



Citizens

FLOYD_VA

02-Jun-2021

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Summary

System: FLOYD_VA

Test Date: 02-Jun-2021

A fly-over test for the system was performed to evaluate the system on the basis of signal leakage in the aeronautical band (108-140 MHz) as required. This has been done to determine the locations and levels of any non-complying leaks out of regulatory compliance ranges; that is, leaks that are in excess of $10\mu\text{V/m}$ at 450 meters.

Included in this report are a description of the procedures used, a probability graph, a list of high readings, and a plotted map. The plotted map the system boundaries, flight pattern, and locations of high leakage levels. The Leakage List report includes these details:

Item	Units
• RF processing path net gain at 133.2625MHz	0.0 dB
• Number of sample points	2084 points
• Number of points $> 10\mu\text{V/m}$	0 points
• Minimum leakage $\mu\text{V/m}$	0.8 $\mu\text{V/m}$
• Maximum leakage $\mu\text{V/m}$	1.4 $\mu\text{V/m}$
• Average field intensity $\mu\text{V/m}$	0.9 $\mu\text{V/m}$
• Percentage of points $< 10\mu\text{V/m}$	100.0 %
• Field Intensity at 90th Percentile	1.0 $\mu\text{V/m}$
• CLI Test Pass/Fail	PASS

Leakage Reports are Indicative, Not Exhaustive

The techniques used in this test and report are designed to indicate general overall compliance with regulations governing leakage and are in line with regulatory requirements and reporting objectives. Leak sources are dynamic, and therefore not every noncomplying leak can be listed in the report or visible on the maps. One reason is that individual leaks change bore sight angle and resonant frequency with changing environmental factors such as temperature and wind. Thus the number of actual number non-complying leaks that exist will usually be much higher than the number of leaks shown on the maps. This is well known and does not at all present a regulatory reporting deficiency.

Interpreting Leak Location Information

The location shown for each reported leak represents the area in which it was detected, which is at an altitude of 450m above ground level. As such, the leakage level may be from a single source or the cumulative effects of several leak sources. While leak sources are always in the general vicinity of the area directly below the highest reading, the geographical location is not determinable with certainty. It is best to use the leak location in this report as a starting point and to work in a radius of up to 1 mile around that area. It is possible to have a leak shown on the map where there is no cable directly below the signal intercept position.

Only leak levels of $10\mu\text{V/m}$ and greater are considered to be non-complying and only these negatively affect the final score. We show leaks which are $6\mu\text{V/m}$ or greater on the map for you to use in locating leakage sources.

Keyhole Markup Language Files (*.kml, *.kmz)

Leakage information is also available in 'keyhole markup language' format (KML) files. These files are viewable in Google's multiplatform freeware application called Google Earth (for Windows, Linux, BSD, and Mac). KML files can be zipped to save space and are called KMZ files. Both are directly viewable and do not need to be unzipped.

The KML files show exact signal field strength readings on a 1-second time interval. These readings are presented along the flight path, and show a record of the exact flight path and anchoring the route and the readings in real time.

The legend is displayed in the upper right hand corner. Field strength is reported in 3dB increments from $\geq 8\text{dB}\mu\text{V/m}$ to $>29\text{dB}\mu\text{V/m}$. Noise-only intervals are shown as white dots along the path. The flight path is a thin, white line and the geographic boundary lines are shown in magenta.

Zooming in using a mouse or the display controls embedded in the legend will gradually resolve the individual signal points. Clicking on any of the points will display the associated "waterfall" power spectrum. Its three dimensions are frequency (x-axis), time (y-axis), and power (z-axis). The monitored leakage frequency is shown centered. Each waterfall generally represents 600sec but may vary somewhat. Note that while the data is plotted in 1 second intervals, the actual data recorded is streamed at very high speed (6Msps through 150Msps, depending on receiver span) and available to the microsecond.

The waterfall plots are repeated later in this report. There are two sets. One set shows a more narrow span, centered on the monitored leak frequency. These show in close detail the leak signal strength in real time. The second set of waterfall plots, which are generated from the exact same data set, show the entire capture span. The resolution bandwidth for both is roughly 3.5KHz.

The dBm power scale corresponds to the calibrated power scale of the digitization platform. To arrive at the field strength values, we convert power in 50Ω to voltage, correct for system gains and losses, and for antenna factor. These converted and normalized values are available when viewing the specific waterfall plot from within Google Earth.

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Testing Procedure

1. Determine system boundaries and correlate to topographic map using either a 7.5' or a 1:100,000 scale print.
2. Determine proper channel and time for testing:

Start Date: 02-Jun-2021 16:50
End Date: 02-Jun-2021 18:35
Frequency: 133.2625MHz

3. Convert between dBm and $\mu\text{V}/\text{m}$ in 50Ω using a tuned dipole:

The digitizing receiver accepts conducted power into nominal impedance of 50Ω . The resulting power spectrums are computed in dBm (1mW into 50Ω). The nominal gain for the 50Ω tuned dipole we used is $\approx 4.65\text{dBi}$ which yields an approximate antenna factor of 8.1 dB/m:

$$\begin{aligned} \text{AF}_{50\Omega} &= 20\log_{10}(f) - (G_{\text{dBi}}) - 29.77 \\ &= 20\log_{10}(133.2625\text{MHz}) - (4.65) - 29.77 \\ &= 42.5 - (4.65) - 29.77 \\ &= 8.1 \text{ dB/m} \end{aligned}$$

The conversion from dBm to $\text{dB}\mu\text{V}$ is:

$$\text{dB}\mu\text{V}_{50\Omega} = \text{dBm}_{50\Omega} + 107$$

Therefore, the mathematical relationship between conducted power in 50Ω and electric field strength using a 50Ω tuned dipole is:

$$\mu\text{V}/\text{m} = 10^{[(\text{dBm} + 107 + 8.1)/20]}$$

Note: Power measurements of wideband digital signals are related to analog carriers using a 300KHz reference bandwidth. This will preserve the power offset relationship of the cable system itself. For example, if the system adjusts its digital carriers to -6dB relative to its analog carriers, digital carrier leaks will appear 6dB lower than analog carrier leaks. This should not be taken to mean that digital signals are always less problematic to off-air signals because they are lower in power; this is strictly not indicated and would be a false conclusion. Also, in practical cases, actual frequencies will make a alter this fixed relationship since system leaks are frequency selective. See the section "Wideband High-Order Modulation Detection" for more details.

4. Measure RF chain gain (loss) and adjust measurement scale accordingly. The receiver RF signal processing chain includes filters, preamplifiers, signal combiners and coaxial switches. These devices affect the conducted power level incident upon the digitizing receiver. Prior to each test, the filters are tuned to the signal of interest, and net gain (loss) is measured. This value, typically +7.7 dB for a 50Ω antenna system is applied to the recorded signal power level

scaling factor. An additional 0.5dB of loss is included in the calculation for the length of cable permanently attached to the antenna as well as any non-ideal properties of its connector.

5. Perform system fly-over at 450m in a grid pattern (all plant covered within 0.8km of pattern) at 195kph. Record streaming geo-location data provided by on-board GPS at approximately 1 second intervals. Continuously record RF spectrum I and Q channels and stream to high-speed recorders.
6. Compute power spectrums from the recorded IQ data and search for leakage frequency power (see *Test Configuration*).
7. Using the defined system boundary polygon, filter all data points outside of system.
8. Develop a frequency distribution graph (see *Probability Graph*) and a listing of all relative high readings.
9. Plot all leak levels on digitized map showing the exact locations of high-level readings with respect to the flight path.

Wideband High-Order Modulation Detection, Measurements, and Graphics

As cable systems migrate away from AM-VSB formatted signals toward high-order wideband formats such as DOCSIS and ITU-J83, detection and reporting details must likewise be modified. Measuring these signals does not require any changes to the measurement system block diagram or capture methodology. There are, however, differences in the exact type of filtering used and to the post processing of the IQ data recordings. For ease of understanding the rest of this narrative, we will refer to all high order modulation signals as "QAM" or "digital carriers", and AM-VSB TV signals as "analog" or "reference signal". But note that this is simply a literary convenience for discussion purposes.

Before conclusions can be made of the reported numerical values, we present the findings in terms of equivalent analog carrier power. In order to relate a QAM signal to its analog equivalent, the QAM signal energy is converted from processed spectral power density to its analog reference equivalent, using its standard power relationship,

$$P_{qam}(refbw) = P_{qam}(fft) + (10 * \log_{10} (RefBW / FFTbw))$$

QAM signals cannot be easily decoded when their passband is contaminated by other signals. Such contamination is quite normal and unavoidable, since the off-air spectrum is heavily populated by legitimate users. Using Spectraq's patent-pending techniques, the essential elements of the QAM signals can be accurately extracted from even very busy off-air spectrum. The Spectraq signal processing equipment is capable of continuous spectrum coverage from 110MHz through 1GHz for cumulative leakage. There are some limitations at present, and these can preclude measurements in certain bands in certain geographic areas. For example, the former TV broadcast spectrum (roughly 470MHz - 694MHz) has been overtaken by very high powered 8VSB transmissions. The more concentrated this band becomes, the more difficult it is to find spectrum that presents a clean thermal noise floor for referencing. For this reason, QAM signal detection in the bands 174-216, 470-694MHz, certain parts of 700MHz and 800MHz spectrum can be difficult or impractical to decode.

Examples of measured signals from previous tests are included as Figure 1 "Power Spectrum Time Slice", Figure 2 "Power Spectrum Waterfall", and Figure 3 "Spectrogram". These graphics, generated directly from the IQ data recordings, reveal the noise-like nature of the QAM signals. These IQ data are actual operating cable system leaks; these are not simulated or contrived. These were recorded at 1500ft altitude and 140kt ground speed.

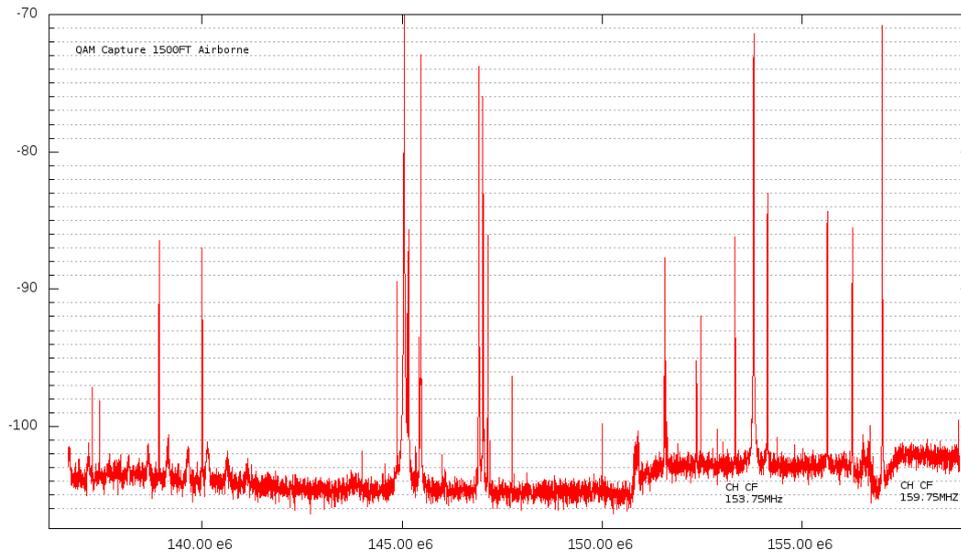


Figure 1

Figure 1, "Power Spectrum Time Slice", reveals the elevated noise floor in the distinct shape of a cable QAM carrier centered at 153.75MHz. Embedded in the signals are the many narrow band analog off-air communications signals. At the far right, the next-adjacent carrier can be seen, centered at 159.75MHz. The capture range of this recording did not contain the entire signal, but it can still be seen and measured. The roll-off at the upper end is a technical consequence of the performance of the digitization process (it traces the -3dB roll-off of the digitizer). This view is a common power-frequency spectrum rendering, scales in dBm and MHz. It represents a 1-second time slice power average.

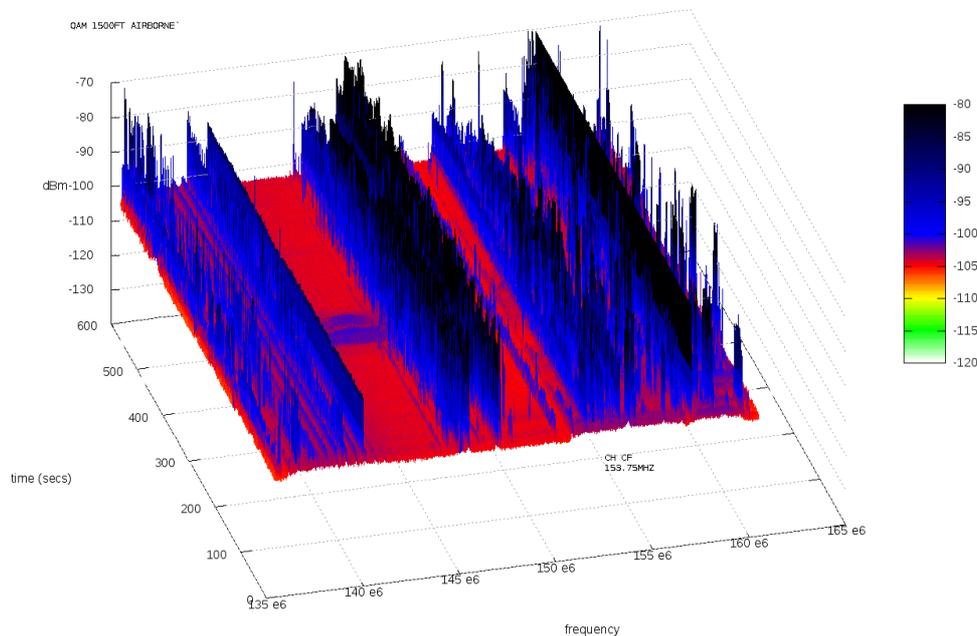


Figure 2

Figure 2, "Power Spectrum Waterfall", is a time-sequenced presentation of time-slice views. These are presented in a perspective view. Power in dBm is color-encoded as well as in Y-axis deflection. The right hand legend relates color to power. Time, in seconds, is shown along the Z-axis. Frequency in MHz is shown along the X-axis. Time relates to aircraft position, and this type of rendering shows the dynamic nature of the measured (recorded) spectrum.

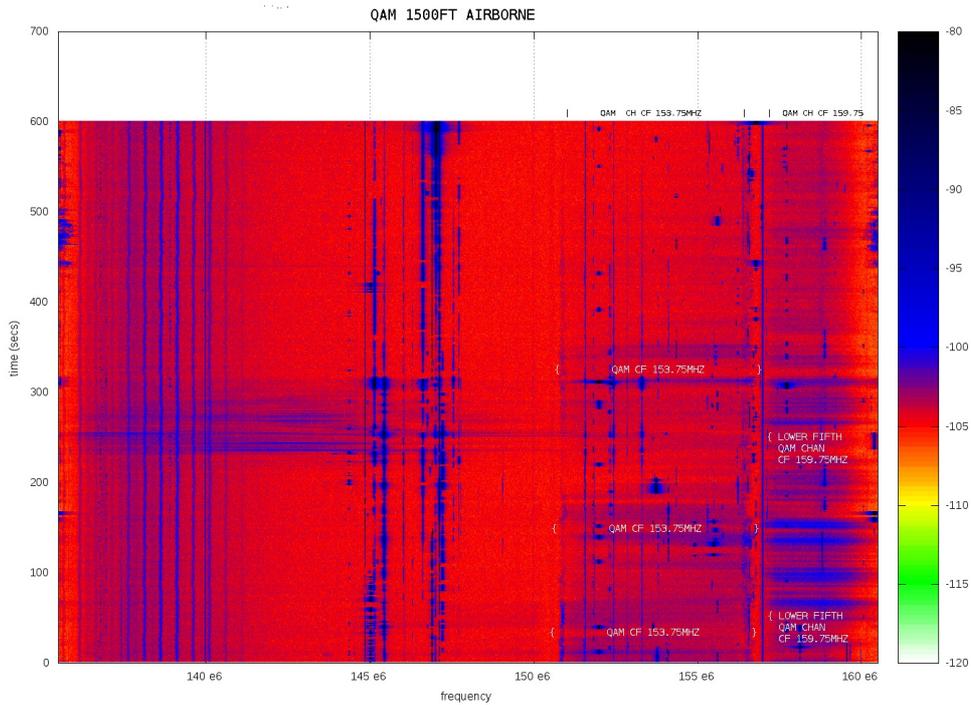


Figure 3

Figure 3, "Spectrogram" is similar to Figure 2, except that it is a 2-dimensional, flat rendering. This view shows the time scale (seconds) and frequency scale (MHz) and Y-axis and X-axis. Power is color-encoded only. It is a less intuitive graphic than a waterfall, but it has the advantage of not obscuring weak events that happen later in time from powerful events.

We do not use graphical information directly to produce measurement results. Rather, the measurement results presented herein are generated mathematically via automated computation from the data directly. Graphics such as these provide visual conformation of the data itself, and provide a very precise means of confirming the mathematical results. These also provide an unmistakable fingerprint of the spectrum data itself. These graphics are included in this report for the measured dataset for this report. The graphics include both full-capture-bandwidth renderings plus subplots of the spectral regions isolated for signal extraction.

Equipment List

Equipment	Calibration Cycle
Cessna 210	Annual Inspection
Garmin G18X GPS Receiver	Quarterly
SPECTRAQ RF Processing Chain	Each Test
Holzworth HSM6000A Synthesizer	Annual
SPECTRAQ High Speed Disk Arrays	N/A
SPECTRAQ RF Signal Filtering System	Quarterly
SPECTRAQ Instrumentation Controller	Quarterly
SPECTRAQ Tunable Bandpass Filter Array	Quarterly
Sinclair Tuned Dipole (Aeronautical Band)	Quarterly

High Points

Center point of system: -80.850381,36.928026 or 36° 55' 41" N, 80° 51' 1" W

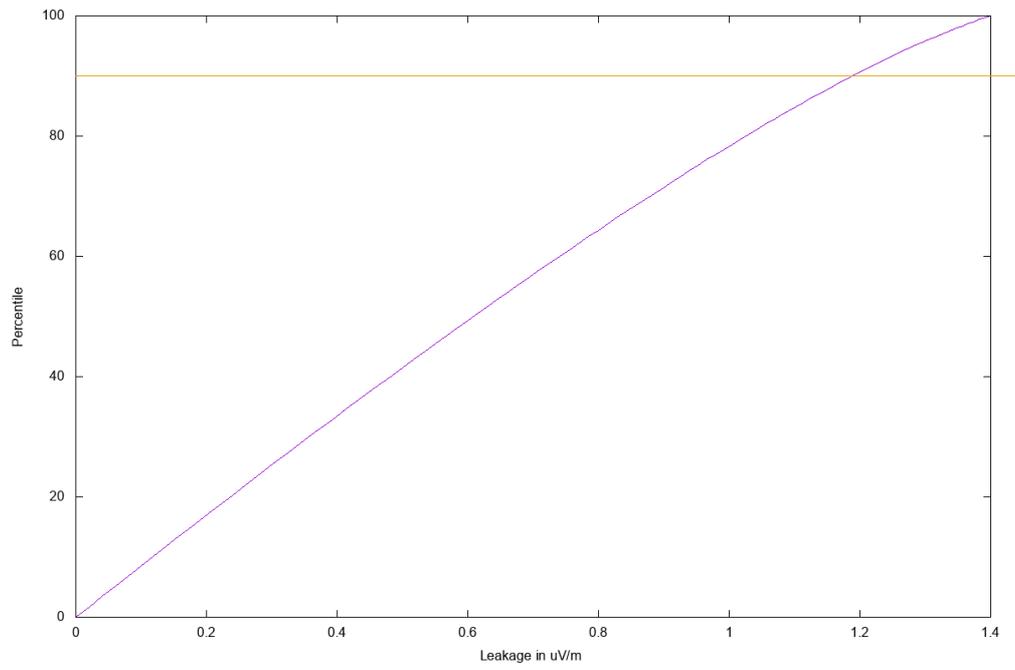
Radius covering entire system: 9195.5 km

Relative high readings for FLOYD_VA:

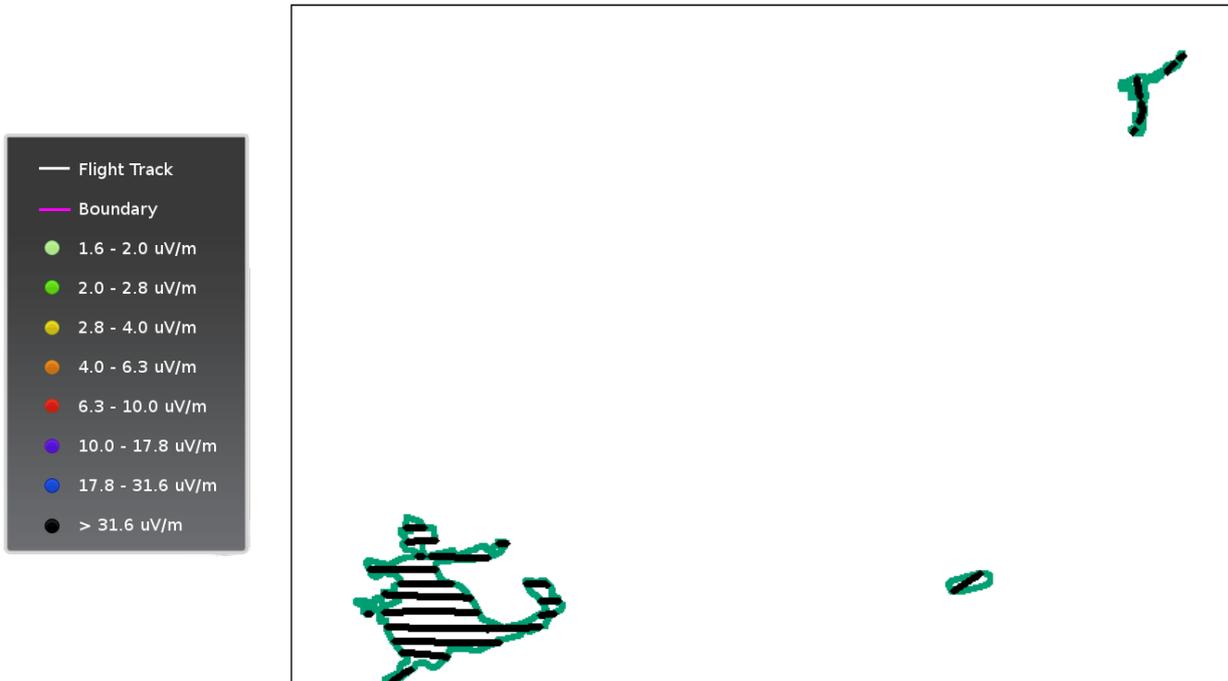
Reference	uV/m	DD MM SS		Decimal Degrees	
		Latitude	Longitude	Latitude	Longitude
984947	1.4	36° 49' 59" N	80° 55' 28" W	36.833169	-80.924394
980769	1.2	36° 53' 10" N	80° 57' 11" W	36.886088	-80.953150
983501	1.2	36° 51' 0" N	80° 51' 26" W	36.849875	-80.857313
980708	1.2	36° 53' 10" N	80° 56' 36" W	36.886215	-80.943351
982419	1.2	36° 51' 55" N	80° 51' 54" W	36.865172	-80.864975
981659	1.2	36° 52' 3" N	80° 59' 15" W	36.867574	-80.987439
983672	1.2	36° 50' 57" N	80° 53' 6" W	36.849079	-80.885071
978497	1.2	36° 54' 12" N	80° 55' 58" W	36.903388	-80.932670
984047	1.2	36° 51' 1" N	80° 56' 45" W	36.850140	-80.945763
970285	1.1	37° 28' 41" N	80° 6' 20" W	37.478041	-80.105546

Probability Chart

Total Points:2084, Field Intensity at 90th Percentile:1.0 $\mu\text{V}/\text{m}$



Area Flown



Approximate location of leaks >10 $\mu\text{V}/\text{m}$

No leaks > 10 $\mu\text{V}/\text{m}$