Citizens

FLOYD_VA

25-Jul-2023

phone: 720-306-1515 -- **email:** reports@spectraq.com

www.spectraq.com

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Summary

System: FLOYD_VA
Test Date: 25-Jul-2023

A flyover 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. The locations and levels of any leaks out of regulatory compliance ranges; that is, leaks that exceed 10µV/m at 450 meters, are noted

Included in this report are a description of the procedures used, a probability graph, a list of high readings, and a map. The map depicts the system boundaries, flight pattern, and locations of high leakage levels. A summary of the report findings are as follows:

Item	Units
• Number of sample points	1448 points
• Number of points > 10µV/m	0 points
• Minimum leakage µV/m	0.1 µV/m
• Maximum leakage µV/m	0.7 µV/m
• Average field intensity µV/m	0.1 µV/m
• Percentage of points < 10µV/m	100.0 %
• Field Intensity at 90th Percentile	0.2 µV/m
• CLI Test Pass/Fail	PASS

Leakage Reports are Indicative, Not Exhaustive

The techniques used in this test and report are designed to indicate overall compliance with regulations governing leakage. Leak sources are dynamic and therefore it is expected that leak amplitude and measured location may change from time to time. Regular repetition of testing using standardized methods is the best mechanism to ensure regulatory compliance and optimum system performance. One reason is that individual leaks change bore sight angle and resonant frequency with changing environmental factors such as temperature and wind. The compliance framework accounts for such variations, provided regular meausrement and reporting are performed. It is not expected that individual leak sources will always be located using different methods or at different times.

Interpreting Leak Location Information

The location shown for each reported leak represents the center of the area in which the meaximum energy was detected from a moving receiver at an altitude of 450m above ground level. The energy detected 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 to identify the leak source. It isThe 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 10µV/m and greater are considered to be non-complying requiring immediate repair and these are shown individually on street view maps to aid in location. We provide locations of leaks as low as 1.6µV/m on the system boundary map to visualize overall system performance.

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

Leakage information is also available in Keyhole Markup Language format (KML) files. These files are viewable in a variety of freeware applications including Google Earth.

The KML files provided with this report 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 actual flight path and the readings as they were seen in real time.

The legend is displayed in the upper right hand corner. Field strength is reported in 3dB increments from >=1.6µV/m to >31.6µV/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 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 roughly 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 near 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 power scale corresponds to the calibrated digitization platform. To arrive at 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.

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:	25-Jul-2023 12:59
End Date:	25-Jul-2023 14:09
Frequency:	133.2250MHz

3. Convert between dBm and μV/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 ≈ 4.65dBi which yields an approximate antenna factor of 8.1 dB/m:

$$
\begin{aligned}
AF50\Omega &= 20\log_{10}(f) - (G_{dBi}) - 29.77 \\
&= 20\log_{10}(133.2250\text{MHz}) - (4.65) - 29.77 \\
&= 42.5 - (4.65) - 29.77 \\
&= 8.1\ \text{dB/m}
\end{aligned}
$$

   The conversion from dBm to dBμV is:

$$dB\mu V_{50\Omega} = dBm_{50\Omega} + 107$$

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

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

   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 a sufficiently sensitive measurement system 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,

Pqam(refbw) = Pqam(fft) + (10 * log10 (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. Explanations of these example graphics follow to help interpret the actual graphics later in this report.

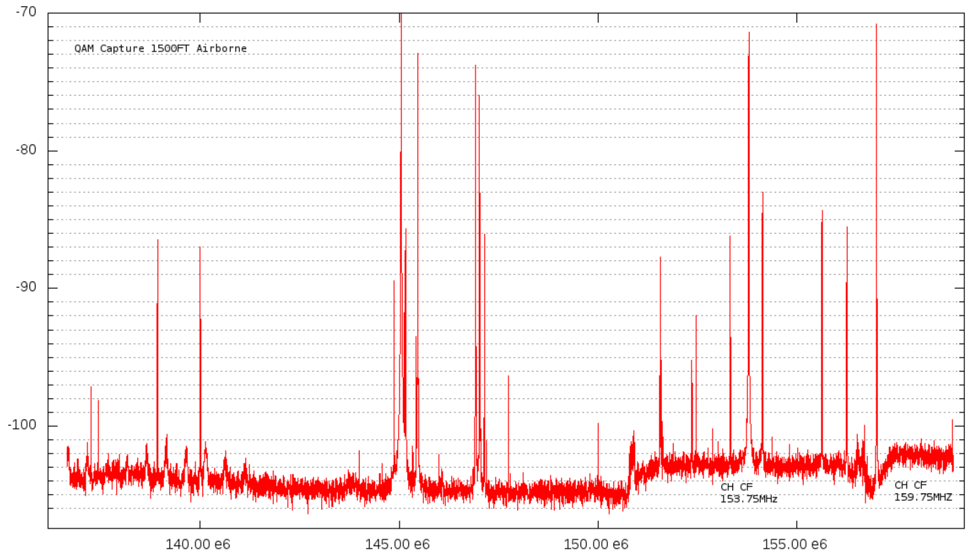


Figure 1

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. This illustrates the need for thorough isolation between cable plant and off-air signals by finding and fixing leaks. 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.

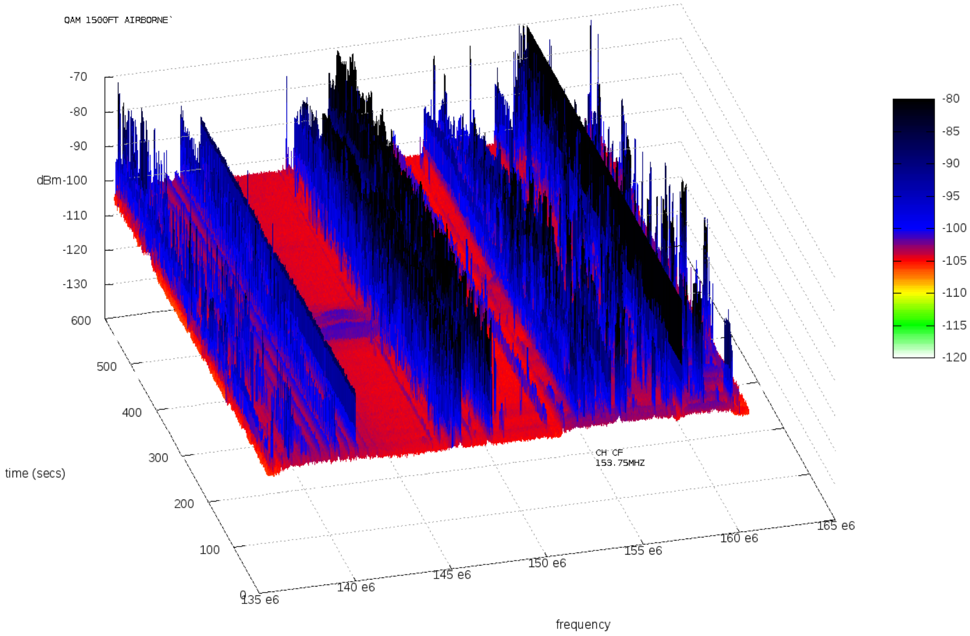


Figure 2

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.

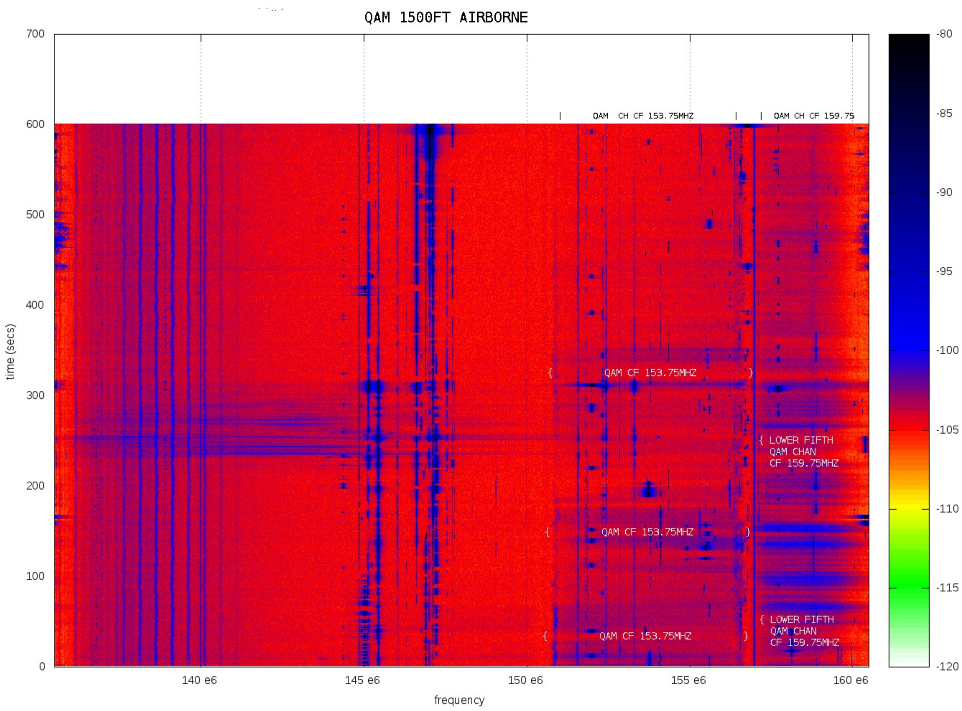


Figure 3

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, capable of distinguishing visually between signals that truly leaked from a cable system, off-air signals and wideband noise. The graphics included in this report 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 GPS Receiver	Quarterly
SPECTRAQ RF Processing Chain	Each Test
Precision RF Synthesizer	Annual
SPECTRAQ High Speed Disk Arrays	N/A
SPECTRAQ RF Signal Filtering System	Quarterly
SPECTRAQ Instrumentation Controller	Quarterly
SPECTRAQ Fixed and/or Tunable Bandpass Filter Array	Quarterly
Sinclair Tuned Dipole (Aeronautical Band)	Quarterly

High Points

Center point of system: -80.539950,37.171200 or 37° 10' 16" N, 80° 32' 24" W

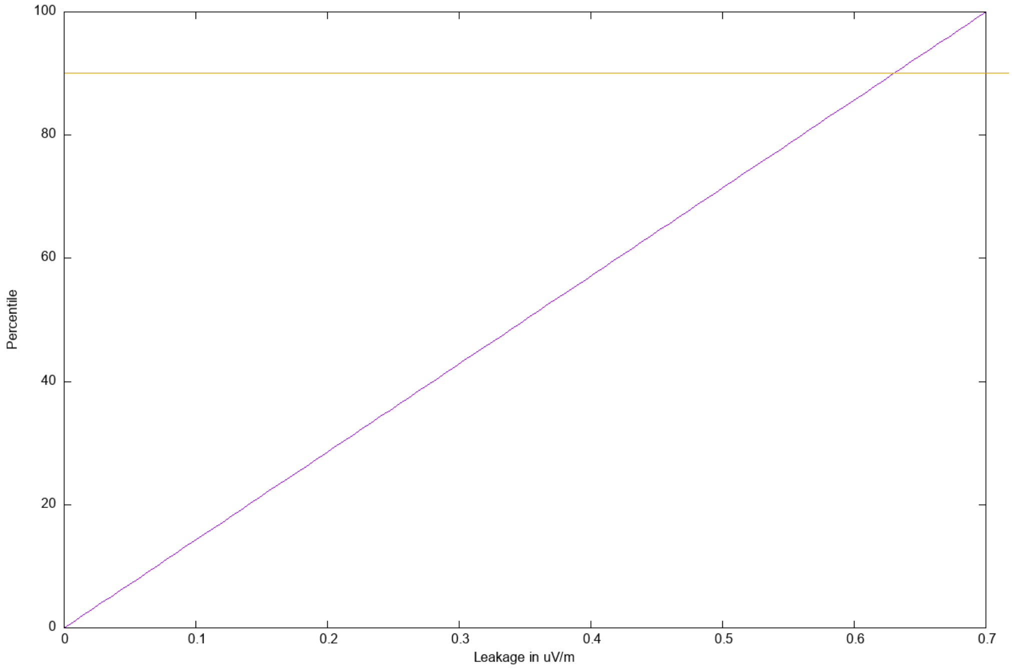
Radius covering entire system: 9170.7 km

Relative high readings for FLOYD_VA:

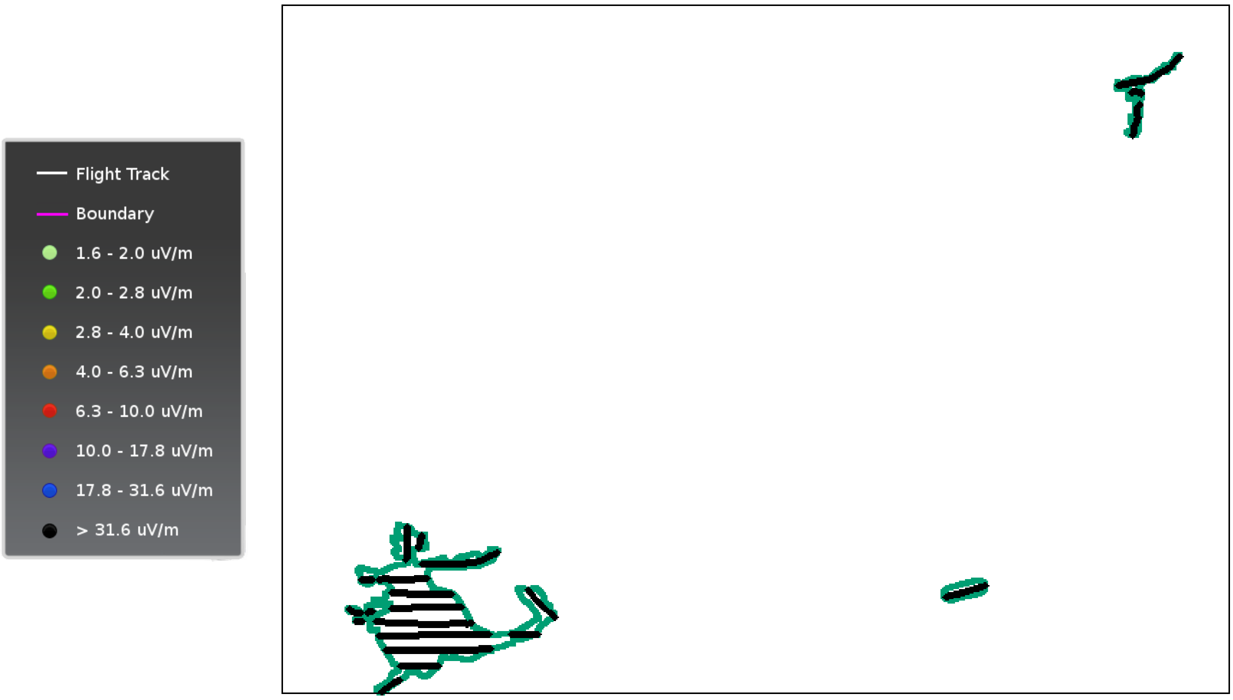
		DD MM SS		Decimal Degrees	
Reference	uV/m	Latitiude	Longitude	Latitiude	Longitude
82768	0.7	36° 52' 8" N	80° 48' 19" W	36.868976	-80.805278
82773	0.6	36° 52' 8" N	80° 48' 16" W	36.868980	-80.804418
82763	0.5	36° 52' 8" N	80° 48' 22" W	36.868971	-80.806140
82748	0.5	36° 52' 8" N	80° 48' 31" W	36.868941	-80.808724
82733	0.5	36° 52' 8" N	80° 48' 41" W	36.868895	-80.811306
82753	0.5	36° 52' 8" N	80° 48' 28" W	36.868954	-80.807863
77481	0.5	36° 55' 57" N	81° 0' 17" W	36.932542	-81.004826
77476	0.5	36° 55' 57" N	81° 0' 20" W	36.932569	-81.005690
77486	0.4	36° 55' 57" N	81° 0' 14" W	36.932541	-81.003964
77471	0.4	36° 55' 57" N	81° 0' 24" W	36.932628	-81.006552

Probability Chart

Total Points:1448, **Field Intensity at 90th Percentile:**0.2 **µV/m**



Area Flown



Approximate location of leaks >10µV/m

No leaks > 10µV/m