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Transmitter Signal Measurements, Task 5C Report

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September 2005

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1 INTRODUCTION

NASA National Aeronautics and Space Administration (NASA) and Delta continue to collect quantitative data through the Cooperative Agreement NCC-1-381. Task 5C – Transmitter Signal Measurements was completed and this report summarizes the work accomplished, the findings, and data that were generated. Signal Measurements were obtained on four (4) different airport systems. Systems measured were Localizer (LOC), Very High Frequency Communication, (VHF), Glideslope, (G/S), and Global Positioning System (GPS). The task calls for path loss measurements to be taken at Hartsfield-Jackson International Airport (ATL) and one smaller airport which was Greenville/Spartanburg Airport (GSP) to determine relative signal strengths on the airport properties.

2 PURPOSE

The purpose of this report is to collect and summarize the data that was collected that will enable us better understand the Radio Frequency (RF) environment at a larger and smaller airport. This data will be used to ensure adequate safety margins of comm/nav (communication and navigation) systems exist in current and future assessments of Portable Electronic Device (PED) policies. These PEDs include all devices operated in or around the aircraft by crews, passengers, servicing personnel, as well as the general public in the airport area. This data may also be used comparatively with theoretical analysis and computer modeling data sponsored by NASA Langley Research Center.

3 TECHNICAL APPROACH & PROCEDURES SET-UP AND CALIBRATION

A mock up aircraft fuselage was designed that housed the four particular antennas for Very High Frequency, Glide Slope, Localizer and Global Positioning System. These antennas were mounted on various positions of the exterior surface of the mockup, similar to the antenna configuration on aircraft. Figures 1, 2, and 3 show the layout of the antennas on the mockup. This mockup was placed on the bed of a truck which was positioned at different locations around the two airport properties collecting samples in the various frequency ranges.

The comm/nav systems were tested one at a time. A RG214 test cable was run from the test equipment location through a side window. This cable was connected to the spectrum analyzer input. The other end of the cable was connected to the test antenna.

All cables, amplifiers, spectrum analyzer, and test antennas were calibrated prior to test, or verified as calibrated by use of the manufacturer's data. This allows the collected data to be corrected after the fact, to remove any effect introduced by the test equipment. The receiving antenna type, polarization, power and location are recorded in a data collection log. The raw uncorrected power received by the spectrum analyzer is entered in the log using the on-screen marker of frequency and power level.

The spectrum analyzer was calibrated, using the internal routine, at each setup before colleting data. The settings, antenna type, and cables used to connect the equipment were recorded for each comm/nav system measured as well as the testing location. The spectrum analyzer was connected to a laptop computer and measurement data was recorded and stored in memory.

Figure 1 – Test Team and Antenna Mockup

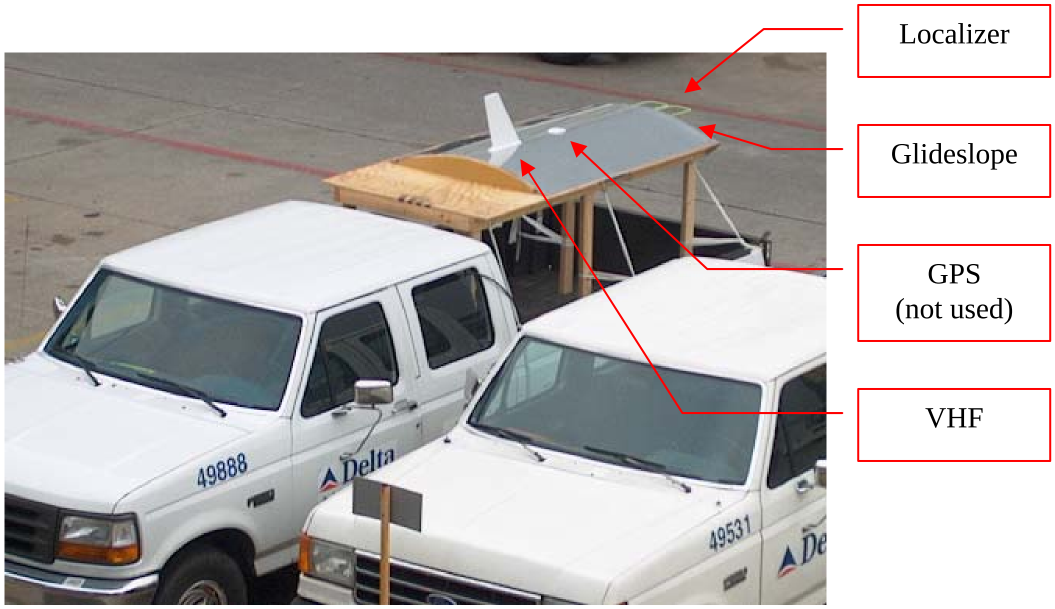

Figure 2 – Truck (overhead view)

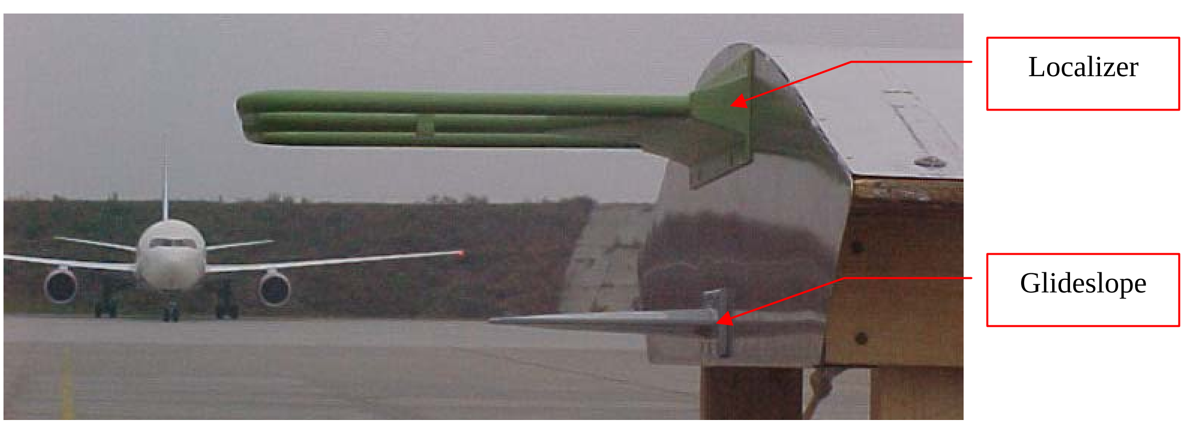

Figure 3 – Close-up of Antenna Mockup

In Atlanta there are currently four runways oriented to the East and West. Figure 4 is a diagram of Atlanta's airport and runways. The test points are indicated with red circles in the figure below.

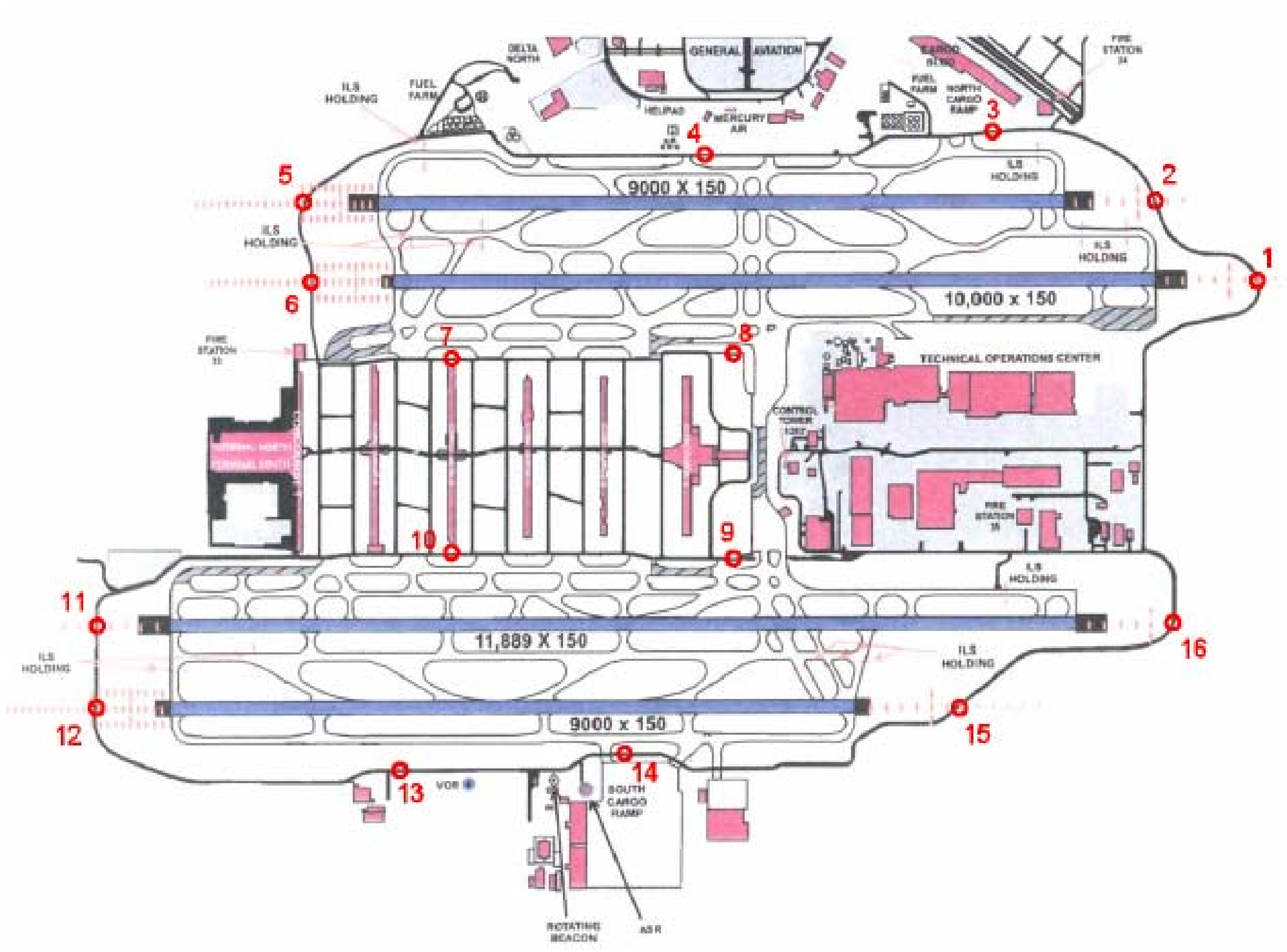

Figure 4 – Atlanta Airport Diagram

Table 1 – Conditions During Testing

Location/Date	Skies	Visibility
Atlanta (ATL) 10/21/04 AM	Overcast/Light Fog	1.5 miles
Atlanta (ATL) 10/21/04 PM	Overcast	2.5 miles
Atlanta (ATL) 10/22/04	Partly Cloudy	Good
Greenville/Spartanburg (GSP) 11/4 Noon	Light to Heavy Rain	0.75 miles

Greenville Spartanburg International Airport was also visited and included in Table 1. Figure 5 shows the aerial view of GSP and the single runway. At GSP six (6) test points were selected – one at each end of the runway, two (2) points on each side of the runway. The test points are indicated with red circles in Figure 5. The same crew operated the equipment in GSP and ATL with essentially the same setup.

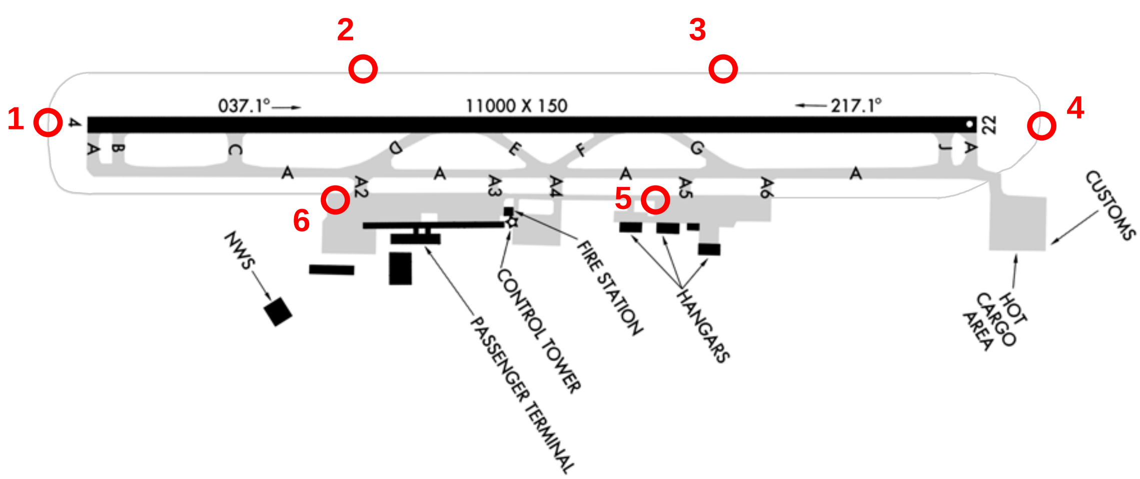

Figure 5 - Greenville/Spartanburg Airport Diagram

Figure 6 - GSP Tower

Figure 7 - GSP Field Conditions

4 DATA GATHERED

4.1 Localizer (LOC)

LOC provides lateral guidance relative to the runway centerline in an ILS landing system. LOC is a highly directional signal using a multi-element phased antenna system that is horizontally polarized. Since we were limited to the elevation of the runway or below and due to the directivity of the LOC signal, it was impossible to measure the desired signal except at one or two test points.

Figure 8 - Localizer Near Atlanta Test Point 2

4.2 Very High Frequency (VHF)

VHF data was collected over the complete commercial aviation VHF frequency range (116-138 MHz) and individual VHF frequency correlated with ground control or tower control. Since we were most interested in safe operations at the terminal environment, a ground control frequency was selected at each site (121.75 MHz-ATL, 121.9 MHz-GSP).

Data was reviewed for the VHF spectrum activity, the strength of signals for ground and tower frequencies, and the corresponding noise floor. ATL and GSP exhibited similar readings and safety margins from the required signal strengths. Average margins were seen to be from 15 to 40 dB. Test points 11 and 12 in Atlanta along with test point 1 in Greenville/Spartanburg were well below the field elevation and across the runway from the VHF transmitter, which resulted in negative signal margins. Tables 5 and 8 in Section 5 summarize the measurement data for each airport.

Figure 9 - VHF Antennas Near Atlanta Test Point 13

4.3 Glideslope (GS)

GS data was taken around the frequency of 332 MHz. GLS is vertically directed and uses amplitude modulations of 90 and 150 kHz like the localizer. Glideslope provides vertical guidance in an ILS instrument landing system.

Figure 10 - GS Antennas Near Atlanta Test Point 3

4.4 Global Positioning System (GPS)

GPS data was initially taken using an aircraft passive GPS antenna, but no signal could be found even when using an amplifier. Alternately, a Garmin GPS receiver was used to determine the number of satellites that could be acquired at each test point and the relative accuracy calculated by the GPS device. A Garmin receiver was used in ATL and GSP. The exact position of each test point was collected and shown in Table 2 and Table 3.

GPS was observed to have at least five (5) satellites available in ATL and at least six (6) in GSP. Overall signals could not be seen by the spectrum analyzer but the relative signal strength was observed to be high on the Garmin receiver. GPS has the advantage of satellite communications and back-up capabilities. Only four (4) satellites must be seen by the aircraft's multi-mode receiver for GPS. GPS's low power requirement and multiple frequency redundant system make it unlikely that anyone could interfere with the aircraft using Part 15 devices.

Table 2 - Atlanta Airport Test Point Locations

Test Point	Latitude (N33◦)	Longitude (W084)	Elevation (ft)
1	38.809	24.066	975
2	38.966	24.326	989
3	39.101	24.646	979
4	39.077	25.573	991
5	38.975	26.539	1014
6	38.799	26.520	1013
7	38.640	26.169	1043
8	38.653	25.463	1005
9	38.232	25.428	1006
10	38.239	26.127	1023
11	38.081	27.069	1002
12	37.906	27.069	1016
13	37.747	26.463	1010
14	37.787	25.704	979
15	37.912	24.829	955
16	38.082	24.283	914

Atlanta - Field Elevation 1026ft

Table 3 – Greenville/Spartanburg Airport Test Locations

Test Point	Latitude (N34)	Longitude (W082)	Elevation
1	52.791	13.860	893
2	54.014	13.038	949
3	53.368	13.595	904
4	54.659	12.429	935
5	54.101	12.677	955
6	53.301	13.231	937

Greenville/Spartanburg - Field Elevation 963ft

5 RESULTS AND CONCLUSIONS

The measured signal levels are organized by system and summarized in tables below. An antenna shadow loss is included for LOC and GS in accordance with DO-233 since these antennas did not always have line-of-sight view of the transmitting antennas. Since the VHF antenna was mounted on top of the mockup and did have line-of-sight view of the VHF tower, no shadow loss was included in VHF Comm calculations. Appendix 1 contains the spectrum analyzer plots recorded during testing.

The directivity of the LOC and Glideslope antennas was observed to be the line of sight and well above the International Civil Aviation Organization (ICAO) minimum signal levels on the airport property near the runway. Aircraft taxing with Part 15 devices onboard and the field should not be able to interfere with the instrument landing system.

VHF, the sole safety and security communication system during ground operations, is heavily relied upon in the aviation industry. This system must perform reliably in order to support the many aircraft movements taking place. Data collected for this task shows that VHF systems have sufficient safety margin when aircraft are operating on all runways and taxiways.

Although signal levels for GPS could not be measured with the spectrum analyzer, the Garmin GPS receiver indicated at least 5 satellites were available at each test point. It is expected that aircraft using GPS antennas with internal preamplifiers will capture satellite signals much better than the Garmin receiver.

Table 4 - Atlanta Airport Localizer Results

Freq. (MHz)	Test Point	Measured Power (dBm)	Cable Loss (dB)	50 Ohm Conversion (dBuV-dBm)	Antenna Factor (dBuV/m-dBuV)	Shadow Loss (dB)	Incident Field @ Test Point (dBuV/m)	ICAO Min (dBuV/m)	Safety Margin (dB)
109.3	1	N/A							
	2	-36.59	0.53	107	9	3	82.94	32	50.94
	3	-60.54	0.53	107	9	3	58.99	32	26.99
	4	-76.8	0.53	107	9	3	42.73	32	10.73
	5	-78.46	0.53	107	9	3	41.07	32	9.07
	6	-78.46	0.53	107	9	3	41.07	32	9.07
	7	-87.36	0.53	107	9	3	32.17	32	0.17
	8	-77.93	0.53	107	9	3	41.6	32	9.6

Table 6 - Atlanta Airport VHF Comm Results

Freq. (MHz)	Test Point	Measured Power (dBm)	Cable Loss (dB)	50 Ohm Conversion (dBuV-dBm)	Antenna Factor (dBuV/m-dBuV)	Shadow Loss (dB)	Incident Field @ Test Point (dBuV/m)	ICAO Min (dBuV/m)	Safety Margin (dB)
121.75	1	-53.76	0.62	107	10.5	0	64.36	37	27.36
	2	-57.91	0.62	107	10.5	0	60.21	37	23.21
	3	-60.9	0.62	107	10.5	0	57.22	37	20.22
	4	-60.76	0.62	107	10.5	0	57.36	37	20.36
	5	-60.02	0.62	107	10.5	0	58.1	37	21.1
	6	-61.8	0.62	107	10.5	0	56.32	37	19.32
	7	-47.94	0.62	107	10.5	0	70.18	37	33.18
	8	-64.76	0.62	107	10.5	0	53.36	37	16.36
	9	-44.97	0.62	107	10.5	0	73.15	37	36.15
	10	-41.94	0.62	107	10.5	0	76.18	37	39.18
	11	-86.31	0.62	107	10.5	0	31.81	37	-5.19
	12	-79.24	0.62	107	10.5	0	38.88	37	1.88
	13	-58.47	0.62	107	10.5	0	59.65	37	22.65
	14	-59.39	0.62	107	10.5	0	58.73	37	21.73
	15	-62.01	0.62	107	10.5	0	56.11	37	19.11
	16	-30.52	0.62	107	10.5	0	87.6	37	50.6

Table 5 – Atlanta Airport Glideslope Results

Freq. (MHz)	Test Point	Measured Power (dBm)	Cable Loss (dB)	50 Ohm Conversion (dBuV-dBm)	Antenna Factor (dBuV/m-dBuV)	Shadow Loss (dB)	Incident Field @ Test Point (dBuV/m)	ICAO Min (dBuV/m)	Safety Margin (dB)
332	5	-63.35	1.29	107	19	3	66.94	46	20.94
	6	-95.16	1.29	107	19	3	35.13	46	-10.87
	7	-99.78	1.29	107	19	3	30.51	46	-15.49
	8	-89.81	1.29	107	19	3	40.48	46	-5.52

Table 7 – Greenville/Spartanburg Airport Localizer Results

Freq. (MHz)	Test Point	Measured Power (dBm)	Cable Loss (dB)	50 Ohm Conversion (dBuV-dBm)	Antenna Factor (dBuV/m-dBuV)	Shadow Loss (dB)	Incident Field @ Test Point (dBuV/m)	ICAO Min (dBuV/m)	Safety Margin (dB)
109.3	1	-108.61	0.53	107	9	3	10.92	32	-21.08
	2	-94.55	0.53	107	9	3	24.98	32	-7.02
	3	-72.12	0.53	107	9	3	47.41	32	15.41
	4	-37.75	0.53	107	9	3	81.78	32	49.78
	5	-71.68	0.53	107	9	3	47.85	32	15.85
	6	-85.67	0.53	107	9	3	33.86	32	1.86

Table 8 - Greenville/Spartanburg Airport VHF Comm Results

Freq. (MHz)	Test Point	Measured Power (dBm)	Cable Loss (dB)	50 Ohm Conversion (dBuV-dBm)	Antenna Factor (dBuV/m-dBuV)	Shadow Loss (dB)	Incident Field @ Test Point (dBuV/m)	ICAO Min (dBuV/m)	Safety Margin (dB)
120.1	1	-71.13	0.62	107	10.5	0	46.99	37	9.99
120.1	2	-58.97	0.62	107	10.5	0	59.15	37	22.15
120.1	3	-39.87	0.62	107	10.5	0	78.25	37	41.25
120.1	4	-69.92	0.62	107	10.5	0	48.2	37	11.2
120.1	5	-51.66	0.62	107	10.5	0	66.46	37	29.46
120.1	6	-60.44	0.62	107	10.5	0	57.68	37	20.68
121.9	1	-80.49	0.62	107	10.5	0	37.63	37	0.63
121.9	2	-54.62	0.62	107	10.5	0	63.5	37	26.5
121.9	3	-36.12	0.62	107	10.5	0	82	37	45
121.9	4	-61.93	0.62	107	10.5	0	56.19	37	19.19
121.9	5	-48.93	0.62	107	10.5	0	69.19	37	32.19
121.9	6	-58.17	0.62	107	10.5	0	59.95	37	22.95

Table 9 - Greenville/Spartanburg Airport Glideslope Results

Freq. (MHz)	Test Point	Measured Power (dBm)	Cable Loss (dB)	50 Ohm Conversion (dBuV-dBm)	Antenna Factor (dBuV/m-dBuV)	Shadow Loss (dB)	Incident Field @ Test Point (dBuV/m)	ICAO Min (dBuV/m)	Safety Margin (dB)
332	1	-80.2	1.29	107	19	3	50.09	46	4.09
332	2	-73.49	1.29	107	19	3	56.8	46	10.8
332	3	-98.2	1.29	107	19	3	32.09	46	-13.91
330.2	4	-79.87	1.29	107	19	3	50.42	46	4.42
330.2	5	-84.71	1.29	107	19	3	45.58	46	-0.42
332	6	-96.56	1.29	107	19	3	33.73	46	-12.27

6 RECOMMENDATIONS

- One reason safety margins were not as high as expected is due to the inability of our truck to access points on the normal taxiway and runway. This test needs to be repeated on aircraft, utilizing the installed systems, by taxiing to various points of interest to get an accurate assessment of the received signal.

- Another reason margins were not as good as expected is the directivity of the localizer and glideslope signals. A shadow loss of 3 dB was included in the calculation due to the mounting location of the receiving antennas on the mockup. (3 dB was used in DO-233 calculations)

- The VHF system provided good results and is the safety system used for ground operations. We should limit the scope of any future tests to the VHF frequency band to access the most critical system on the ground.

- Readers should only utilize data from the VHF system at points at or above field elevation.

- TCAS might be included in future testing depending on the progress of multilateration initiatives.

1 APPENDIX 1 – SPECTRUM ANALYZER PLOTS

1.1 Atlanta Localizer (Aircraft Landing on Runway 8L)

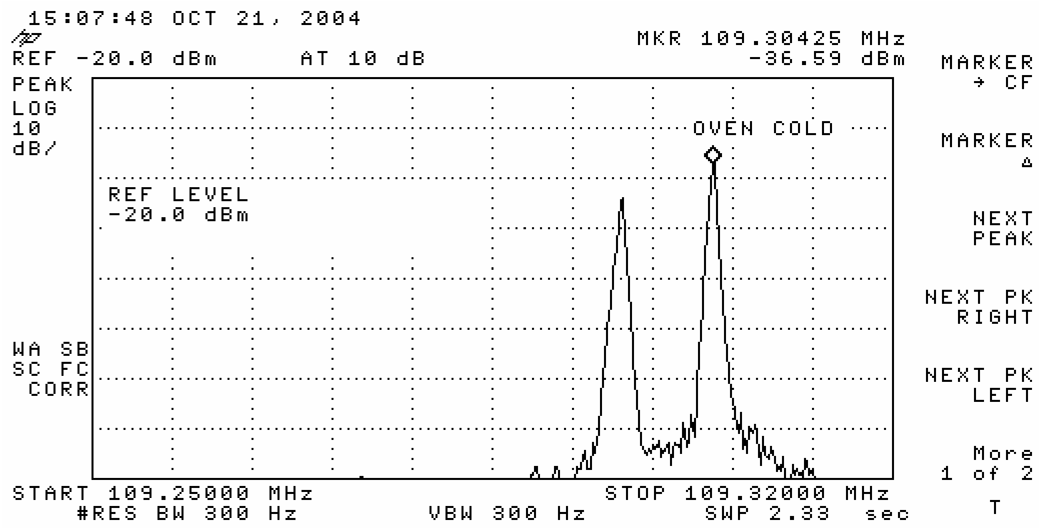

Figure 1 - Test Point 2 LOC Signal

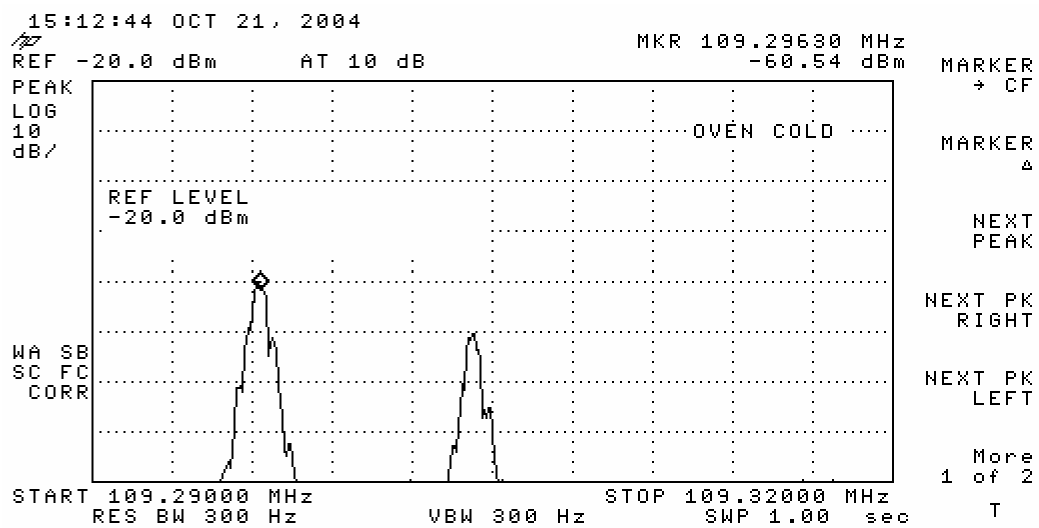

Figure 2 - Test Point 3 LOC Signal

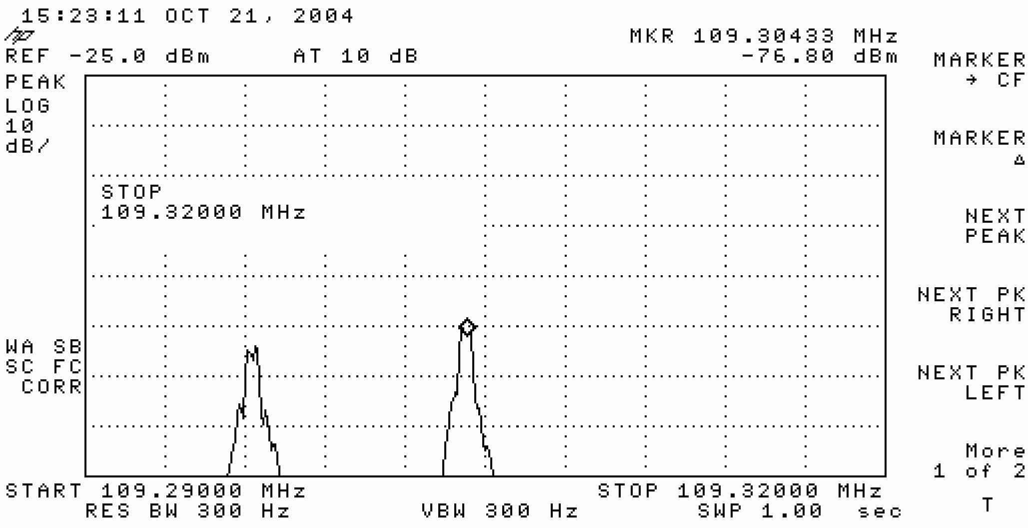

Figure 3 - Test Point 4 LOC Signal

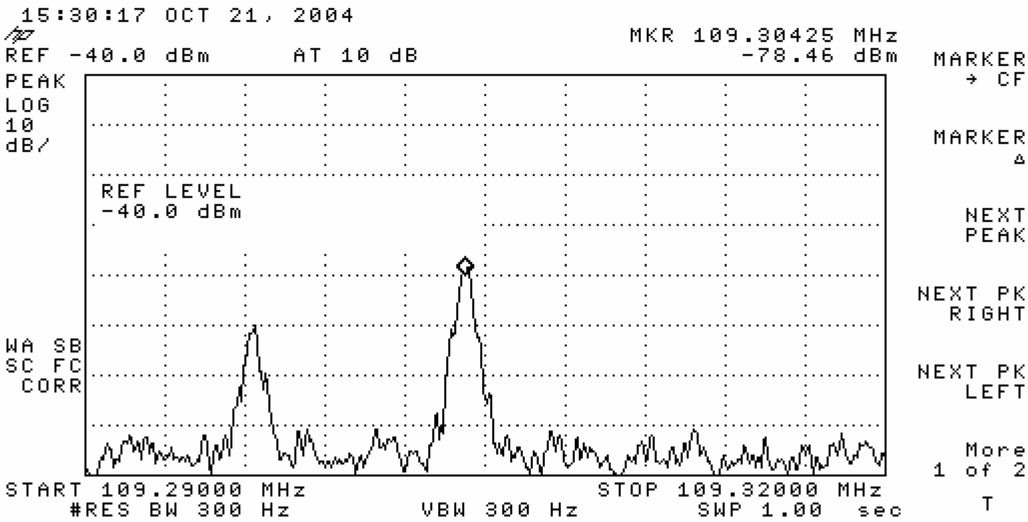

Figure 4 - Test Point 5 and 6 LOC Signal

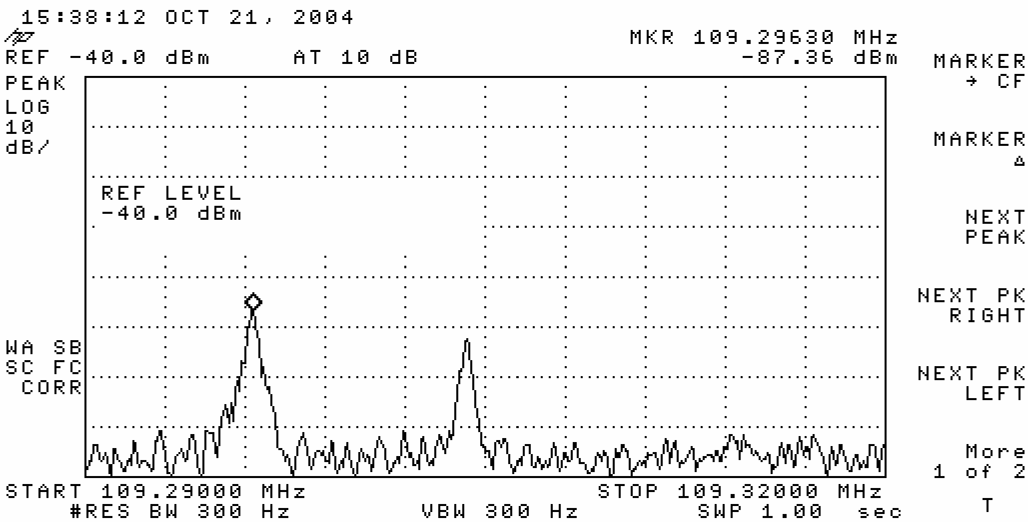

Figure 5 - Test Point 7 LOC Signal

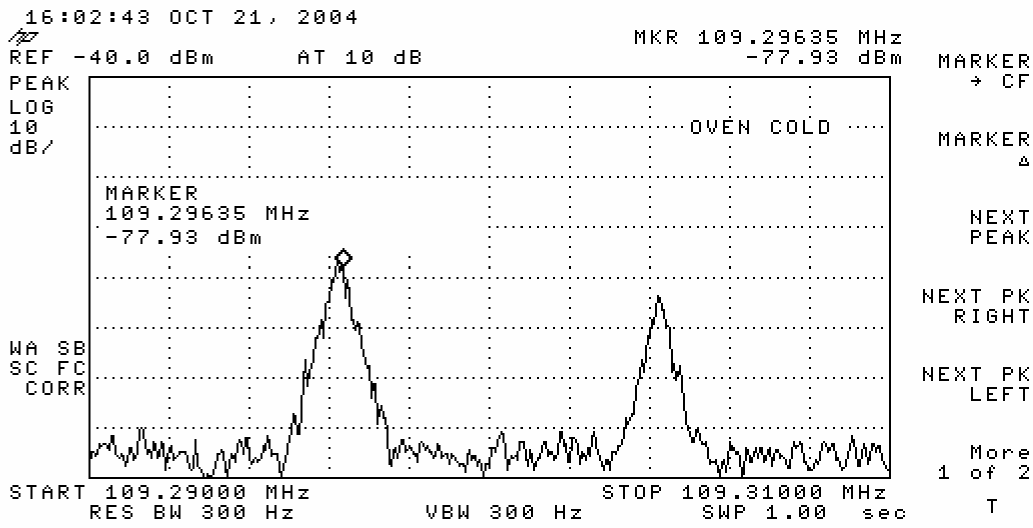

Figure 6 - Test Point 8 LOC Signal

1.2 Atlanta VHF Comm (121.75 MHz)

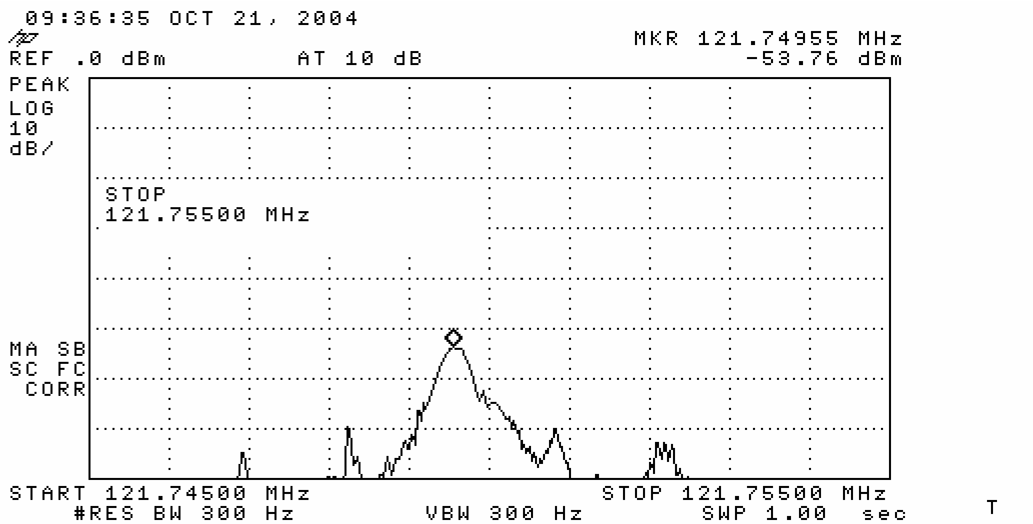

Figure 7 - Test Point 1 VHF Signal

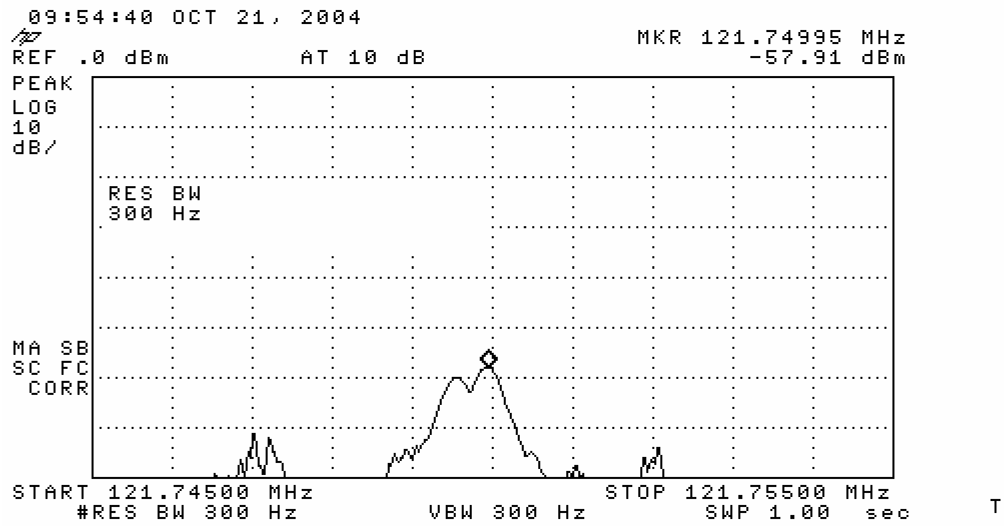

Figure 8 - Test Point 2 VHF Signal

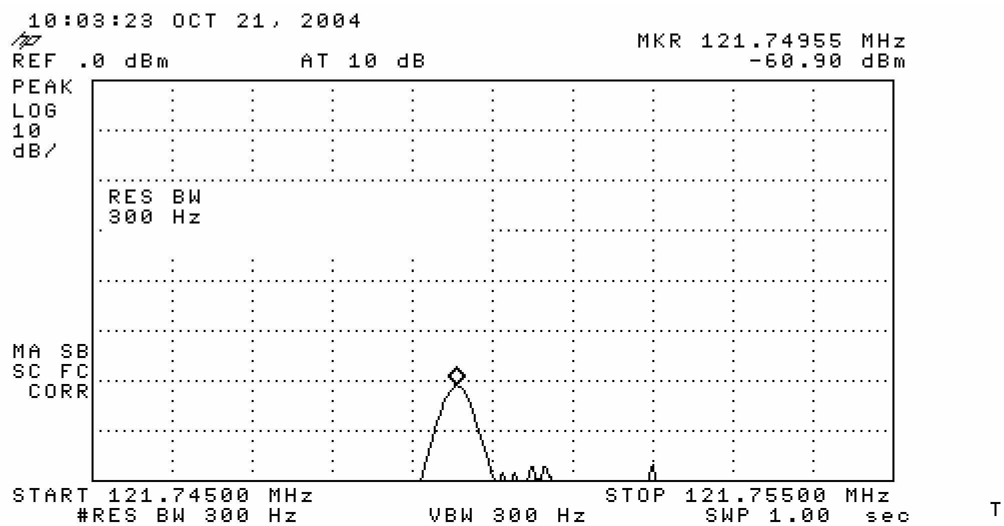

Figure 9 - Test Point 3 VHF Signal

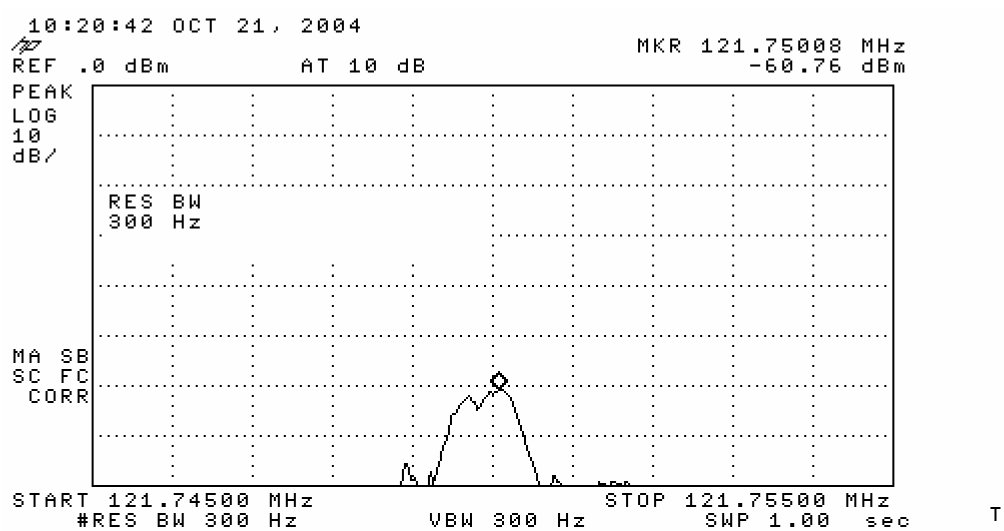

Figure 10 - Test Point 4 VHF Signal

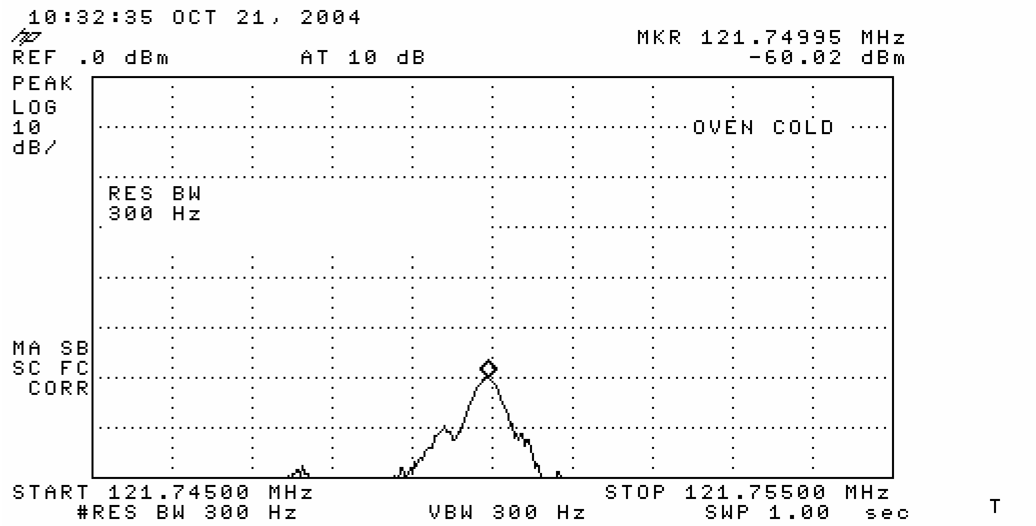

Figure 11 - Test Point 5 VHF Signal

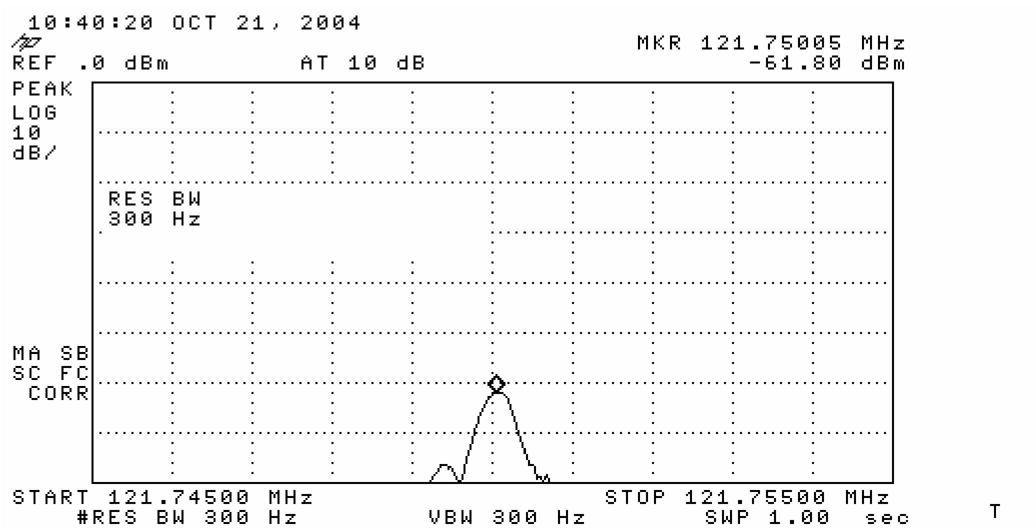

Figure 12 - Test Point 6 VHF Signal

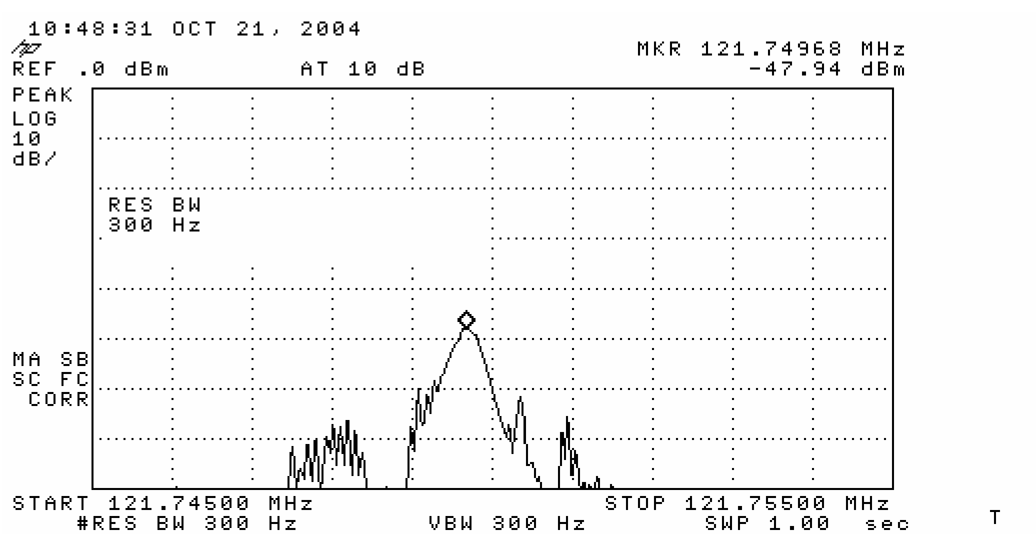

Figure 13 - Test Point 7 VHF Signal

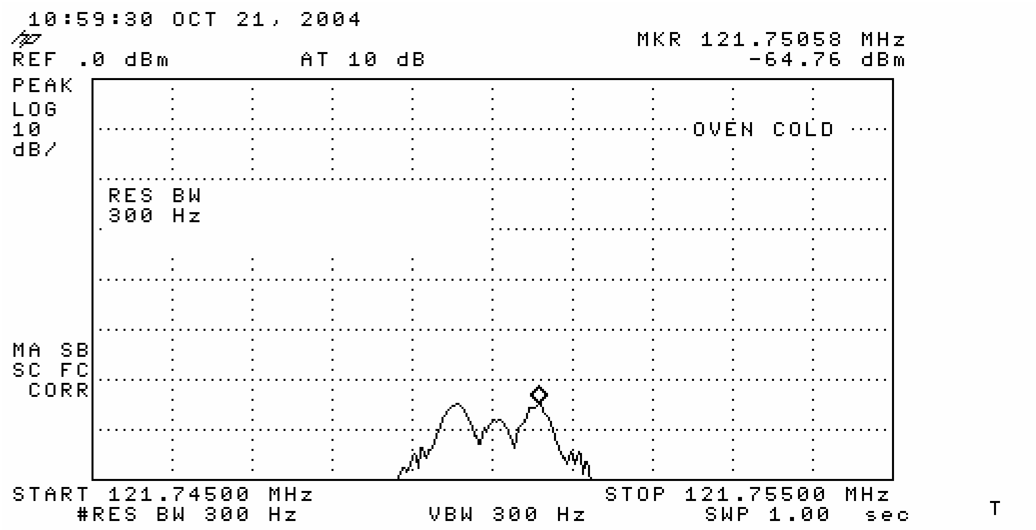

Figure 14 - Test Point 8 VHF Signal

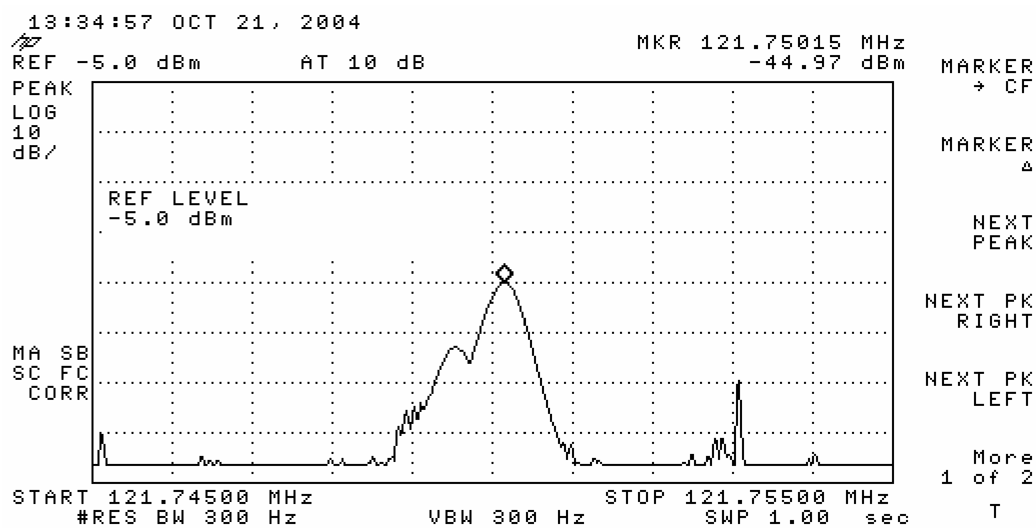

Figure 15 - Test Point 9 VHF Signal

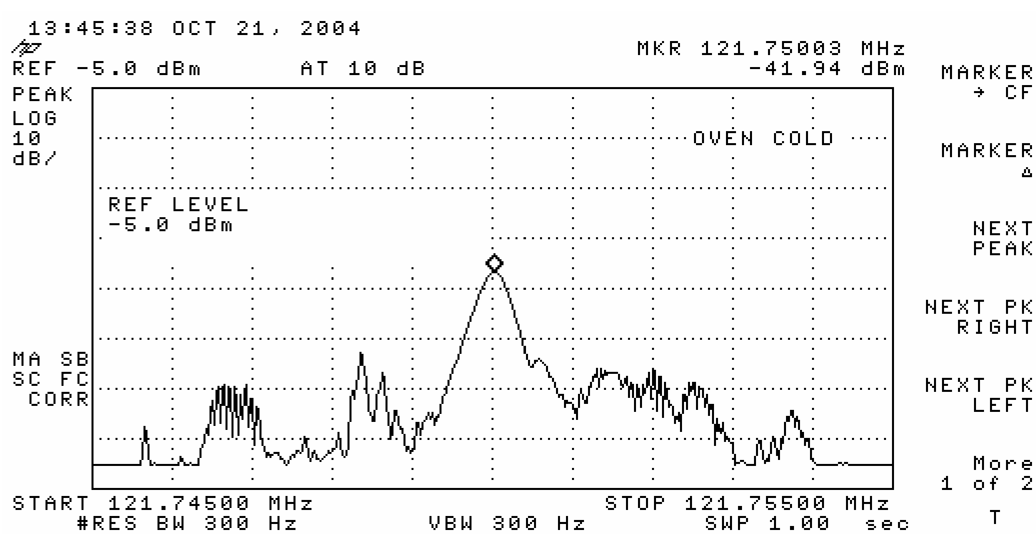

Figure 16 - Test Point 10 VHF Signal

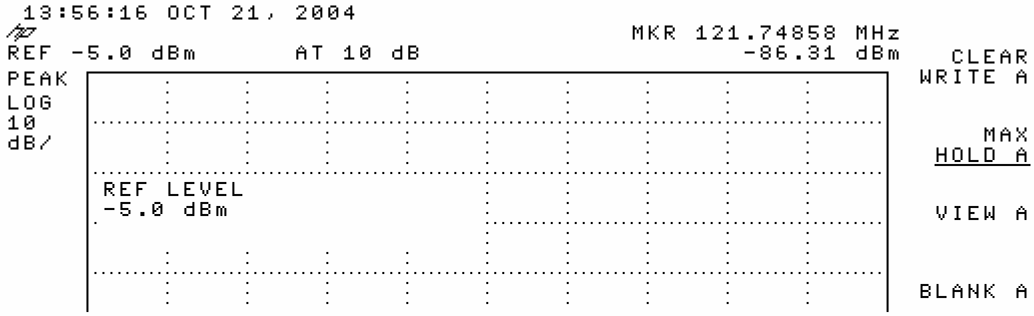

Figure 17 - Test Point 11 VHF Signal (image incomplete)

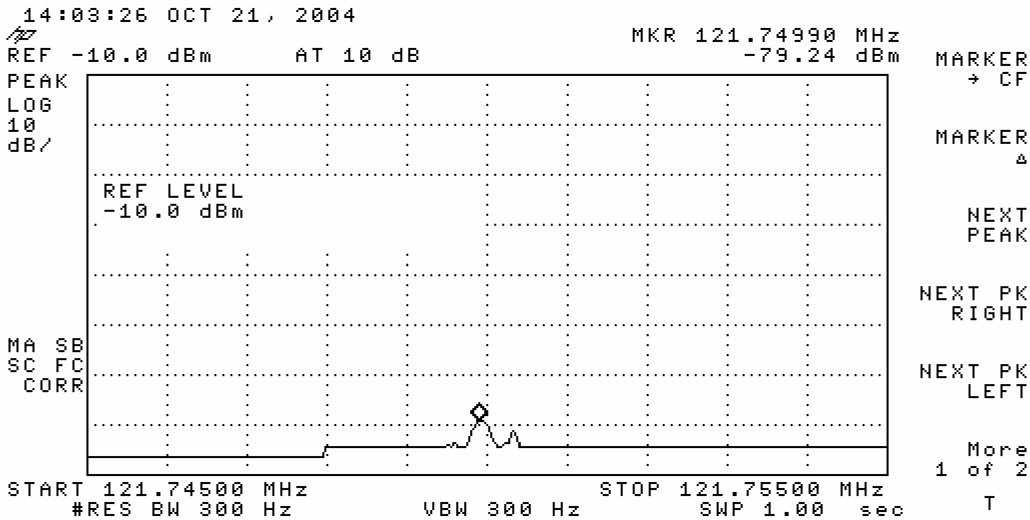

Figure 18 - Test Point 12 VHF Signal

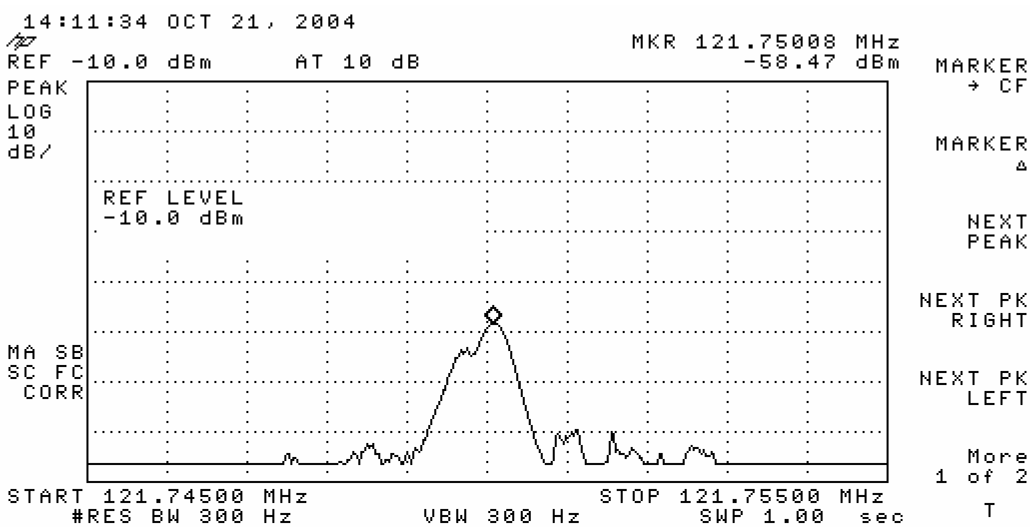

Figure 19 - Test Point 13 VHF Signal

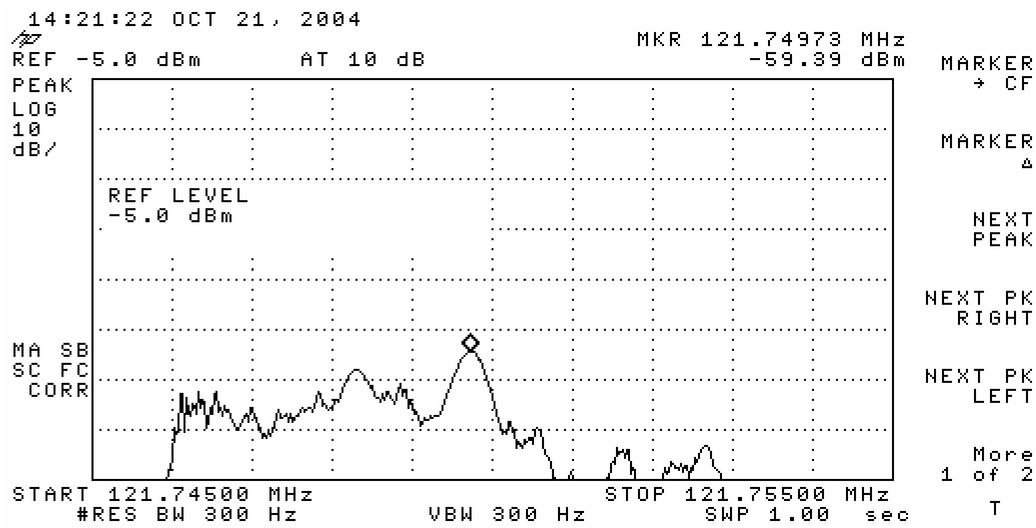

Figure 20 - Test Point 14 VHF Signal

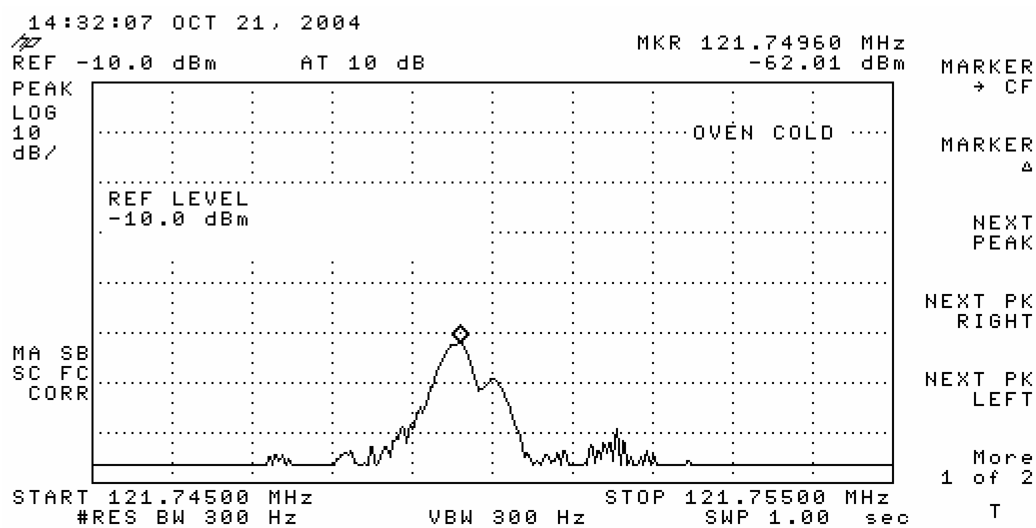

Figure 21 - Test Point 15 VHF Signal

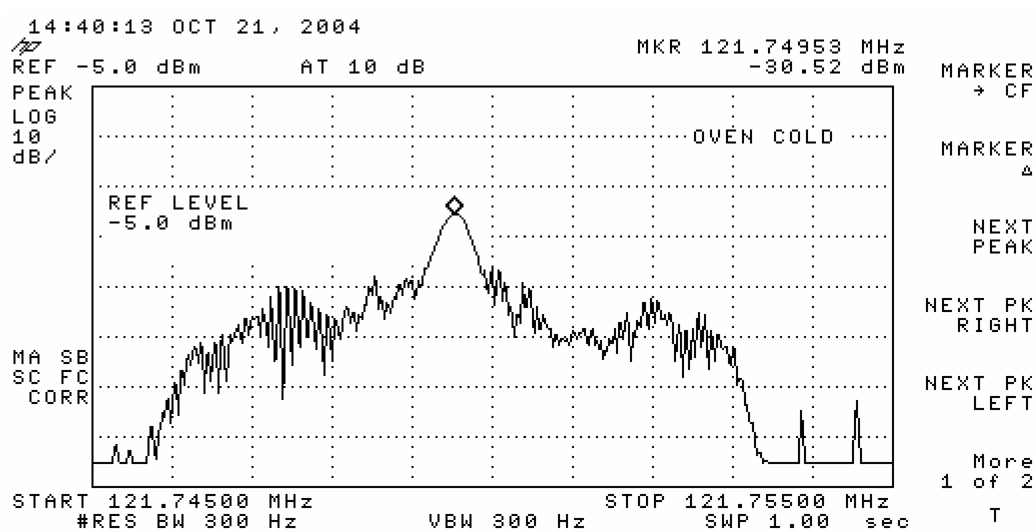

Figure 22 - Test Point 16 VHF Signal

1.3 Atlanta Glideslope (Aircraft Landing on Runway 8L)

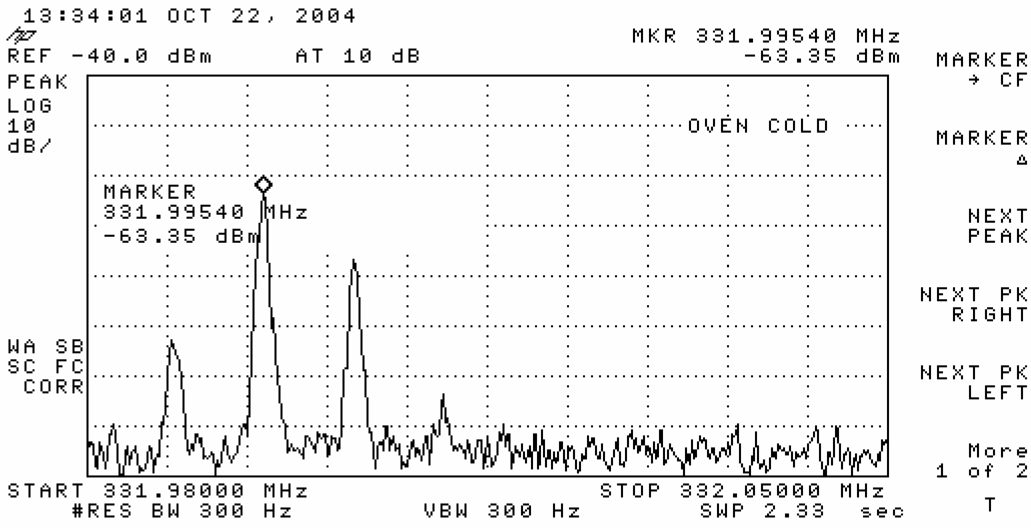

Figure 23 - Test Point 5 GS Signal

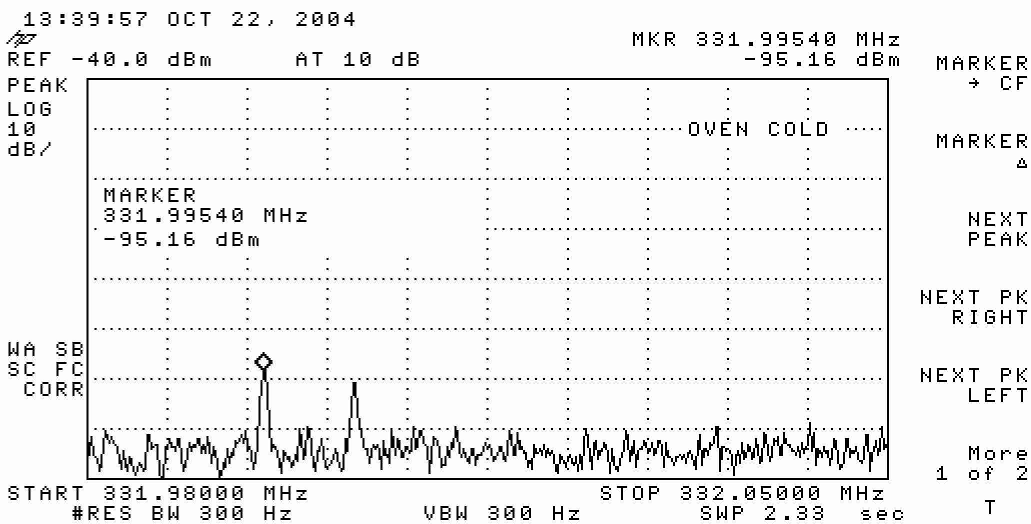

Figure 24 - Test Point 6 GS Signal

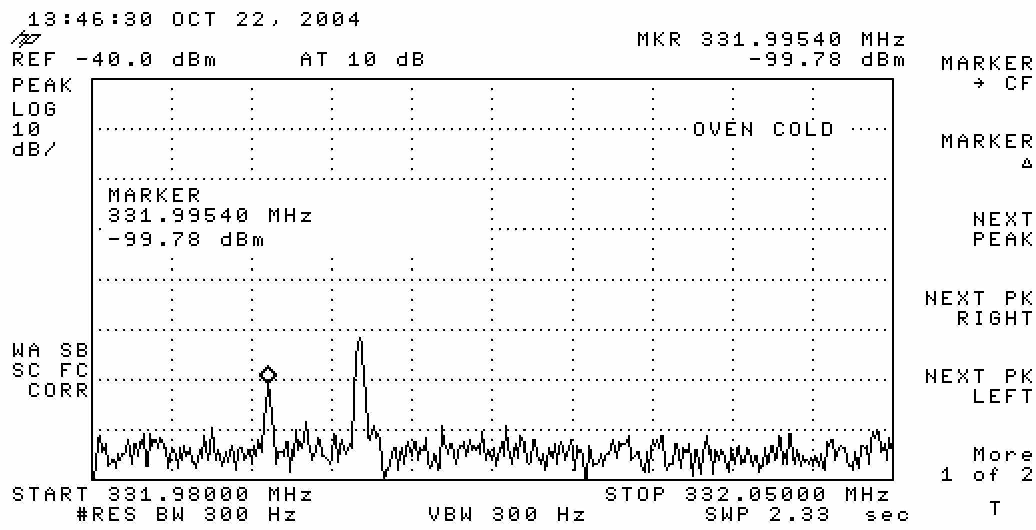

Figure 25 - Test Point 7 GS Signal

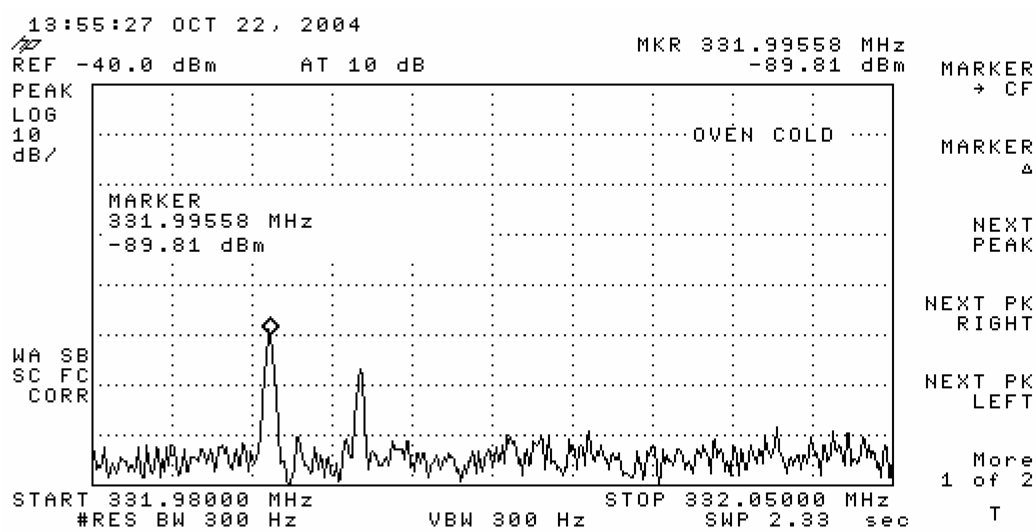

Figure 26 – Test Point 8 GS Signal

1.4 Greenville Localizer (Aircraft Landing on Runway 4)

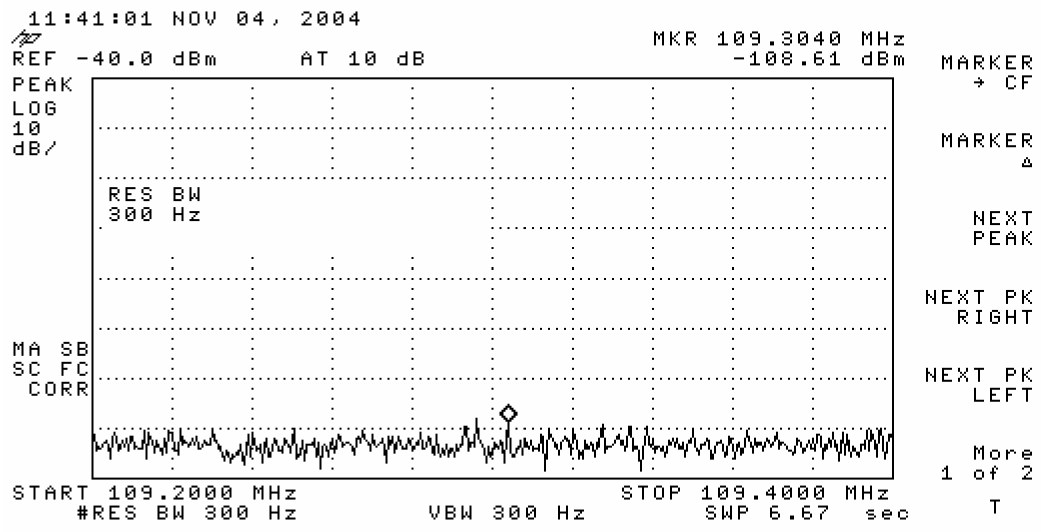

Figure 27 - Test Point 1 LOC Signal

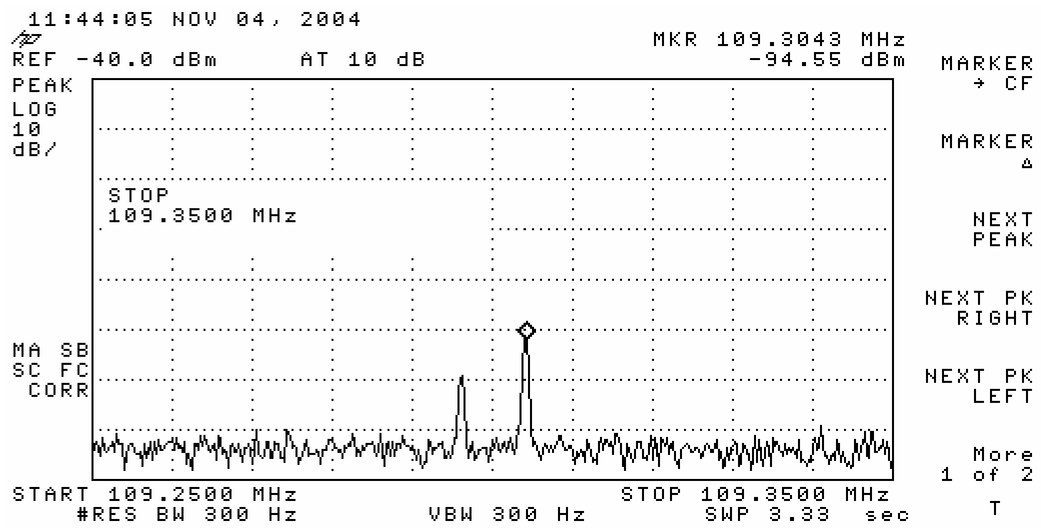

Figure 28 - Test Point 2 LOC Signal

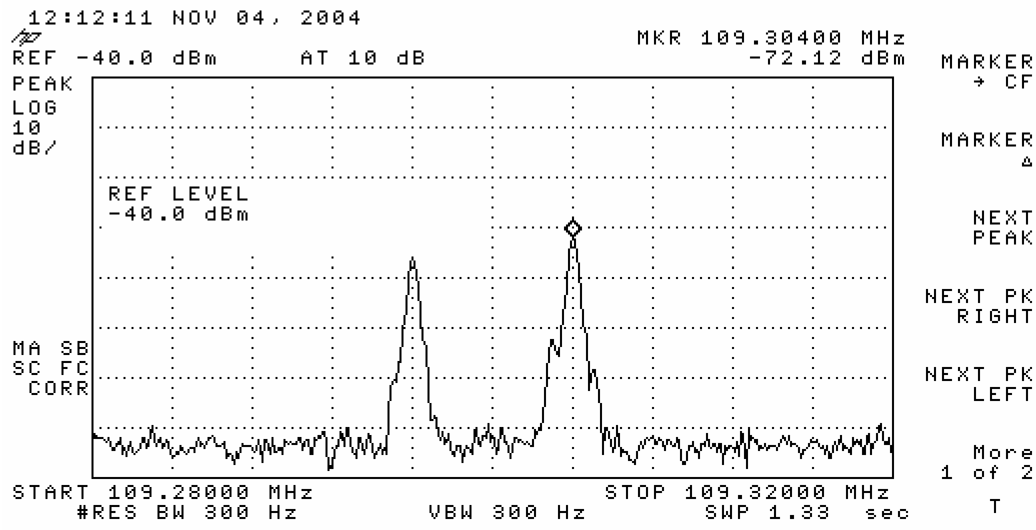

Figure 29 - Test Point 3 LOC Signal

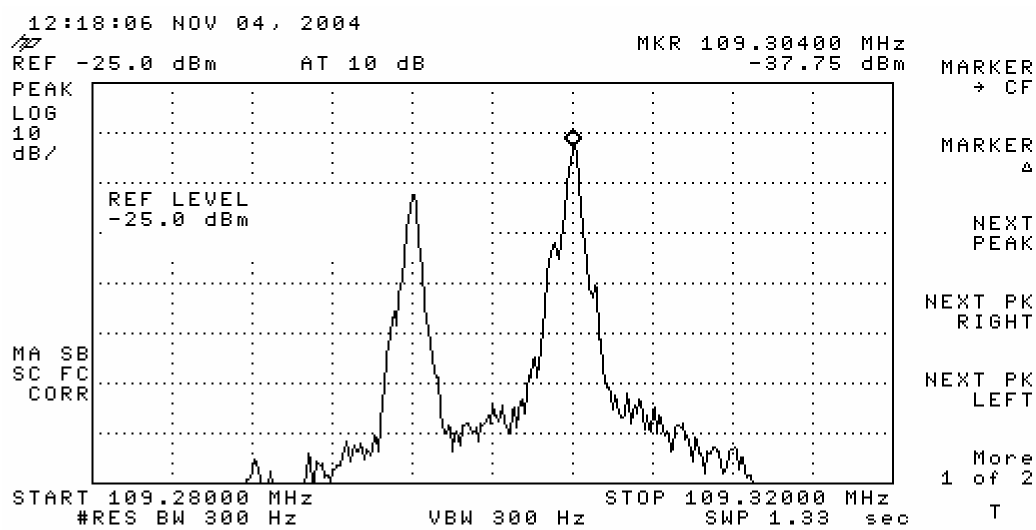

Figure 30 - Test Point 4 LOC Signal

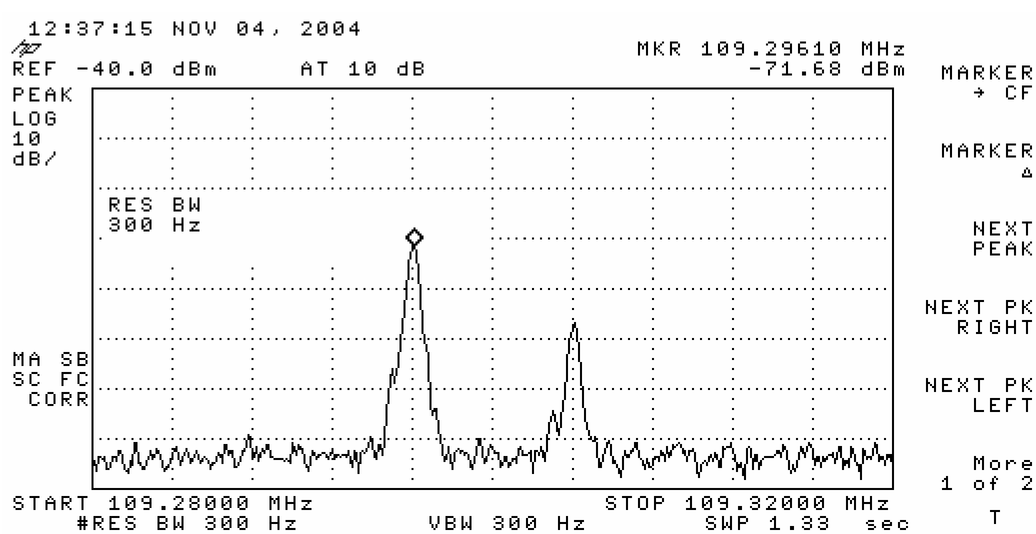

Figure 31 - Test Point 5 LOC Signal

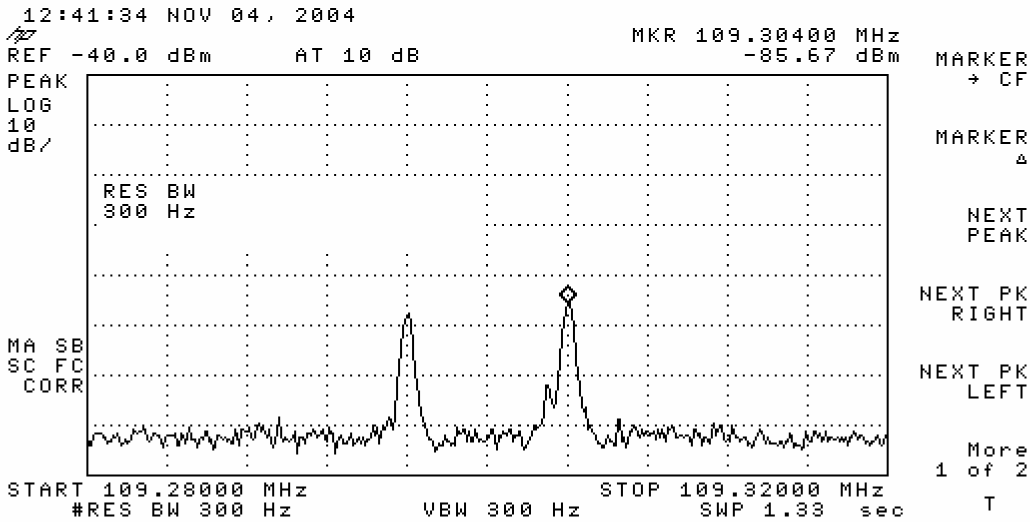

Figure 32 - Test Point 6 LOC Signal

1.5 Greenville VHF Comm

1.5.1 120.1 MHz

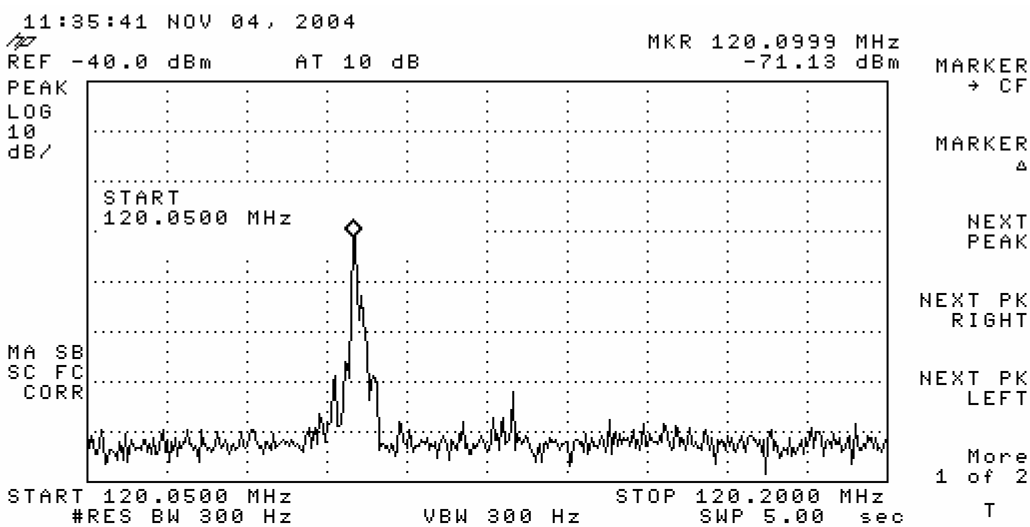

Figure 33 - Test Point 1 VHF Signal

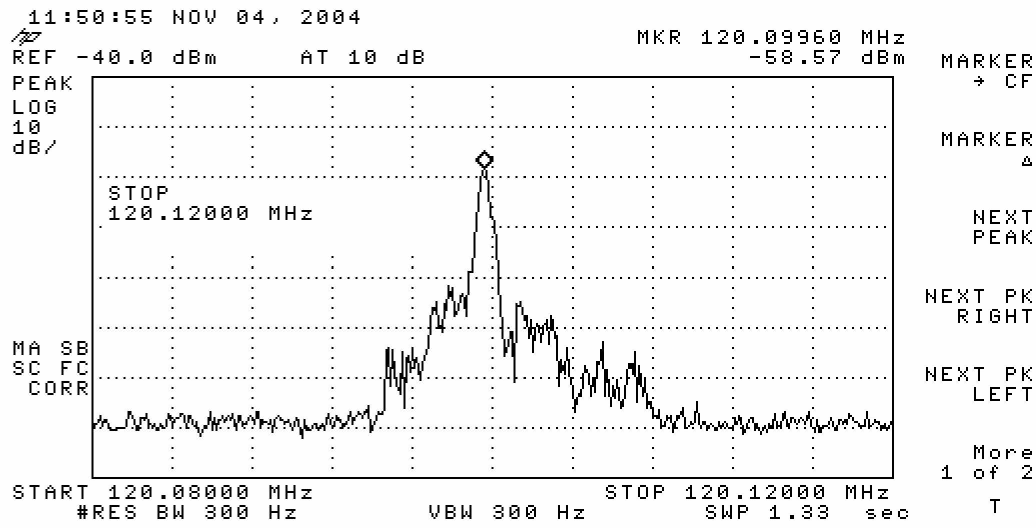

Figure 34 - Test Point 2 VHF Signal

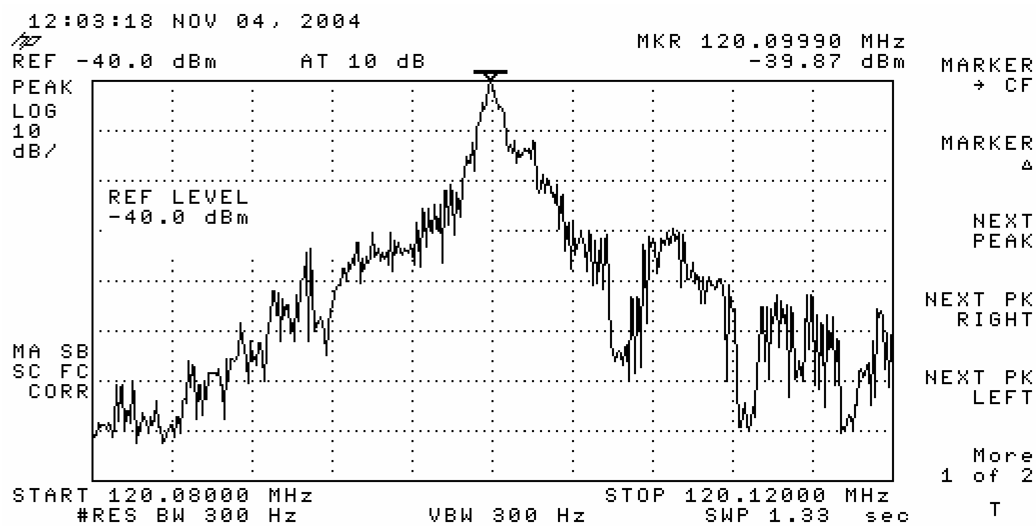

Figure 35 - Test Point 3 VHF Signal

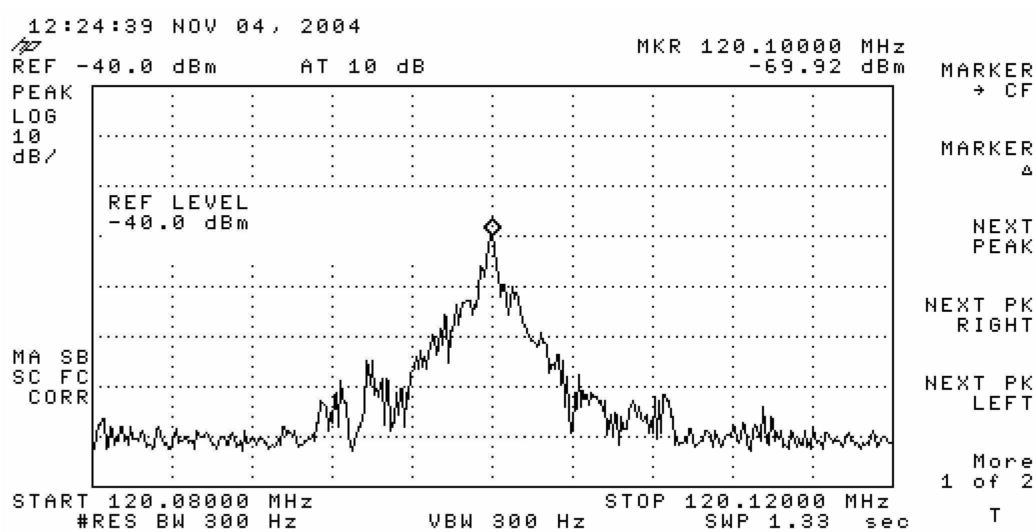

Figure 36 - Test Point 4 VHF Signal

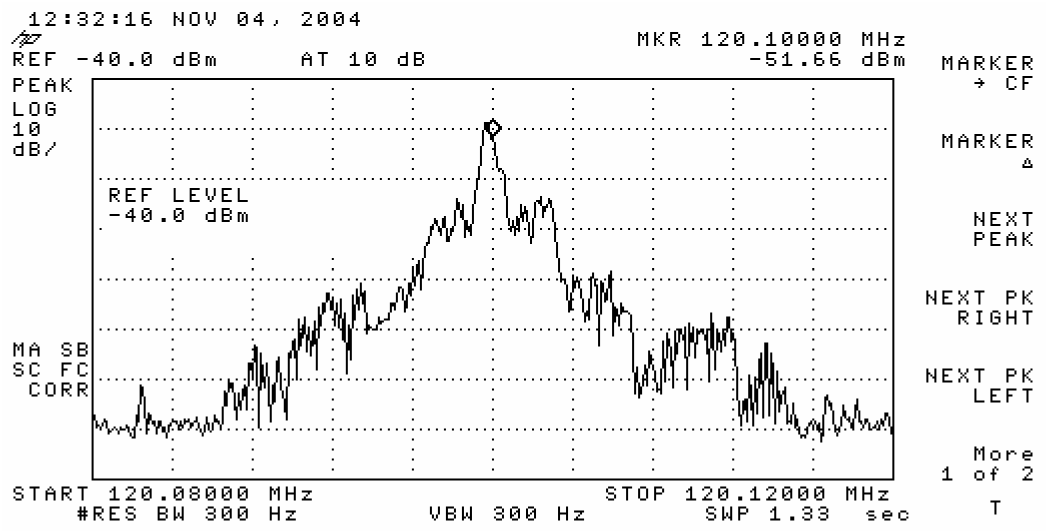

Figure 37 - Test Point 5 VHF Signal

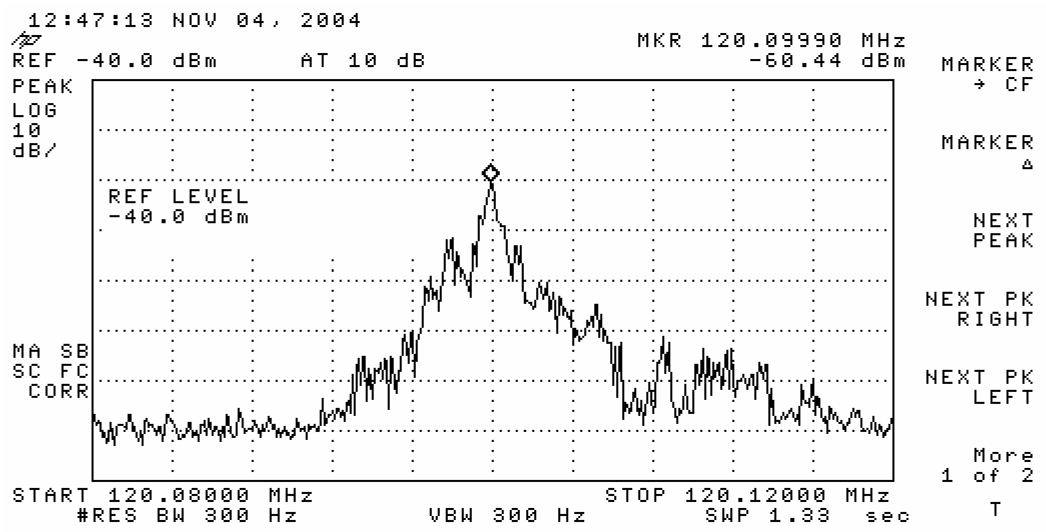

Figure 38 - Test Point 6 VHF Signal

1.5.2 121.9 MHz

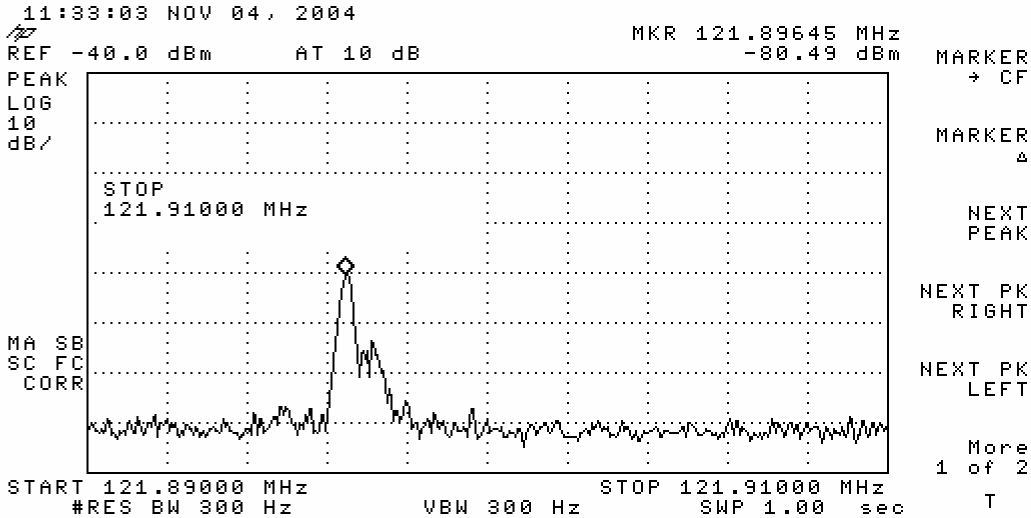

Figure 39 - Test Point 1 VHF Signal

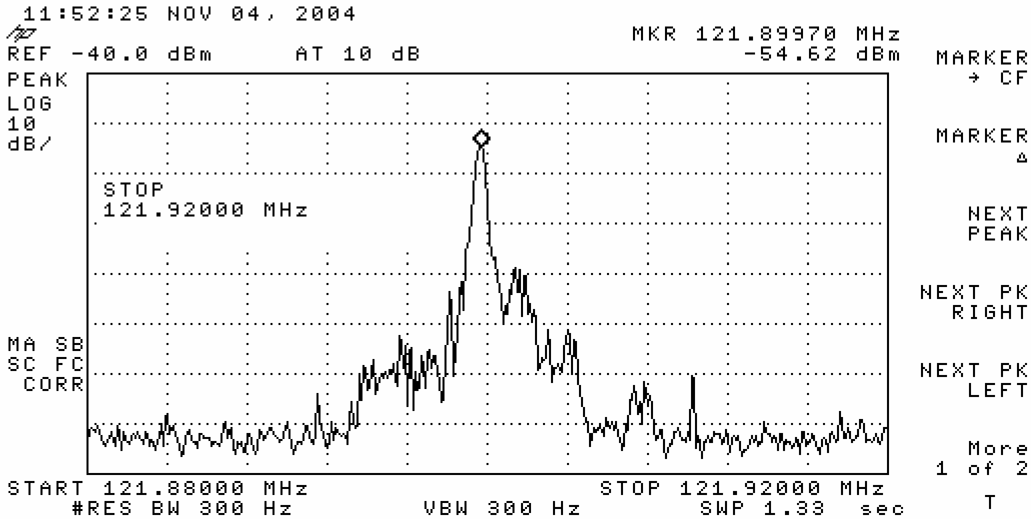

Figure 40 - Test Point 2 VHF Signal

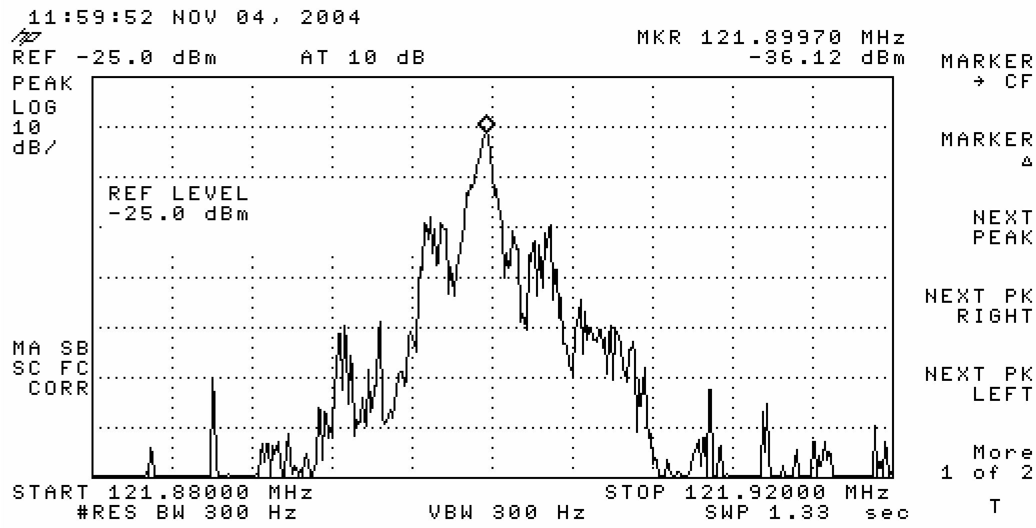

Figure 41 - Test Point 3 VHF Signal

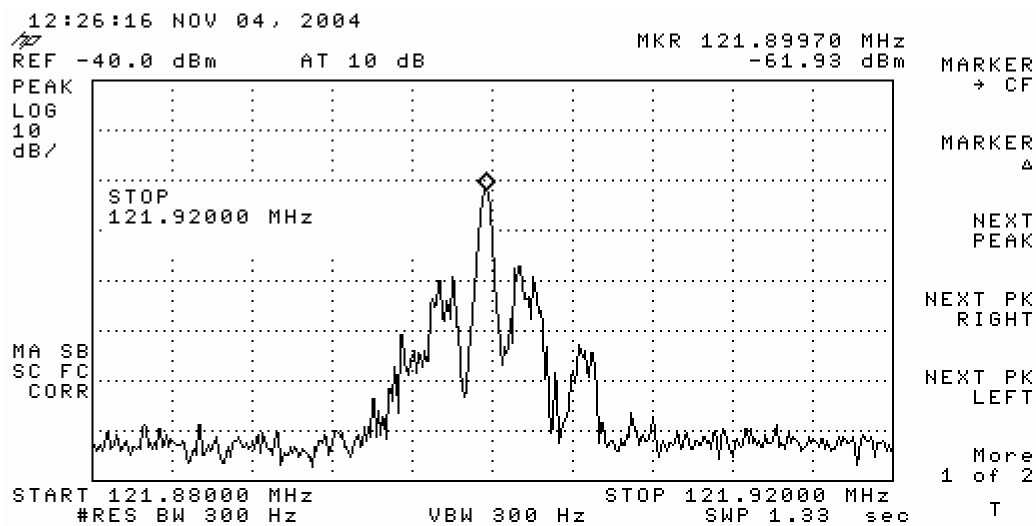

Figure 42 - Test Point 4 VHF Signal

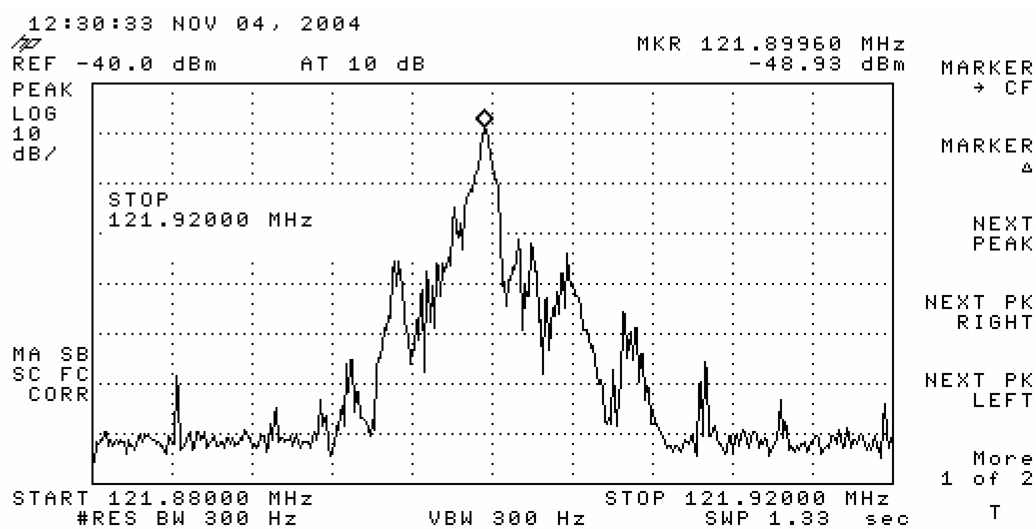

Figure 43 - Test Point 5 VHF Signal

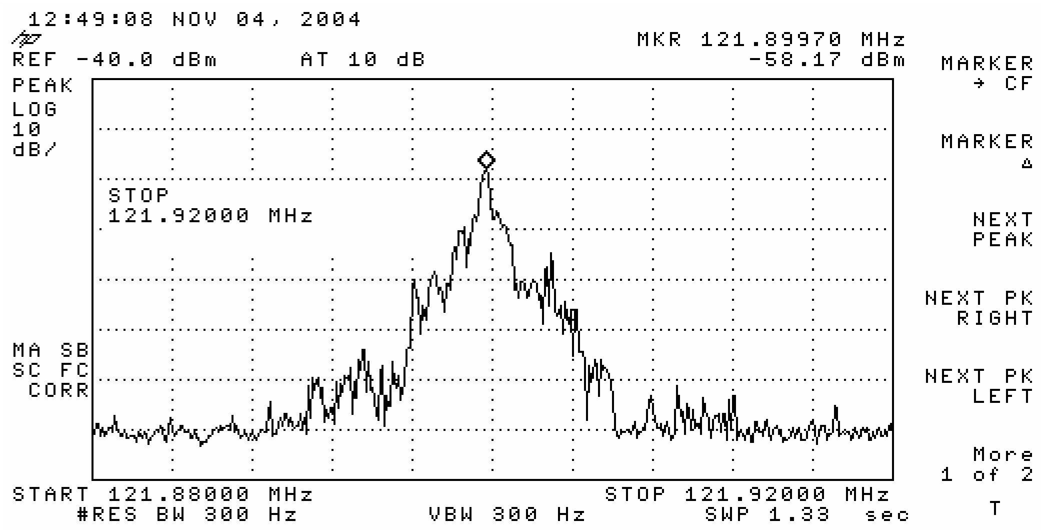

Figure 44 - Test Point 6 VHF Signal

1.6 Greenville Glideslope (Aircraft Landing on Runway 4)

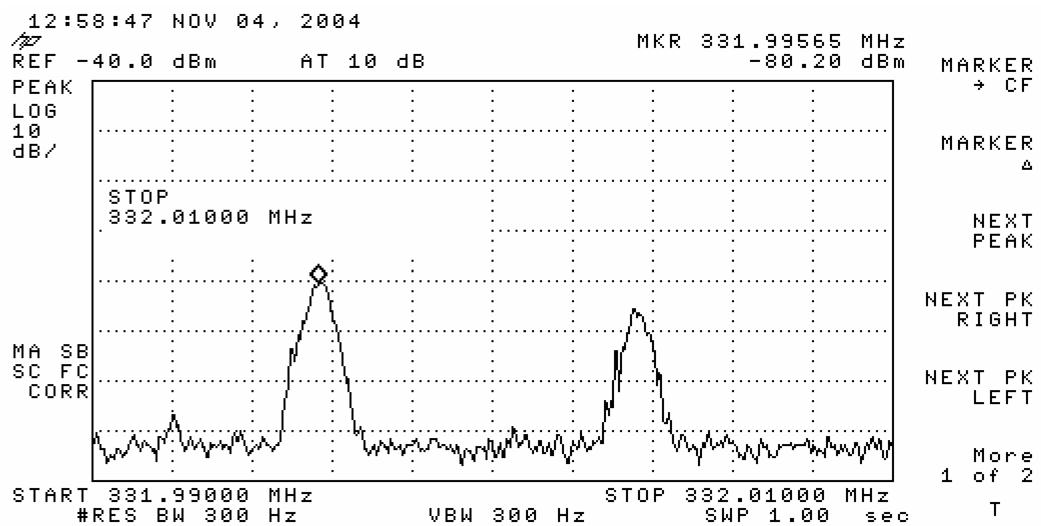

Figure 45 - Test Point 1 GS Signal

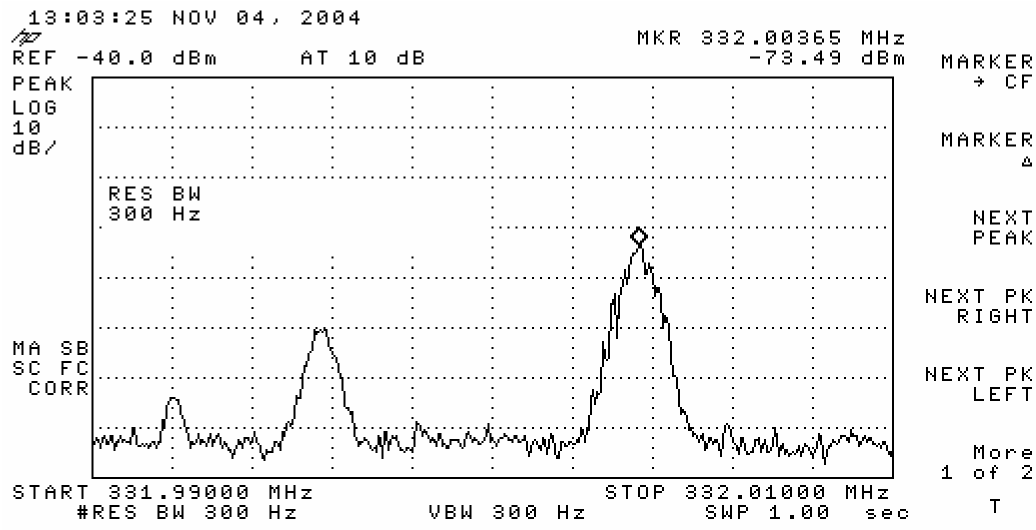

Figure 46 - Test Point 2 GS Signal

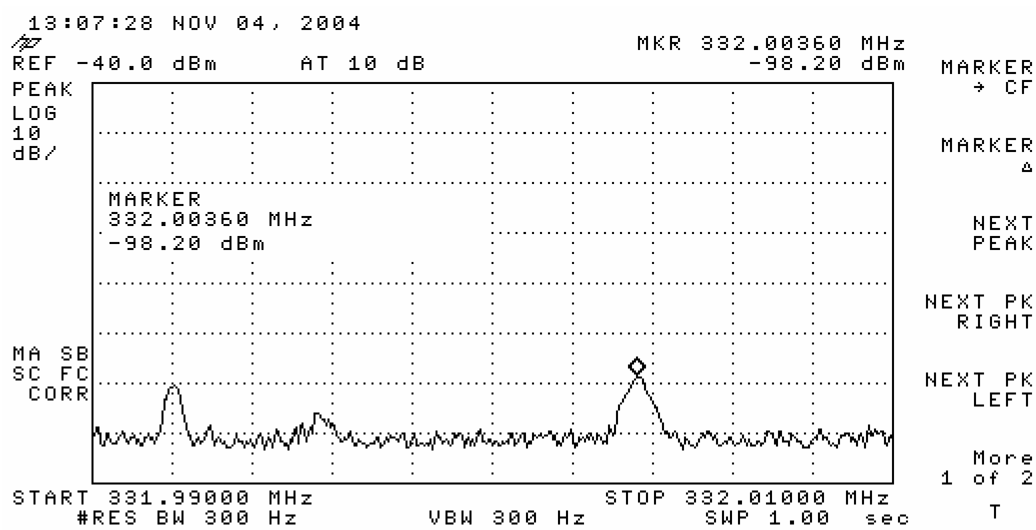

Figure 47 - Test Point 3 GS Signal

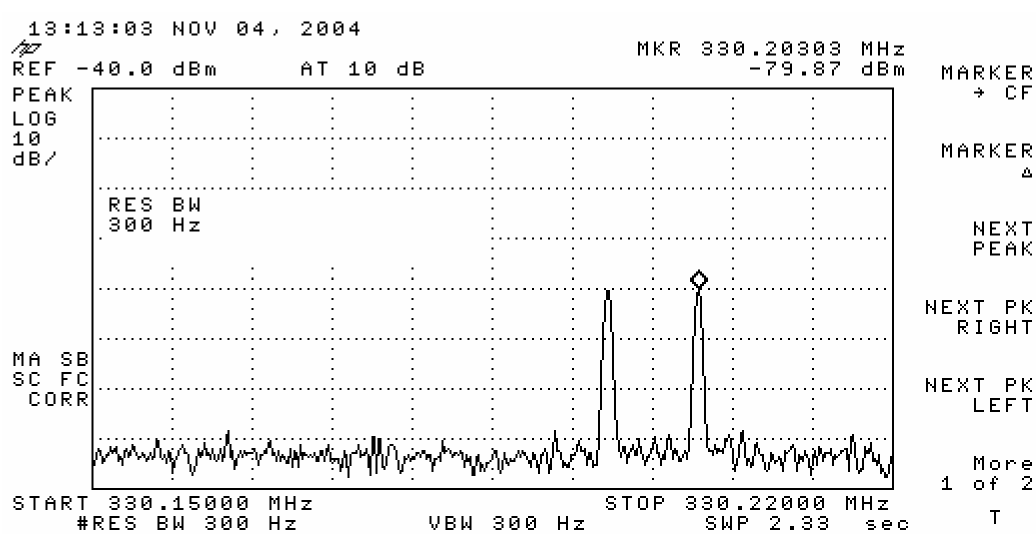

Figure 48 - Test Point 4 GS Signal

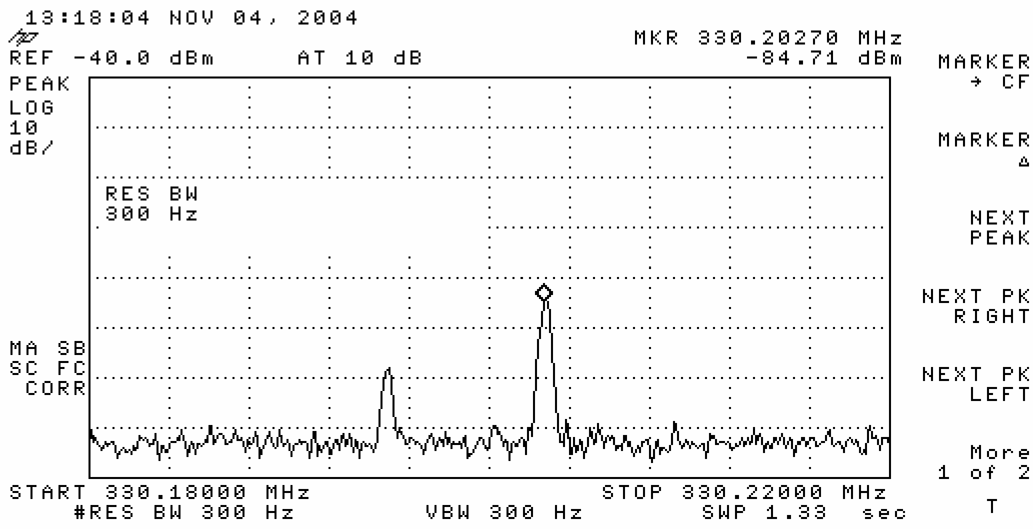

Figure 49 - Test Point 5 GS Signal

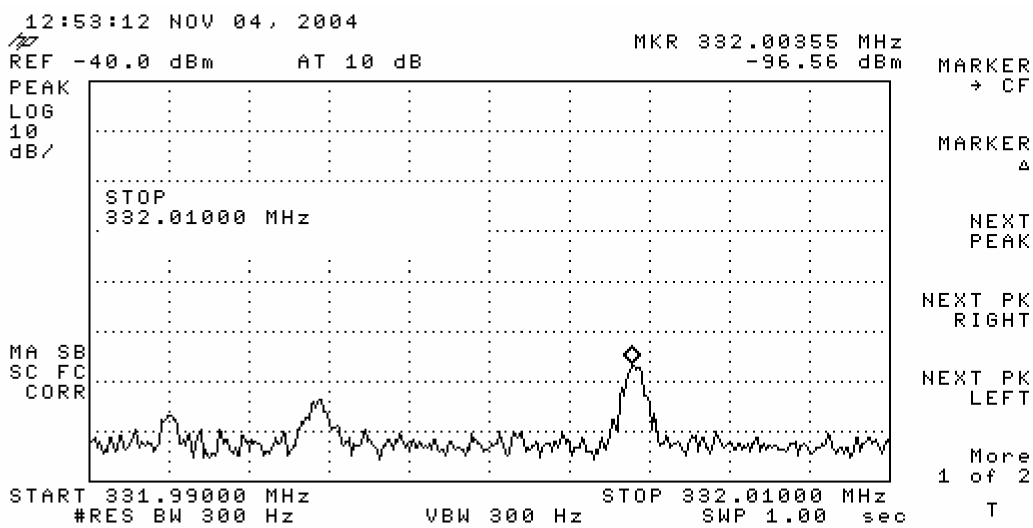

Figure 50 - Test Point 6 GS Signal

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14. ABSTRACT
Signal Measurements were obtained on four (4) different airport systems. Systems measured were Localizer (LOC), Very High Frequency Communication, (VHF), Glideslope, (G/S), and Global Positioning System (GPS). The task calls for path loss measurements to be taken at Hartsfield-Jackson International Airport (ATL) and one smaller airport which was Greenville/ Spartanburg Airport (GSP) to determine relative signal strengths on the airport properties.

15. SUBJECT TERMS
Airport; GPS; Glideslope; ILS; Localizer

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