Appendix B.
220 MHz PTC Locomotive Filter Test Plan and Procedures

1 Testing Plan

1.1 Introduction

Radio desensing can occur between any combination of two radios, including base stations, wayside, and locomotive onboard radios. Freight railroads using the ITC system will operate on channels in the 220 MHz to 222 MHz band. Most railroads using ACSES will operate between 217 and 219 MHz. As long as adequate frequency separation exists between ITC and ACSES radio frequency (RF) bands, a combination of filtering and antenna separation can be used to mitigate desensing between any two fixed sites. Due to physical constraints and mobility, the problem is significantly more difficult to solve on a locomotive.

Radio frequency (RF) filters may be applied to locomotives to reduce the impact of desense between ACSES and ITC mobile radios. The amount of RF isolation provided by filters is dependent upon the spectral separation between frequencies used by ACSES and ITC radios, the limit on acceptable passband insertion loss, and the extent of restrictions on physical size. In order to mitigate an ACSES radio and ITC radio installed on a single locomotive mutually desensing one another, the ITC radio transmission is required to be attenuated by an estimated minimum of 56 dB, and the ACSES radio transmission is required to be attenuated by an estimated minimum of 58 db.

Both passive cavity filters and active crystal filters may be suitable for use in locomotives. Each of these types of filters offer benefits and tradeoffs with respect to physical size and the RF isolation they may provide. Regardless of the size and isolation provided, these filters need to be capable of reliable operation within the locomotive temperature and vibration/shock environment.

1.1.1 Scope

The intent of the tests to be conducted and measurements to be collected, is to provide a means to evaluate if a filter sample meets the meets the requirements defined in the NEC 220 MHz Locomotive Radio Filter Requirements document. The testing is not intended to deem filter samples as pass or fail, nor is the testing intended as lifecycle testing.

1.2 Testing Overview

The test plan is defined by three stages of tests: laboratory baseline tests, laboratory environmental tests, and field tests. The tests and measurements to be collected to characterize the filter performance prior to, during, and/or after the tests is defined in this document.

1.2.1 Laboratory Baseline Tests

The purpose of the laboratory baseline tests is to establish the characteristics and performance of each filter test sample prior to exposure to environmental testing. Baseline filter test results will be used as a means of comparison to determine the impact of the exposure of the test samples to conditions defined within the environmental test and field test procedures. The baseline testing will occur at TTCI before any environmental testing takes place.

The following baseline filter characteristics will be recorded:

- 220 MHz Band Amplitude Response
- Phase Response
- VSWR
- Impedance
- 160 MHz Band Amplitude Response • 210 MHz Band Amplitude Response • 450 MHz Band Amplitude Response
- 900 MHz Band Amplitude Response
- Broadband Response Amplitude Response

1.2.2 Laboratory Environmental Tests

TTCI collaborated with members of the NEC to determine which environmental tests were most critical in determining the suitability of a filter for use on a locomotive. The following tests were selected in alignment with the key environmental operating conditions of concern, which were temperature variation, vibration, and mechanical shock:

- Sinusoidal Vibration
- Thermal Exposure (Temperature Cycling and Extremes)
- PTC Signal Testing During Random Vibration
- Random Vibration

In accordance with the AAR MSRP S-9401.V1.0, section 3.2.4, either sinusoidal vibration and random vibration could be completed, or mechanical shock testing could be completed, but not both. TTCI and the NEC Comms team chose to complete the sinusoidal and vibration testing. The testing will take place at an environmental testing facility located in Longmont, CO.

1.2.2.1 Sinusoidal Vibration

The purpose of sinusoidal vibration testing is to collect filter performance measurements after exposure to a range of frequencies that reflect the fundamental and harmonic frequencies that may be present within an operating locomotive environment. The vibration profile (frequencies and associated acceleration levels) and duration of the test is in accordance with the AAR Manual of Standards and Recommended Practices S-9401.V1.0 section 3.2.4.1. Each filter will be subjected to sinusoidal vibration for four hours on each of the three mutually perpendicular axes, totaling 12 hours of sinusoidal vibration per filter.

1.2.2.2 Thermal Exposure

Together, the NEC Comms Team and TTCI identified the most pertinent thermal testing to be conducted was exposure of the filters to temperature extremes and temperature cycling.

1.2.2.2.1 Temperature Extremes

The intent of the temperature extreme test is to collect filter performance measurements at high and low temperature extremes that may exist in a locomotive environment. The test consists of soaking the filters in a thermal chamber overnight to ensure both the internal and surface temperature of the filter reach the extreme temperature prior to taking measurements. The minimum temperature to test is 45°C, and the maximum temperature to test is 75°C. The temperature extreme test was designed in accordance with the AAR Manual of Standards and Recommended Practices S-9401.V1.0 section 3.2.2.3.1.

1.2.2.2.2 Temperature Cycling

The temperature cycling is intended to collect filter performance measurements after exposure to the rapid temperature change that can occasionally occur in a locomotive environment. The temperature cycling test consists of placing the filter in a thermal chamber set to -45°C, until the surface temperature of the filter reached -45°C. The filter is then transferred, in less than a minute, to a thermal chamber set to 105°C, and the amplitude response will be captured approximately every 10°C until the filter reached

75°C. Once the filter surface temperature reaches 75°C, the filter will be removed. Posttest measurements will be completed after the filters are exposed to room temperature for a minimum of one day, thereby having internal and surface temperatures of approximately 23°C.

The temperature cycling test was designed in accordance with the AAR Manual of Standards and Recommended Practices S-9401.V1.0 section 3.2.2.3.2, with the exception of conducting only two temperature cycles, rather than 75 cycles, as identified in the MSRP. The primary concern and driving factor for NEC Comms Team and TTCI to choose abbreviated cycling was to assess if exposure to rapid temperature change resulted in permanent changes to the filter response; and not life cycle testing.

1.2.2.3 PTC Signal Testing

The PTC signal test is designed to assess if PTC message loss occurred as a result of the filter being exposed to vibration representative of a locomotive environment. The filter will be secured to the vibration table and placed in line between a transmitting PTC radio and a receiving PTC radio. The test will be setup such that only the filter is exposed to vibration; the vibration profile was in accordance with the random vibration frequency profile defined in the AAR MSRP S-9401.V1.0 section 3.2.4.2.

For ACSES filters, the transmitting and receiving radios utilized will be the GE TD220x radios, and the transmitting signal level will be attenuated to achieve a received signal strength of -85dBm at the receiving TD220x radio. For ITC filters, the transmitting radio utilized will be the ITC Meteorcomm (MCC) Base radio, and the receiving radio will be the ITC MCC Locomotive radio. The transmitting signal level will be attenuated to achieve a received signal strength of -94dBm at the receiving ITC MCC Locomotive radio. A noise generator will be included in the RF network to inject white noise at a level resulting in the receiving radio having an approximate packet error rate of two to three percent, prior to vibration beginning. Received signal strengths and noise levels will be measured with a calibrated vector network analyzer.

With the receiving radio experiencing a packet error rate of two to three percent, it will be more sensitive to additional message loss that could be induced if filter performance was degraded during vibration. During each test run, the radios will transmit and receive for five minutes while white noise is injected into the RF network. Transmit and receive message logs, noise signal measurements, and RF signal measurements at the receive radio will be collected for each test run. Five test runs will be completed without vibration, followed by five test runs while the filter is exposed to random vibration.

1.2.2.4 Random Vibration

The purpose of the random vibration test is to collect measurements of the filter performance during and after exposure to vibration conditions that may exist in a locomotive environment. The random vibration test will subject the filters to four hours of random vibration on each of the three axes, totaling 12 hours of random vibration. The vibration profile for this test was designed in accordance with the AAR Manual of Standards and Recommended Practices S-9401.V1.0 section 3.2.4.2.

1.2.3 Field Test

After the conclusion of environmental lab testing, four filters will be mounted on a shelf in the nose of one of TTCI's Facility for Accelerated Service Testing (FAST) locomotives. The FAST train runs Monday through Thursday on a 5 km loop at a typical operating speed for the train which is 40 miles per hour. This test will subject the filters to locomotive operations over a six-week period.

1.2.4 Post Test

A full set of baseline measurements will be repeated as a set of post measurements for each filter. The measurements will be collected at the conclusion of environmental lab testing, or after field testing for applicable filters.

2 Laboratory Baseline Tests - Baseline Filter Characterization Test Group

The objective of the test is to gather data for identifying the following filter characteristics:

- passband amplitude response
- stopband amplitude response
- passband insertion loss
- filter attenuation at stopband
- passband phase response
- passband VSWR
- passband impedance
- broadband amplitude response
- 160 MHz amplitude response • 210 MHz amplitude response • 450 MHz amplitude response
- 900 MHz amplitude response

2.1 Test Equipment:

Equipment	Details

Refer to individual test procedure identified in section 2.4.	

2.2 Test Setup:

Refer to individual test procedure identified in section 2.4.

2.3 Test Equipment Configuration:

VNA Configuration

Mode:	Network Analyzer (NA) / S21
Format and Configuration:	Refer to individual test procedure identified in section 2.4.

2.4 Test Procedure:

Step	Action
1	Set up and configure test equipment as defined in the individual test procedure
2	Complete the Filter Amplitude Response Test procedure, LFT-AR.
3	Complete the Passband Phase Response Test procedure, LFT-PH.
4	Complete the Passband VSWR Response Test procedure, LFT-VSWR.
5	Complete the Passband Impedance Test procedure, LFT-IMP.
6	Complete the Filter Amplitude Response 160 MHz Band, LFT-160.
7	Complete the Filter Amplitude Response 210 MHz Band, LFT-210.
7	Complete the Filter Amplitude Response 450 MHz Band, LFT-450.
8	Complete the Filter Amplitude Response 900 MHz Band, LFT-900.
9	Complete the Broadband Amplitude Response Test procedure, LFT-BB.

2.5 Test Artifacts:

Artifact #	**Description**	**Test Procedure Step**	**Artifact Name**

1	Refer to individual test procedure identified in section 2.4.	n/a	n/a

2.6 Notes:

Allow spectrum analyzer to warm-up for 30 minutes prior to use.

3 Laboratory Environmental Tests - Sinusoidal Vibration Test Group

The objective of the test is to expose each filter to sinusoidal vibration conditions in accordance with MSRP 9401.3.2.4.1 and gather data (post vibration) for identifying the following filter characteristics:

- passband amplitude response
- stopband amplitude response
- passband insertion loss
- filter attenuation at stopband
- passband phase response
- passband VSWR
- passband impedance • broadband amplitude response

3.1 Test Equipment:

Equipment	**Details**
Refer to individual test procedures identified in section 3.4.	n/a

3.2 Test Setup:

See Figure 1. Configure vibration test environment per requirements of AAR S-9401 section 3.2.4.1.1, found in Appendix A, then refer to the individual test procedure identified in section 3.4.

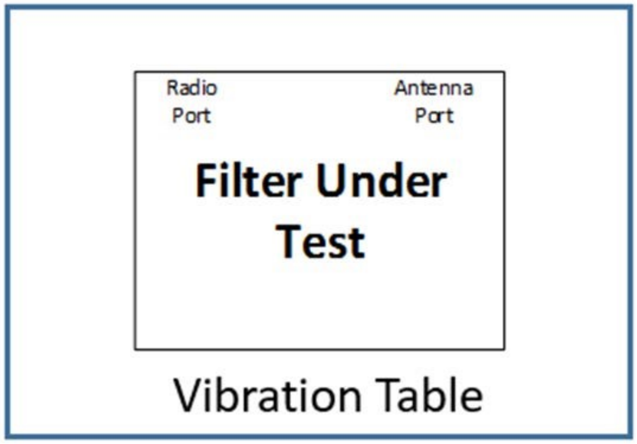

Figure 1

3.3 Test Equipment Configuration:

VNA Configuration

Mode:	Network Analyzer (NA) / S21 &S11
Format and Configuration:	Refer to individual test procedures identified in section 3.4.

3.4 Test Set Procedure:

Step	Action
1	Environmental lab personnel will configure the vibration table to conduct the Sinusoidal Vibration test in accordance with AAR MSRP 9401 3.2.4.1, found in Appendix A.
2	Place and clamp the filter under test on the vibration table in such a way that the vibration will be performed along only one of its 3 mutually perpendicular axis.
3	Before the table begins to vibrate, conduct the Pre Sinusoidal Vibration filter characterization (steps 4 to 7).
4	Complete the Filter Amplitude Response Test procedure, LFT-AR.
5	Complete the Passband Phase Response Test procedure, LFT-PH.
6	Complete the Passband VSWR Response Test procedure, LFT-VSWR.
7	Complete the Passband Impedance Test procedure, LFT-IMP.
8	While the table vibrates, perform the Sinusoidal Vibration filter characterization (steps 9 and 10) after every hour of test (4 characterizations in total).
9	Complete the Filter Amplitude Response Test procedure, LFT-AR.
10	Complete the Passband Phase Response Test procedure, LFT-PH.

11	Once the sinusoidal vibration is complete, begin the Post Sinusoidal Vibration filter characterization (steps 12 to 16).
12	Complete the Filter Amplitude Response Test procedure, LFT-AR.
13	Complete the Passband Phase Response Test procedure, LFT-PH.
14	Complete the Passband VSWR Response Test procedure, LFT-VSWR.
15	Complete the Passband Impedance Test procedure, LFT-IMP.
16	Complete the Broadband Amplitude Response Test procedure, LFT-BB.
17	Change the orientation of the filter in order to perform the sinusoidal vibration test in the next axis. Repeat steps 3 to 16.

3.5 Test Artifacts:

Artifact #	**Description**	**Test Procedure Step**	**Artifact Name**
1	Refer to individual test procedures identified in section 3.4.	n/a	n/a

3.6 Notes:

Allow spectrum analyzer to warm-up for 30 minutes prior to use.

4 Laboratory Environmental Tests - Thermal Exposure Test Group

The objective of the test is to collect amplitude and phase response data while each filter is exposed to increasing temperatures in accordance with MSRP 9401.3.2.2.3.2 and gather data (post thermal cycling) for identifying the following filter characteristics:

- passband amplitude response
- stopband amplitude response
- passband insertion loss
- filter attenuation at stopband
- passband phase response
- passband VSWR
- passband impedance
- broadband amplitude response

4.1 Test Equipment:

Equipment	**Details**
Refer to individual test procedures identified in section 4.4.	

4.2 Test Setup:

Configure temperature cycling test environment per requirements of AAR S-9401 section 3.2.2.3.2, found in Appendix A, then refer to the individual test procedure identified in section 4.4. See Figure 2

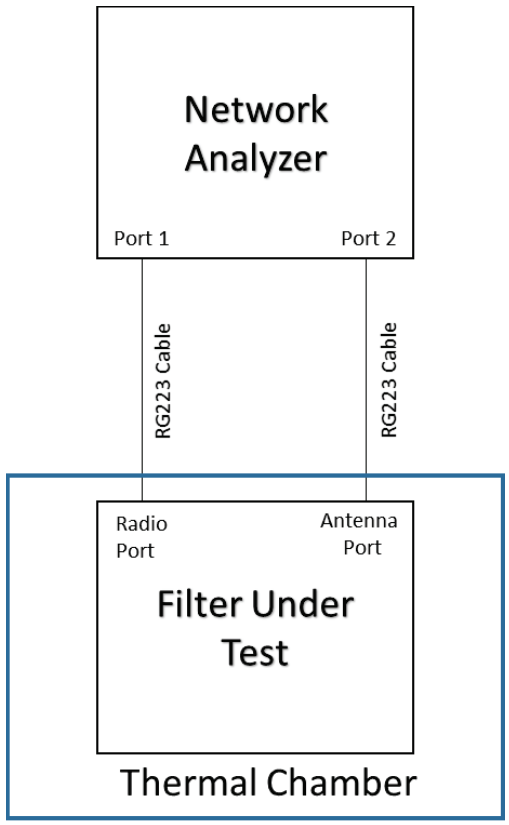

Figure 2

4.2 Test Equipment Configuration:

VNA Configuration

Mode:	Network Analyzer (NA) / S21 &S11
Format and Configuration:	Refer to individual test procedures identified in section 4.4.

4.3 Test Set Procedure:

Step	Action
1	Environmental lab personnel will configure the thermal chamber to conduct the Thermal Cycling test in accordance with AAR MSRP 9401 3.2.2.3.2 included on Appendix A. Note: This test will only include 2 thermal cycles instead of the 75 listed in the MSRP

2	Place the filter in the cold chamber at -45°C. Leave the filter in the chamber overnight, and perform the cold soaking filter characterization (step 3) the following morning
3	Complete the Filter Amplitude Response Test procedure
4	Place the filter in the cold chamber at -45°C until it reaches thermal equilibrium. Move the filter to the hot chamber where it will be exposed to a temperature of 105°C. While the filter is being heated, conduct the Thermal Cycling filter characterization (step 5) each time the temperature increases 10°C until the filter's temperature is 75°C.
5	Complete the Filter Amplitude Response Test procedure, LFT-AR.
6	Leave the filter at room temperatures until filter temperature is room temperature
7	Place the filter in the hot chamber at 75°C. Leave the filter in the chamber overnight, and perform the hot soaking filter characterization (step 8) the following morning.
8	Complete the Filter Amplitude Response Test procedure, LFT-AR.
9	Repeat steps 4 to 5 to perform thermal cycle 2 test.
10	Remove the filter from the hot chamber and leave it at room temperature overnight. At the next morning conduct the Post Thermal Cycling filter characterization (steps 11 to 15)
11	Complete the Filter Amplitude Response Test procedure, LFT-AR.
12	Complete the Passband Phase Response Test procedure, LFT-PH.
13	Complete the Passband VSWR Response Test procedure, LFT-VSWR.
14	Complete the Passband Impedance Test procedure, LFT-IMP.
15	Complete the Broadband Amplitude Response Test procedure, LFT-BB.

4.4 Test Artifacts:

Artifact #	**Description**	**Test Procedure Step**	**Artifact Name**
1	Refer to individual test procedures identified in section 4.4.		

4.5 Notes:

Allow spectrum analyzer to warm-up for 30 minutes prior to use.

5 Laboratory Environmental Tests - Random Vibration Test Group

The objective of the test is to collect amplitude and phase response data while each filter is exposed to random vibration conditions in accordance with MSRP 9401.3.2.4.2 and gather data (post vibration) for identifying the following filter characteristics:

- passband amplitude response
- stopband amplitude response
- passband insertion loss
- filter attenuation at stopband
- passband phase response
- passband VSWR
- passband impedance
- broadband amplitude response

5.1 Test Equipment:

Equipment	**Details**
Refer to individual test procedures identified in section 5.4.	

5.2 Test Setup:

See Figure 3. Configure vibration test environment per requirements of AAR S-9401 section 3.2.4.2, found in Appendix A, then refer to the individual test procedure identified in section 5.4.

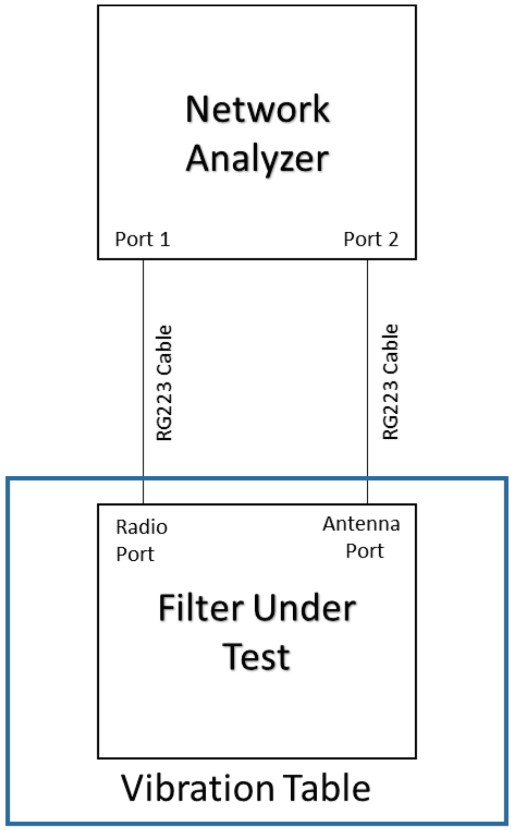

Figure 3

5.3 Test Equipment Configuration:

VNA Configuration

Mode:	Network Analyzer (NA) / S21 &S11
Format and Configuration:	Refer to individual test procedures identified in section 5.4.

5.4 Test Set Procedure:

Step	Action
1	Environmental lab personnel will configure the vibration table to conduct the Random Vibration test in accordance with AAR MSRP 9401 3.2.4.2, found in Appendix A.
2	Place and clamp the filter under test on the vibration table in such a way that the vibration will be performed along only one of its 3 mutually perpendicular axis.
3	Before the table begins to vibrate, conduct the Pre Random Vibration filter characterization (steps 4 to 7).
4	Complete the Filter Amplitude Response Test procedure, LFT-AR.
5	Complete the Passband Phase Response Test procedure, LFT-PH.
6	Complete the Passband VSWR Response Test procedure, LFT-VSWR.

7	Complete the Passband Impedance Test procedure, LFT-IMP.
8	While the table vibrates, perform the Random Vibration filter characterization (steps 9 and 10) after every hour of test (4 characterizations in total).
9	Complete the Filter Amplitude Response Test procedure, LFT-AR.
10	Complete the Passband Phase Response Test procedure, LFT-PH.
11	Once the random vibration is complete, begin the Post Random Vibration filter characterization (steps 12 to 16).
12	Complete the Filter Amplitude Response Test procedure, LFT-AR.
13	Complete the Passband Phase Response Test procedure, LFT-PH.
14	Complete the Passband VSWR Response Test procedure, LFT-VSWR.
15	Complete the Passband Impedance Test procedure, LFT-IMP.
16	Complete the Broadband Amplitude Response Test procedure, LFT-BB.
17	Change the orientation of the filter in order to perform the random vibration test in the next axis. Repeat steps 3 to 16.

5.5 Test Artifacts:

Artifact #	**Description**	**Test Procedure Step**	**Artifact Name**
1	Refer to individual test procedures identified in section 5.4.		

5.6 Notes:

Allow spectrum analyzer to warm-up for 30 minutes prior to use.

6 Laboratory Environmental Tests - ACSES PTC Signal Testing During Random Vibration Test Group

The objective of the test is to expose each filter to random vibration conditions in accordance with MSRP 9401 3.2.4.2 while a PTC signal is being transmitted through the filter in order to determine if the vibration of the filter causes an increased Packet Error Rate (PER) due to phase noise induced by vibration.

6.1 Test Equipment:

Equipment	**Details**
Vector Network Analyzer (VNA)	Keysight FieldFox N9914A
RG223 Cables with N type plug connectors	10x cables variable length
Filter under test	
Computer with test software	Network Traffic Generator NTG version 1.1.14, Putty, GE RUT Firmware version 2.0.15
Variable and fixed attenuators	2x 10 dB fixed attenuator, and 2x variable attenuators up to 50 dB.
Combiner	2 way N type combiner
Splitter	2 way N type splitter
Radio Transmitting	GE MDS TD220X
Radio Receiving	GE MDS TD220X
Vibration table	
GPS	GPS Garmin

6.2 Test Setup:

Refer to individual test procedure and Figure 4.

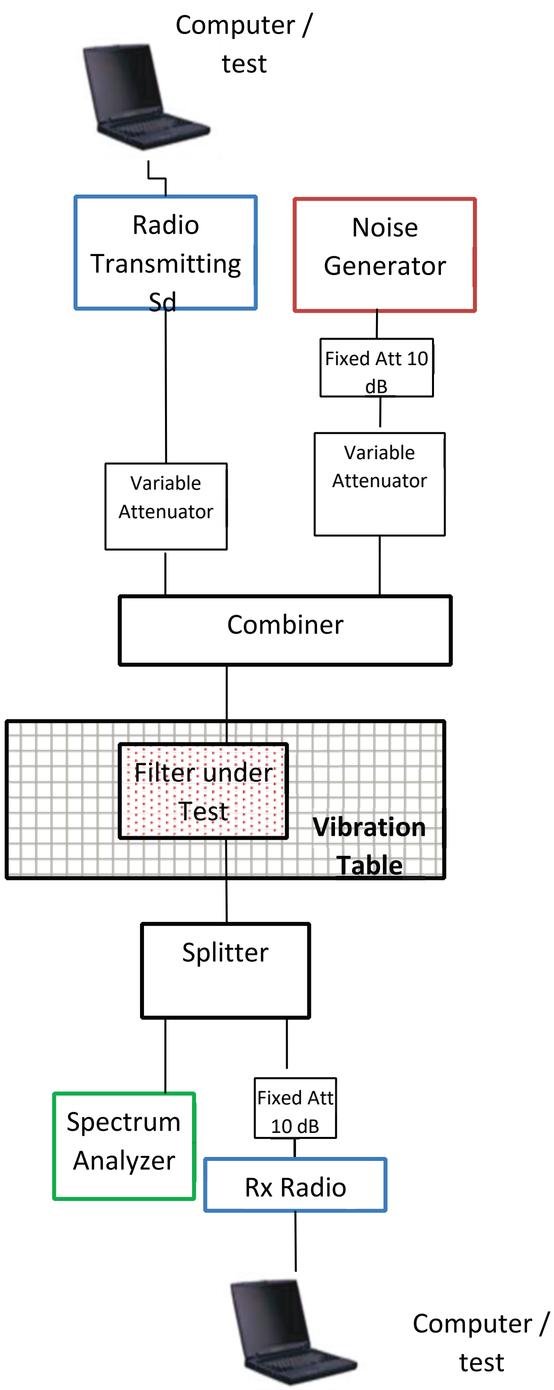

Figure 4

6.3 Test Equipment Configuration: VNA Configuration

Mode:	Network Analyzer (NA) / S22
Format:	Refer to individual test procedures

6.4 Test Set Procedure:

Step	Action
1	Place and clamp the filter under test on the vibration table in such a way that the vibration will be performed along only one of its 3 mutually perpendicular axis.
2	Connect the equipment according to figure 1.
3	Configure the operating frequencies on both radios, transmitter and receiver, according to the type of filter being tested: • 217.00625 MHz or 218.99375 MHz Write down the basic test information on the worksheet (date, session id, radio equipment, frequency).
4	While logging, transmit Tx radio packets to Rx radio. Dynamically adjust attenuation to achieve target Sd (desired signal) level. • Sd of -85dBm Complete signal level measurement procedure twice. Write down the signal level on the worksheet.
5	Introduce noise signal (Sn) and dynamically increase its output level until the PER is approximately 2-3%. Sn is white noise (uniform power spectral density) over the passband of the filter under test. Turn off Sd and complete signal level measurement procedure twice. Write down the noise level on the worksheet.
6	With Sd level determined from Step 4 and Sn level determined from Step 5, allow radios to Tx/Rx for 5 min while logging transmit and receive radio messages, and measuring Sd and Sn. Complete signal level measurement. Minimum number of Tx messages = 1200. Write down transmission and reception statistics from the radios on the worksheet.
7	Repeat step 6 to collect 5 measurements in total.
8	Environmental lab personnel will configure the vibration table to perform Random Vibration with a max of 1.5G peak.
9	Once the table is vibrating, repeat steps 6 and 7.
10	Repeat steps 1 to 9 to perform the test on the next axis.

6.5 Test Artifacts:

Artifact #	Description	Test Procedure Step	Artifact Name

1	Refer to individual test procedures		
2	Message Radio Logs	4, 5, 6, 7, 9	TD220X_RUT_zz_A_bbb “RUT” being the radio under test, “zz” specifying if the TX or RX equipment, “A” designating the if the Sd1 was established or dyn if it is being established, and “bbb” indicates if the test was on initial conditions IC or during vibration VB and a numeric unique identifier. For example: TD220X_RUT_RX_Sn1_VB3.
3	PTC Signal Testing Worksheet	3, 4, 5, 6, 7, 9	X ACSES PTC Signal Testing, where “X” is the manufacturer name. For example: Fiplex ACSES PTC Signal Testing.

6.6 Notes:

Allow spectrum analyzer to warm-up for 30 minutes prior to use.

6.7 Signal level measurement

The objective of the test is to gather a network analyzer screen capture with markers and trace data for identifying:

- Signal level.
- Noise level.

6.7.1 Test Equipment:

Equipment	Details
Vector Network Analyzer (VNA)	Keysight FieldFox N9914A
RG223 Cables with N type plug connectors	1x cables 10 feet long with unique # labels

6.7.2 Test Setup:

Set up test as shown in Figure 5.

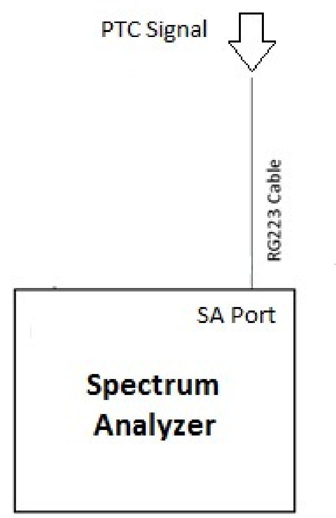

Figure 5

6.7.3 Test Equipment Configuration:

VNA Configuration

Mode:	Spectrum Analyzer (SA), Built-in Power Meter
Format:	Log Magnitude
Center frequency:	Depending on the test frequency: • 217.00625 MHz or 218.99375 MHz
Span:	250 KHz
Resolution Bandwidth:	1.500 KHz
Reference Level:	-30 dBm
VBW:	1.500 KHz
Sweep:	FFT
Sweep Resolution:	401 points
Sweep Rate:	144 ms
Average Mode:	Sweep
Average <n>:	50
Detection Mode:	#RMS: Average.

Scan Mode:	1A: Range channel defined.
Attenuation:	5 dB
Integration Bandwidth:	
Marker 1:	Depending on the test frequency: • 217.00625 MHz or 218.99375 MHz
Marker 2:	Noise level, 100 KHz from center frequency.

6.7.4 Test Procedure:

Step	Action
1	Set up test equipment as defined in Figure 2. Configure it according to section 2.3.
3	Allow at least 10 seconds to pass after connecting cables to VNA ports to permit trace to average
4	After having applied max hold for a minimum of 2 mins, take and save spectrum analyzer screen capture, see section 2.5, Test Artifacts.
5	After having applied max hold for a minimum of 2 mins, take and save Trace Data in .csv file format, see section 2.5, Test Artifacts.

6.7.5 Test Artifacts:

Artifact #	**Description**	**Test Procedure Step**	**Artifact Name**

1	ACSES Signal level Screen Capture (.png)	4	“xxx_A_PTC_zz_aaa_SDv_SNv_bbb_cc with “xxx” being the manufacturer name, “A” designating ACSES, “zz” designating the axis to be tested, “aaa” the frequency of the test, “v” indicates if the signal is on with a 1 or OFF, “bbb” designating the test group name, and “cc” the unique identifier. For example “FPX_A_PTC_X1_217_SD1_SNOFF_IC1_01” describes a Fiplex filter ACSES on PTC test, axis 1, frequency 217 MHz, Sd is on but Sn is off, Measurement 1 of initial conditions and identifier 01.
2	ACSES Signal level	5	“xxx_A_PTC_zz_aaa_SDv_SNv_bbb_cc with “xxx” being the manufacturer name, “A” designating
	Trace Data (.csv)		ACSES, “zz” designating the axis to be tested, “aaa” the frequency of the test, “v” indicates if the signal is on with a 1 or OFF, “bbb” designating the test group name, and “cc” the unique identifier. For example “FPX_A_PTC_X1_217_SD1_SNOFF_IC1_01” describes a Fiplex filter ACSES on PTC test, axis 1, frequency 217 MHz, Sd is on but Sn is off, Measurement 1 of initial conditions and identifier 01.

6.7.6 Notes:

Allow spectrum analyzer to warm-up for 30 minutes prior to use.

7 Laboratory Environmental Tests - ITC PTC Signal Testing During Random Vibration Test Group

The objective of the test is to expose each filter to random vibration conditions in accordance with MSRP 9401 3.2.4.2 while a PTC signal is being transmitted through the filter in order to determine if the vibration of the filter causes an increased Packet Error Rate (PER) due to phase noise induced by vibration.

7.1 Test Equipment:

Equipment	**Details**
Vector Network Analyzer (VNA)	Keysight FieldFox N9914A
RG223 Cables with N type plug connectors	10x cables variable length
Filter under test	
Computer with test software	xTerm, RTCS, Socket Share, MCC Software version 02020601.A18, MCC BASE Firmware BS4012V2.xts for 220.0625 MHz and BS4012V3.xts for 221.9375 MHz
Variable and fixed attenuators	2x 10 dB fixed attenuator, and 2x variable attenuators up to 50 dB.
Combiner	2 way N type combiner
Splitter	2 way N type splitter
Radio Transmitting	MCC Base
Radio Receiving	MCC LOCO
Vibration table	
GPS	GPS Garmin

7.2 Test Setup:

Refer to individual test procedure and Figure 6.

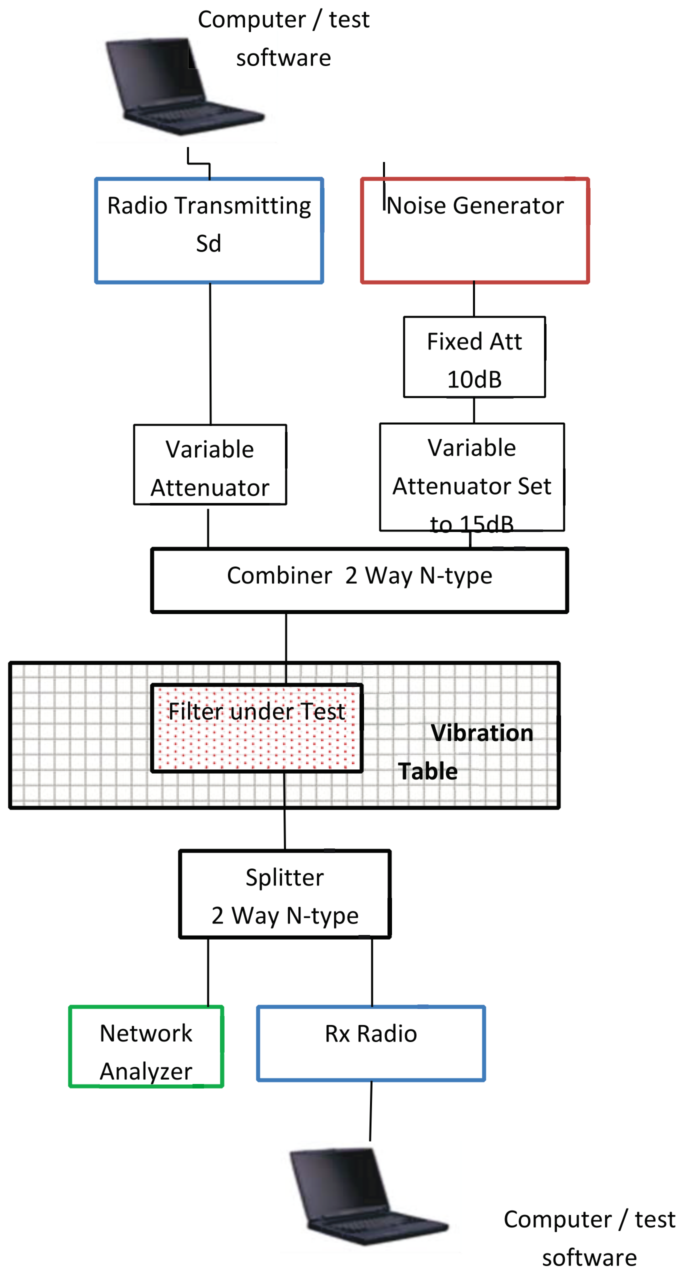
Computer / test software
Radio Transmitting Sd
Noise Generator
Fixed Att 10dB
Variable Attenuator
Variable Attenuator Set to 15dB
Combiner 2 Way N-type
Filter under Test
Vibration Table
Splitter 2 Way N-type
Network Analyzer
Rx Radio
Computer / test software

Figure 6

7.3 Test Equipment Configuration: VNA Configuration

Mode:	Network Analyzer (NA) / S22
Format:	Refer to individual test procedures

7.4 Test Set Procedure:

Step	Action
1	Place and clamp the filter under test on the vibration table in such a way that the vibration will be performed along only one of its 3 mutually perpendicular axis.
2	Connect the equipment according to figure 1.
3	Configure the operating frequencies on both radios, transmitter and receiver, according to the type of filter being tested: • 220.11250 MHz or 221.93750 MHz Write down the basic test information on the worksheet (date, session id, radio equipment, frequency).
4	While logging, allow Tx radio to transmit packets to Rx radio. Dynamically adjust attenuation to achieve target Sd (desired signal) level. • Sd of -94dBm Write down the signal level on the worksheet.
5	Introduce noise signal (Sn) and dynamically increase its output level until the PER is approximately 2-3%. Sn is white noise (uniform power spectral density) over the passband of the filter under test. Turn off Sd and complete signal level measurement procedure twice. Write down the noise level on the worksheet.
6	With Sd level determined from Step 4 and Sn level determined from Step 5, allow radios to Tx/Rx for 5 min while logging transmit and receive radio messages, and measuring Sd and Sn as described in step 5. Complete signal level measurement. Minimum number of Tx messages = 3600. Write down transmission and reception statistics from the radios on the worksheet.
7	Repeat step 6 to collect 5 measurements in total.
8	Environmental lab personnel will configure the vibration table to perform Random Vibration with a max of 1.5G peak.
9	Once the table is vibrating, repeat steps 6 and 7.
10	Repeat steps 1 to 9 to perform the test on the next axis.

7.5 Test Artifacts:

Artifact #	Description	Test Procedure Step	Artifact Name
1	Refer to individual test procedures		
2	Message Radio Logs	4, 5, 6, 7, 9	ITC_Y_zz_A_bbb with “Y” being the radio equipment, “zz” specifying if the TX or RX equipment, “A” designating the if the Sd1 was established or dyn if it is being established, and “bbb” indicates if the test was on initial conditions IC or during vibration VB and a numeric unique identifier. For example: ITC_LOCO_RX_Sn1_VB3.
3	PTC Signal Testing Worksheet	3, 4, 5, 6, 7, 9	X ITC PTC Signal Testing, where “X” is the manufacturer name. For example: Fiplex ITC PTC Signal Testing.

7.6 Notes:

Allow spectrum analyzer to warm-up for 30 minutes prior to use.

7.7 Signal level measurement

The objective of the test is to gather a network analyzer screen capture with markers and trace data for identifying:

- Signal level.
- Noise level.

7.7.1 Test Equipment:

Equipment	Details
Vector Network Analyzer (VNA)	Keysight FieldFox N9914A
RG223 Cables with N type plug connectors	1x cables 10 feet long with unique # labels

7.7.2 Test Setup:

Set up test as shown in Figure 7.

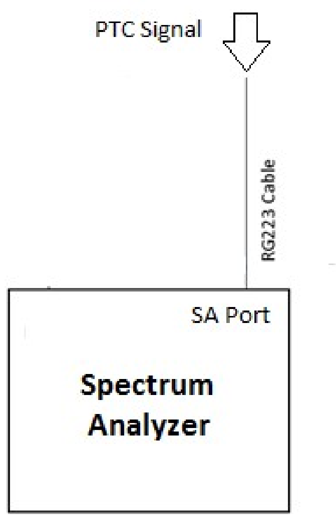

Figure 7

7.7.3 Test Equipment Configuration:

VNA Configuration

Mode:	Spectrum Analyzer (SA)
Format:	Log Magnitude
Center frequency:	Depending on the test frequency: • 220.11250 MHz or 221.93750 MHz
Span:	250 KHz
Resolution Bandwidth:	1.500 KHz
Reference Level:	-30 dBm
VBW:	1.500 KHz
Sweep:	FFT
Sweep Resolution:	401 points
Sweep Rate:	144 ms
Average Mode:	Sweep
Average <n>:	50
Detection Mode:	#RMS: Average.

Scan Mode:	1A: Range channel defined.
Attenuation:	5 dB
Integration Bandwidth:	
Marker 1:	Depending on the test frequency: • 220.11250 MHz or 221.93750 MHz
Marker 2:	Noise level, 100 KHz from center frequency.

7.7.4 Test Procedure:

Step	Action
1	Set up test equipment as defined in Figure 2. Configure it according to section 2.3.
3	Allow at least 10 seconds to pass after connecting cables to VNA ports to permit trace to average
4	After having applied max hold for a minimum of 1 min, take and save spectrum analyzer screen capture, see section 2.5, Test Artifacts.
5	After having applied max hold for a minimum of 1 min, take and save Trace Data in .csv file format, see section 2.5, Test Artifacts.

7.7.5 Test Artifacts:

Artifact #	**Description**	**Test Procedure Step**	**Artifact Name**

1	ITC Signal level Screen Capture (.png)	4	“xxx_I_PTC_zz_aaa_SDv_SNv_bbb_cc with “xxx” being the manufacturer name, “I” designating ITC, “zz” designating the axis to be tested, “aaa” the frequency of the test, “v” indicates if the signal is on with a 1 or OFF, “bbb” designating the test group name, and “cc” the unique identifier. For example “FPX_I_PTC_X1_217_SD1_SNOFF_IC1_01” describes a Fiplex filter ITC on PTC test, axis 1, frequency 217 MHz, Sd is on but Sn is off, Measurement 1 of initial conditions and identifier 01.
2	ITC Signal level Trace Data (.csv)	5	“xxx_I_PTC_zz_aaa_SDv_SNv_bbb_cc with “xxx” being the manufacturer name, “I” designating ITC, “zz” designating the axis to be tested, “aaa” the frequency of the test, “v” indicates if the signal is on
			with a 1 or OFF, “bbb” designating the test group name, and “cc” the unique identifier. For example “FPX_I_PTC_X1_217_SD1_SNOFF_IC1_01” describes a Fiplex filter ITC on PTC test, axis 1, frequency 217 MHz, Sd is on but Sn is off, Measurement 1 of initial conditions and identifier 01.

7.7.6 Notes:

Allow spectrum analyzer to warm-up for 30 minutes prior to use.

8 Field Testing

8.1 Test Equipment:

Equipment	Details
FAST Locomotive	NS2595
Filter Under Test	

8.2 Test Setup:

Bolt filter to appropriate shelf in the nose section of the locomotive. Apply dust caps to the ports on each filter.

8.3 Test Equipment Configuration:

Mode:	Network Analyzer (NA) / S21
Format and Configuration:	Refer to individual test procedure identified in section 8.4.

8.4 Test Set Procedure:

Step	Action
1	Leave filters on locomotive for the duration of testing
2	Remove filters from the locomotive
3	Complete the Filter Amplitude Response Test procedure, LFT-AR.
4	Complete the Passband Phase Response Test procedure, LFT-PH.
5	Complete the Passband VSWR Response Test procedure, LFT-VSWR.
6	Complete the Passband Impedance Test procedure, LFT-IMP.
7	Complete the Filter Amplitude Response 160 MHz Band, LFT-160.
8	Complete the Filter Amplitude Response 210 MHz Band, LFT-210.
9	Complete the Filter Amplitude Response 450 MHz Band, LFT-450.
10	Complete the Filter Amplitude Response 900 MHz Band, LFT-900.
11	Complete the Broadband Amplitude Response Test procedure, LFT-BB.

8.5 Test Artifacts:

Artifact #	Description	Test Procedure Step	Artifact Name

1	Refer to individual test procedures identified in section 8.4.		

8.6 Notes:

Allow spectrum analyzer to warm-up for 30 minutes prior to use.

9 Vector Network Analyzer (VNA) Calibration Procedure

The objective of this procedure is to outline when to and how to properly calibrate the FieldFox Vector Network Analyzer (VNA) using the Quick Cal built in function. No calibration kit is required.

9.1 Test Equipment:

Equipment	Details
Vector Network Analyzer (VNA)	FieldFox N9914A
RG223 Cables with N-type plug connectors	2x cables 10 feet long with unique # labels
50 ohm load	Bird Model 50-NT-MN
Adapter	N- Type Male to N-Type Male adapter

9.2 Test Setup:

Set up test as shown in Figure 8. Connect a coaxial, RG223, cable with N-type plug connectors to the VNA port 1 and port 2. Have the 50 ohm load and N-type adapter on hand and ready to connect during the appropriate steps in the procedure in section 19.4 below.

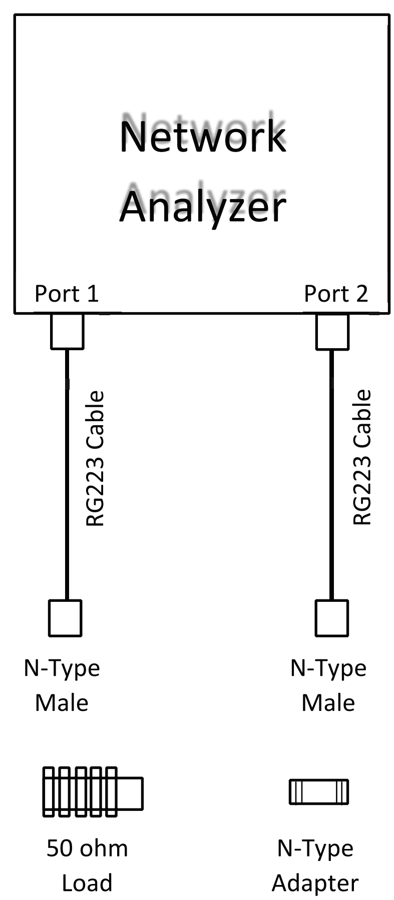

Figure 8

9.3 Test Equipment Configuration:

NA Configuration

Mode:	Network Analyzer (NA) / S21
IF BW:	3 kHz
Center frequency:	Desired (e.g., 219.5 MHz)
Span:	Desired (e.g., 7 MHz)
Reference Level	0 dBm
Power Level:	-15 dBm
Sweep Resolution:	201 points

9.4 Calibration Conditions

The Quick Cal function should be completed after the following measurement changes:

- Frequency range
- Power level
- IF BW
- Sweep resolution
- Cables / Jumpers
- The temperature of the FieldFox changes more than 10° F

9.5 Test Procedure:

Step	Action
1	Set up and configure test equipment as defined in sections 7.2, 7.3 and Figure 8.
2	Enter into the Quick Cal function menu by pressing the “Cal” button and selecting “Quick Cal”
3	Verify “Calibration Type: Full 2- Port” and “S-parameters: S21” and correct DUT port types.
4	Select “Start Calibration” and follow Cal Wizard steps
5	Step 1 of 4: Leave both ports open and select “Measure”
6	Step 2 of 4: Connect the 50 ohm load to the port 1 cable and select “Measure”
7	Step 3 of 4: Connect the 50 ohm load to the port 2 cable and select “Measure”
8	Step 4 of 4: Using the N-type adapter, connect the port 1 and port 2 cables together and select “Measure”
9	Select “Finish” to return to the measurement screen
10	“Cal ON Q” should now be displayed in the left side of the measurement screen to indicate measurements are corrected with QuickCal
11	Save State (.sta) file to device internal memory if needed

9.6 Test Artifacts:

Artifact #	Description	Test Procedure Step	Artifact Name
1	State file containing calibration information for a pair of cables	11	Cable Cal#_#

9.7 Notes:

Allow spectrum analyzer to warm-up for 30 minutes prior to use. See Appendix B for uncertainty values associated with the QuickCal function.

10 LFT-AR: Filter Amplitude Response

The objective of the test is to gather a network analyzer screen capture with markers and trace data for identifying the filter:

- passband amplitude response
- stopband amplitude response
- passband insertion loss • filter attenuation at stopband.

10.1 Test Equipment:

Equipment	Details
Vector Network Analyzer (VNA)	Keysight FieldFox N9914A
RG223 Cables with N type plug connectors	2x cables 10 feet long with unique # labels
Filter under test	

10.2 Test Setup:

Set up test as shown in Figure 9.

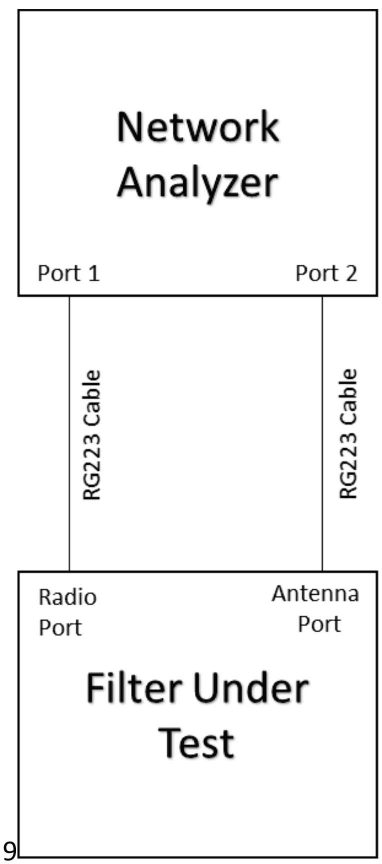

Figure 9

Figure 9

10.3 Test Equipment Configuration:

VNA Configuration

Mode:	Network Analyzer (NA) / S21
Format:	Log Magnitude
Center frequency:	219.5 MHz
Span:	7 MHz
Power Level:	-15 dBm
Reference Level:	0 dBm
IF BW:	3 kHz
Sweep:	Continuous
Sweep Resolution:	201 points
Average Mode:	Sweep
Average <n>:	5
Marker 1:	217.000 MHz
Marker 2:	219.000 MHz
Marker 3:	220.000 MHz
Marker 4:	222.000 MHz
Marker 5:	220.1375 MHz

10.4 Test Procedure:

Step	Action
1	Set up and configure test equipment as defined in Figure 9
2	Ensure the VNA calibration procedure is completed as needed in accordance with the VNA Calibration Procedure

3	Allow at least 10 seconds to pass after connecting cables to VNA ports to permit trace to average
4	Take and save spectrum analyzer screen capture in .png file format, see section 8.5, *Test Artifacts.*
5	Take and save Trace Data in .csv file format, see section 8.5, Test *Artifacts* .

10.5 Test Artifacts:

Artifact #	Description	Test Procedure Step	Artifact Name
1	ITC/ ACSES Filter Characterization Screen Capture (.png)	4	"xxx_y_AR_zzz_## with "xxx" being the manufacturer name, "y" designating ITC or ACSES, "zzz" designating the test group name, and "##" designating the unique identifier. For example, "TRX_I_AR_RVB_03" describes a TX RX ITC Amplitude Response Filter Characterization during Random Vibration 03.
2	ITC/ ACSES Filter Characterization Trace Data (.csv)	5	"xxx_y_AR_zzz_## with "xxx" being the manufacturer name, "y" designating ITC or ACSES, "zzz" designating the test group name, and "##" designating the unique identifier. For example, "TRX_I_AR_RVB_03" describes a TX RX ITC Amplitude Response Filter Characterization during Random Vibration 03.

10.6 Notes:

Allow spectrum analyzer to warm-up for 30 minutes prior to use.

11 LFT-PH: Filter Phase Response

The objective of the test is to gather a network analyzer screen capture with markers and trace data for identifying the filter:

- Passband phase response.

11.1 Test Equipment:

Equipment	Details
Vector Network Analyzer (VNA)	Keysight FieldFox N9914A
RG223 Cables with N type plug connectors	2x cables at TBD length with unique # labels
Filter under test	

11.2 Test Setup:

Set up test as shown in Figure 10.

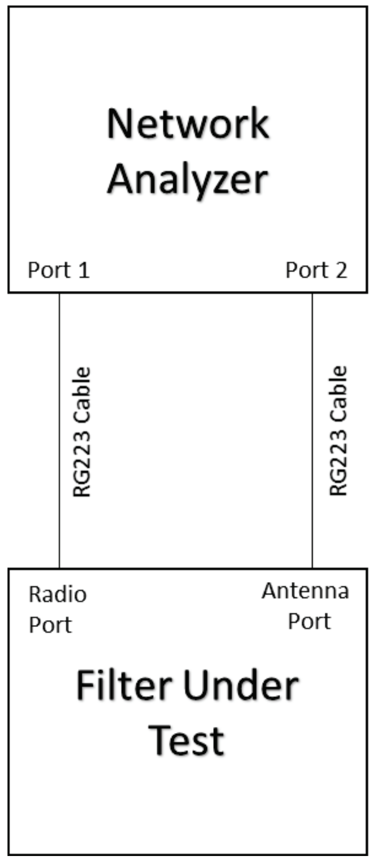

Figure 10

11.3 Test Equipment Configuration:

VNA Configuration

Mode:	Network Analyzer (NA) / S21
Format:	Phase
Center frequency:	219.5 MHz
Span:	7 MHz

Power Level:	-15 dBm
Reference Level:	0 dBm
IF BW:	3 kHz
Sweep:	Continuous
Sweep Resolution:	201 points
Average Mode:	Sweep
Average <n>:	5
Marker 1:	217.000 MHz
Marker 2:	219.000 MHz
Marker 3:	220.000 MHz
Marker 4:	222.000 MHz
Marker 5:	220.1375 MHz

11.4 Test Procedure:

Step	Action
1	Set up and configure test equipment as defined in Figure 10
2	Ensure the VNA calibration procedure is completed as needed in accordance with the VNA Calibration Procedure
3	Allow at least 5 seconds to pass after connecting cables to VNA ports to permit trace to average
4	Take and save spectrum analyzer screen capture in .png file format, see *Test Artifact section.*
5	Take and save Trace Data in .csv file format, see *Artifact section.*

11.5 Test Artifacts:

Artifact #	**Description**	**Test Procedure Step**	**Artifact Name**
1	ITC/ ACSES Filter Phase Response Screen Capture	4	“xxx_y_PR_zzz_## with “xxx” being the manufacturer name, “y” designating ITC or ACSES, “zzz” designating the test group name, and “##” designating the unique identifier. For example, “TRX_I_PR_RVB_03” describes a TX RX ITC Phase Response Filter Characterization during Random Vibration 03.

2	ITC/ ACSES Filter Phase Response Trace Data (.csv)	5	“xxx_y_PR_zzz_## with “xxx” being the manufacturer name, “y” designating ITC or ACSES, “zzz” designating the test group name, and “##” designating the unique identifier. For example, “TRX_I_PR_RVB_03” describes a TX RX ITC Phase Response Filter Characterization during Random Vibration 03.

11.6 Notes:

Allow spectrum analyzer to warm-up for 30 minutes prior to use.

12 LFT-VSWR: Filter Passband Voltage Standing Wave Ratio (VSWR)

The objective of the test is to gather a network analyzer screen capture with markers and trace data for identifying the filter:

- Passband VSWR.

12.1 Test Equipment:

Equipment	Details
Vector Network Analyzer (VNA)	Keysight FieldFox N9914A
RG223 Cables with N type plug connectors	1x cable 10 feet long with unique # label
50 ohm load	Bird Model 50-NT-MN (for non-RFS filters)
50 ohm load	Cinch Connectivity Model 26-8023 (for RFS filters)
Filter under test	

12.2 Test Setup:

Set up test as shown in Figure 11.

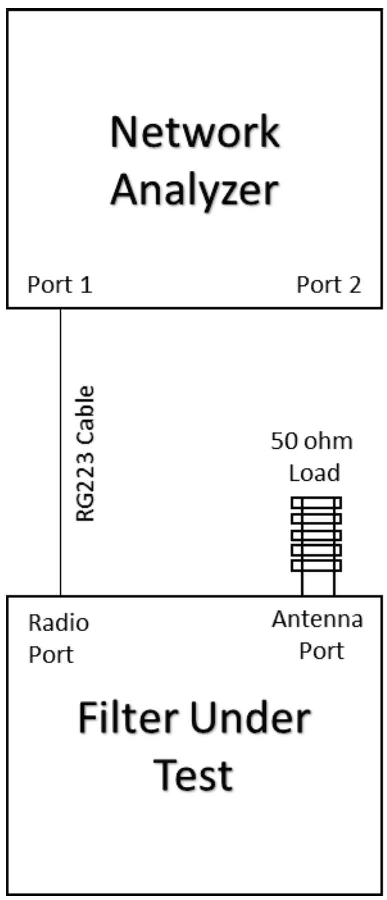

Figure 11

12.3 Test Equipment Configuration:

VNA Configuration

Mode:	Network Analyzer (NA) / S11
Format:	VSWR
Center frequency:	219.5 MHz
Span:	7 MHz
Power Level:	-15 dBm
Reference Level:	0 dBm
IF BW:	3 kHz
Sweep:	Continuous
Sweep Resolution:	201 points
Average Mode:	Sweep
Average <n>:	5
Marker 1:	217.000 MHz
Marker 2:	219.000 MHz
Marker 3:	220.000 MHz
Marker 4:	222.000 MHz
Marker 5:	220.1375 MHz

12.4 Test Procedure:

Step	Action
1	Set up and configure test equipment as defined in Figure 11.
2	Ensure the VNA calibration procedure is completed as needed in accordance with the VNA Calibration Procedure
3	Allow at least 5 seconds to pass after connecting cables to VNA ports to permit trace to average
4	Take and save spectrum analyzer screen capture in .png file format, see *Test Artifact section.*
5	Take and save Trace Data in .csv file format, see *Artifact section.*

12.5 Test Artifacts:

Artifact #	**Description**	**Test Procedure Step**	**Artifact Name**

1	ITC/ ACSES Filter VSWR Screen Capture (.png)	4	“xxx_y_VSWR_zzz_## with “xxx” being the manufacturer name, “y” designating ITC or ACSES, “zzz” designating the test group name, and “##” designating the unique identifier. For example, “TRX_I_VSWR_RVB_03” describes a TX RX ITC Voltage Standing Wave Ratio Filter Characterization during Random Vibration 03.
2	ITC/ ACSES Filter VSWR Trace Data (.csv)	5	“xxx_y_VSWR_zzz_## with “xxx” being the manufacturer name, “y” designating ITC or ACSES, “zzz” designating the test group name, and “##”
			designating the unique identifier. For example, “TRX_I_VSWR_RVB_03” describes a TX RX ITC Voltage Standing Wave Ratio Filter Characterization during Random Vibration 03.

12.6 Notes:

Allow spectrum analyzer to warm-up for 30 minutes prior to use.

13 LFT-IMP: Filter Passband Impedance

The objective of the test is to gather a network analyzer screen capture with markers and trace data for identifying the filter:

- Passband Impedance.

13.1 Test Equipment:

Equipment	Details
Vector Network Analyzer (VNA)	Keysight FieldFox N9914A
RG223 Cables with N type plug connectors	1x cable 10 feet long with unique # label
50 ohm load	Bird Model 50-NT-MN (for non-RFS filters)
50 ohm load	Cinch Connectivity Model 26-8023 (for RFS filters)
Filter under test	

13.2 Test Setup:

Set up test as shown in Figure 12.

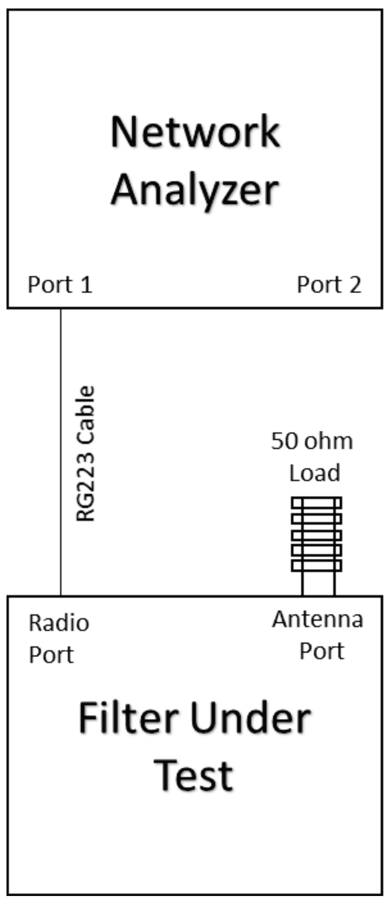

Figure 12

13.3 Test Equipment Configuration:

VNA Configuration

Mode:	Network Analyzer (NA) / S11
Format:	Z Magnitude
Center frequency:	219.5 MHz
Span:	7 MHz
Power Level:	-15 dBm
Reference Level:	0 dBm
IF BW:	3 kHz
Sweep:	Continuous
Sweep Resolution:	201 points
Average Mode:	Sweep
Average <n>:	5
Marker 1:	217.000 MHz
Marker 2:	219.000 MHz
Marker 3:	220.000 MHz
Marker 4:	222.000 MHz
Marker 5:	220.1375 MHz

13.4 Test Procedure:

Step	Action
1	Set up and configure test equipment as defined in Figure 12.
2	Ensure the VNA calibration procedure is completed as needed in accordance with the VNA Calibration Procedure
3	Allow at least 5 seconds to pass after connecting cables to VNA ports to permit trace to average
4	Take and save spectrum analyzer screen capture in .png file format, see *Test Artifact section.*
5	Take and save Trace Data in .csv file format, see *Artifact section.*

13.5 Test Artifacts:

Artifact #	**Description**	**Test Procedure Step**	**Artifact Name**

1	ITC/ ACSES Filter Impedance Screen Capture (.png)	4	“xxx_y_IMP_zzz_## with “xxx” being the manufacturer name, “y” designating ITC or ACSES, “zzz” designating the test group name, and “##” designating the unique identifier. For example, “TRX_I_IMP_RVB_03” describes a TX RX ITC Impedance Filter Characterization during Random Vibration 03.
2	ITC/ ACSES Filter Impedance Trace Data (.csv)	5	“xxx_y_IMP_zzz_## with “xxx” being the manufacturer name, “y” designating ITC or ACSES, “zzz” designating the test group name, and “##”
			designating the unique identifier. For example, “TRX_I_IMP_RVB_03” describes a TX RX ITC Impedance Filter Characterization during Random Vibration 03.

13.6 Notes:

Allow spectrum analyzer to warm-up for 30 minutes prior to use.

14 LFT-AR160: Filter Amplitude Response 160 MHz Band

The objective of the test is to gather a network analyzer screen capture and trace data for identifying the filter amplitude response across the frequency range used by the railroads. AAR frequencies in this band are from 160.1775 MHz to 161.5725 MHz.

14.1 Test Equipment:

Equipment	Details
Vector Network Analyzer (VNA)	Keysight FieldFox N9914A
RG223 Cables with N type plug connectors	2x cables 10 feet long with unique # labels
Filter under test	

14.2 Test Setup:

Set up test as shown in Figure 13.

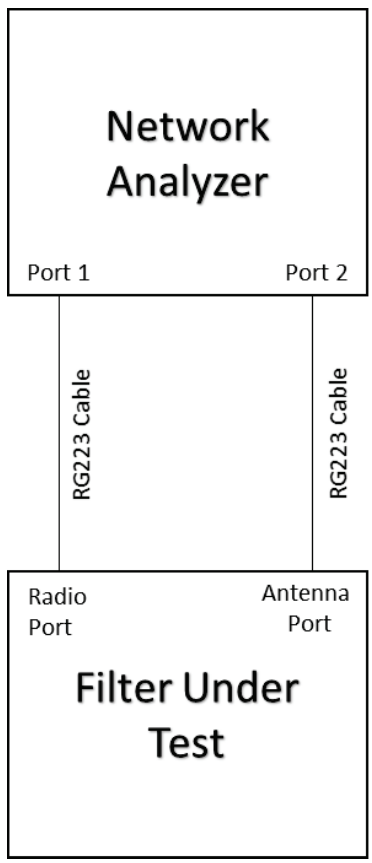

Figure 13

14.3 Test Equipment Configuration:

VNA Configuration

Mode:	Network Analyzer (NA) / S21
Format:	Log Magnitude
Center frequency:	161 MHz
Span:	2 MHz
Power Level:	-15 dBm
Reference Level:	0 dBm
IF BW:	3 kHz
Sweep:	Continuous
Sweep Resolution:	201 points
Average Mode:	Sweep
Average <n>:	5
Marker 1:	160.1000 MHz
Marker 2:	161.6000 MHz

14.4 Test Procedure:

Step	Action
1	Set up and configure test equipment as defined in Figure 13
2	Ensure the VNA calibration procedure is completed as needed in accordance with the VNA Calibration Procedure
3	Allow at least 5 seconds to pass after connecting cables to VNA ports to permit trace to average
4	Take and save spectrum analyzer screen capture in .png file format, see *Test Artifact section.*
5	Take and save Trace Data in .csv file format, see *Artifact section.*

14.5 Test Artifacts:

Artifact #	**Description**	**Test Procedure Step**	**Artifact Name**
1	160 MHz Filter Characterization Screen Capture (.png)	4	“xxx_y_160_zzz_## with “xxx” being the manufacturer name, “y” designating ITC or ACSES, “zzz” designating the test group name, and “##” designating the unique identifier. For example, “TRX_I_160_RVB_03” describes a TX RX ITC 160 MHz Amplitude Response Filter Characterization during Random Vibration 03.

2	160 MHz Filter Characterization Trace Data (.csv)	5	"xxx_y_160_zzz_## with "xxx" being the manufacturer name, "y" designating ITC or ACSES, "zzz" designating the test group name, and "##" designating the unique identifier. For example, "TRX_I_160_RVB_03" describes a TX RX ITC 160 MHz Amplitude Response Filter Characterization during
			Random Vibration 03.

14.6 Notes:

Allow spectrum analyzer to warm-up for 30 minutes prior to use.

15 LFT-AR210: Filter Amplitude Response 210 MHz Band

The objective of the test is to gather a network analyzer screen capture and trace data for identifying the filter amplitude response across the frequency range used by the railroads. AAR frequencies in this band are from 160.1775 MHz to 161.5725 MHz.

15.1 Test Equipment:

Equipment	Details
Vector Network Analyzer (VNA)	Keysight FieldFox N9914A
RG223 Cables with N type plug connectors	2x cables 10 feet long with unique # labels
Filter under test	

15.2 Test Setup:

Set up test as shown in Figure 13.

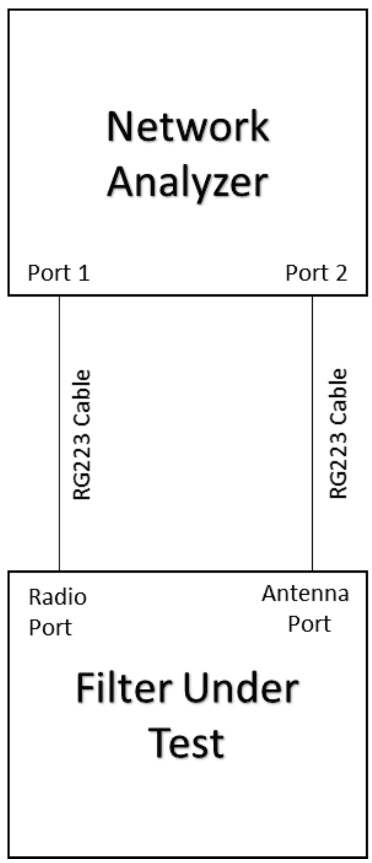

Figure 14

15.3 Test Equipment Configuration:

VNA Configuration

Mode:	Network Analyzer (NA) / S21
Format:	Log Magnitude
Center frequency:	213 MHz
Span:	6 MHz
Power Level:	-15 dBm
Reference Level:	0 dBm
IF BW:	3 kHz
Sweep:	Continuous
Sweep Resolution:	201 points
Average Mode:	Sweep
Average <n>:	5
Marker 1:	210.0000 MHz
Marker 2:	213.0000 MHz
Marker 3:	216.0000 MHz

15.4 Test Procedure:

Step	Action
1	Set up and configure test equipment as defined in Figure 13
2	Ensure the VNA calibration procedure is completed as needed in accordance with the VNA Calibration Procedure
3	Allow at least 5 seconds to pass after connecting cables to VNA ports to permit trace to average
4	Take and save spectrum analyzer screen capture in .png file format, see *Test Artifact section.*
5	Take and save Trace Data in .csv file format, see *Artifact section.*

15.5 Test Artifacts:

Artifact #	**Description**	**Test Procedure Step**	**Artifact Name**
1	210 MHz Filter Characterization Screen Capture (.png)	4	"xxx_y_210_zzz_## with "xxx" being the manufacturer name, "y" designating ITC or ACSES, "zzz" designating the test group name, and "##" designating the unique identifier. For example, "TRX_I_210_RVB_03" describes a TX RX ITC 210 MHz Amplitude Response Filter Characterization during Random Vibration 03.

2	210 MHz Filter Characterization Trace Data (.csv)	5	“xxx_y_210_zzz_## with “xxx” being the manufacturer name, “y” designating ITC or ACSES, “zzz” designating the test group name, and “##” designating the unique identifier. For example, “TRX_I_210_RVB_03” describes a TX RX ITC 210 MHz
			Amplitude Response Filter Characterization during Random Vibration 03.

15.6 Notes:

Allow spectrum analyzer to warm-up for 30 minutes prior to use.

16 LFT-AR450: Filter Amplitude Response 450 MHz Band

The objective of the test is to gather a network analyzer screen capture and trace data for identifying the filter amplitude response across the frequency range used by the railroads. Railroad frequencies in this band are from 452.32500 MHz to 457.96250 MHz.

16.1 Test Equipment:

Equipment	Details
Vector Network Analyzer (VNA)	Keysight FieldFox N9914A
RG223 Cables with N type plug connectors	2x cables 10 feet long with unique # labels
Filter under test	

16.2 Test Setup:

Set up test as shown in Figure 15.

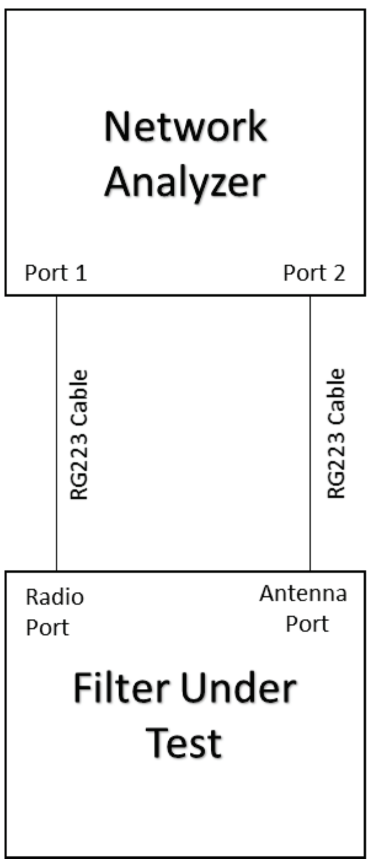

Figure 15

16.3 Test Equipment Configuration:

VNA Configuration

Mode:	Network Analyzer (NA) / S21
Format:	Log Magnitude
Center frequency:	454.8 MHz
Span:	7.4 MHz
Power Level:	-15 dBm
Reference Level:	0 dBm
IF BW:	3 kHz
Sweep:	Continuous
Sweep Resolution:	201 points
Average Mode:	Sweep
Average <n>:	5
Marker 1:	452.3000 MHz
Marker 2:	458.0000 MHz

16.4 Test Procedure:

Step	Action
1	Set up and configure test equipment as defined in Figure 15.
2	Ensure the VNA calibration procedure is completed as needed in accordance with the VNA Calibration Procedure
3	Allow at least 5 seconds to pass after connecting cables to VNA ports to permit trace to average
4	Take and save spectrum analyzer screen capture in .png file format, see *Test Artifact section.*
5	Take and save Trace Data in .csv file format, see *Artifact section.*

16.5 Test Artifacts:

Artifact #	**Description**	**Test Procedure Step**	**Artifact Name**
1	450 MHz Filter Characterization Screen Capture (.png)	4	“xxx_y_450_zzz_## with “xxx” being the manufacturer name, “y” designating ITC or ACSES, “zzz” designating the test group name, and “##” designating the unique identifier. For example, “TRX_I_450_RVB_03” describes a TX RX ITC 450 MHz Amplitude Response Filter Characterization during Random Vibration 03.

2	450 MHz Filter Characterization Trace Data (.csv)	5	“xxx_y_450_zzz_## with “xxx” being the manufacturer name, “y” designating ITC or ACSES, “zzz” designating the test group name, and “##” designating the unique identifier. For example, “TRX_I_450_RVB_03” describes a TX RX ITC 450 MHz Amplitude Response Filter Characterization during Random Vibration 03.

16.6 Notes:

Allow spectrum analyzer to warm-up for 30 minutes prior to use.

17 LFT-AR900: Filter Amplitude Response 900 MHz Band

The objective of the test is to gather a network analyzer screen capture and trace data for identifying the filter amplitude response across the frequency range used by the railroads. Railroad frequencies in this band are from 896.8875 MHz to 921.5000 MHz.

17.1 Test Equipment:

Equipment	Details
Vector Network Analyzer (VNA)	Keysight FieldFox N9914A
RG223 Cables with N type plug connectors	2x cables 10 feet long with unique # labels
Filter under test	

17.2 Test Setup:

Set up test as shown in Figure 16.

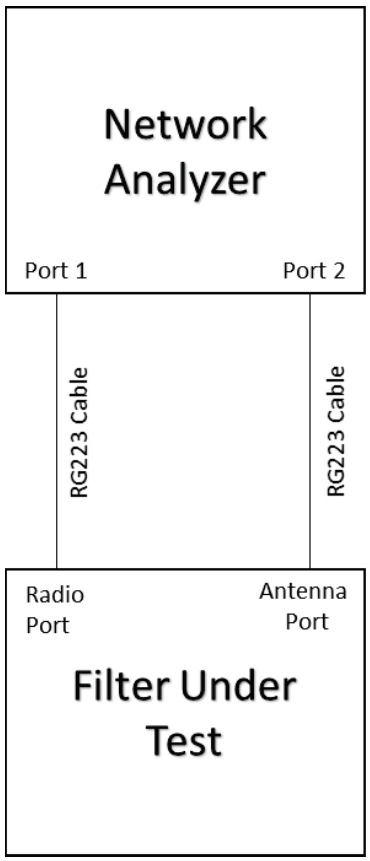

Figure 16

17.3 Test Equipment Configuration:

VNA Configuration

Mode:	Network Analyzer (NA) / S21
Format:	Log Magnitude
Center frequency:	909 MHz
Span:	26 MHz
Power Level:	-15 dBm
Reference Level:	0 dBm
IF BW:	3 kHz
Sweep:	Continuous
Sweep Resolution:	201 points
Average Mode:	Sweep
Average <n>:	5
Marker 1:	896.8000 MHz
Marker 2:	921.6000 MHz

17.4 Test Procedure:

Step	Action
1	Set up and configure test equipment as defined in Figure 16.
2	Ensure the VNA calibration procedure is completed as needed in accordance with the VNA Calibration Procedure
3	Allow at least 10 seconds to pass after connecting cables to VNA ports to permit trace to average
4	Take and save spectrum analyzer screen capture in .png file format, see *Test Artifact section.*
5	Take and save Trace Data in .csv file format, see *Artifact section.*

17.5 Test Artifacts:

Artifact #	**Description**	**Test Procedure Step**	**Artifact Name**

1	900 MHz Filter Characterization Screen Capture (.png)	4	“xxx_y_900_zzz_## with “xxx” being the manufacturer name, “y” designating ITC or ACSES, “zzz” designating the test group name, and “##” designating the unique identifier. For example, “TRX_I_900_RVB_03” describes a TX RX ITC 900 MHz Amplitude Response Filter Characterization during Random Vibration 03.
2	900 MHz Filter Characterization Trace Data (.csv)	5	“xxx_y_900_zzz_## with “xxx” being the manufacturer name, “y” designating ITC or ACSES, “zzz” designating the test group name, and “##” designating the unique identifier. For example,
			“TRX_I_900_RVB_03” describes a TX RX ITC 900 MHz Amplitude Response Filter Characterization during Random Vibration 03.

17.6 Notes:

Allow spectrum analyzer to warm-up for 30 minutes prior to use.

18 LFT-BBFC: Broadband Filter Amplitude Response

The objective of the test is to gather a network analyzer screen capture spanning 160 MHz to 900 MHz with markers and trace data for identifying the filter broadband amplitude response across the frequency range used by the railroads.

18.1 Test Equipment:

Equipment	**Details**
Vector Network Analyzer (VNA)	Keysight FieldFox N9914A
RG223 Cables with N type plug connectors	2x cables 10 feet long with unique # labels
Filter under test	

18.2 Test Setup:

Set up test as shown in Figure 17.

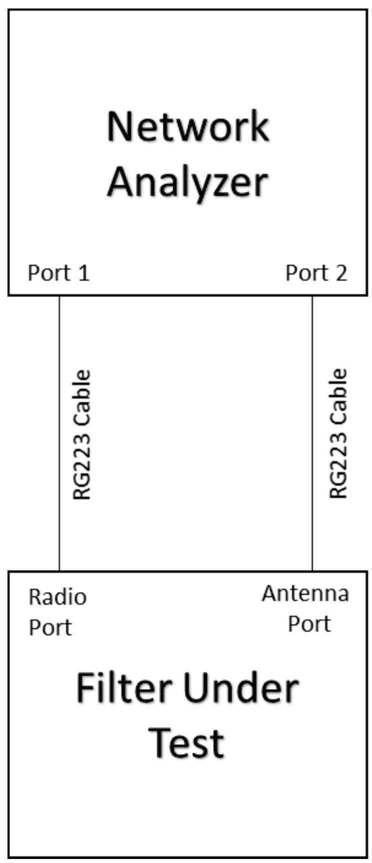

Figure 17

18.3 Test Equipment Configuration:

VNA Configuration

Mode:	Network Analyzer (NA) / S21
Format:	Log Magnitude
Center frequency:	550 MHz
Span:	800 MHz
Power Level:	-15 dBm
Reference Level:	0 dBm
IF BW:	3 kHz
Sweep:	Continuous
Sweep Resolution:	201 points
Average Mode:	Sweep
Average <n>:	5
Marker 1:	160.000 MHz
Marker 2:	220.000 MHz
Marker 3:	450.000 MHz
Marker 4:	900.000 MHz
Marker 5:	220.1375 MHz

18.4 Test Procedure:

Step	Action
1	Set up and configure test equipment as defined in Figure 17.
2	Ensure the VNA calibration procedure is completed as needed in accordance with the VNA Calibration Procedure
3	Allow at least 10 seconds to pass after connecting cables to VNA ports to permit trace to average
4	Take and save spectrum analyzer screen capture in .png file format, see *Test Artifact section.*
5	Take and save Trace Data in .csv file format, see *Artifact section.*

18.5 Test Artifacts:

Artifact #	**Description**	**Test Procedure Step**	**Artifact Name**

1	Broadband Filter Characterization Screen Capture (.png)	4	"xxx_y_BB_zzz_## with "xxx" being the manufacturer name, "y" designating ITC or ACSES, "zzz" designating the test group name, and "##" designating the unique identifier. For example, "TRX_I_BB_RVB_03" describes a TX RX ITC Broadband Amplitude Response Filter Characterization during Random Vibration 03.
2	Broadband Filter Characterization Trace Data (.csv)	5	"xxx_y_BB_zzz_## with "xxx" being the manufacturer name, "y" designating ITC or ACSES, "zzz" designating the test group name, and "##" designating the unique identifier. For example,
			"TRX_I_BB_RVB_03" describes a TX RX ITC Broadband Amplitude Response Filter Characterization during Random Vibration 03.

18.6 Notes:

Allow spectrum analyzer to warm-up for 30 minutes prior to use.

Appendix A Applicable Excerpts from AAR Manual of Standards and Recommended Practices S-9401.V1.0

3.2.4.1 Sinusoidal Vibration

3.2.4.1.1 Vibration test shall be performed according to the standards contained in Test Method 514.4 of MIL-STD-810E (3-axis cycled vibration test) and to the levels indicated in Table 3.3. The equipment shall operate satisfactorily when subjected to sinusoidal vibration in the frequency range of 1 to 300 Hz applied along each of three mutually perpendicular axes for a period of 4 hours per axis.

3.2.4.1.2 The railway electronics equipment under test shall function per the procuring specification without failure after sinusoidal vibration testing. After testing, the railway electronics equipment under test shall also meet the failure requirements of MIL-STD-810E Section 5.2.7 and the requirements of Section I 4.11 of Method 514.4 of MIL-STD-810E.

Table 3.3 Sinusoidal vibration profile

Vibration	Condition	Vehicle Mounted
	1–20 Hz	1 G
	20–120 Hz	2 G
	120–200 Hz	2–3 G ramp
	200–300 Hz	3 G

3.2.2.3.2 Temperature Cycling

This test will commence for 75 cycles. The test extreme temperatures will be T_{max} +5 °C and T_{min} –5 °C. T_{max} and T_{min} can be found in the applicable environmental specification. Once the equipment temperature has stabilized within 2 °C of the extreme temperature, "equilibrium" is reached and the test may advance to the next excursion. The temperature ramp rate of the equipment shall be maximized with a goal of 5 °C per minute, minimum. The ramp rate of an excursion is defined as the rate achieved after 80% of the total temperature excursion is completed. The equipment shall be powered on during the transition from cold to hot. The unit shall be powered off during the transition from hot to cold. Health monitoring of the unit shall be performed whenever the equipment is powered on.

3.2.4.2 Random Vibration

3.2.4.2.1 Random vibration tests shall be performed according to the standards contained in Procedure I, Test Method 514.5 of MIL-STD-810E. The equipment shall be subjected to random vibration with the power spectral density as shown in Fig. 3.1, applied along each of the three mutually perpendicular axis for a period of 4 hours per axis. Note that the vibration environment varies by locomotive model and location within a given area on the locomotive.

3.2.4.2.2 The railway electronics equipment under test shall function per the procuring specification without failure during and after random vibration testing. After testing, the railway electronics equipment under test shall also meet the failure requirements of MIL-STD-810E Section 5.2.7 and the requirements of Section I 4.11 of Method 514.4 of MIL-STD-810E.

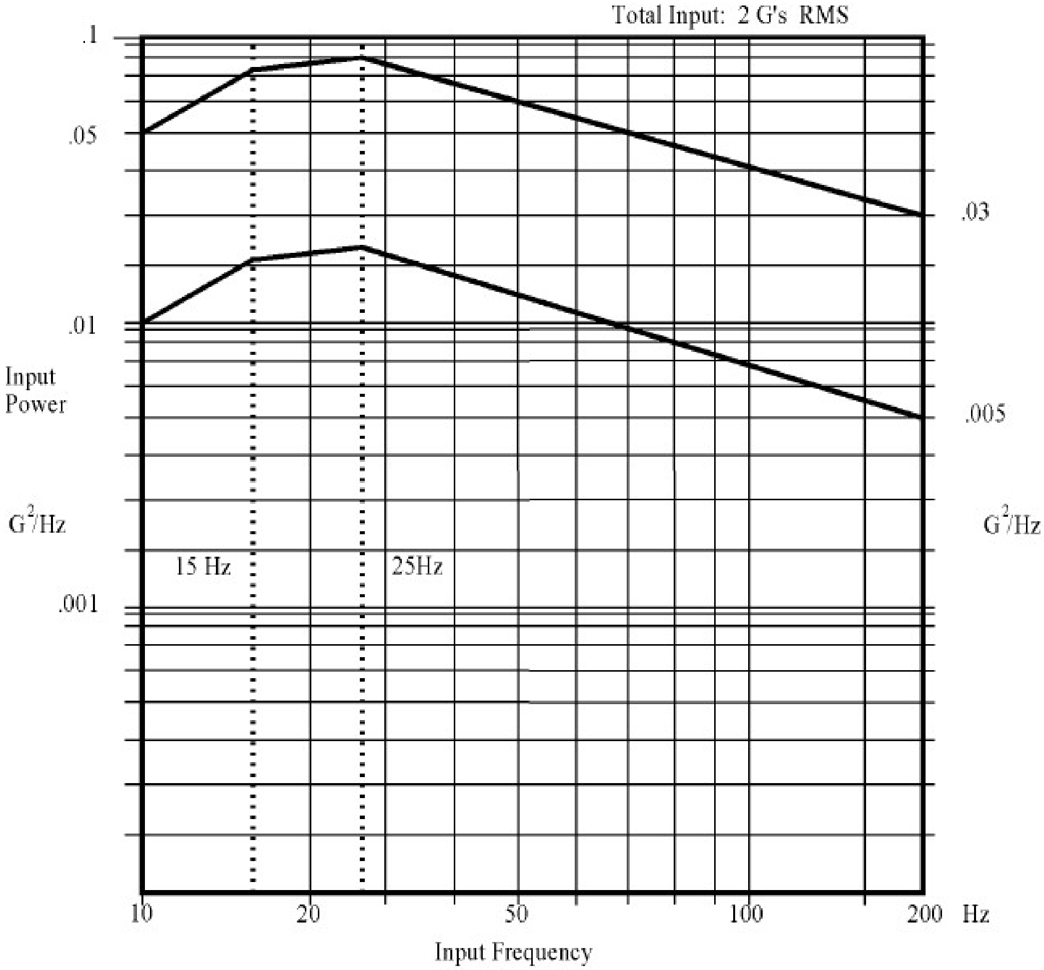

Fig. 3.1 Power spectral density graph for random vibration testing

19 Appendix B

The PDF for Cal Uncertainty levels can be found by following this Web link:
http://literature.cdn.keysight.com/litweb/pdf/5990-9783EN.pdf.

20 Appendix C

Naming Convention Acronyms

1st	2nd	3rd	4th
TRX – TX/RX	I – ITC	AR – Amplitude Response	BSL – Baseline
PLY - Polyphaser	A - ACSES	PR – Phase Response	PSV – Post Sine Vibration
DBS – DB Spectra		IMP – Impedance	RV – Random Vibration
RFS – Radio Frequency Systems		VSWR – Voltage Standing Wave Ratio	PRV – Post Random Vibration
FPX - Fiplex		BB – Broadband	TCY – Thermal Cycling
		160 – 160 MHz Frequency Band	PTCY – Post Thermal Cycling
		450 – 450 MHz Frequency Band	TNL – Tunnel Temperature
		900 – 900 MHz Frequency Band	PTNL – Post Tunnel Temperature
			PTC – PTC Signal