technical note

TEST REPORT DESCRIBING THE EMISSION CHARACTERISTICS AND QUALTITATIVE ASSESSMENT OF THE EFFECTS OF A GROUND PENETRATING RADAR (GPR) ON SELECTED AERONAUTICAL SYSTEMS OPERATING BELOW 960 MHz

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Federal Aviation Administration
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Spectrum and Speciality Engineering Branch
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16. Abstract

Ultra Wide Band (UWB) equipment is a technology that proponents claim has been in use for years but in very limited numbers. Recently the Federal Communications Commission (FCC) amended Title 47, Part 15 of the Code of Federal Regulations to allow such devices. The Office of Spectrum Policy and Management (ASR-1) is concerned about the effect these UWB systems will have on FAA systems. The UWB emissions cover very large bandwidths that include restricted frequency bands reserved for critical civil aviation safety services.

At the request of ASR-1, the FAA Technical Center conducted Part 15 emission measurements and Operational Tests on an available Ground Penetrating Radar (GPR) which is an UWB device. These tests were designed to provide a qualitative assessment of the effects on aeronautical systems operating below 960 Megahertz (MHz). At the time of this data collection effort no Part 15 certified UWB devices were available, consequently a grandfathered device was used. This Report describes these tests.

The tests show that this grandfathered Ground Penetrating Radar GPR exceeded the new FCC Part 15 requirements by as much as 12 decibels (dB), caused severe interference in some scenarios to the FAA’s Air Traffic Control receivers making Air to Ground communications difficult if not impossible, and interfered with the audio portion of airborne communications and NAVAIDS radios.

It is recommended that the FCC Part 15 regulations be amended to require that UWB testing utilize smaller spectrum analyzer bandwidths so that individual spectral lines that may cause interference would be visible on the spectral analyzer. The FAA also recommends that the FCC require that GPRs be shielded so that emissions other than those required for proper operation of the equipment, are suppressed.

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EXECUTIVE SUMMARY

Ultra Wide Band (UWB) equipment is a technology that has been in use for years but in very limited numbers. Recently the Federal Communications Commission (FCC) has amended Title 47, Part 15 of the Code of Federal Regulations to license such devices. The Office of Spectrum Policy and Management (ASR-1) is extremely concerned about the effect these UWB systems will have on FAA systems. The UWB emissions cover very large bandwidths that include frequency bands reserved for FAA use to provide critical safety services to civil aviation.

At the request of ASR-1, the FAA Technical Center conducted Part 15 emission measurements and Operational Tests on an available Ground Penetrating Radar (GPR) which is an UWB device. These tests were designed to provide a qualitative assessment of the effects on aeronautical systems operating below 960 Megahertz (MHz). At the time of this data collection effort no Part 15 certified UWB devices were available, consequently a grandfathered device was used. This Report describes these tests.

The FCC Part 15 tests demonstrated that this grandfathered GPR exceeded the new FCC requirements by as much as 12 decibels (dB). Since the GPR is horizontally polarized the FCC tests showed greater signal levels emitted by the GPR when the calibrated measurement antenna was also horizontally polarized.

The Ground Operational tests showed that, in some scenarios, this GPR would cause severe interference to the FAA's Air Traffic Control receivers making Air to Ground communications difficult if not impossible. This operational interference was demonstrated at both the FAA Technical Center's Experimental RCAG facility and at JFK International Airport's receiver facility.

Additional demonstrations with the FAA Technical Center's helicopter showed the GPR interfered with the audio portion of airborne communications and NAVAIDS radios. The NAVAID flag, needle, and lamp indicators were unaffected in these scenarios.

It is recommended that the FCC Part 15 regulations be amended to require lower spectrum analyzer bandwidths (for example, 10 kilohertz) so that individual spectral lines that may cause interference would be visible on the spectral analyzer. These individual spectral lines are invaluable in assisting the FAA in making a determination whether interference will occur.

The FAA also requests that the FCC require that GPRs be shielded so that emissions other than those required for proper operation of the equipment, are suppressed. This would direct the GPR signal more towards the ground and thus lessen the effect on FAA systems.

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INTRODUCTION

OBJECTIVE.

These tests were conducted to characterize the emission levels of one Ground Penetrating Radar (GPR) in aeronautical frequency bands of interest below 960 MHz and to observe any effects of this GPR on the following Federal Aviation Administration (FAA) safety-of-life equipment within operational scenarios:

75 MHz Instrument Landing System (ILS) Marker Beacon
108 to 118 MHz ILS Localizer/VHF Omni directional Range (VOR)
118 to 137 MHz Very High Frequency (VHF) Communications
225 to 400 MHz Ultra High Frequency (UHF) Communications
328.6 to 335.4 MHz ILS Glide Slope
406 to 420 MHz Wind Shear.

This was accomplished by determining the GPR's emissions characteristics using the Federal Communications Commission's (FCC) Measurement Procedures found in Appendix F of "First Report and Order" FCC 02-48. The FCC Measurement Procedure was used to determine which GPR antenna caused the maximum emission in each of the above FAA frequency bands.

Operational Tests were performed to observe the effects of the GPR on aeronautical facilities and equipment. The *Ground* Operational Test looked at the effect of the GPR on *ground* VHF and UHF communications receivers. The *Airborne* Operational Tests looked at effects from the GPR to avionics listed in the first paragraph. The Airborne Operational Tests used a fully certified FAA Project helicopter that is used for airborne testing. However, full characterization of any effects was not possible.

Additional tests were conducted at the JFK International Airport. These tests investigated the extent and path of the interference to air/ground communications suspected to have been caused by a GPR.

The results of these tests cannot be used independently to establish GPR interference criteria to aeronautical communications and navigation systems that provide critical safety-of-life services. These tests do, however, provide a qualitative demonstration of the potential for GPR devices to interfere with aeronautical systems. Although the GPR unit tested does not meet the requirements of FCC Part 15, it is one of the units waived by the FCC to allow for its operation. Because the GPR interference mechanisms are not yet fully understood and simple "free space loss" adjustments may not be valid, these test results should not be used to extrapolate to estimate the interference potential of a GPR that does meet the requirements of FCC Part 15. FAA plans further testing and analysis of other GPRs, and other UWB equipment to fully characterize the interference issues associated with implementation of UWB devices.

BACKGROUND.

The GPR is an electronic imaging device that transmits an Ultra Wide Band (UWB) signal, which is capable of "seeing" objects underground; or when configured differently can "see" what is within or behind walls. The UWB aspect of the signal means that it radiates across extremely large portions of the electromagnetic spectrum including frequency bands reserved for FAA safety-of-life systems.

In 1998, the FCC granted a waiver requested by a GPR manufacturer. This request and others led to the adoption of rules for the *unlicensed* use of UWB technology under Part 15 of Title 47 of the Code of Federal Regulations. GPRs have been in operation for many years without any authorization until the 1998 waiver and subsequent 2003 blanket waiver. These qualitative tests complement the theoretical analyses performed by the Federal Aviation Administration (FAA) and bench tests being conducted under contract to the FAA.

TEST DESIGN

TEST APPROACH

Test scenarios representing real operational conditions were used. Interference criteria were based on documented aviation standards. The emission characteristics of the GPR were determined. Emissions were measured from all GPR antennas. Data was collected from those GPR antennas that impacted the bands of interest to the greatest extent.

GPR EMISSION CHARACTERISTICS

The FAA tested a GPR with six interchangeable antennas that are centered on frequencies 300, 400, 500, 900, 1000, and 1500 MHz.

The GPR tested produces a signal with a specified pulse rate of 85 kHz peak and a specified 64 kHz average pulse rate. A transmitter is contained within the housing of each antenna. The largest antenna (300 MHz model) has the following emission characteristics (as provided by the GPR operator's manual):

Radiated peak power: 1.0 watt
Radiated average power: 0.20 watts
Approximate radiated average power per MHz: 0.65 Microwatt/MHz
Approximate center frequency: 300 MHz
Approximate pulse duration: 3 nanoseconds
Approximate bandwidth +/- 50%. (i.e. +/- 50% x 300 MHz = +/-150 MHz. Total 10 dB bandwidth of 300 MHz.)

SECTION 1A: FCC MEASUREMENT PROCEDURES (FCC 02-48 APPENDIX F) EMISSIONS TESTS

Test Setup. Figure 1 shows the FCC Measurement Procedures test setup. All test equipment was calibrated according to manufacturer's specifications.

Test Methodology. The FAA measured the GPR emission characteristics *in FAA frequency bands* using the Measurements Procedures of FCC 02-48 Appendix F. A sand pit 20 inches deep with a diameter of 46 inches was constructed near building 176. This diameter is 6 inches greater than the diagonal measurement of the largest GPR antenna. At frequencies below 960 MHz, the FCC Procedures require quasi-peak and peak field strength measurements.

The GPR was operated as it is intended, i.e., in direct contact with the sand pit. A calibrated measurement antenna was placed 3 meters (m) from the closest point of the GPR antenna enclosure. The calibrated antenna was raised or lowered until the height that produced the maximum signal was found. This signal level was measured using a calibrated spectrum analyzer with a CISPR quasi-peak detector. This measurement was performed with the calibrated antenna operated in its horizontal polarization mode and then in its vertical polarization mode in each of the above tested FAA frequency bands. Since a ground plane was not used, 4.7 dB was added to each measurement as recommended by the FCC measurement procedure.

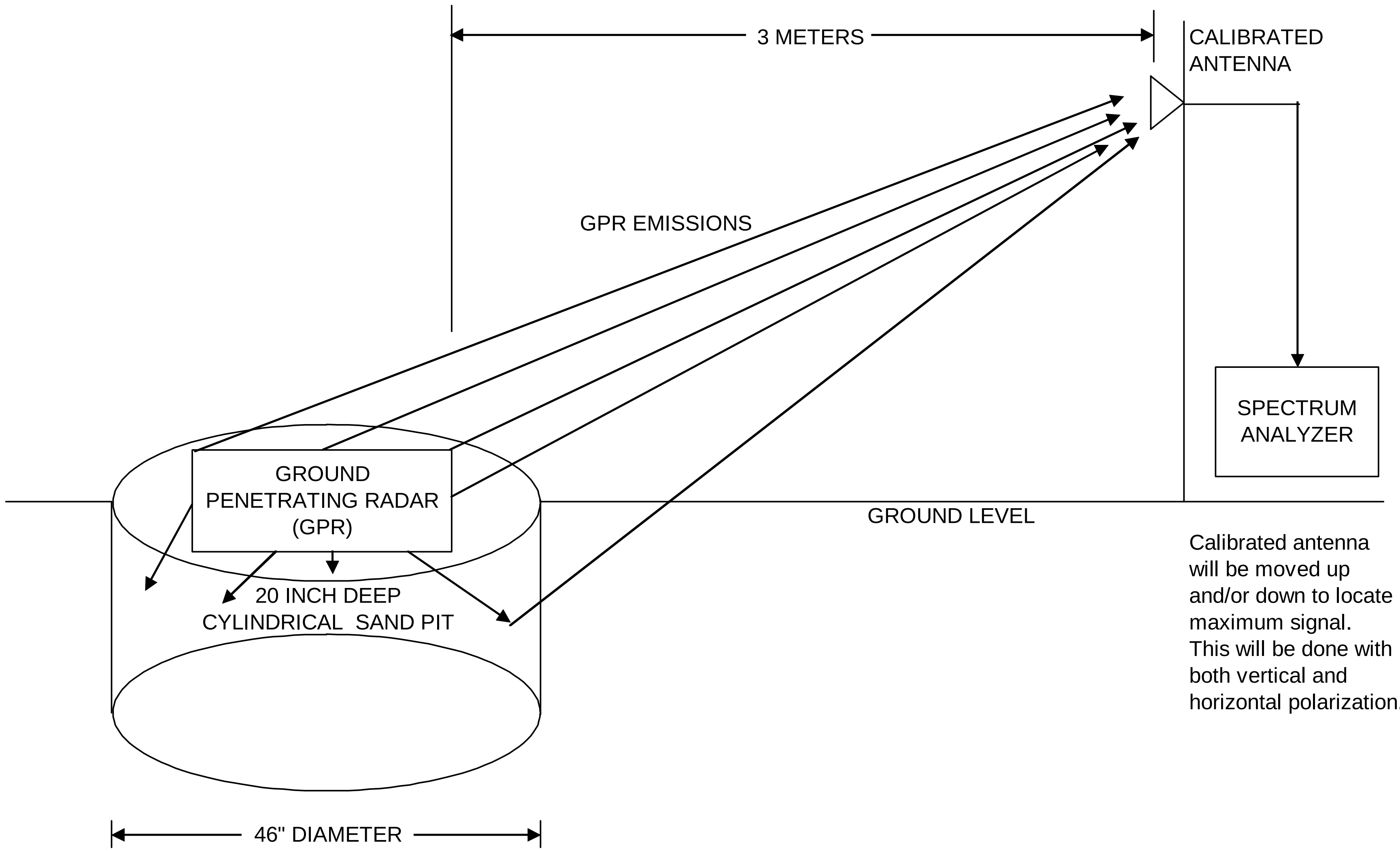

FIGURE 1. TEST SETUP FOR "FIRST REPORT AND ORDER FCC 02-48 MEASUREMENT PROCEDURES APPENDIX F"

In addition to the quasi-peak detector measurements, the spectrum analyzer was used to measure the peak radiated emission. These measurements were made at the same distances/heights/antenna polarizations as the quasi-peak measurements. The spectrum analyzer's resolution and video bandwidths were set for 3 MHz and measurements were made using the analyzer's maximum-hold trace mode.

The GPR antenna was then rotated 45^{o} (about its vertical axis) and the above measurements repeated. This process was repeated every 45^{o} for the 300 MHz GPR antenna with the calibrated antenna in its horizontal polarization mode. Since the vertical polarization mode produced lower signal levels than the horizontal polarization mode, only the worst-case azimuth in the vertical polarization mode data was recorded.

The 300 MHz GPR antenna was also turned on its side facing the calibrated antenna so bore site measurements could be performed. It was then rotated around its horizontal axis and emission levels were measured at four orientations – front of antenna pointing up, down, left, and right (the bottom of the GPR antenna faced the calibrated antenna in each of these orientations and left/right are as viewed from the calibrated antenna towards the GPR antenna).

The 400, 500, 900, 1000, and 1500 MHz GPR antenna emissions were at lower signal levels below 1 GHz than the 300 MHz antenna. The quasi-peak measurements for the 400 and 500 MHz antennas were only recorded for the worst-case orientation with the calibrated antenna *horizontally* polarized (no *vertically* polarized data recorded). Peak measurements were not recorded for the 400 and 500 MHz antennas because of their lower signal levels and the lack of FCC criteria for peak measurements. The 900, 1000, and 1,500 MHz GPR antenna emissions produced no difference between the ambient and the GPR on spectrum analyzer quasi-peak and peak levels. Therefore, no data was recorded for these antennas.

Although FCC 02-48 Appendix F does not specify a system noise measurement, it was performed in each FAA frequency band. This was accomplished by replacing the calibrated antenna with a 50-ohm termination. This measurement produced a signal level in dbμV (decibel referenced to 1 microvolt) that indicated the noise floor level of the cable and spectrum analyzer. This ensured that any low level GPR emissions could be distinguished from the test equipment internal noise.

All FCC 02-48 Appendix F emissions were measured in dBμV with the spectrum analyzer and then converted to field strength in dBμV/m and then to μV/m (microvolts per meter) using the below formulas. The conversion to μV/m was done to conform to the measurement units used by the FCC.

$$\text{dB}\mu\text{V/m} = \text{Spectrum Analyzer Signal Level in dB}\mu\text{V} + 4.7\text{ dB (Ground Plane Factor)} + \text{Antenna Factor in dB/m} + \text{Cable Loss in dB}$$

$$\mu\text{V/m} = \text{Antilog}((\text{dB}\mu\text{V/m})/20)$$

For example:

If,

The spectrum analyzer indicates a signal level of 35.3 dBμV,
The no-ground plane factor is 4.7 dB,
The antenna factor is 9 dB/m,
The cable loss is 3 dB.

Then:

$$\text{Field Strength in dB}\mu\text{V/m} = 35.3 + 4.7 + 9 + 3 = 52\text{ dB}\mu\text{V/m}.$$
$$\text{Field Strength in }\mu\text{V/m} = \text{Antilog}(52/20) = 398\ \mu\text{V/m}.$$

OPERATIONAL TESTS

Prior to any ground or airborne operational tests, the emissions from the GPR were measured with a spectrum analyzer and frequencies where maximum GPR emissions occurred were recorded. This was repeated with each GPR antenna to determine which antenna creates the maximum emission in each frequency band.

The receiver under test was tuned to the frequency corresponding to the maximum GPR signal found in its operating band. In addition, the GPR antenna that produced the maximum emission was used with this receiver.

SECTION 2A: FAA GROUND EQUIPMENT OPERATIONAL TESTS.

All the ground VHF and UHF communications receivers used meet the FAA maintenance specification requirements for operational systems. They were all tuned according to the manufacturer's tune-up procedures. These tests were designed to demonstrate qualitative effects that will augment other UWB tests and analyses being conducted by the FAA.

Baseline Measurements. All ground tests started with the GPR turned off to ensure there were no other radiation sources that may have affected the measurements. Baseline background (ambient) measurements were made several times throughout the tests.

Interference Criteria. The interference criteria for the FAA VHF and UHF ground communications receivers were:

> GPR signal breaking squelch with desired aeronautical radio signal *off*.
>
> GPR disrupting the desired signal, i.e. hearing GPR in background, with desired signal *on* and voice (using recorded standard aviation phrases) modulated 90%.

Test Setup**.** Figure 2 shows the test setup for determining the effects on the VHF and UHF communications receivers due to the GPR.

Test Methodology**.** A CM-200 VHF (UHF) receiver was tuned to the frequency corresponding to the maximum GPR signal found in their respective bands. The GPR antenna that produced this maximum was used. The GPR was oriented (in azimuth only, not in elevation) to maximize emissions towards the victim receiver antenna. The GPR was operated in normal mode.

FAA Order 6580.5 requires VHF (UHF) ground communications receivers to break squelch with the desired on-tune signals as low as -103 dBm (decibels below 1 milliwatt). These tests were conducted with the receiver's squelch adjusted for -103 dBm.

The signal generator was tuned to the VHF (UHF) communications receiver's frequency and connected to a 50-foot tower mounted VHF (UHF) antenna. This antenna was used to transmit the desired signal to the other 50-foot tower mounted VHF (UHF) communications receiver antenna. This antenna received both the desired radiated signal and the GPR radiated emissions. The audio output of the receiver was recorded.

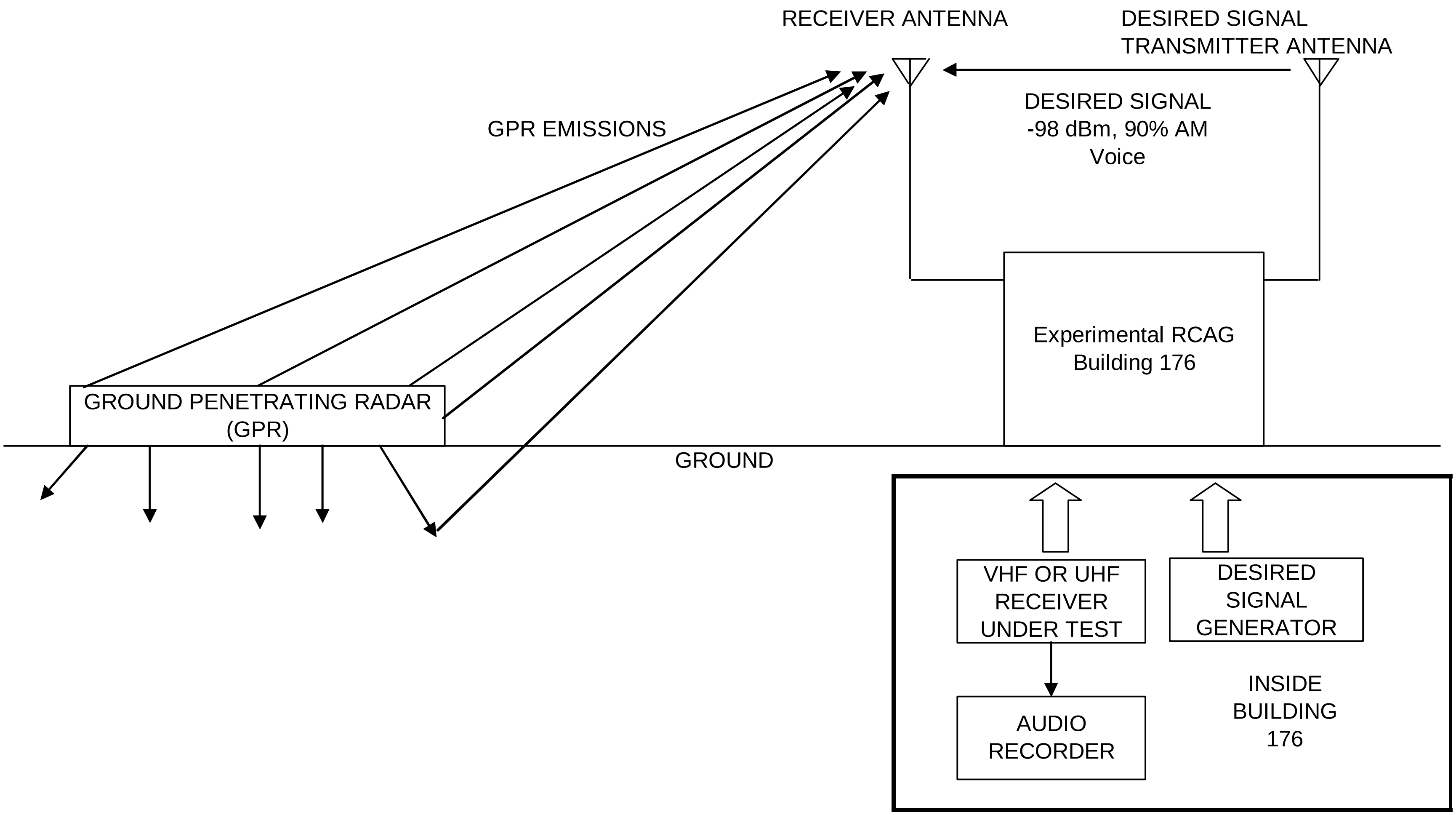

FIGURE 2. TEST SETUP FOR DETERMINING THE EFFECT OF GROUND PENETRATING RADAR ON VHF AND UHF GROUND COMMUNICATIONS RECEIVERS

The signal generator was adjusted to produce a desired carrier signal level of -98 dBm at the receiver's antenna port as measured with a spectrum analyzer. The signal generator was amplitude modulated 90% with voice.

A baseline condition was established prior to the test with the GPR turned *off* and audio recordings of live air traffic control communications phrases. A listening panel of air traffic controllers to evaluate voice quality for new communications equipment used these recordings previously. This baseline condition was performed with a -98 dBm desired carrier signal that was amplitude modulated 90%.

Next the GPR was turned *on* and the above tests repeated. The GPR was initially placed on the ground in the vicinity of the test receiver antenna and was moved away from the test antenna with effects on test receiver observed and recorded. Audio recordings were made at two locations.

SECTION 3A: FAA AIRBORNE EQUIPMENT OPERATIONAL DEMONSTRATION.

The airborne demonstration used an FAA helicopter and its installed avionics as the victim receivers. The airborne (helicopter) radios used were certified by the FAA Avionics Lab and met all required specifications. These are the same radios used by the helicopter pilots to communicate with Air Traffic Control and for navigation. All airborne demonstrations began with the GPR turned *off* to ensure that no other signals were present that may have produced erroneous results. The demonstrations were designed to show qualitative effects on an aircraft in flight that will augment other UWB tests and analyses being conducted by the FAA

Test Setup. Figure 3 details the equipment setup for conducting the airborne demonstrations. Flight regulations and equipment limitations onboard the helicopter prohibited the measurements of any received signal level.

Communications Interference Criteria. These radios use preset squelch levels. The tests were performed with squelch enabled and disabled. The interference criteria for VHF airborne communications receivers were:

> GPR signal breaking squelch with desired signal *off*
>
> GPR disrupting the desired signal, i.e., hearing GPR in background, with desired signal *on* and voice (using recorded standard Air Traffic Control phrases) modulated 90%.

ILS Localizer, VOR, and ILS Glide Slope Interference Criteria. The pilot observed the ILS Localizer, VOR, and ILS Glide Slope needle and flag for any abnormal conditions and monitored the localizer or VOR audio for GPR interference. Interference criteria are defined as:

> Flag *dis*appearance or needle deviation with *no* desired signal
>
> Flag appearance or needle deviation with desired signal on
>
> GPR causing interference in the localizer or VOR audio with or without a desired signal present. (This criterion does not apply to Glide Slope.)[1]

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[1] Audio noise can inhibit the pilot's ability to decipher the ILS/VOR Morse code identifier or the VOR voice signal (e.g., Automatic Terminal Information System). The Glide Slope receiver does not contain audio circuitry.

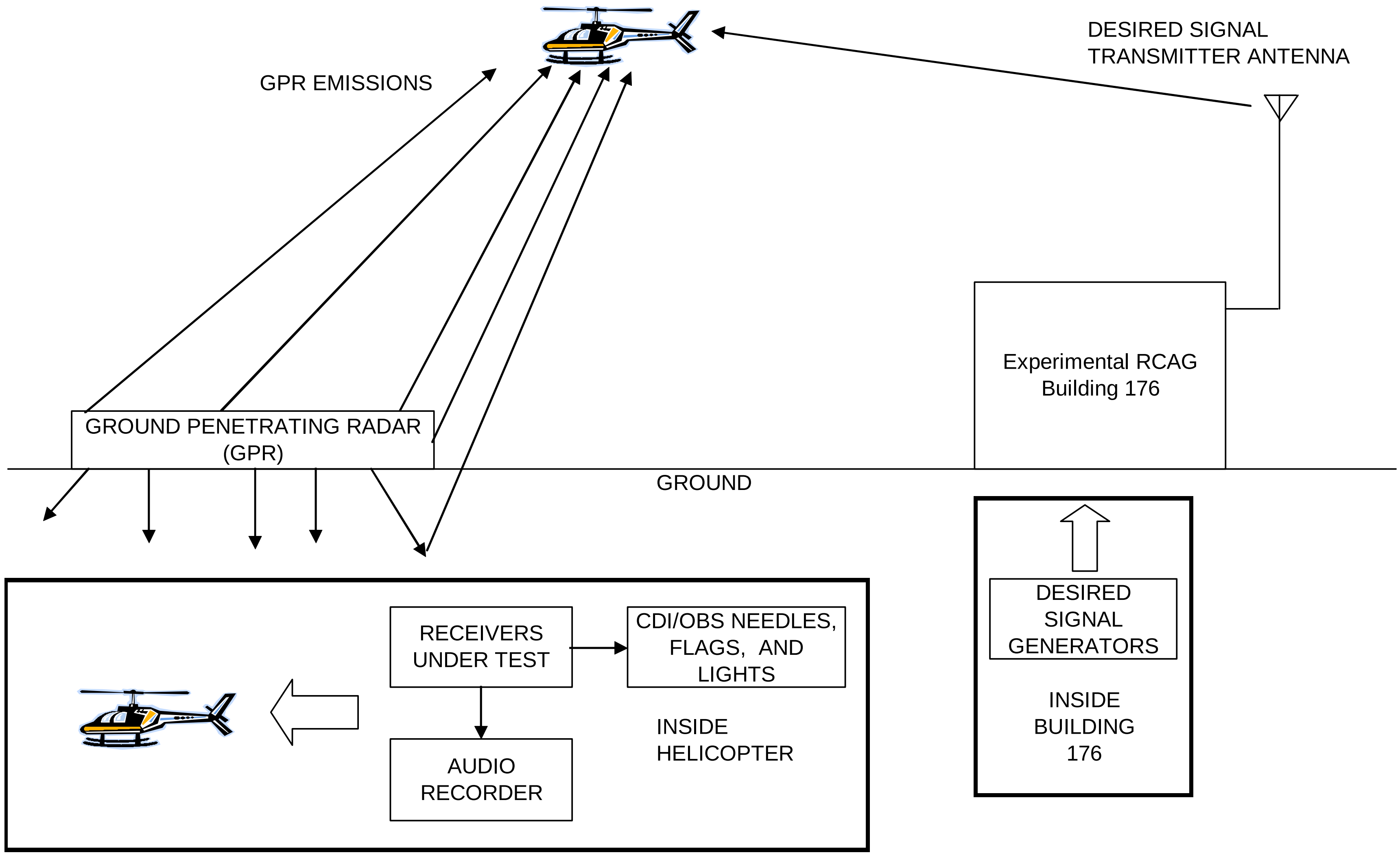

FIGURE 3. TEST SETUP FOR DETERMINING THE EFFECT OF GROUND PENETRATING RADAR ON AIRBORNE RADIO EQUIPMENT

75 MHz Marker Beacon Interference Criteria. The pilot observed the Marker Beacon display for instrument light indication and monitored the audio with GPR turned off and GPR turned on with no desired signal present in either case. Interference is defined as:

a light *on*, or Marker Beacon tone, or GPR emissions present.[2]

Communications, Localizer, VOR, Glide Slope, and Marker Beacon Methodology. The FAA helicopter hovered 100 feet[3] over the setup at the FAA Technical Center's Experimental Remote Center Air/Ground facility, building 176. The pilot determined if aircraft communications and/or navigation systems were experiencing interference.

The pilot did this with the GPR *off* by:

listening for Communications receiver squelch breaks with desired signal turned *off*
listening for Communications receiver background noise with desired signal turned *on* with voice (using standard aviation phrases) modulated 90%

listening to Localizer/VOR/Marker Beacon audio with desired signal turned *off*
listening to Localizer/VOR audio with desired signal turned *on*

monitoring Localizer/VOR/Glide Slope CDI/flag with desired signal turned *off*
monitoring Localizer/VOR/Glide Slope CDI/flag with desired signal turned *on*
monitoring Marker Beacon lights with desired signal turned *off*[2]

The pilot did this with the GPR *on* by:

listening for Communications receiver squelch breaks with desired signal turned *off*
listening for Communications receiver background noise with desired signal turned *on* with voice (using standard aviation phrases) modulated 90%

listening to Localizer/VOR/Marker Beacon audio with desired signal turned *off*
listening to Localizer/VOR audio with desired signal turned *on*

monitoring Localizer/VOR/Glide Slope CDI/flag with desired signal turned *off*
monitoring Localizer/VOR/Glide Slope CDI/flag with desired signal turned *on*
monitoring Marker Beacon lights with desired signal turned *off*[2]

When the pilots observed squelch breaks, background noise, abnormal flag indication, abnormal needle movement, or incorrect Marker Beacon light indications with the GPR turned *on* the pilots gradually increased their altitude until the interference ceased. Helicopter heights were recorded and audio recordings were made on the helicopter for all conditions.

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[2] A demonstration with the desired signal was not possible, because the test site was not near the Marker Beacon. Also, generating a simulated Marker Beacon Signal would cause misleading navigation information to aircraft near the airport.
[3] Due to operational limitations at the site, 100 feet was the closest safe distance that could be used.

SECTION 4A: JFK INTERNATIONAL AIRPORT INTERFERENCE TESTS.

On December 18, 2001, a GPR was demonstrated to FAA maintenance technicians at JFK International Airport by a GPR service provider. During this sales demonstration, Air Traffic reported interference on 119.1, 121.9, 125.25 and 135.05 MHz, possibly from the GPR being demonstrated. The demonstration was terminated immediately. It is not known if the GPR caused the interference or if some other source was the cause. This test done by Technical Center engineers attempted to reconstruct the same GPR scenario that existed during the interference noted during the GPR sales demonstration. It should be noted that the FAA was not able to acquire the GPR involved in the original demonstration to replicate this radio frequency interference event.

Test Setup. Figure 4 shows the test configuration for the JFK Airport tests.

Interference Criteria. The communication receiver's audio output(s) were monitored while the GPR was operating to determine if interference or noise was occurring.

Test Methodology. The GPR with the 300 MHz antenna tested at the FAA Technical Center was taken to the same location at JFK Airport where the December 2001 demonstration took place. The GPR was activated and moved over the ground similar to how it was operated during the demonstration in an attempt to recreate the interference.

There are two potential mechanisms for radio frequency interference. One is the path from the GPR to an underground cable nearby where the GPR was operating during the December tests. This cable controls the ATC receivers and sends the received audio signal back to the Air Traffic Controller but does not contain the actual RF desired signal. The second is a direct RF path to the receiver antenna on the top of the remote communications facility tower approximately 50 feet tall that feeds the receiver under test.

In order to determine which path caused the interference, the following procedure was used. When interference was detected, the antenna cable was disconnected from the affected receivers to determine if the interference was radiated to the antenna or coupled into the receiver via the control cables running under ground and near the GPR. The interfering RF signal levels were measured and audio recordings were made.

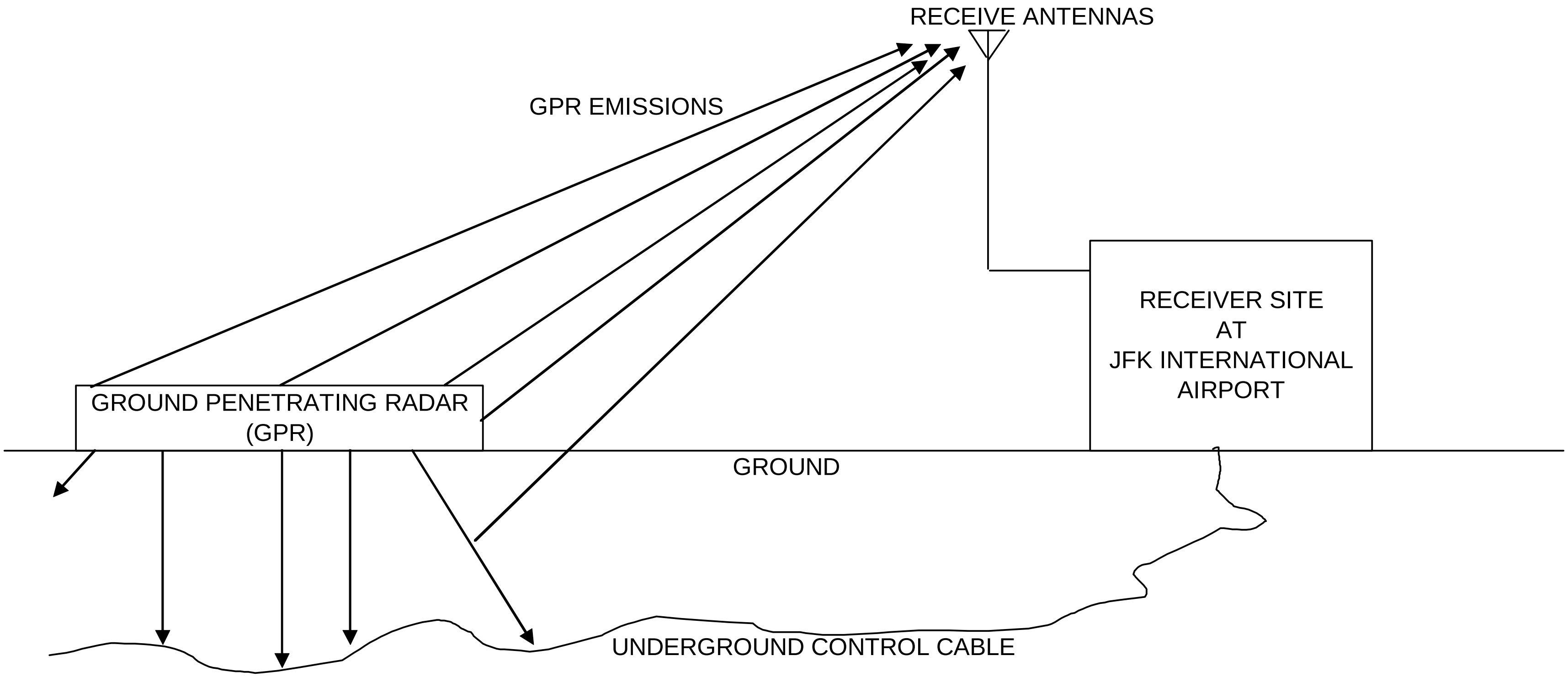


FIGURE 4. TEST SETUP FOR REPLICATING GROUND PENETRATING RADAR DEMONSTRATION AT JFK INTERNATIONAL AIRPORT

TEST RESULTS AND ANALYSIS

SECTION 1B: FCC MEASUREMENT PROCEDURES (FCC 02-48 APPENDIX F) EMISSIONS TEST RESULTS.

FCC Intentional Interference Criteria. The Code of Federal Regulations, Title 47, Part 15, Section 15.209 specifies the maximum field strength emissions for intentional radiators. These requirements are summarized below in table 1 and are referenced to quasi-peak measurements. (There are no FCC requirements for peak measurements).

TABLE 1. SUMMARY OF FCC PART 15.209 REQUIREMENTS

Frequency (MHz)	Field Strength (microvolts/meter)	Measurement Distance (meters)
30 -88	100	3
88 – 216	150	3
216 – 960	200	3

Data Analysis with GPR in Normal Operation Mode. The data for the GPR emission characteristics *in FAA frequency bands* using the Measurements Procedures of FCC 02-48 Appendix F are contained in tables 3 through 8.

Table 2 below is a small portion of table 3 that is reproduced here to explain how the data is presented in tables 3 through 8. At the top left of the table is the height of the calibrated antenna where the maximum GPR emissions were measured. Below the height data are the resolution bandwidth (RBW), video bandwidth (VBW), and frequency span used for these measurements. The values shown here are for quasi-peak measurements.

To the right of these entries is information that describes the type of measurement. In this case, the maximum quasi-peak field strength and the frequency were it occurred along with ambient field strength are measured. In the block below this, it shows which GPR antenna was used. In this case it was the 300 MHz antenna.

The left column shows the FAA frequency band and measured system noise in dBμV. The next column shows whether the calibrated antenna was horizontally or vertically polarized.

The third column describes the three measured parameters (Field Strength, Ambient, and Frequency) that are recorded in the 0^{o} through 315^{o} columns to the right.

For example: The VHF Communications band had a system noise of 17 dBμV. With the calibrated antenna horizontally polarized and the 300 MHz GPR antenna at a 0^{o} orientation, a field strength of 479 μV/m was produced. With the GPR turned off, the ambient field strength was 68 μV/m. (Orientation is the angle that the GPR is rotated with respect to the calibrated antenna. The calibrated antenna is *not* rotated). This data was collected at a frequency of 124.150 MHz.

TABLE 2. EXAMPLE OF DATA COLLECTION FORMAT

<table>
<tr><td colspan="3">Calibrated Antenna Height = 110".
RBW = 120 kHz, VBW =300 kHz, Span = 25 kHz</td><td colspan="8">Maximum Quasi-Peak Field Strength Level, Ambient Field Strength Level, and Frequency in the following FAA Bands</td></tr>
<tr><td rowspan="2">Equipment Frequency Band and System Noise</td><td>Polarization</td><td>Parameters Measured at Maximum Signal Level</td><td colspan="8">300 MHz GPR ANTENNA CENTER FREQUENCY

GPR Antenna Angle with Respect to the Calibrated Antenna</td></tr>
<tr><td>H or V</td><td></td><td>0^0</td><td>45^0</td><td>90^0</td><td>135^0</td><td>180^0</td><td>225^0</td><td>270^0</td><td>315^0</td></tr>
<tr><td rowspan="3">VHF Comm.
System Noise is
17 dBuV</td><td rowspan="3">H</td><td>Field Strength (uV/m)</td><td>479</td><td>269</td><td>214</td><td>302</td><td>537</td><td>240</td><td>302</td><td>380</td></tr>
<tr><td>Ambient (uV/m)</td><td>68</td><td>68</td><td>68</td><td>68</td><td>68</td><td>68</td><td>68</td><td>68</td></tr>
<tr><td>Frequency (MHz)</td><td>124.15</td><td>124.15</td><td>124.15</td><td>124.15</td><td>124.15</td><td>124.15</td><td>124.15</td><td>124.15</td></tr>
</table>

Comparing the FCC field strength requirements in table 1 to the horizontally polarized data in table 3 shows the 300 MHz GPR antenna to Marker interference data exceeds the FCC's 100 µV/m quasi-peak requirement by as much as 12 dB. Similarly, it is seen that the GPR interference in the VOR, Localizer, and VHF Communications bands also exceeds the FCC's 150 µV/m requirement by as much as 12 dB (VOR at 0^0 orientation). The worse case UHF band emission exceeded the FCC criteria by 5.6 dB (UHF Communications 0^0 and 180^0 orientations). It should be noted that the GPR emission level varies with orientation.

NOTE: Data points that exceed FCC Title 47, Part 15.209 requirements are shaded.

The vertical polarization data at the bottom of table 3 shows the GPR signal level is less than horizontal polarization. The VHF emissions produced by the GPR still failed to meet the FCC criteria but the UHF meets it except in the wind shear band where it fails by 0.9 dB (20log[223uV/m/200uV/m] = 0.9 dB).

The 400 MHz and 500 MHz GPR antennas met the FCC emission requirements except in the Wind Shear Band (1.9 dB and 3.9 dB, respectively). This data is presented at the end of this report in tables 5 and 6. Peak 300 MHz GPR antenna emission data was also collected but since there are no FCC criteria for peak emissions we had no means to analyze this data. This data is presented in tables 7 and 8 at the end of this report. The emissions below 960 MHz of the GPR with the 900, 1000, and 1,500 MHz GPR antennas were too low to distinguish them from the ambient using the FCC test procedures.

NOTE: Although this GPR doesn't meet the FCC criteria of Title 47, Part 15.209, it is one that would qualify as a legacy GPR covered by the FCC blanket waiver.

Data Analysis with GPR Turned on its Side. Table 4 shows the interfering quasi-peak field strengths caused by the GPR when it was turned on its side (still on the sand pit) with its bottom facing the calibrated antenna. The Up, Down, Left, and Right GPR antenna orientations are the location of the front of the GPR antenna when looking from the calibrated antenna towards the GPR antenna.

Comparing table 1 to the horizontally polarized data in table 4 shows the 300 MHz GPR produces signal levels that exceed the FCC field strength requirements in the Up and Down orientations. The Left and Right orientations produced lower level signals but many still failed the requirement.

When the calibrated antenna was turned to its vertical polarization mode the worst case conditions switched from Up and Down to Left and Right. The worst case signal level was 3151 µV/m which occurred with the calibrated antenna horizontally polarized in the wind shear band. This value was 24 dB above the 200 µV/m FCC requirement.

Peak data with the 300 MHz antenna on its side is presented in table 7 and for comparison table 8 shows the peak signal levels when the GPR is in its normal upright position.

TABLE 3. QUASI-PEAK FIELD STRENGTH DATA WITH 300 MHz GPR ANTENNA

Calibrated Antenna Height = 110". RBW = 120 kHz, VBW =300 kHz, Span = 25 kHz			Maximum ***Quasi-Peak*** Field Strength Level, Ambient Field Strength Level, and Frequency in the following FAA Bands							
Equipment Frequency Band and System Noise	Polarization	Parameters Measured at Maximum Signal Level	***300*** MHz GPR ANTENNA CENTER FREQUENCY GPR Antenna Angle with Respect to the Calibrated Antenna							
	H or V		0^0	45^0	90^0	135^0	180^0	225^0	270^0	315^0
Marker System Noise is 17 dBuV	H	Field Strength (uV/m)	398	224	89	251	355	282	200	282
		Ambient (uV/m)	79	79	79	79	79	79	79	79
		Frequency (MHz)	74.83	74.83	74.83	74.83	74.83	74.83	74.83	74.83
VOR System Noise is 17 dBuV	H	Field Strength (uV/m)	610	272	97	243	305	216	216	432
		Ambient (uV/m)	68	68	68	68	68	68	68	68
		Frequency (MHz)	109.27	109.27	109.27	109.27	109.27	109.27	109.27	109.27
Localizer System Noise is 17 dBuV	H	Field Strength (uV/m)	556	248	111	221	351	197	248	442
		Ambient (uV/m)	79	79	79	79	79	79	79	79
		Frequency (MHz)	111.99	111.99	111.99	111.99	111.99	111.99	111.99	111.99
VHF Comm. System Noise is 17 dBuV	H	Field Strength (uV/m)	479	269	214	302	537	240	302	380
		Ambient (uV/m)	68	68	68	68	68	68	68	68
		Frequency (MHz)	124.15	124.15	124.15	124.15	124.15	124.15	124.15	124.15
UHF Comm. System Noise is 17 dBuV	H	Field Strength (uV/m)	380	214	135	269	380	240	135	269
		Ambient (uV/m)	120	120	120	120	120	120	120	120
		Frequency (MHz)	225.85	225.85	225.85	225.85	225.85	225.85	225.85	225.85
Glide Slope System Noise is 17 dBuV	H	Field Strength (uV/m)	211	133	168	150	211	211	211	211
		Ambient (uV/m)	133	133	133	133	133	133	133	133
		Frequency (MHz)	327.98	327.98	327.98	327.98	327.98	327.98	327.98	327.98
Wind shear System Noise is 17 dBuV	H	Field Strength (uV/m)	315	250	281	250	223	250	223	281
		Ambient (uV/m)	199	199	199	199	199	199	199	199
		Frequency (MHz)	415.05	415.05	415.05	415.05	415.05	415.05	415.05	415.05
Marker System Noise is 17 dBuV	V	Field Strength (uV/m)	-	-	-	-	-	-	-	200
		Ambient (uV/m)	-	-	-	-	-	-	-	56
		Frequency (MHz)	-	-	-	-	-	-	-	74.83
VOR System Noise is 17 dBuV	V	Field Strength (uV/m)	-	-	-	-	-	-	-	380
		Ambient (uV/m)	-	-	-	-	-	-	-	60
		Frequency (MHz)	-	-	-	-	-	-	-	109.27
Localizer System Noise is 17 dBuV	V	Field Strength (uV/m)	-	-	-	-	-	-	-	351
		Ambient (uV/m)	-	-	-	-	-	-	-	62
		Frequency (MHz)	-	-	-	-	-	-	-	111.99
VHF Comm. System Noise is 17 dBuV	V	Field Strength (uV/m)	-	-	-	-	-	-	-	214
		Ambient (uV/m)	-	-	-	-	-	-	-	60
		Frequency (MHz)	-	-	-	-	-	-	-	124.15
UHF Comm. System Noise is 17 dBuV	V	Field Strength (uV/m)	-	-	-	-	-	-	-	170
		Ambient (uV/m)	-	-	-	-	-	-	-	120
		Frequency (MHz)	-	-	-	-	-	-	-	225.85
Glide Slope System Noise is 17 dBuV	V	Field Strength (uV/m)	-	-	-	-	-	-	-	133
		Ambient (uV/m)	-	-	-	-	-	-	-	133
		Frequency (MHz)	-	-	-	-	-	-	-	327.98
Wind shear System Noise is 17 dBuV	V	Field Strength (uV/m)	-	-	-	-	-	-	-	223
		Ambient (uV/m)	-	-	-	-	-	-	-	199
		Frequency (MHz)	-	-	-	-	-	-	-	415.05

TABLE 4. QUASI-PEAK FIELD STRENGTH DATA WITH 300 MHz GPR ANTENNA TURNED ON ITS SIDE

Calibrated Antenna Height = 110". RBW = 120 kHz, VBW =300 kHz, Span = 25			Maximum ***Quasi-Peak*** Field Strength Level, Ambient Field Strength Level, and Frequency in the following FAA Bands							
Equipment Frequency Band and System Noise	Polarization	Parameters Measured at Maximum Signal Level	***300*** MHz GPR ANTENNA CENTER FREQUENCY (GPR ANTENNA TURNED ON SIDE) GPR Antenna Position with Respect to the Calibrated Antenna							
	H or V		Right	Up	Left	Down	-	-	-	-
Marker System Noise is 17 dBuV	H	Field Strength (uV/m)	97	306	68	432	-	-	-	-
		Ambient (uV/m)	54	54	54	54	-	-	-	-
		Frequency (MHz)	74.83	74.83	74.83	74.83	-	-	-	-
VOR System Noise is 17 dBuV	H	Field Strength (uV/m)	134	752	95	946	-	-	-	-
		Ambient (uV/m)	75	75	75	75	-	-	-	-
		Frequency (MHz)	109.27	109.27	109.27	109.27	-	-	-	-
Localizer System Noise is 17 dBuV	H	Field Strength (uV/m)	153	768	108	966	-	-	-	-
		Ambient (uV/m)	77	77	77	77	-	-	-	-
		Frequency (MHz)	111.99	111.99	111.99	111.99	-	-	-	-
VHF Comm. System Noise is 17 dBuV	H	Field Strength (uV/m)	214	954	107	1201	-	-	-	-
		Ambient (uV/m)	68	68	68	68	-	-	-	-
		Frequency (MHz)	124.15	124.15	124.15	124.15	-	-	-	-
UHF Comm. System Noise is 17 dBuV	H	Field Strength (uV/m)	214	1905	240	2398	-	-	-	-
		Ambient (uV/m)	107	107	107	107	-	-	-	-
		Frequency (MHz)	225.85	225.85	225.85	225.85	-	-	-	-
Glide Slope System Noise is 17 dBuV	H	Field Strength (uV/m)	250	1773	354	2504	-	-	-	-
		Ambient (uV/m)	141	141	141	141	-	-	-	-
		Frequency (MHz)	327.98	327.98	327.98	327.98	-	-	-	-
Wind shear System Noise is 17 dBuV	H	Field Strength (uV/m)	397	3151	397	3151	-	-	-	-
		Ambient (uV/m)	199	199	199	199	-	-	-	-
		Frequency (MHz)	415.05	415.05	415.05	415.05	-	-	-	-
Marker System Noise is 17 dBuV	V	Field Strength (uV/m)	485	68	485	86	-	-	-	-
		Ambient (uV/m)	54	54	54	54	-	-	-	-
		Frequency (MHz)	74.83	74.83	74.83	74.83	-	-	-	-
VOR System Noise is 17 dBuV	V	Field Strength (uV/m)	752	134	670	75	-	-	-	-
		Ambient (uV/m)	60	60	60	60	-	-	-	-
		Frequency (MHz)	109.27	109.27	109.27	109.27	-	-	-	-
Localizer System Noise is 17 dBuV	V	Field Strength (uV/m)	768	137	768	77	-	-	-	-
		Ambient (uV/m)	61	61	61	61	-	-	-	-
		Frequency (MHz)	111.99	111.99	111.99	111.99	-	-	-	-
VHF Comm. System Noise is 17 dBuV	V	Field Strength (uV/m)	954	170	1070	68	-	-	-	-
		Ambient (uV/m)	60	60	60	60	-	-	-	-
		Frequency (MHz)	124.15	124.15	124.15	124.15	-	-	-	-
UHF Comm. System Noise is 17 dBuV	V	Field Strength (uV/m)	1349	269	1349	151	-	-	-	-
		Ambient (uV/m)	107	107	107	107	-	-	-	-
		Frequency (MHz)	225.85	225.85	225.85	225.85	-	-	-	-
Glide Slope System Noise is 17 dBuV	V	Field Strength (uV/m)	1255	199	1580	199	-	-	-	-
		Ambient (uV/m)	141	141	141	141	-	-	-	-
		Frequency (MHz)	327.98	327.98	327.98	327.98	-	-	-	-
Wind shear System Noise is 17 dBuV	V	Field Strength (uV/m)	1988	315	2809	250	-	-	-	-
		Ambient (uV/m)	199	199	199	199	-	-	-	-
		Frequency (MHz)	415.05	415.05	415.05	415.05	-	-	-	-

Comment on FCC Measurement Procedures. As mentioned previously, FCC 02-48 Appendix F requires both a quasi-peak (RBW = 120 KHz) and a peak (RBW=3 MHz) data for measurements below 960 MHz. These wide resolution bandwidths display the GPR interference as a relatively flat line across the spectrum analyzer. This flat line provides no information on the spectral characteristics of the GPR. A spectrum analyzer resolution bandwidth that more closely matches the receiver's intermediate frequency (i.f.) should be included in the measurement requirements.

Figure 5 shows the measured GPR signal using a resolution bandwidth of 10 kHz. It can be seen that the wide resolution bandwidth is actually composed of individual spectral lines. These spectral lines are critical to the FAA for determining interference effects to aviation systems. This GPR produced spectral lines every 85 kHz.

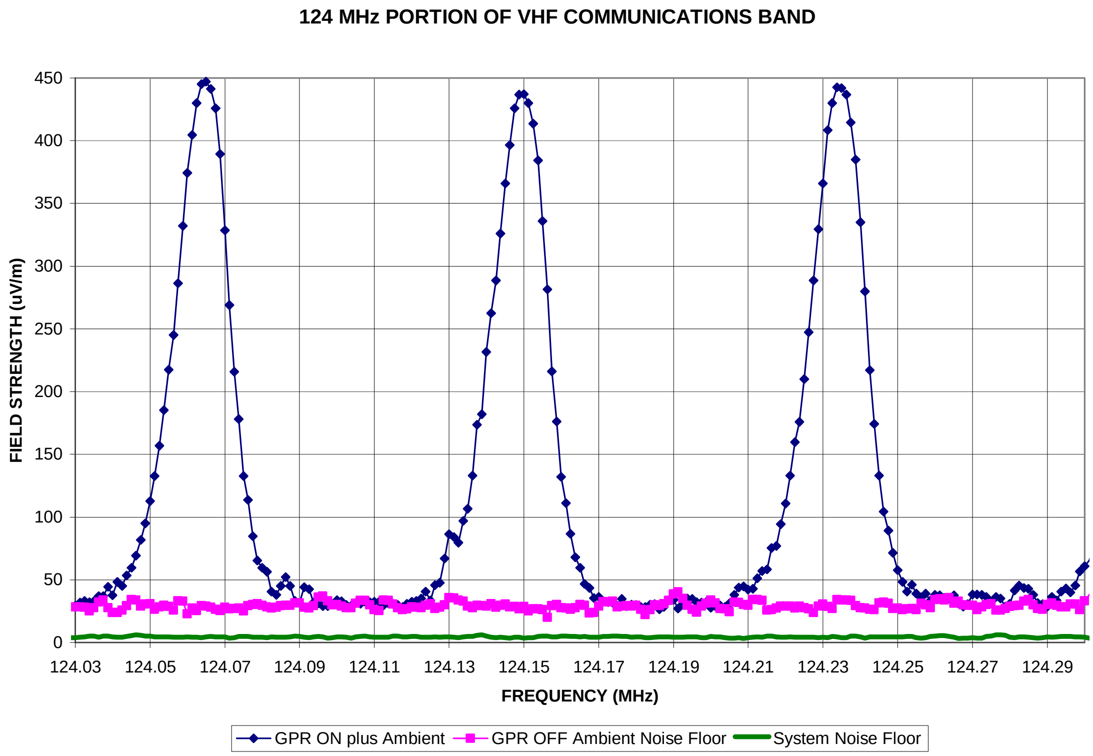
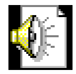


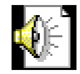
FIGURE 5. INDIVIDUAL GPR SPECTRAL LINES AS VIEWED WITH A 10 kHz SPECTRUM ANALYZER RESOLUTION BANDWIDTH

SECTION 2B: FAA GROUND EQUIPMENT OPERATIONAL TEST RESULTS.

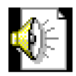
Ground Equipment Data Analysis. The Motorola CM-200 Air Traffic Control ground receiver was connected to a VHF (UHF) antenna at building 176. These antennas are approximately 55 feet above the ground. The GPR was moved across the ground in the vicinity of the antennas. (All audio recordings in this Report are available at: www.faa.gov/ats/aaf/asr/library/downloads.htm).

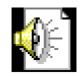
Two locations were chosen for data collection. The first position was 35 feet from the base of the antenna tower and the second location was 100 feet from the tower. At these two locations the GPR caused receiver squelch breaks. This can be heard on the below audio files.


35ft squelch breaks

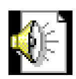

100ft squelch breaks

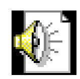
Next, the desired signal was turned on and adjusted to produce a -98 dBm signal level at the receiver's antenna input. This signal was modulated 90% by air traffic control phrases. At both locations the GPR signal almost completely obliterated the desired signal. The beeping sound is a heterodyne tone caused by the frequency difference between the desired signal and the GPR emission. This can be heard on the below audio files.


35ft neg98 GPR plus des voice


100ft neg98 GPR plus des voice

Finally, the GPR was turned off so the receiver output with no GPR interference could be heard for comparison. The following two recordings begin with the GPR turned on and end with the GPR turned off. The GPR turn off point is that where the heterodyne tone ceases and the voice is heard clearly.


35ft neg98 GPR turnoff


100ft neg98 GPR turnoff

Additional tests were performed with the desired signal increased by 30 dB to -68 dBm. This is 35 dB above the squelch level. This was done to determine the affect of the GPR on strong Air Traffic Control signals. Although the GPR interference wasn't as severe with the stronger desired signal level, it still produced unacceptable audio quality.

The ground UHF receivers operating in the 225-400 MHz band were not affected by the GPR.

<u>Analysis of GPR VHF Figure 2 Test Data</u>

<u>Background</u>

The tests in the above sections were based on a GPR that does not satisfy the Part 15 source emission requirement of 150 μV/m @ 3 m. The Part 15 reference measurement (table 3, vertical polarization section) on the GPR tested at the FAA Technical Center recorded 214 μV/m @ 4 m.

<u>Test Geometry and Analysis</u>

The geometry for the tests under discussion is given Figure 2 of the FAA report. Referring to Figure 2 the VHF receiver tower (antenna phase center height = 55 ft) was separated about 80 ft from the VHF transmitter tower. The desired signal power was adjusted to give -98 dBm at the antenna port of a VHF DSB-AM Air Traffic Control (ATC) communications receiver. The receiver squelch was set to -103 dBm. As stated previously, there were two ground positions of the GPR, 35 ft and 100 ft. Since the receiver antenna height = 55 ft, the slant distance from the GPR to the VHF receiver antenna is

$$D1 = \sqrt{55^2 + 35^2} = 65.2\,\text{ft} = 19.88\text{m} \cong 20\text{m} \qquad (1)$$

$$D2 = \sqrt{55^2 + 100^2} = 114.1\,\text{ft} = 34.79\text{m} \cong 35\text{m} \qquad (2)$$

As noted in Table 3, the measured quasi-peak field strength of the GPR for vertical polarization is E_{GPR} = 214 μV/m @ 4 m. The 4 m arises because the quasi-peak emission of 214 μV/m was measured at a height of 110 inches. With the base of the measuring antenna 3 m from the GPR, the resulting slant range is 4 m. Thus given the vertically polarized 214 μV/m @ 4 m the actual vertically polarized source power of the GPR is

$$P_{GPR} = 10\log_{10} [(E^2_{GPR}/Z_0)4\pi R^2] + 30$$
$$= 10\log_{10} [0.000214^2/377)4\pi 4^2] + 30 = -46.12 \text{ dBm/120 kHz} \qquad (3)$$

where R = 4m, and E_{GPR} = 0.000214 μV/m. The impedance of free space is Z_0 = 377. The factor of 30 dB is the conversion from dBW to dBm.

Measured GPR Values

Table 3a summarizes the data for the GPR. As noted in Table 3a all the RFI levels are above the -103 dBm noise squelch level and simultaneously the Signal-to-Interference levels are below the Signal-to-Noise Squelch Level = -98 – (-103) = 5 dB. This means that the aural distortion for the actual levels should be observable and severe which was obvious from the recorded audio output signals given above in this report.

Table 3a. Actual GPR RFI and Part 15 RFI Link Budget

Effective Power at FAA Ground Receiver	GPR 214 μV/m @ 4 m
GPR Power Source	-46.12 dBm
Path loss at 20 m (dB)	-40.3
Path loss at 35 m (dB)	-45.2
Antenna gain (dBi)	0
Line loss (dB)	-2
Bandwidth correction (dB)	0
GPR Power at Receiver input port @ 20 m (dBm)	-88.4
GPR Power at Receiver input port @ 35 m (dBm)	-93.3
Desired Signal Strength (dBm)	-98
S/I for GPR at 20 m (dBm)	-9.6
S/I for GPR at 35 m (dBm)	-4.7

GPR VHF Figure 2 Test Data Conclusions

As noted in Table 3a the noise alone condition at both 20 m and at 35 m would break squelch (-103.0 dBm) as indicated under the Ground Equipment Data section and the large noisy aural output would be unacceptable to air traffic controllers. For the condition where the -98 dBm desired signal was present, the aural information output was severely distorted at both the 20 m and 35 m distances as stated in Ground Equipment Data Analysis section. In other words the audio records given in this report confirm as an observed fact that when the noise is above the squelch threshold and the S/I is less than 5 dB severe audio distortion will be present in the audio output whether the signal is present or not.

Table 3b. Detected RFI (GPR Measurements) for Quasi-Peak GPR RFI Only and Signal Plus Quasi-Peak GPR RFI

	Quasi-Peak GPR RFI Only	-98 dBm Desired Signal Plus Quasi-Peak GPR RFI
214 μV/m D_1= 65.2 ft (20 m)	-88.4 dBm (aurally observed large interference)	(aurally observed large distortion level)
214 μV/m D_2= 114.1 ft (35 m)	-93.3 dBm (aurally observed large interference)	(aurally observed large distortion level)

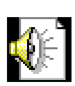
The distortion is predictable because observations recorded in this report (elsewhere) and summarized above confirm that 1) when the noise is above the receiver squelch threshold, aural information is distorted and 2) air traffic controller acceptance factors are violated when no signal is present. Table 3b summarizes the test observations and the predictions.

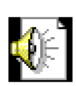
SECTION 3B: FAA AIRBORNE EQUIPMENT OPERATIONAL DEMONSTRATION RESULTS.

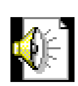
Airborne Data Analysis. Airborne demonstrations of GPR interference were performed with the FAA helicopter N38. Due to the complexities of providing and maintaining the desired signal at a constant level as the helicopter moved around the area, these were qualitative tests. These tests checked for incorrect needle movement on the localizer/glide slope and VOR indicators. Marker lights and audio tones were monitored for proper operation. Localizer, VOR, and Communications audio were monitored for interference.

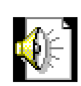
The helicopter pilot reported that the GPR did *not* cause any abnormal localizer, glide slope, or VOR needle indications or Marker tones or lights to the onboard operational systems. Interference was heard on the localizer and VOR receiver's audio output. This interference could cause ambiguity in deciphering the system's Morse code identifier.

The following recordings are from the audio output of the VHF communications receiver in the helicopter. The first recording demonstrates the squelch break that occurs as the helicopter flies over the GPR at 100 feet altitude; on the second recording the squelch break is heard as the helicopter hovers 100 feet over the GPR; in the third recording the helicopter increases its altitude until the squelch break ceases (290 feet); the fourth recording was made with the squelch disabled and the helicopter increasing its height to 600 feet where the interference was still heard.


comm interference flyby


comm interference hover

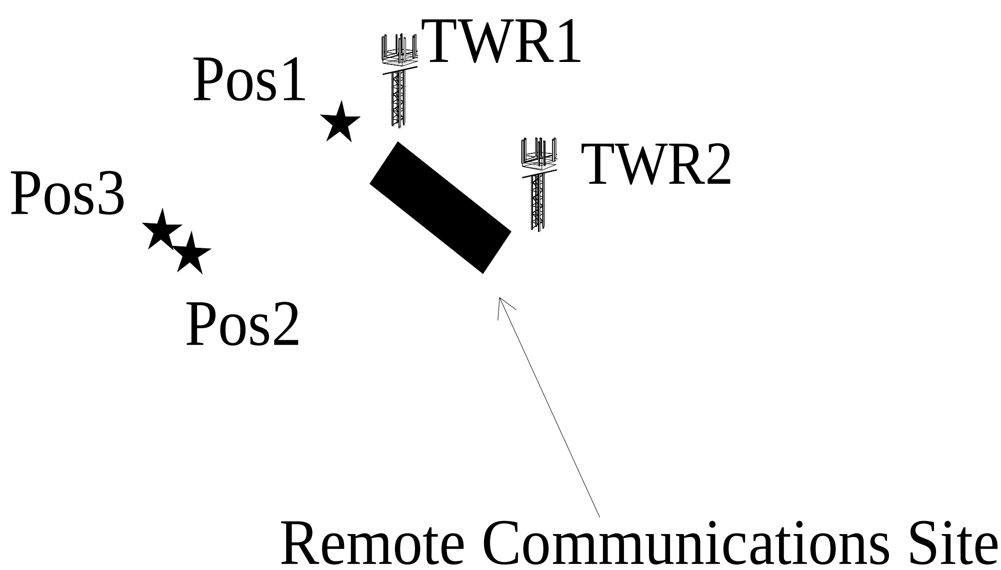

comm interference squelch break 290 ft


comm interference squelch disabled 600

SECTION 4B: SIMULATION OF JFK INTERNATIONAL AIRPORT INTERFERENCE TEST RESULTS.

The table and picture below show the position (Pos) of the GPR (Pos 1, Pos2, and Pos3) with respect to the Remote Communications Site's antennas on tower 1 (TWR). Position 1 produced the most objectionable audio interference. Position 2 was the point where the receiver no longer broke squelch. Position 3 was where audio interference ceased *with receiver squelch disabled*.

FROM	TO	MEASURED DISTANCE (Feet)
TWR 1	POS 1	35
TWR 1	POS 2	155
TWR 1	POS 3	160



Four Air Traffic Control frequencies used at the site were affected: 119.1, 123.9, 134.35, and 132.4 MHz. At position 1, the measured GPR signal level entering the receivers was -95 dBm on frequency 132.4 MHz and -98 dBm on frequency 123.9 MHz. On the 132.4 MHz receiver the GPR interfering frequency was on channel while the GPR interfering frequency for the 123.9 MHz receiver was 2 kHz off channel.

When the antenna cable was disconnected from the affected receiver, the GPR interference ceased indicating that the GPR interference was being radiated through the air. The GPR was repeatedly passed over the underground cables while the antenna cable was disconnected. In this condition, no audio interference was detected.

CONCLUSIONS

<u>Federal Communications Commission's (FCC) Measurement Procedures found in appendix F of "First Report and Order" FCC 02-48 Testing:</u>

1. The GPR operating with the 300 MHz antenna exceeded the FCC's Code of Federal Regulations, Title 47, Part 15, Section 15.209 quasi-peak emission requirements, which are also in the Memorandum Opinion and Order (MO&O). In the frequency bands used by Federal Aviation Administration's (FAA) Marker and VHF communications and navigation systems (75 MHz and 108-137 MHz, respectively), with the calibrated measurement antenna horizontally polarized, the GPR emissions exceeded the requirement by as much as 12 dB. In the UHF band (225-400 MHz) by as much as 5.6 dB.

2. With the calibrated measurement antenna in its vertical polarization mode the GPR emission levels were less than those measured with the calibrated antenna in its horizontal polarization mode. However, in many cases the GPR still failed the criteria.

3. The GPR operating with the 400 and 500 MHz antennas met the FCC requirements below 960 MHz except in the band 406.1 to 420 MHz used for Wind Shear detection.

4. When the GPR was turned on its side, the GPR operating with the 300 MHz antenna exceeded the criteria by as much as 24 dB.

5. The 120 kHz and 3 MHz spectrum analyzer resolution bandwidths, required by the FCC for measurements below 960 MHz, produce spectrum analyzer displays that are relatively straight lines. This provides no information on the spectral line content of the GPR emissions. Narrower resolutions bandwidths are necessary.

<u>FAA Ground Operational Tests (GPR operating with the 300 MHz antenna):</u>

1. With the desired signal turned off, the GPR broke squelch on the FAA's ground VHF and receivers. The ground UHF receivers were unaffected by this GPR.

2. When the -98 dBm desired signal modulated 90% by Air Traffic Control phrases was turned on, the GPR overrode the signal making the receiver audio unintelligible.

3. When the desired signal was increased 30 dB from -98 dBm to -68 dBm (35 dB above squelch level), the GPR still caused unacceptable receiver audio quality.

<u>FAA Airborne Equipment Operational Demonstrations (GPR operating with the 300 MHz antenna):</u>

1. The pilot observed *no* abnormal needle movement or flags on the localizer, VOR, or glide slope indicators.

2. The pilot noted no abnormal marker beacon receiver lights or audio interference.

3. With the desired signal turned on *or* off the pilots heard audio interference on their localizer, VOR, and VHF communication receivers from the GPR.

<u>JFK International Airport Tests (GPR operating with the 300 MHz antenna):</u>

1. Testing at JFK International Airport demonstrated that four of the site's operational Air Traffic Control frequencies were interfered with by the GPR.

2. The interference was caused by radiated emission from the GPR antenna to the FAA ground receiver's antennas and not conducted through the underground cables.

RECOMMENDATIONS

1. Make spectrum analyzer signal level measurements with lower resolution bandwidths so that individual spectral lines can be observed. A 10 kHz resolution bandwidth produced good results with this GPR.

2. Perform tests on a GPR unit that meets the FCC's Code of Federal Regulations, Title 47, Part 15, Section 15.209 quasi-peak emission requirements.

3. Request that FCC require the GPRs be shielded so that emissions other than those required for proper operation of the equipment, are suppressed.

TABLE 5. QUASI-PEAK FIELD STRENGTH DATA WITH 400 MHz GPR ANTENNA

Calibrated Antenna Height = 110". RBW = 120 kHz, VBW =300 kHz, Span = 25 kHz			Maximum ***Quasi-Peak*** Field Strength Level, Ambient Field Strength Level, and Frequency in the following FAA Bands							
Equipment Frequency Band and System Noise	Polarization	Parameters Measured at Maximum Signal Level	***400*** MHz GPR ANTENNA CENTER FREQUENCY GPR Antenna Angle with Respect to the Calibrated Antenna							
	H or V		0^0	45^0	90^0	135^0	180^0	225^0	270^0	315^0
Marker System Noise is 17 dBuV	H	Field Strength (uV/m)	77	-	-	-	-	-	-	-
		Ambient (uV/m)	77	-	-	-	-	-	-	-
		Frequency (MHz)	74.83	-	-	-	-	-	-	-
VOR System Noise is 17 dBuV	H	Field Strength (uV/m)	60	-	-	-	-	-	-	-
		Ambient (uV/m)	67	-	-	-	-	-	-	-
		Frequency (MHz)	109.27	-	-	-	-	-	-	-
Localizer System Noise is 17 dBuV	H	Field Strength (uV/m)	77	-	-	-	-	-	-	-
		Ambient (uV/m)	77	-	-	-	-	-	-	-
		Frequency (MHz)	111.99	-	-	-	-	-	-	-
VHF Comm. System Noise is 17 dBuV	H	Field Strength (uV/m)	85	-	-	-	-	-	-	-
		Ambient (uV/m)	68	-	-	-	-	-	-	-
		Frequency (MHz)	124.15	-	-	-	-	-	-	-
UHF Comm. System Noise is 17 dBuV	H	Field Strength (uV/m)	135	-	-	-	-	-	-	-
		Ambient (uV/m)	107	-	-	-	-	-	-	-
		Frequency (MHz)	225.85	-	-	-	-	-	-	-
Glide Slope System Noise is 17 dBuV	H	Field Strength (uV/m)	177	-	-	-	-	-	-	-
		Ambient (uV/m)	141	-	-	-	-	-	-	-
		Frequency (MHz)	327.98	-	-	-	-	-	-	-
Wind shear System Noise is 17 dBuV	H	Field Strength (uV/m)	250	-	-	-	-	-	-	-
		Ambient (uV/m)	199	-	-	-	-	-	-	-
		Frequency (MHz)	415.05	-	-	-	-	-	-	-

TABLE 6. QUASI-PEAK FIELD STRENGTH DATA WITH 500 MHz GPR ANTENNA

Calibrated Antenna Height = 110". RBW = 120 kHz, VBW =300 kHz, Span = 25 kHz			Maximum ***Quasi-Peak*** Field Strength Level, Ambient Field Strength Level, and Frequency in the following FAA Bands							
Equipment Frequency Band and System Noise	Polarization	Parameters Measured at Maximum Signal Level	***500*** MHz GPR ANTENNA CENTER FREQUENCY GPR Antenna Angle with Respect to the Calibrated Antenna							
	H or V		0^0	45^0	90^0	135^0	180^0	225^0	270^0	315^0
Marker System Noise is 17 dBuV	H	Field Strength (uV/m)	86	-	-	-	-	-	-	-
		Ambient (uV/m)	77	-	-	-	-	-	-	-
		Frequency (MHz)	74.83	-	-	-	-	-	-	-
VOR System Noise is 17 dBuV	H	Field Strength (uV/m)	84	-	-	-	-	-	-	-
		Ambient (uV/m)	67	-	-	-	-	-	-	-
		Frequency (MHz)	109.27	-	-	-	-	-	-	-
Localizer System Noise is 17 dBuV	H	Field Strength (uV/m)	97	-	-	-	-	-	-	-
		Ambient (uV/m)	77	-	-	-	-	-	-	-
		Frequency (MHz)	111.99	-	-	-	-	-	-	-
VHF Comm. System Noise is 17 dBuV	H	Field Strength (uV/m)	85	-	-	-	-	-	-	-
		Ambient (uV/m)	68	-	-	-	-	-	-	-
		Frequency (MHz)	124.15	-	-	-	-	-	-	-
UHF Comm. System Noise is 17 dBuV	H	Field Strength (uV/m)	151	-	-	-	-	-	-	-
		Ambient (uV/m)	107	-	-	-	-	-	-	-
		Frequency (MHz)	225.85	-	-	-	-	-	-	-
Glide Slope System Noise is 17 dBuV	H	Field Strength (uV/m)	158	-	-	-	-	-	-	-
		Ambient (uV/m)	141	-	-	-	-	-	-	-
		Frequency (MHz)	327.98	-	-	-	-	-	-	-
Wind shear System Noise is 17 dBuV	H	Field Strength (uV/m)	315	-	-	-	-	-	-	-
		Ambient (uV/m)	199	-	-	-	-	-	-	-
		Frequency (MHz)	415.05	-	-	-	-	-	-	-

TABLE 7. PEAK FIELD STRENGTH DATA WITH 300 MHz GPR ANTENNA TURNED ON ITS SIDE

Calibrated Antenna Height = 110". RBW = 120 kHz, VBW =300 kHz, Span = 25			Maximum **Peak** Field Strength Level, Ambient Field Strength Level, and Frequency in the following FAA Bands							
Equipment Frequency Band and System Noise	Polarization	Parameters Measured at Maximum Signal Level	***300*** MHz GPR ANTENNA CENTER FREQUENCY (GPR ANTENNA TURNED ON SIDE) GPR Antenna Position with Respect to the Calibrated Antenna							
	H or V		Right	Up	Left	Down	-	-	-	-
Marker System Noise is 17 dBuV	H	Field Strength (uV/m)	3852	9675	2430	13667	-	-	-	-
		Ambient (uV/m)	1533	1533	1533	1533	-	-	-	-
		Frequency (MHz)	74.83	74.83	74.83	74.83	-	-	-	-
VOR System Noise is 17 dBuV	H	Field Strength (uV/m)	4743	23771	2993	26672	-	-	-	-
		Ambient (uV/m)	1888	1888	1888	1888	-	-	-	-
		Frequency (MHz)	109.27	109.27	109.27	109.27	-	-	-	-
Localizer System Noise is 17 dBuV	H	Field Strength (uV/m)	4844	24277	3429	27239	-	-	-	-
		Ambient (uV/m)	1365	1365	1365	1365	-	-	-	-
		Frequency (MHz)	111.99	111.99	111.99	111.99	-	-	-	-
VHF Comm. System Noise is 17 dBuV	H	Field Strength (uV/m)	6018	26882	2396	33842	-	-	-	-
		Ambient (uV/m)	1512	1512	1512	1512	-	-	-	-
		Frequency (MHz)	124.15	124.15	124.15	124.15	-	-	-	-
UHF Comm. System Noise is 17 dBuV	H	Field Strength (uV/m)	5369	53691	6759	67593	-	-	-	-
		Ambient (uV/m)	2398	2398	2398	2398	-	-	-	-
		Frequency (MHz)	225.85	225.85	225.85	225.85	-	-	-	-
Glide Slope System Noise is 17 dBuV	H	Field Strength (uV/m)	6289	56053	9968	70567	-	-	-	-
		Ambient (uV/m)	3152	3152	3152	3152	-	-	-	-
		Frequency (MHz)	327.98	327.98	327.98	327.98	-	-	-	-
Wind shear System Noise is 17 dBuV	H	Field Strength (uV/m)	9966	99655	9966	99655	-	-	-	-
		Ambient (uV/m)	4451	4451	4451	4451	-	-	-	-
		Frequency (MHz)	415.05	415.05	415.05	415.05	-	-	-	-
Marker System Noise is 17 dBuV	V	Field Strength (uV/m)	13667	1930	15334	2166	-	-	-	-
		Ambient (uV/m)	1218	1218	1218	1218	-	-	-	-
		Frequency (MHz)	74.83	74.83	74.83	74.83	-	-	-	-
VOR System Noise is 17 dBuV	V	Field Strength (uV/m)	23771	5322	21186	3358	-	-	-	-
		Ambient (uV/m)	2667	2667	2667	2667	-	-	-	-
		Frequency (MHz)	109.27	109.27	109.27	109.27	-	-	-	-
Localizer System Noise is 17 dBuV	V	Field Strength (uV/m)	21637	3848	21637	1532	-	-	-	-
		Ambient (uV/m)	1719	1719	1719	1719	-	-	-	-
		Frequency (MHz)	111.99	111.99	111.99	111.99	-	-	-	-
VHF Comm. System Noise is 17 dBuV	V	Field Strength (uV/m)	30162	4260	30162	675	-	-	-	-
		Ambient (uV/m)	1696	1696	1696	1696	-	-	-	-
		Frequency (MHz)	124.15	124.15	124.15	124.15	-	-	-	-
UHF Comm. System Noise is 17 dBuV	V	Field Strength (uV/m)	38011	7584	42649	3019	-	-	-	-
		Ambient (uV/m)	3019	3019	3019	3019	-	-	-	-
		Frequency (MHz)	225.85	225.85	225.85	225.85	-	-	-	-
Glide Slope System Noise is 17 dBuV	V	Field Strength (uV/m)	35367	4452	44525	4452	-	-	-	-
		Ambient (uV/m)	3152	3152	3152	3152	-	-	-	-
		Frequency (MHz)	327.98	327.98	327.98	327.98	-	-	-	-
Wind shear System Noise is 17 dBuV	V	Field Strength (uV/m)	62878	7055	79159	3967	-	-	-	-
		Ambient (uV/m)	4451	4451	4451	4451	-	-	-	-
		Frequency (MHz)	415.05	415.05	415.05	415.05	-	-	-	-

TABLE 8. PEAK FIELD STRENGTH DATA WITH 300 MHz GPR ANTENNA

Calibrated Antenna Height = 110". RBW = 120 kHz, VBW =300 kHz, Span = 25 kHz			Maximum ***Peak*** Field Strength Level, Ambient Field Strength Level, and Frequency in the following FAA Bands							
Equipment Frequency Band and System Noise	Polarization	Parameters Measured at Maximum Signal Level	***300*** MHz GPR ANTENNA CENTER FREQUENCY GPR Antenna Angle with Respect to the Calibrated Antenna							
	H or V		0^0	45^0	90^0	135^0	180^0	225^0	270^0	315^0
Marker System Noise is 50 dBuV	H	Field Strength (uV/m)	5623	3548	1778	4467	6310	4467	3162	5012
		Ambient (uV/m)	1585	1585	1585	1585	1585	1585	1585	1585
		Frequency (MHz)	74.83	74.83	74.83	74.83	74.83	74.83	74.83	74.83
VOR System Noise is 50 dBuV	H	Field Strength (uV/m)	8610	4842	2163	4315	4842	3846	3846	7674
		Ambient (uV/m)	1928	1928	1928	1928	1928	1928	1928	1928
		Frequency (MHz)	109.27	109.27	109.27	109.27	109.27	109.27	109.27	109.27
Localizer System Noise is 49 dBuV	H	Field Strength (uV/m)	7852	3936	1567	3508	6237	3508	4416	6237
		Ambient (uV/m)	1396	1396	1396	1396	1396	1396	1396	1396
		Frequency (MHz)	111.99	111.99	111.99	111.99	111.99	111.99	111.99	111.99
VHF Comm. System Noise is 50 dBuV	H	Field Strength (uV/m)	6761	3802	2692	4266	7586	3388	4786	5370
		Ambient (uV/m)	1514	1514	1514	1514	1514	1514	1514	1514
		Frequency (MHz)	124.15	124.15	124.15	124.15	124.15	124.15	124.15	124.15
UHF Comm. System Noise is 50 dBuV	H	Field Strength (uV/m)	5370	3802	3020	4266	5370	3802	3020	4266
		Ambient (uV/m)	2692	2692	2692	2692	2692	2692	2692	2692
		Frequency (MHz)	225.85	225.85	225.85	225.85	225.85	225.85	225.85	225.85
Glide Slope System Noise is 50 dBuV	H	Field Strength (uV/m)	3758	3350	3758	3350	3758	3350	3758	4217
		Ambient (uV/m)	2985	2985	2985	2985	2985	2985	2985	2985
		Frequency (MHz)	327.98	327.98	327.98	327.98	327.98	327.98	327.98	327.98
Wind shear System Noise is 17 dBuV	H	Field Strength (uV/m)	7916	4995	5604	4995	3536	4995	3151	7055
		Ambient (uV/m)	3151	3151	3151	3151	3151	3151	3151	3151
		Frequency (MHz)	415.05	415.05	415.05	415.05	415.05	415.05	415.05	415.05
Marker System Noise is 50 dBuV	V	Field Strength (uV/m)	-	-	-	-	-	-	-	3162
		Ambient (uV/m)	-	-	-	-	-	-	-	1259
		Frequency (MHz)	-	-	-	-	-	-	-	74.83
VOR System Noise is 50 dBuV	V	Field Strength (uV/m)	-	-	-	-	-	-	-	6761
		Ambient (uV/m)	-	-	-	-	-	-	-	2692
		Frequency (MHz)	-	-	-	-	-	-	-	109.27
Localizer System Noise is 49 dBuV	V	Field Strength (uV/m)	-	-	-	-	-	-	-	4955
		Ambient (uV/m)	-	-	-	-	-	-	-	1758
		Frequency (MHz)	-	-	-	-	-	-	-	111.99
VHF Comm. System Noise is 50 dBuV	V	Field Strength (uV/m)	-	-	-	-	-	-	-	3020
		Ambient (uV/m)	-	-	-	-	-	-	-	1698
		Frequency (MHz)	-	-	-	-	-	-	-	124.15
UHF Comm. System Noise is 50 dBuV	V	Field Strength (uV/m)	-	-	-	-	-	-	-	3020
		Ambient (uV/m)	-	-	-	-	-	-	-	3388
		Frequency (MHz)	-	-	-	-	-	-	-	225.85
Glide Slope System Noise is 50 dBuV	V	Field Strength (uV/m)	-	-	-	-	-	-	-	3350
		Ambient (uV/m)	-	-	-	-	-	-	-	2985
		Frequency (MHz)	-	-	-	-	-	-	-	327.98
Wind shear System Noise is 17 dBuV	V	Field Strength (uV/m)	-	-	-	-	-	-	-	3151
		Ambient (uV/m)	-	-	-	-	-	-	-	3151
		Frequency (MHz)	-	-	-	-	-	-	-	415.05