

## Another Look at Signal Leakage

### The Need to Monitor at Low and High Frequencies

A Technical Paper prepared for the Society of Cable Telecommunications Engineers  
By

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## Overview

The U.S. cable industry has for decades been monitoring for signal leakage in or near the 108-137 MHz VHF aeronautical band in order to ensure compliance with FCC regulations. Two key factors have shown that monitoring just the aeronautical band doesn't tell the whole story. The first is a number of instances of signal leakage in the 700+ MHz spectrum found to be causing harmful interference to LTE service providers (and related cases of ingress from LTE and other higher-frequency signals). The second is the introduction of new technology over the past year that is able to measure higher frequency signals – including QAM signals – leaking from our networks, allowing cable operators to see how the plant behaves outside of the aeronautical band.

The conclusion is that, in general, our networks are not as tight as we previously believed. Furthermore, field measurements have shown that there is little or no correlation between the leakage field strengths in the VHF aeronautical band and at higher frequencies. This paper and its accompanying technical workshop discuss why high frequency leakage and ingress are important to a plant's overall quality assurance, the benefits of fixing high-frequency impairments, and the importance of monitoring both low and high frequencies for leakage.

## Another Look at Signal Leakage: The Need to Monitor at Low and High Frequencies

The cable industry is in a unique position of being able to transport signals in its networks on frequencies that are often used for completely different purposes in the over-the-air environment. This so-called frequency reuse is possible because the coaxial cable and other components comprise a closed network. If any portion of a closed network's shielding integrity is compromised or degraded, signals inside the network can leak out<sup>1</sup> and potentially interfere with over-the-air users, and over-the-air signals can leak into the cable network<sup>2</sup> and potentially interfere with the cable company's signals.

### Signal leakage monitoring today

For many years, U.S. cable operators have been required to comply with the signal leakage regulations in Part 76 of the Federal Communications Commission's Rules<sup>3</sup>. The following table, taken from §76.605(a)(12), clearly states the maximum allowable signal leakage field strengths-versus-frequency at specified measurement distances:

Frequencies	Signal leakage limit (micro-volt per meter)	Distance in meters (m)
Less than and including 54 MHz and over 216 MHz	15	30
Over 54 up to and including 216 MHz	20	3

**Table 1. Maximum allowable signal leakage field strengths-versus-frequency at specified measurement distances**

Measurement of signal leakage must be done as described in §76.609(h)(1) through (5). In the event that leakage causes harmful interference – defined by the FCC in §76.613 as “any emission, radiation or induction which endangers the functioning of a radionavigation service or of other safety services or seriously degrades, obstructs or repeatedly interrupts a radiocommunication service operating in accordance with this

<sup>1</sup> The phenomenon of signals leaking out of a cable network is known as *signal leakage* or *egress*.

<sup>2</sup> Over-the-air signals leaking into a cable network is known as *ingress*.

<sup>3</sup> Code of Federal Regulations, Title 47, Part 76

chapter” – the cable operator *must* “take appropriate measures to eliminate the harmful interference.” The harmful interference clause in §76.613 applies even if the field strength of the leakage causing the harmful interference is below the maximum allowable limits specified in §76.605(a)(12). Finally, §76.617 defines the responsibility for leakage from devices inside the home.

Where things get tricky is in §76.610, which spells out the various sections of Part 76 that are applicable if a cable operator carries signals in the aeronautical bands (108-137 MHz and/or 225-400 MHz) *and* the average power of any of those signals equals or exceeds  $10^{-4}$  watt (+38.75 dBmV) across a 25 kHz bandwidth in any 160  $\mu$ s period. According to §76.610, “the provisions of §§76.605(a)(12), 76.611, 76.612, 76.613, 76.614, 76.616, 76.617, 76.1803 and 76.1804 are applicable...” [to aeronautical band operation].


Of the other sections referenced in §76.610, most specifically include a statement relating to operation in the 108-137 MHz and/or 225-400 MHz aeronautical bands. Those sections of the rules that include a direct or indirect reference to aeronautical band operation are §76.611, §76.612, §76.614, §76.616, §76.1803, and §76.1804. The sections that do not include a statement about aeronautical band operation are the previously discussed §76.605(a)(12), §76.613, and §76.617.

From this, it can be argued that §76.605(a)(12), §76.613, and §76.617 apply whether or not signals are carried in the 108-137 MHz and/or 225-400 MHz aeronautical bands. When signals are carried in the aeronautical band(s) and the per-signal power equals or exceeds  $10^{-4}$  watt (+38.75 dBmV) across a 25 kHz bandwidth in any 160  $\mu$ s period, then §76.605(a)(12), §76.613, and §76.617, *and* sections §76.610, §76.611, §76.612, §76.614, §76.616, §76.1803, and §76.1804 all apply.

Nearly all U.S. cable operators monitor for signal leakage in or near the 108-137 MHz aeronautical band, within which the maximum allowable leakage field strength is 20 microvolts per meter ( $\mu$ V/m)<sup>4</sup> at a distance of 3 meters (~10 feet) from the plant. Most commercial leakage detection equipment is designed to operate in this same frequency range, typically tuned to an analog TV channel’s visual carrier or sometimes a dedicated leakage carrier. One example of a common monitoring frequency is the 133.2625 MHz visual carrier of CEA cable channel 16, although other channels in or near the 108-137 MHz frequency range are often used.

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<sup>4</sup> While many cable operators use the FCC’s 20  $\mu$ V/m limit as a threshold for when leaks must be repaired, some operators are even more aggressive and use a tighter spec along the lines of 10  $\mu$ V/m or maybe even 5  $\mu$ V/m. A handful of cable operators simply say if there’s a leak of *any* field strength, fix it.



Legacy leakage detection equipment is widely deployed – indeed, there are many thousands of units in use – and is a proven technology designed for monitoring and measurement of leakage in or near the 108-137 MHz aeronautical band. That equipment works very well, provides accurate field strength measurements of cable leakage, and is ideal for measurement of analog TV channel modulated visual carriers, or even continuous wave (CW) carriers. It is important to note, however, that legacy leakage detection equipment was not designed to be digital-compatible, nor was it designed to operate outside of the VHF mid-band.

### **Is monitoring for leakage in or near the VHF aeronautical band enough?**

Monitoring for signal leakage in or near the 108-137 MHz aeronautical band satisfies the FCC requirements in §76.611 and §76.614. It has long been assumed in some circles that correlation of leakage-related field strengths at most or all frequencies exists. In other words, if a given leak mechanism such as a loose connector or cracked cable shield produces measureable leakage at one frequency, measureable leakage exists at most, if not all frequencies, and one can correlate the field strength intensity at one frequency with the field strength at other frequencies. Field experience has shown the assumption of field strength correlation across frequency to be untrue.

Monitoring for leakage solely in or near the 108-137 MHz frequency range does not necessarily provide an indication of the performance of the cable network at other frequencies. The latter was not a major concern until one to two years ago, when reports of cable-related interference to long term evolution (LTE) service in the 700 MHz spectrum began to surface.

LTE is the next generation of mobile wireless broadband technology. What are known as LTE bands 12, 13, 14, and 17 are in a frequency range that overlaps frequencies used in many cable networks, specifically 698 to 806 MHz.



### A look at today's over-the-air environment

A number of years ago the upper end of the old North American UHF TV band—channels 70-83, or 806-890 MHz—was reallocated to other services such as 800 MHz trunked two-way radio and some cellular telephony. More recently, UHF channels 52-69 (698-806 MHz, the so-called 700 MHz band) were reallocated to new services such as LTE and some public safety communications. There is pressure to reallocate additional portions of the remaining UHF TV broadcast spectrum for telecommunications services.

Full power broadcast TV stations have migrated to digital operation (many translators and low-power stations still transmit analog NTSC signals), and some cable operators have experienced ingress interference from the 8-VSB over-the-air digital TV signals. Ingress interference from broadcast TV digital signals has proven to be challenging to troubleshoot because of those signals' noise-like characteristics.

Yet another potential source of ingress interference is looming on the horizon: White space devices operating between 54-698 MHz. According to Wikipedia<sup>5</sup>, "**white spaces** refer to frequencies allocated to a broadcasting service but not used locally." Proposals are under consideration to use the white space frequencies in various markets for high-speed Internet access and possibly other non-broadcast applications.

Cable operators should consider conducting periodic over-the-air signal surveys using a broadband antenna and spectrum analyzer, and see just what signals are present and how they overlap the cable network's downstream spectrum.

Why is any of this a concern? After all, cable networks have been operating in the presence of a variety of over-the-air signals for decades. Keep the plant tight, and ingress and leakage shouldn't be major issues. In theory, that's absolutely correct. In practice, the industry is seeing some issues in those higher frequency ranges.

As previously mentioned, during the last one to two years several cases of downstream signal leakage from cable networks have been identified as the source of interference to LTE service. At least one operator in a major metropolitan area has abandoned CEA channels 116 and 117 because of ingress interference from LTE. Some other operators have experienced ingress interference in portions of their networks that are near LTE towers.

Verizon is among the telecommunications companies with nationwide LTE allocations in the 700 MHz spectrum. The 746-756 MHz and 777-787 MHz LTE bands, collectively known as LTE Band 13, are assigned to Verizon. Other carriers operate on different bands in the 698-806 MHz range. Some of Verizon's field engineers have been responding to interference issues in the Band 13 uplink spectrum (777-787 MHz, the user equipment (UE)-to-tower band). In a number of cases Verizon's engineers have found leakage from cable networks at sometimes rather high field strengths, and the leaking signals have been quadrature amplitude modulation (QAM) signals! Cable

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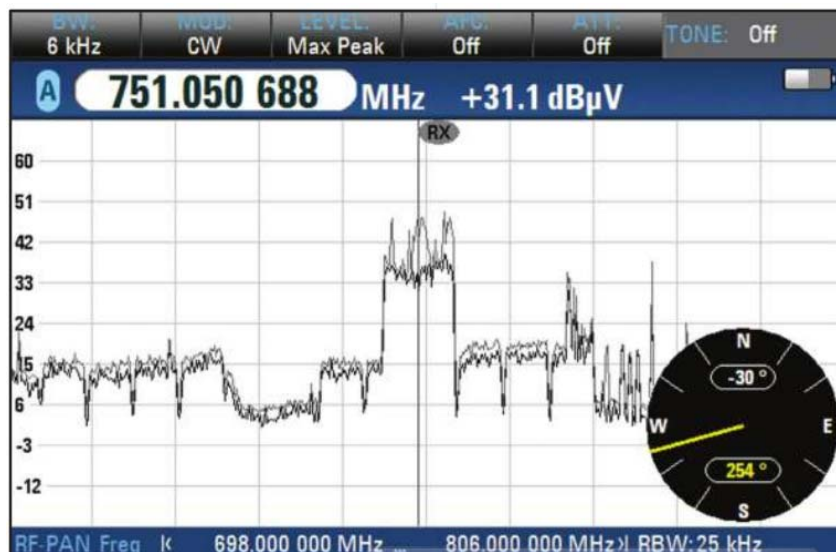
<sup>5</sup> [http://en.wikipedia.org/wiki/White\\_spaces\\_\(radio\)](http://en.wikipedia.org/wiki/White_spaces_(radio))

operators have for the most part been cooperative, and worked with Verizon to confirm the leakage sources and make necessary repairs.

In one case a 700+ MHz leak with a measured field strength greater than 100  $\mu\text{V}/\text{m}$  was found, despite the fact that leakage in the VHF aeronautical band was well below the FCC's 20  $\mu\text{V}/\text{m}$  limit. The problem was a defective tap. A replacement tap took care of the leakage, but follow-up lab testing of the replaced tap showed that it had less shielding effectiveness at 700+ MHz than it did in the aeronautical band because of a defective faceplate gasket. What this says is that under the right conditions leakage can be significant at 700+ MHz even though leakage in the VHF aeronautical band is within spec. One cannot assume that just because leakage is okay in the VHF midband it's also okay at much higher frequencies.

One of this paper's authors [Hranac] had an opportunity to team up with several colleagues to look for signal leakage in the 700+ MHz spectrum from an operating cable network. A Rohde & Schwarz PR100 and companion HE300 active directional antenna were obtained for the field tests. This is the same equipment AT&T's and Verizon's field engineers use to look for interference to their LTE service. Other test equipment included a conventional signal leakage detector tuned to the VHF aeronautical band, a home-brew near-field probe to locate specific sources of 700+ MHz leakage, a couple 750 MHz antennas (half-wave dipole and magnetic mount monopole), and a spectrum analyzer.

The following are a few highlights of the field work.



**Figure 1. PR100 screen shot showing signal leakage in the 698-806 MHz spectrum.**

It was fairly easy to find signal leakage in the 698-806 MHz LTE band. Active device locations—nodes and amplifiers—were for the most part the only places where any leakage was measureable, at least in the limited field tests. Most of what is referred to here as 700+ MHz leakage was very low-level, not of sufficient field strength to cause harmful

interference, and relatively easy to fix. In all but two instances where 700+ MHz leakage was found with the PR100, the conventional leakage detector showed absolutely nothing in the aeronautical band. The field tests confirmed that leakage can exist at 700+ MHz even when the 108-137 MHz aeronautical band is leak-free. The 700+ MHz leakage field strength that was observed was low enough in all cases to be well below the FCC's limit of 15  $\mu\text{V}/\text{m}$  at 30 meters (~100 feet) for that frequency range<sup>6</sup>.

Figure 1 is a captured screen shot from the PR100, showing leakage observed at one of the locations checked. Leaking QAM signals are evident across about three-quarters of the 698-806 MHz measurement span, although they are low level. The large "haystack" in the middle of the screen is Verizon's 746-756 MHz LTE downlink signal (tower-to-UE), and the carriers on top of the last QAM haystack and just to its right are LTE uplink signals from UE to tower. A leaking unmodulated analog TV channel can be seen partially covered by the screen shot's compass display. There was no measureable leakage in the VHF aeronautical band at this particular location. Here the fix was a simple tightening of a slightly loose 90-degree connector in the pedestal, which completely eliminated the 700+ MHz leakage.

Another location checked was a metal cabinet housing an active device and assorted passives. No leakage at any frequency was apparent until the cabinet was opened, at which point it was possible to see low-level 700+ MHz leakage, but nothing in the aeronautical band. Here the near-field probe connected to the PR100 was used to sniff around various devices, connectors, and so forth in the cabinet in an attempt to localize the leakage source(s). The probe identified the leak source to within a couple inches, which turned out be a loose center conductor seizure screw access cap on a 90-degree adapter. Tightening that cap eliminated most of the 700+ MHz leakage. When the PR100 and its antenna were more than about three feet from the equipment in the cabinet, no leakage could be seen.

The next location checked was a plastic pedestal containing an active device. Here both VHF aeronautical band and 700+ MHz leakage were found. The problem at this location was a loose KS-port chassis terminator. Tightening the terminator eliminated all of the leakage.

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<sup>6</sup> Even if signal leakage at any frequency is at or below relevant FCC field strength limits, if that leakage causes harmful interference it *must* be fixed. §76.613 of the FCC's rules is quite clear about this.



The causes of leakage – whether 700+ MHz-only or a combination of VHF aeronautical band and 700+ MHz – proved to be nothing out of the ordinary. One active device location that was checked did have very high measured leakage field strengths in the VHF aeronautical band and at 700+ MHz. Tightening some loose components in the pedestal dropped the leakage field strengths about 6 dB, but follow-up work by the

cable company had to be scheduled to fix the remainder of the leakage (damaged underground cable).

A key takeaway from the field testing is that 700+ MHz leakage can exist even when aeronautical band leakage is unmeasurable. While most of the 700+ MHz leakage was fairly low level, the point is there was leakage (to be fair, other locations that were checked had no measureable leakage at any frequency).

Separately, Arcom Digital has been actively demonstrating and installing their QAM Snare – a QAM-compatible leakage detection product. A common observation in every system tested is that numerous locations were identified where leakage was found at higher frequencies, and little or no leakage was measureable in the VHF aeronautical band using a commercial leakage detector. The following are some examples.



**Figure 2. Leakage results showing differing levels from aeronautical band (analog TV channel) detection at 121.2625 MHz (Ch. 14) and high frequency QAM signal detection at 591 MHz (Ch. 85).**

the Ch. 85 leaks and their causes: 141  $\mu\text{V/m}$  (loose 90 degree connector), 178  $\mu\text{V/m}$  (loose hardline connector), 35  $\mu\text{V/m}$  (corroded RF gasket in amplifier housing), 501

In one system in early 2012, several leaks on CEA cable channel 85 (QAM signal) were found, but nothing was measureable in the aeronautical band.

Here are the field strengths of some of

$\mu\text{V/m}$  (amplifier and hardline connector), and  $79 \mu\text{V/m}$  (tap and connectors). All of these field strengths are 3 meters (~10 ft.) measurement values, which from a free space loss perspective would have been 20 dB lower at 30 meters (~100 ft.) measurement distance.

In another system QAM Snare was configured to measure leakage on two QAM signals, one carried on CEA channel 66 and the other on CEA channel 115. Here it was useful to see leakage field strengths on the two channels reported by the QAM Snare equipment, plus VHF aeronautical band leakage on a conventional detector. Some examples (3 meters measurement distance): A loose hardline connector underneath heat shrink tubing produced a  $25 \mu\text{V/m}$  leak on Ch. 115,  $17 \mu\text{V/m}$  on Ch. 66, and  $<10 \mu\text{V/m}$  in the VHF aeronautical band. Another leak, caused by a bad drop, created field strengths of  $20 \mu\text{V/m}$  (Ch. 115),  $44 \mu\text{V/m}$  (Ch. 66), and “low level” in the aeronautical band. A damaged hardline cable that a tree limb had grown over produced field strengths of  $158 \mu\text{V/m}$ ,  $35 \mu\text{V/m}$ , and  $8 \mu\text{V/m}$  respectively. And so it goes, where several other leaks were found at higher frequencies but leakage in the VHF aeronautical band was either low level or non-existent. Pictures illustrating several examples of high frequency leakage sources are included later in this paper.

In these field tests, too, it was surprisingly easy to find 700+ MHz signal leakage. There is no apparent correlation between low and high frequency leakage field strengths. As well, 700+ MHz leakage appears to be overwhelmingly related to hard line issues.

### **A closer look at comparison data at low and high frequency**

In one field test to acquire comparison data, aeronautical band analog and high frequency digital leakage detection equipment was mounted side by side in the same vehicle. For analog, a Cable Leakage Technologies' Wavetracker was utilized which operated at 139.25 MHz (Ch. 17). For digital, an Arcom Digital QAM Snare Navigator was installed. The selected cable system was in a densely populated suburban market of a major cable operator. The test procedure was to simply drive around until a leak was detected by one of the systems, at which point comparative data was accumulated and recorded. Since QAM Snare is agile, a procedure was established that if a leak was detected at analog and not detected at the high frequency digital detection channel at 735 MHz (Ch. 114), that QAM Snare would be incrementally shifted to the next lowest frequency (with a corresponding antenna adjustment) to determine at what frequency leakage could be detected. For this additional testing the selected test frequencies were at 477 MHz (Ch. 66), 393 MHz (Ch. 52), and 201 MHz (Ch. 11). A summary of the detected leak results is shown in Figure 3.

Qty of leaks that exist at 139MHz and not at 735 MHz	13	13%
Qty of leaks that exist at both frequencies	19	20%
Qty of leaks that exist at 735MHz and not at 139 MHz	<u>65</u>	<u>67%</u>
Total leaks detected	97	

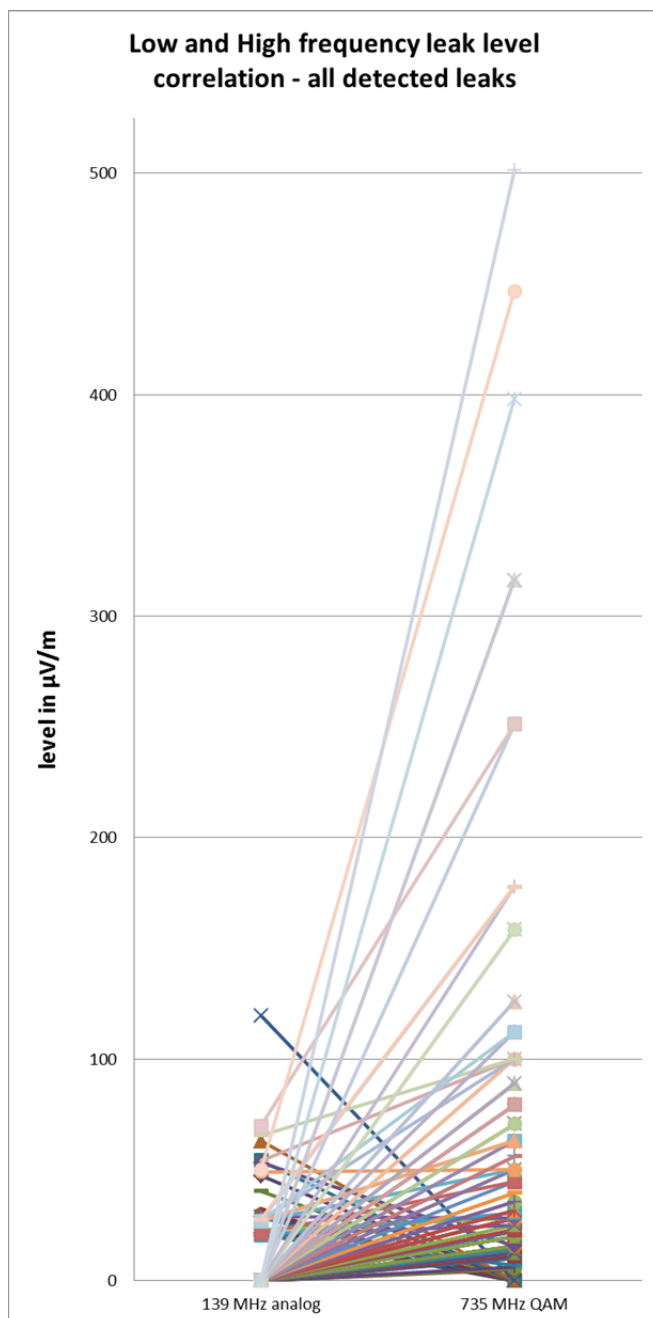
**Figure 3. Summary of Test Results**

A majority of the detected leaks, 67%, existed at high frequency but did not exist at low frequency. Figure 4 shows a graphical representation of all detected leaks, and the corresponding detected field strengths at both high and low frequency (the lines display the relationship between the two discrete measurement points, and do not represent leakage values at intermediate frequencies). As can be seen, a significant number of the high frequency leaks, including four out of the six leaks with levels greater than 200  $\mu\text{V/m}$ , have no corresponding leaks at 139.25 MHz.

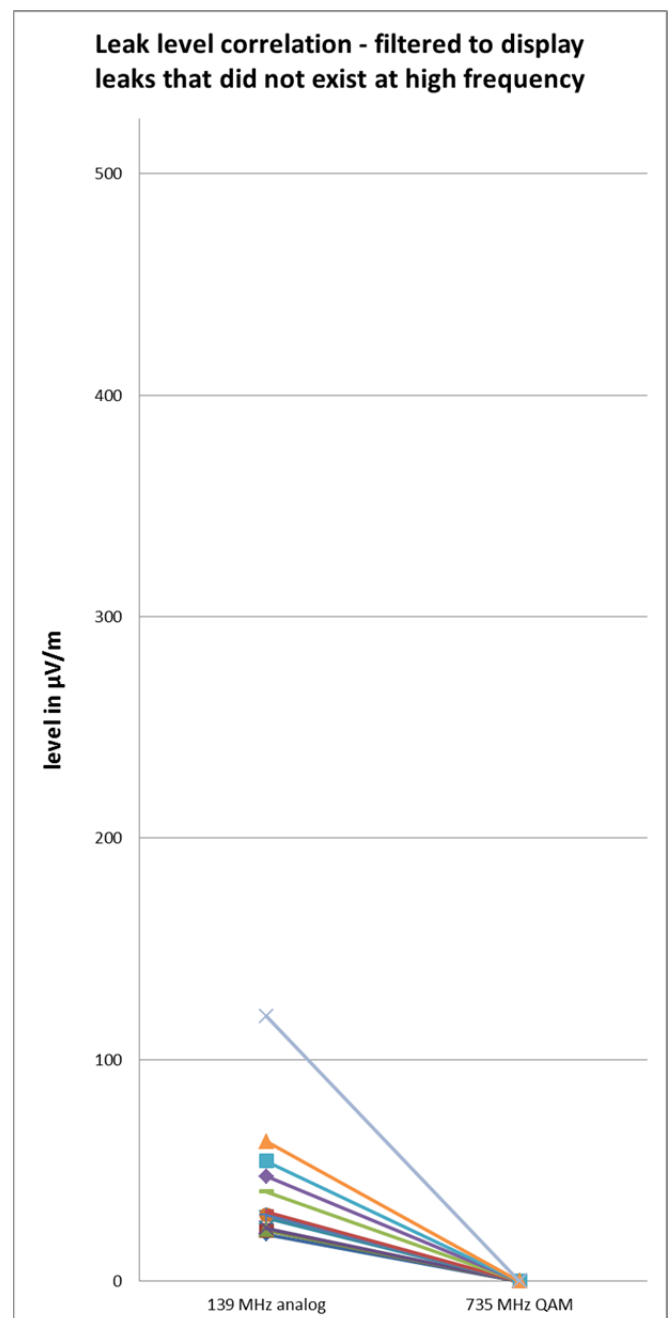
Figures 5, 6, and 7 contain the same data as Figure 4, separated into three graphs. The first, in Figure 5, shows those cases where leaks were measurable with the low frequency analog detection equipment, but were not measureable at high frequency using the QAM detection equipment. This scenario occurred at 13% of the detected leak locations. Figure 6 displays the data sets where the leakage was visible at both low and high frequencies, which occurred 20% of the time. Figure 7 shows the most prevalent scenario, which occurred 67% of the time. Here, high frequency leakage was found, but leakage was unmeasurable at low frequency.

It is clear from this data that it would be impossible to make a measurement at either low or high frequency, and from that information predict what the corresponding level would be at the other frequency.





**Figure 4. Results displaying low and high frequency detected field strengths for all 97 leaks.**



**Figure 5. Results filtered to display data pairs for only those leaks that were not measurable at high frequency.**



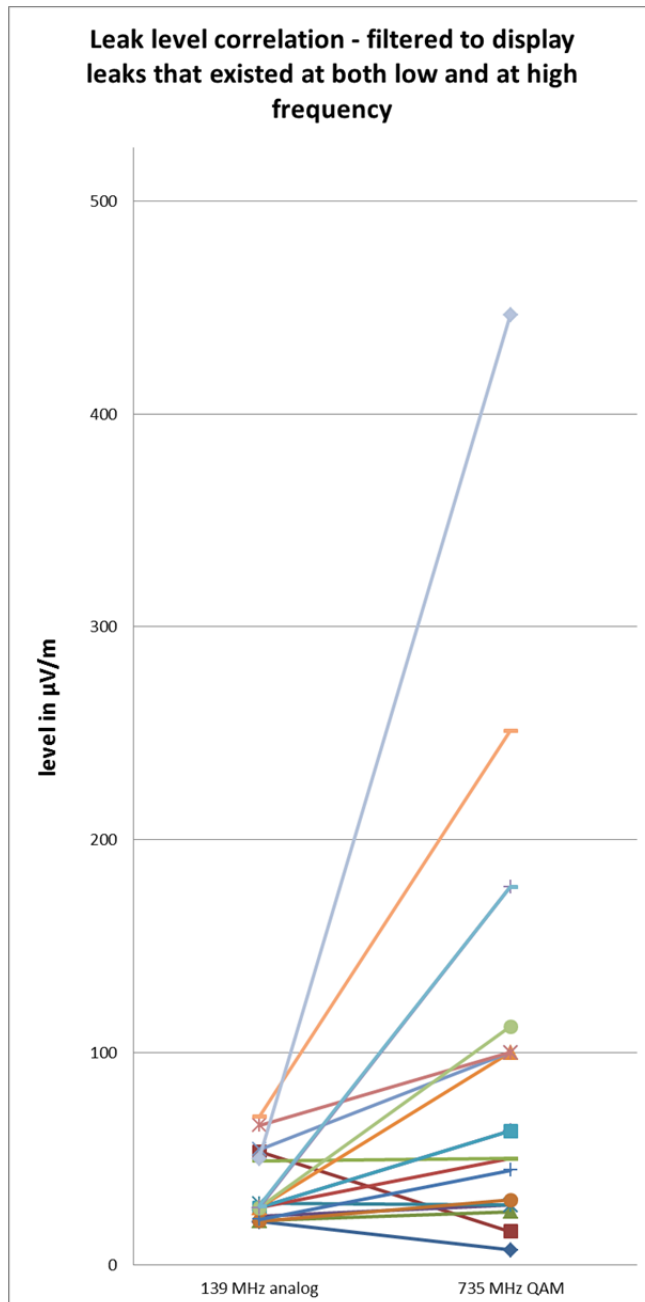


Figure 6. Results filtered to display data pairs for those leaks that existed at both low and high frequency.

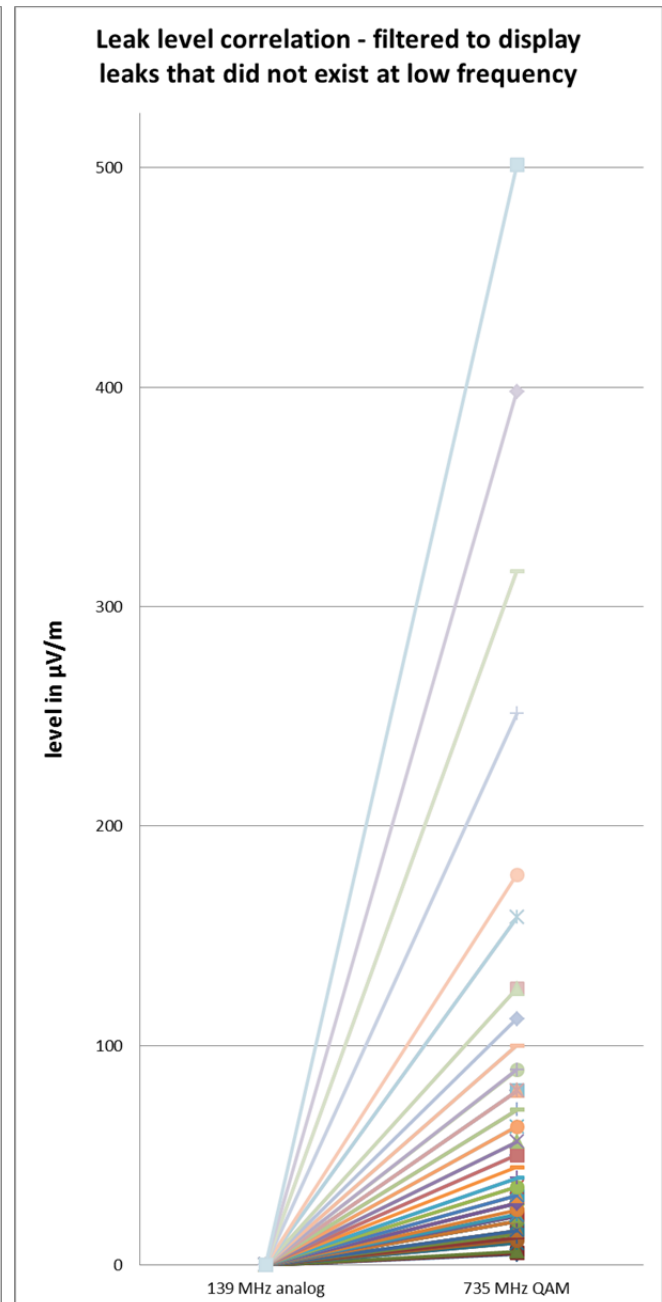


Figure 7. Results filtered to display data pairs for only those leaks that were not measurable at low frequency.

As was discussed earlier, part of the test plan was to move to lower frequencies and do additional digital measurements in scenarios where no high frequency leakage was detected at 735 MHz (Ch. 114). Figure 8 shows these test results. 13% of the detected leaks fell into this category. Of these, two were able to be detected at 477 MHz (Ch. 66), an additional four were able to be detected at 393 MHz (Ch. 52), and an additional three were able to be detected at 201 MHz (Ch. 11). Of the total number of leaks, only four were detected at low frequency and were not detected at any of the higher frequencies tested. As no channel tag was utilized on the analog detection equipment, it is possible that that these four instances were not actual leaks coming from the network – and should this be the case the digital detection equipment would not indicate the signals as leaks. It is also a possibility that the leaks were real and simply did not exist at the higher frequencies. No effort was made to determine which of these two scenarios was correct.

Detected level for each frequency (μV/m)				
analog	digital			
139 MHz	201 MHz	393 MHz	477 MHz	735 MHz
119.8	0	0	0	0
63.1	n/a	63.1	0	0
54.3	0	0	0	0
47.3	n/a	n/a	50.1	0
40.5	6.3	0	0	0
31.4	n/a	n/a	15.8	0
30	n/a	44.7	0	0
30	0	0	0	0
28.64	0	0	0	0
23.9	158.5	0	0	0
23.1	n/a	20	0	0
22.9	6.3	0	0	0
21.2	n/a	15.8	0	0

**Figure 8. Results of lower frequency digital detection for those cases where leakage was not detected at 735 MHz.**

## A closer look at QAM leakage at multiple frequencies in an all-digital network

During field tests performed in an all-digital network in a suburban location, a vehicle was outfitted with four QAM Snare Navigators, each tuned to a different frequency. The goal was to simultaneously record QAM leakage at various frequencies across the spectrum. Selected frequencies were 135 MHz (Ch. 16), 315 MHz (Ch. 39), 441 MHz (Ch. 60), and 711 MHz (Ch. 110).



**Figure 9. Vehicle setup showing different antennas utilized at the four test frequencies.**

Detailed results in the form of four QAM Snare Navigator screen captures at each of the test frequencies are presented in the following figures for four different leak locations. The QAM Snare Navigator response display indicates the amplitude of the cross-correlation<sup>7</sup> result. Peaks represent detected leakage at the time, distance, and

<sup>7</sup> The term “cross-correlation” mentioned here refers to the process by which QAM Snare detects leaks. It correlates samples of the desired channel taken at the headend with samples of the desired channel taken at the local antenna. If the two sample sets are the same, then with certainty the detected signal originated at the headend, traveled through the fiber and coax network to the leak location, and then traveled through the air to the local receive antenna. This reference to correlation or cross-correlation is different from the subject of this paper, lack of correlation between low and high frequency leaks.

amplitude indicated by the marker. The red horizontal line is a threshold level above the instrument noise floor at which leaks are recorded.

The results highlight a variety of different scenarios, indicating that the characteristics of each leak (e.g., the leak's field strength versus frequency, or "frequency response"), varies from leak to leak.

Figure 10 shows that the leak had a detected field strength of 5.8  $\mu\text{V/m}$  at Ch. 16, a field strength of 31.5  $\mu\text{V/m}$  at Ch. 39, and no measureable leakage at the two upper frequencies.

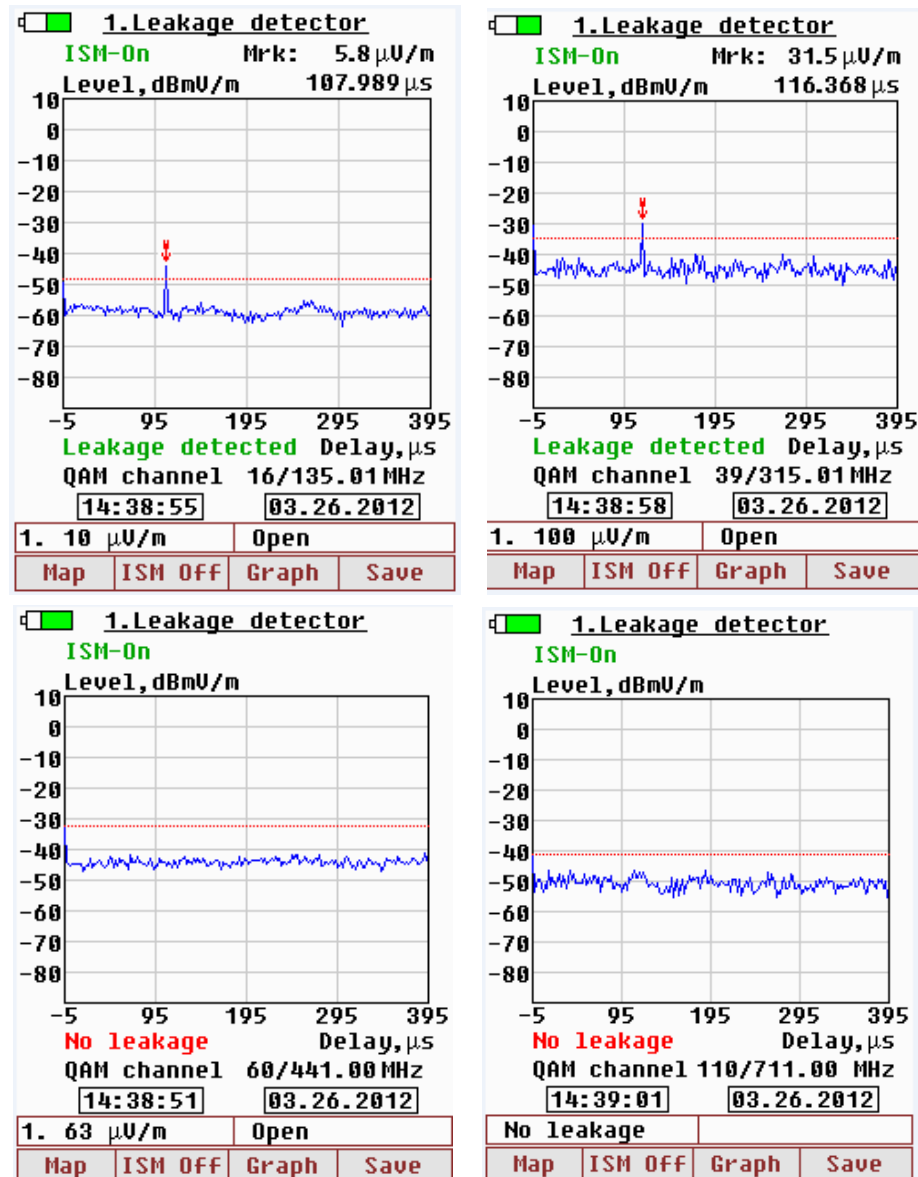


Figure 10. Leakage detection results at a location where leakage existed at channels 16 and 39, but was unmeasurable at channels 60 and 110.



At a second location (Figure 11), leakage was measureable at all tested frequencies except channel 16.

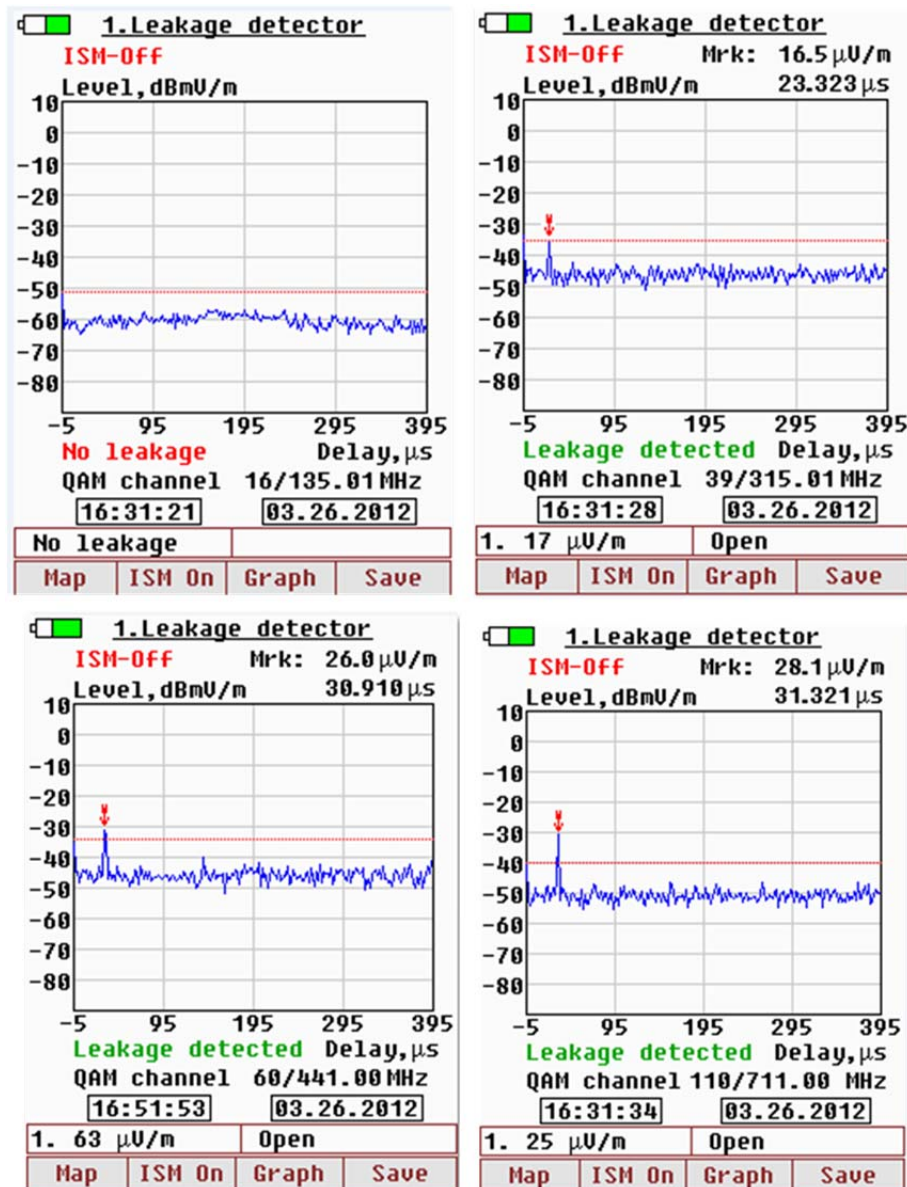


Figure 11. Leakage detection results at a location where leakage was measureable on all test channels except channel 16.

At a third location (Figure 12) leakage was measureable only at the highest frequency, channel 110.

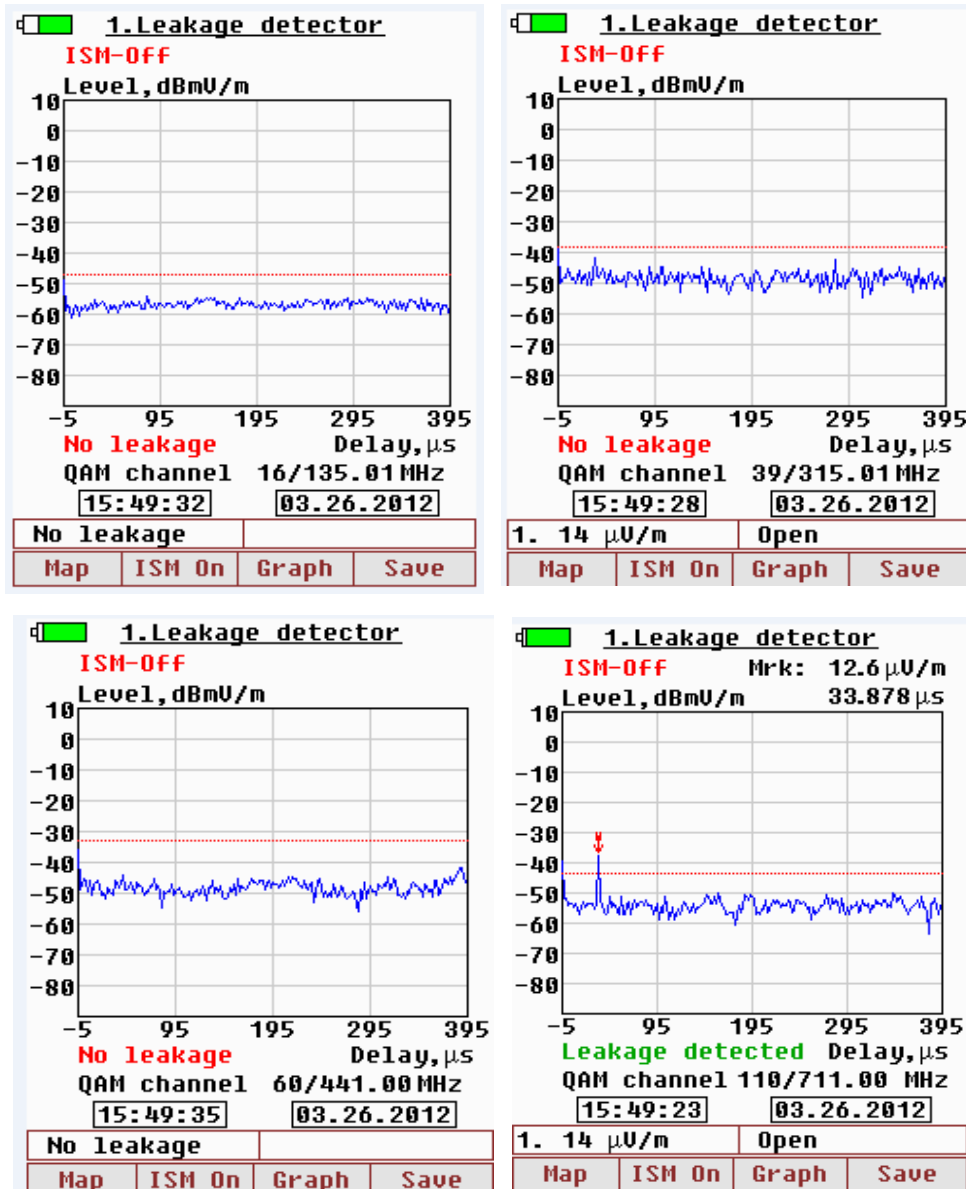


Figure 12. Leakage detection results at a location where the leakage was found only on channel 110.

At the last location shown in Figure 13, leakage was found only on Ch. 60, although at channel 110 the response is just below the threshold line where automatic detection occurs. No leakage was found on Ch. 16 or Ch. 39.

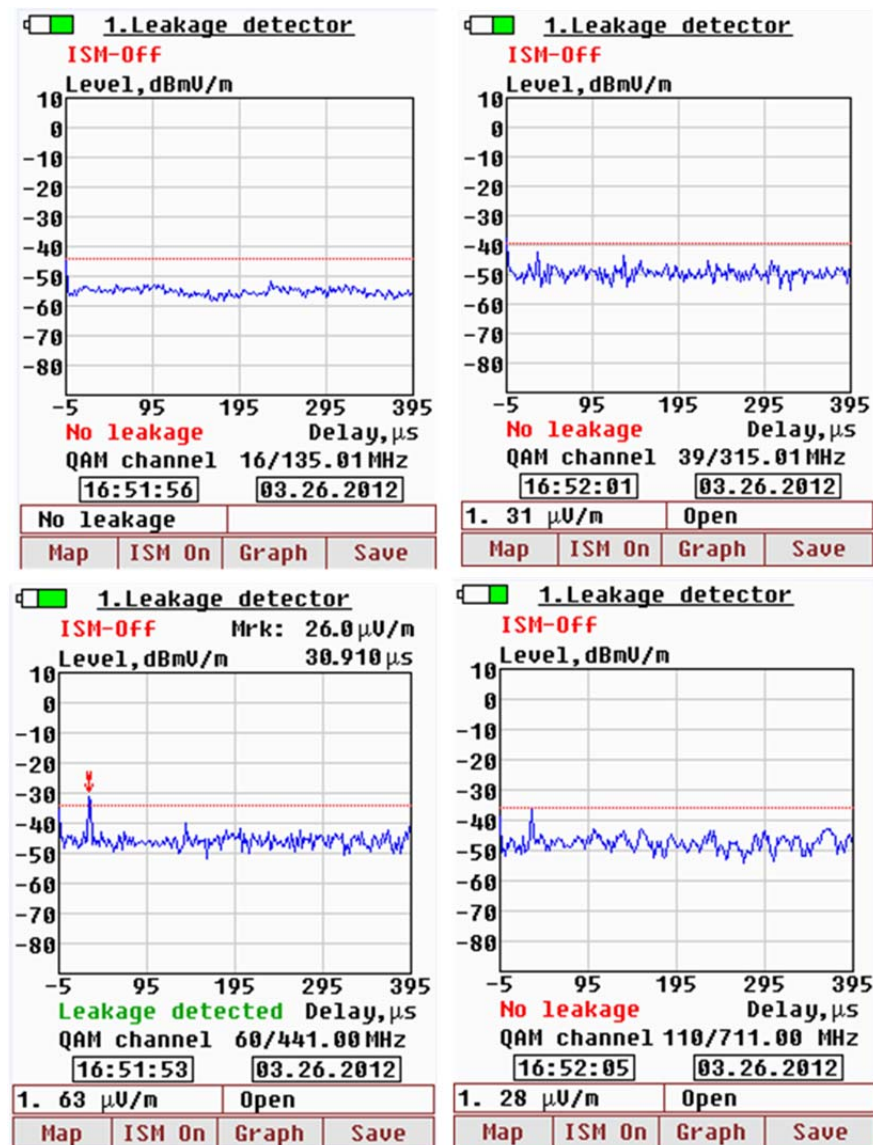


Figure 13. Leakage detection results at a location where the leakage was found only on channel 60.



It is clear from the data sets in Figures 10-13 that different leaks can and do have frequency responses that vary depending upon the specifics of the source and/or leak mechanism.

## Sources of high frequency leakage with little or no low frequency leakage

This paper has presented data showing that no correlation exists between high frequency leakage and low frequency leakage, and it has presented data showing that there is a frequency response associated with leaks. The specific mechanisms that determine said frequency response are beyond the scope of this paper, but the subject can be approached in a show-and-tell fashion by providing examples of the types of devices and the types of problems that have been found in the field, at locations where high frequency leaks have existed without significant corresponding low frequency leakage. The following examples were found in several different cable systems at various detection frequencies, but all were >450 MHz.



**Figure 14. 63 µV/m leak at 543 MHz – diagnosis was a loose housing-to-housing connector.**





Figure 15. 200  $\mu\text{V/m}$  leak at 711 MHz – diagnosis was a loose tap plate screw.

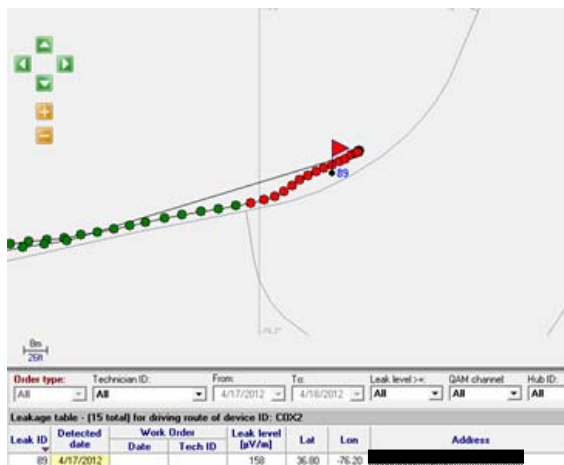


Figure 16. 155  $\mu\text{V/m}$  leak at 711 MHz – diagnosis was a cracked tap housing that subsequently broke off.

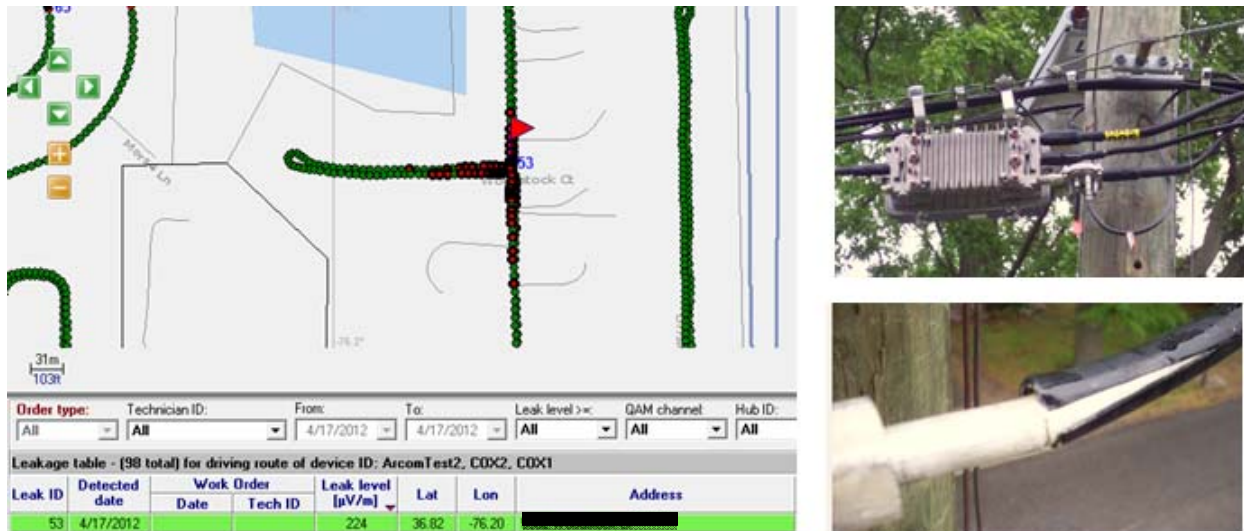


Figure 17. 224 μV/m leak at 711 MHz – diagnosis was radial crack in feeder cable.

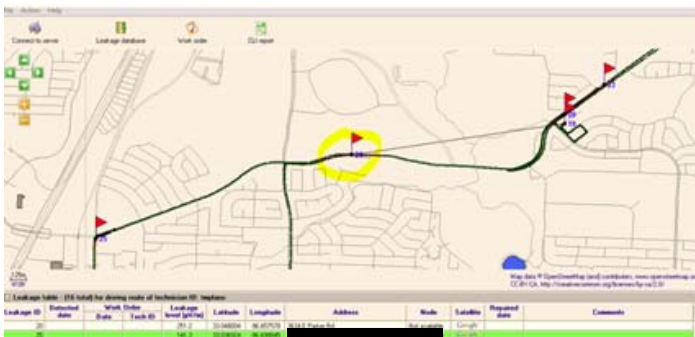


Figure 18. 100 μV/m leak at 711 MHz – diagnosis was a burnt tap which also caused a suck out at 470 MHz.





**Figure 19.** 141 µV/m leak at 543 MHz (this was at a location where there was a Verizon complaint). Diagnosis was a defective splitter housing.



**Figure 20.** 112 µV/m leak detected at 729 MHz – diagnosis was a leaking tap. Subsequent analysis of the tap in a GTEM chamber determined that defective RF braid with degraded high frequency performance was the cause of the leak. This specific device was referenced earlier in the paper.



**Figure 21.** 224 µV/m leak detected at 711 MHz – diagnosis was an improperly crimped connector on the subscriber drop cable.



Figure 22. 56  $\mu\text{V/m}$  leak detected at 543 MHz – diagnosis was an illegal drop.



Figure 23. 20  $\mu\text{V/m}$  leak detected at 711 MHz – diagnosis was found to be cracked underground feeder 6 feet away from amplifier.

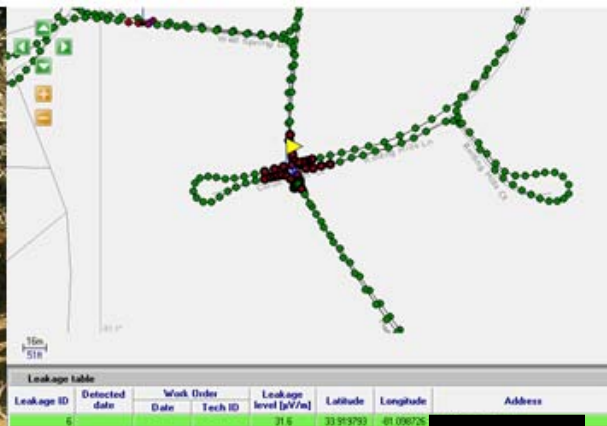


Figure 24. 31  $\mu\text{V/m}$  leak at 543 MHz – diagnosis was a bad splice in a pedestal, in an ant colony.





**Figure 25.** 158  $\mu\text{V}/\text{m}$  leak 735 MHz on ground, 8  $\mu\text{V}/\text{m}$  leak at analog on ground – diagnosis was damaged feeder cable.



**Figure 27.** 32  $\mu\text{V}/\text{m}$  leak 735 MHz – diagnosis was squirrel chew.



**Figure 28.** 40  $\mu\text{V}/\text{m}$  leak 735 MHz – diagnosis was an old “temporary” hardline jumper.



**Figure 29.** 60  $\mu\text{V}/\text{m}$  leak at 477 MHz – diagnosis was bad drop splitter



**Figure 30.** 247  $\mu\text{V}/\text{m}$  leak at 735 MHz – aerial cable used underground had two cracks in shield.



**Figure 31.** 30  $\mu\text{V}/\text{m}$  leak 735 MHz on ground – diagnosis was cracked hardline, hidden by the hanging metal bracket.





**Figure 32. 125  $\mu\text{V}/\text{m}$  leak at 735 MHz – diagnosis was a loose connector under heat-shrink at the node; image at left is before the fix, image to the right is after tightening the connector.**



**Figure 33. 25  $\mu\text{V}/\text{m}$  leak at 735 MHz – diagnosis was a loose connector under the heat-shrink tubing.**

## **Availability of technology to monitor and measure high-frequency leakage**

Clearly, monitoring for signal leakage only in or near the 108-137 MHz aeronautical band isn't enough. Test equipment manufacturers have responded to the need for signal leakage equipment that operates outside the traditional 108-137 MHz aeronautical band. Depending on manufacturer and model, some of these products operate in the 108-137 MHz aeronautical band and at higher frequencies; some operate at higher frequencies only; and some operate over a wide range of frequencies. Examples include<sup>8</sup>:

- Interference-type receivers such as the Rohde & Schwarz's PR100, which is the same equipment used by cellular (AT&T, Verizon, etc.) field engineers.
- Arcom Digital's QAM Snare, which directly measures leaking QAM signals over a wide range of frequencies, up to three channels simultaneously.
- New leakage detection equipment available from or under development by companies such as ComSonics and Trilithic. Some of this equipment operates by detecting a low level carrier inserted between adjacent QAM signals.

The variety of available or soon-to-be available equipment allows cable operators to see how their plants behave at higher frequencies. One conclusion, based on field tests and operators' experience with LTE interference, is that our cable networks are not as tight as previously believed. Monitoring for leakage in or near the 108-137 MHz aeronautical band does not tell the whole story.

## **Summary and recommendations**

Given the poor correlation of signal leakage field strengths in or near the 108-137 MHz aeronautical band and at higher frequencies (e.g., 698-806 MHz LTE band), it is critical that cable operators monitor for low frequency and high frequency leakage. Monitoring in or near the 108-137 MHz aeronautical band maintains compliance with existing FCC rules, and monitoring high frequencies provides visibility into potential problems that are unseen if only low frequencies are monitored.

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<sup>8</sup> An alternative is a combination of conventional spectrum analyzer, Ch. 14-69 UHF TV antenna (RadioShack, Winegard, etc.), bandpass filter, and preamplifier to search for leakage at higher frequencies. Note that this option is likely better for fixed location monitoring rather than portable or mobile use.



A comprehensive and effective multi-frequency leakage monitoring and repair program will help to avoid cable-related interference to over-the-air services such as LTE, as well as ensure compliance with the harmful interference clause in §76.613. At the same time, ingress from UHF broadcast TV, LTE, and other over-the-air services operating at higher frequencies will be easier to manage. Other benefits include improved plant performance and customer satisfaction, and improved visibility of points of weakness in the network.

As mentioned earlier, at least one cable operator is known to have abandoned CEA cable channels 116 and 117 in a major metropolitan area because of ingress interference from Verizon's LTE tower-to-UE downlink band. This is a short-term fix, because as the 698-806 MHz spectrum fills up with other LTE providers and public safety communications, it will not be practical to abandon or avoid using cable channels in that same frequency range. Indeed, the same is true of any downstream frequency in a cable network. The RF spectrum is simply too valuable.

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## Abbreviations and Acronyms

CATV	cable television (formerly community antenna television)
CEA	Consumer Electronics Association
CPE	customer premises equipment
CW	continuous wave
dB	decibel
dBmV	decibel millivolt
FCC	Federal Communications Commission
GTEM	gigahertz transverse electromagnetic
HFC	hybrid fiber coax
kHz	kilohertz
LTE	long term evolution
MHz	megahertz
NTSC	National Television System Committee
QAM	quadrature amplitude modulation
RF	radio frequency
TV	television
UE	user equipment
UHF	ultra high frequency
$\mu$ S	microsecond
$\mu$ V/m	microvolt per meter
VHF	very high frequency
8-VSB	eight-level vestigial sideband