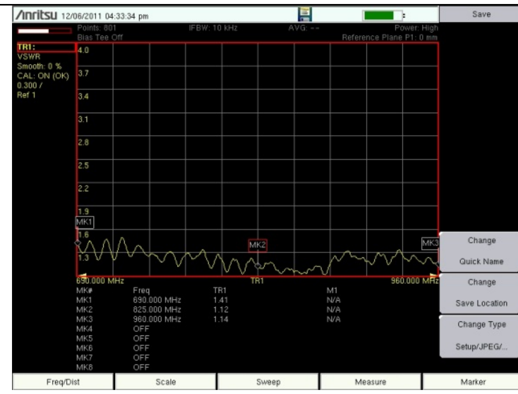

DPB Cable

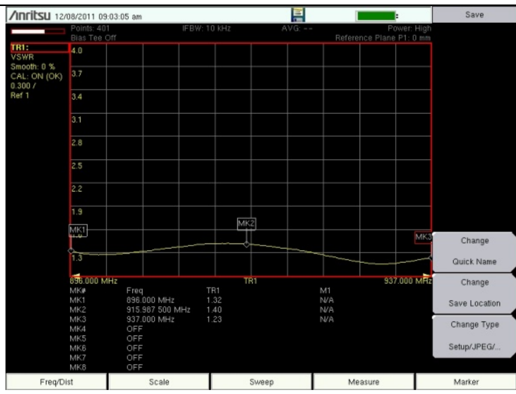
TABLE A VSWR Plots



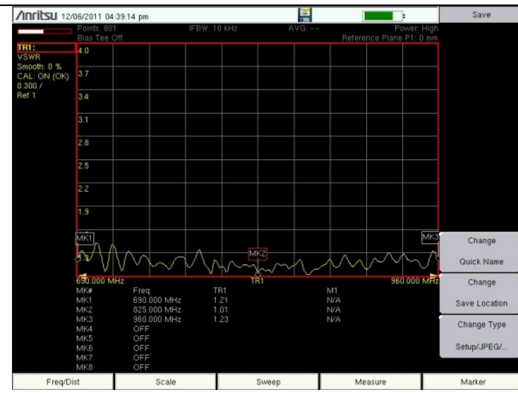
ENG CEL A Antenna



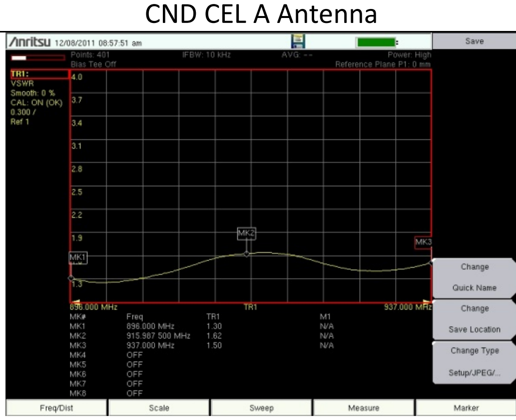
ENG CEL A Cable



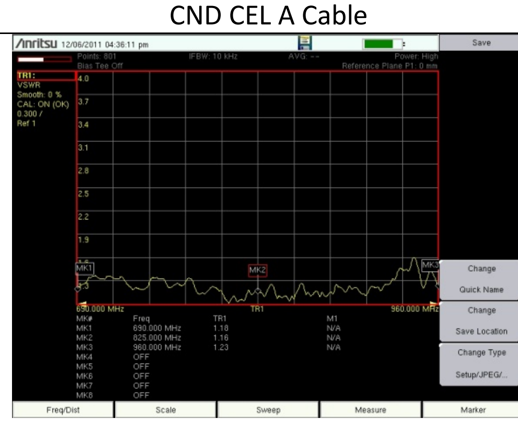
CND CEL A Antenna



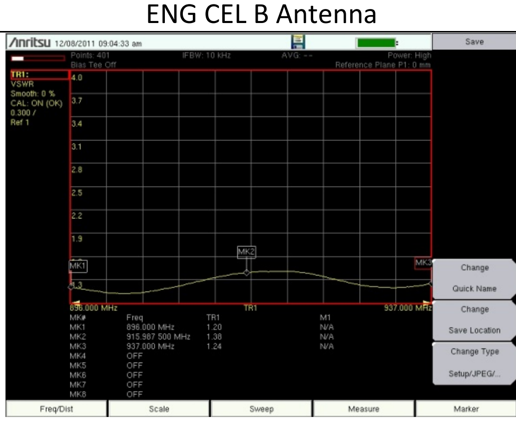
CND CEL A Cable



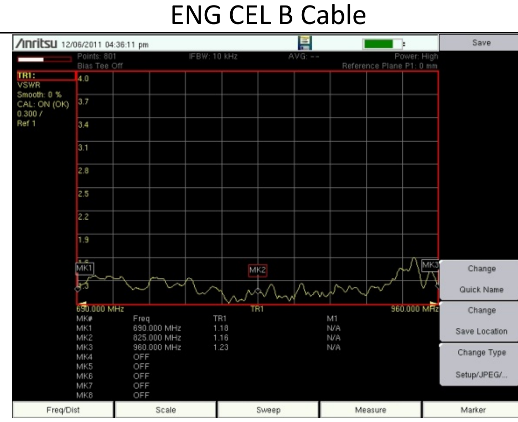
ENG CEL B Antenna



ENG CEL B Cable

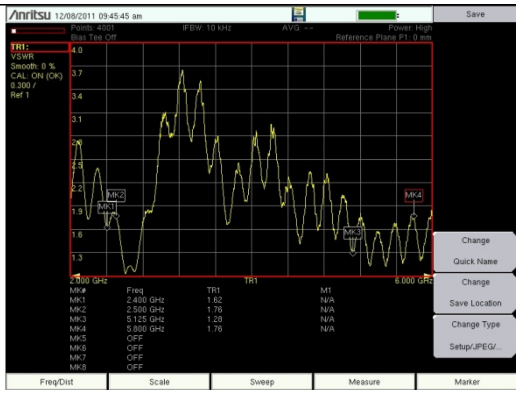
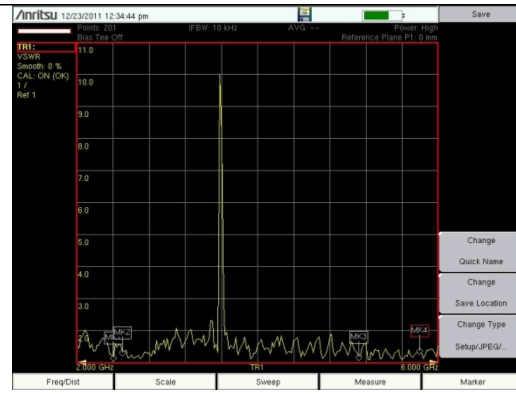
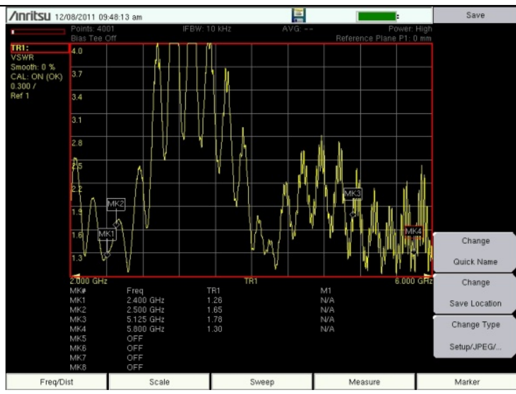
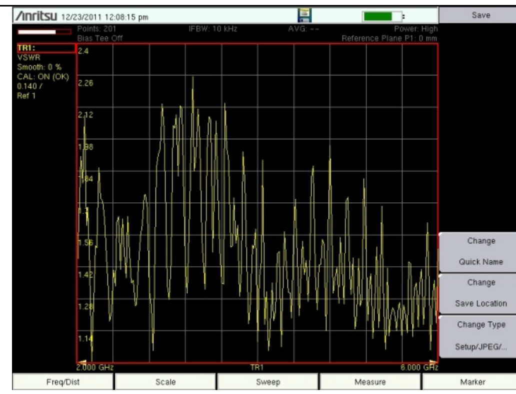
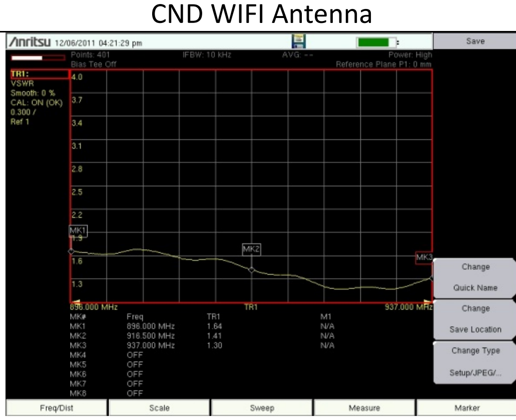
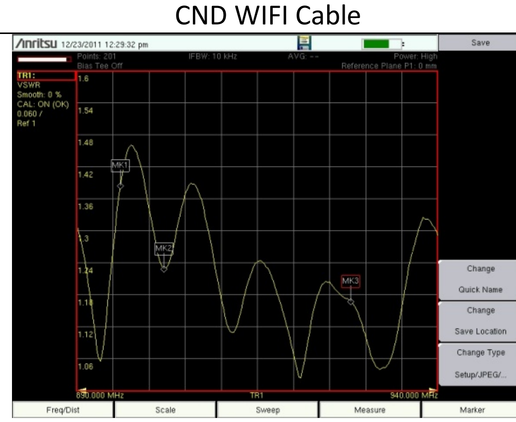


CND CEL B Antenna



CND CEL B Cable

TABLE A VSWR Plots

 ENG WIFI Antenna	 ENG WIFI Cable
 CND WIFI Antenna	 CND WIFI Cable
 ATCS 900 MHz Antenna	 ATCS 900 MHz Cable

Insertion Loss

This test is designed to collect insertion loss data in several formats for use in locomotive noise and intermodulation reporting. The test involved collecting insertion loss data in the following formats; insertion loss in dB, S1P scatter parameters, comma separated values, and a portable network graphics. It is important to know how much loss is experienced in the system in order to determine the impact on transmitted power and intermodulation effects. The test was performed on the transmission lines by measuring the loss from the antenna connection port to the equipment port. The test is frequency specific and each cable was measured based on the appropriate frequency range.

This report is useful for evaluating cable integrity and is representative of any losses that are present in the system. At the completion of this testing it was found that all on-board elements were in compliance as compared to planned values. Full size charts are included in Appendix B.

TABLE B Insertion Loss Plots

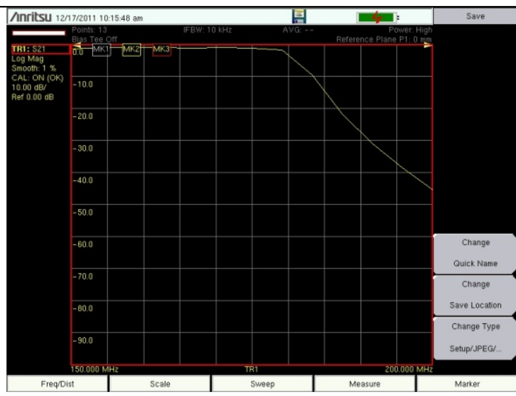
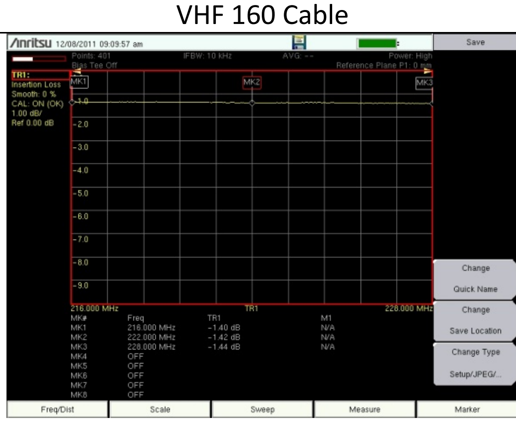
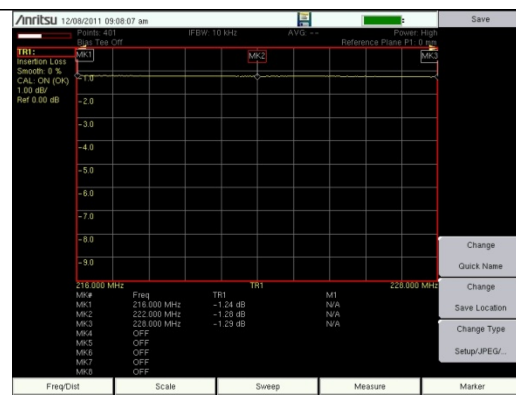
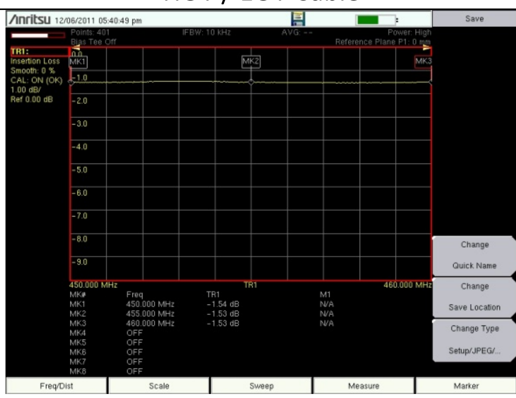
 VHF 160 Cable	
 PTC ENG Cable	 PTC CND Cable

TABLE B Insertion Loss Plots

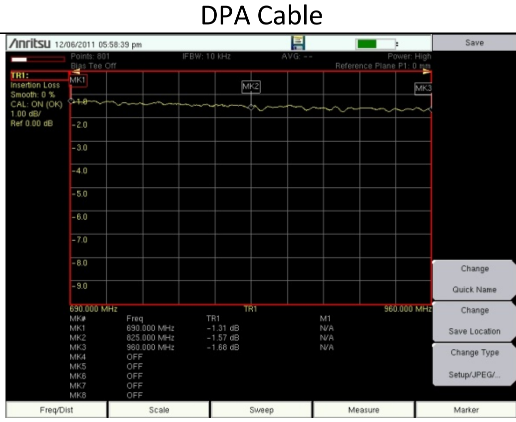
HOT / EOT Cable

ATCS Cable

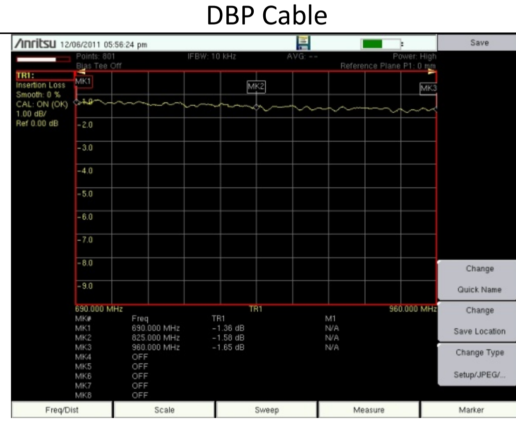


DPA Cable

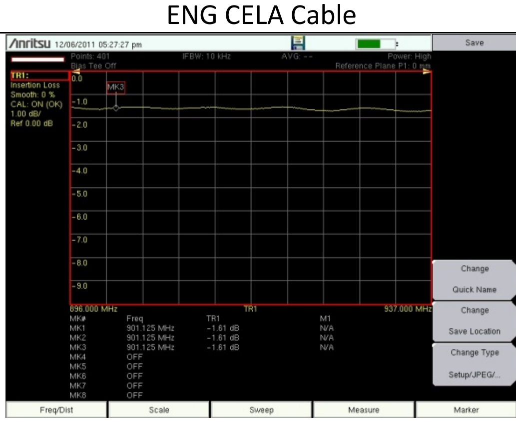
DBP Cable



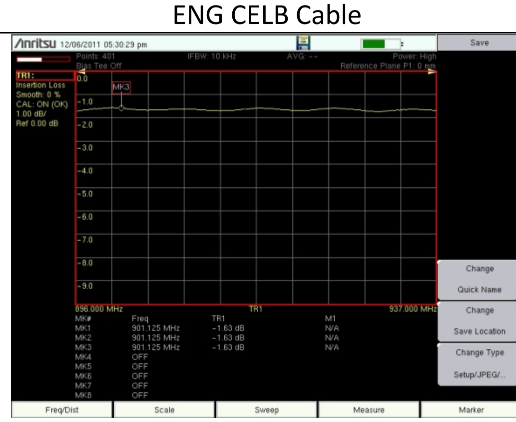
ENG CELA Cable



ENG CELB Cable

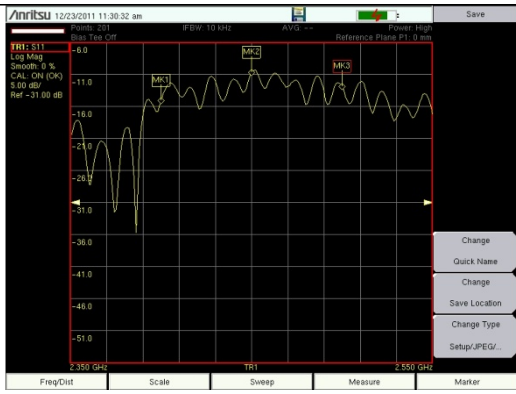
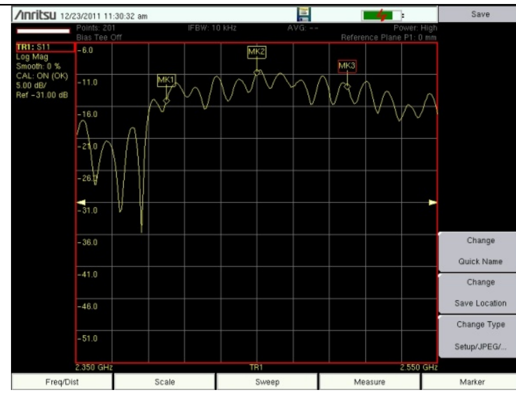


CND CELA Cable



CND CELB Cable

TABLE B Insertion Loss Plots

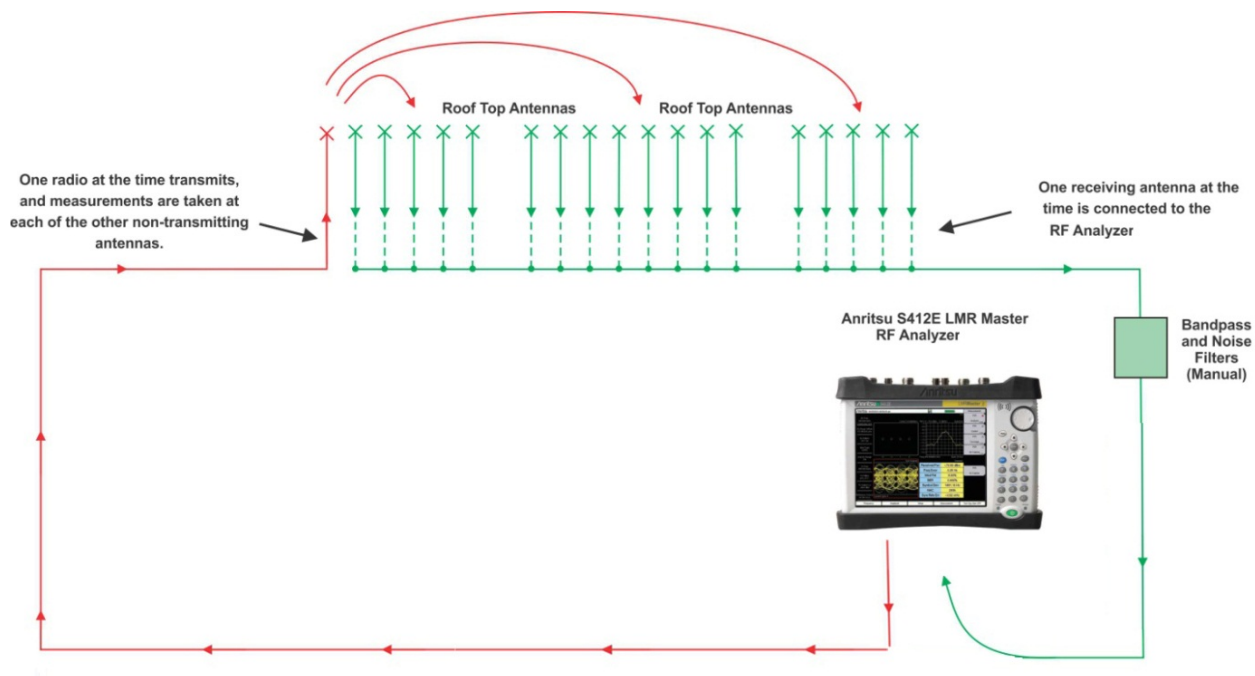
	
ENG WIFI Cable	CND WIFI Cable

Antenna Isolation Test

This test is designed to collect information on the amount of free space isolation between each antenna and each other antenna. This value is in decibels and is used to calculate the amount of power from each radio transmitter impacting each radio receiver front end during transmission. High signal levels impacting the receiver front end of a radio in receive mode will cause intermodulation products in proportion to the power received from the transmitting radio. The antenna isolation data is also used to determine the need for filtering in the system.

The test was performed by measuring the loss from the transmitting radio antenna to each other antenna, and the data was recorded in decibel format. The information gathered from this test correlates to the amount on intermodulation that is present in the roof environment, and possible prevention methods.

The test is executed without filters, and then executed with any filters under consideration by the Railroad.



Antenna Isolation Testing Configuration
Figure 13

TABLE C Antenna Isolation Plots

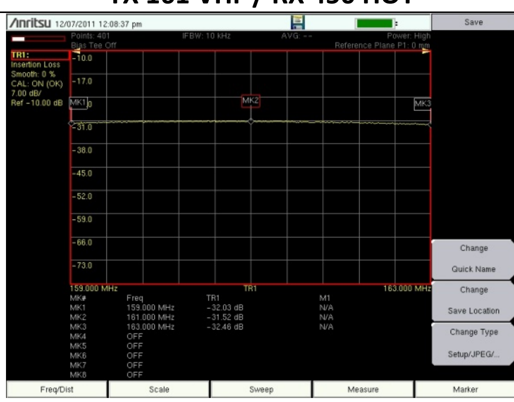
AAR Voice Transmit Non-Filtered	
 **TX 161 VHF / RX 220 ENG**	 **TX 161 VHF / RX 220 CON**
 **TX 161 VHF / RX 450 HOT**	 **TX 161 VHF / RX 450 DPA**
 **TX 161 VHF / RX 450 DPB**	

TABLE C Antenna Isolation Plots

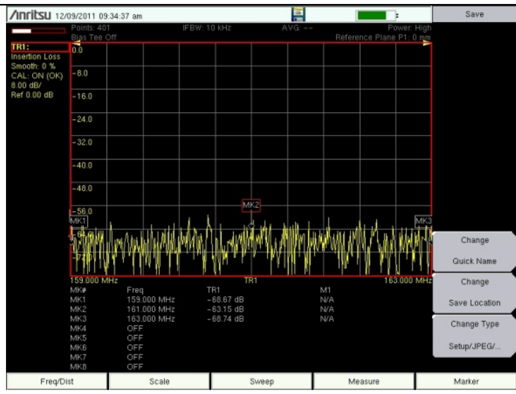
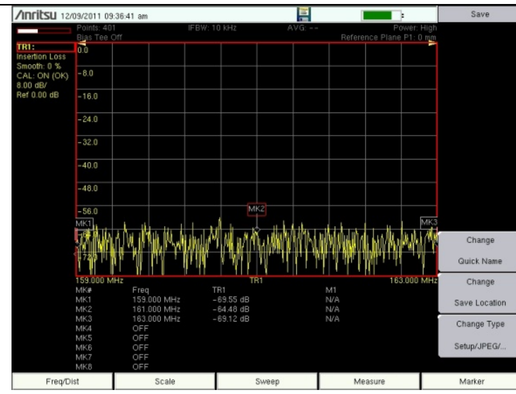
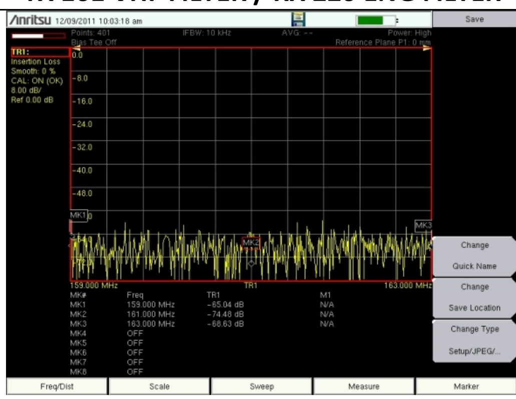
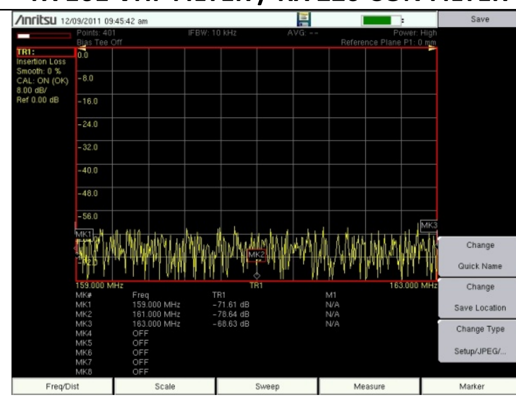
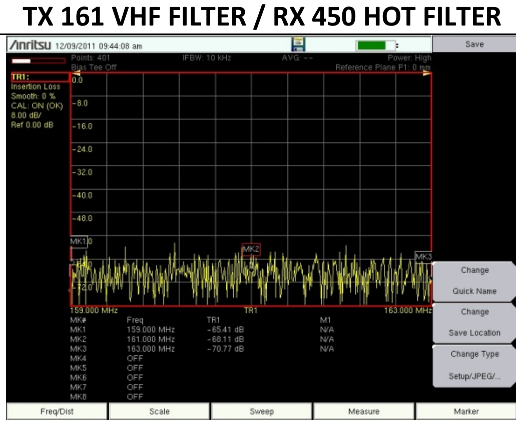
AAR Voice Transmit Filtered	
 **TX 161 VHF FILTER / RX 220 ENG FILTER**	 **TX 161 VHF FILTER / RX 220 CON FILTER**
 **TX 161 VHF FILTER / RX 450 HOT FILTER**	 **TX 161 VHF FILTER / RX 450 DPA FILTER**
 **TX 161 VHF FILTER / RX 450 DPB FILTER**	

TABLE C Antenna Isolation Plots

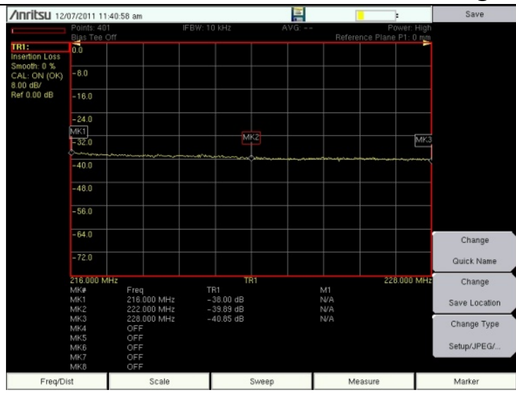
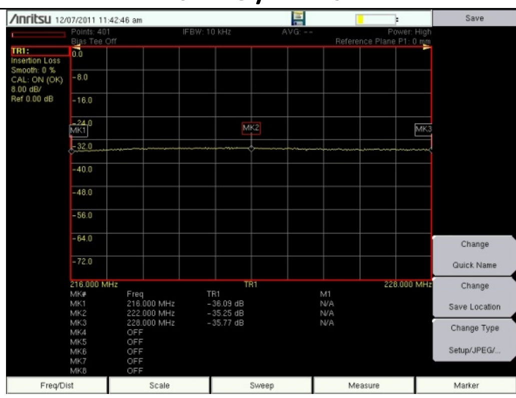
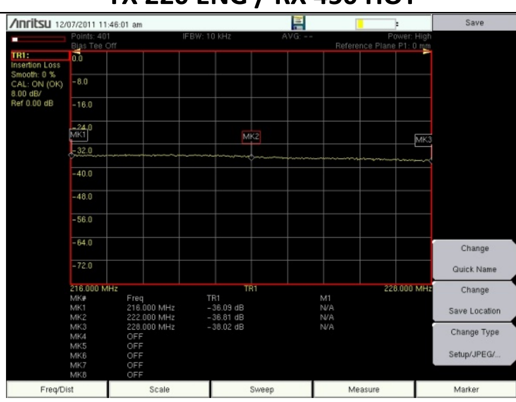
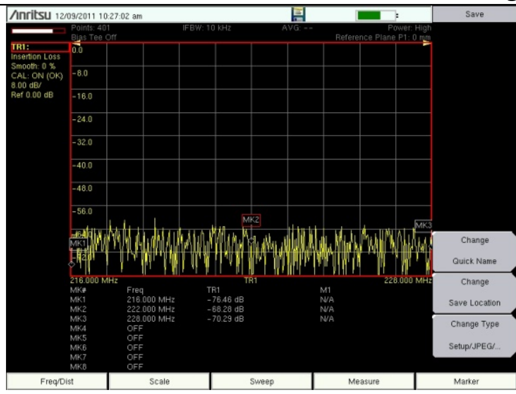
PTC 220 Engineer Transmit Non-Filtered	
 **TX 220 ENG / RX 161 VHF**	 **TX 220 ENG / RX 220 CON**
 **TX 220 ENG / RX 450 HOT**	 **TX 220 ENG / RX 450 DPA**
 **TX 220 ENG / RX 450 DPB**	

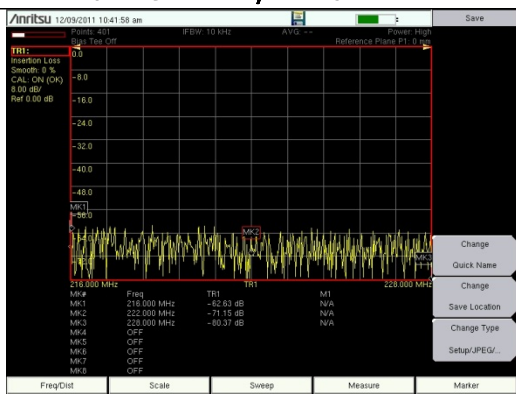
TABLE C Antenna Isolation Plots

PTC 220 Engineer Transmit Filtered

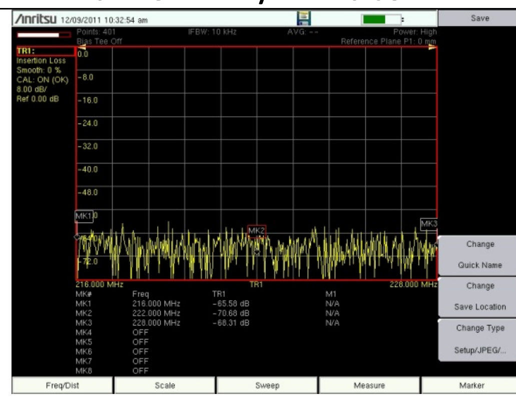


TX 220 ENG FILTER / RX 161 VHF FILTER

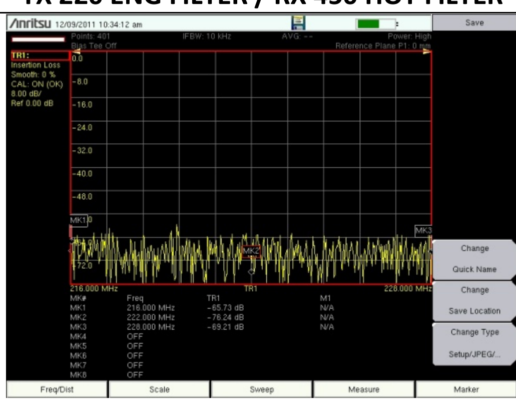
TX 220 ENG FILTER / RX 220 CON FILTER



TX 220 ENG FILTER / RX 450 HOT FILTER



TX 220 ENG FILTER / RX 450 DPA FILTER



TX 220 ENG FILTER / RX 450 DPB FILTER

TABLE C Antenna Isolation Plots

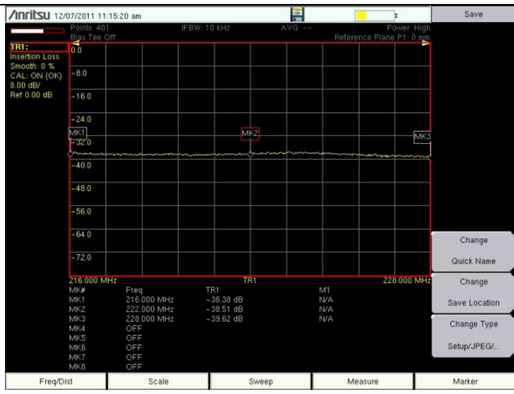
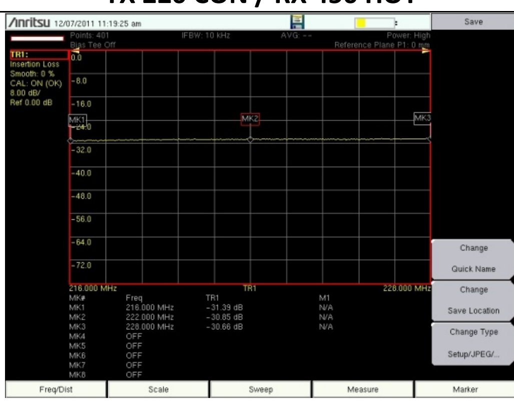
PTC 220 Conductor Transmit Non-Filtered	
 **TX 220 CON / RX 161 VHF**	 **TX 220 CON / RX 220 ENG**
 **TX 220 CON / RX 450 HOT**	
 **TX 220 CON / RX 450 DPB**	

TABLE C Antenna Isolation Plots

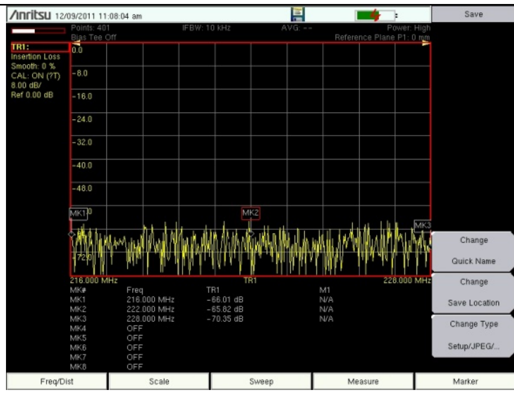
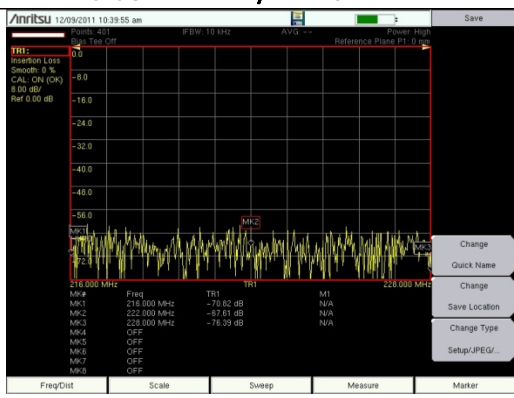
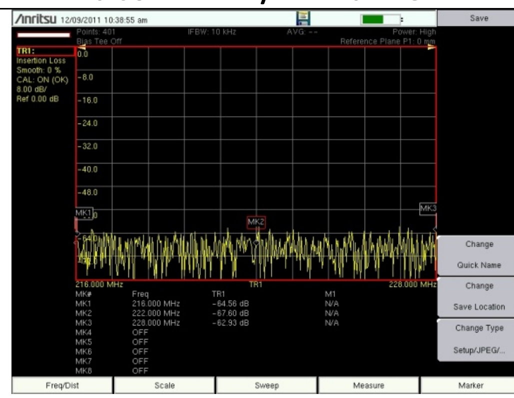
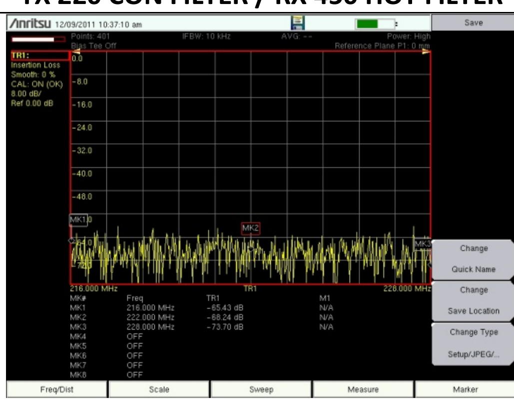
PTC 220 Conductor Transmit Filtered	
 **TX 220 CON FILTER / RX 161 VHF FILTER**	 **TX 220 CON FILTER / RX 220 ENG FILTER**
 **TX 220 CON FILTER / RX 450 HOT FILTER**	 **TX 220 CON FILTER / RX 450 DPA FILTER**
 **TX 220 CON FILTER / RX 450 DPB FILTER**	

TABLE C Antenna Isolation Plots

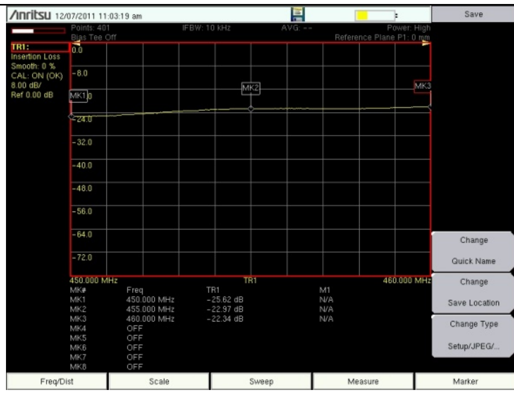
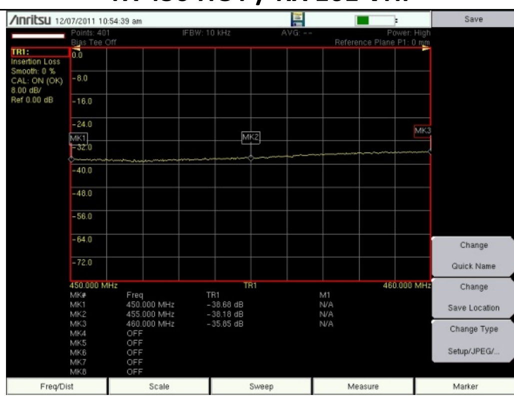
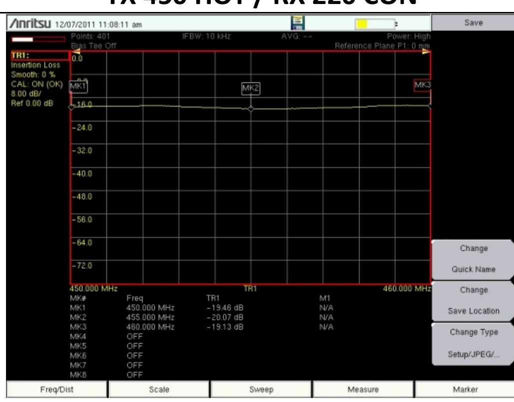
HOT/EOT Transmit Non-Filtered	
 **TX 450 HOT / RX 161 VHF**	 **TX 450 HOT / RX 220 ENG**
 **TX 450 HOT / RX 220 CON**	 **TX 450 HOT / RX 450 DPA**
 **TX 450 HOT / RX 450 DPB**	

TABLE C Antenna Isolation Plots

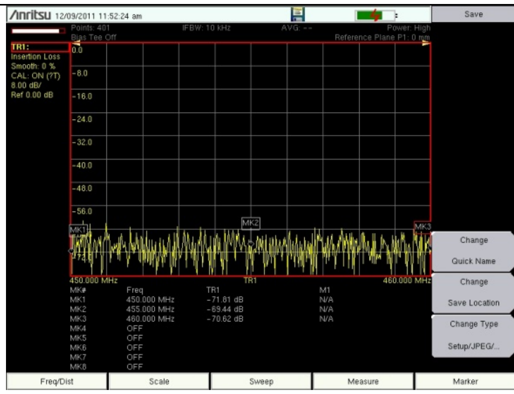
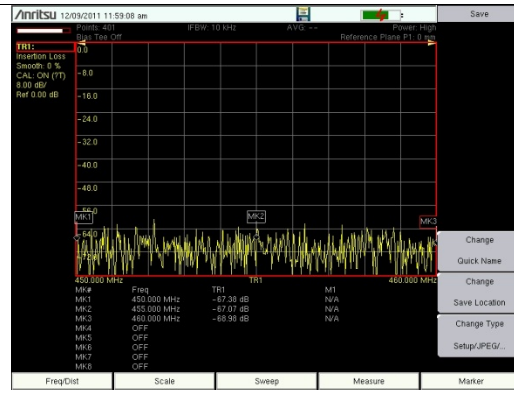
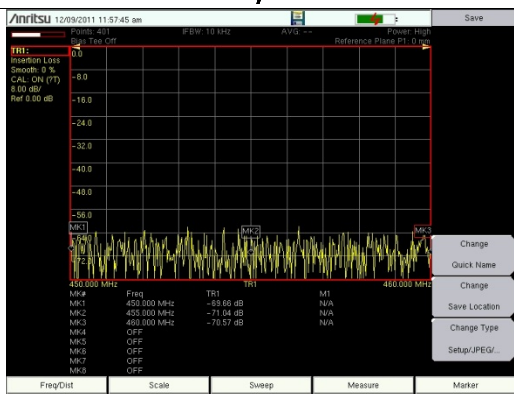
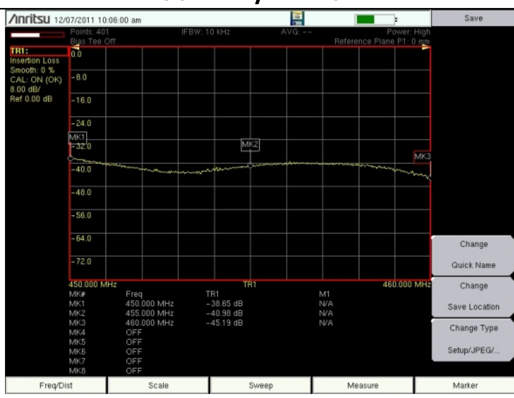
HOT/EOT Transmit Filtered	
 **TX 450 HOT FILTER / RX 161 VHF FILTER**	 **TX 450 HOT FILTER / RX 220 ENG FILTER**
 **TX 450 HOT FILTER / RX 220 CON FILTER**	 **TX 450 HOT FILTER / RX 450 DPA FILTER**
 **TX 450 HOT FILTER / RX 450 DPB FILTER**	

TABLE C Antenna Isolation Plots

DPA Transmit Non-Filtered

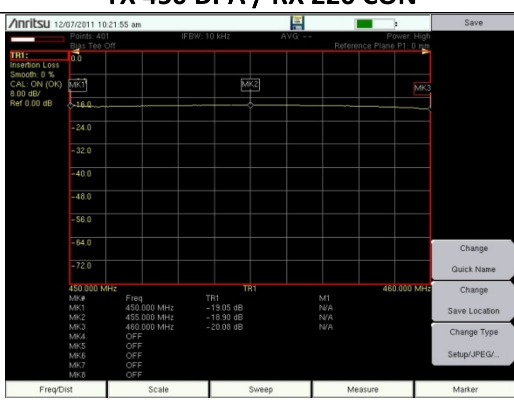
TX 450 DPA / RX 161 VHF

TX 450 DPA / RX 220 ENG



TX 450 DPA / RX 220 CON

TX 450 DPA / RX 450 HOT



TX 450 DPA / RX 450 DPB

TABLE C Antenna Isolation Plots

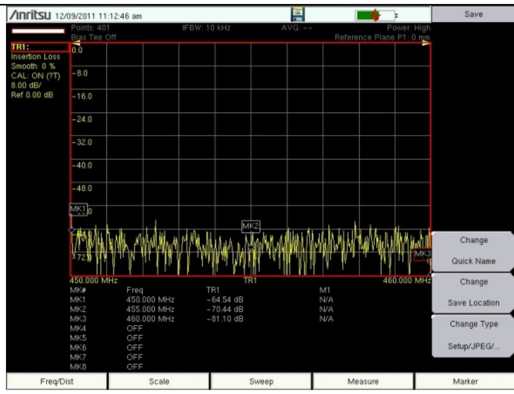
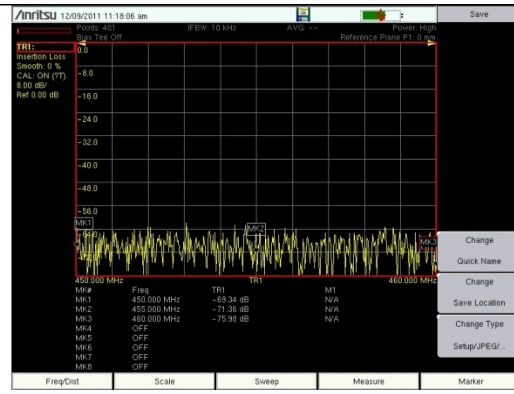
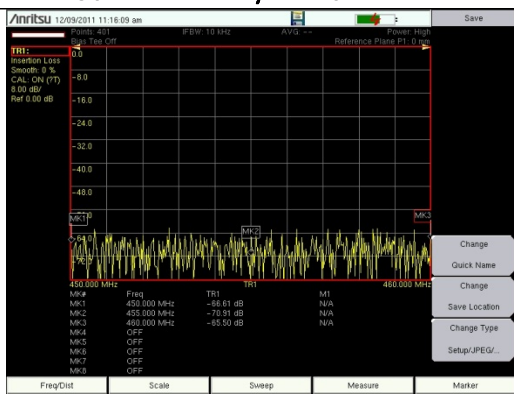
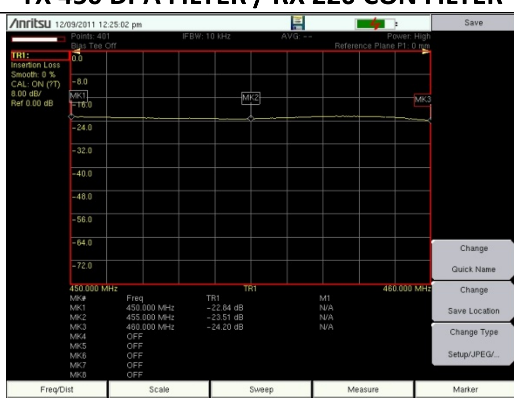
DPA Transmit Filtered	
 TX 450 DPA FILTER / RX 161 VHF FILTER	 TX 450 DPA FILTER / RX 220 ENG FILTER
 TX 450 DPA FILTER / RX 220 CON FILTER	 TX 450 DPA FILTER / RX 450 HOT FILTER
 TX 450 DPA FILTER / RX 450 DPB FILTER	

TABLE C Antenna Isolation Plots

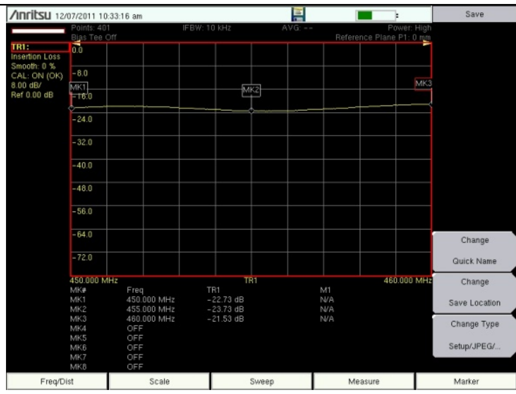
DPB Transmit Non-Filtered	
 TX 450 DPB / RX 161 VHF	 TX 450 DPB / RX 220 ENG
 TX 450 DPB / RX 220 CON	 TX 450 DPB / RX 450 HOT
 TX 450 DPB / RX 450 DPA	

TABLE C Antenna Isolation Plots

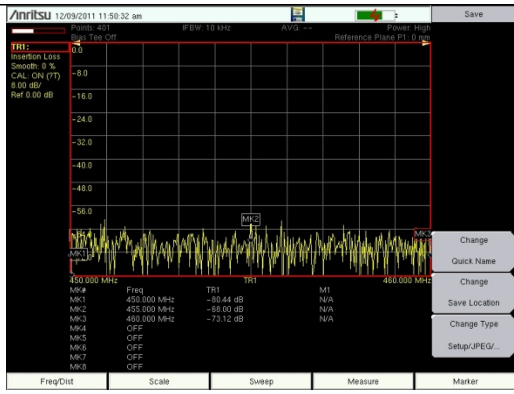
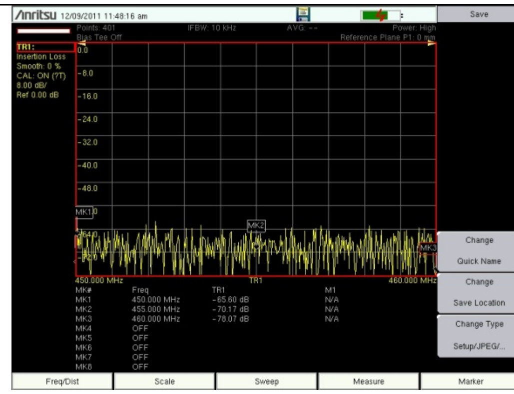
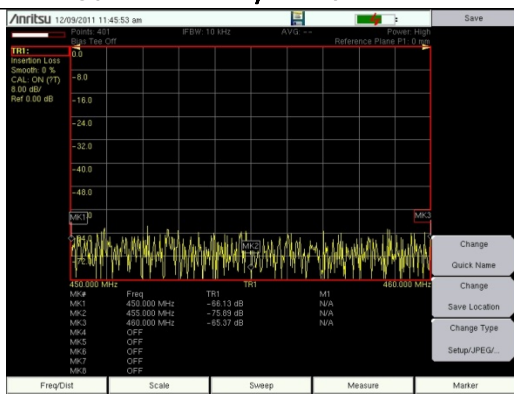
DPB Transmit Filtered	
 **TX 450 DPB FILTER / RX 161 VHF FILTER**	 **TX 450 DPB FILTER / RX 220 ENG FILTER**
 **TX 450 DPB FILTER / RX 220 CON FILTER**	 **TX 450 DPB FILTER / RX 450 HOT FILTER**
 **TX 450 DPB FILTER / RX 450 DPA FILTER**	

TABLE D Antenna Isolation Chart

Antenna Isolation Report Form

Receive Band	VHF 161	220 ENG	220 CON	HOT 450	Dist. PWR A	Dist. PWR B	ATCS 900	YARD 900	ENG CEL A BLUE	ENG CEL B GRAY	ENG WIFI ORG	CON CEL A BLUE	CON CEL B GRAY	CON WIFI ORG
Transmit Band	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)
VHF 161	TB	-33.0	-35.0	-28.0	-31.8	-31.5	-29.7	-29.8	-37.1	-39.6	NF	-37.0	-38.6	NF
220 ENG	-39.7	TB	-24.3	-35.1	-35.6	-36.4	-47.5	-46.3	-32.0	-36.0	NF	-45.7	-41.7	NF
220 CON	-39.0	-24.4	TB	-35.3	-31.1	-30.8	-48.0	-41.2	-45.0	-50.0	NF	-31.3	-32.9	NF
HOT 450	-23.0	-32.1	-38.1	TB	-19.9	-20.1	-28.9	-29.2	-25.5	-34.2	-52.4	-25.5	-31.1	-49.1
Dist. Power A	-22.2	-31.1	-41.6	-19.9	TB	-19.0	-24.8	-34.2	-23.2	-21.8	-41.5	-33.0	-35.7	-54.8
Dist. Power B	-23.7	-39.8	-29.2	-20.1	-18.9	TB	-24.7	-24.9	-34.7	-34.1	-53.0	-23.9	-29.8	-44.3
ATCS 900	-34.0	-32.1	-32.5	-30.0	-34.0	-32.5	TB	-17.6	-28.0	-30.0	-31.0	-26.8	-26.0	-32.0
YARD 900	-34.6	-32.9	-31.0	-31.1	-35.0	-31.7	-17.4	TB	-28.3	-29.4	-31.3	-26.6	-26.6	-31.0
Receive Band	VHF 161 Filter	220 ENG Filter	220 CON Filter	HOT 450 Filter	Dist. PWR A Filter	Dist. PWR B Filter	ATCS 900	YARD 900	ENG CEL A BLUE	ENG CEL B GRAY	ENG WIFI ORG	CON CEL A BLUE	CON CEL B GRAY	CON WIFI ORG
Transmit Band	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)
VHF 161 Filter	TB	NF	NF	NF	NF	NF	-	-31.2	-39.0	-40.5	NF	-39.0	-40.2	NF
220 ENG Filter	NF	TB	-29.1	NF	NF	NF	-	-49.0	-35.7	-38.7	NF	-48.1	-45.5	NF
220 CON Filter	NF	-29.1	TB	NF	NF	NF	-	-44.6	-47.1	-55.0	NF	-34.7	-36.1	NF
HOT 450 Filter	NF	NF	NF	TB	-24.1	-23.6	-	-32.4	-32.5	-36.5	-52.6	-27.8	-36.5	-53.3
Dist. Power A Filter	NF	NF	NF	-24.1	TB	-23.5	-	-40.9	-26.2	-26.3	-44.1	-35.7	-42.0	-60.2
Dist. Power B Filter	NF	NF	NF	-23.7	-23.5	TB	-	-28.0	-35.0	-36.2	-53.7	-27.6	-36.1	-47.5

Antenna Isolation Table
Appendix C

The data recorded from the locomotive included both non-filtered and filtered information if the locomotive was equipped, or if future versions were to be equipped with band specific filters.

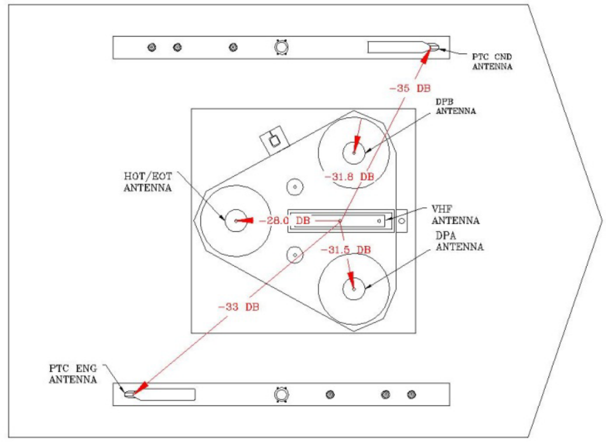
In the set of figures below, the data from the chart is represented graphically. The arrows indicate where the transmission source originates. The “A” drawing shows the isolation data with no filtering and indicates the relationship between antenna spacing and free space path loss with the single element as the transmission source. The “B” figures show how the addition of the filters provides the increased isolation required by such a small ground plane area. The “C “diagrams indicate what energy is seen by the primary element from different frequency bands un-filtered, and again the “D” diagrams show the effect of filtering.

Note that measurements designated “<-60 dB” are actually below the noise floor of the instrument.

In addition to spatial separation, there are other factors to be considered such as the antenna element type and frequency response and filter performance which will contribute to out of band rejection characteristics, and these have been accounted for in the measurements in this section. In the cases where there is diversity or redundant antennas spaced across the locomotive, there is symmetry in the isolation numbers which tracks with the layout of the antenna elements. The data shows the improvements in isolation that can be achieved by adding filtering to the antenna system. The results here will correlate to the intermodulation data collected in later testing.

Receive Band	VHF 161	220 ENG	220 CON	HOT 450	Dist. PWR A	Dist. PWR B	ATCS 900	YARD 900	ENG CEL A BLUE	ENG CEL B GRAY	ENG WIFI ORG	CON CEL A BLUE	CON CEL B GRAY	CON WIFI ORG
Transmit Band	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)
VHF 161	TB	-33.0	-35.0	-28.0	-31.8	-31.5	-29.7	-29.8	-37.1	-39.6	NF	-37.0	-38.6	NF
220 ENG	-39.7	TB	-24.3	-35.1	-35.6	-36.4	-47.5	-46.3	-32.0	-36.0	NF	-45.7	-41.7	NF
220 CON	-39.0	-24.4	TB	-35.3	-31.1	-30.8	-48.0	-41.2	-45.0	-50.0	NF	-31.3	-32.9	NF
HOT 450	-23.0	-32.1	-38.1	TB	-19.9	-20.1	-28.9	-29.2	-25.5	-34.2	-52.4	-25.5	-31.1	-49.1
Dist. Power A	-22.2	-31.1	-41.6	-19.9	TB	-19.0	-24.8	-34.2	-23.2	-21.8	-41.5	-33.0	-35.7	-54.8
Dist. Power B	-23.7	-39.8	-29.2	-20.1	-18.9	TB	-24.7	-24.9	-34.7	-34.1	-53.0	-23.9	-29.8	-44.3
ATCS 900	-34.0	-32.1	-32.5	-30.0	-34.0	-32.5	TB	-17.6	-28.0	-30.0	-31.0	-26.8	-26.0	-32.0
YARD 900	-34.6	-32.9	-31.0	-31.1	-35.0	-31.7	-17.4	TB	-28.3	-29.4	-31.3	-26.6	-26.6	-31.0
Receive Band	VHF 161 Filter	220 ENG Filter	220 CON Filter	HOT 450 Filter	Dist. PWR A Filter	Dist. PWR B Filter	ATCS 900	YARD 900	ENG CEL A BLUE	ENG CEL B GRAY	ENG WIFI ORG	CON CEL A BLUE	CON CEL B GRAY	CON WIFI ORG
Transmit Band	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)
VHF 161 Filter	TB	NF	NF	NF	NF	NF	-	-31.2	-39.0	-40.5	NF	-39.0	-40.2	NF
220 ENG Filter	NF	TB	-29.1	NF	NF	NF	-	-49.0	-35.7	-38.7	NF	-48.1	-45.5	NF
220 CON Filter	NF	-29.1	TB	NF	NF	NF	-	-44.6	-47.1	-55.0	NF	-34.7	-36.1	NF
HOT 450 Filter	NF	NF	NF	TB	-24.1	-23.6	-	-32.4	-32.5	-36.5	-52.6	-27.8	-36.5	-53.3
Dist. Power A Filter	NF	NF	NF	-24.1	TB	-23.5	-	-40.9	-26.2	-26.3	-44.1	-35.7	-42.0	-60.2
Dist. Power B Filter	NF	NF	NF	-23.7	-23.5	TB	-	-28.0	-35.0	-36.2	-53.7	-27.6	-36.1	-47.5

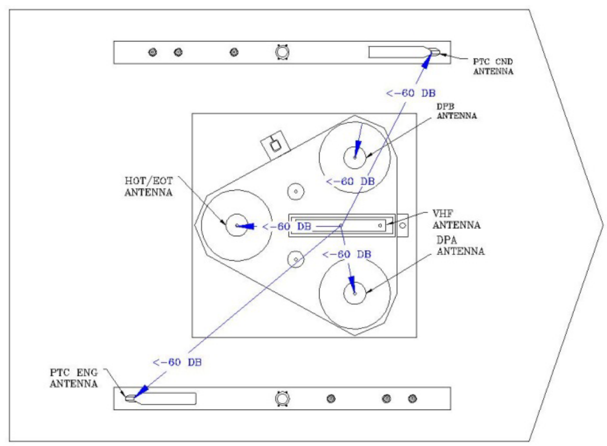
Transmit Energy is Single Frequency Band
Un-filtered



Transmit from single source
Unfiltered

Receive Band	VHF 161	220 ENG	220 CON	HOT 450	Dist. PWR A	Dist. PWR B	ATCS 900	YARD 900	ENG CEL A BLUE	ENG CEL B GRAY	ENG WIFI ORG	CON CEL A BLUE	CON CEL B GRAY	CON WIFI ORG
Transmit Band	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)
VHF 161	TB	-33.0	-35.0	-28.0	-31.8	-31.5	-29.7	-29.8	-37.1	-39.6	NF	-37.0	-38.6	NF
220 ENG	-39.7	TB	-24.3	-35.1	-35.6	-36.4	-47.5	-46.3	-32.0	-36.0	NF	-45.7	-41.7	NF
220 CON	-39.0	-24.4	TB	-35.3	-31.1	-30.8	-48.0	-41.2	-45.0	-50.0	NF	-31.3	-32.9	NF
HOT 450	-23.0	-32.1	-38.1	TB	-19.9	-20.1	-28.9	-29.2	-25.5	-34.2	-52.4	-25.5	-31.1	-49.1
Dist. Power A	-22.2	-31.1	-41.6	-19.9	TB	-19.0	-24.8	-34.2	-23.2	-21.8	-41.5	-33.0	-35.7	-54.8
Dist. Power B	-23.7	-39.8	-29.2	-20.1	-18.9	TB	-24.7	-24.9	-34.7	-34.1	-53.0	-23.9	-29.8	-44.3
ATCS 900	-34.0	-32.1	-32.5	-30.0	-34.0	-32.5	TB	-17.6	-28.0	-30.0	-31.0	-26.8	-26.0	-32.0
YARD 900	-34.6	-32.9	-31.0	-31.1	-35.0	-31.7	-17.4	TB	-28.3	-29.4	-31.3	-26.6	-26.6	-31.0
Receive Band	VHF 161 Filter	220 ENG Filter	220 CON Filter	HOT 450 Filter	Dist. PWR A Filter	Dist. PWR B Filter	ATCS 900	YARD 900	ENG CEL A BLUE	ENG CEL B GRAY	ENG WIFI ORG	CON CEL A BLUE	CON CEL B GRAY	CON WIFI ORG
Transmit Band	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)
VHF 161 Filter	TB	NF	NF	NF	NF	NF	-	-31.2	-39.0	-40.5	NF	-39.0	-40.2	NF
220 ENG Filter	NF	TB	-29.1	NF	NF	NF	-	-49.0	-35.7	-38.7	NF	-48.1	-45.5	NF
220 CON Filter	NF	-29.1	TB	NF	NF	NF	-	-44.6	-47.1	-55.0	NF	-34.7	-36.1	NF
HOT 450 Filter	NF	NF	NF	TB	-24.1	-23.6	-	-32.4	-32.5	-36.5	-52.6	-27.8	-36.5	-53.3
Dist. Power A Filter	NF	NF	NF	-24.1	TB	-23.5	-	-40.9	-26.2	-26.3	-44.1	-35.7	-42.0	-60.2
Dist. Power B Filter	NF	NF	NF	-23.7	-23.5	TB	-	-28.0	-35.0	-36.2	-53.7	-27.6	-36.1	-47.5

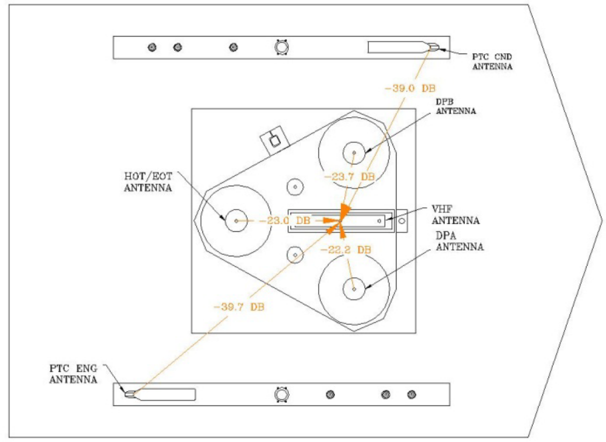
Transmit Energy is Single Frequency Band
Filtered



Transmit from single source
Filtered

Receive Band	VHF 161	220 ENG	220 CON	HOT 450	Dist. PWR A	Dist. PWR B	ATCS 900	YARD 900	ENG CEL A BLUE	ENG CEL B GRAY	ENG WIFI ORG	CON CEL A BLUE	CON CEL B GRAY	CON WIFI ORG
Transmit Band	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)
VHF 161	TB	-33.0	-35.0	-28.0	-31.8	-31.5	-29.7	-29.8	-37.1	-39.6	NF	-37.0	-38.6	NF
220 ENG	-39.7	TB	-24.3	-35.1	-35.6	-36.4	-47.5	-46.3	-32.0	-36.0	NF	-45.7	-41.7	NF
220 CON	-39.0	-24.4	TB	-35.3	-31.1	-30.8	-48.0	-41.2	-45.0	-50.0	NF	-31.3	-32.9	NF
HOT 450	-23.0	-32.1	-38.1	TB	-19.9	-20.1	-28.9	-29.2	-25.5	-34.2	-52.4	-25.5	-31.1	-49.1
Dist. Power A	-22.2	-31.1	-41.6	-19.9	TB	-19.0	-24.8	-34.2	-23.2	-21.8	-41.5	-33.0	-35.7	-54.8
Dist. Power B	-23.7	-39.8	-29.2	-20.1	-18.9	TB	-24.7	-24.9	-34.7	-34.1	-53.0	-23.9	-29.8	-44.3
ATCS 900	-34.0	-32.1	-32.5	-30.0	-34.0	-32.5	TB	-17.6	-28.0	-30.0	-31.0	-26.8	-26.0	-32.0
YARD 900	-34.6	-32.9	-31.0	-31.1	-35.0	-31.7	-17.4	TB	-28.3	-29.4	-31.3	-26.6	-26.6	-31.0
Receive Band	VHF 161 Filter	220 ENG Filter	220 CON Filter	HOT 450 Filter	Dist. PWR A Filter	Dist. PWR B Filter	ATCS 900	YARD 900	ENG CEL A BLUE	ENG CEL B GRAY	ENG WIFI ORG	CON CEL A BLUE	CON CEL B GRAY	CON WIFI ORG
Transmit Band	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)
VHF 161 Filter	TB	NF	NF	NF	NF	NF	-	-31.2	-39.0	-40.5	NF	-39.0	-40.2	NF
220 ENG Filter	NF	TB	-29.1	NF	NF	NF	-	-49.0	-35.7	-38.7	NF	-48.1	-45.5	NF
220 CON Filter	NF	-29.1	TB	NF	NF	NF	-	-44.6	-47.1	-55.0	NF	-34.7	-36.1	NF
HOT 450 Filter	NF	NF	NF	TB	-24.1	-23.6	-	-32.4	-32.5	-36.5	-52.6	-27.8	-36.5	-53.3
Dist. Power A Filter	NF	NF	NF	-24.1	TB	-23.5	-	-40.9	-26.2	-26.3	-44.1	-35.7	-42.0	-60.2
Dist. Power B Filter	NF	NF	NF	-23.7	-23.5	TB	-	-28.0	-35.0	-36.2	-53.7	-27.6	-36.1	-47.5

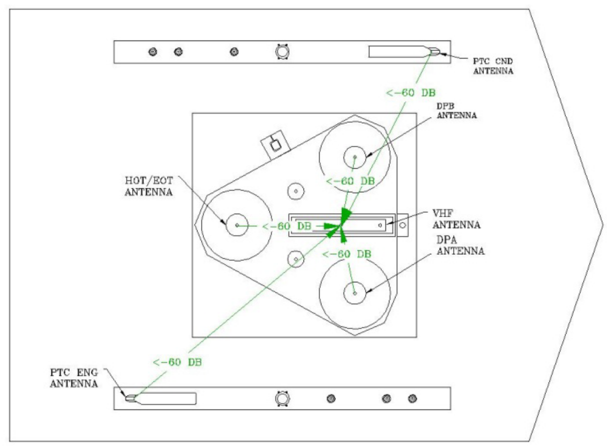
Receive Energy is Multiple Frequency Bands
Unfiltered



Receive from multiple sources
Unfiltered

Receive Band	VHF 161	220 ENG	220 CON	HOT 450	Dist. PWR A	Dist. PWR B	ATCS 900	YARD 900	ENG CEL A BLUE	ENG CEL B GRAY	ENG WIFI ORG	CON CEL A BLUE	CON CEL B GRAY	CON WIFI ORG
Transmit Band	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)
VHF 161	TB	-33.0	-35.0	-28.0	-31.8	-31.5	-29.7	-29.8	-37.1	-39.6	NF	-37.0	-38.6	NF
220 ENG	-39.7	TB	-24.3	-35.1	-35.6	-36.4	-47.5	-46.3	-32.0	-36.0	NF	-45.7	-41.7	NF
220 CON	-39.0	-24.4	TB	-35.3	-31.1	-30.8	-48.0	-41.2	-45.0	-50.0	NF	-31.3	-32.9	NF
HOT 450	-23.0	-32.1	-38.1	TB	-19.9	-20.1	-28.9	-29.2	-25.5	-34.2	-52.4	-25.5	-31.1	-49.1
Dist. Power A	-22.2	-31.1	-41.6	-19.9	TB	-19.0	-24.8	-34.2	-23.2	-21.8	-41.5	-33.0	-35.7	-54.8
Dist. Power B	-23.7	-39.8	-29.2	-20.1	-18.9	TB	-24.7	-24.9	-34.7	-34.1	-53.0	-23.9	-29.8	-44.3
ATCS 900	-34.0	-32.1	-32.5	-30.0	-34.0	-32.5	TB	-17.6	-28.0	-30.0	-31.0	-26.8	-26.0	-32.0
YARD 900	-34.6	-32.9	-31.0	-31.1	-35.0	-31.7	-17.4	TB	-28.3	-29.4	-31.3	-26.6	-26.6	-31.0
Receive Band	VHF 161 Filter	220 ENG Filter	220 CON Filter	HOT 450 Filter	Dist. PWR A Filter	Dist. PWR B Filter	ATCS 900	YARD 900	ENG CEL A BLUE	ENG CEL B GRAY	ENG WIFI ORG	CON CEL A BLUE	CON CEL B GRAY	CON WIFI ORG
Transmit Band	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)
VHF 161 Filter	TB	NF	NF	NF	NF	NF	-	-31.2	-39.0	-40.5	NF	-39.0	-40.2	NF
220 ENG Filter	NF	TB	-29.1	NF	NF	NF	-	-49.0	-35.7	-38.7	NF	-48.1	-45.5	NF
220 CON Filter	NF	-29.1	TB	NF	NF	NF	-	-44.6	-47.1	-55.0	NF	-34.7	-36.1	NF
HOT 450 Filter	NF	NF	NF	TB	-24.1	-23.6	-	-32.4	-32.5	-36.5	-52.6	-27.8	-36.5	-53.3
Dist. Power A Filter	NF	NF	NF	-24.1	TB	-23.5	-	-40.9	-26.2	-26.3	-44.1	-35.7	-42.0	-60.2
Dist. Power B Filter	NF	NF	NF	-23.7	-23.5	TB	-	-28.0	-35.0	-36.2	-53.7	-27.6	-36.1	-47.5

Receive Energy is Multiple Frequency Bands
Filtered



Receive from multiple sources
Filtered

BNSF 5018 Antenna Isolation
VHF XMIT Mapping

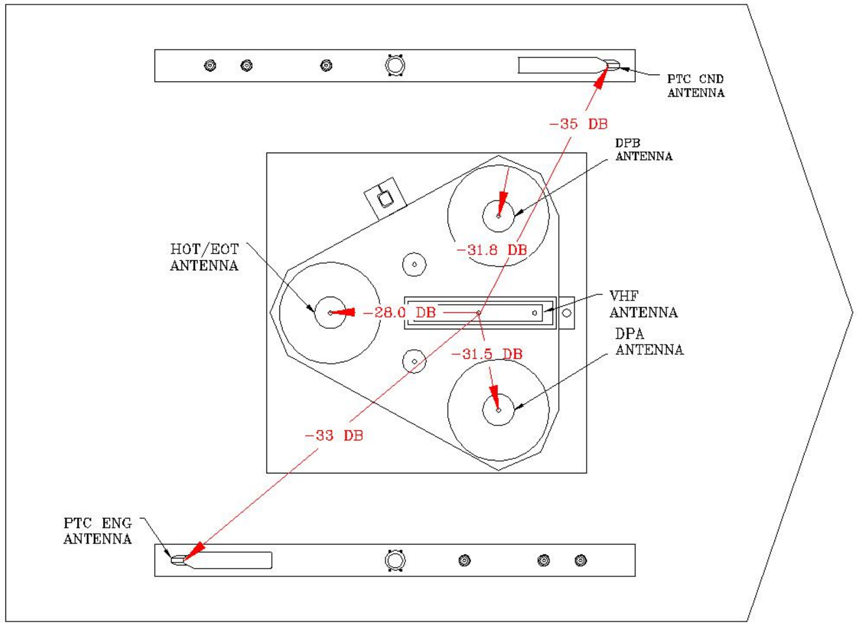


Figure 14 A
Non-Filtered

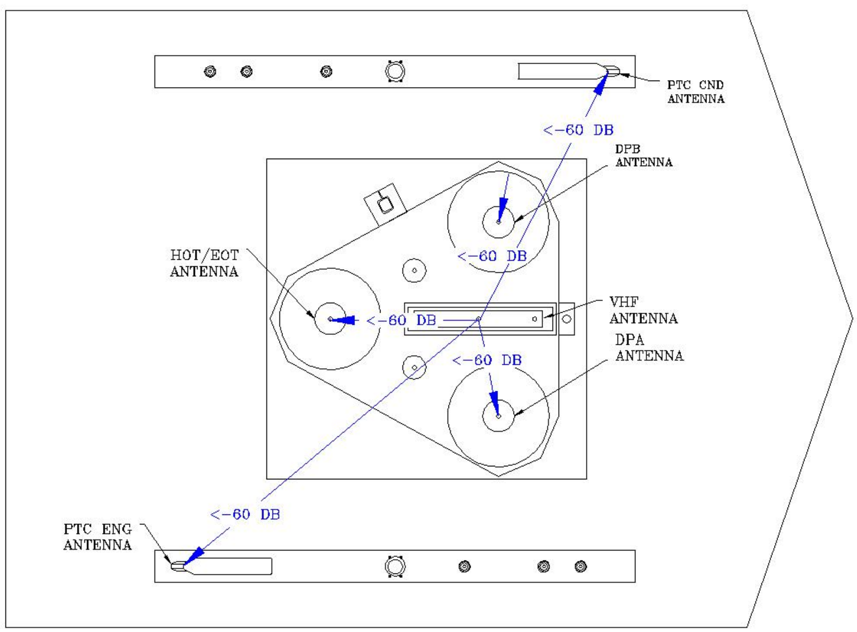


Figure 14 B
Filtered

BNSF 5018 Antenna Isolation
VHF RCV Mapping

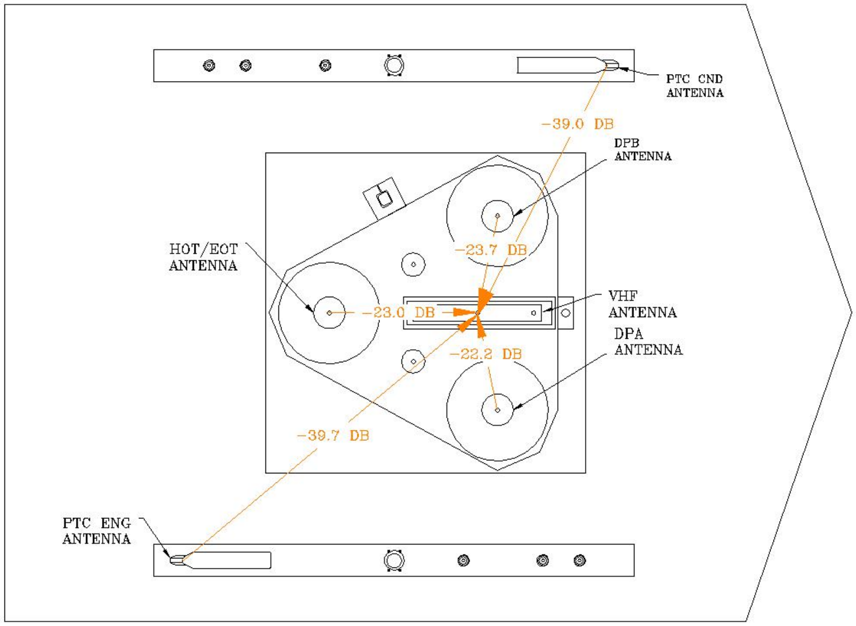


Figure 14 C
Non-Filtered

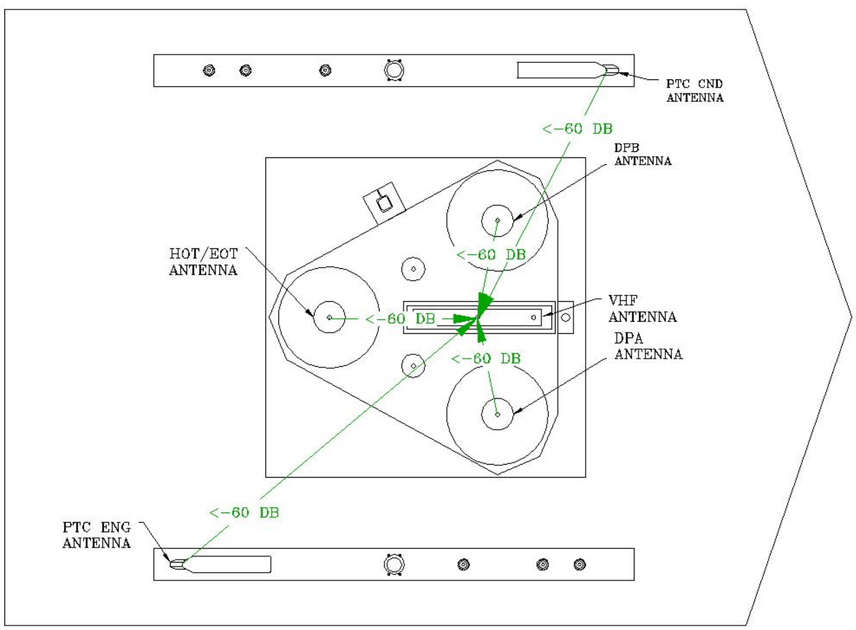


Figure 14 D
Filtered

BNSF 5018 Antenna Isolation
PTC ENG XMIT Mapping

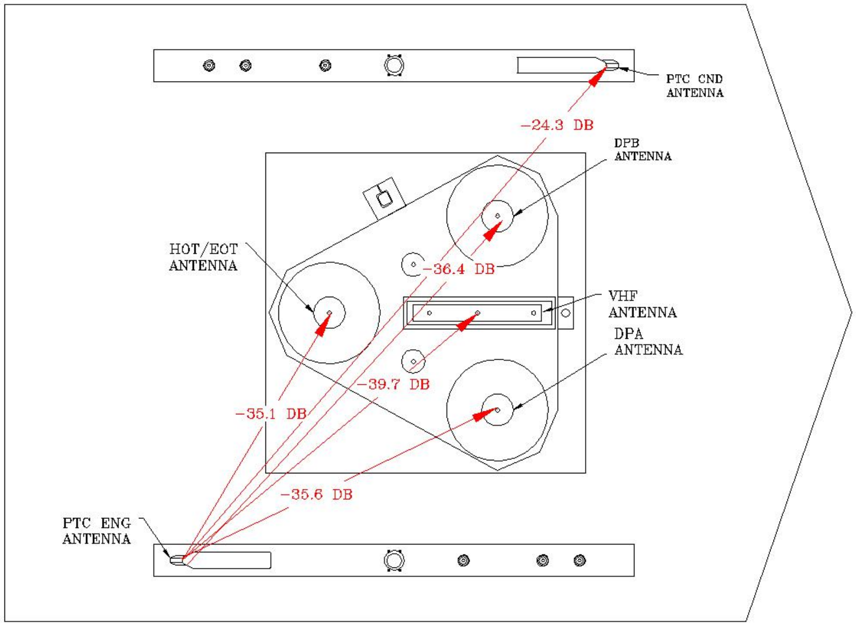


Figure 15 A
Non-Filtered

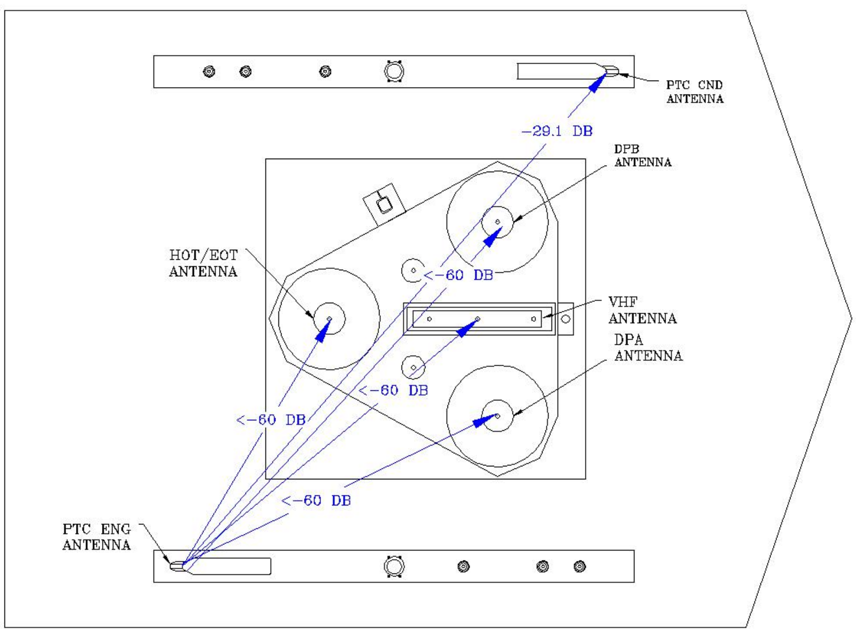


Figure 15 B
Filtered

BNSF 5018 Antenna Isolation
PTC ENG RCV Mapping

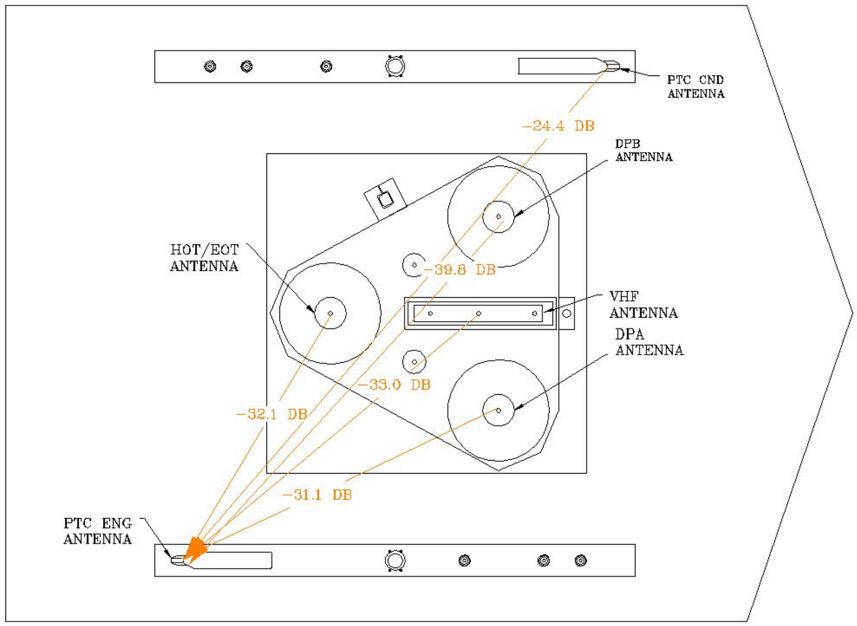


Figure 15 C
Non-Filtered

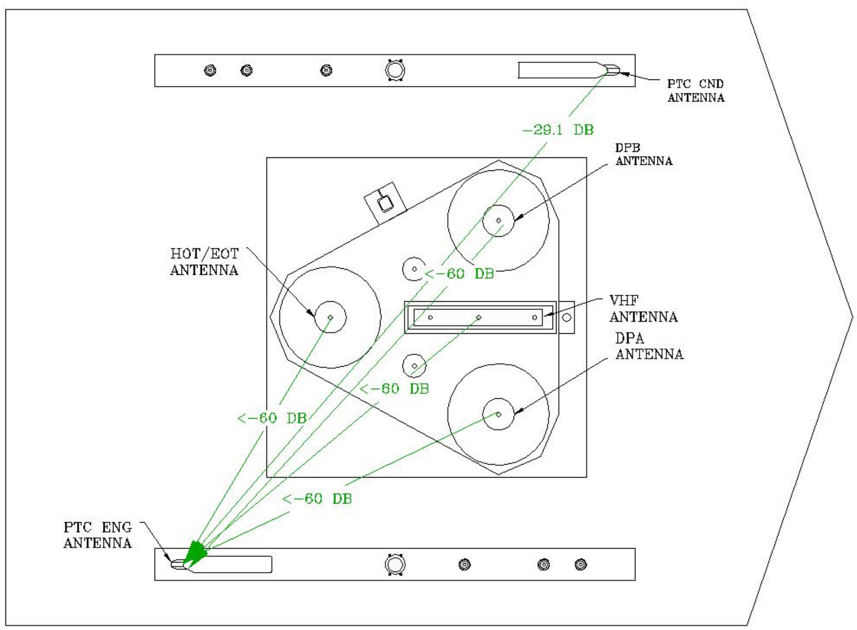


Figure 15 D
Filtered

BNSF 5018 Antenna Isolation
PTC CND XMIT Mapping

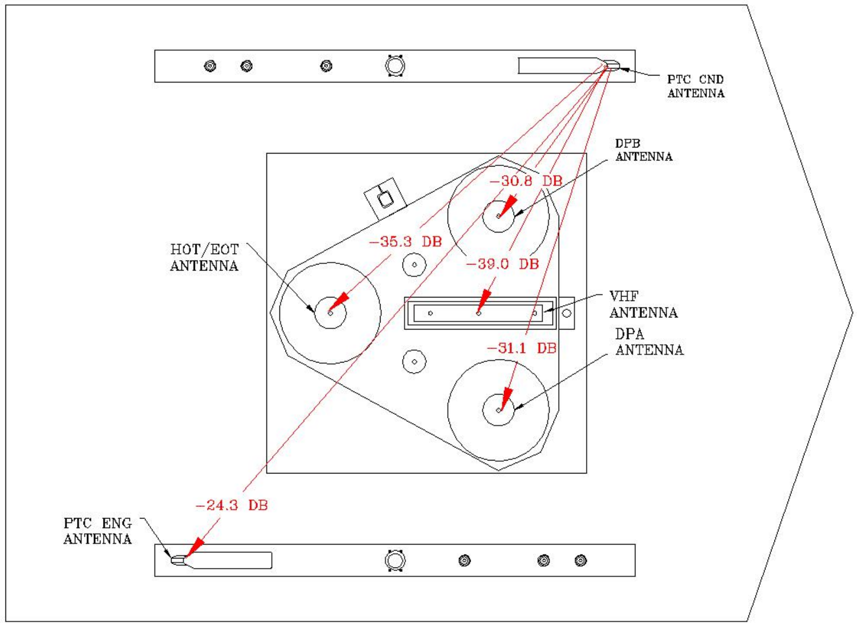


Figure 16 A
Non-Filtered

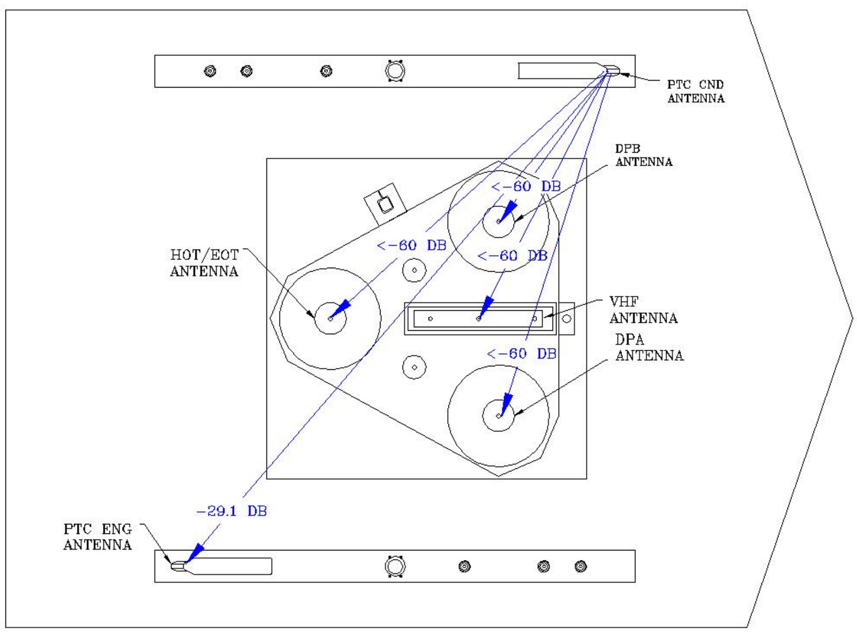


Figure 16 B
Filtered

BNSF 5018 Antenna Isolation
PTC CND RCV Mapping

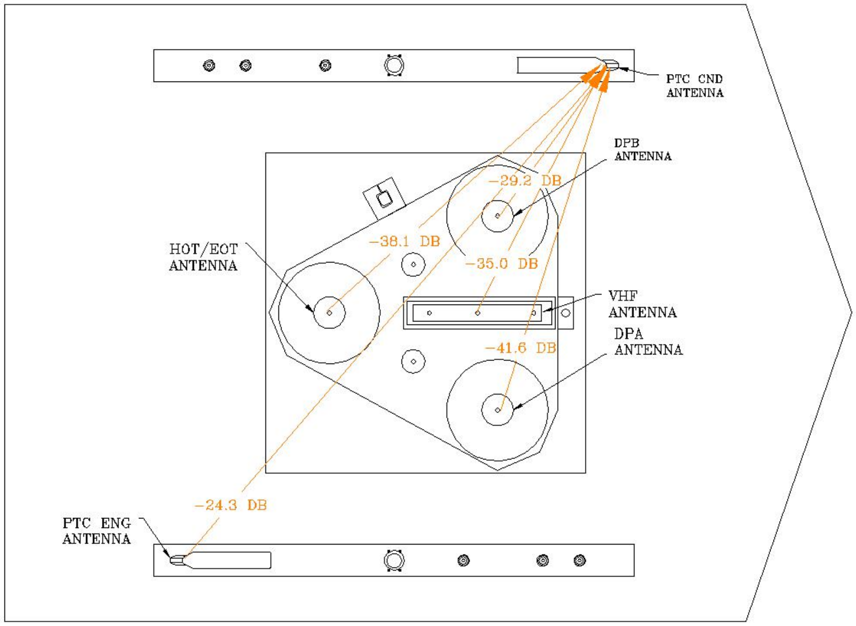


Figure 16 C
Non-Filtered

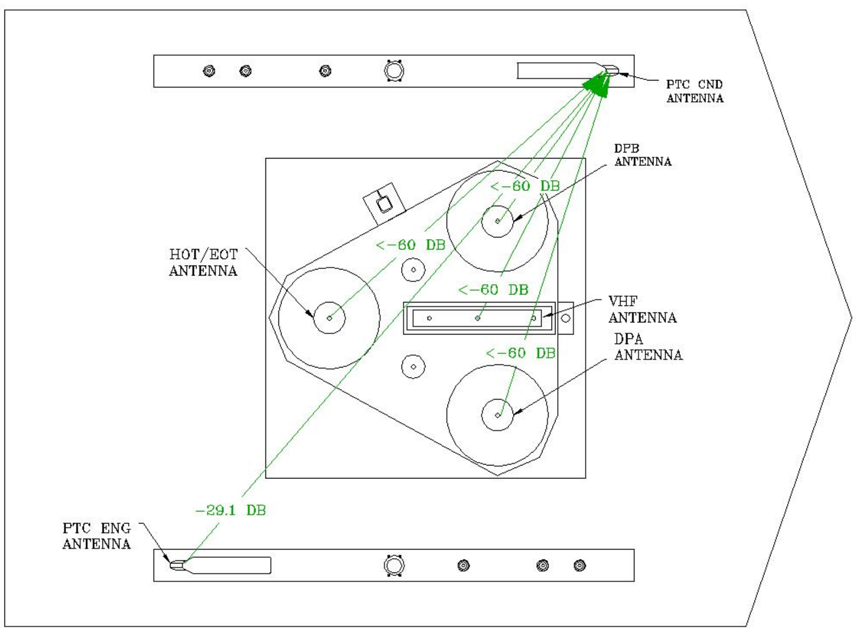


Figure 16 D
Filtered

BNSF 5018 Antenna Isolation
HOT XMIT Mapping

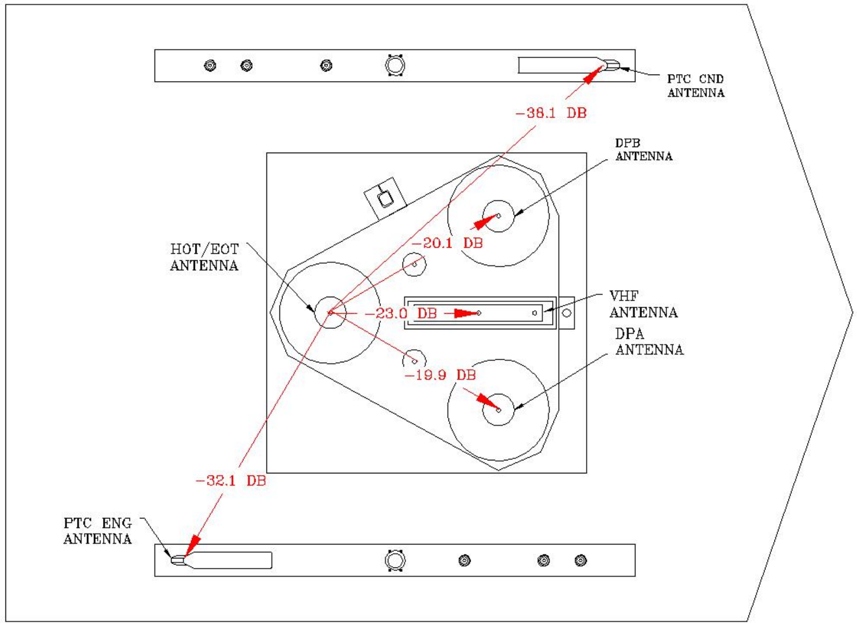


Figure 17 A
Non-Filtered

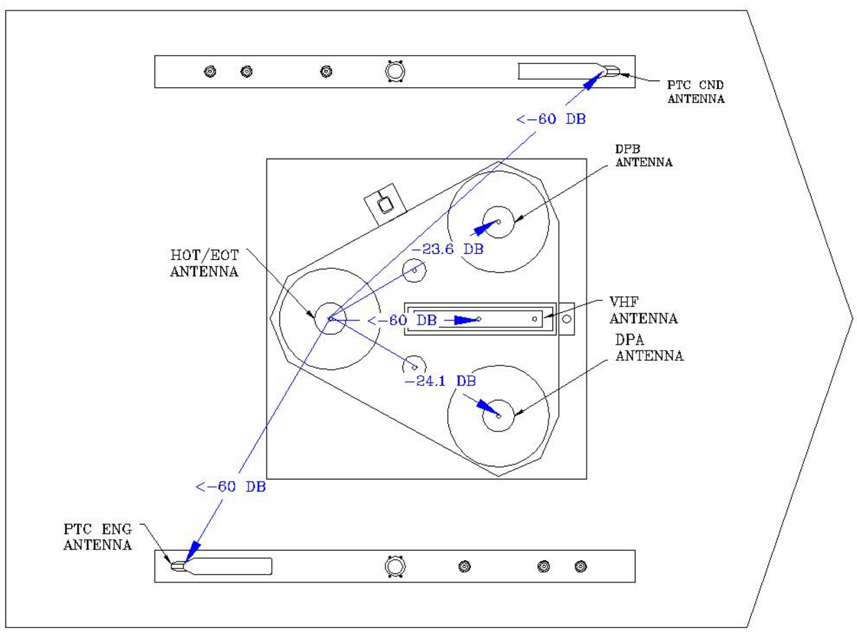


Figure 17 B
Filtered

BNSF 5018 Antenna Isolation
HOT RCV Mapping

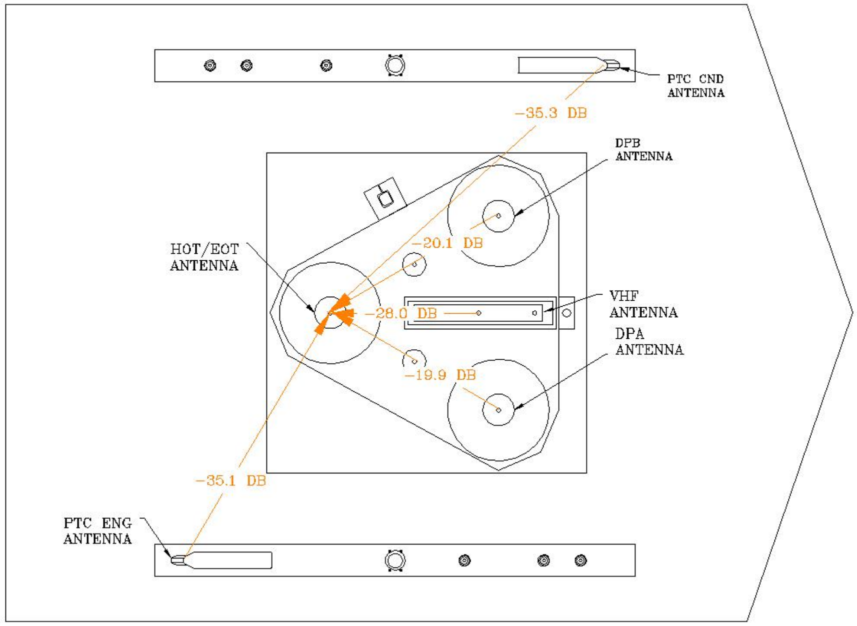


Figure 17 C
Non-Filtered

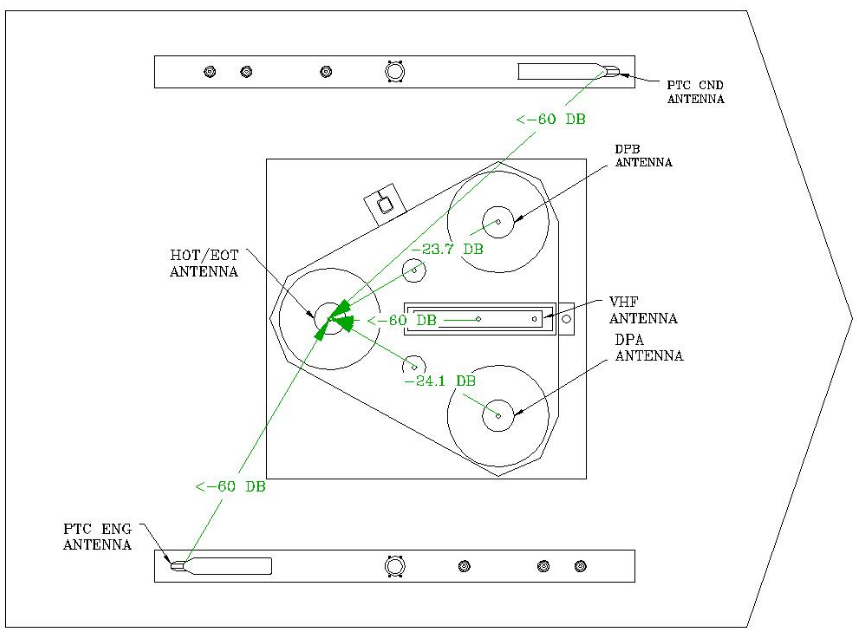


Figure 17 D
Filtered

BNSF 5018 Antenna Isolation
DPA XMIT Mapping

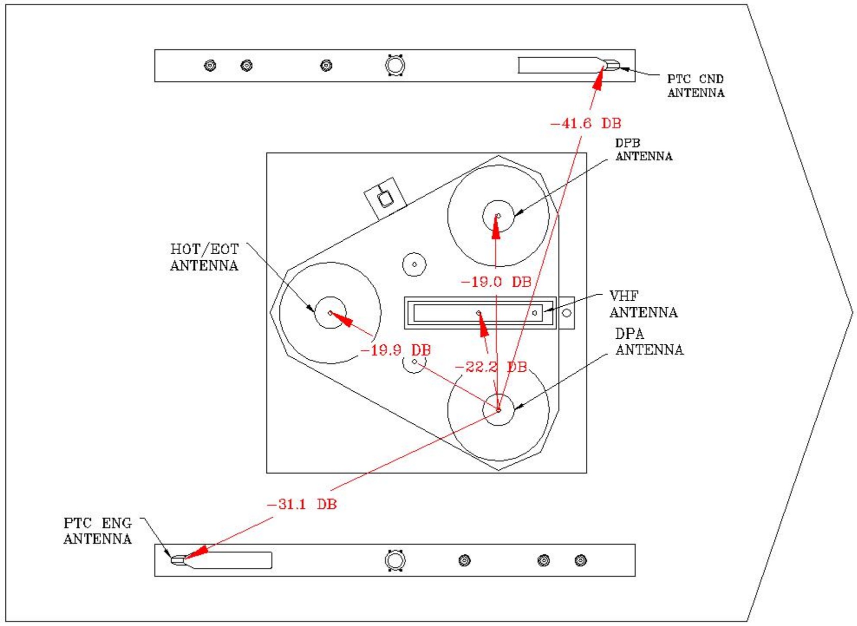


Figure 18 A
Non-Filtered

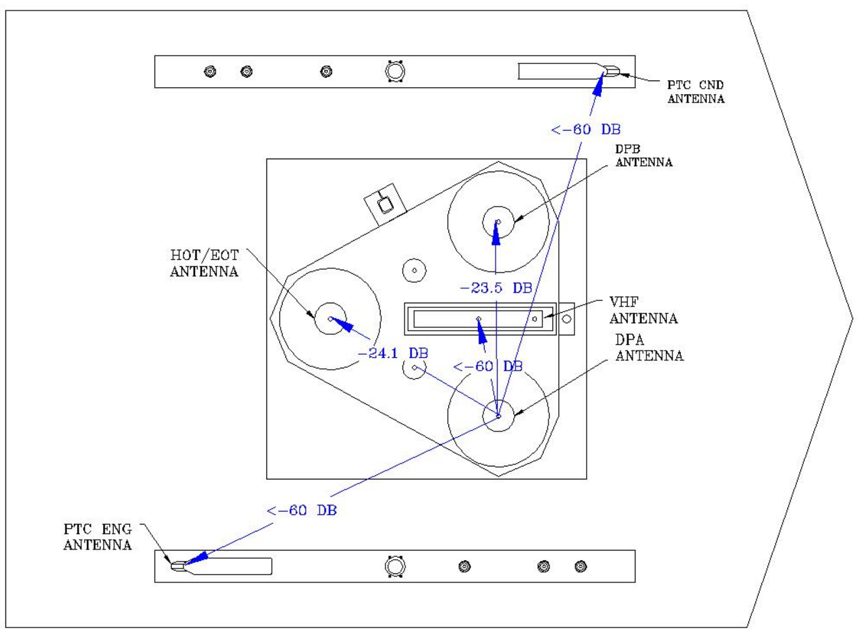


Figure 18 B
Filtered

BNSF 5018 Antenna Isolation
DPA RCV Mapping

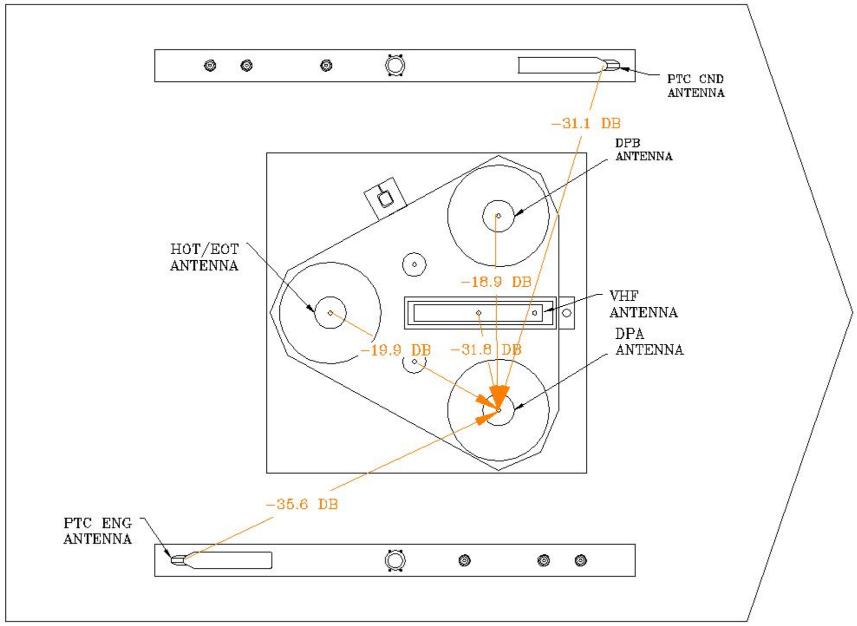


Figure 18 C
Non-Filtered

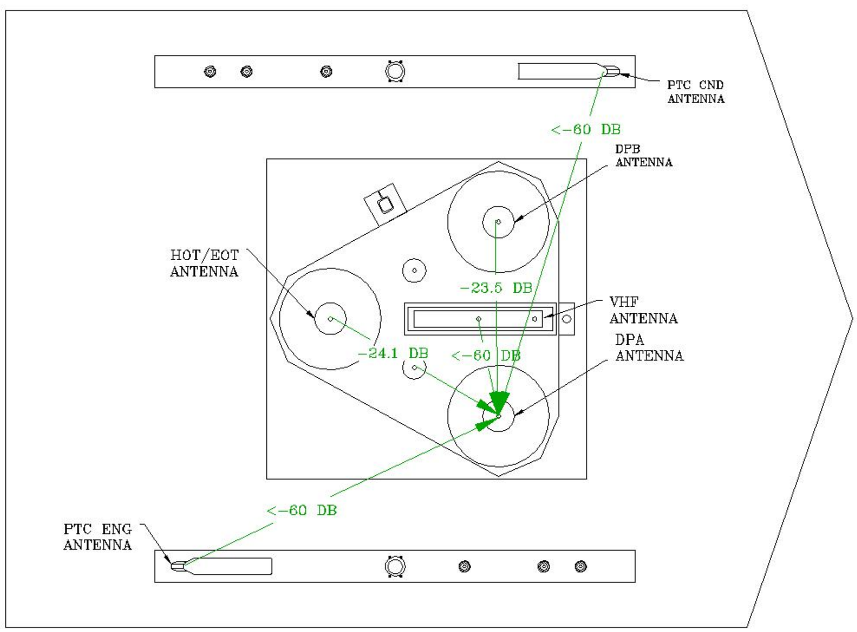


Figure 18 D
Filtered

BNSF 5018 Antenna Isolation
DPB XMIT Mapping

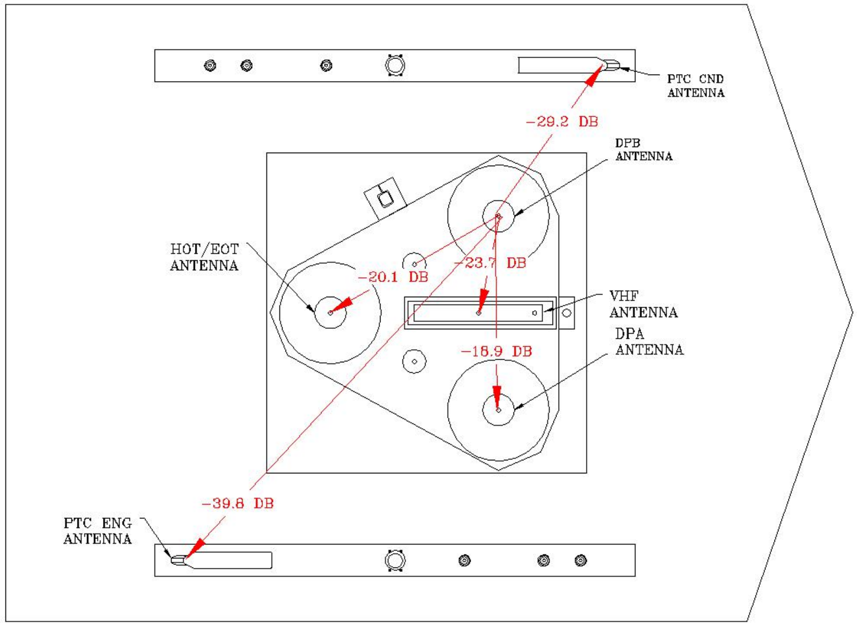


Figure 19 A
Non-Filtered

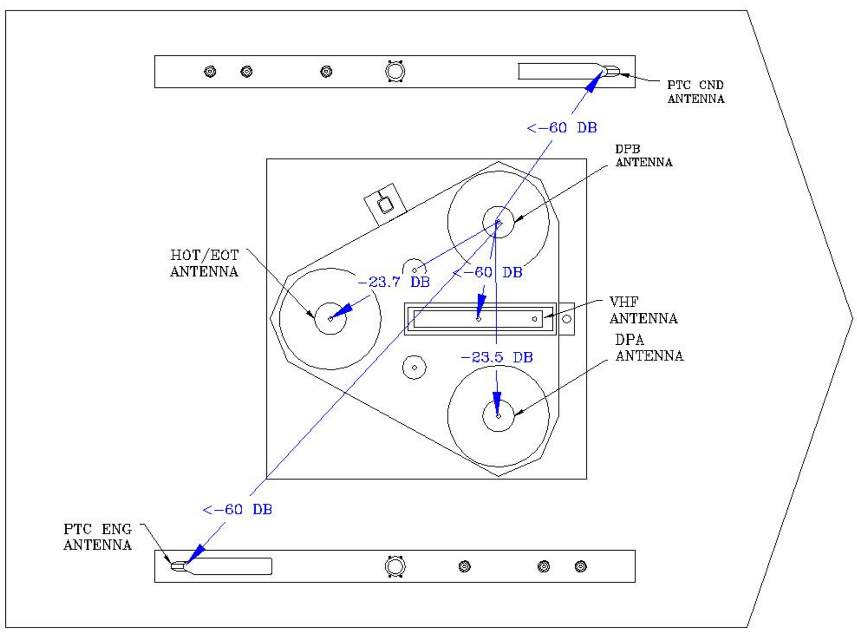


Figure 19 B
Filtered

BNSF 5018 Antenna Isolation
DPB XMIT Mapping

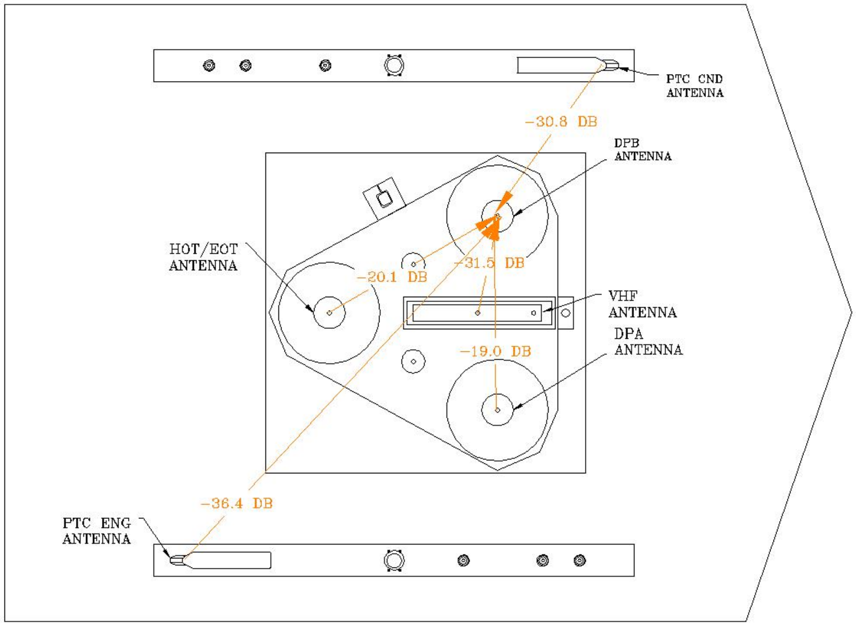


Figure 19 C
Non-Filtered

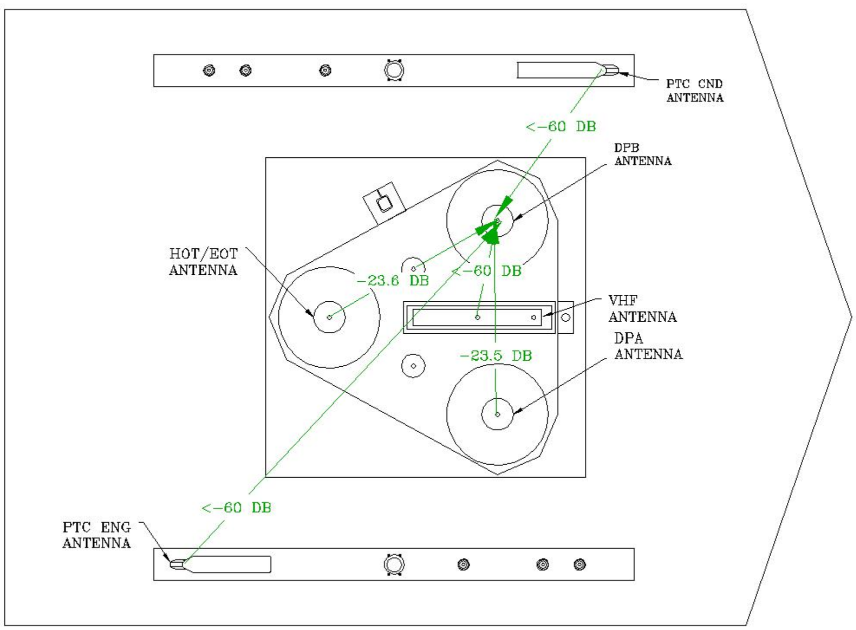


Figure 19 D
Filtered

Receive Intermodulation Test

This test provides information on intermodulation products generated at the front end of each radio receiver when it is impacted by high power signals from the transmitting radio.

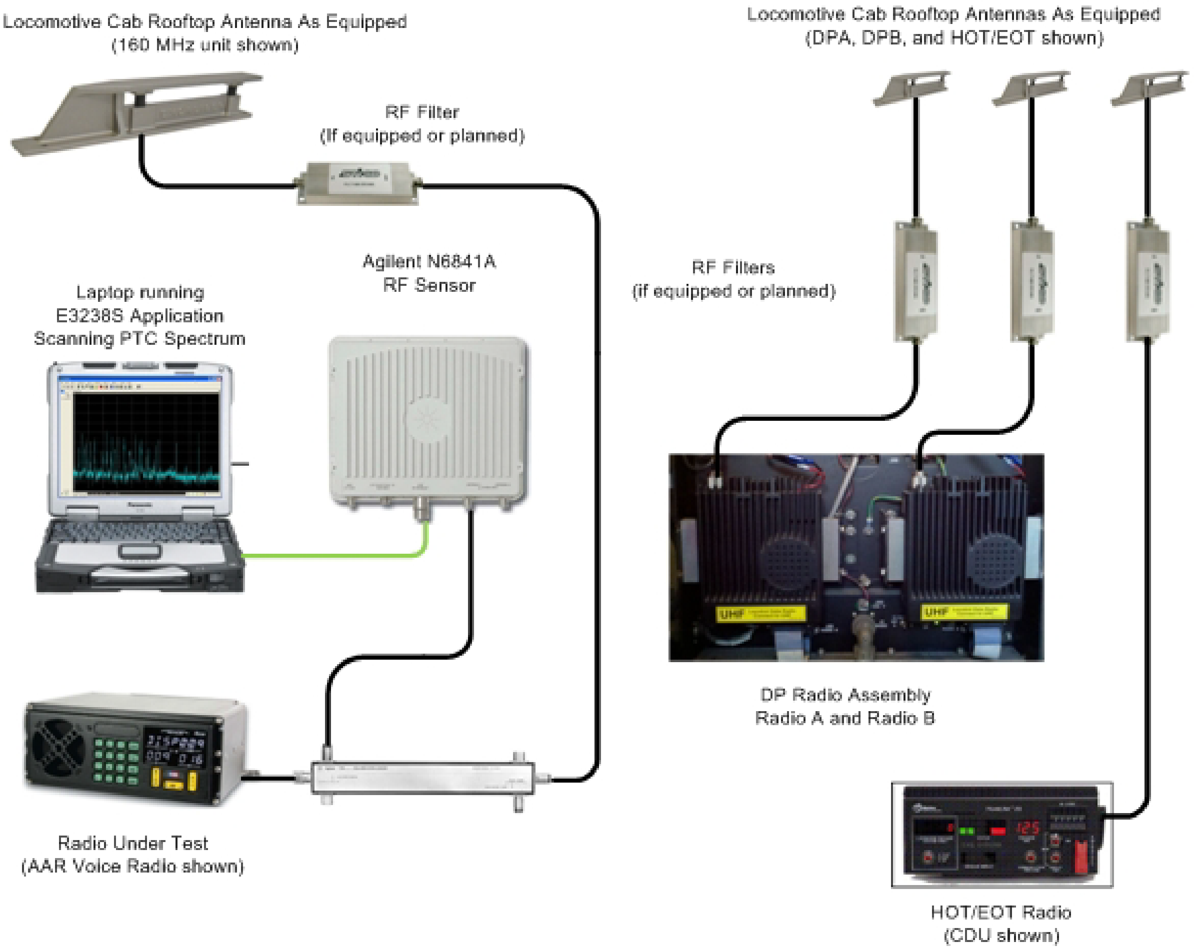
Each of the on board radios transmits at nominal power, and using a dual directional coupler the radio under test is measured for the amount of intermodulation products generated at the front end of the radio receiver and re-radiated back through the same antenna. Note that the radio under test is not transmitting.

A Dual Directional Coupler rated for a maximum power handling of 500 Watts was used to separately measure signals coming from the antenna to the radio receiver front end, and from the receiver front end travelling to the antenna and being transmitted as intermodulation products.

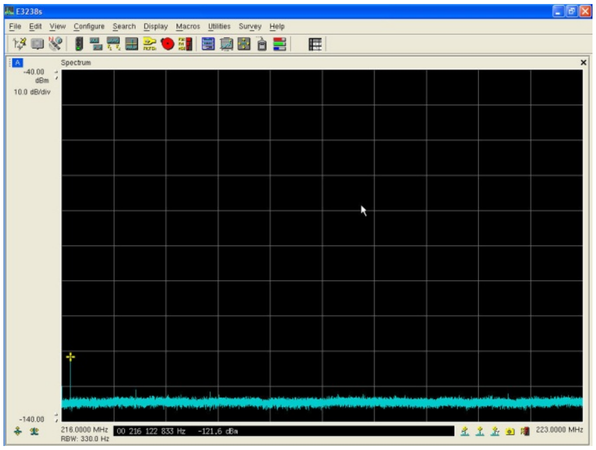
This Dual Directional Coupler has six ports, one for Antenna, one for Radio, two for 50 ohms loads, one to measure signals coming from the antenna to the radio transceiver, and one port to measure signals from the radio transceiver to the antenna.

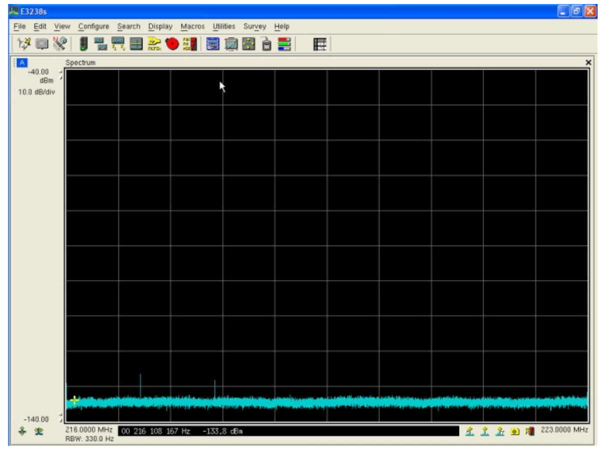
In the IMD Test Apparatus diagram, the initial radio under test shown is the AAR Voice Radio, operating at ~ 160 MHz. Its Receiver is coupled directly to its existing transmission path, including Antenna (and Filter, if equipped or planned). The RF Sensor is coupled 20 dB down to the Receiver in the Radio under Test. The other radios of interest on the Locomotive (DPA, DPB, and HOT/EOT) are then keyed and RF energy from those radios pass through their respective existing transmission paths, including Antennas (and Filters, if equipped or planned). The RF energy then propagates into the Antenna of the Radio under Test, and then into the Receiver under test. Any IMD products in the 220 MHz spectrum generated in the Receiver that would be propagated via the Antenna System are measured by the RF Sensor.

A permutation of the IMD Test Apparatus is configured for each of the other radios of interest (DPA, DPB, and HOT/EOT), so that each of them is connected as a Radio under Test, and the process is repeated.



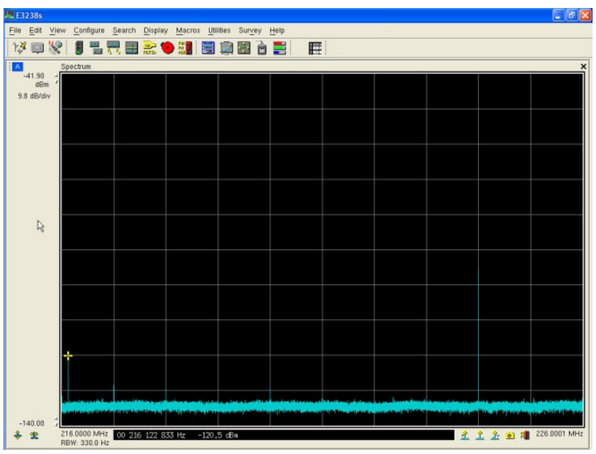
Receive Intermodulation Testing Configuration
Figure 20

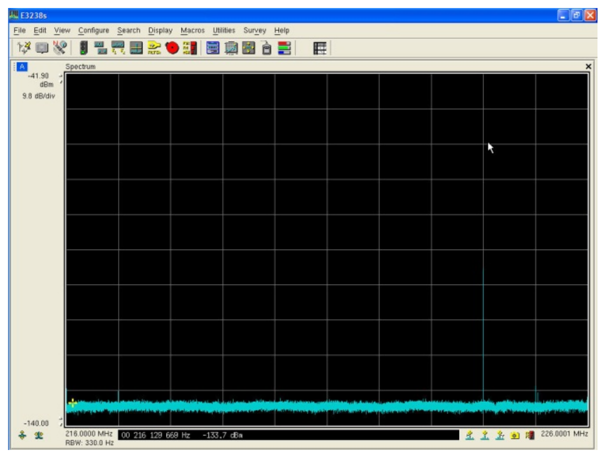

DPB Transmit
DPA Antenna (Non filtered)


DPB Transmit
DPA Filtered (STI-CO FILT-NB-UHF-MIL-U)

DPA Receiver Measurement

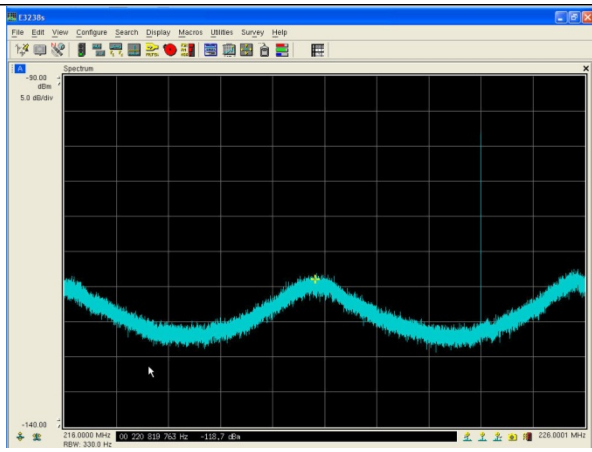
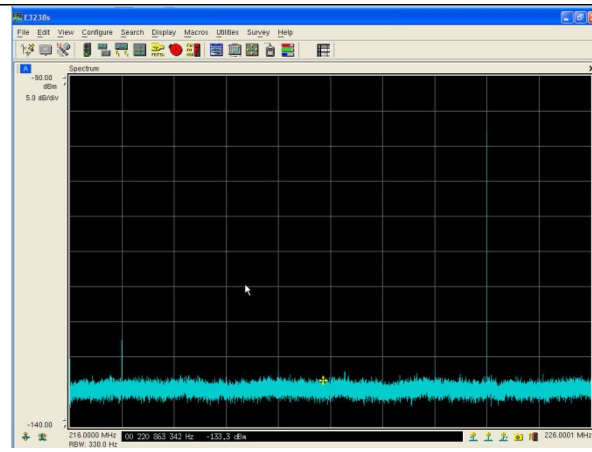
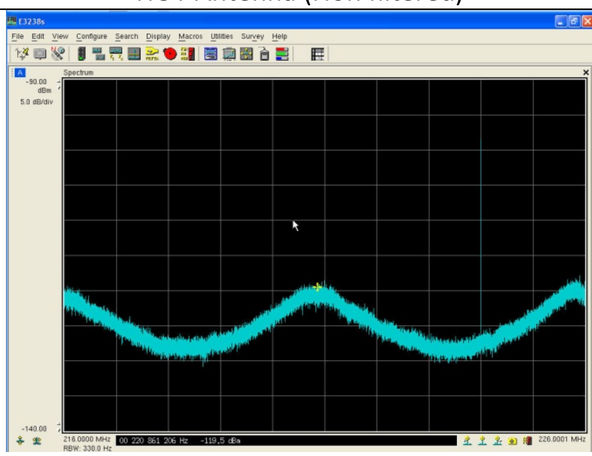
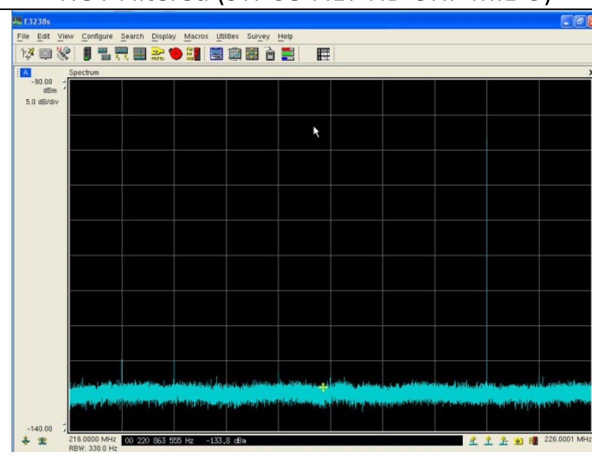
While transmitting on DPB a spur was recorded at 216.1 MHz.


DPA Transmit
DPB Antenna (Non filtered)

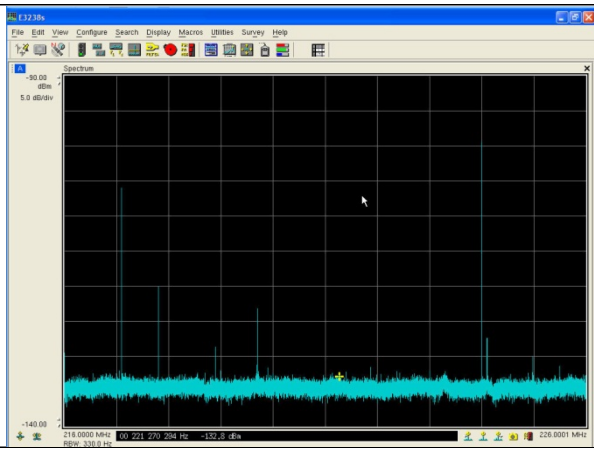
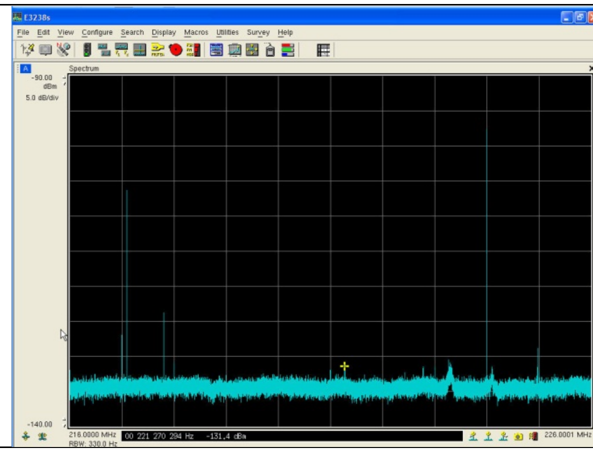

DPA Transmit
DPB Filtered (STI-CO FILT-NB-UHF-MIL-U)

DPB Receiver Measurement

While transmitting on DPA a spur was recorded at 216.1 MHz.

	
DPA Transmit HOT Antenna (Non filtered)	DPA Transmit HOT Filtered (STI-CO FILT-NB-UHF-MIL-U)
	
DPB Transmit HOT Antenna (Non filtered)	DPB Transmit HOT Filtered (STI-CO FILT-NB-UHF-MIL-U)

A broadband problem was observed when either distriuted power radio was transmitting while the AAR voice radio was transmitting simultaneously.

	
VHF Transmit HOT Antenna (Non filtered)	VHF Transmit HOT Filtered (STI-CO FILT-NB-UHF-MIL-U)

Two spikes were noted at 218.9 and 219.7 these occurred when the VHF transmitter was active.

Transmit Intermod Test

This test provides information on intermodulation products produced by multiple radio transmissions at the same time. Several radios on a locomotive, such as Voice 161 MHz, PTC 220 MHz, DP A UHF or DP B UHF, HOT UHF and SPEC 200 900 MHz, may transmit simultaneously. These simultaneous transmissions may occur on two, three or more radios at the same time.

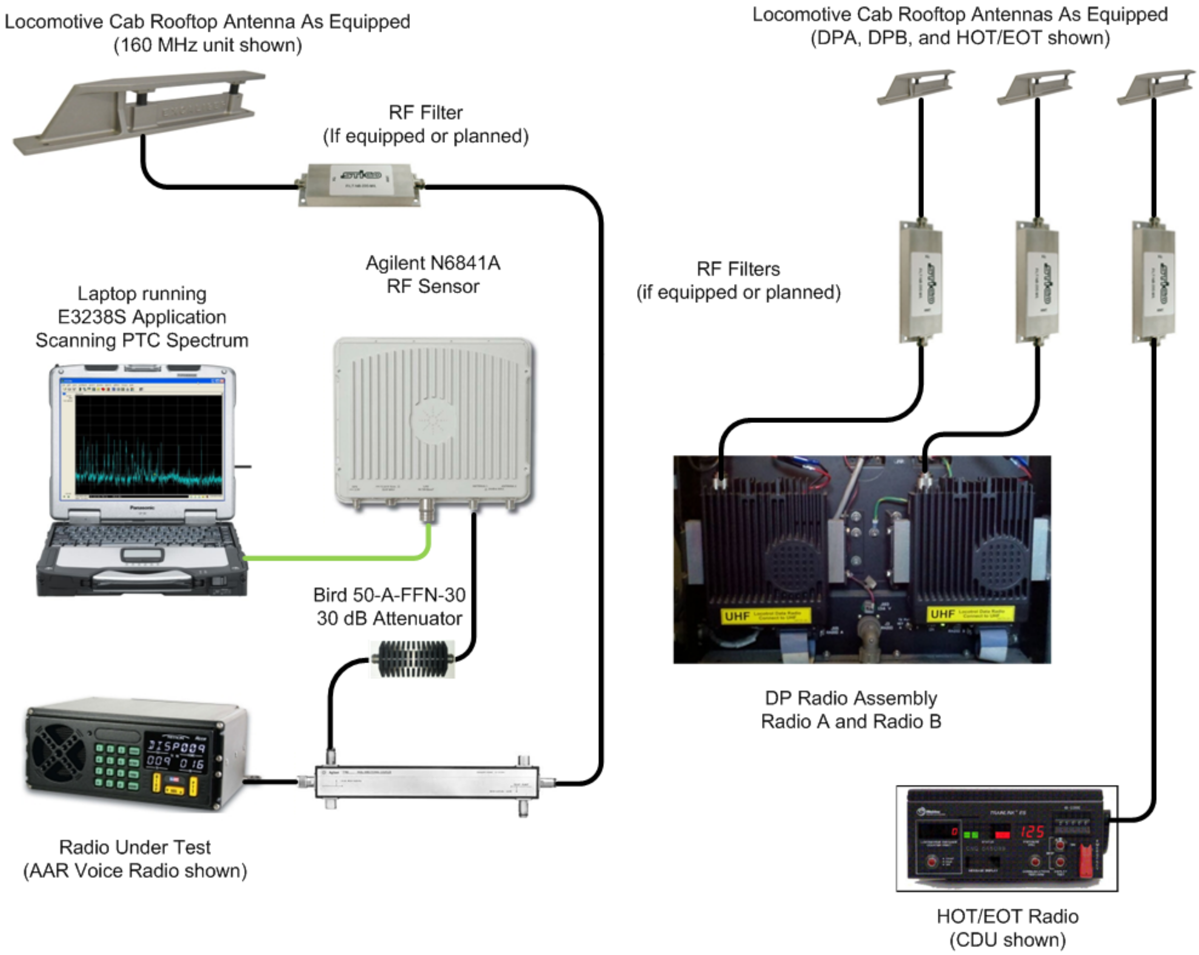
Two, three, four or more on-board radios combined in different groups transmit simultaneously. Each of the radios transmits at nominal power, and using a dual directional coupler each other non-transmitting radio is measured for the amount of signals received from the transmitting radios entering through the antenna, and for the amount of intermodulation products generated at the front end of the radio receiver and transmitted back through the same antenna.

A Dual Directional Coupler rated for a maximum power handling of 500 Watts is used to separately measure signals coming from the antenna to the radio receiver front end, and from the receiver front end travelling to the antenna and being transmitted as intermodulation products.

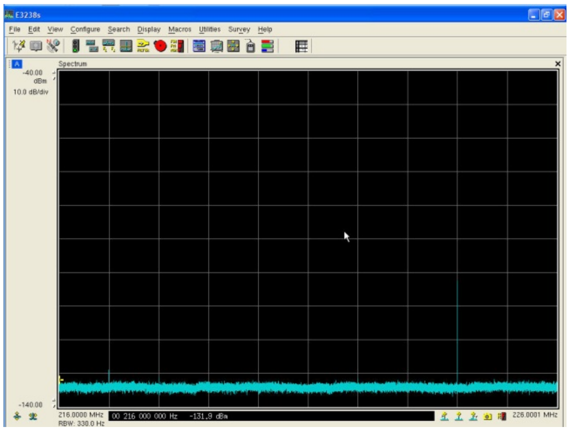
This Dual Directional Coupler has six ports, one for Antenna, one for Radio, two for 50 ohms loads, one to measure signals coming from the antenna to the radio transceiver, and one port to measure signals from the radio transceiver to the antenna.

In the IMD Test Apparatus diagram, the initial radio under test shown is the AAR Voice Radio, operating at ~ 160 MHz. Its Transmitter is coupled directly to its existing transmission path, including Antenna (and Filter, if equipped or planned). The RF Sensor is coupled 20 dB down (or more, as needed to protect the RF Sensor) to the Transmitter in the Radio under Test. The other radios of interest on the Locomotive (DPA, DPB, and HOT/EOT) are then keyed and RF energy from those radios pass through their respective existing transmission paths, including Antennas (and Filters, if equipped or planned). The RF energy then propagates into the Antenna of the Radio under Test, and then into the Transmitter under test. Any IMD products in the 220 MHz spectrum generated in the Transmitter that would be propagated via the Antenna system are measured by the RF Sensor.

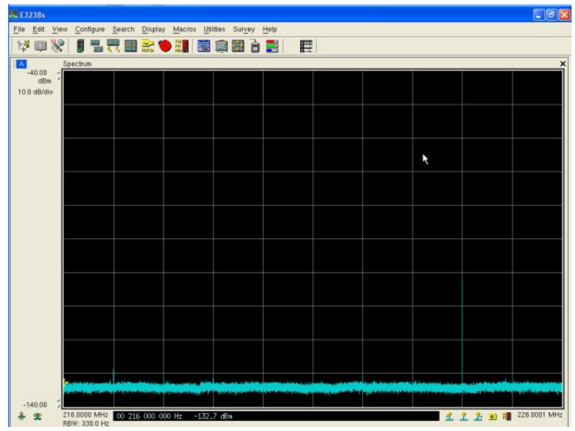
A permutation of the IMD Test Apparatus is configured for each of the other radios of interest (DPA, DPB, and HOT/EOT), so that each of them is connected as a Radio under Test, and the process is repeated.



Transmit Intermodulation Testing Configuration
Figure 21

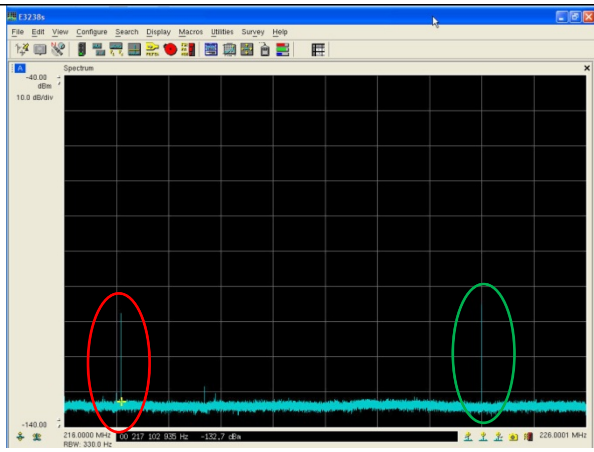


VHF System (Non-Filtered) Baseline

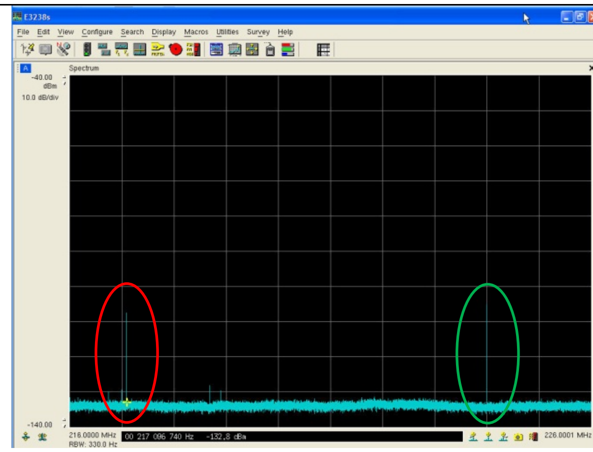


VHF Transmit (Filtered)

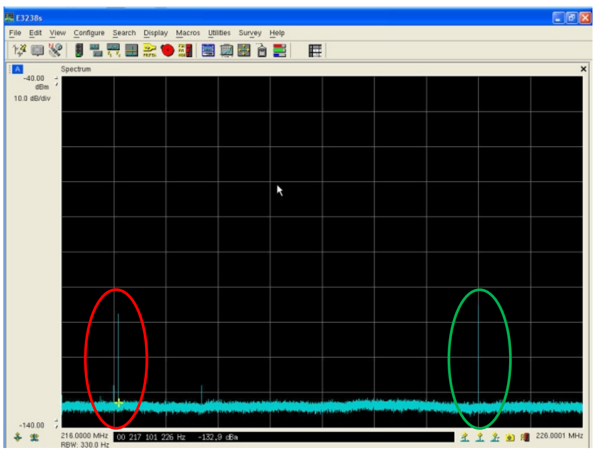
A baseline measurement of the VHF transmission system with no other transmitting sources is shown on the left. Two non-reactive signals were present throughout the testing at 216 and 224 MHz. The baseline response was the same for each radio system tested. It was noted that for the single VHF transmit source there was no difference from the baseline non-transmission in the characteristic noise floor. No spurious response was found.



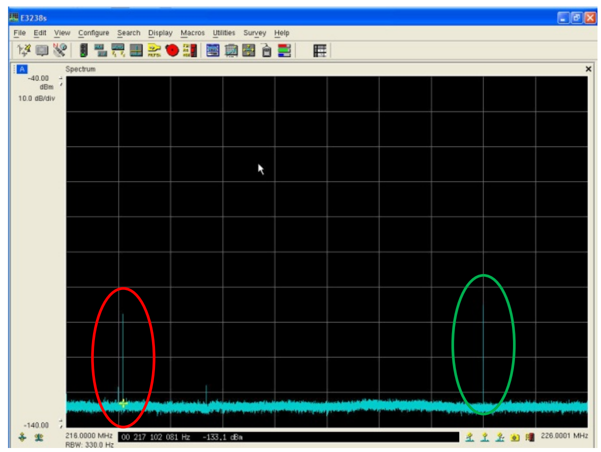
VHF Transmit (Filtered)
DPA Antenna (Non filtered)



VHF Transmit (Filtered)
DPA Antenna (Filtered)

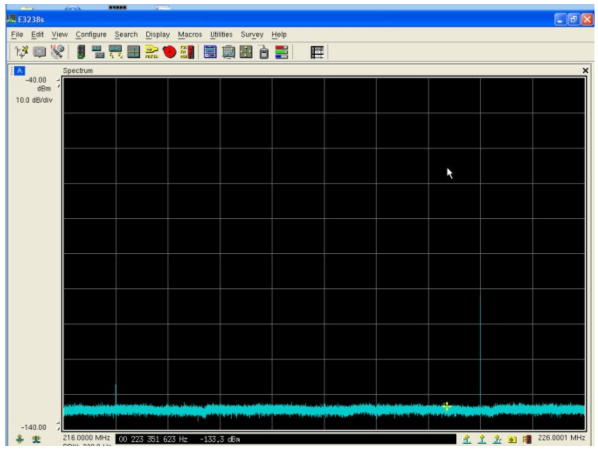


VHF Transmit (Filtered)
DPB Antenna (Non filtered)

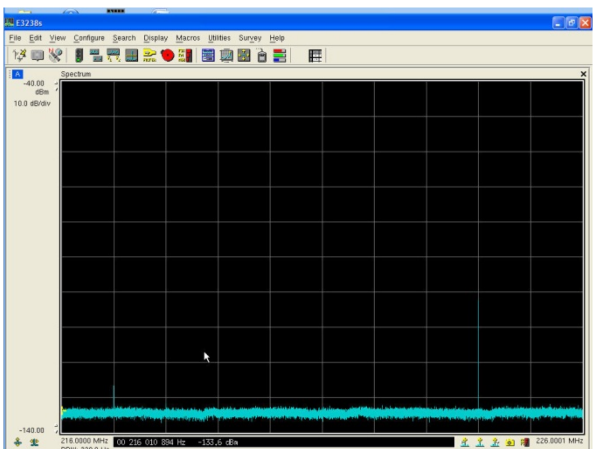


VHF Transmit (Filtered)
DPB Antenna (Filtered)

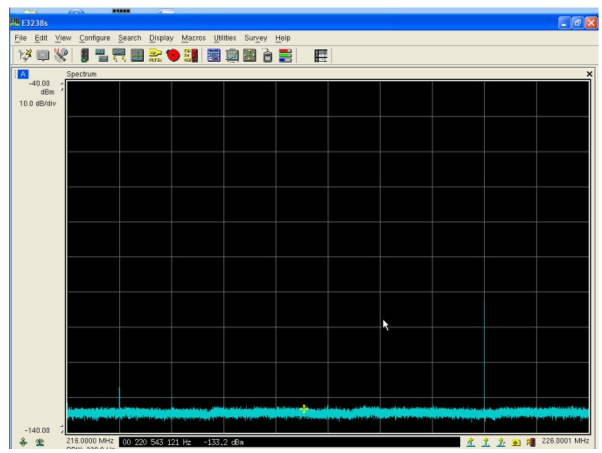
When transmitting on multiple on-board antennas a single noise spur at 217 MHz was found (red circle). This signal was present regardless of filtering combinations. A second energy level at 224 MHz was recorded (green circle), however this appeared to be an artifact generated internally by the RF sensor.



DPA Transmit (Non-Filtered)



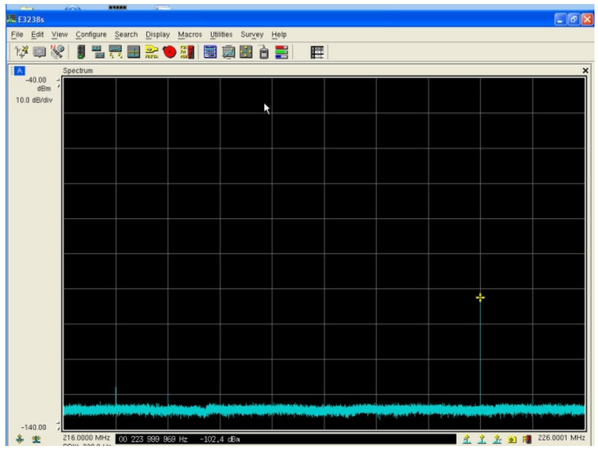
DPA Transmit (Non-Filtered)
VHF Transmit (Filtered)



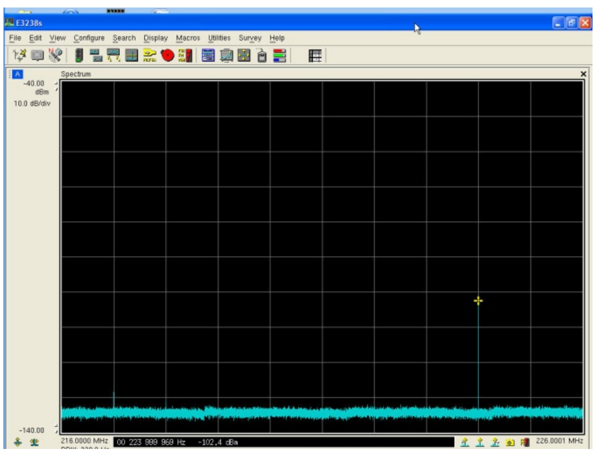
DPA Transmit (Filtered)
VHF Transmit (Filtered)

In the DPA single transmit there was no difference between the baseline response and the transmit test.

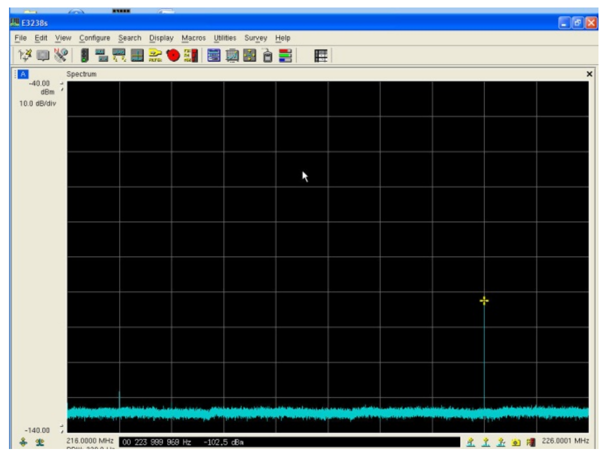
The test was performed with multiple transmit scenarios the signal response remained un-changed in the 220 MHz band.



DPB Transmit (Non-Filtered)



DPB Transmit (Non-Filtered)
VHF Transmit (Filtered)



DPB Transmit (Filtered)
VHF Transmit (Filtered)

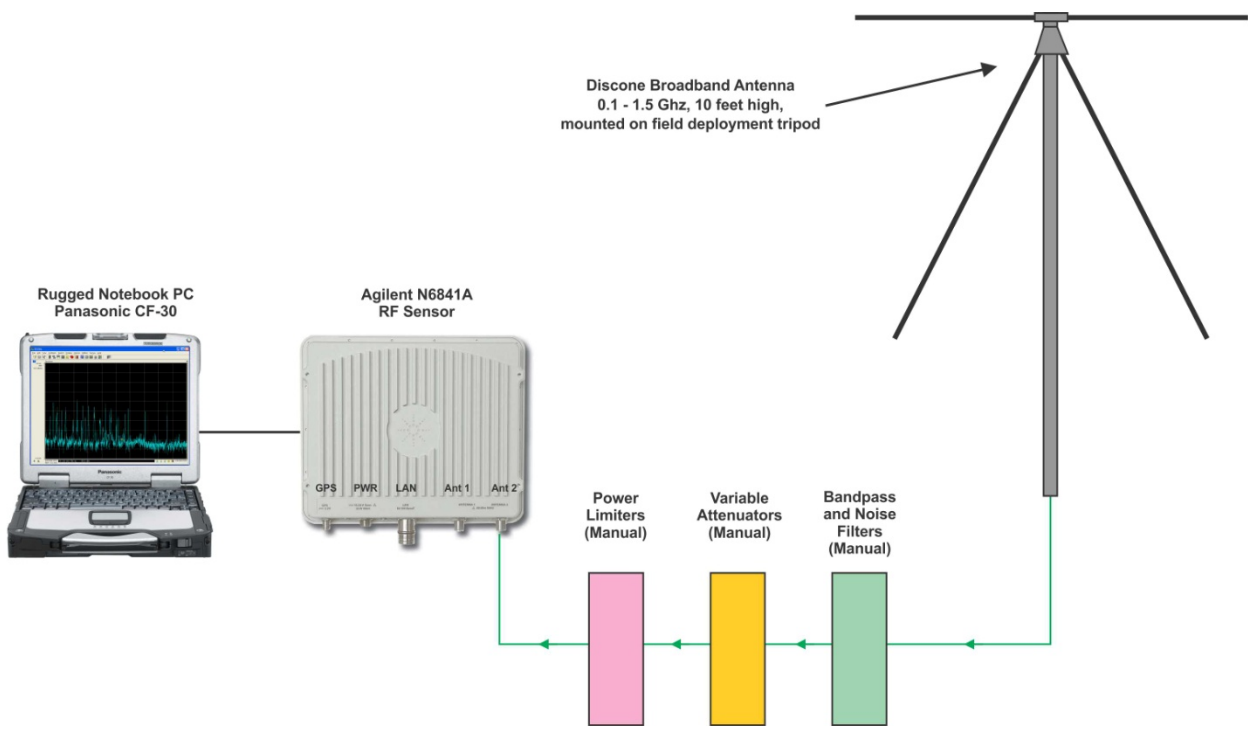
In the DPB single transmit there was no difference between the baseline response and the transmit test as in the DPA testing.

The test was performed with multiple transmit scenarios the signal response remained un-changed.

RF Site Survey

The purpose of this test is to detect the presence of external signals that might affect the accuracy of all the tests carried out on a locomotive.

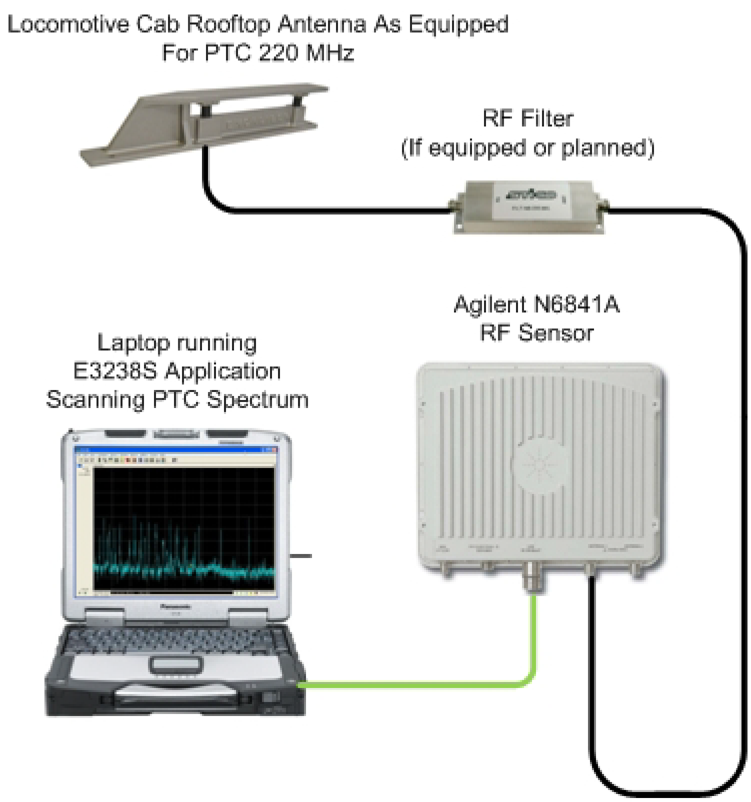
The testing results (See Appendix F) show that there were anomalies that occurred throughout our testing period each day. In order to ensure that the off-site signals did not affect our test results the sampling was run multiple times to make sure the results were consistent. It was also noted that the data collected by the off platform dis-cone antenna was identical to that collected by the on-board PTC antennas (in the 220 MHz range). Therefore it was determined that the off locomotive testing set-up was not necessary in subsequent locomotives which will save time by not duplicating efforts.



RF Site Survey Testing Configuration
Figure 22

EMI Testing

The purpose of this test is to characterize the EMI produced by the unintentional radiators present in the electromechanical equipment and any electronic support equipment ancillary to the power plant operation. The testing results showed some increases in the noise floor level while operating through the start-up and shut-down phases. A very minor difference between the conductor and engineer side noise floor (only about 1-2 DB) was indicated during testing. This may be attributed to the physical location of the antenna feed point relative to some on-board power sources, the pattern characteristic differences between the two antennas related to Antenna orientation, or the routing of the two different cable bundles.

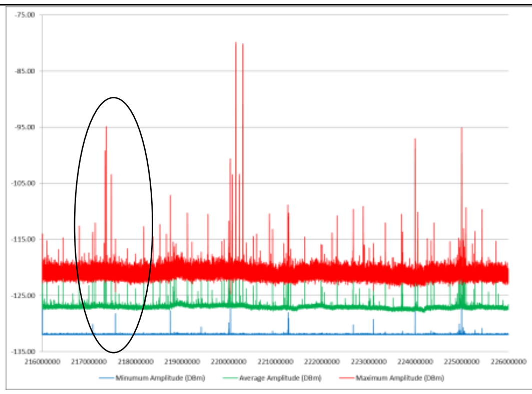


EMI Testing Configuration
Figure 23

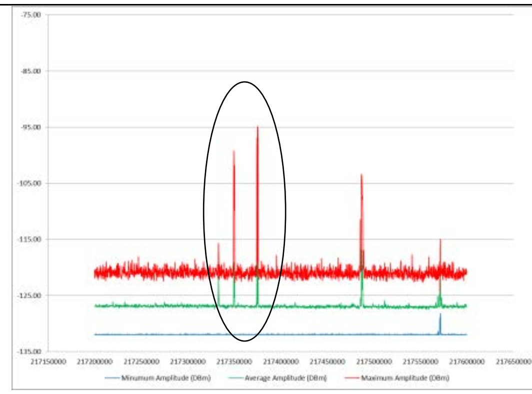
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	Frequency	Bandwidth	Number Sweeps	Intercepts	Detections	Minumum Amplitude (DBm)	Average Amplitude (DBm)	Maximum Amplitude (DBm)	Minimum Bandwidth	Average Bandwidth	Maximum Bandwidth	Minimum Duration	Average Duration	Maximum Duration	Percent Occupancy
2	216000214	214	1314	85	10.00	-131.57	-125.99	-120.80	213.62	213.62	213.62	0.05	0.01	0.06	6.5%
3	216000427	214	1341	254	29.00	-131.92	-126.97	-120.89	213.62	213.62	213.62	0.05	0.01	0.27	18.9%
4	216000641	214	1334	330	60.00	-131.98	-126.83	-121.90	213.62	213.62	213.62	0.05	0.01	0.30	24.7%
5	216000855	214	1339	288	48.00	-131.80	-127.21	-121.00	213.62	213.62	213.62	0.05	0.01	0.20	21.5%
6	216001068	214	1341	190	23.00	-131.98	-126.77	-121.79	213.62	213.62	213.62	0.05	0.01	0.23	14.2%
7	216001282	214	1342	545	131.00	-131.94	-124.90	-119.33	213.62	214.01	427.25	0.05	0.02	0.38	40.6%
8	216001495	214	1340	420	92.00	-131.87	-125.24	-119.77	213.62	214.13	427.25	0.05	0.02	0.20	31.3%
9	216001709	214	1334	174	16.00	-131.86	-126.68	-120.89	213.62	214.85	427.25	0.05	0.00	0.11	13.0%
10	216001923	214	1342	361	71.00	-131.98	-126.29	-120.77	213.62	213.62	213.62	0.05	0.02	1.45	26.9%
11	216002136	214	1336	406	82.00	-131.95	-125.97	-119.31	213.62	213.62	213.62	0.05	0.01	0.25	30.4%
12	216002350	214	1342	252	39.00	-131.94	-126.71	-121.37	213.62	213.62	213.62	0.05	0.01	0.11	18.8%
13	216002564	214	1329	262	41.00	-131.98	-127.02	-122.01	213.62	213.62	213.62	0.05	0.01	0.16	19.7%
14	216002777	214	1341	329	59.00	-131.98	-125.90	-119.16	213.62	214.27	427.25	0.05	0.01	0.16	24.5%
15	216002991	214	1338	463	102.00	-131.92	-125.54	-119.63	213.62	213.62	213.62	0.05	0.02	0.27	34.6%
16	216003204	214	1340	307	59.00	-131.84	-125.81	-120.77	213.62	213.62	213.62	0.05	0.01	0.16	22.9%
17	216003418	214	1342	305	48.00	-131.71	-126.40	-119.80	213.62	214.32	427.25	0.05	0.01	0.16	22.7%
18	216003632	214	1341	301	53.00	-131.80	-126.54	-120.70	213.62	213.62	213.62	0.05	0.01	0.20	22.4%
19	216003845	214	1337	289	56.00	-131.98	-127.10	-120.43	213.62	214.36	427.25	0.05	0.01	0.22	21.6%
20	216004059	214	1336	308	58.00	-131.97	-127.08	-122.06	213.62	213.62	213.62	0.05	0.01	0.27	23.1%
21	216004273	214	1338	298	53.00	-131.98	-126.85	-120.96	213.62	214.34	427.25	0.05	0.01	0.20	22.3%
22	216004486	214	1339	332	65.00	-131.80	-127.04	-121.12	213.62	213.62	213.62	0.05	0.01	0.33	24.8%
23	216004700	214	1341	381	75.00	-131.98	-126.40	-121.15	213.62	213.62	213.62	0.05	0.02	0.23	28.4%
24	216004913	214	1335	277	44.00	-131.97	-127.08	-120.32	213.62	213.62	213.62	0.05	0.01	0.11	20.7%
25	216005127	214	1337	296	49.00	-131.98	-127.02	-121.40	213.62	213.62	213.62	0.05	0.01	0.22	22.1%
26	216005341	214	1341	327	65.00	-131.97	-127.02	-119.80	213.62	213.62	213.62	0.05	0.01	0.16	24.4%
27	216005554	214	1342	293	52.00	-131.98	-126.89	-121.16	213.62	213.62	213.62	0.05	0.01	0.20	21.8%
28	216005768	214	1335	311	56.00	-131.87	-127.15	-121.00	213.62	214.31	427.25	0.05	0.01	0.11	23.3%
29	216005981	214	1338	293	54.00	-131.98	-126.86	-120.96	213.62	214.35	427.25	0.05	0.01	0.13	21.9%
30	216006195	214	1342	312	59.00	-131.97	-126.99	-120.94	213.62	213.62	213.62	0.05	0.02	1.45	23.2%
31	216006409	214	1338	302	55.00	-131.98	-127.35	-122.10	213.62	214.33	427.25	0.05	0.01	0.16	22.6%
32	216006622	214	1342	322	60.00	-131.98	-127.00	-121.25	213.62	214.29	427.25	0.05	0.01	0.25	24.0%
33	216006836	214	1339	296	49.00	-131.92	-127.08	-122.56	213.62	213.62	213.62	0.05	0.01	0.25	22.1%
34	216007050	214	1341	325	63.00	-131.97	-127.04	-121.10	213.62	214.94	427.25	0.05	0.01	0.23	24.2%
35	216007263	214	1336	313	64.00	-131.98	-127.22	-121.77	213.62	213.62	213.62	0.05	0.01	0.31	23.4%

Energy File Data Format
Figure 24

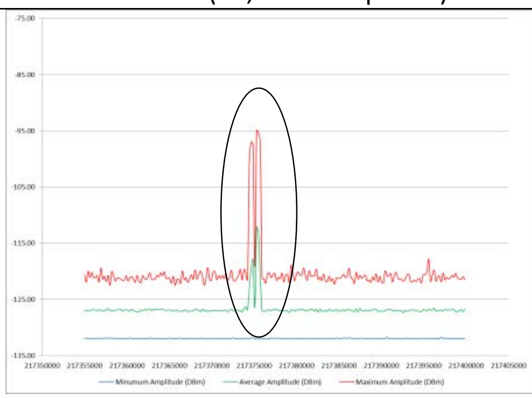
This is a sample of the data captured per locomotive, each excel file is approximately 10 MB, comprised 46000 frequency information points and the associated amplitude, duration, bandwidth and percent occupancy information. Without a Locomotive-scaled Faraday Cage and Anechoic Chamber, it is not possible to fully isolate the locomotive from its environment. However, by perusing the following charts, with less focus on the discrete signals present (spikes), and more focus on the overall changes between Locomotive operational states, it is possible to characterize the noise. The Energy Files are provided in the Appendix to permit further manipulation of the data, if desired.



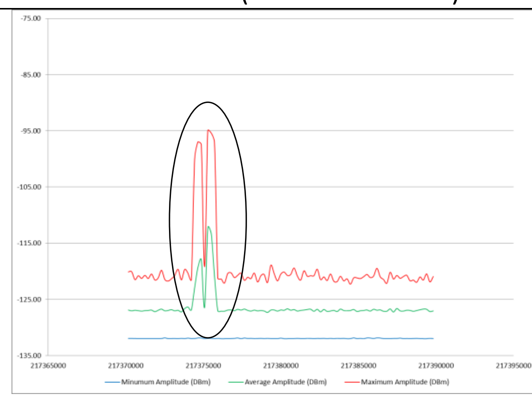
Full Scale (46,000 data points)



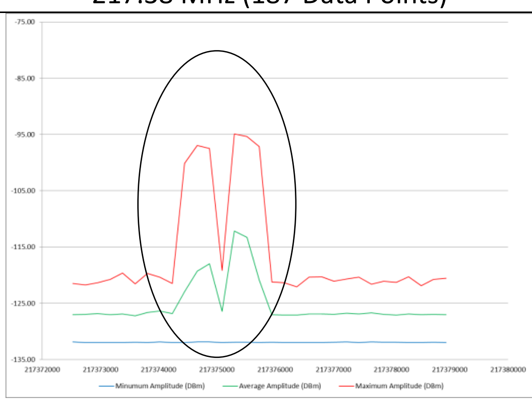
217.38 MHz (1872 Data Points)



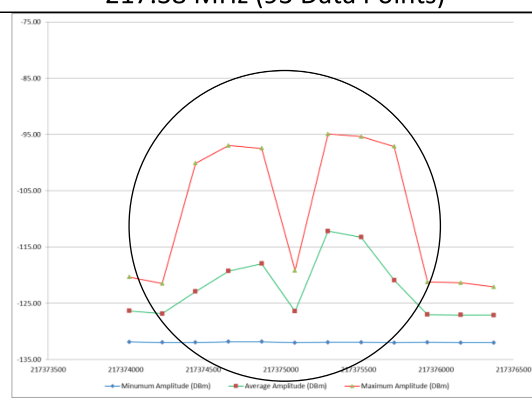
217.38 MHz (187 Data Points)



217.38 MHz (93 Data Points)



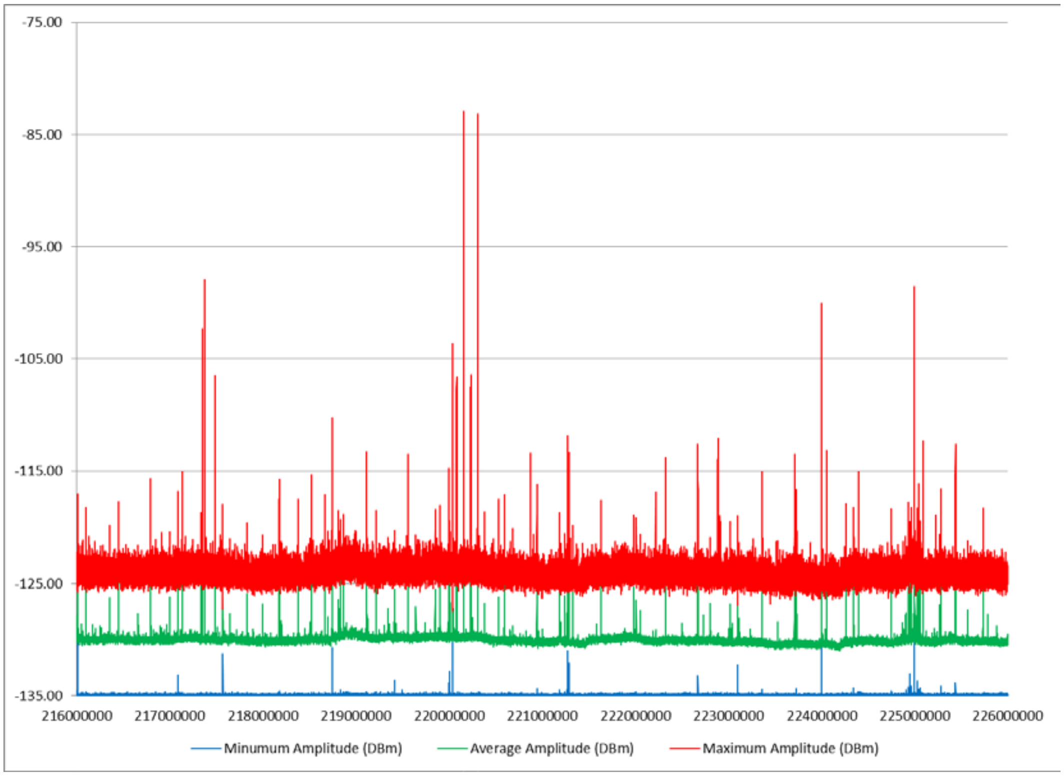
217.38 MHz (31 Data Points)



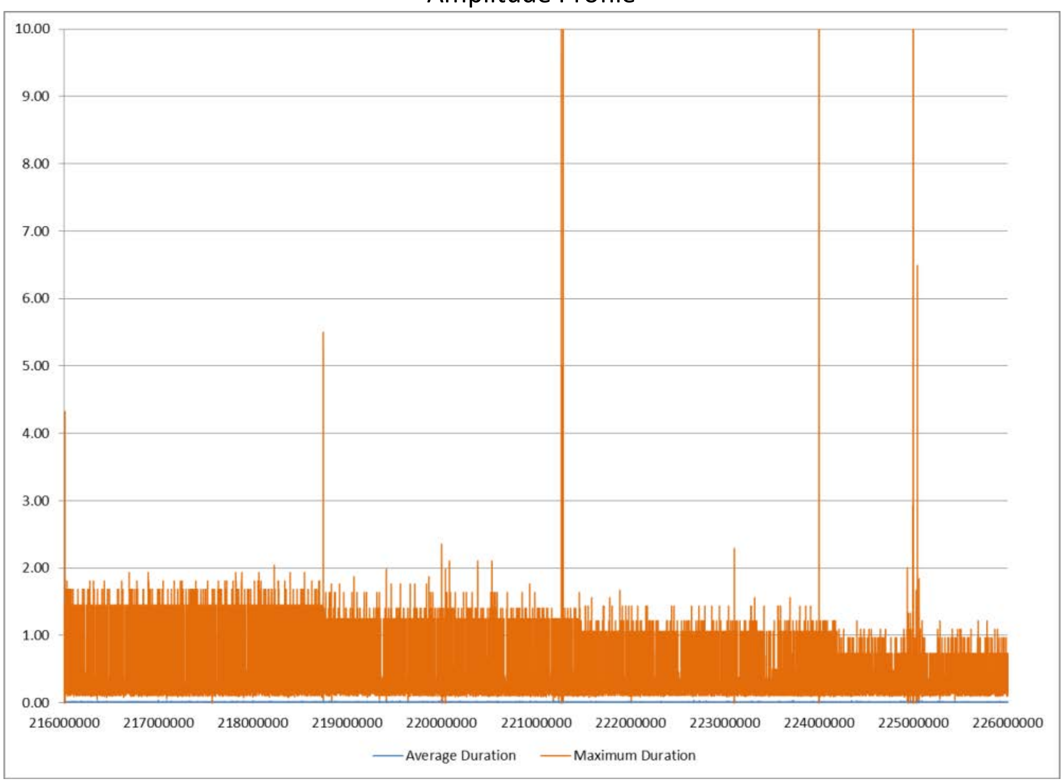
217.38 MHz (12 Data Points)

Figure 25

The following charts represent XY scatter chart with lines in EXCEL. Because of the amount of information shown in each chart the data might appear to be a spectrograph exported from a spectrum analyzer, rather than a record of the signal amplitude levels or duration information extracted and plotted from the energy history files that it actually represents. In Figure 25, six different resolutions of the information have been created to show the individual data points and how they are interconnected. It is important to note, for both Amplitude and Duration, that there is a significant difference between Maximum and Average magnitudes for any given Frequency measured.



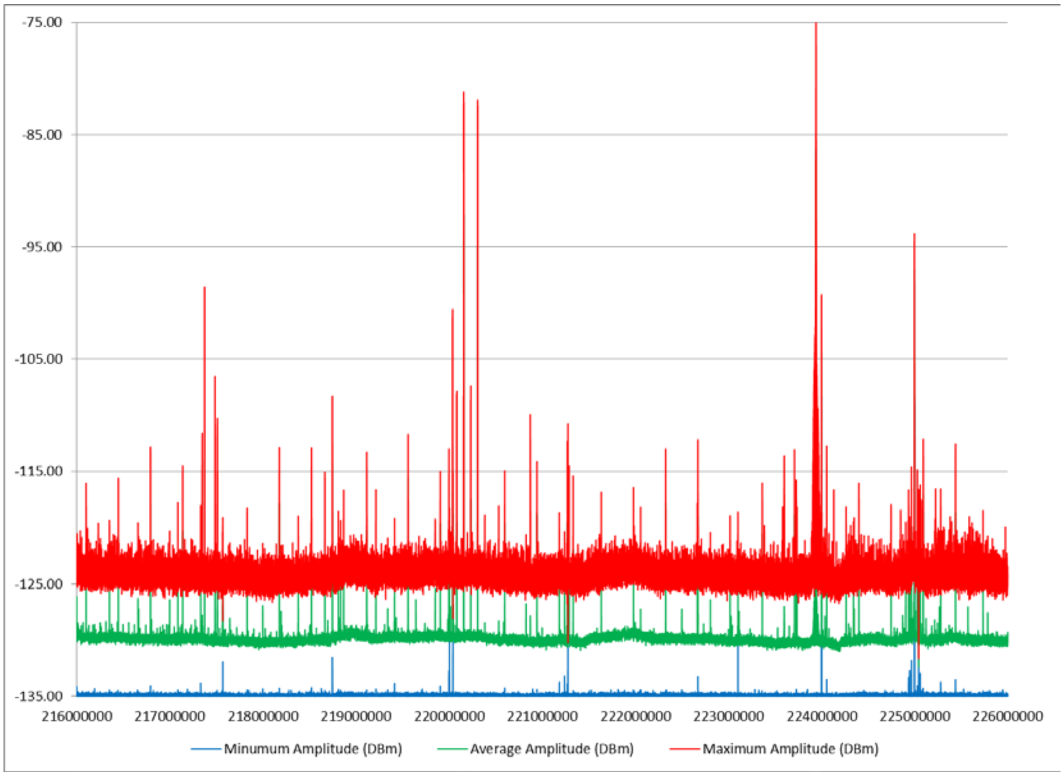
Amplitude Profile



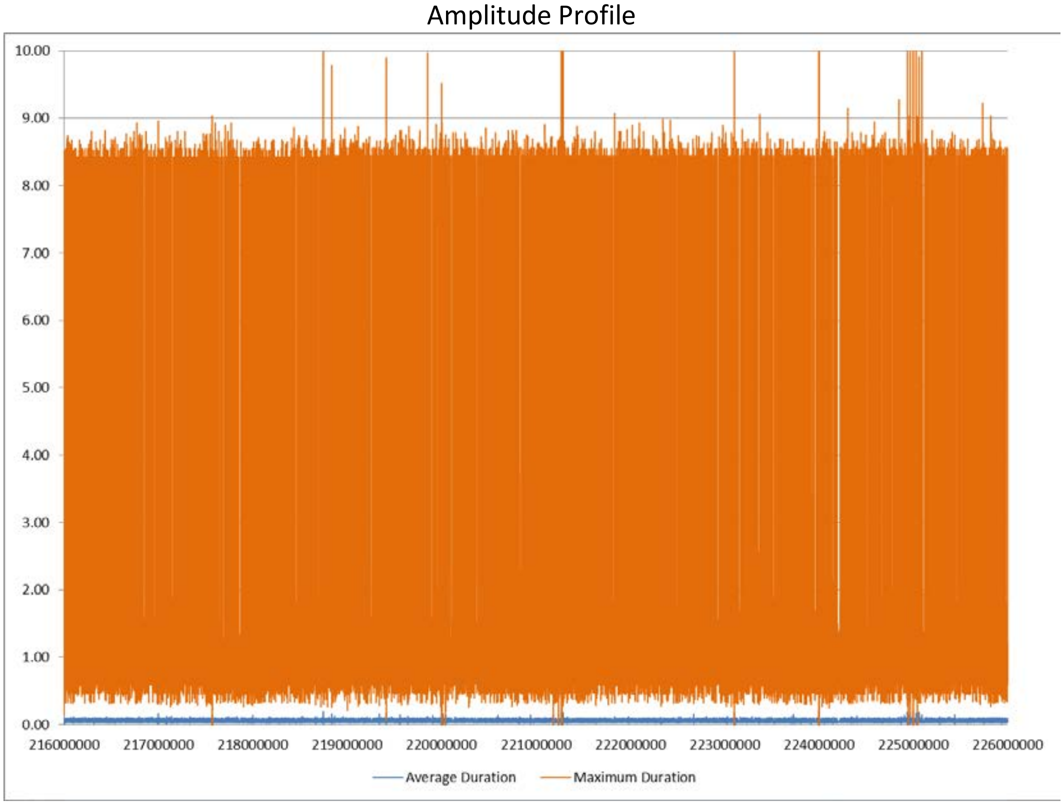
Duration Profile

BNSF 5018 Engine Off State

Figure 26



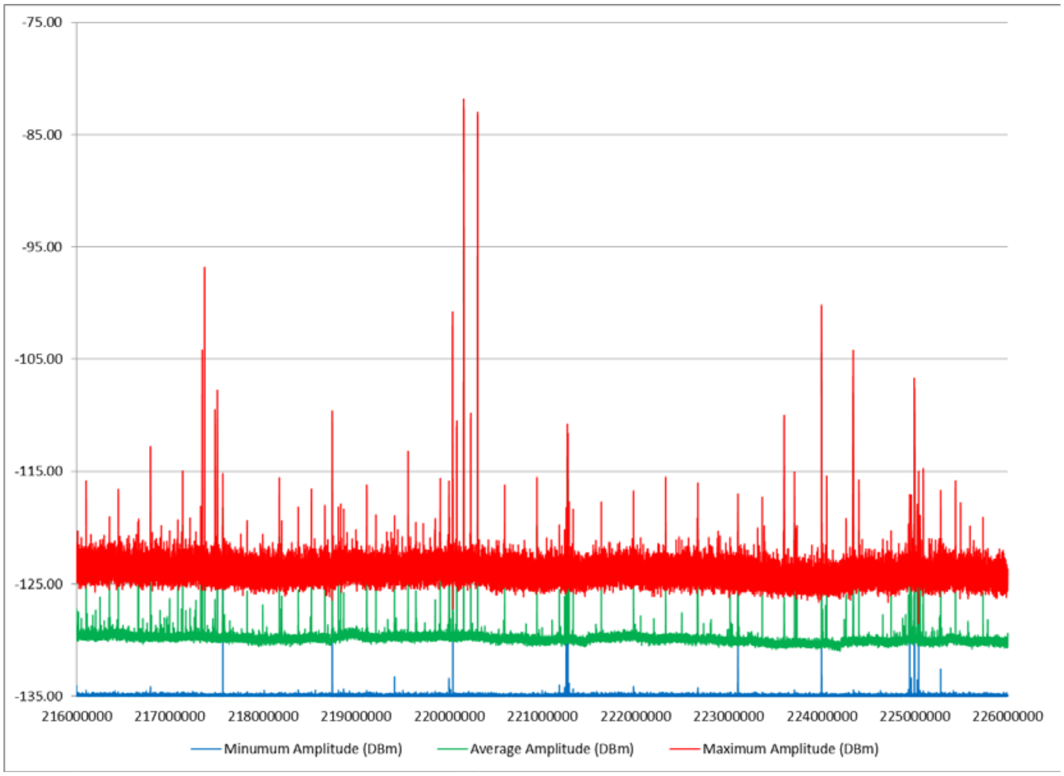
Amplitude Profile



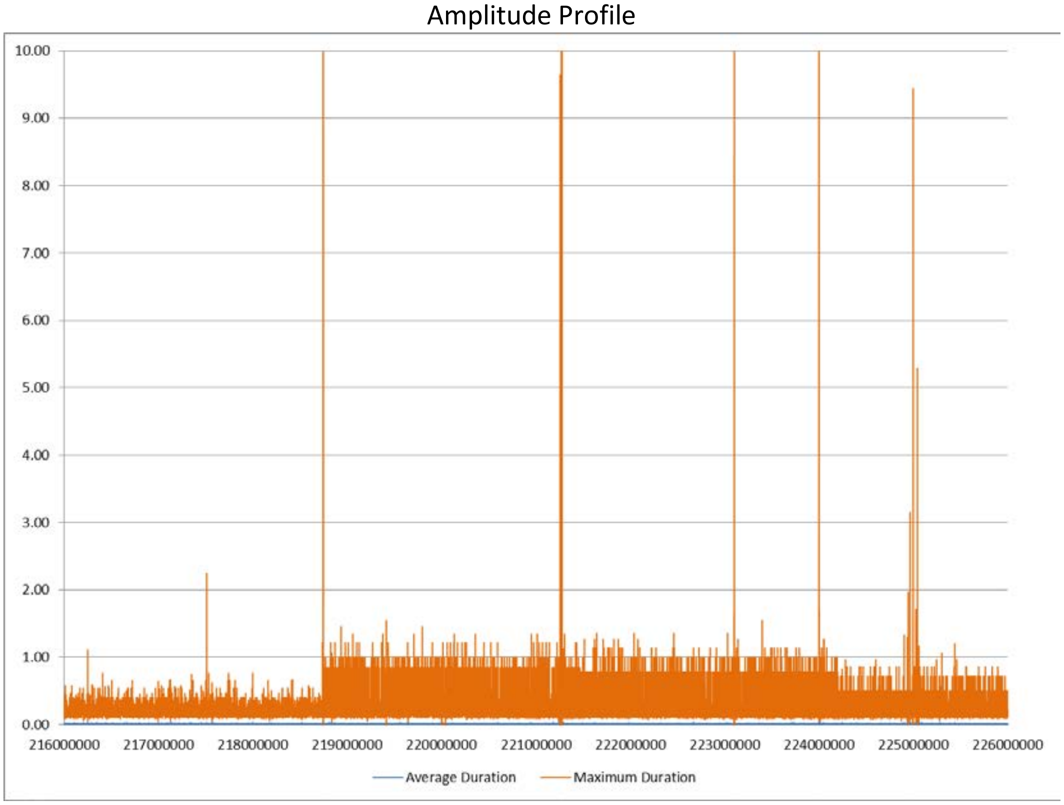
Duration Profile

BNSF 5018 Startup Sequence

Figure 27



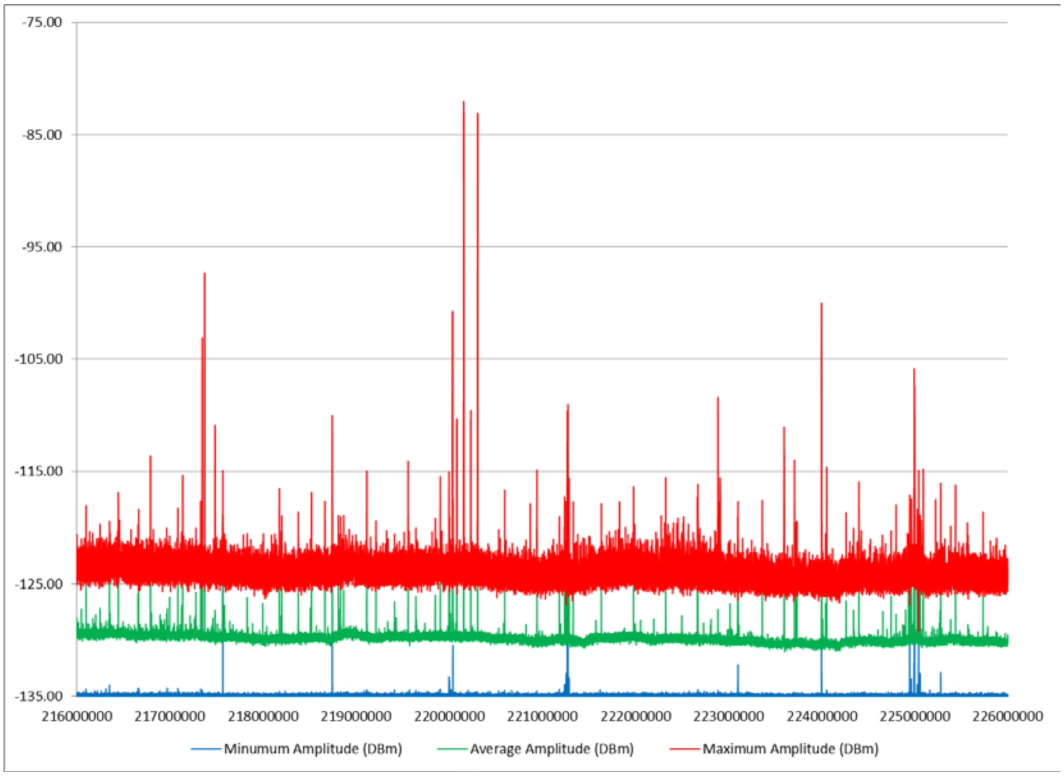
Amplitude Profile



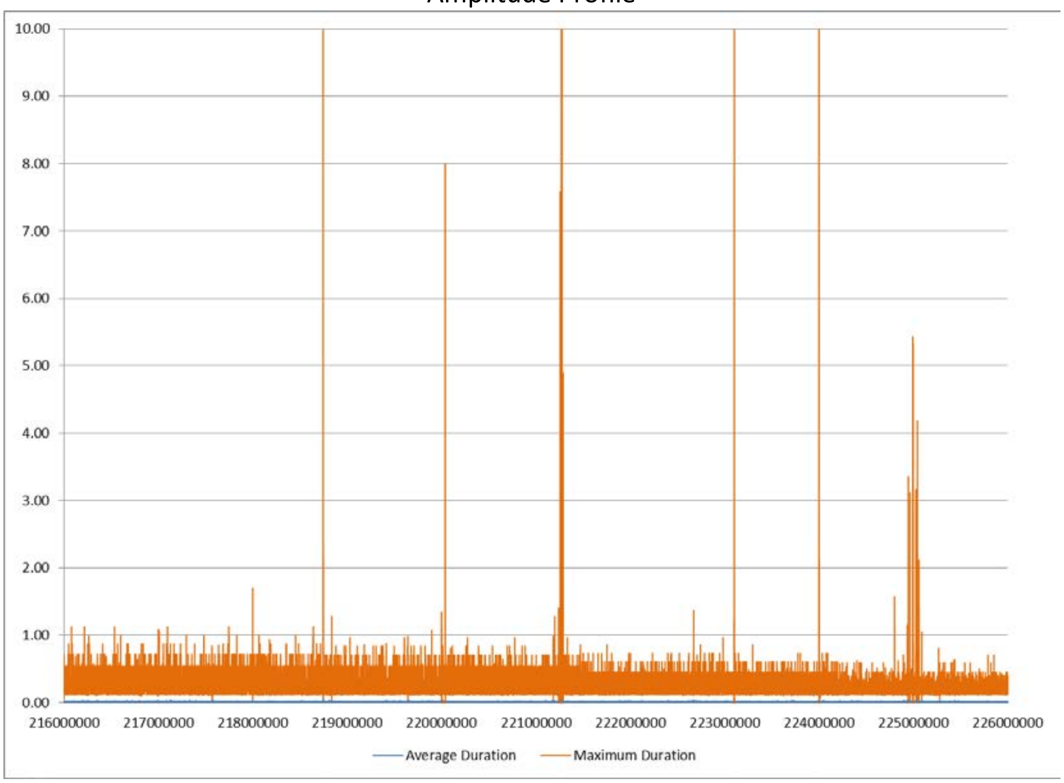
Duration Profile

BNSF 5018 Engine Idle

Figure 28



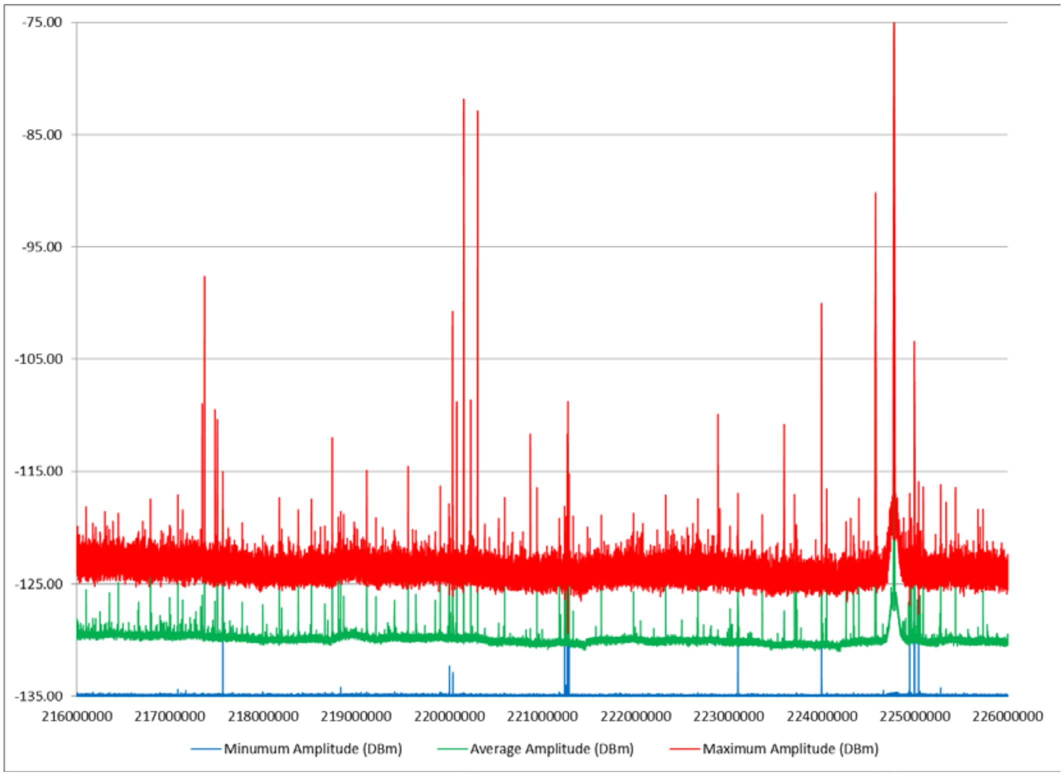
Amplitude Profile



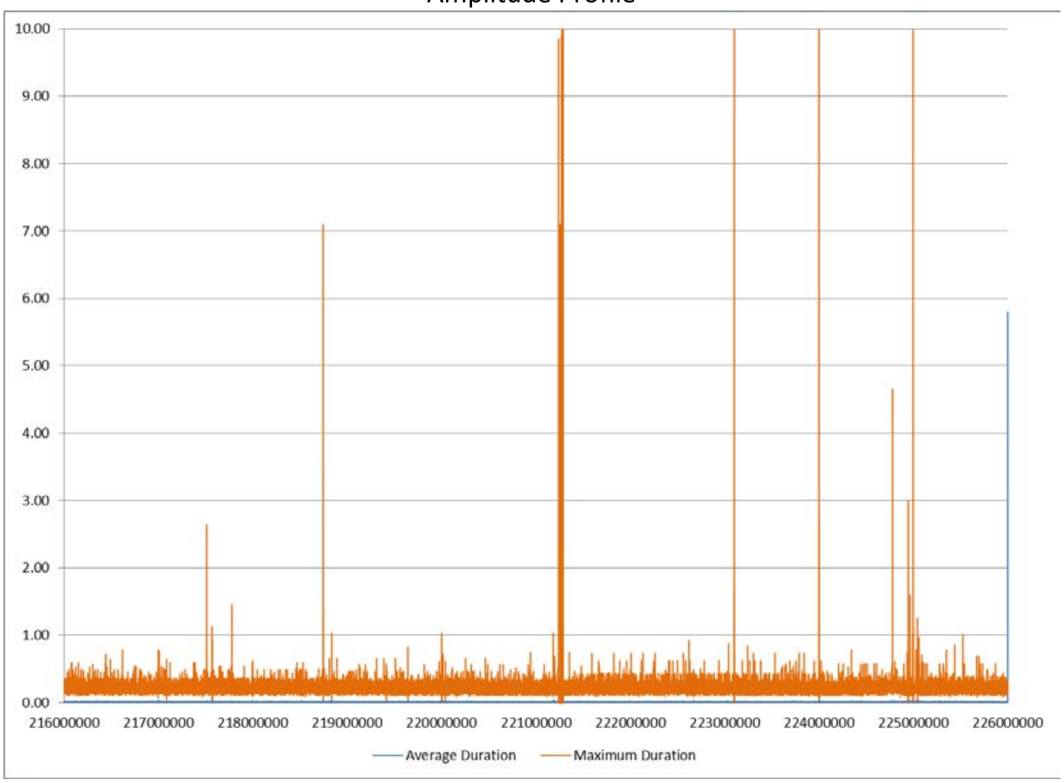
Duration Profile

BNSF 5018 Notch 1

Figure 29



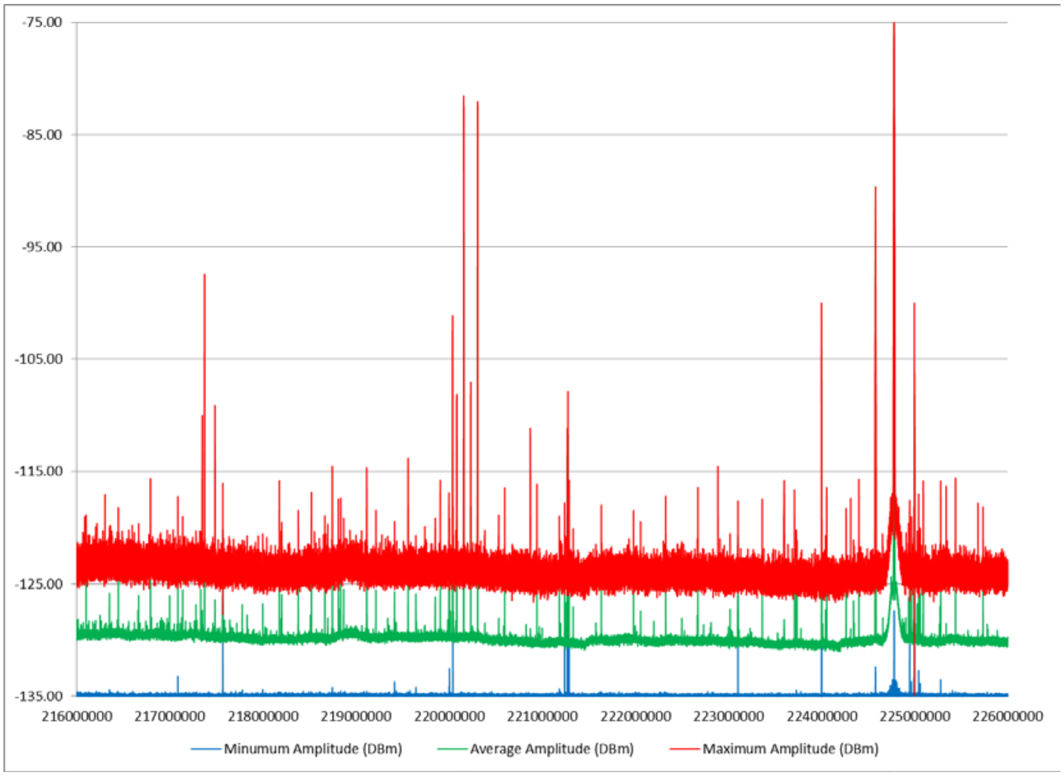
Amplitude Profile



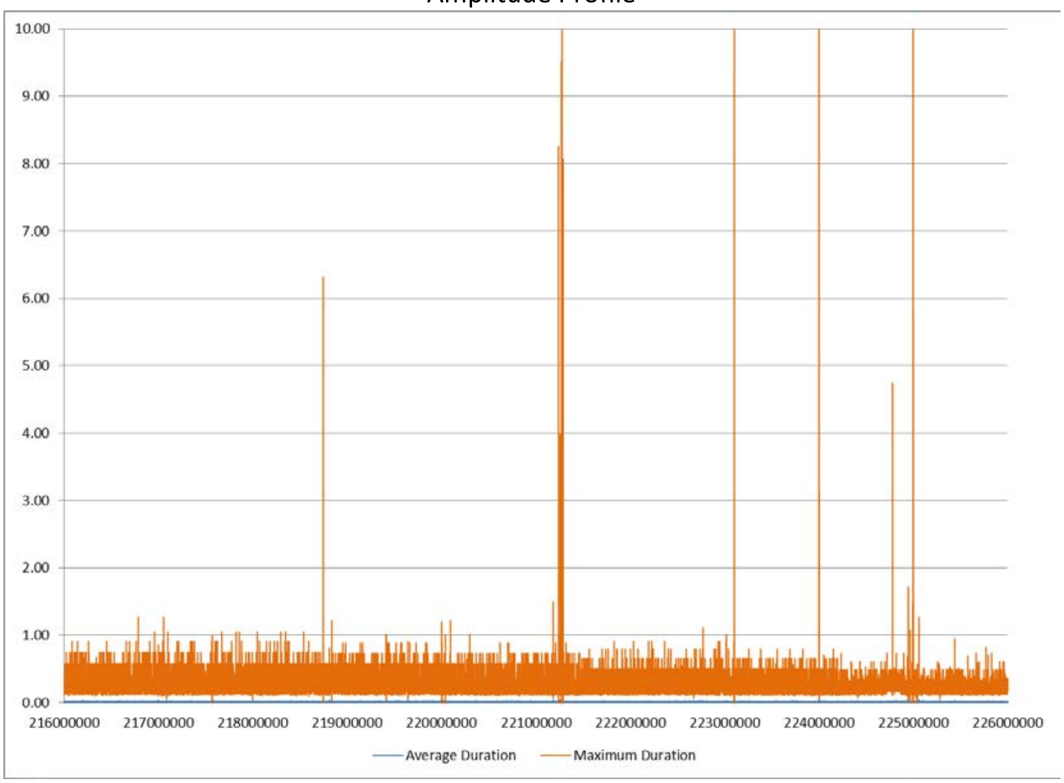
Duration Profile

BNSF 5018 Notch 2

Figure 30



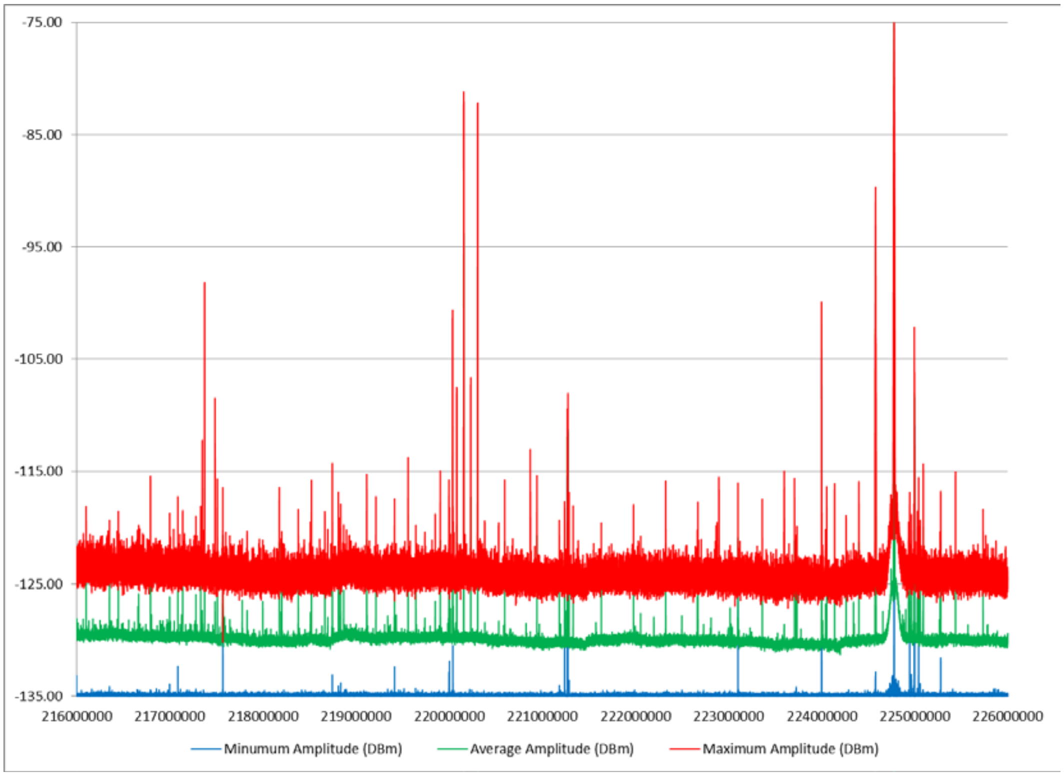
Amplitude Profile



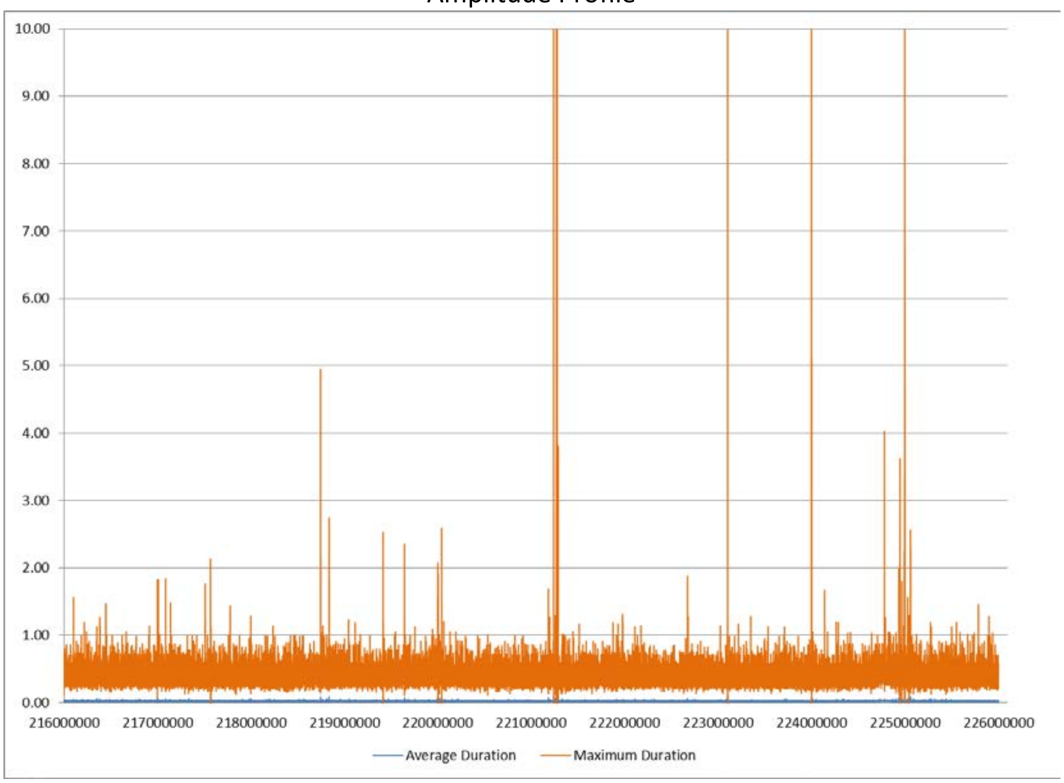
Duration Profile

BNSF 5018 Notch 3

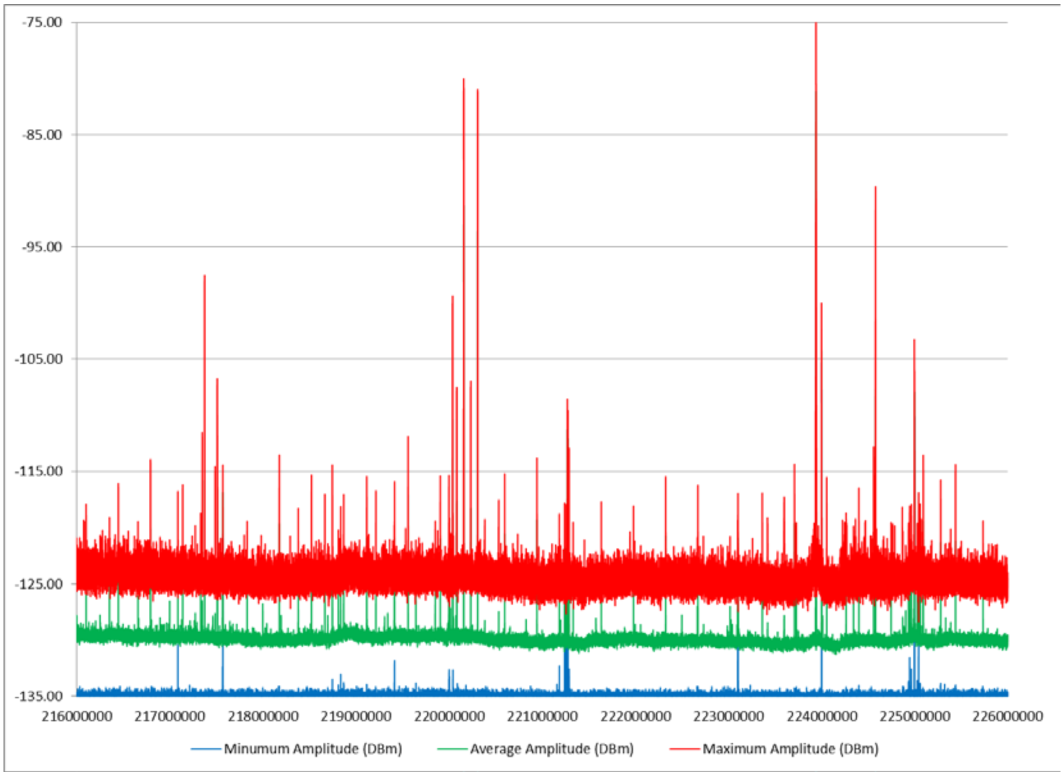
Figure 31



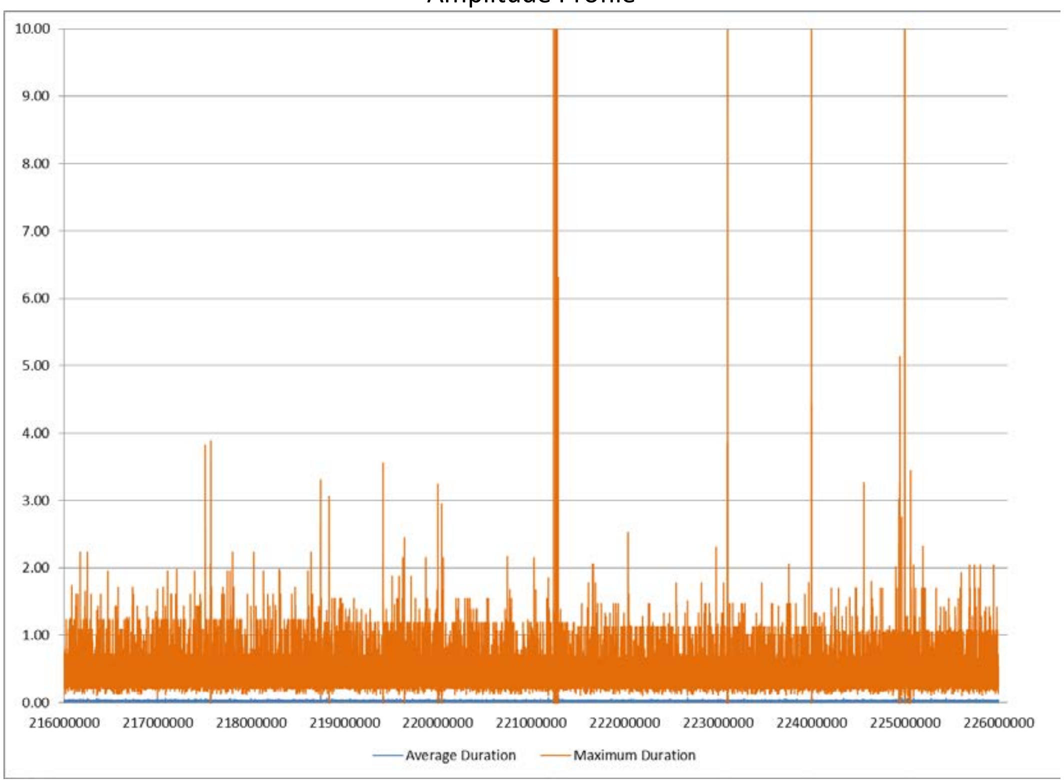
Amplitude Profile



Duration Profile
BNSF 5018 Notch 4
Figure 32



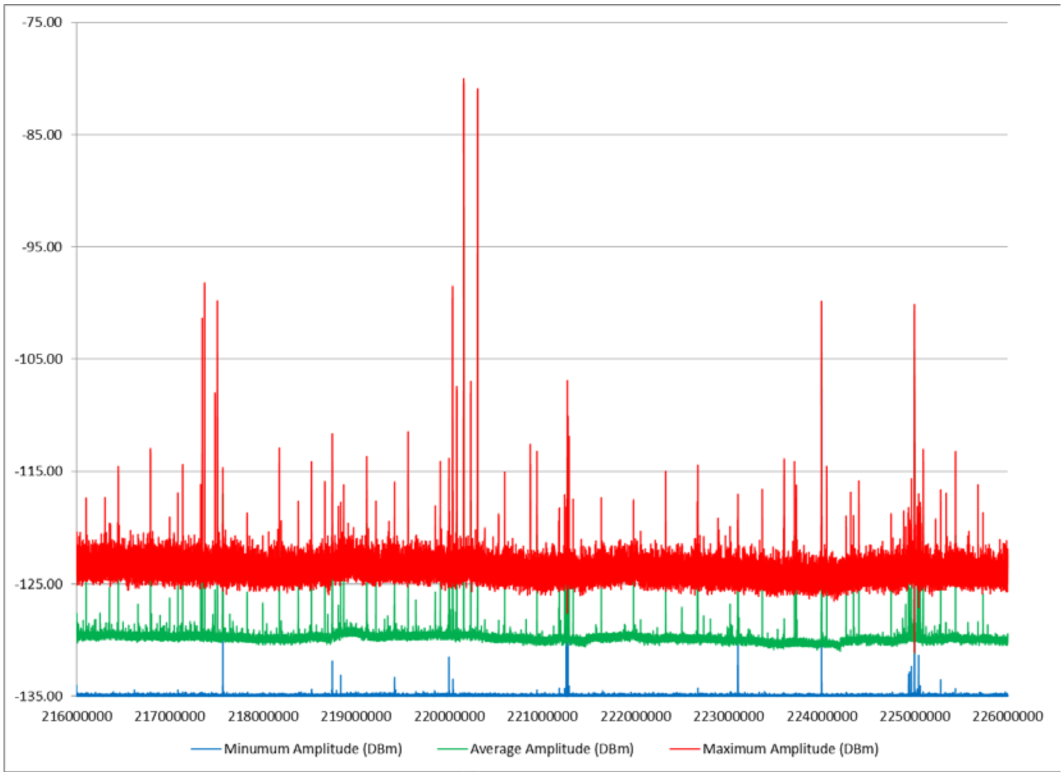
Amplitude Profile



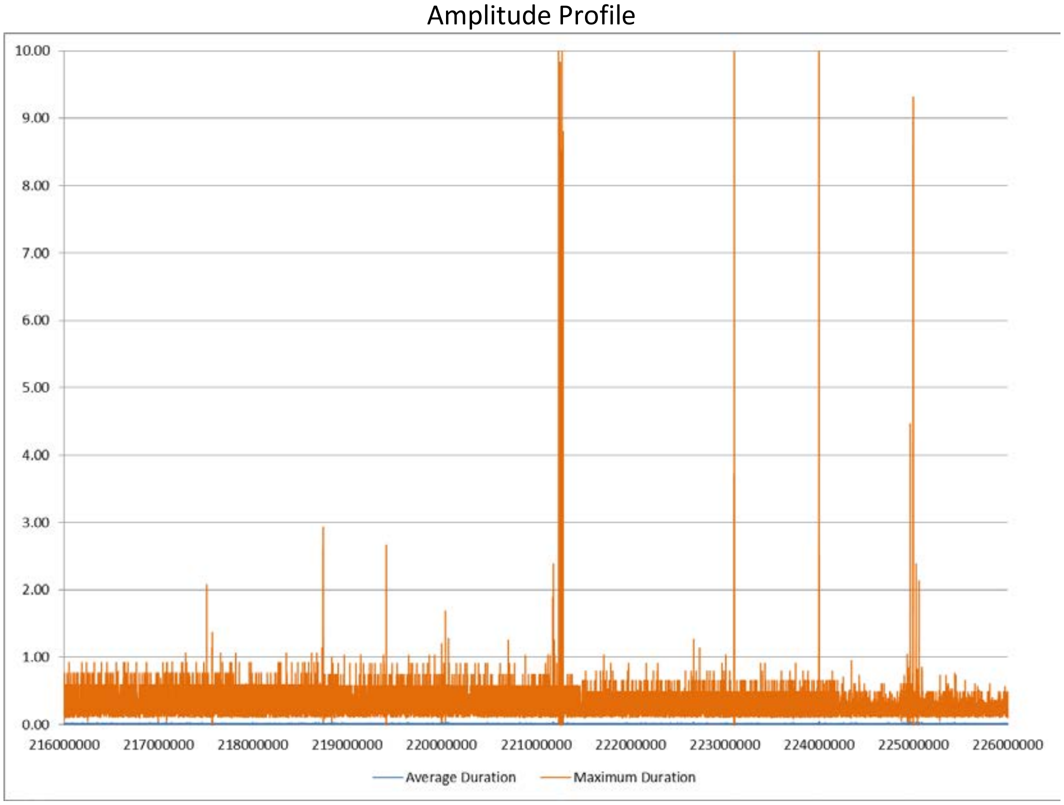
Duration Profile

BNSF 5018 Notch 5

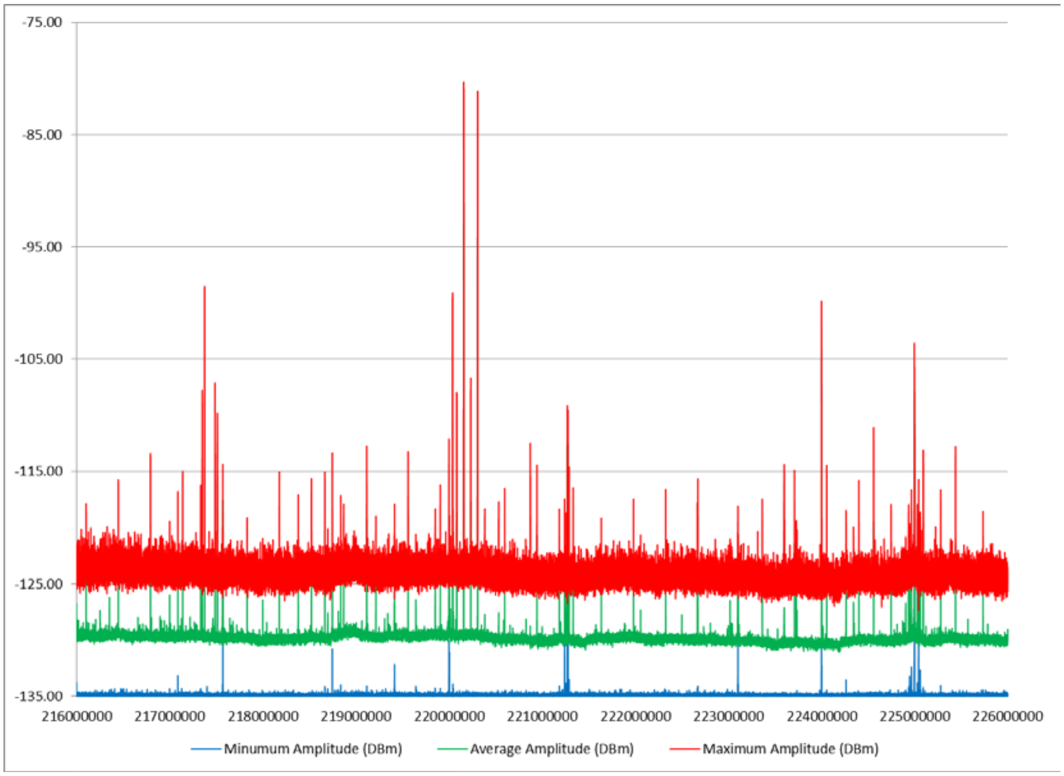
Figure 33



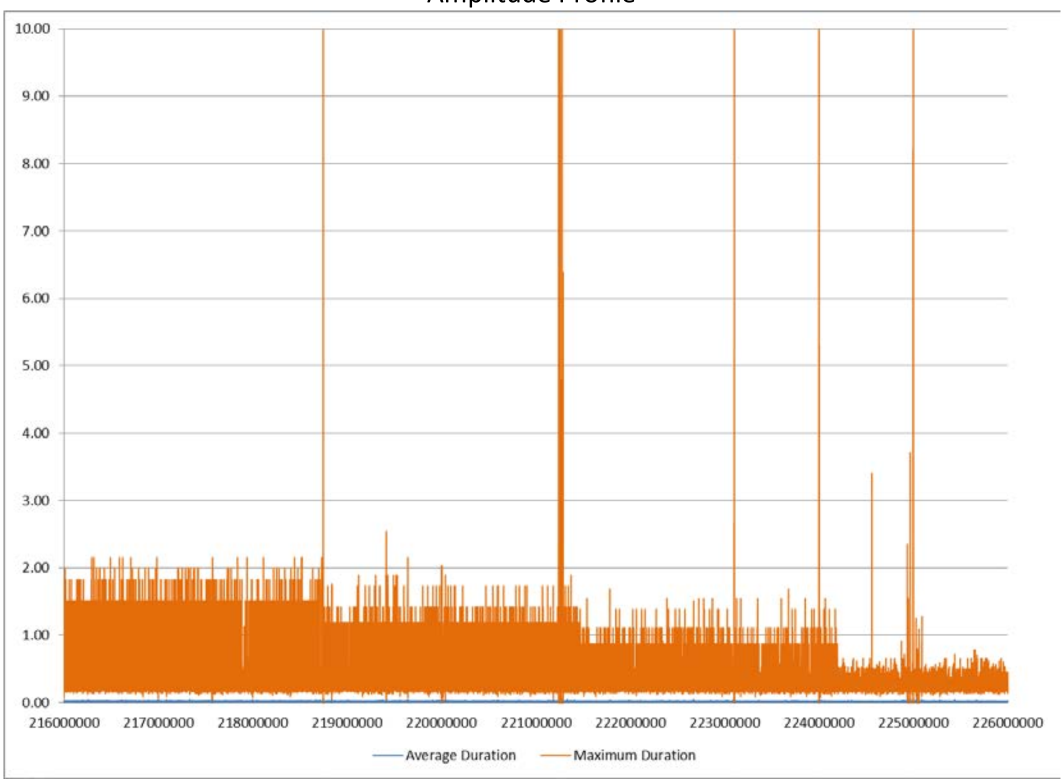
Amplitude Profile



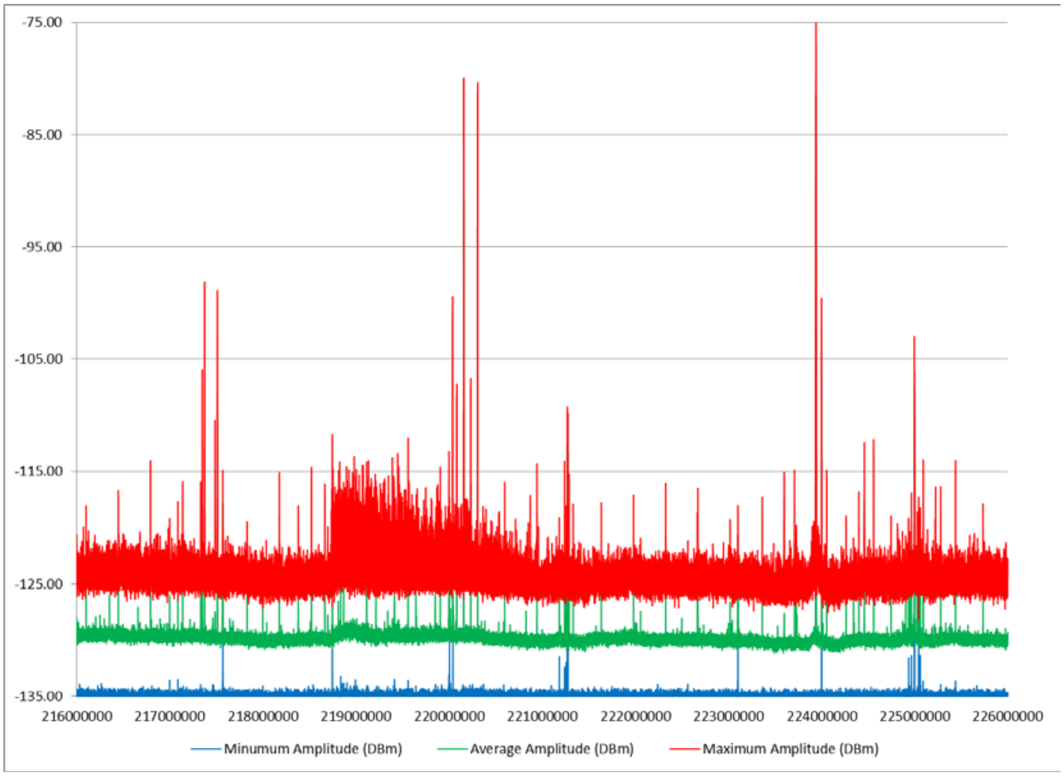
Duration Profile
BNSF 5018 Notch 6
Figure 34



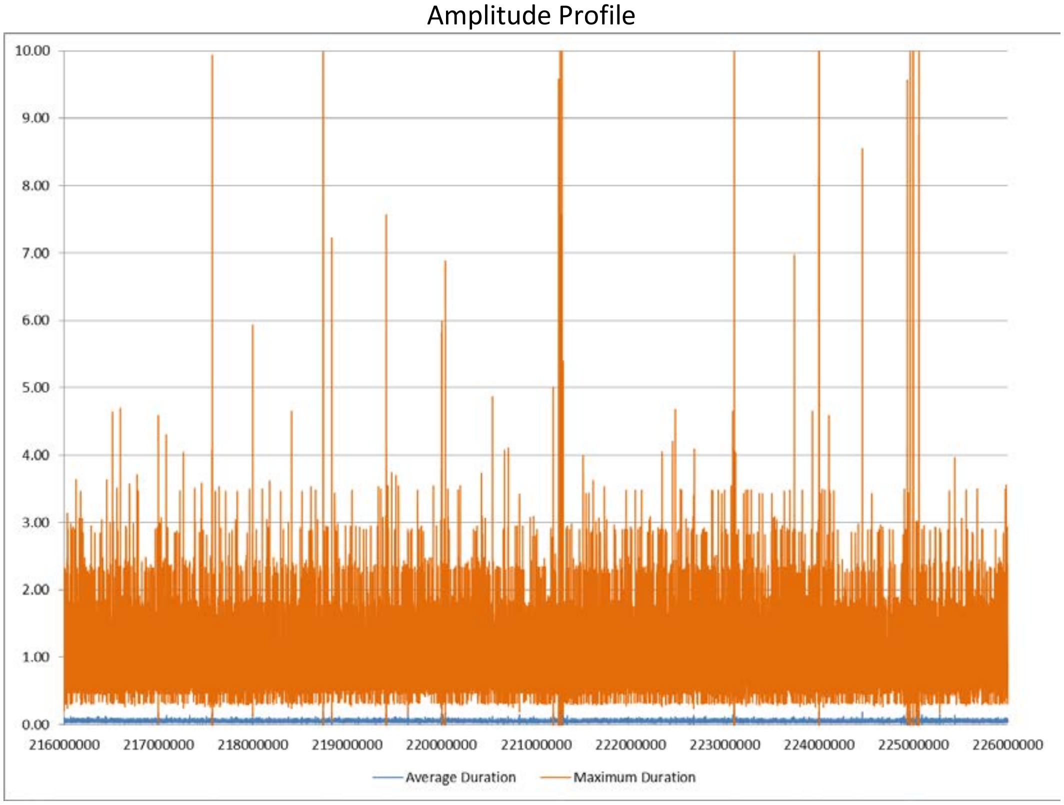
Amplitude Profile



Duration Profile
BNSF 5018 Notch 7
Figure 35



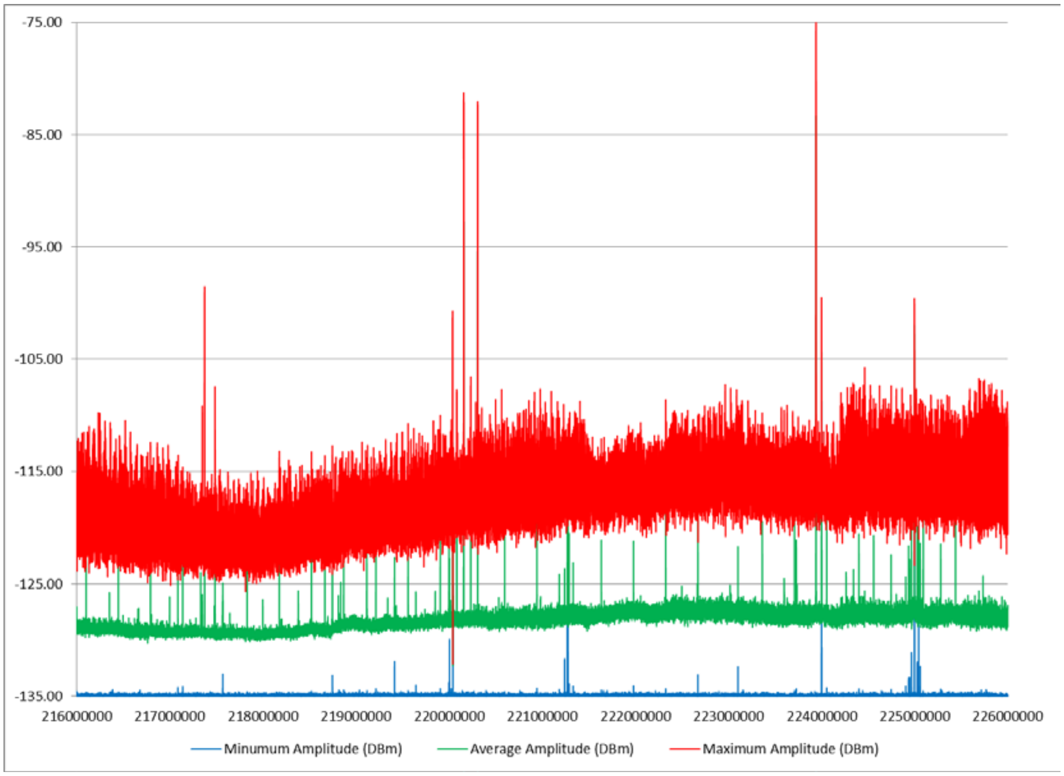
Amplitude Profile



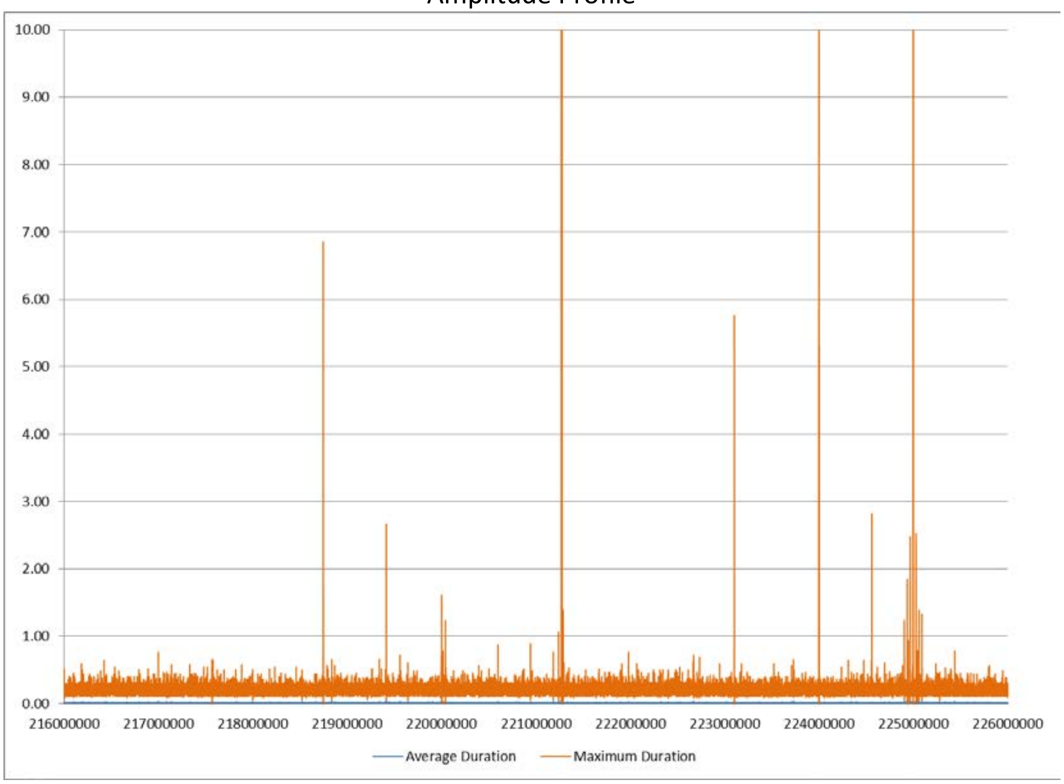
Duration Profile

BNSF 5018 Notch 8

Figure 36



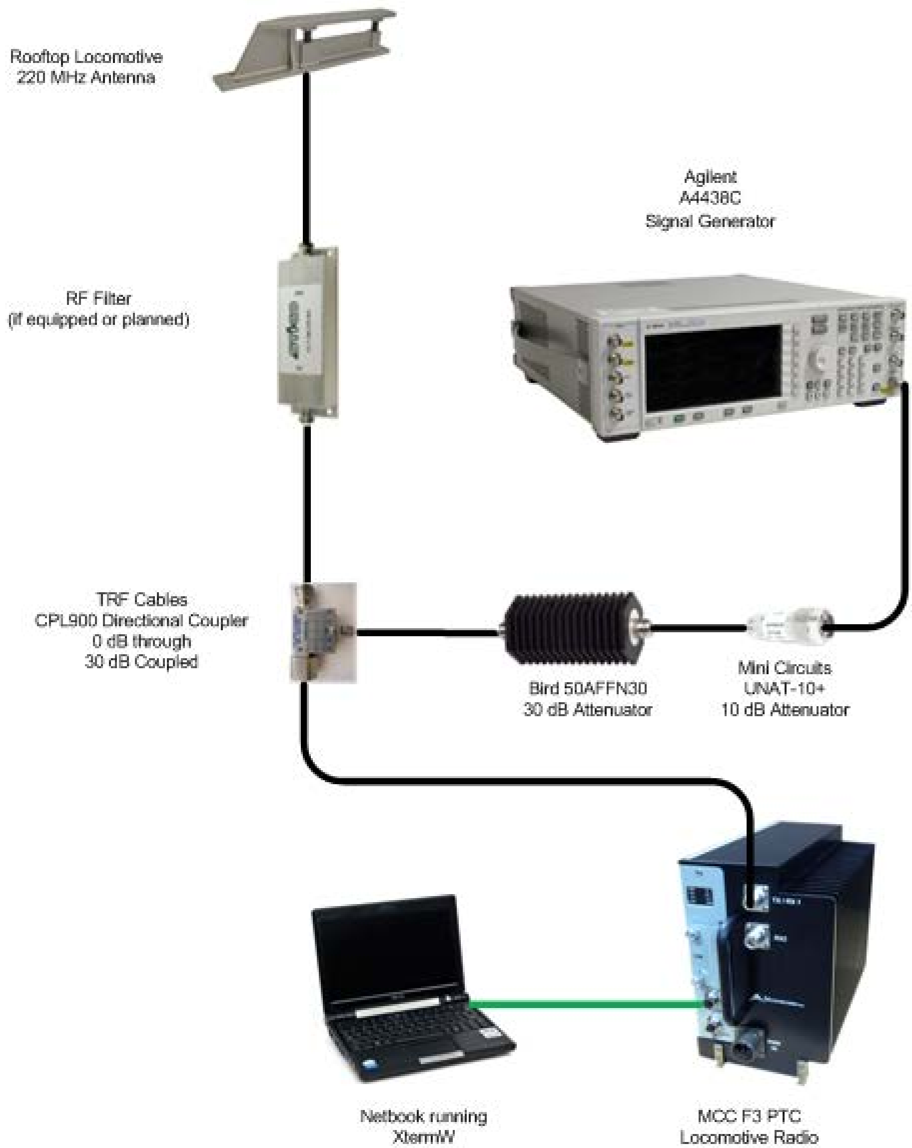
Amplitude Profile



Duration Profile
BNSF 5018 Shutdown Sequence
Figure 37

BER Testing

The purpose of this test is to determine the impact on receiving PTC transmissions in the locomotive noise environment, with the focus on capturing the Locomotive Noise Number, which is to be included in the Locomotive Receive Path Link Budget, and the minimum signal level needed for Radio Network Planning. To accomplish this, a PTC Locomotive Radio (F3) was connected through a Directional Coupler to a Signal Generator equipped with an attenuator pad, and to the worse-case locomotive PTC Antenna. See Figure 38.



BER Testing Configuration
Figure 38

The PTC Radio's design is based on a Receiver noise floor of -123 dBm and a C/N ratio (for sustaining a BER of E-4) of 11 dB, and a C/I (for sustaining a BER of E-4) of 14 decibels.

To establish a baseline, the PTC Antenna was disconnected from the Directional Coupler port, and the port was terminated. This effectively isolated the radio from the noise environment. The Signal Generator was configured to send a Test Pattern, and the signal level was set so that a BER of E-4 was sustainable. In this configuration, the PTC Radio was able to report a BER of E-4 at -113 dBm. Note that this radio, under these test conditions, was performing slightly better than spec with a C/N of 10 dB.

The PTC Antenna was then reconnected, and the test was repeated for each of ten Locomotive Operational States (Engine Off, Idle, and Notches 1 through 8). The limitations of the test do not permit reliable BER measurements for brief conditions such as Startup Sequence and Shutdown Sequence, so these two locomotive operational states were not tested.

The worse-case level observed for a reliable BER of E-4 was -103 dBm. Using this value (-103 dBm), and the Radio Isolated value for a reliable BER of E-4 (-113 dBm), the locomotive noise number can be derived as 10 dB.

The following table shows the observed minimum signal levels required to sustain a BER of E-4 for the Baseline, and for the ten Locomotive Operational States.

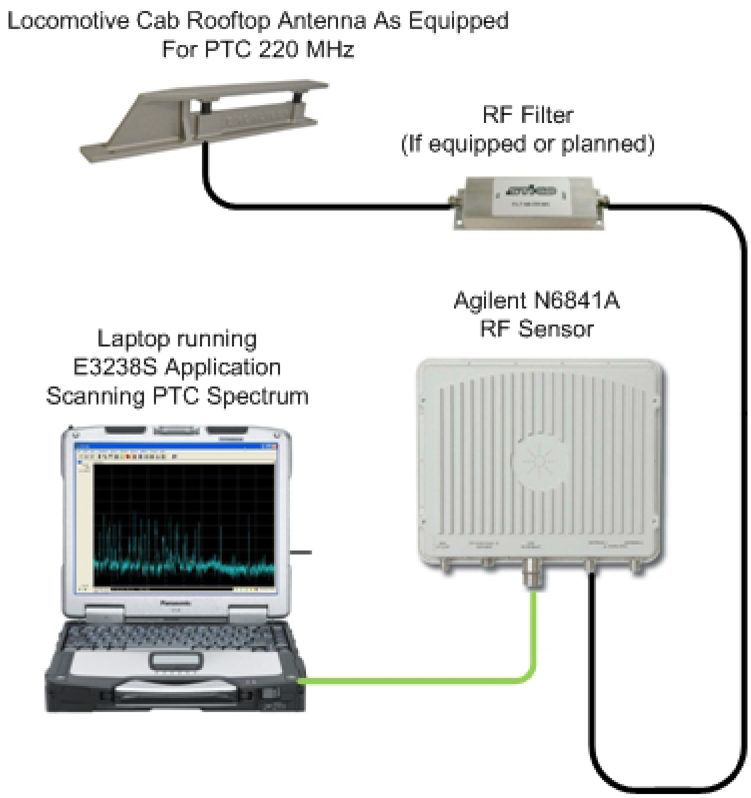
TABLE E BER Test Results

Locomotive State	BER E-4 Level
Radio Isolated	-113
Off	-105
Idle	-104
Notch 1	-103
Notch 2	-104
Notch 3	-104
Notch 4	-105
Notch 5	-103
Notch 6	-104
Notch 7	-104
Notch 8	-103

Locomotive run through Stevens Pass

Stevens Pass Run
Figure 39

During testing of the Locomotive, an opportunity to measure aggregate noise in the 220 MHz spectrum while in motion and under load was presented. The locomotive under test was coupled into a Consist of seven Locomotives, carrying a typical revenue train from the BNSF Delta Yard in Everett, Washington, following the US Route 2, over Stevens Pass (see Figure 39), through some tunnels, most notably, the Cascade Tunnel (red line segment), which is some 8 miles in length, finally terminating in Wenatchee Washington. The route was then reversed. The original intent was to capture any detectable EMI being generated by the Traction Motors of this specific locomotive. During testing, it soon became evident that separating the EMI of the locomotive under test from the other six locomotives in the Consist, as well as the passing Locomotives of other trains would not be possible. However, the information is still useful in that it reflects what the PTC-220 Radio receiver would be exposed to in an actual operating environment.



EMI Testing Configuration
Figure 40

EMI Observations- Revenue Run From Everett, Washington to Wenatchee, Washington

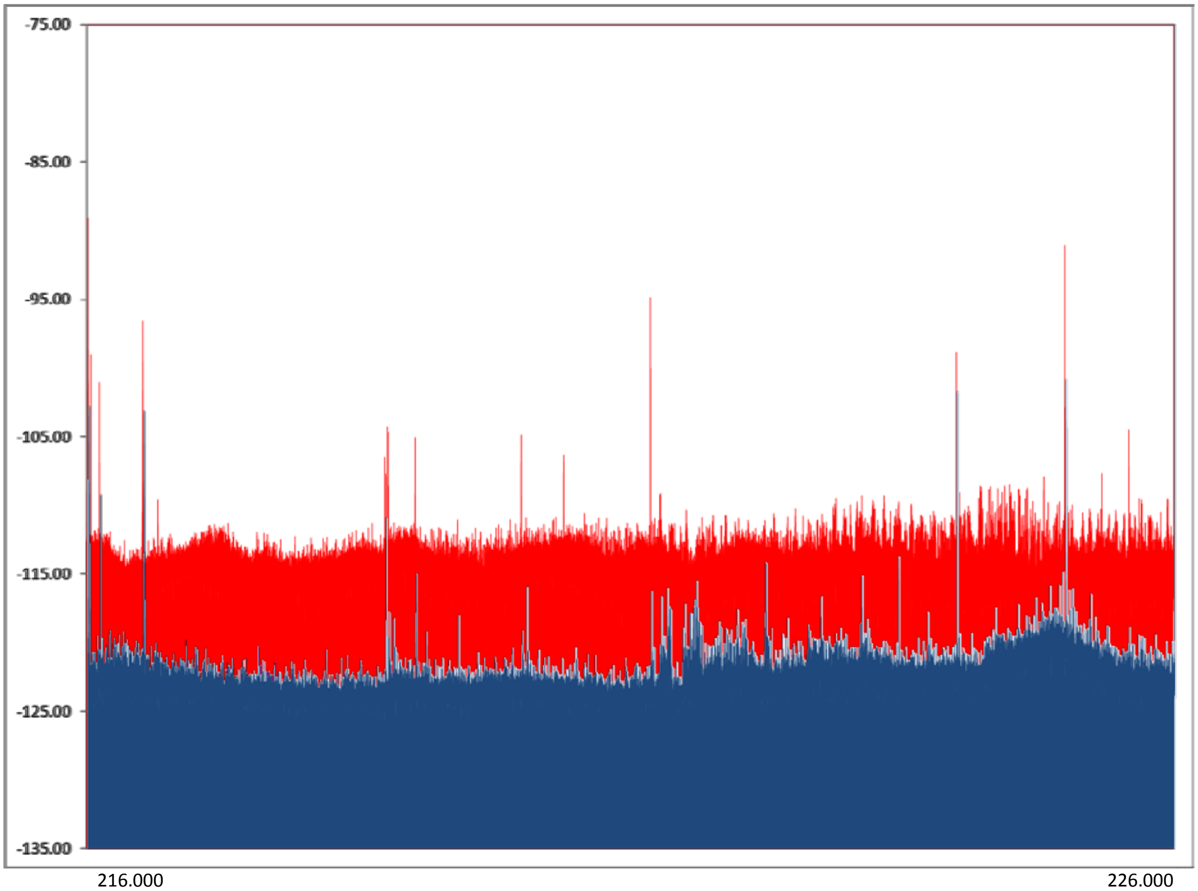
The text below will reflect observations from both test locomotives in the Consist (BNSF 5018, and UP 5802), and will reference data files from both. While still useful for understanding the EMI environmental exposure to PTC-220 Radios installed on locomotives, the discussion will be more qualitative than quantitative, even though the Energy History Files will be included in the Appendix.

The Agilent RF Sensor (Model N6841A) was connected to the Conductor-side PTC 220 Antenna and Filter. Energy History Files were generated under various conditions of interest as they presented themselves.

Two data-capture methods were available during this set of observations. The RF Sensor captures data for its Energy History files using an Energy Threshold setting. Any energy exceeding the amplitude of the Energy Threshold setting will be captured and quantified. The two types of Energy Thresholds of interest are:

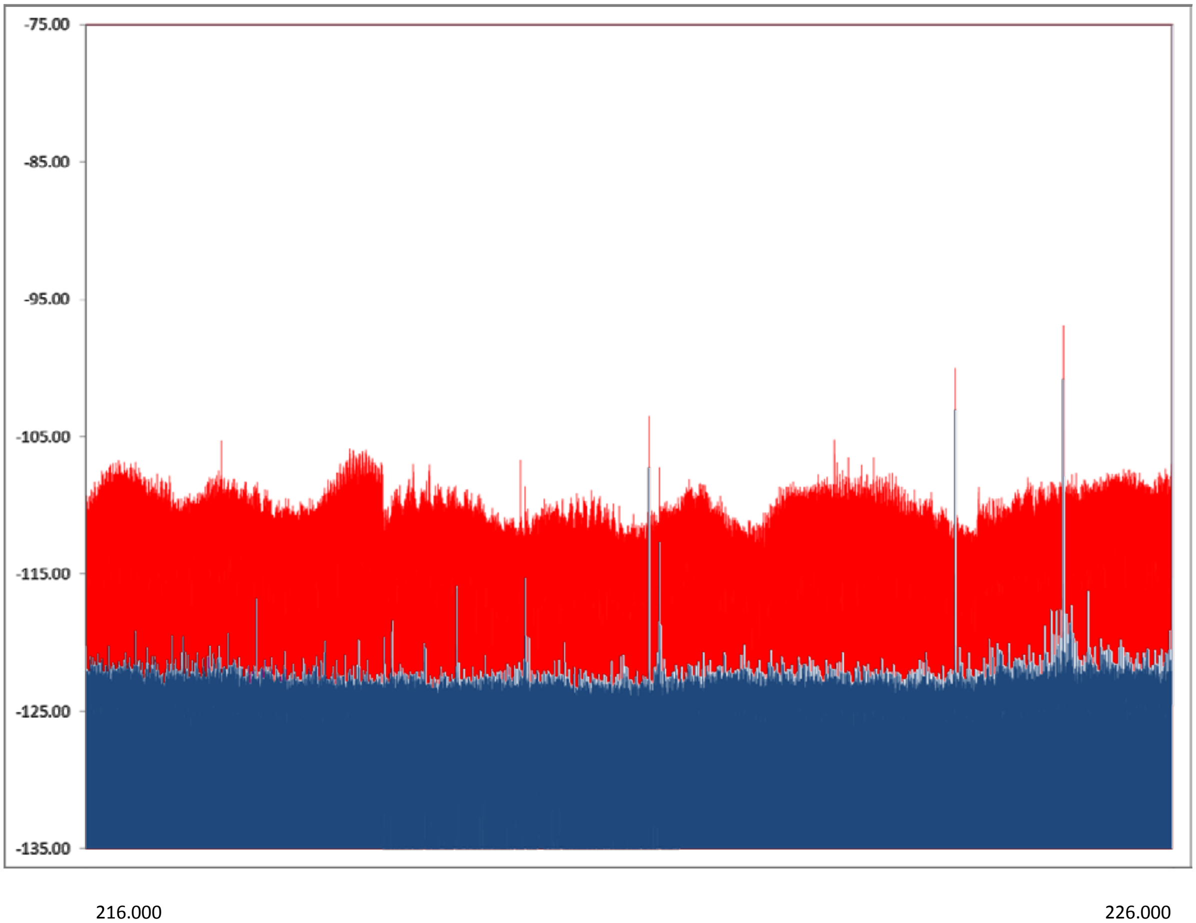
- Flat Energy Threshold—the operator selects a specific threshold, in dBm, and any Energy encountered across the frequency sweep that exceeds that level is measured and collected in the Energy History File. This approach is most useful in reasonably controlled conditions, such as Static EMI Testing and Intermodulation Testing;
- Energy Environment Threshold—the operator chooses some value, in dB, above the ambient Energy, and lets the instrument characterize the ambient peak Energy. This builds a mask, under which all Energy encountered will be ignored, and any Energy above the mask is measured and collected in the Energy History File. This approach is most useful in uncontrolled conditions, where a change in environment is anticipated;

The Energy Environment Threshold, in this test environment, is the more useful of the two, and files so captured are referenced in the discussion that follows.



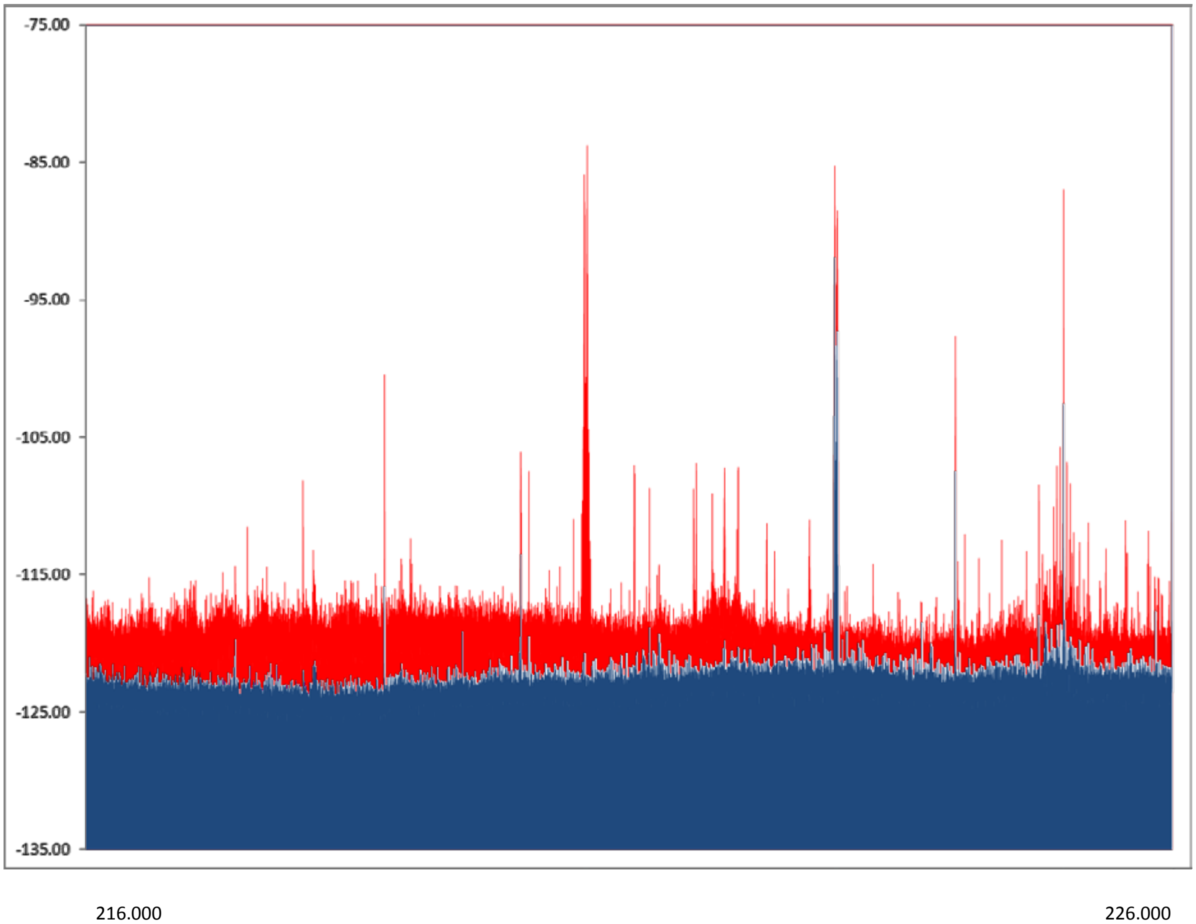
Departing yard
Figure 41

The first condition of interest that presented itself occurred as the Consist departed the yard. The instrument had been allowed to build an Energy Environment Threshold, and the threshold was set at 1 dB above Ambient Peak. As the train left the yard, there was a series of very brief transient events ranging from 4 dB to 11 dB over Ambient Peak. The events were few (order of magnitude of E+1 detections or less), narrow in bandwidth, and short lived (E-1 milliseconds or less). It is unclear what equipment on the yard perimeter may have been responsible for these disturbances, and, given the revenue nature of the run, it was not feasible to stop the train in order to explore the disturbances. See associated files labeled ‘Idle Rolling Noise Departing Yard’.



Power Lines
Figure 42

The next condition of interest involved passing another freight train. The instrument had been allowed to build an Energy Environment Threshold, and, again, the threshold was set to 1 dB above Ambient Peak. As the other train's locomotives passed, there were no Detections of any energy above Ambient Peak. However, there was a series of brief transient events when several Automobile Carrier type rolling stock passed by. It appeared that the rolling stock was empty, and a quick visual scan of the surrounding environment identified a three phase power utility line running parallel to the tracks, then diverging way. These appeared to be at least sub-station intertie level voltages (likely in the 120kV range or higher). Given the nature of the disturbance, and no easily associative observations regarding the passing train, it is possible that the transient events were generated by the proximal electrical utility facilities. See associated files labeled 'Rolling Noise 3'.



Cascade Tunnel
Figure 43

The next condition of interest involved the approach to, and the traverse within, the Cascade Tunnel. The instrument had been allowed to build an Energy Environment Threshold, and, again, the threshold was set to 1 dB above Ambient Peak. The intent was to observe how much, if any, EMI Noise generated by the locomotive would be reflected by the confined space and materials of such a tunnel back into the PTC 220 Antenna aperture. Not surprisingly, Energy Amplitude rose once inside the tunnel. Much of the noise characteristics captured are similar to what was seen in the Static EMI Testing elsewhere in this report. However, given the isolated nature of the tunnel environment, it is unlikely that the anomalous signals (spikes) shown in the above figure were being generated by 'non-PTC-220 users' when actually inside the tunnel. However, it is of note to explain that human occupation of any Locomotives other than the Lead locomotive while inside the Cascade Tunnel is prohibited by BNSF for Environmental Human Exposure reasons, so it is possible that these anomalous signals (spikes) were intercepted at the Tunnel Portals while the Test Operators were unable to observe the Test Equipment in real time. Given the logistics of a revenue run, it was not feasible to stop the train to explore the source of these disturbances. See associated files labeled 'Cascade Tunnel'.

Summary:

VSWR:
The VHF antenna passed the VSWR frequency range for the radio that it is used with.
Both of the 220 MHz PTC antennas passed VSWR testing per the manufacturers published specification.
All three UHF antennas were compliant in the UHF mid-range at 450 MHz.
The cellular antennas performed within specification at both the cellular and PCS frequencies. The 802.11 antenna met the manufacturer's specification as well.

Insertion Loss:
All cables were within specification once the connectors had been added to the cables.

Antenna Isolation:
The antenna isolation testing shows how the addition of filtering will improve the electrical isolation between the different antenna systems. Filtering of all significant contributor radios is emphatically recommended. Significant contributor radios include AAR VHF Voice, Distributed Power UHF A, Distributed Power UHF B, HOT, and both branches of the PTC 220 Radio.

Receive Intermodulation Testing:
The spur identified during testing was eliminated by placing a filter in-line on DPB. Filtering of all three UHF Radios is recommended.

The broadband problem identified when either distriuted power radio was transmitting while the AAR voice radio was transmitting simultaneously was determined to be the in-coming energy being mixed and re-radiated out of the EOT/HOT receiver in the 220 PTC spectrum. The phenomena was eliminated when a UHF pass band filter was placed in-line with the HOT/EOT receiver.

Transmit Intermodulation Testing:
No issues were noted during testing of this Locomotive at this Location. However, there is a known issue with High Level FM Broadcast signals mixing in the PA section of the AAR VHF Voice Radio when it is transmitting. See Locomotive Noise Test Battery Reports for CSX-4022, CSX-985, NS-2623, and NS-8898.

EMI Testing:
Electromechanically generated power plant noise during the twelve Locomotive Operational States (Engine Off, Startup Sequence, Idle, Notches 1 through 8, and Shutdown Sequence) were less disruptive than expected, except for the Shutdown Sequence. However, some auxiliary devices not fully identified produced intermittent disruptions. Methods to isolate and measure the emissions of these devices on a similar Locomotive have been subsequently developed. See Locomotive Noise Test Battery Report CSX-985.

BER Testing:
Since the EMI Noise is an on-platform phenomenon, any EMI produced travels with the PTC Radio Receivers. The testing, to date, has established a worse case noise number of 10 dB, and this should be accounted for in the PTC Locomotive Radio Receive Path Link Budget.