



LTE interference and CATV

ARCOM

July 2014



Introduction

For decades cable operators have managed signal leakage by monitoring the aeronautical band. A relatively new problem has cropped up over the past few years: Signal leakage in the UHF spectrum, causing interference to long term evolution (LTE) services and LTE Interfering with some of the CATV services.

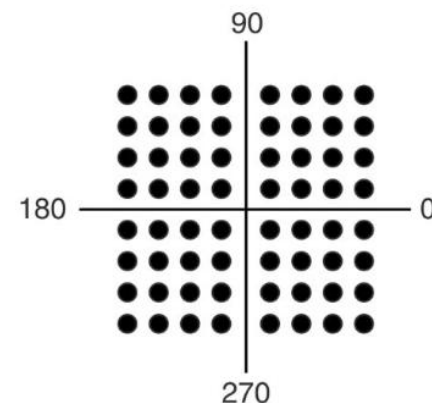
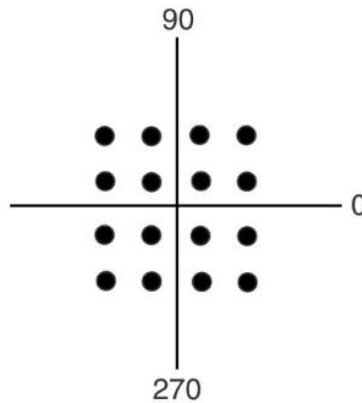
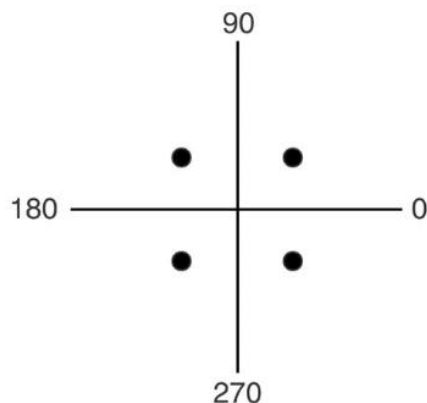
Signal leakage at higher frequencies is more common than many assume, and it's impact clearly poses challenges for the cable industry.

This session will discuss why the CATV operator must control digital leaks so they do not affect LTE and how there is no correlation between High, Medium and Low frequency leaks and why the CATV operators must monitor the spectrum at different frequencies to fully maintain the health of the network.

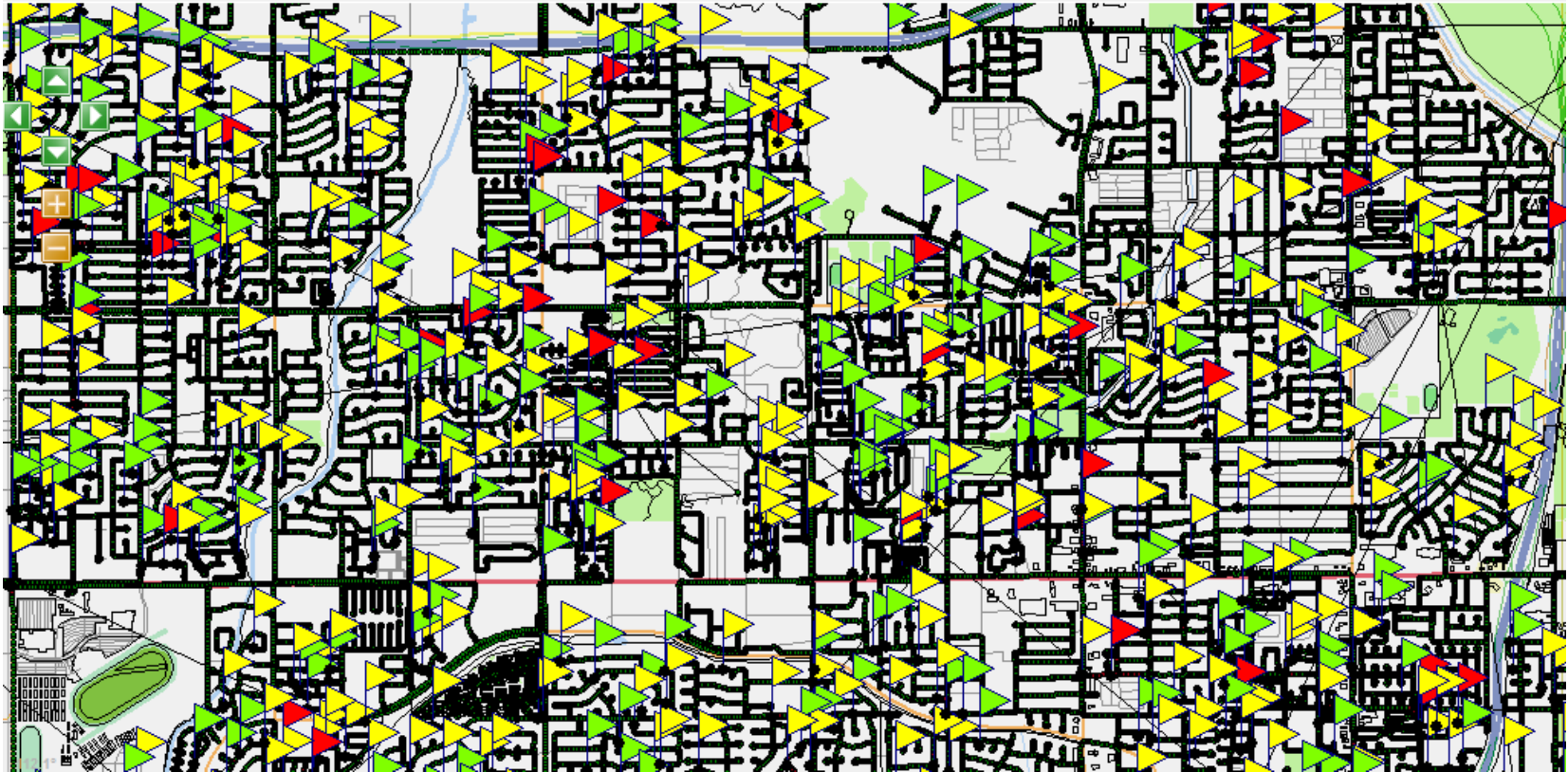
4G LTE Overview



- LTE means (Long Term Evolution)
- 4G – 4th Generation
- Downlink: OFDMA - (QPSK, 16QAM and 64QAM)
- Uplink: SC-FDMA (QPSK and 16QAM)
- Paired Duplex: FDD (Frequency-division duplex) – paired downlink and uplink
- Bandwidth: 5 or 6MHz generally



High Frequency Leakage affecting 4G LTE



High frequency leakage measured at 717MHz.

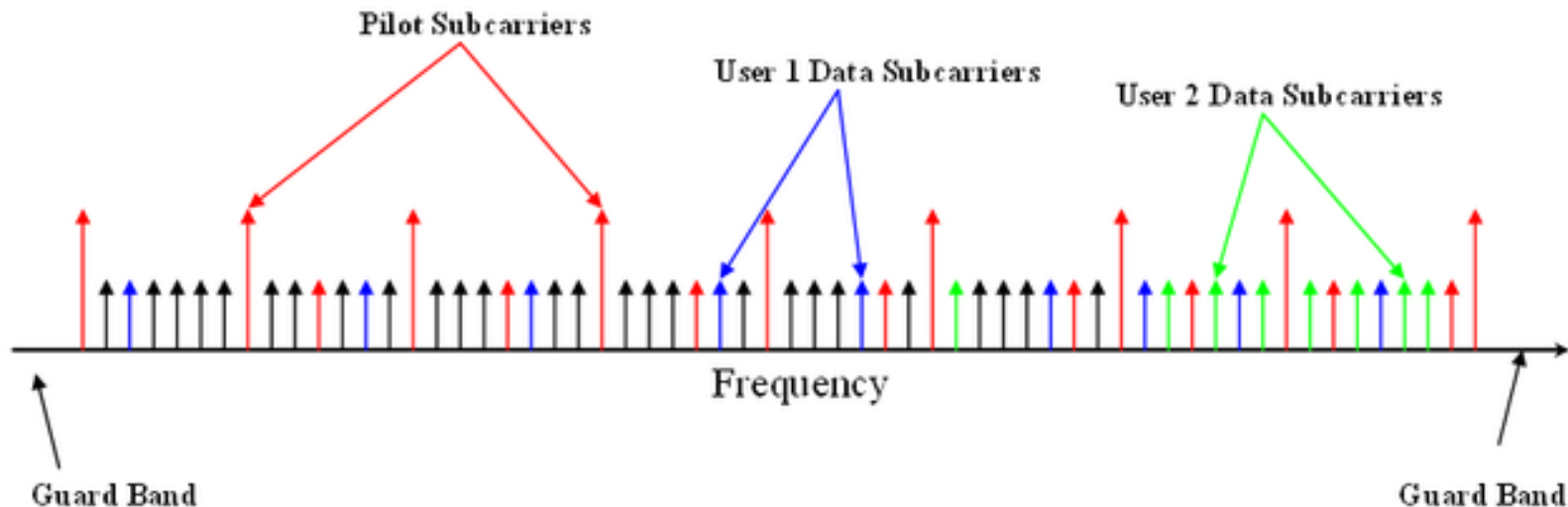


What makes 4G LTE different to Traditional Cell technology?

- 4G LTE falls into the CATV frequency band 698-805MHz. Compared to traditional cell (CDMA and GSM) at 1.7GHz, 1.9GHz and 2.1GHz.
- Signals in the 700 MHz band travel further and are less attenuated by structures.
- Signal energy is more concentrated in a smaller allocated bandwidth.
- Will be used more for data download. Longer periods to generate interference.
- The higher modulation scheme of 4G LTE is more susceptible to interference. Requires a 20dB greater SNR than 3G.

LTE bandwidth and frequency allocation

- LTE bandwidth is allocated in “Resource Blocks” allowing signal sharing by multiple users
- “Resource Blocks” are a set of subcarriers and OFDM symbols
- For a 10MHz signal there are 50 “Resource Blocks”. (5 per 1MHz)



Frequency Allocation Example

- Frequency Allocations:
 - Band 13 (DL 746-756 MHz, UL 777-787 MHz) for Verizon
 - Band 17 (DL 734-746 MHz, UL 704-716 MHz) for AT&T.
 - Nationwide Public Safety (763-775, 793-805 MHz)



Verizon and AT&T spent a combined \$16.3 billion for this spectrum.

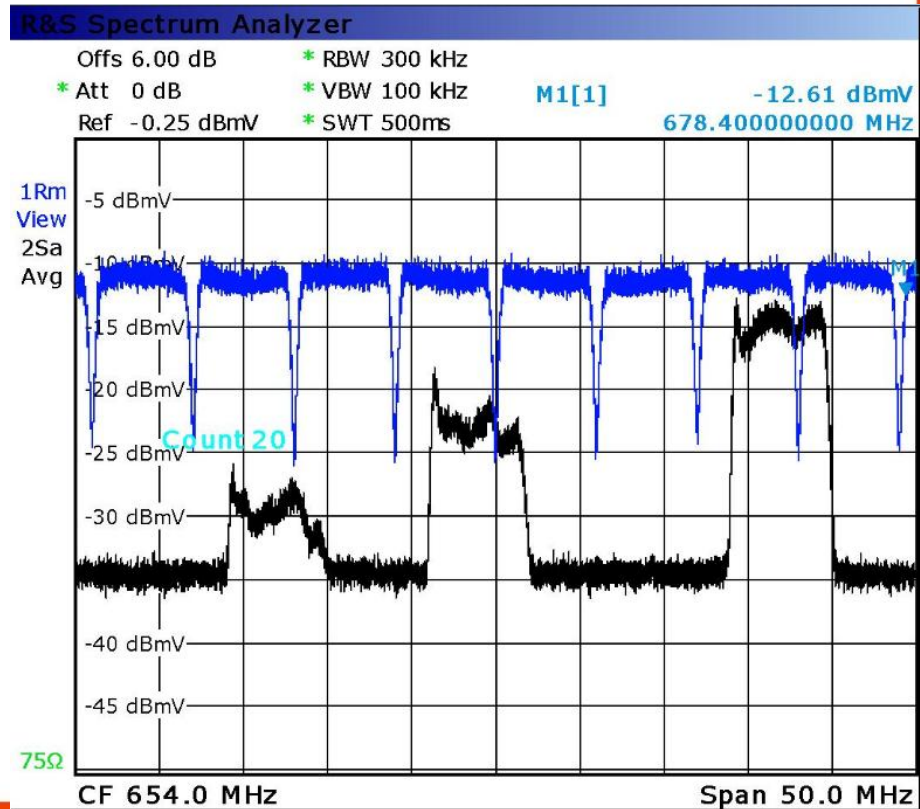
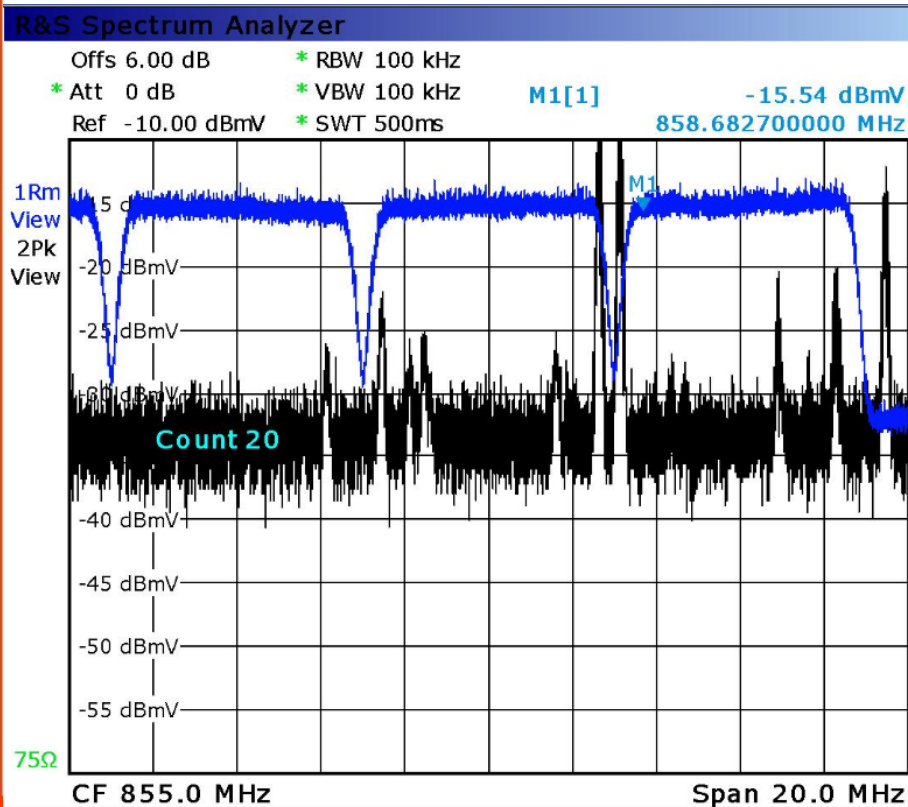


Influences of digital leaks on communication systems

- So from the Hranac and Thomas test results it was known that high level digital leaks can be harmful to narrow band communications.
- But intuitively, there will be significantly more impact on modern wide-band communication systems like LTE, where the energy of several leaking QAM channels collides with the 20 MHz LTE band.
- In our discussion with numerous people in the industry, we got the sense that the general mindset was the occasions where there would be very large level digital leaks such that could interfere with LTE - would be relatively rare.
- The spectrum shots and pictures contained in the next several slides were taken by an LTE operator in the United States, and were part of a complaint made by the LTE provider to the cable operator. This is all from one system – numerous high level leaks.
- An important note is that it is known that very high level leaks can be seen using a spectrum analyzer and a good antenna at very short distances – but it is not a practical or scalable method to find leaks.

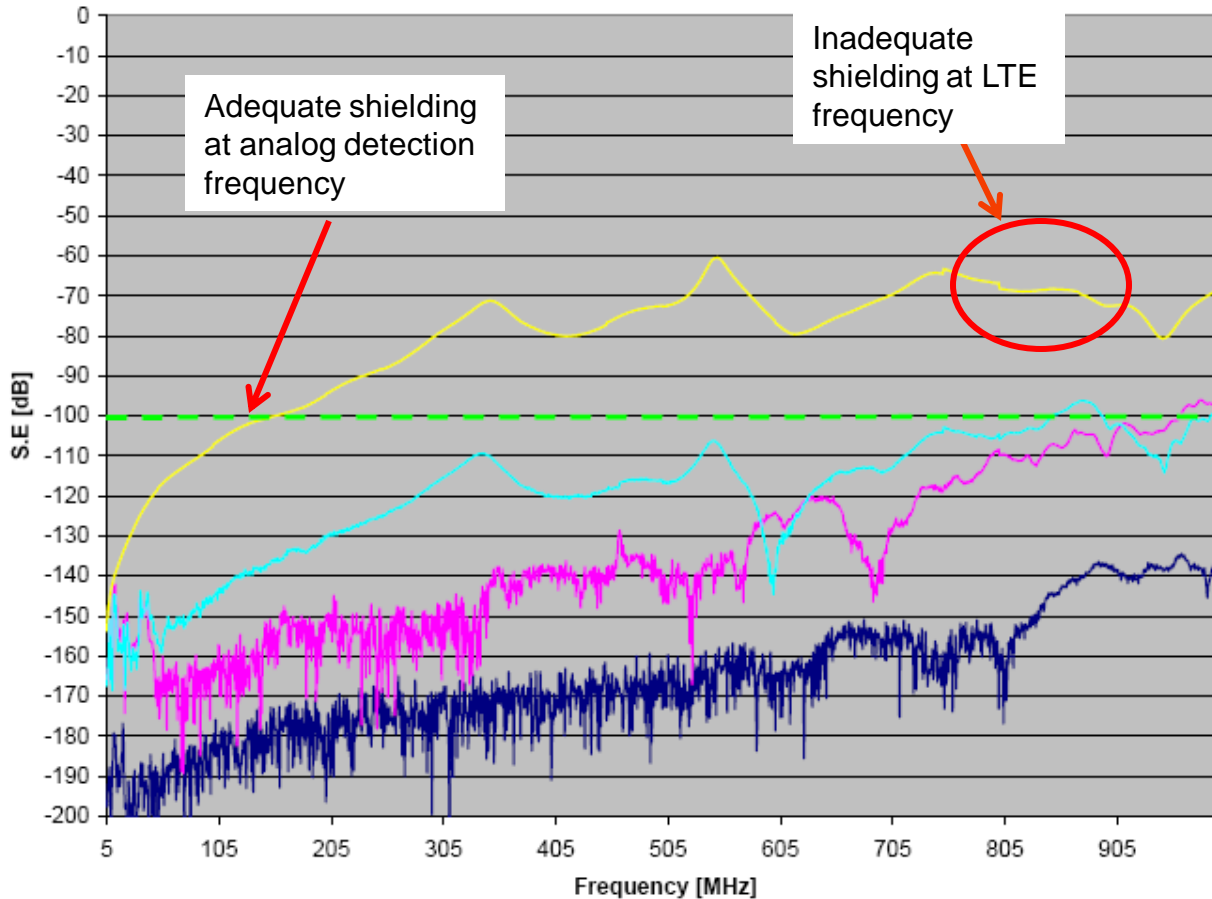
Influences of digital leaks on communication systems

- Egress is not the only issue!
- Certainly there are occasions when cellular service and broadcast channel affect our QAM performance.



Diagnosis of problem found in the field, one reason why a leak could exist at digital frequency and not be detected by status quo analog equipment

GTEM Tap Test, 7/6/2011



- Terminated Chamber
- Terminated reference tap (competing brand)
- Terminated leaking tap (in field condition)
- Terminated leaking tap (with new RFI braid)

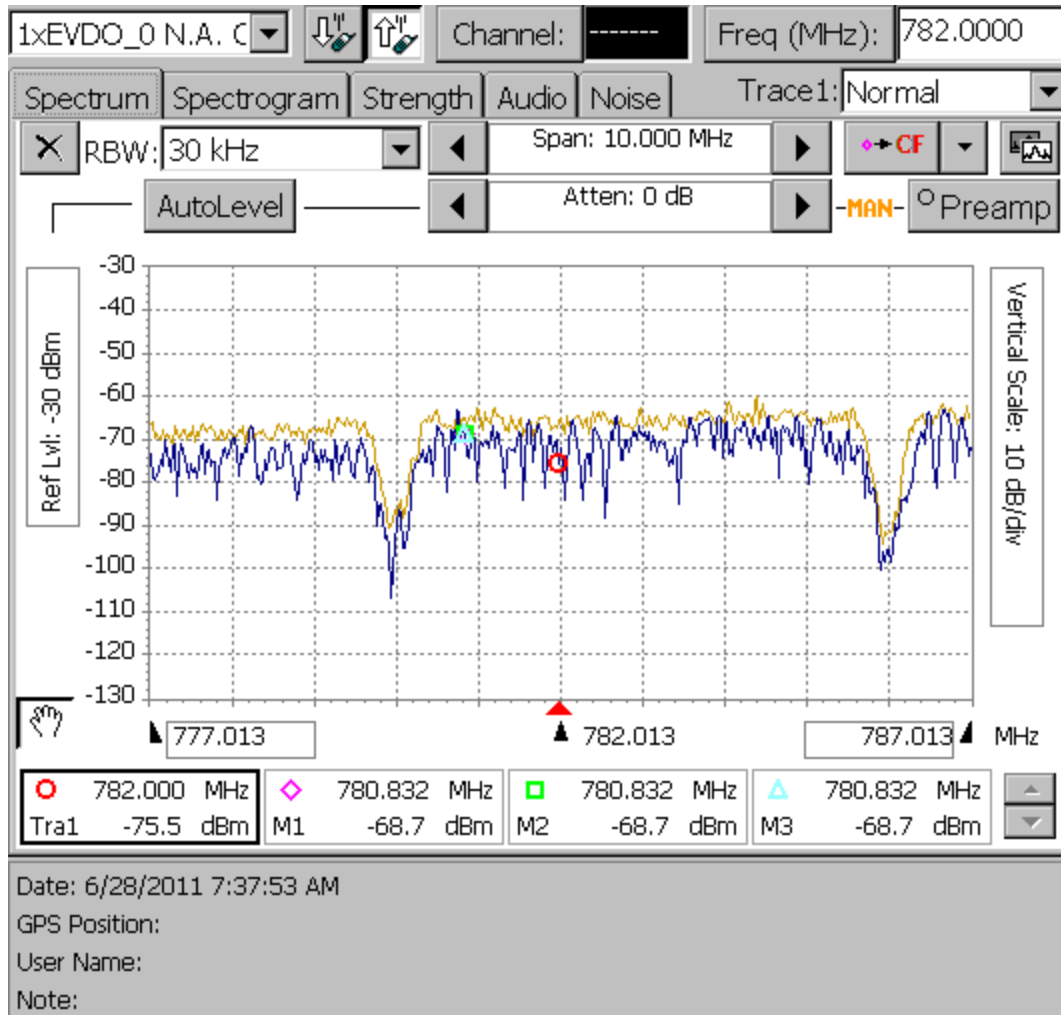


Verizon QAM Leakage Report



Verizon Interference Troubleshooting Steps

- Cell tower coverage broken into quadrants.
- Verizon would alarm poor SNR or high RSSI (Received Signal Strength Indicator) in a quadrant.
- Drive out the quadrant with an analyzer and a monopole antenna.
- Once the general area of the noise is located they use the analyzer and a Yagi antenna to isolate the source.



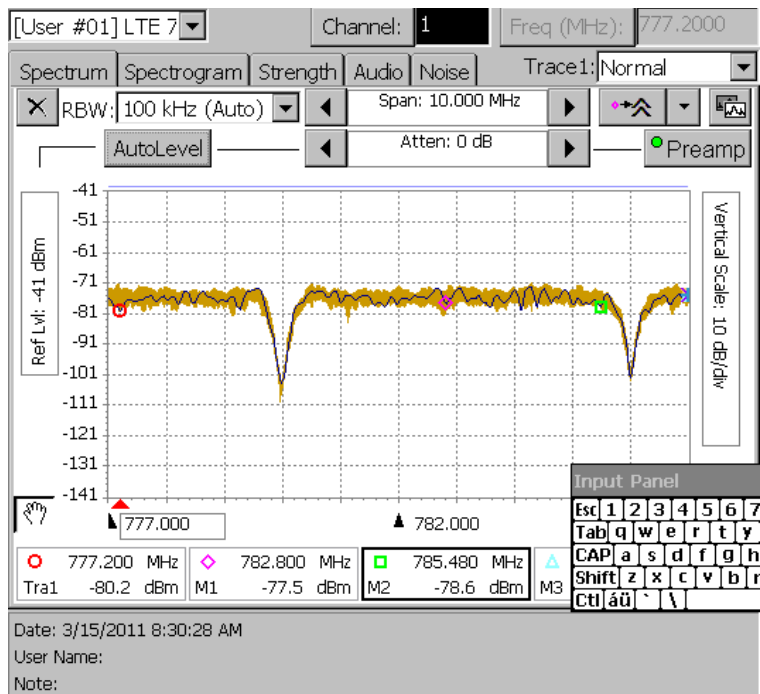
Here the measurement was made at a distance of ≈ 10 ft with an 11dBi Yagi at 780 MHz. The signal level at the top of the QAM at the input of the SA is ≈ -25 dBmV for the 30kHz ResBW. The field strength calculation at 10 ft comes out to a substantial **2200 μ V/m**.



Courtesy Verizon

Finding:
This CATV interference is coming from:
The Treehouse Apartments
3207 Walnut Hill Ln.

GPS Coordination:
3x.86586 -9x.98910



Courtesy Verizon

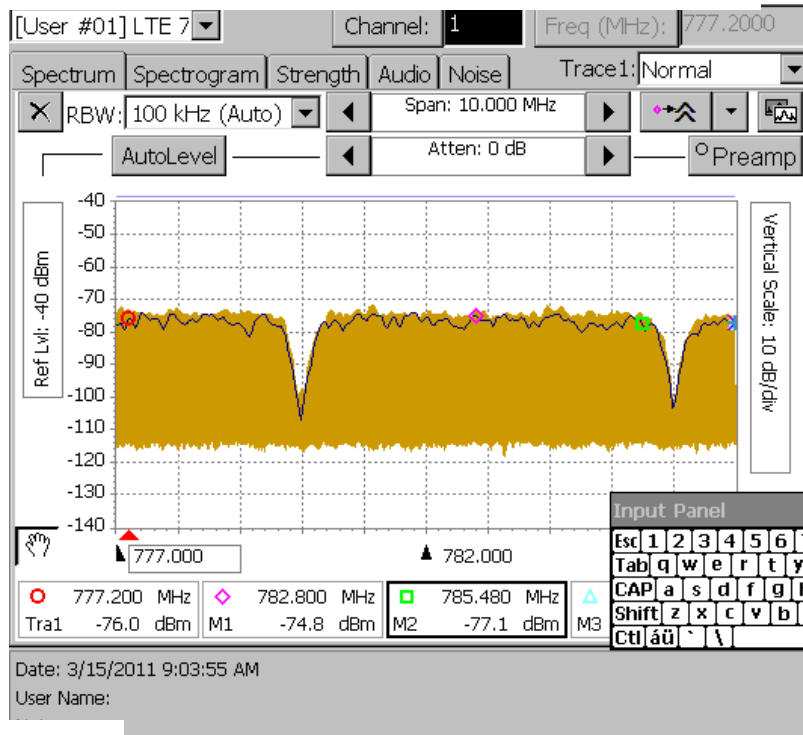
Finding:

This CATV interference is coming from:

Hillcrest Apartments
3151 Walnut Hill Ln.

GPS Coordinance:

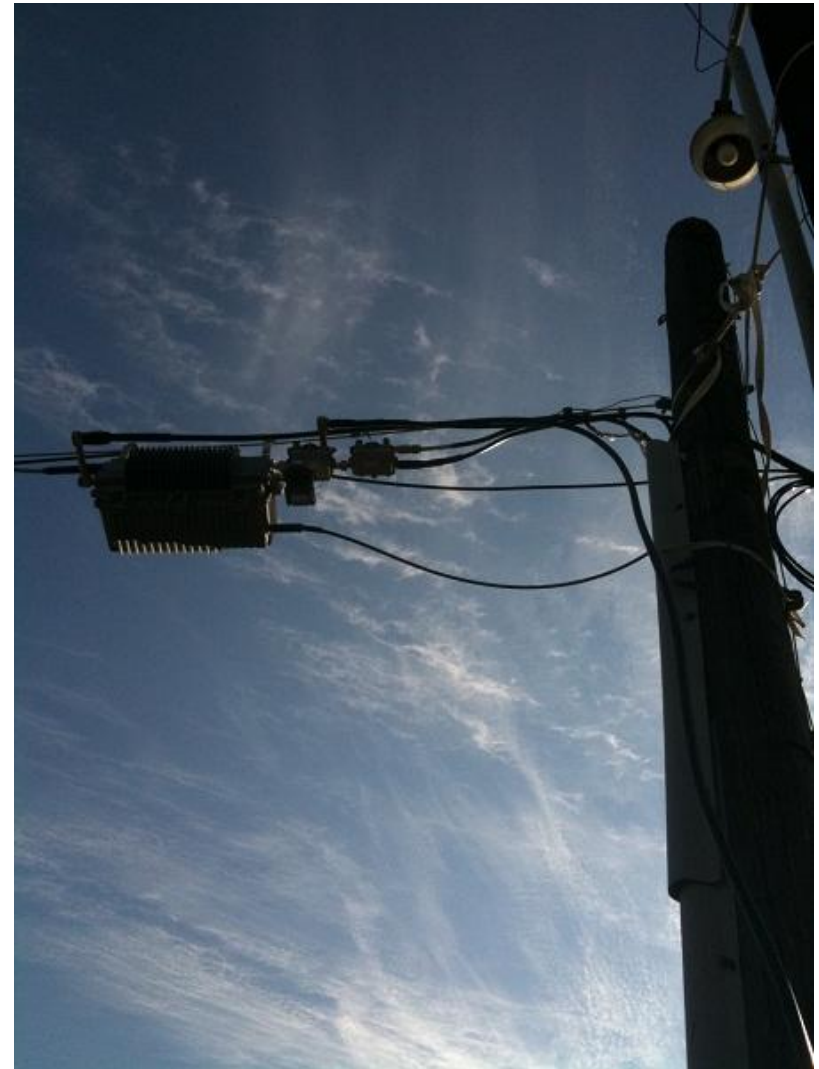
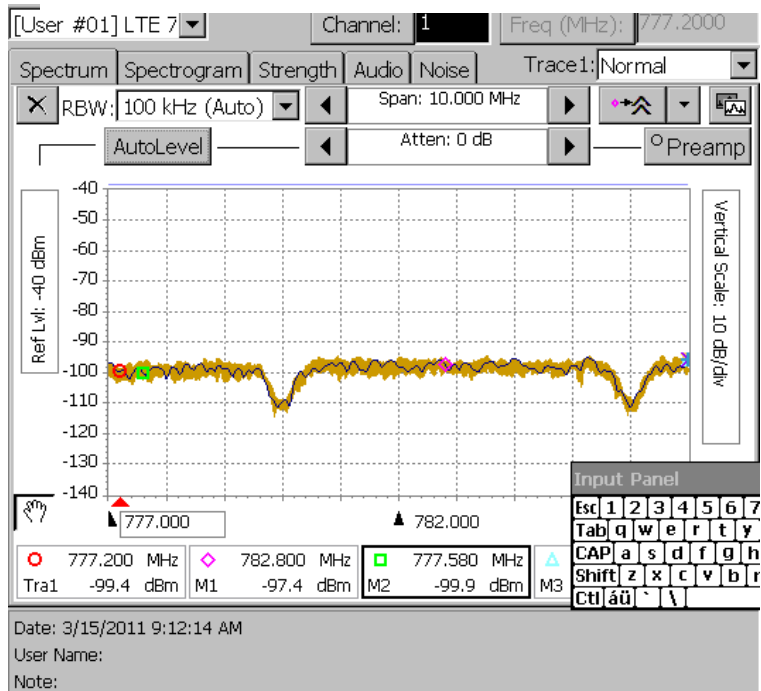
3x.86615 -9x.98810



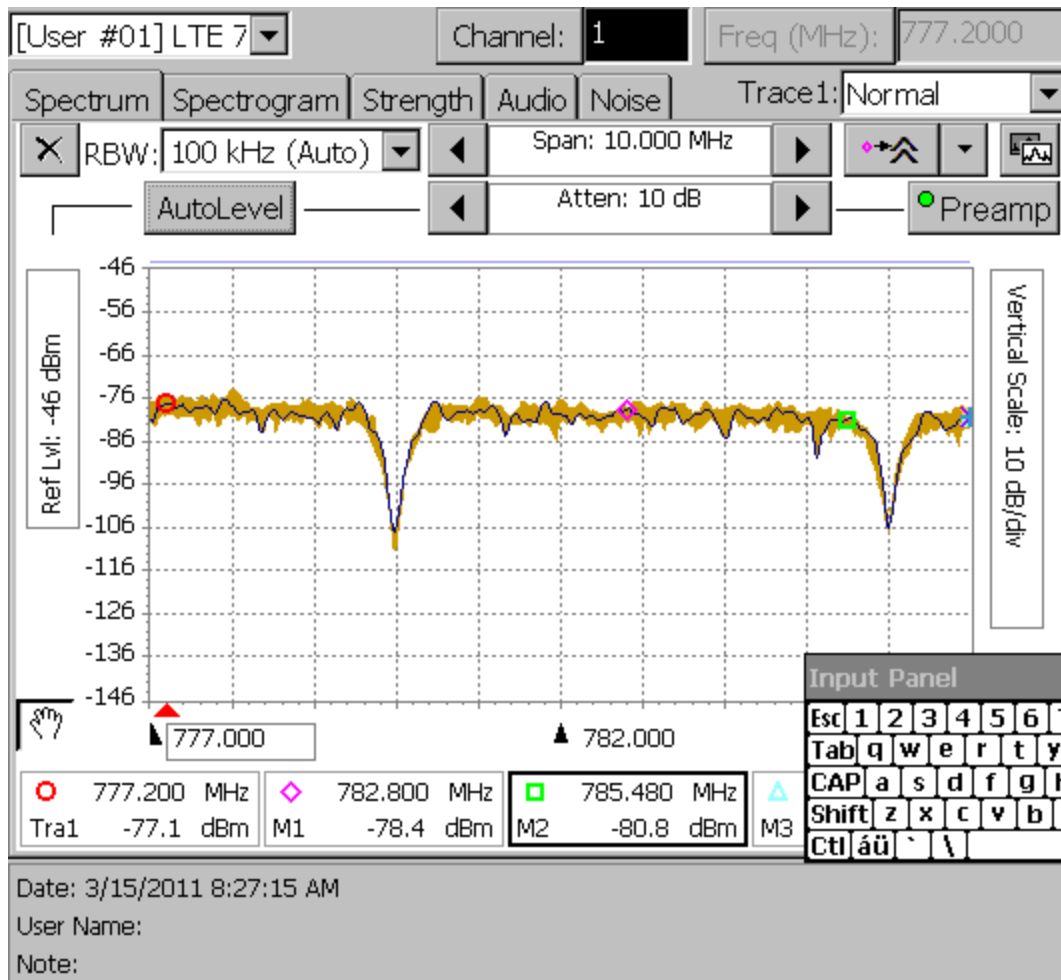
Courtesy Verizon

Finding:
This CATV interference is coming
from a pole by the tennis courts at:
Hillcrest Apartments
3101 Walnut Hill Ln.

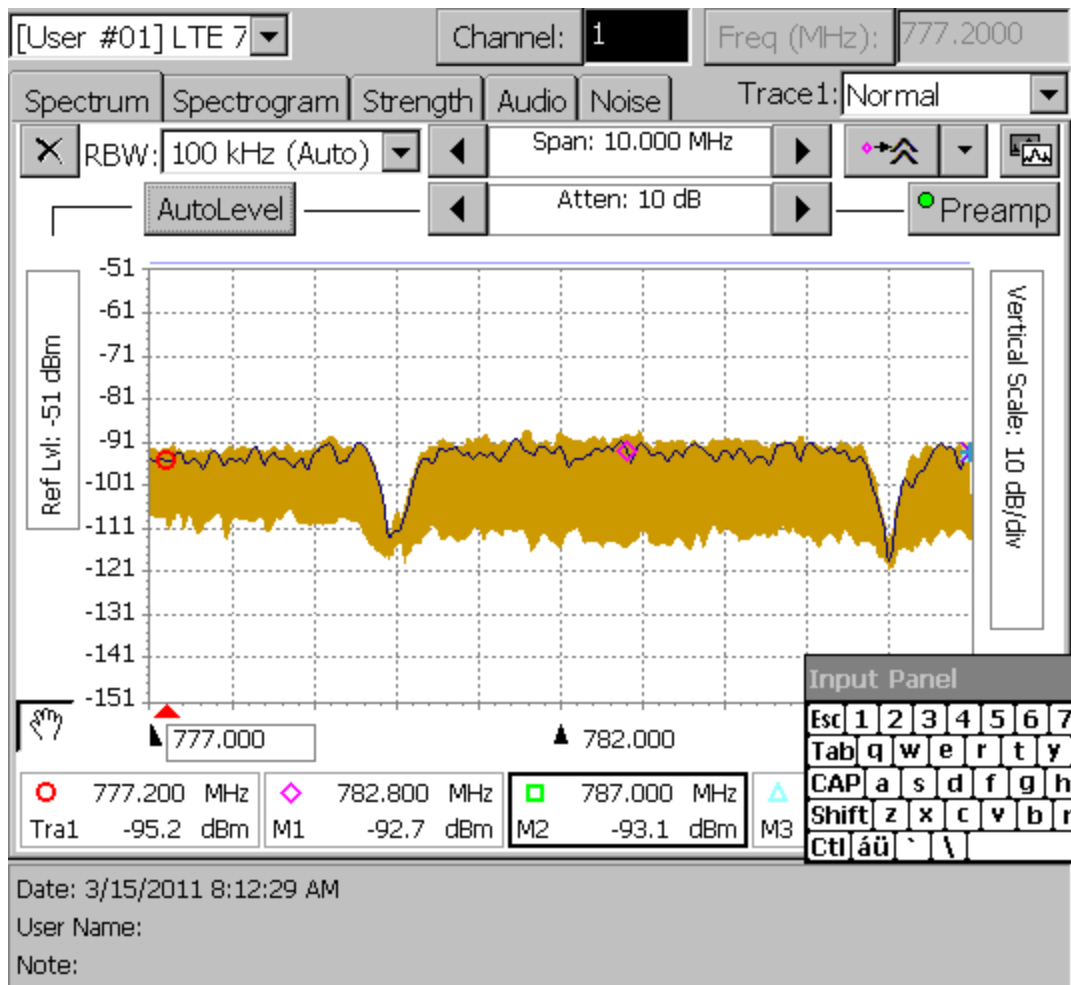
GPS Coordinance:
3x.86794 -9x.98722



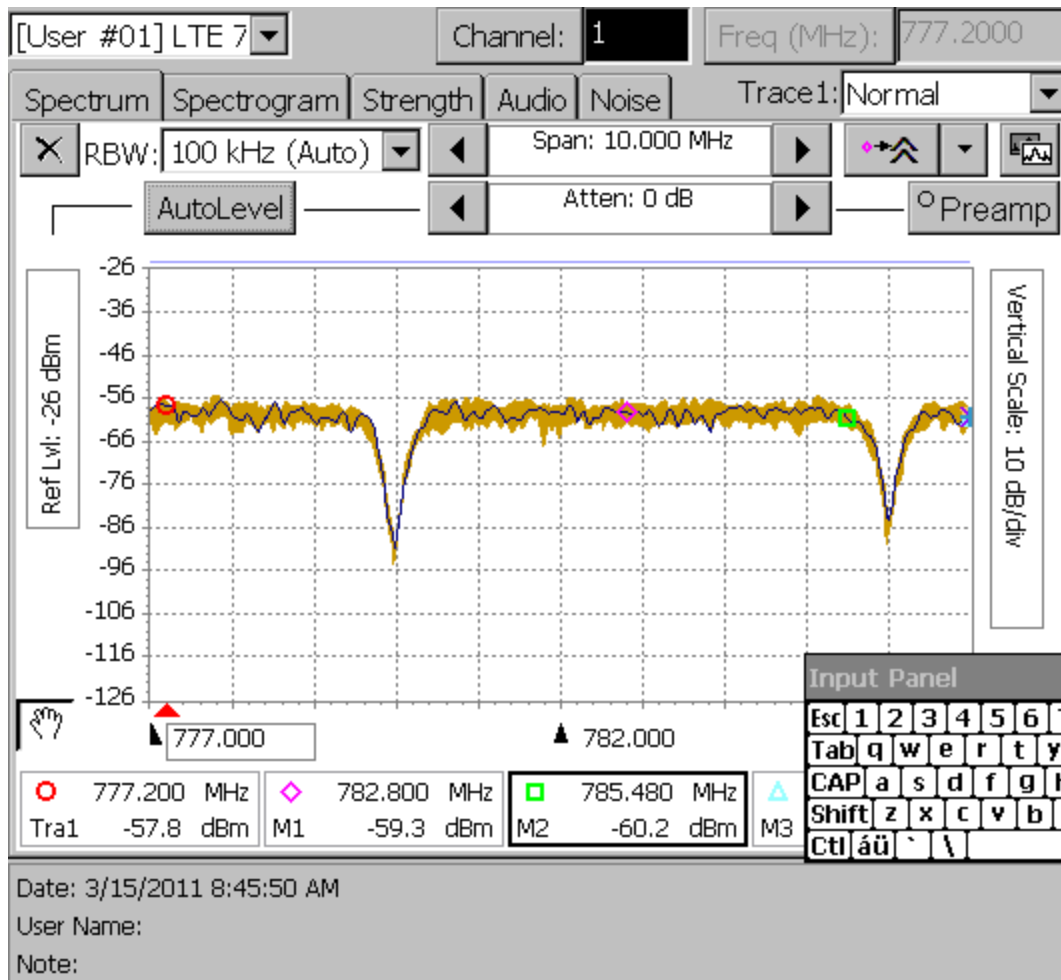
Courtesy Verizon



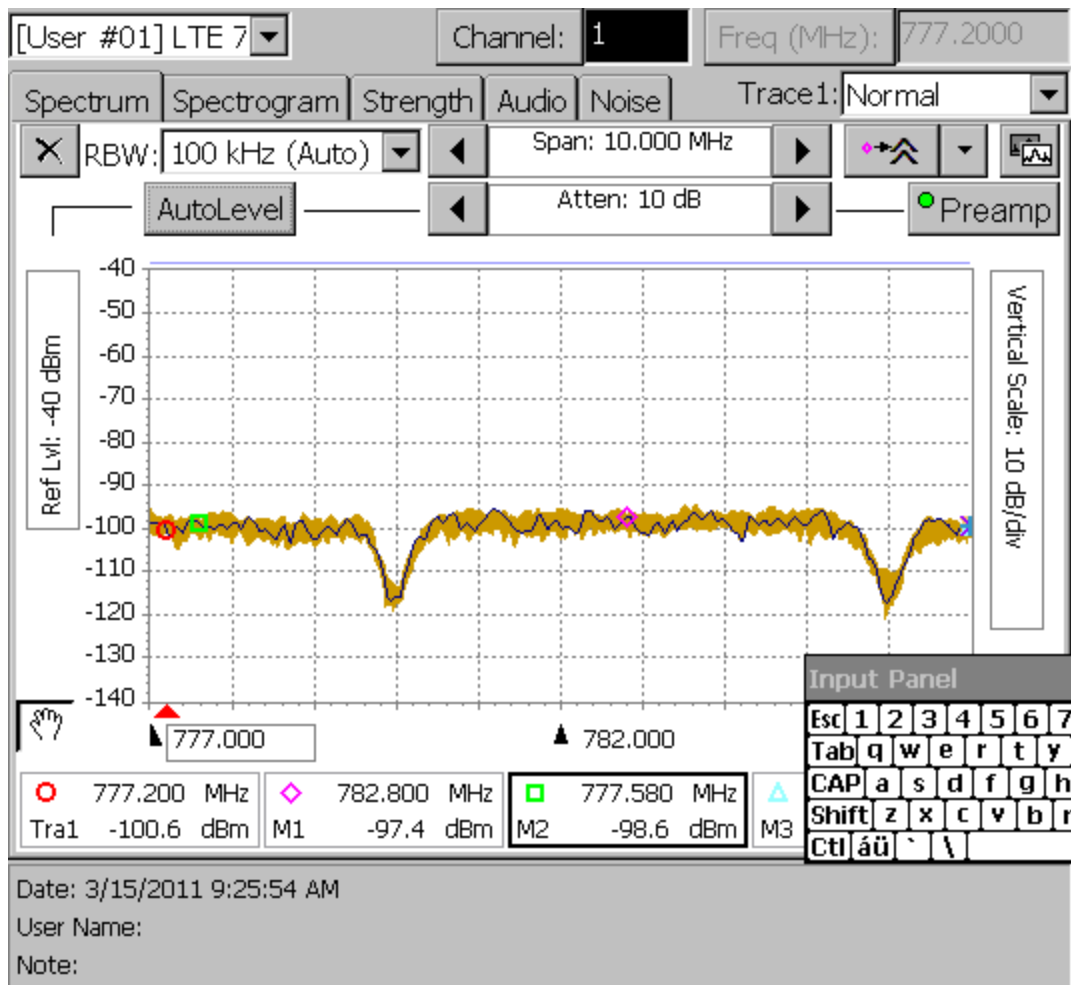
Courtesy Verizon



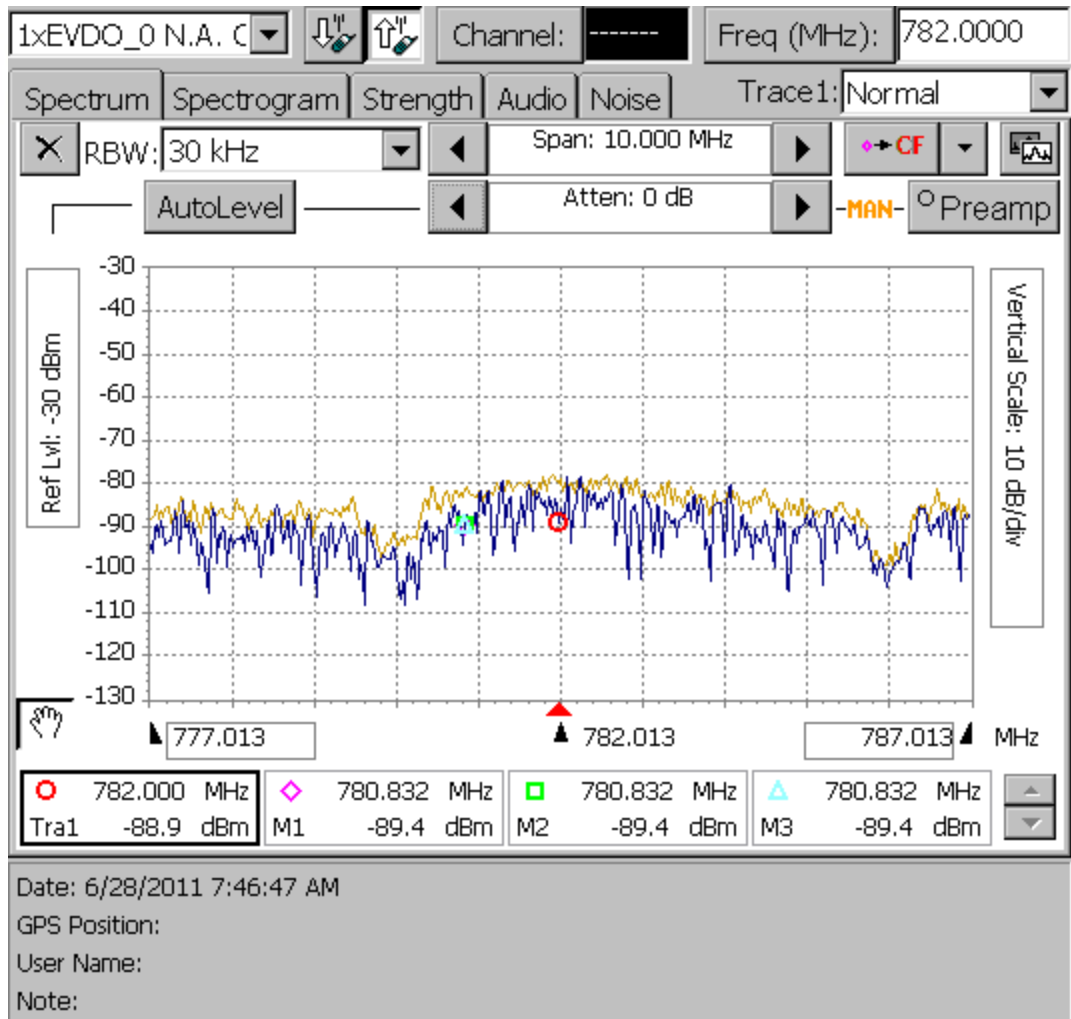
Courtesy Verizon



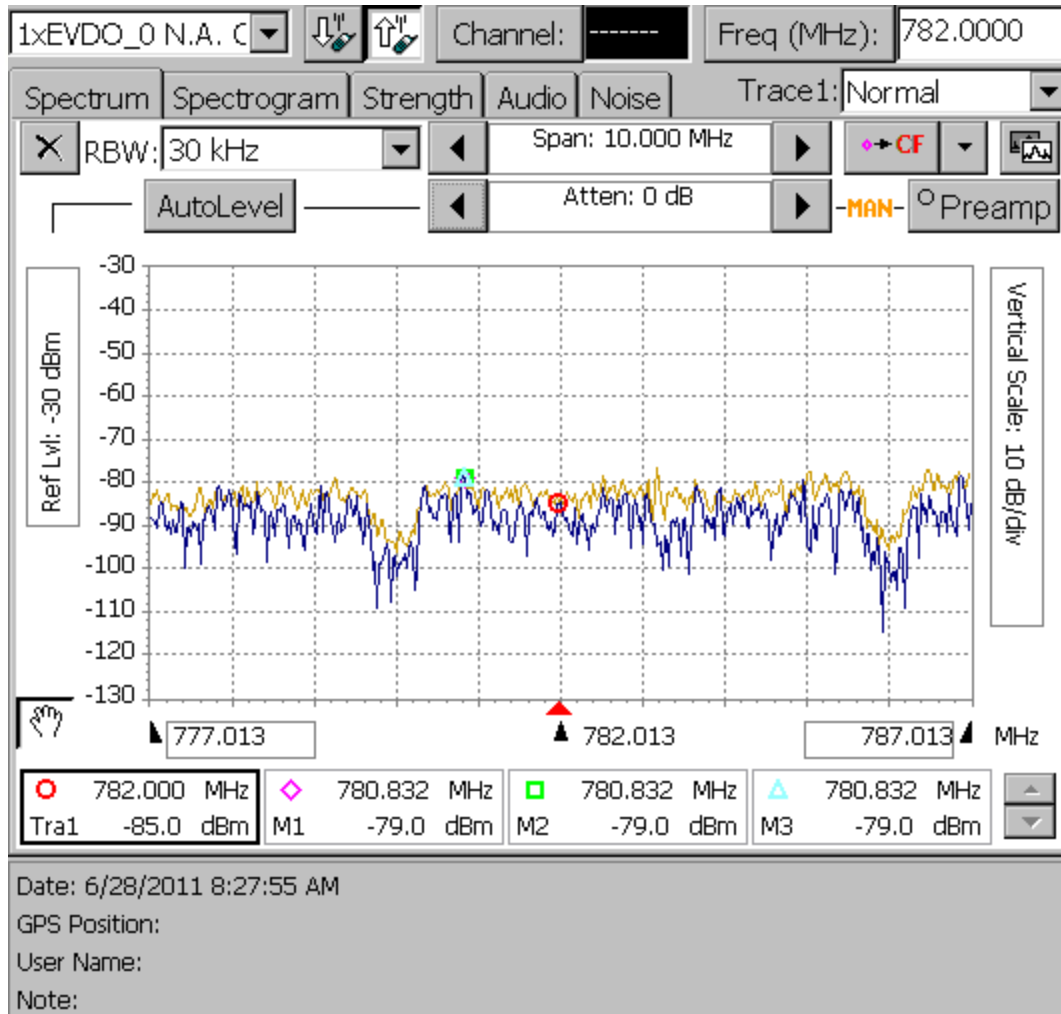
Courtesy Verizon



Courtesy Verizon



Courtesy Verizon



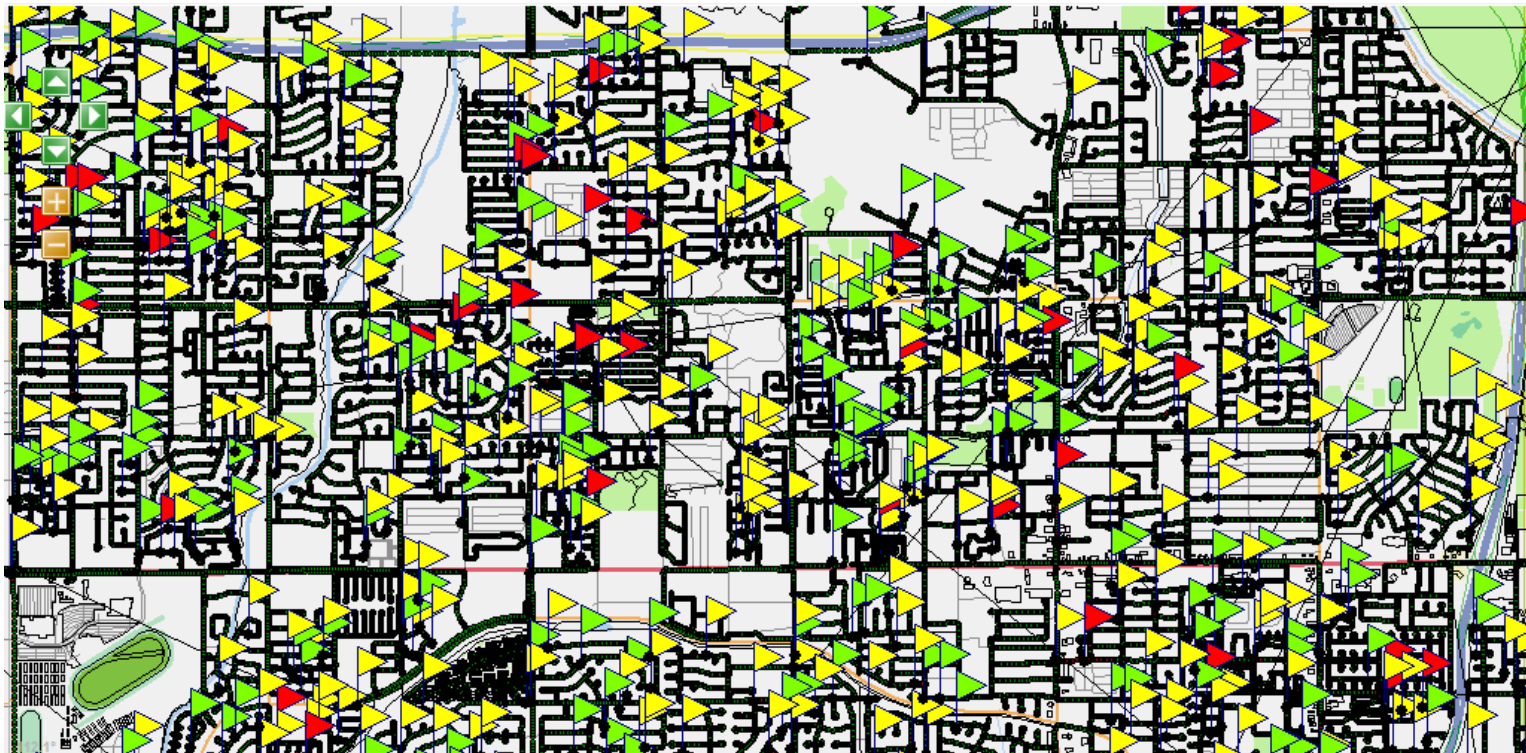
Courtesy Verizon



Field Data

High Frequency Leakage – 717MHz

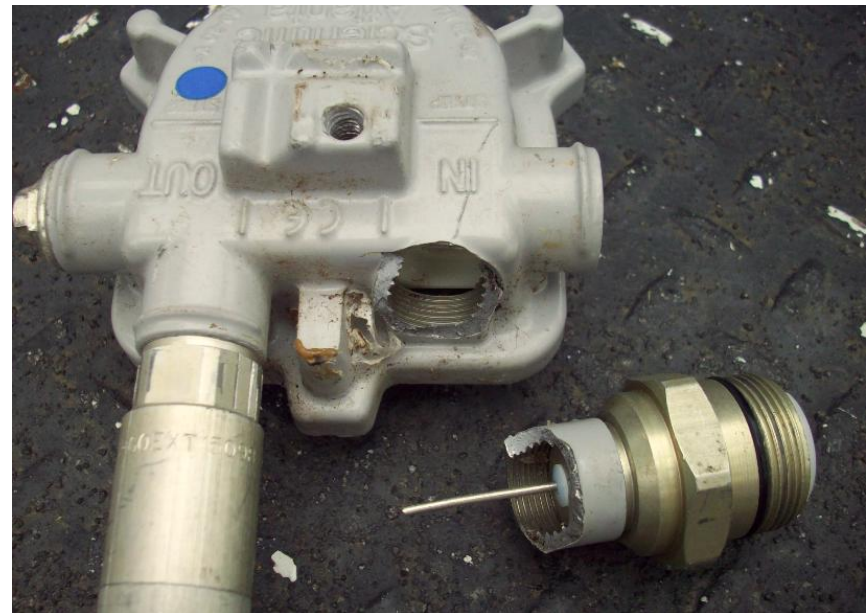
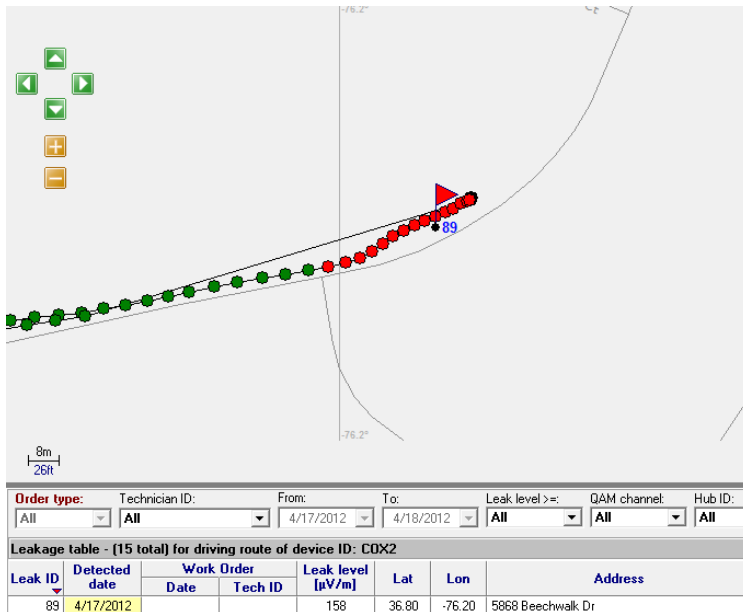
Red Flags are leaks $>100\mu\text{V}/\text{m}$, Yellow $20\text{-}100\mu\text{V}/\text{m}$, Green $<20\mu\text{V}/\text{m}$





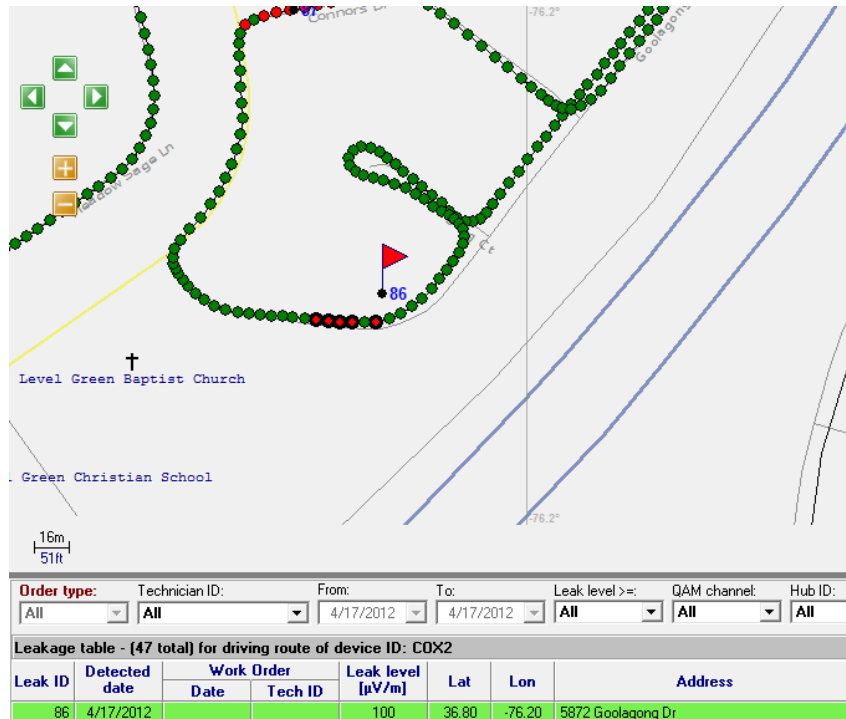
**Examples of impairments
measuring a high
frequency leak but no
measurable low
frequency leak**

Flag 89 – 158uV/m – 5868 Beachwalk Dr



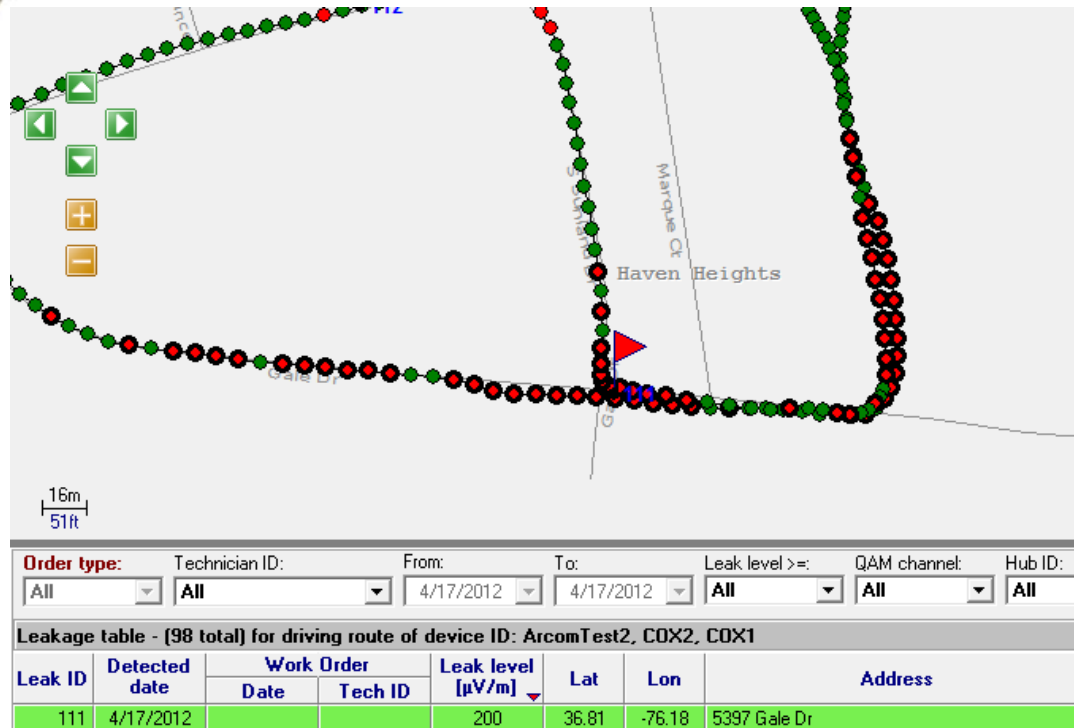
At Flag 89 was found a cracked tap housing

Flag 86 – 100uV/m – 5876 Goolagong Dr



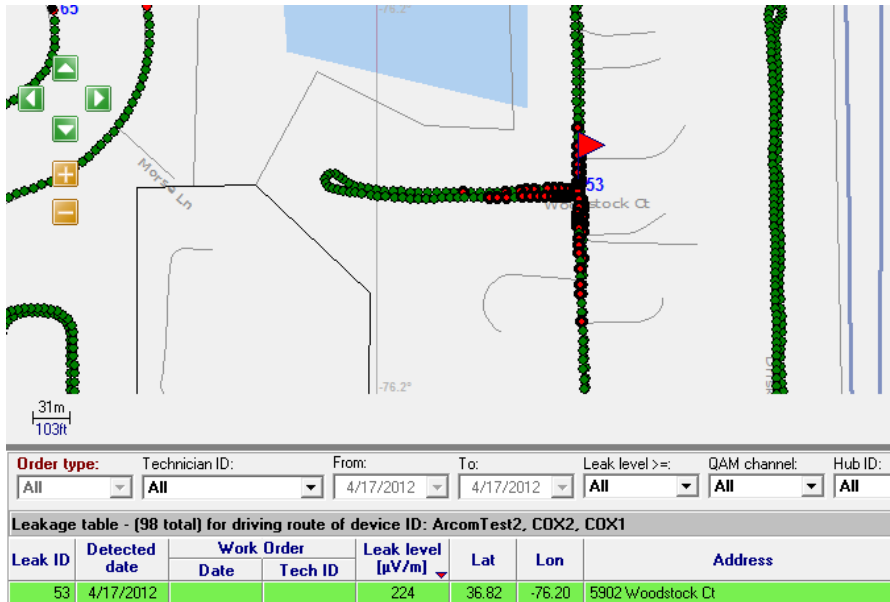
Burnt out tap with suck out around 470MHz..

Flag 111 – 200uV/m – 5397 Gale Dr



At this location the tap was missing a screw in the tap plate. This is a good example of Time Difference of Arrival technology for calculating the GPS coordinates of a leak. TDOA puts the flag at the exact location of the leak.

Flag 53 – 224uV/m – 5902 Woodstock Ct



Radial crack on the feeder cable.

Flag 80 – 224uV/m – 5878 Clear Springs Rd



Drop cable had crimp on connector. Pulled drop cable out of the connector. This dropped the leak down in level but a smaller leak was still detected. The tap screws were also loose.

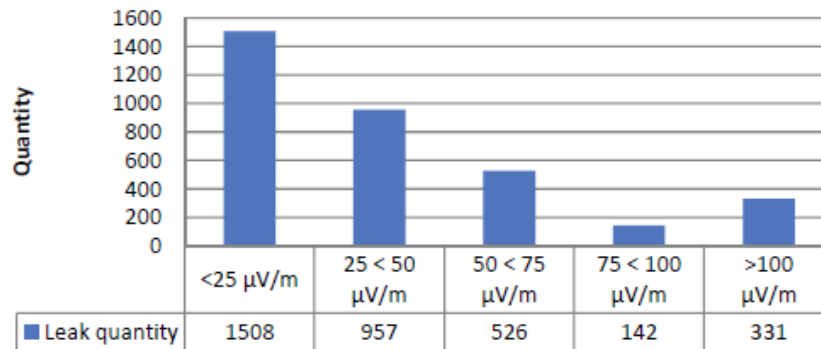
Flag 77 – 20uV/m – 5916 Cedar Springs Rd



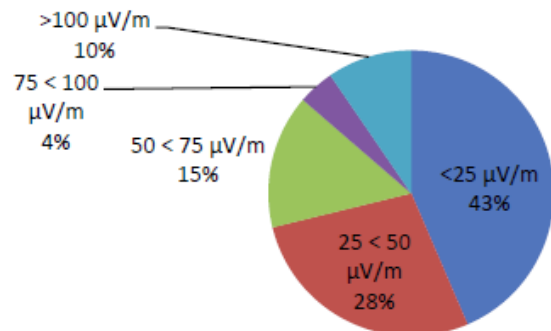
At this amplifier, the source of the leak was not identified immediately. The night crew went back that evening, dug up the hardline and found damage 6 feet from the amp.

High Frequency Leakage Level Distribution

Quantity of leaks grouped by 10 ft. scaled level - 3,464 detected leaks



Leak level - total of 3,464 leaks

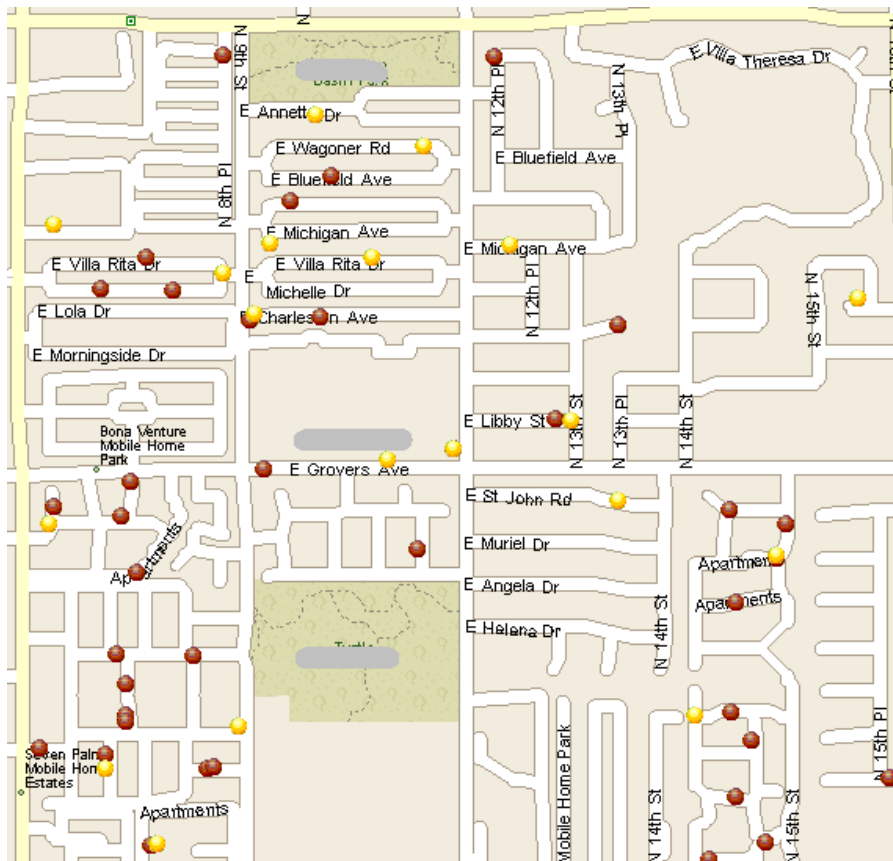


Average 1 leak per mile.

In 1000 mile plant there will most likely be 100 leaks over 100uV/m.

High Freq and Low Freq Leakage Comparison

Data exported from QAM Snare and an analog leakage platform then imported into Streets and Trips to show difference in data points. Red dots are QAM Snare recorded leaks at 717MHz , Yellow are analog aeronautical band leaks.



70% High Freq Only
20% Low Freq Only
10% Both High and Low



High Frequency and Low Frequency Sources

High frequency only leaks are generally hardline impairments

- Housing to housing connector, hardline connectors, tap plates, cracked cables, animal damage,
- Tilt, smaller wavelength, physical properties

Low frequency only leaks are generally soft plant impairments.

- Home, drop cable, drop connectors, illegals,

(There are some instances of high frequency leaks measured within the home, drop and illegals. These leak locations generally have measureable leaks at both high and low frequencies)



Technology available to measure high band leaks

Using a pre-amp, spectrum analyzer and antenna:

Rohde&Schwarz:

Portable radio monitoring receiver.

Comsonics/Trilithic/CPAT:

-30dB injected carrier at 612MHz
between QAM ch88/89.

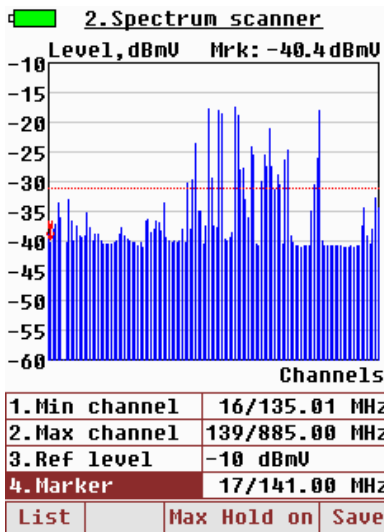
Arcom Digital:

Cross correlation process, matching
QAM's leaving the headend with QAM's
leaking from the plant



LTE Ingress

Terrestrial Spectrum Scan – Ingress Sources



| Channel | Level |
|----------------|------------|
| 87/603.00 MHz | -26.0 dBmV |
| 88/609.00 MHz | -40.0 dBmV |
| 89/615.00 MHz | -40.0 dBmV |
| 90/621.00 MHz | -30.0 dBmV |
| 91/627.00 MHz | -25.0 dBmV |
| 92/633.00 MHz | -27.0 dBmV |
| 93/639.00 MHz | -21.0 dBmV |
| 94/645.00 MHz | -28.0 dBmV |
| 100/651.00 MHz | -31.0 dBmV |
| 101/657.00 MHz | -29.0 dBmV |
| 102/663.00 MHz | -30.0 dBmV |
| 103/669.00 MHz | -40.0 dBmV |
| 104/675.00 MHz | -27.0 dBmV |
| 105/681.00 MHz | -25.0 dBmV |
| 106/687.00 MHz | -39.0 dBmV |
| 107/693.00 MHz | -40.0 dBmV |
| 108/699.00 MHz | -41.0 dBmV |

| | | | |
|--------|---------|-----------|------|
| Spectr | Page Up | Page Down | Save |
|--------|---------|-----------|------|

| Channel | Level |
|---------------|------------|
| 70/501.00 MHz | -18.0 dBmV |
| 71/507.00 MHz | -29.0 dBmV |
| 72/513.00 MHz | -37.0 dBmV |
| 73/519.00 MHz | -37.0 dBmV |
| 74/525.00 MHz | -18.0 dBmV |
| 75/531.00 MHz | -18.0 dBmV |
| 76/537.00 MHz | -39.0 dBmV |
| 77/543.00 MHz | -40.0 dBmV |
| 78/549.00 MHz | -39.0 dBmV |
| 79/555.00 MHz | -38.0 dBmV |
| 80/561.00 MHz | -17.0 dBmV |
| 81/567.00 MHz | -19.0 dBmV |
| 82/573.00 MHz | -29.0 dBmV |
| 83/579.00 MHz | -28.0 dBmV |
| 84/585.00 MHz | -33.0 dBmV |
| 85/591.00 MHz | -36.0 dBmV |
| 86/597.00 MHz | -24.0 dBmV |

| | | | |
|--------|---------|-----------|------|
| Spectr | Page Up | Page Down | Save |
|--------|---------|-----------|------|

| Channel | Level |
|----------------|------------|
| 109/705.00 MHz | -41.0 dBmV |
| 110/711.00 MHz | -41.0 dBmV |
| 111/717.00 MHz | -41.0 dBmV |
| 112/723.00 MHz | -40.0 dBmV |
| 113/729.00 MHz | -41.0 dBmV |
| 114/735.00 MHz | -35.0 dBmV |
| 115/741.00 MHz | -31.0 dBmV |
| 116/747.00 MHz | -25.0 dBmV |
| 117/753.00 MHz | -12.0 dBmV |
| 118/759.00 MHz | -40.0 dBmV |
| 119/765.00 MHz | -40.0 dBmV |
| 120/771.00 MHz | -41.0 dBmV |
| 121/777.00 MHz | -40.0 dBmV |
| 122/783.00 MHz | -41.0 dBmV |
| 123/789.00 MHz | -41.0 dBmV |
| 124/795.00 MHz | -41.0 dBmV |
| 125/801.00 MHz | -41.0 dBmV |

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| Spectr | Page Up | Page Down | Save |
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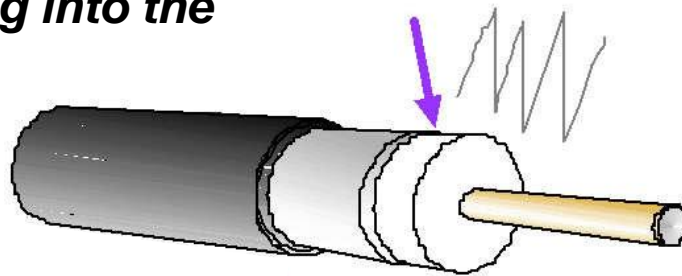
Taken with a high frequency antenna. Shows amount of terrestrial noise that could be a source of downstream ingress.

LTE Ingress Interference

LTE interfering with the CATV system

- LTE Uplink and Downlink can interfere with STB's, Cable Modems and TV's at the customer premise
- Most frequent issues to customers devices are direct pickup due to lack of sufficient shielding of the equipment.
- Interference also enters on the cable plant where there are areas of damaged cable and connectors (potential leak locations)

Ingress:
RF signal leaking into the coaxial plant..





LTE Ingress Interference

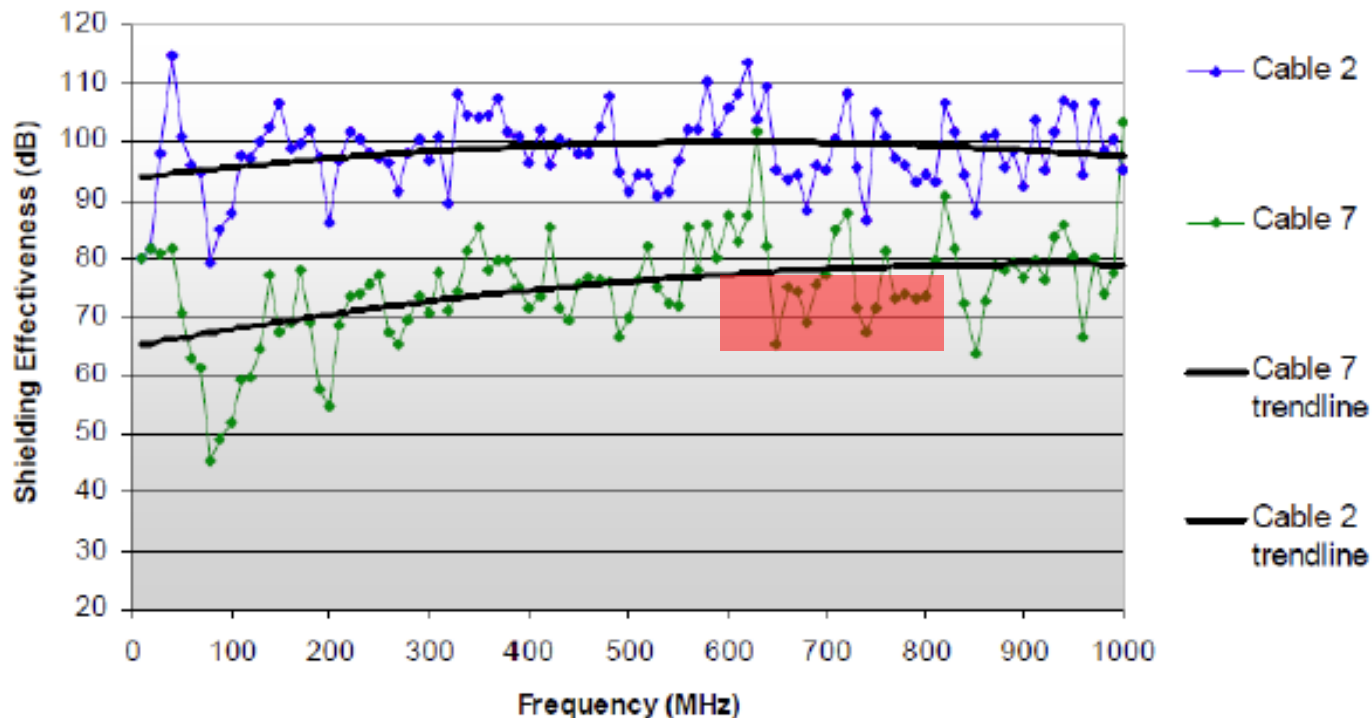
LTE base station (downlink) ingress affecting QAM CNR:

- Dependent upon the QAM signal level at the leak location.
- More likely to cause interference in the home.
- A $5\mu\text{V/m}$ LTE signal from 700 meters away of an ingress location could begin to cause CNR deterioration for all downstream subscribers.

LTE user equipment (uplink) affecting QAM CNR in the home:

- The home is the most susceptible to CNR deterioration from LTE user equipment because of the low signal level and short distances.
- LTE user equipment with an output power $1.0\ \mu\text{V/m}$ at 5 meters from a ingress point can begin to cause interference.
- Shielding effectiveness of home wiring can be problematic.

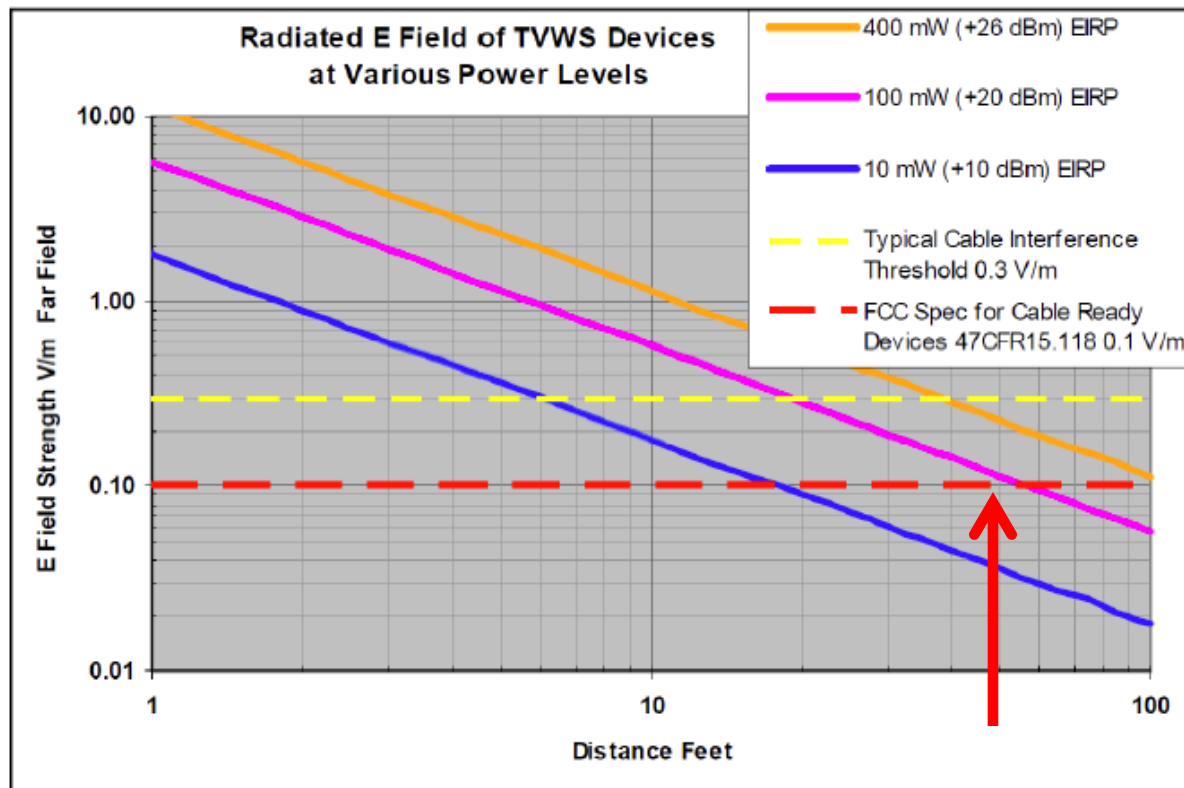
Shielding Effectiveness of Coaxial Cable



Trend lines of shielding effectiveness showing best and worst coaxial cables tested. Best cable shows 95-100dB of shielding while worst case only has 65-80dB of shielding. Will need test equipment that can measure less than 1uV/m leaks in order to find cable with poor shielding.

(Worst case is consumer grade cable with screw on F connectors)

Shielding Effectiveness of Coaxial Cable



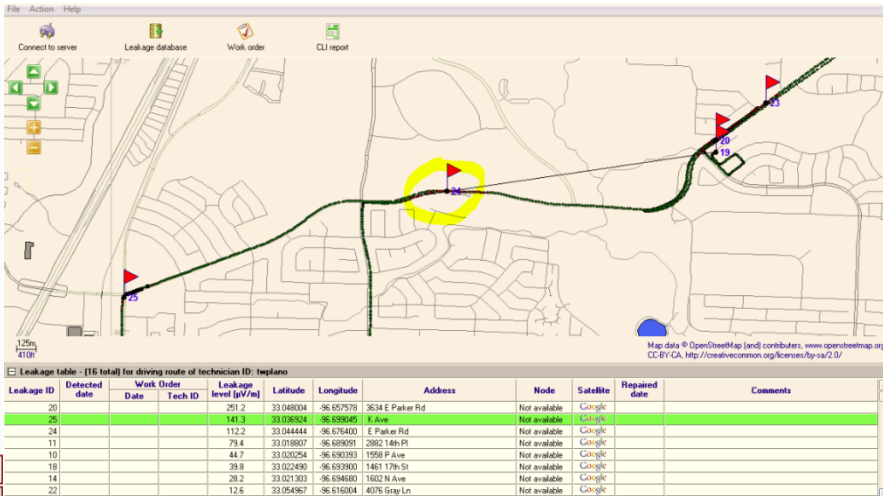
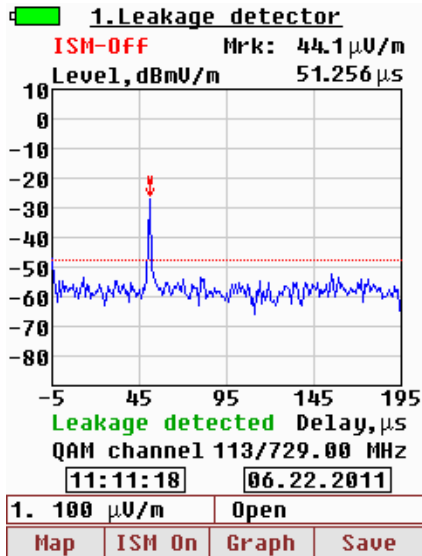
Current FCC requirement for Cable Ready Devices defines the threshold for field strength of interfering signal as 0.1 V/m. In the example above, a Smartphone with a 100mW output would need to be 57 feet away from cable device to not cause interference. Not possible within a home environment.



QAM Leakage And LTE Interference

High Level QAM Leak - No Analog Leak

Detected a 112uV/m QAM leak at tap but analog leakage equipment didn't detect any leak. Operator said this is where Verizon was complaining of LTE interference. Asked operator not to take tap apart but give it to Arcom for testing. We re-spliced a new tap and resolved the impairment.





Analysis of leaking tap



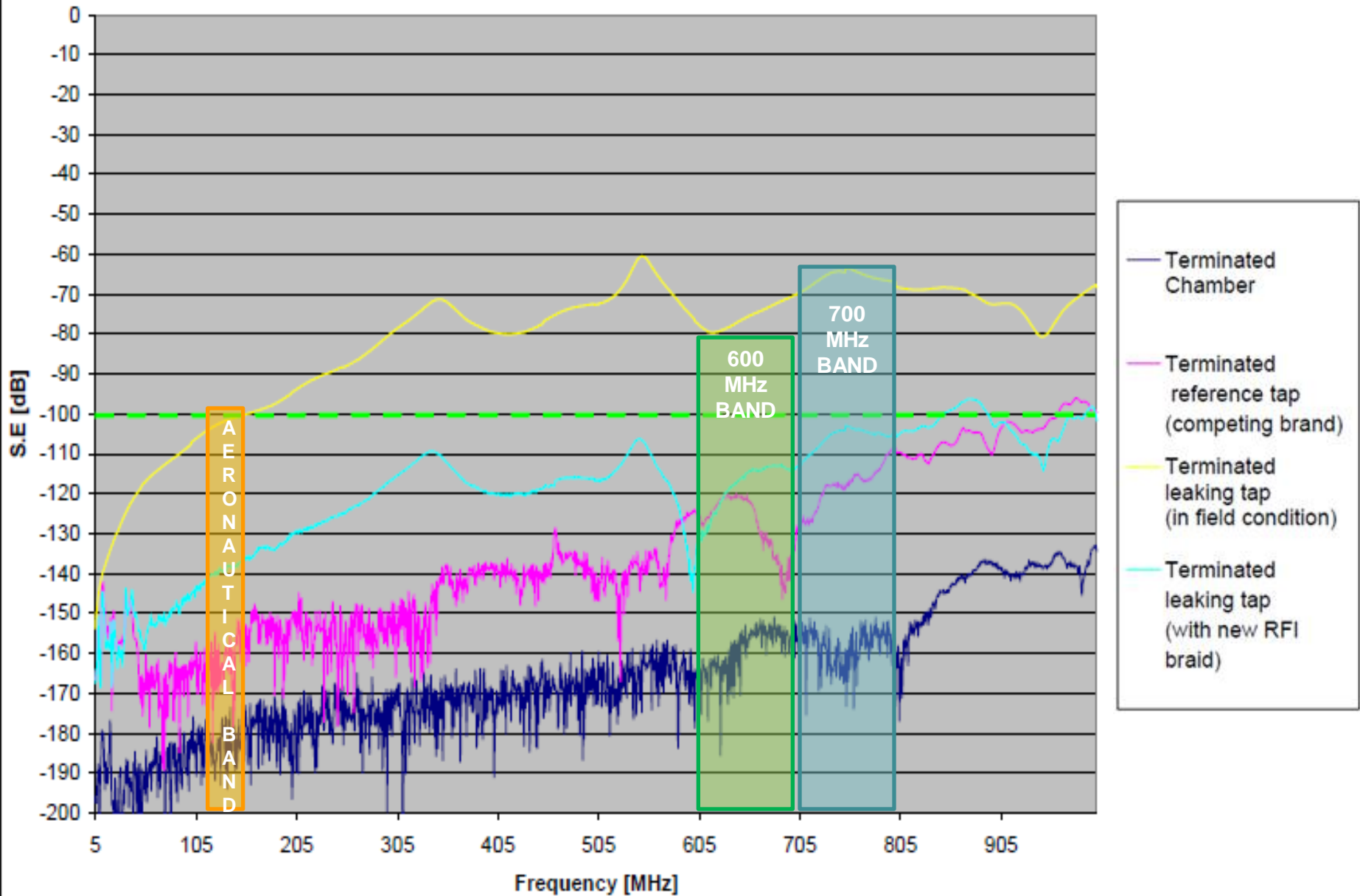
In our lab, the tap was tested using a GTEM in our lab, (precision electromagnetic emissions test equipment).

After testing the tap, was found that the RFI braid around the seal was bad. The results are show on the next page.

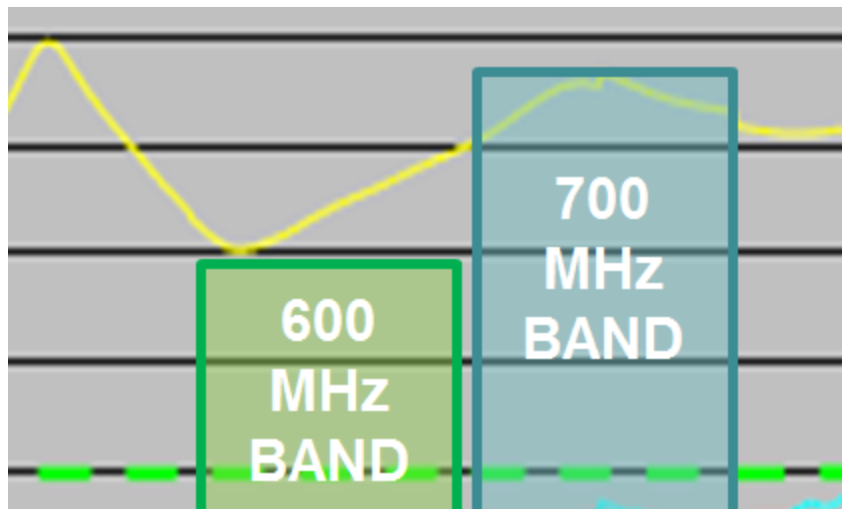
Note that at lower frequencies, below 150mHz, the RFI passes the -100dB standard. This is why traditional leakage equipment set in the aeronautical band wouldn't alarm. Was compared the original test with changing the braid and there was an improvement. Finally, was compared a different tap that we had in our labs.

Graph from GTEM

GTEM Tap Test, 7/6/2011



Dramatic Differences in Frequency Response



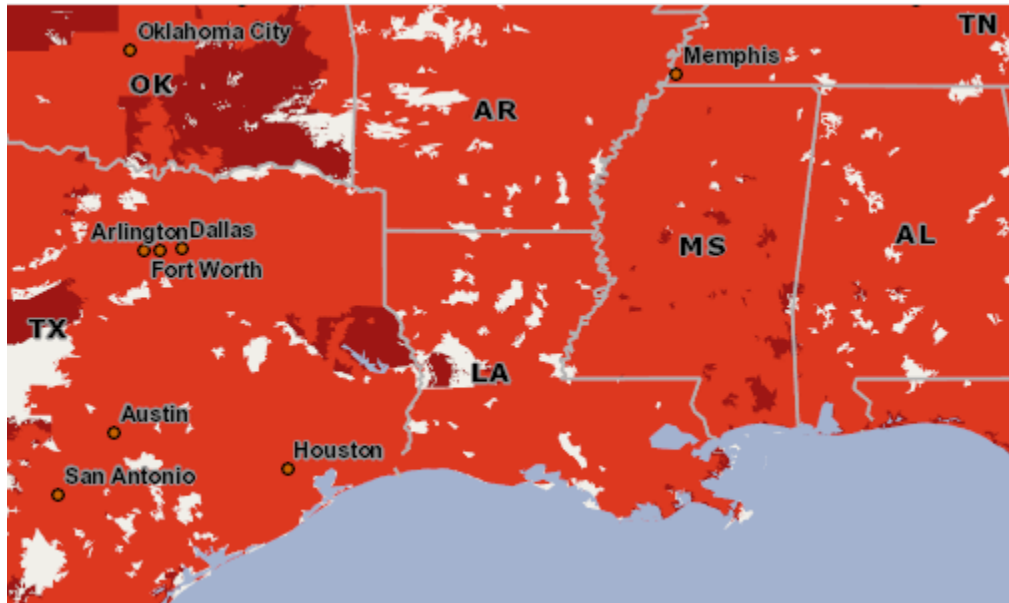
This tap was leaking at 112uV/m at 729MHz. With an 18dB difference between 605MHz and 729MHz, the leak only measured 14uV/m at 605MHz.



Growth of LTE



4G LTE Coverage



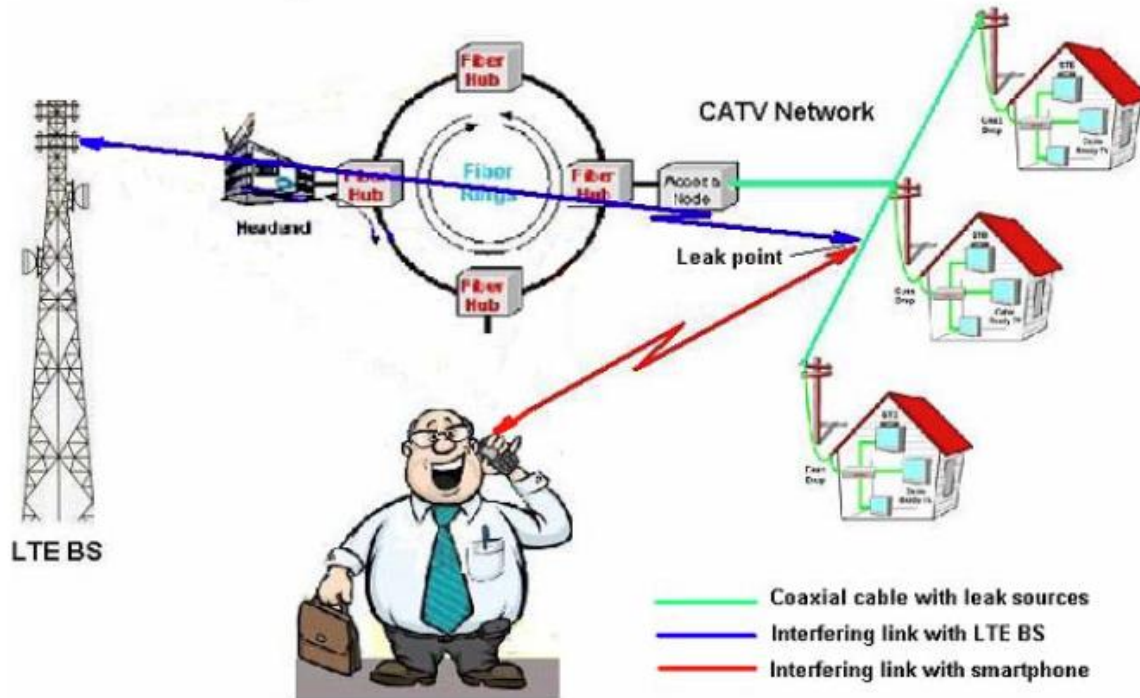
Verizon, AT&T and Sprint have deployed 4G LTE in Shreveport.

Mobile Data Growth



Source: IHS iSuppli Research, January 2013

More Traffic, More Noise, Less Bandwidth, More Problems



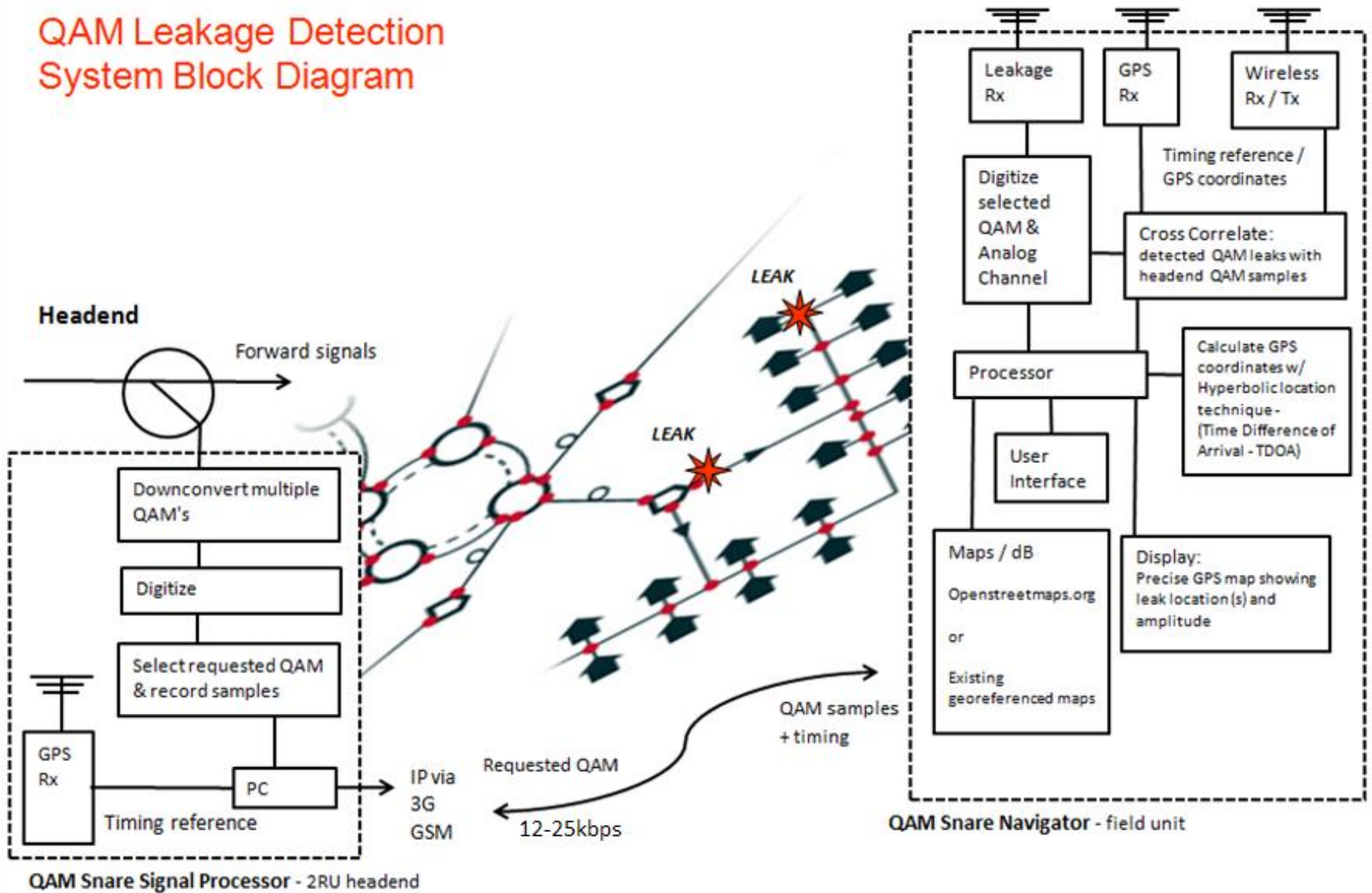
LTE user equipment affected by QAM egress: A $50\mu\text{V/m}$ leak can deteriorate the threshold noise floor of the user equipment from a distance of 3 meters, a $100\mu\text{V/m}$ from 6m, a $500\mu\text{V/m}$ from 30m, etc.

LTE base stations affected by QAM egress: An unobstructed $20\mu\text{V/m}$ leak can adversely affect the noise floor from 20 meters, a $100\mu\text{V/m}$ from 100m, a $500\mu\text{V/m}$ from 500m, etc.



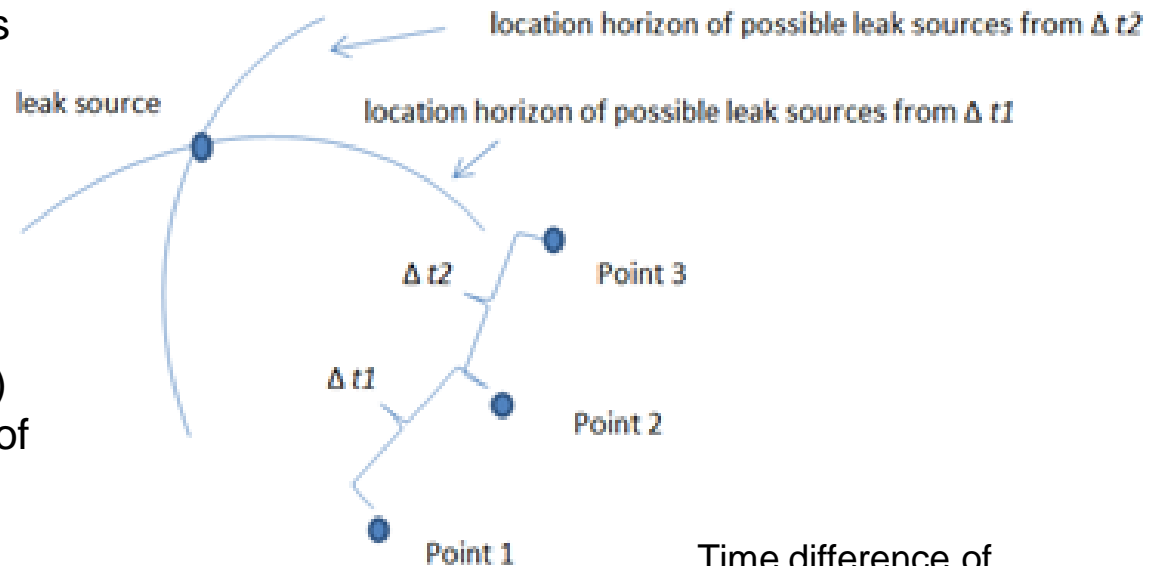
Behind the new detection technology

QAM Leakage Detection System Block Diagram



Advanced location methodology

Because of the employed correlation detection process and inherent time delay output – we have a unique opportunity to make use of this data and employ the most accurate location methodology called Time Difference of Arrival (TDOA) to resolve the GPS location of the leak.



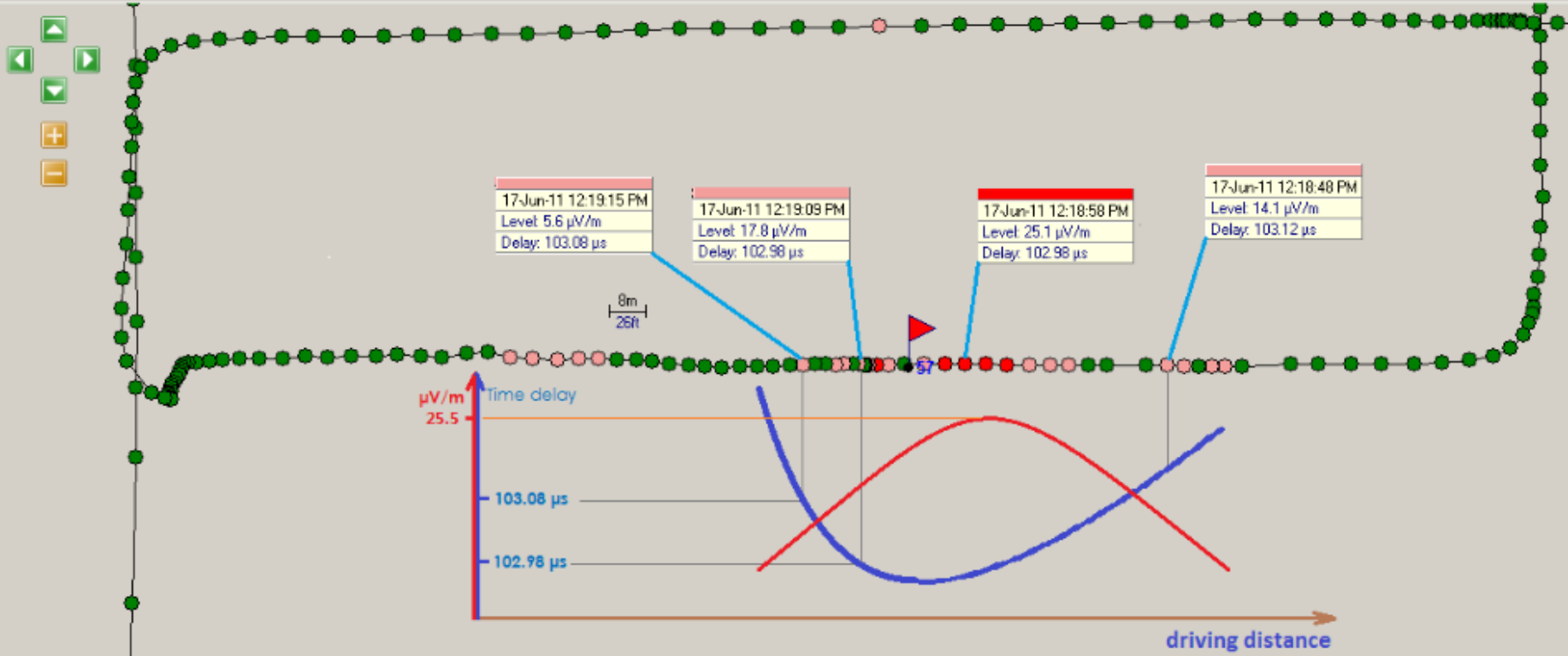
Time difference of arrival (TDOA) – hyperbolic location

Advanced location methodology – software implementation

QAM Snare [client] - 17-06-2011.qstf

File Action Help

Connect to server Leakage database Work order CLI report



System Architecture



Repair Technician Field unit

- Detects leakage from one QAM
- Automatically connects to correct hub based on GPS coordinates of plant
- Display flagged location of assigned work order
- Close out work orders after repair

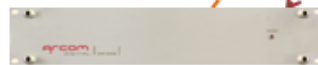


Passive Monitoring Black Box Field unit

- Detects leakage from any QAM channel
- Automatically connects to correct hub based on GPS coordinates of plant
- Operates passively, database is updated in real time as leaks are detected

1. Send QAM samples
2. Send calculated GPS leak coordinates and leak magnitude
3. Send work order showing previously mapped leaks and status

1. Request QAM samples
2. Reports every few seconds on current GPS coordinates and leakage parameters
3. Update status on resolved work orders



Hub 1



Hub 2

.....



Hub N

Headend Signal Processor

- 2 RU, internal PC, Linux OS
- Samples two QAM channels simultaneously
- Collects leak data from field units
- Calculates coordinates and level of leakage source
- Stores information on all new and previously identified leaks in its internal Work Order database.
- Tracks status of leaks: open, pending, closed
- Allows for leaks to be assigned to various technicians
- Export work order and leak data for use by other applications

Client Software

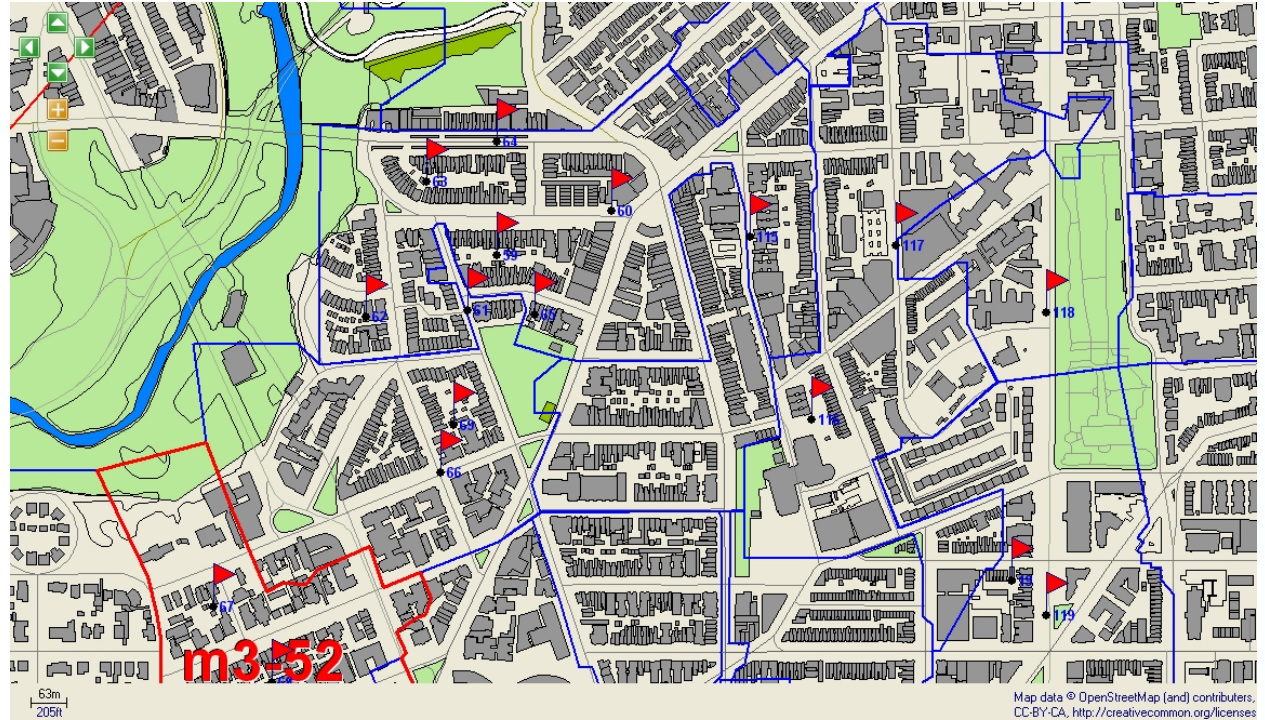
- Windows OS
- Communicate with any hub and view leak data remotely
- Manage Work Orders remotely
- Manage truck routings

Data export - to any other application

- Internal or External impairment tracking applications
- Leakage work orders to ticketing
- CLI data to any CLI server if measuring QAM near aeronautical frequencies

Real world results

Digital leaks are quite prevalent, this happens to be what was found one of the field tests



Leakage table - open leaks (126 total)

| Leakage ID | Detected date | Work Order Date | Tech ID | Leakage level [µV/m] | Latitude | Longitude | Address | Node | Satellite | Repaired date | Comments |
|------------|---------------|-----------------|---------|----------------------|-----------|------------|---------------------|---------------|-----------|---------------|------------------|
| 114 | 06.07.2011 | | | 112.2 | 38.924244 | -77.028815 | 1209 Euclid St NW | m6-60 | Google | | |
| 9 | 23.03.2011 | 24.03.2011 | SNARE1 | 100.0 | 38.912195 | -77.035681 | 1563 Corcoran St NW | m3-70 | Google | | BROKEN TAP PLATE |
| 57 | 17.06.2011 | | | 100.0 | 38.966136 | -77.034742 | 1445 Sheridan St NW | Not available | Google | | |
| 139 | 08.07.2011 | | | 100.0 | 38.901884 | -77.018428 | 912 9th St NW | m3-58 | Google | | |
| 126 | 08.07.2011 | | | 89.1 | 38.908936 | -77.028491 | 1406 12th St NW | m3-47 | Google | | |

Example of high level QAM Leak at a location with no analog leak

The screenshot displays a software interface for signal analysis. The main window shows a map with a green line representing a signal path. A red triangle marker is highlighted with a yellow circle at a specific location. Below the map is a table of data points. In the bottom-left corner, there is a detailed analysis window for a 'Leakage detector' showing a spectrum plot and various parameters.

| Age | Latitude | Longitude | Address | Node | Satellite | Repair date |
|-----|-----------|------------|------------------|---------------|-----------|-------------|
| 0 | 33.050666 | -96.654039 | E Parker Rd | Not available | Google | |
| 1 | 33.044542 | -96.676436 | E Parker Rd | Not available | Google | |
| 4 | 33.036788 | -96.698698 | K Ave | Not available | Google | |
| 8 | 33.037587 | -96.699188 | 3321 K Ave | Not available | Google | |
| 0 | 33.043432 | -96.726176 | 1637 Belgrade Dr | Not available | Google | |
| 9 | 33.043813 | -96.729381 | 3495 Carriage Ln | Not available | Google | |
| 1 | 33.040757 | -96.716460 | W Parker Rd | Not available | Google | |
| 6 | 33.034681 | -96.716144 | Alma Dr | Not available | Google | |

1. Leakage detector
ISM-OFF **Mrk: 44.1 μ V/m**
Level, dBmV/m **51.256 μ s**

Leakage detected Delay, μ s
QAM channel 113/729.00 MHz
11:11:18 **06.22.2011**

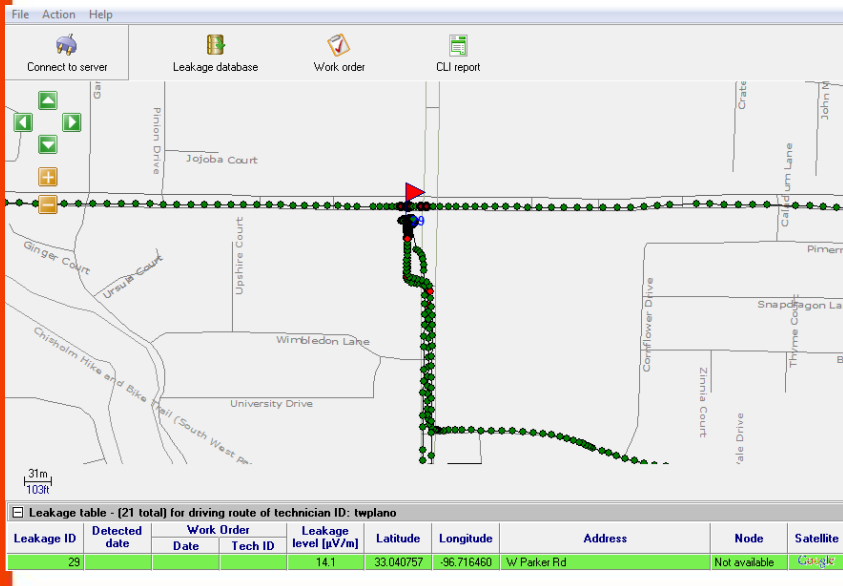
1. 100 μ V/m **Open**

Map **ISM On** **Graph** **Save**

2nd example of QAM leak with no corresponding analog leak

This location corresponds to the area where the cable operator received a complaint of LTE interference. Truck roll 1 – operator went to the location with analog equipment and detected nothing. Truck roll 2 – operator revisited the location with spectrum analyzer and detected nothing. Truck roll 3 – digital leakage was detected utilizing the new technology we are discussing.

Flag





FCC Proposed Rules on Digital Leakage

Current FCC Rules based on analog carrier

- Aeronautical band fix $>20\mu\text{V}/\text{m}$ at 3 meters.
- Outside aeronautical band fix $>150\text{mV}/\text{m}$ at 3meters.
- Must fix anything that interferes.

Potential future FCC rules based on a QAM

NPRM – Notice of Proposed Rulemaking

- FCC asked for input at the end of 2012
- New high frequency and QAM leak limits
- If any QAM in the Aeronautical band then must measure with new limits

| Frequencies | Signal leakage limit | Distance in meters (m) |
|---|--|------------------------|
| Analog signals less than and including 54 MHz, and over 216 MHz | $15\ \mu\text{V}/\text{m}$ | 30 |
| Digital signals less than and including 54 MHz, and over 216 MHz | $13.1\ \mu\text{V}/\text{m}$ | 30 |
| Analog signals over 54 MHz up to and including 216 MHz | $20\ \mu\text{V}/\text{m}$ | 3 |
| Digital signals over 54 MHz up to and including 216 MHz | $17.4\ \mu\text{V}/\text{m}$ | 3 |



Conclusions

- Egress from digital leaks can be harmful to communication systems
- Ingress from digital leaks can be harmful to traffic on the HFC network
- Status quo leakage detection equipment is not capable of detection digital leaks
- The described new technology is able to detect digital leaks, and because of the information on time delay resultant from the process, is able to make use of the more advanced and more accurate TDOA location technique.
- The new technology is impervious to multipath issues that made the previous analog detection process time consuming to isolate the source
- The new technology is scalable and can be implemented in a fashion consistent with cable operator work flow processes.



In Closing

- There will be new operational challenges with the deployment of 4G LTE in the 700MHz and 600MHz bands.

High frequency QAM leaks do interfere with LTE

LTE can interfere with operators downstream signals

- There is little to no correlation between low frequency and high frequency leak sources.
- High frequency leaks are generally located at hardline impairments.
- New leakage standards and practices will need to be developed.



References

Quantifying Leakage Thresholds for QAM/LTE Interference - Arcom

Another Look at Signal Leakage – SCTE Technical Paper – by Ron Hranac (Cisco) and Greg Tresness (Arcom)

Recognizing and Resolving LTE/CATV Interference Issues – Rohde&Schwartz



Thank you

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