WRAU-2120

Exhibit F – Required Measurements

Exhibit F – Required Measurements

The data required by Sections 2.1046 through 2.1057 inclusive, measured in accordance with the procedures set out in Section 2.1041. (2.1033 (c) (14))

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F.1 Test Procedure and Compliance Matrix

This section documents the test procedures used, and records the results of tests to demonstrate compliance with the applicable requirements of parts 2 and 87 of the FCC Rules and Regulations.

The Table F-1 below identifies the applicable sections of this document and its relationship between the Parts 2 and 87 requirements. The test results are included within each individual test section.

Table F-1. Test Requirements Matrix

FCC Part 2 Section	FCC Part 87 Section	Test Description Summary	Section
2.1047	87.141	Modulation Characteristics	F.2
2.1046	87.131	RF Power Output	F.4
2.1055	87.133	Frequency Stability	F.5
2.1049	87.135	Occupied Bandwidth	F.6
2.1051	87.139	Spurious Emissions at Antenna Terminals	F.7
2.1053	87.139	Field Strength of Spurious Radiation	F.8

F.2 WRAU-2120 Modulation Characteristics (2.1047)

Requirement:

Section 2.1047(d) states: "A curve or equivalent data which shows that the equipment will meet the modulation requirements of the rules under which the equipment is to be licensed."

The WRAU-2120 utilizes un-modulated rectangular pulses.

The following paragraphs describe the transmitted output waveform and frequency utilization. The WRAU-2120 Weather Radar System utilizes two different sets of transmitter pulse patterns, pulse widths and operating frequencies depending on operating mode.

Weather/Turbulence/Map Operation:

A single fixed pulse pattern is utilized for all Weather, Turbulence and Map modes of operation. This same pattern is utilized regardless of whether the system is in Manual operation or Automatic MultiScan operation.

The transmitter pulse pattern consists of a sequence of five pulses, a single 25 microsecond transmitter pulse for long-range weather detection and a series of 4, 6 microsecond pulses for measuring weather and turbulence out to 40 nm. Figure F-1 below shows this pattern. The time period for this group of 5 pulses is called an Epoch. A small variable delay is inserted between epochs to reduce mutual interference between radar systems by dithering the pulse timing.

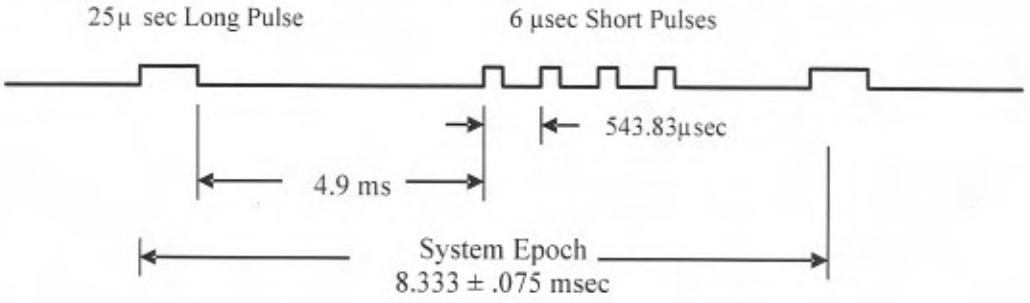

Figure F-1. Transmit Pulse Pattern

Windshear Operation:

Windshear mode is activated during the landing and takeoff phases of flight. In Windshear Mode, the transmitter operates at a 3000 Hz pulse repetition rate with a 2 microsecond pulse width. The pulse pattern for windshear mode is shown in Figure F-2. A small variable delay is inserted between epochs to reduce mutual interference between radar systems by dithering the pulse timing. When Windshear Mode is active, the Windshear sweeps of the antenna are alternated with the normal Weather/Turbulence/Map Sweeps. The left to right sweep is Weather/Turbulence/Map mode with the transmit pulse pattern in Figure F-1. The right to left sweep is Windshear mode with the transmit pulse pattern in Figure F-2. Each sweep direction requires approximately 3 seconds for completion.

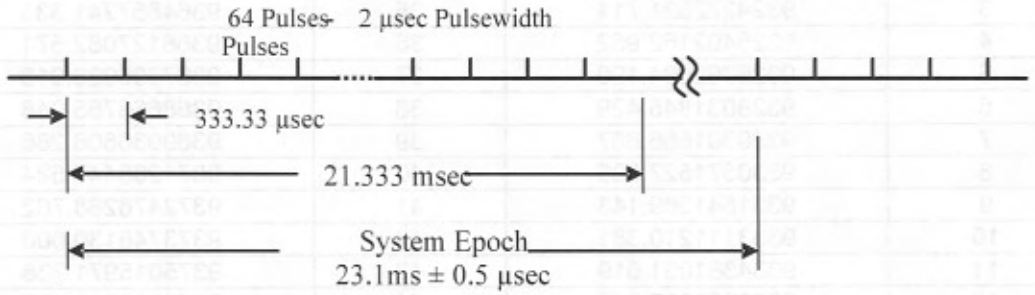

Figure F-2. Transmit Pulse Pattern – Windshear Mode

Frequency Selection:

The WRAU-2120 is capable of tuning to 64 different frequencies which are listed in Table F-2 below. Use of multiple frequencies significantly improves the accuracy of weather and ground target amplitude estimations. Each operating mode uses a subset of the available frequencies.

Table F-2. WRAU-2120 Channel Frequencies

DDS CH	X Band TX (Hz)	DDS CH	X Band TX (Hz)
0	9320412798.000	32	9361047717.619
1	9321682639.238	33	9362317558.857
2	9322952480.476	34	9363587400.095
3	9324222321.714	35	9364857241.333
4	9325492162.952	36	9366127082.571
5	9326762004.190	37	9367396923.810
6	9328031845.429	38	9368666765.048
7	9329301686.667	39	9369936606.286
8	9330571527.905	40	9371206447.524
9	9331841369.143	41	9372476288.762
10	9333111210.381	42	9373746130.000
11	9334381051.619	43	9375015971.238
12	9335650892.857	44	9376285812.476
13	9336920734.095	45	9377555653.714
14	9338190575.333	46	9378825494.952
15	9339460416.571	47	9380095336.190
16	9340730257.810	48	9381365177.429
17	9342000099.048	49	9382635018.667
18	9343269940.286	50	9383904859.905
19	9344539781.524	51	9385174701.143
20	9345809622.762	52	9386444542.381
21	9347079464.000	53	9387714383.619
22	9348349305.238	54	9388984224.857
23	9349619146.476	55	9390254066.095
24	9350888987.714	56	9391523907.333
25	9352158828.952	57	9392793748.571
26	9353428670.190	58	9394063589.810
27	9354698511.429	59	9395333431.048
28	9355968352.667	60	9396603272.286
29	9357238193.905	61	9397873113.524
30	9358508035.143	62	9399142954.762
31	9359777876.381	63	9400412796.000

Weather Operation:

Ten frequencies from Table F-2 are allocated for Weather, Turbulence and Mapping. These are:

F1 – 9354.698511429 MHz (Channel 27)
F2 – 9355.968352667 MHz (Channel 28)
F3 – 9357.238193905 MHz (Channel 29)
F4 – 9358.508035143 MHz (Channel 30)
F5 – 9359.777876381 MHz (Channel 31)
F6 – 9361.047717619 MHz (Channel 32)
F7 – 9362.317558857 MHz (Channel 33)
F8 – 9363.587400095 MHz (Channel 34)
F9 – 9364.857241333 MHz (Channel 35)
F10 – 9366.127082571 MHz (Channel 36)

The radar randomly selects one of the ten frequencies for each Epoch and transmits a set of one 25 μsec pulse followed by four 6 μsec pulses on the same frequency. The next Epoch transmitted pulse set (one 25 μsec pulse and four 6 μsec pulses) occurs on one of the nine remaining frequencies. This pattern is repeated until all ten frequencies are used. The software ensures that the same frequency is not repeated between adjacent pulse sets.

Windshear Operation:

One frequency from Table F-2 is allocated to Windshear operation. This frequency is fixed for all pulse sets. Each Windshear Epoch transmits 64, two-microsecond pulses on the same frequency. The next epoch is transmitted on the same frequency. The Windshear frequency is:

F11 – 9333.111210381 MHz (Channel 10)

During normal Weather/Turbulence/Map operation without Windshear mode activated, both the left to right and right to left sweeps of the antenna utilize the ten weather frequencies and pulse patterns from Figure F-1 above. In this condition, each antenna sweep is 180 degrees wide and requires 4 seconds each direction.

When Windshear mode is activated along with Weather/Turbulence/Map mode, the right to left sweep of the antenna employs the Windshear pulse pattern in Figure F-2 and the Windshear frequency. The left to right sweep of the antenna is per the weather pulse pattern and frequencies described above. In Windshear mode, the total width of the antenna scan is reduced to 120 degrees which requires 3 seconds each direction.

Internal Test Operation:

At the end of each antenna sweep seven test functions are performed.

1. Freq channeling monitor results in transmissions on two designated frequencies, Channel 10 (9333.111210381 MHz) for Windshear sweeps and Channel 31 (9359.777876381 MHz) for weather sweeps,
2. Noise figure,
3. Gain Accuracy,
4. VGA Gain Monitor,
5. AM Modulation, on Channel 10,
6. Droop, on Channel 10, and
7. RX Spectrum, during Windshear.

F.3 Special FCC Test Conditions

To demonstrate compliance of the WRAU-2120 over the full range of frequencies listed in Table F-2, it is necessary to configure the R/T unit in a special test condition. Two types of special configurations were used.

1. Fixed Frequency Operation

The WRAU-2120 can be locked onto a single fixed frequency by commands through the maintenance channel input. The radar operates identically in all respects to normal operation including transmitter pulse patterns with the exception that the transmit frequency is locked to a single channel. Fifteen conditions were defined; 14 fixed frequency channels and one normal operating condition with the normal channel selections. The 14 fixed frequencies were selected to represent the lowest and highest channel extremes plus the normal channels and one additional channel between the highest normal channel and the highest possible channel. These special test conditions were used during subsequent testing described in this exhibit.

2. Maximum Channel Frequency

To measure Occupied Bandwidth over the maximum channel extremes, the WRAU-2120 was locked to each of the 14 fixed channels (lowest, highest, and 12 intermediate) while the spectrum analyzer captured an entire plot of each channel in the peak hold mode of operation. The peak hold mode of operation allowed a composite spectrum analyzer plot to be generated representing the maximum possible occupied bandwidth. The frequencies and assignments utilized for the Maximum Channel Frequency test configuration are listed below.

F1 – 9320.412798000 MHz	(Channel 0)	Weather/Turb/Windshear
F2 – 9333.111210381 MHz	(Channel 10)	Weather/Turb/Windshear
F3 – 9354.698511429 MHz	(Channel 27)	Weather/Turb/Windshear
F4 – 9355.968352667 MHz	(Channel 28)	Weather/Turb/Windshear
F5 – 9357.238193905 MHz	(Channel 29)	Weather/Turb/Windshear
F6 – 9358.508035143 MHz	(Channel 30)	Weather/Turb/Windshear
F7 – 9359.777876381 MHz	(Channel 31)	Weather/Turb/Windshear
F8 – 9361.047717619 MHz	(Channel 32)	Weather/Turb/Windshear
F9 – 9362.317558857 MHz	(Channel 33)	Weather/Turb/Windshear
F10 – 9363.587400095 MHz	(Channel 34)	Weather/Turb/Windshear
F11 – 9364.857241333 MHz	(Channel 35)	Weather/Turb/Windshear
F12 – 9366.127082571 MHz	(Channel 36)	Weather/Turb/Windshear
F13 – 9383.904859905 MHz	(Channel 50)	Weather/Turb/Windshear
F14 – 9400.412796000 MHz	(Channel 63)	Weather/Turb/Windshear

Table F-3 lists the Special FCC Test Conditions described above and lists which FCC test paragraphs utilized these conditions.

Table F-3. Special FCC Test Conditions

Test Condition	Frequency	Comments	2.1046 RF Pwr Out	2.1049 Occ BW	2.1051 Spur Emiss	2.1053 Spur Radiat	2.1055 Freq Stab
Normal	Switching	Normal Operation	X	X	X	X	
Fixed Channel 0	9320.412798000	Lowest Extreme	X	X	X	X	X
Fixed Channel 10	9333.111210381	Windshear	X	X	X		X
Fixed Channel 27	9354.698511429	Lowest Normal	X	X	X		X
Fixed Channel 28	9355.968352667	Low Normal	X	X	X		X
Fixed Channel 29	9357.238193905	Low-Mid Normal	X	X	X		X
Fixed Channel 30	9358.508035143	Mid-Lowest Normal	X	X	X		X
Fixed Channel 31	9359.777876381	Mid-Low Normal	X	X	X		X
Fixed Channel 32	9361.047717619	Mid-High Normal	X	X	X		X
Fixed Channel 33	9362.317558857	Mid-Highest Normal	X	X	X		X
Fixed Channel 34	9363.587400095	High-Mid Normal	X	X	X		X
Fixed Channel 35	9364.857241333	High Normal	X	X	X		X
Fixed Channel 36	9366.127082571	Highest Normal	X	X	X		X
Fixed Channel 50	9383.904859905	High-Mid	X	X	X		X
Fixed Channel 63	9400.412796000	Highest	X	X	X	X	X
Maximum Channel	Composite	Widest Freq Range		X			

F.4 WRAU-2120 RF Power Output (2.1046)

Requirement:

Section 2.1046(a) "For transmitters other than single sideband, independent sideband and controlled carrier radiotelephone, power output shall be measured at the RF output terminals when the transmitter is adjusted in accordance with the tune-up procedure to give the value of current and voltage on circuit elements specified in 2.1033 (c)(8). The electrical characteristics of the radio frequency load attached to the output terminals when this test is made shall be stated."

Section 2.1033(c)(8) "The dc voltages applied to and dc currents into the several elements of the final radio frequency amplifying device for normal operation over the power range."

Section 87.131, Note 7 "Frequency, emission, and maximum power will be determined by appropriate standards during the certification process".

Test Procedure:

The peak power output of the WRAU-2120 was measured using test equipment connected to the WRAU-2120 antenna terminal. The equipment used for the RF Power Output Test is shown in Table F-4.

Table F-4. Test Equipment Used for RF Power Output Test

Equipment	Manufacturer/Model Number	Specific Identification
Receiver/Transmitter Module	Rockwell Collins RTM-2100 (822-2127-001)	S/N 2GJ4L
Antenna Pedestal	Rockwell Collins DRV-2120 (822-2131-001)	S/N 04
Test Harness	Rockwell Collins Test Harness	827-3389-121
Variable DC Power Source	Sorensen DCR40-13B DC Power Supply	SN 00001257 460-0059-555
Directional Coupler (20 dB)	HP X752D	SN 622 460-0132-809 Component of 460-0132-809
Waveguide Termination	CMT LPT90-1B	SN 970005-001 460-0133-413 Component of 460-0132-809
Waveguide to Coax Adapter	HP X281C	SN 3032A-06660 460-0210-312 Component of 460-0132-809
Attenuator (20 dB)	Weinschel WA1-20	460-0203-439 Component of 460-0132-809
Peak Power Meter	HP 8900D	SN 3607U00446 460-0205-518
Personal Computer	IBM Compatible with WRAU Controller Software	Dell Optiplex GX260 CRP09003

Test Setup:

A functional block diagram of the equipment setup for the RF Power Output Test is shown in Figure F-3. The test equipment setup is shown in Figure F-4.

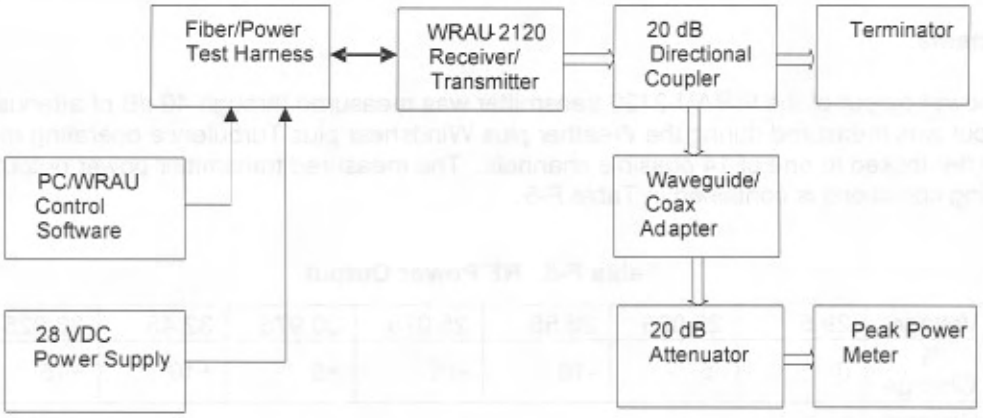

Figure F-3. RF Power Output Test Setup

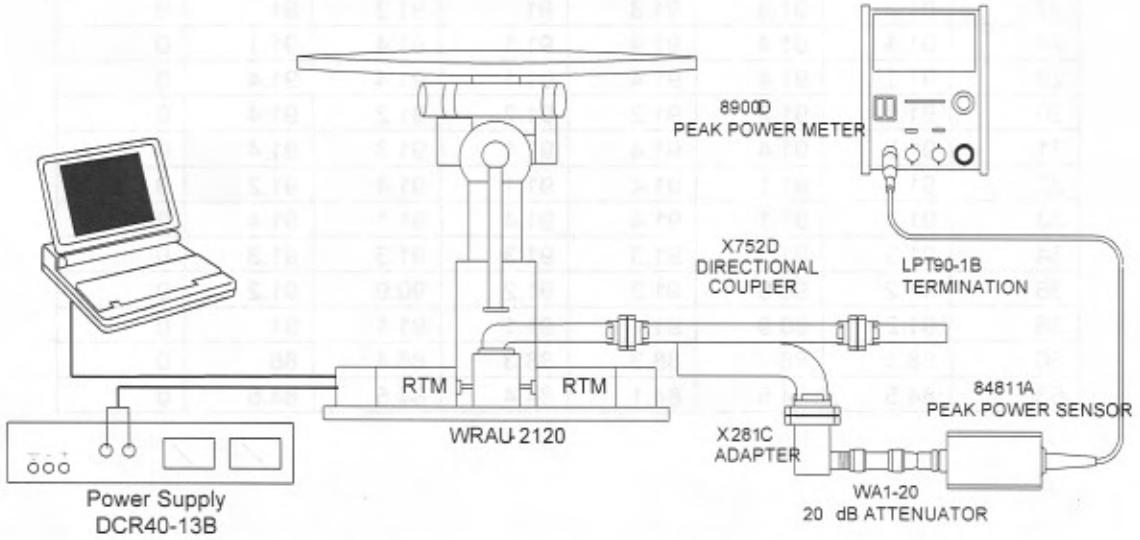

Figure F-4. RF Power Output Test Equipment Setup

Measurements:

Peak RF power output of the WRAU-2120 transmitter was measured through 40 dB of attenuation. The power output was measured during the Weather plus Windshear plus Turbulence operating mode with the transmitter locked to one of 14 possible channels. The measured transmitter power output for each of the operating conditions is contained in Table F-5.

Table F-5. RF Power Output

Voltage	29.5	28.025	26.55	25.075	30.975	32.45	33.925
% Change	0	-5	-10	-15	+5	+10	+15
Channel							
Normal	91.3	91.1	91.4	91.3	91	91.4	0
0	84.3	84.5	84.5	84.3	84.3	84.3	0
10	87.7	87.7	87.7	87.9	88	87.7	0
27	91.3	91.3	91.3	91	91.3	91	0
28	91.4	91.4	91.4	91.1	91.4	91.1	0
29	91.1	91.4	91.4	91.1	91.4	91.4	0
30	91.2	91.2	91.2	91.2	91.2	91.4	0
31	91.5	91.4	91.4	91.1	91.3	91.4	0
32	91.1	91.1	91.4	91.1	91.4	91.2	0
33	91.4	91.1	91.4	91.4	91.1	91.4	0
34	91.3	91.3	91.3	91.3	91.3	91.3	0
35	91.2	90.9	91.2	91.2	90.9	91.2	0
36	91.2	90.9	91.1	91.1	91.1	91	0
50	88.4	88	88.3	88.3	88.4	88	0
63	84.5	84.5	84.1	84.4	84.5	84.5	0

F.5 Frequency Stability (2.1055)

Requirement:

(a) (2) The frequency shall be measured with variation of ambient temperature from -20° to +50° centigrade for equipment licensed for use aboard aircraft in the Aviation Services under part 87 of FCC Code of Federal Regulations Title 47.

(b) The frequency measurement shall be made at the extremes and at intervals of not more than 10° centigrade through the range. A period of time sufficient to stabilize all of the components of the oscillator circuit at each temperature level shall be allowed prior to frequency measurement.

(d) (1) (3) The frequency stability shall be measured with variation of primary supply voltage from 85 to 115 percent of the nominal value. The supply voltage shall be measured at the input to the cable normally provided with the equipment, or at the power supply terminals if cables are not normally provided.

Per 87.133 (a) Frequency tolerance for Frequency band (8) 2450 to 10500 MHz – Note 9,

"Where specific frequencies are not assigned to radar stations, the bandwidth occupied by the emissions of such stations must be maintained within the band allocated to the service and the indicated tolerance (1250 ppm) does not apply."

Procedure:

The transmitted frequency of the WRAU-2120 was measured using a temperature chamber and test equipment. The equipment used for the Frequency Stability test is shown in Table F-6.

Table F-6. Equipment Used for Frequency Stability Test

Equipment	Manufacturer/Model Number	Specific Identification
Receiver/Transmitter	Rockwell Collins RTM-2100 (822-2127-001)	S/N 2GJ4L
Antenna Pedestal	Rockwell Collins DRV-2120 (822-2131-001)	S/N 04
Test Harness	Rockwell Collins Test Harness	827-3389-121
Variable Power Source	Sorensen DCR40-13B DC Power Supply	SN 00001257 460-0059-555
Waveguide to Coax Adapter	HP X281C	SN 3032A-06660 460-0210-312 Component of 460-0132-809
Attenuator (3 dB)	Weinschel 33-3-34	SN AU5874 460-0085-771
Attenuator (3 dB)	Weinschel 33-3-34	SN AW1613 460-0200-978
Attenuator (20 dB)	Weinschel WA1-20	460-0203-439 Component of 460-0132-809
Spectrum Analyzer	Agilent 8564EC	SN 4123A00551 460-0132-916
Temperature Chamber	Thermotron M-8C	SN 21046 460-0075-030

Equipment Setup:

The test setup for the Frequency Stability test is shown in Figure F-5.

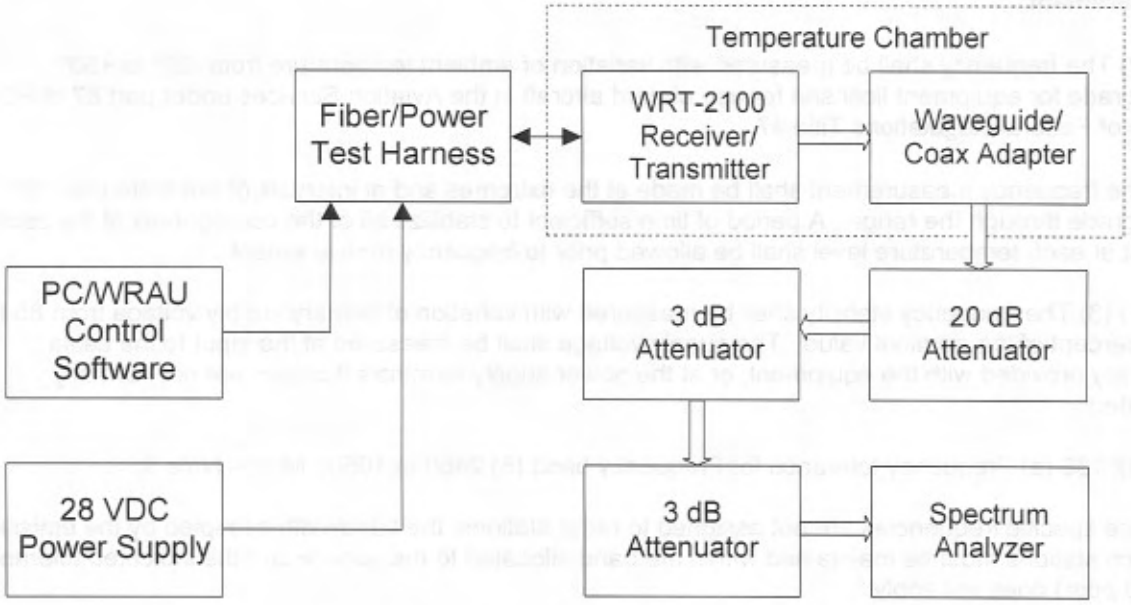

Figure F-5. Frequency Stability Test Setup

Line Voltage Test:

The unit was operated on the bench at ambient temperature. The line voltage was varied from 85% to 115% of 29.5 VDC (25.08 VDC to 33.93 VDC). All frequency stability tests were conducted with the Receiver/Transmitter operating in the Weather plus Turbulence plus Windshear mode with the frequency locked to a fixed specified in Table F-7 below.

Line Voltage Test Measurements:

Frequency Stability vs Line Voltage Test results are shown in Table F-7.

Table F-7. Transmitted Frequency vs. Input Voltage

Line Voltage (VDC)	Frequency (Spectrum Analyzer) (MHz)							
	Chan 0	Chan 9	Chan 18	Chan 27	Chan 36	Chan 45	Chan 54	Chan 63
25.08 (29.5-15%)	9,320.355	9,331.778	9,343.208	9,354.638	9,366.066	9,377.495	9,388.923	9,400.351
26.55 (29.5-10%)	9,320.353	9,331.776	9,343.209	9,354.637	9,366.066	9,377.493	9,388.922	9,400.350
28.03 (29.5-5%)	9,320.352	9,331.779	9,343.208	9,354.637	9,366.066	9,377.494	9,388.924	9,400.351
29.5	9,320.355	9,331.785	9,343.210	9,354.640	9,366.068	9,377.498	9,388.925	9,400.350
30.98 (29.5+5%)	9,320.351	9,331.780	9,343.207	9,354.637	9,366.065	9,377.492	9,388.923	9,400.350
32.45 (29.5+10%)	9,320.349	9,331.779	9,343.209	9,354.633	9,366.063	9,377.493	9,388.919	9,400.349
33.93 (29.5+15%)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Results:

There were no out of tolerance frequency variations as a result of line voltage variations from 25.08 VDC to 32.45 VDC. At approximately 33 VDC, the UUT shut itself off.

Temperature Test:

The WRAU-2120 was placed in a temperature chamber with all other equipment outside at room ambient. The test unit was operated using nominal 29.5 VDC primary power and the temperature varied from –55 °C to +70 °C. The WRAU-2120 frequency was measured on the Spectrum Analyzer. Sufficient time was allowed to stabilize the unit after the chamber reached the desired temperature. Data was taken in 10 degree (or less) steps.

Temperature Test Measurements:

Raw temperature test results are shown in Table F-8. Figure F-6 shows a plot temperature vs. frequency for all channels. Figure F-7 shows a magnification of channels 27-36.

Table F-8. Transmitted Frequency vs. Temperature

Temp. (°C)	Frequency (Spectrum Analyzer) (MHz)						
	Chan 0	Chan 10	Chan 27	Chan 28	Chan 29	Chan 30	Chan 31
-55	9319.9625	9332.6592	9354.2433	9355.5100	9356.7805	9358.0505	9359.3192
-50	9320.0425	9332.7392	9354.3266	9355.5949	9356.8651	9358.1342	9359.4033
-40	9320.1784	9332.8750	9354.4625	9355.7334	9357.0033	9358.2734	9359.5425
-30	9320.2842	9332.9842	9354.5700	9355.8400	9357.1108	9358.3809	9359.6508
-20	9320.3559	9333.0541	9354.6408	9355.9108	9357.1825	9358.4500	9359.7217
-10	9320.3951	9333.0950	9354.6825	9355.9517	9357.2225	9358.4925	9359.7625
0	9320.4126	9333.1117	9354.6983	9355.9684	9357.2383	9358.5084	9359.7775
10	9320.4008	9333.1000	9354.6867	9355.9575	9357.2267	9358.4958	9359.7659
20	9320.3683	9333.0683	9354.6550	9355.9242	9357.1942	9358.4642	9359.7334
30	9320.3175	9333.0167	9354.6016	9355.8725	9357.1425	9358.4117	9359.6817
40	9320.2492	9332.9484	9354.5350	9355.8051	9357.0708	9358.3425	9359.6125
50	9320.1791	9332.8767	9354.4646	9355.7334	9357.0033	9358.2725	9359.5425
60	9320.1016	9332.8000	9354.3875	9355.6557	9356.9258	9358.1958	9359.4658
70	9320.0183	9332.7158	9354.3025	9355.5717	9356.8416	9358.1108	9359.3800

Temp. (°C)	Frequency (Spectrum Analyzer) (MHz)						
	Chan 32	Chan 33	Chan 34	Chan 35	Chan 36	Chan 50	Chan 63
-55	9360.5900	9361.8583	9363.1295	9364.3987	9365.6692	9383.4442	9399.9508
-50	9360.6734	9361.9425	9363.2125	9364.4825	9365.7517	9383.5291	9400.3470
-40	9360.8125	9362.0825	9363.3525	9364.6225	9365.8933	9383.6691	9400.1775
-30	9360.9208	9362.1900	9363.4608	9364.7308	9366.0000	9383.7775	9400.2858
-20	9360.9916	9362.2608	9363.5316	9364.8000	9366.0717	9383.8484	9400.3558
-10	9361.0166	9362.3017	9363.5725	9364.8425	9366.1125	9383.8900	9400.3983
0	9361.0483	9362.3184	9363.5875	9364.8584	9366.1283	9383.9050	9400.4133
10	9361.0359	9362.3059	9363.5758	9364.8458	9366.1150	9383.8933	9400.4008
20	9361.0033	9362.2725	9363.5425	9364.8124	9366.0824	9383.8592	9400.3661
30	9360.9516	9362.2217	9363.4908	9364.7607	9366.0299	9383.8076	9400.3150
40	9360.8825	9362.1517	9363.4208	9364.6915	9365.9624	9383.6658	9400.2466
50	9360.8100	9362.0800	9363.3500	9364.6184	9365.8892	9383.5916	9400.1733
60	9360.7358	9362.0050	9363.2750	9364.5442	9365.8142	9383.5916	9400.0975
70	9360.6492	9361.9200	9363.1900	9364.4592	9365.7292	9383.5066	9400.0142

Results:

There were no out of tolerance frequency variations as a result of temperature extremes from -55C to +70C.

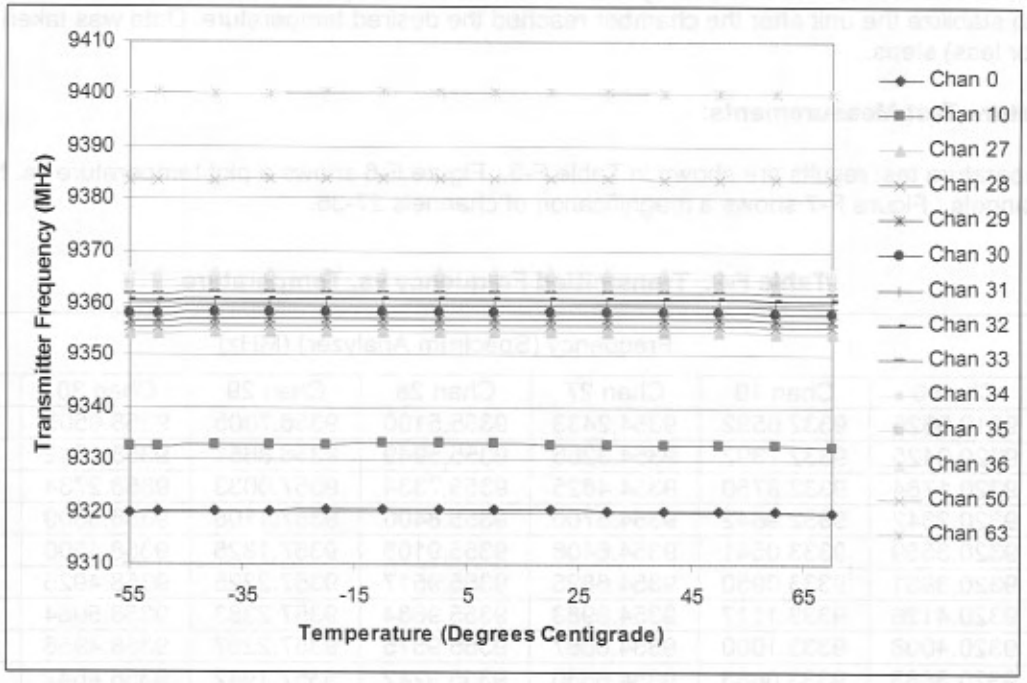

Figure F-6. Transmitter Frequency Stability vs. Temperature

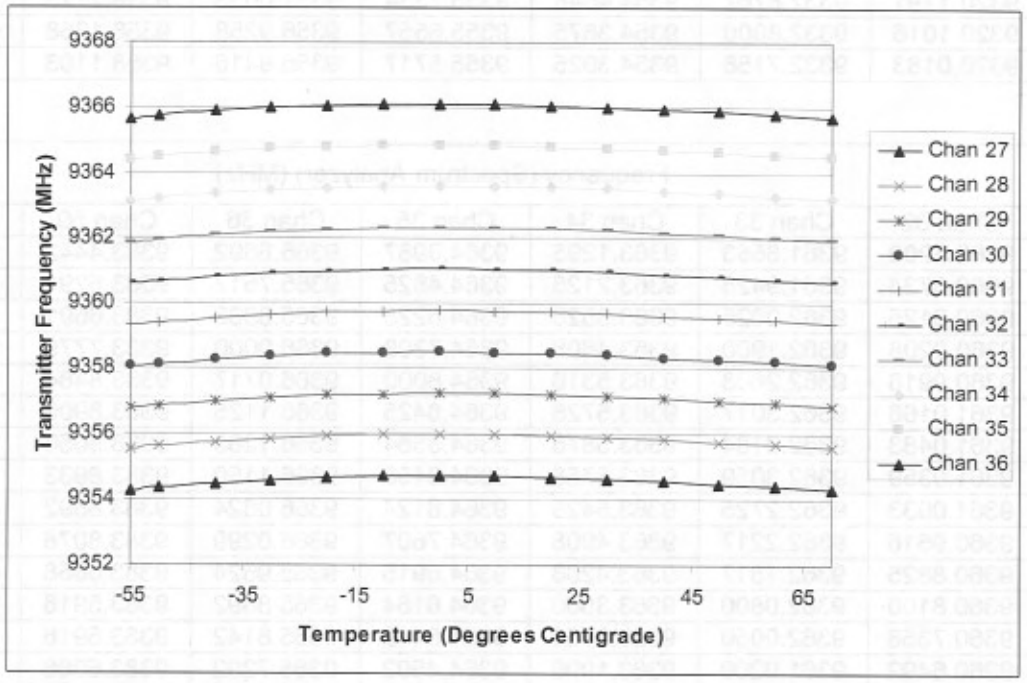

Figure F-7. Magnification of Center Frequencies vs. Temperature