

# LTE Interference

## The New Challenge

Presented To

**San Diego Chapter SCTE**

by

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PCT International**





- ✓ **Signal egress and ingress has been a major concern in the cable industry since the late '70s**
- ✓ **Much work has been done to control this issue**
- ✓ **A relatively new ingress and egress concern is 4G/LTE cellular telephone service**

# LTE (Long-Term Evolution)

## Older Cellphone Technologies

### ✓ 2G and 3G

- Mostly for voice – data was an add on
- Less complex modulation – simply more robust
- Takes a beating and you can still talk
- Doesn't use the same frequencies used by most cable systems

Common name	Uplink	Downlink
GSM/CDMA/WCDMA850	869-894 MHz	824-849 MHz
GSM900	880-915 MHz	925-960 MHz
GSM1800	1710-1785 MHz	1805-1880 MHz
GSM/CDMA1900	1850-1910 MHz	1930-1990 MHz
WCDMA2100 (AWS)	1710-1755 MHz	2110-2170 MHz

# LTE (Long-Term Evolution)

## LTE is Different - 4G

### ✓ Designed with Emphasis on More Data than Voice

- Video streaming has different requirements
  - Wider bandwidth (photos, web pages, etc.)
  - Longer duration (SMS or phone call vs. YouTube video)

### ✓ 700 MHz LTE – Different Behavior than 2G and 3G

- 2G & 3G were higher in frequency
- 4G signals travel farther – lower in frequency
- Less attenuation from structures, walls, etc.

**LTE**



# LTE (Long-Term Evolution)

## LTE is Different

✓ 4G

- More complex modulation
  - Downlink uses OFDMA with QPSK, 16QAM and 64QAM constellations
  - Uplink uses SC-FDMA with QPSK and 16QAM constellations
  - Bandwidth is allocated in “resource blocks” (set of subcarriers and OFDM symbols to allow bandwidth sharing)
  - A 10 MHz signal contains 50 resource blocks

# LTE



# LTE (Long-Term Evolution)

## LTE is Different

### ✓ 4G

- Wider bandwidth than 2G or 3G
  - 1.5, 5, 10, and 20 MHz bandwidths available
  - Primarily 5 MHz and 10 MHz being deployed
- More energy over wider spectrum on the downlink
- On the uplink:
  - Fewer resource blocks allocated per user
  - Total signal power is divided among fewer subcarriers
  - Energy is concentrated in a smaller portion of the allocated bandwidth

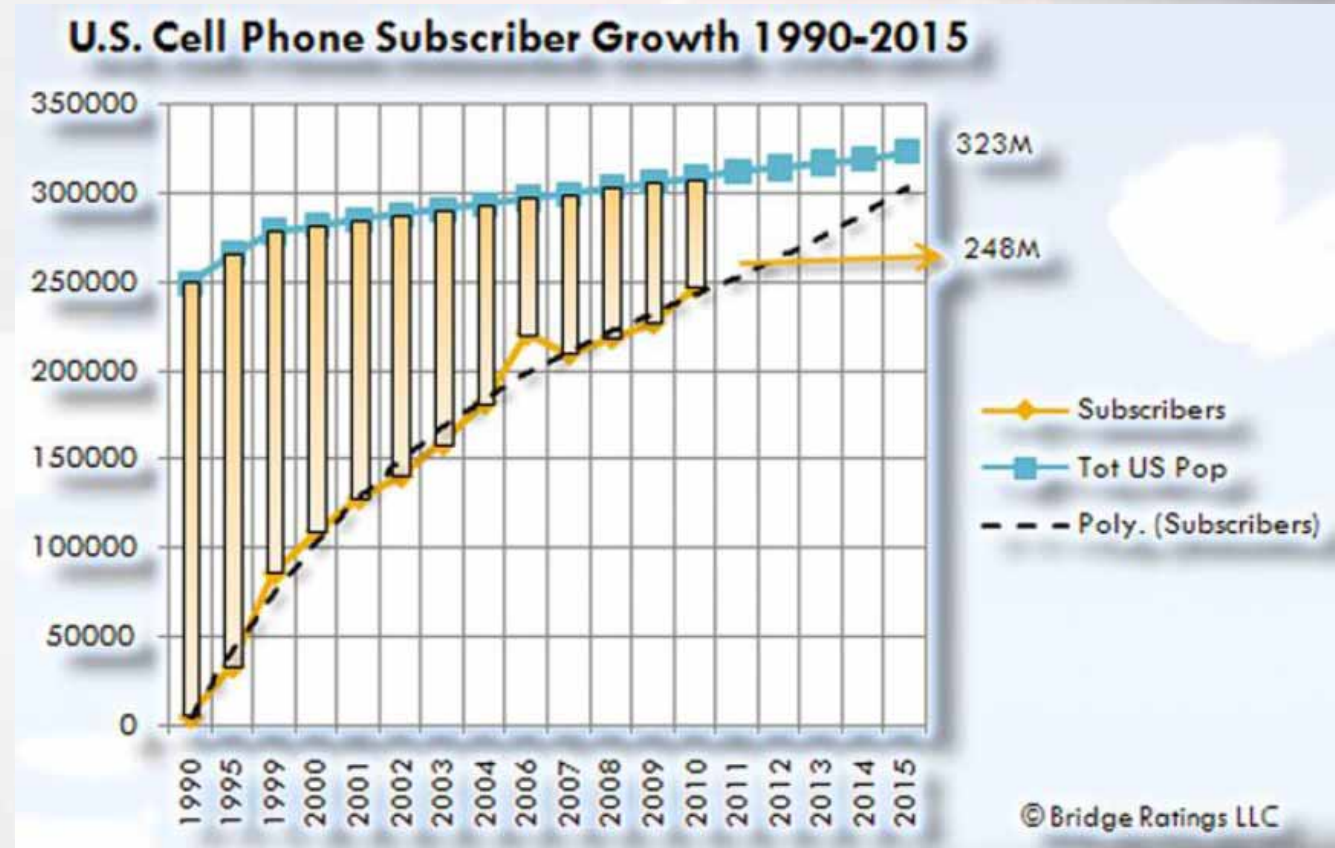
# LTE



# LTE (Long-Term Evolution)

✓ We just can't get enough!

- Cellular growth is almost exponential
- Move from 3G to 4G means more towers
- Here to stay

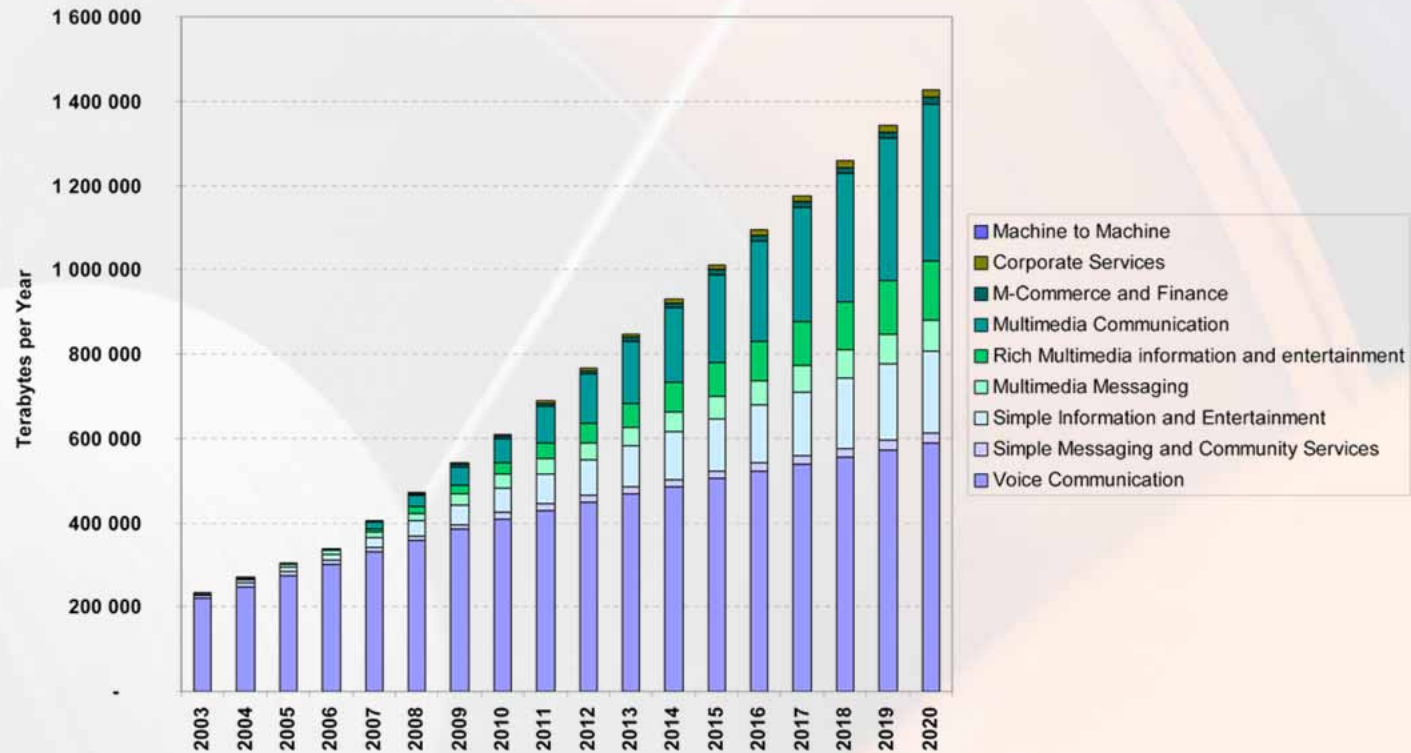


# LTE (Long-Term Evolution)

✓ Data is growing faster than voice

- Multimedia
- Entertainment
- Video
- Music

Total World Usage Forecast - Voice and Data Services

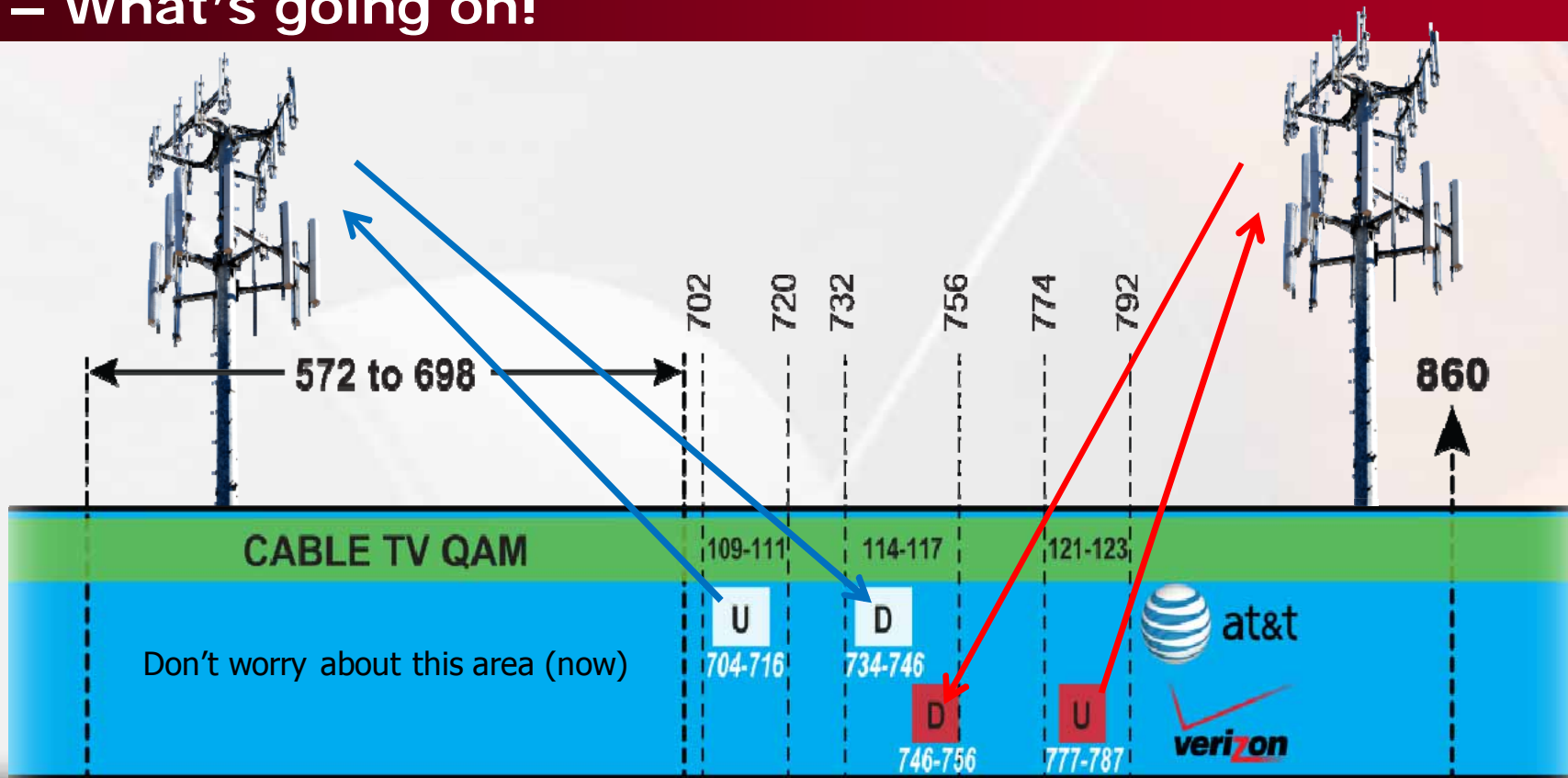


Source: Report ITU-R M.2072 "World mobile telecommunication market forecast"



# LTE (Long-Term Evolution)

OK – What's going on!

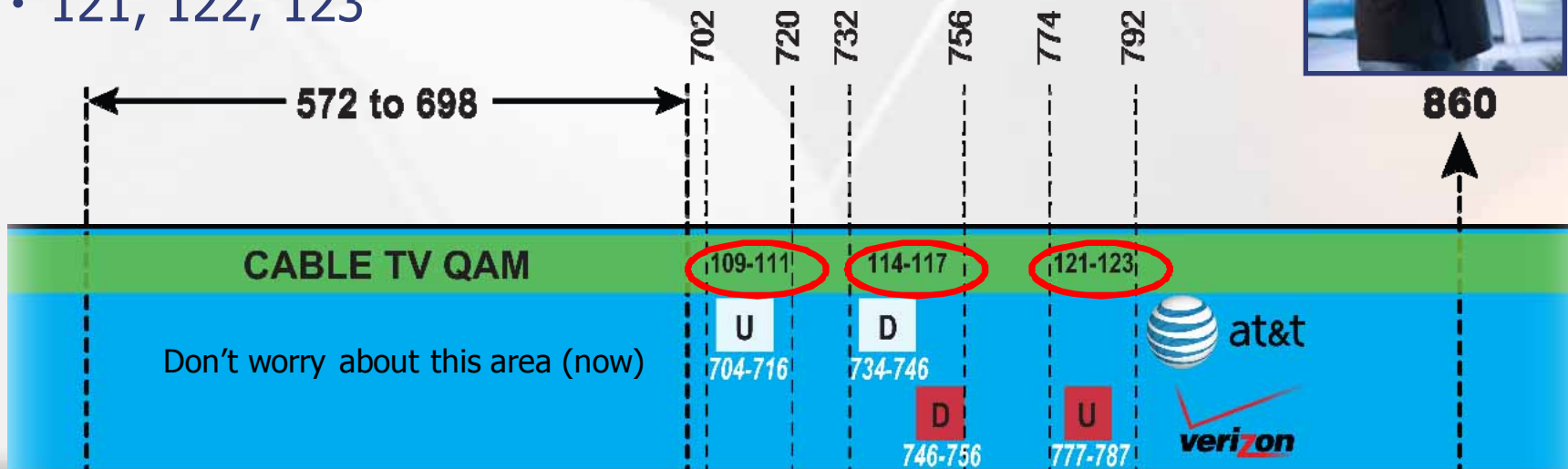


# LTE (Long-Term Evolution)

## A Bit More Detail

### ✓ Existing QAM Channels

- 109, 110, 111
- 114, 115, 116, 117
- 121, 122, 123



# LTE (Long-Term Evolution)

## FirstNet Is An Additional Concern

### ✓ What is FirstNet?

- Interoperability between emergency response agencies and groups has been a challenge due to different frequency assignments and radio technologies in use
- FCC specified that LTE would be the technology used for broadband public safety networks
- The First Responder Network Authority (FirstNet) is an independent authority within NTIA responsible for creating the first nationwide, high-speed, broadband network dedicated to public safety
- Frequency allocations are 758-768 MHz and 788-798 MHz (cable channels 118, 119, 120, 123, and 124)
- Trail deployments started in 2012, but full deployment is delayed

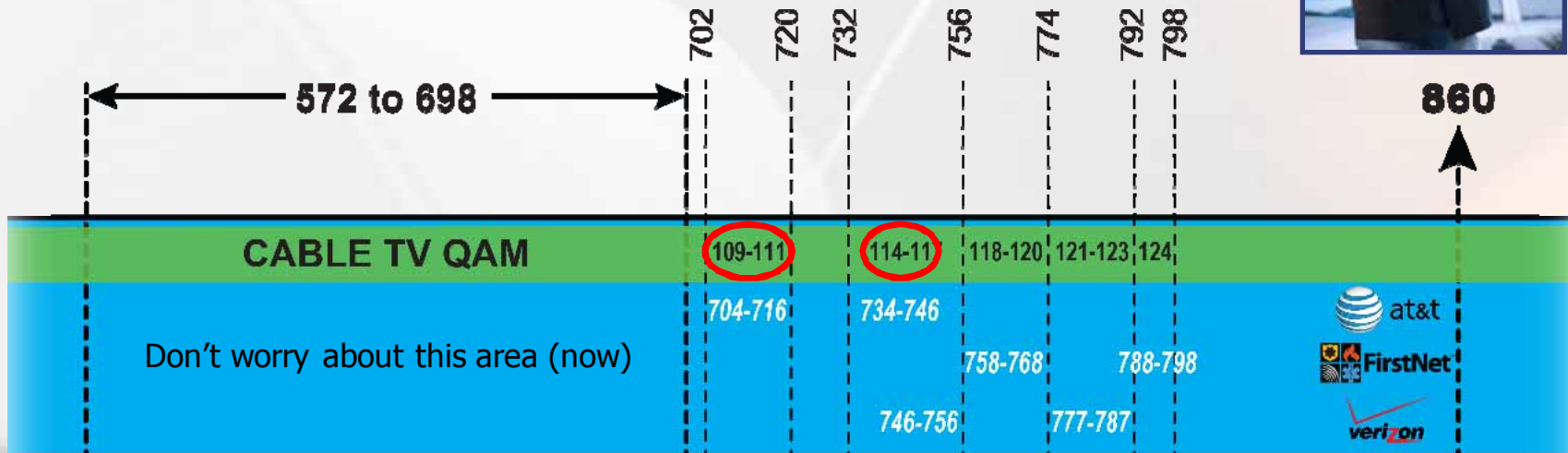


# LTE (Long-Term Evolution)

## A Bit More Detail

### ✓ Existing QAM Channels

- AT&T: 109, 110, 111, 114, 115, 116
- FirstNet: 118, 119, 120, 123, 124
- Verizon: 116, 117, 121, 122, 123

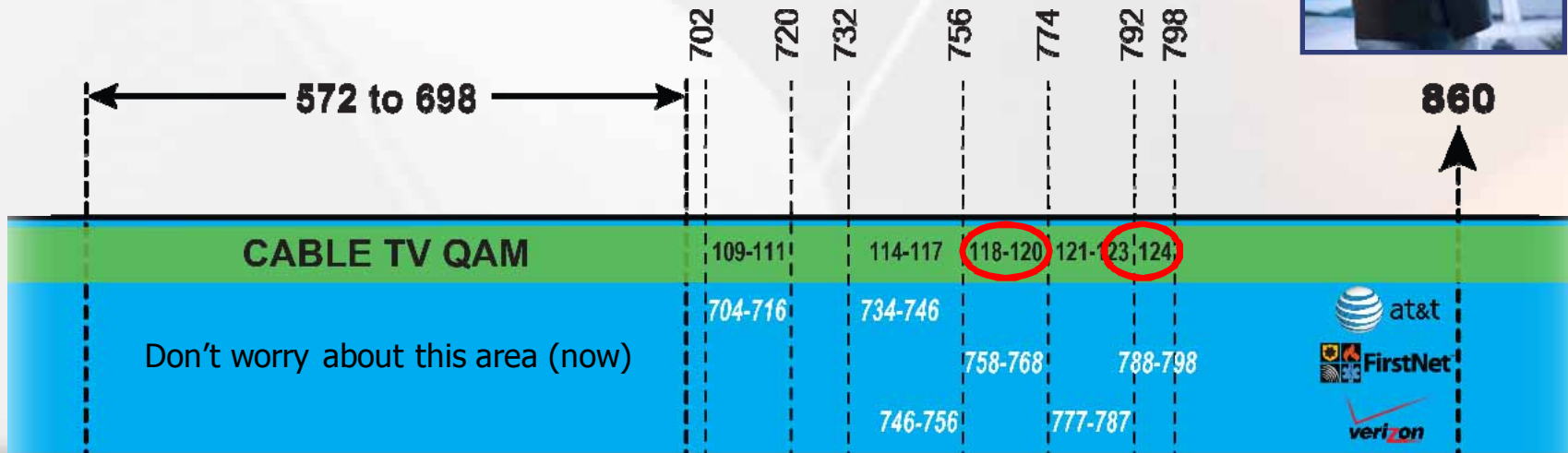


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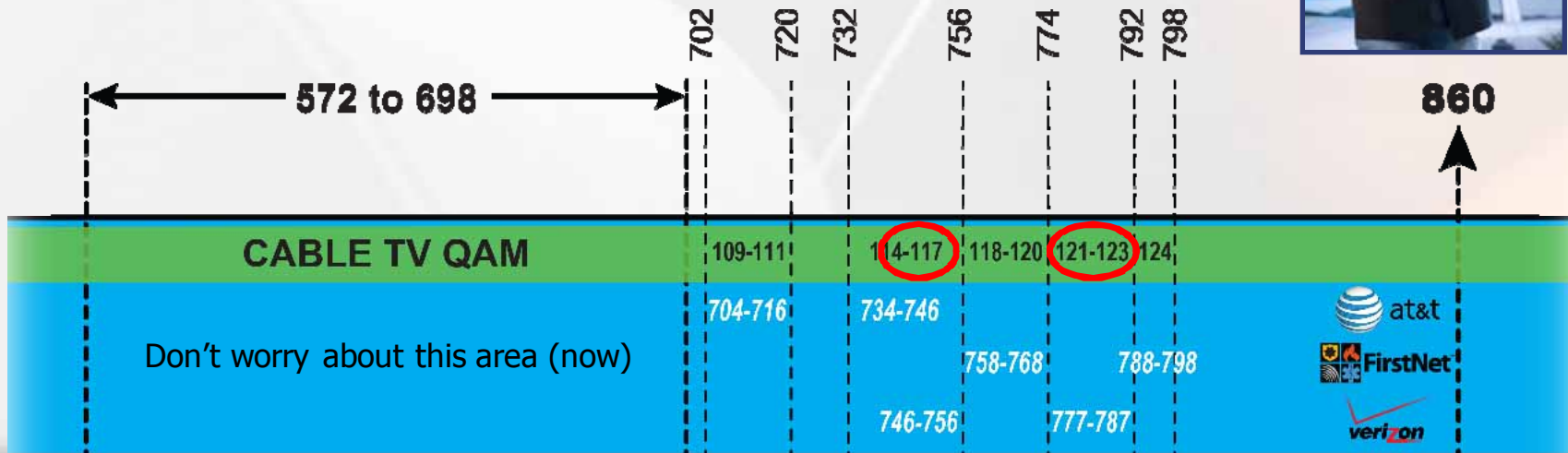


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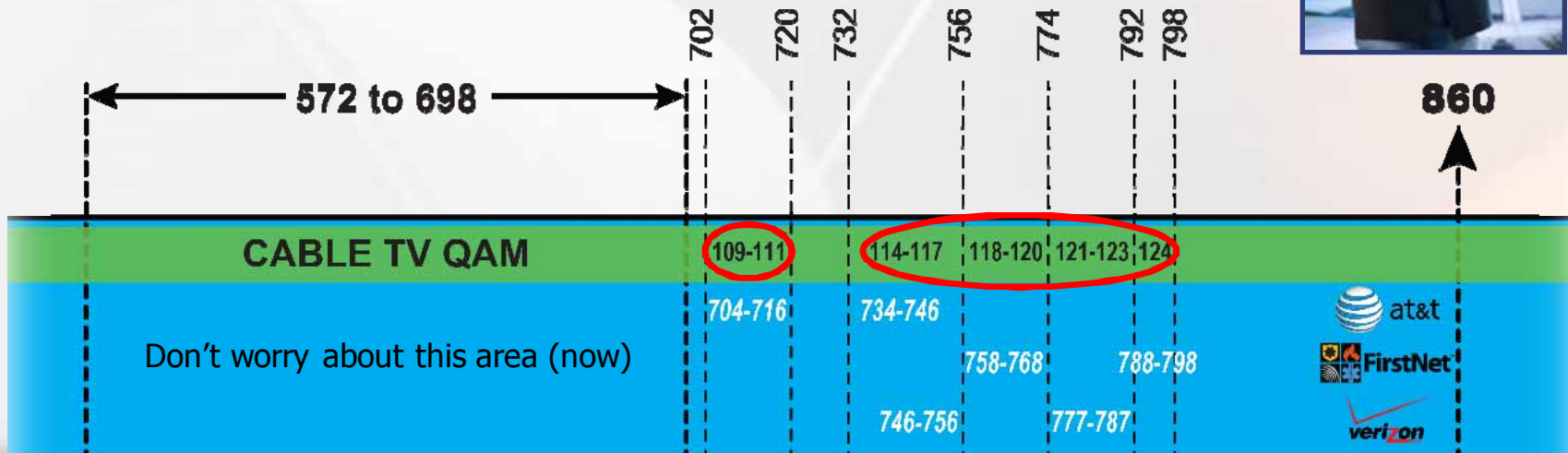


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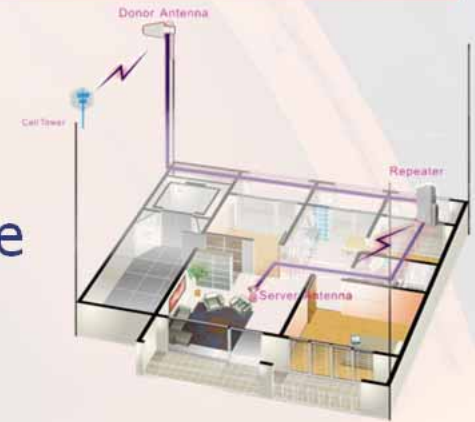


# LTE (Long-Term Evolution)

## And Even More...

### ✓ LTE Repeaters/Bidirectional Amplifiers

- Used to improve coverage in buildings
- Includes an outside and an inside antenna with a bidirectional amplifier covering the 700-800 MHz range
- Typically self installed



### ✓ LTE Femtocells

- Small base stations used to improve coverage in buildings or complexes
- Full LTE uplink/downlink system – not a repeater
- Requires an IP link
- Can be self installed



# LTE (Long-Term Evolution)

## Time for a Review

### ✓ Review of Leakage Issues

- All of these LTE signals are potential interference sources to our networks
- Our networks are potential interference sources to these LTE signals
- Signals leaking into and out of our networks is a problem we've been dealing with for many years
- We're not done yet...

# Ingress & Egress



## ✓ Ingress

- Unwanted RF signals leaking into the coaxial cable

## ✓ Egress

- RF signals leaking out of the coaxial cable

## What is Signal Leakage?

**Undesired emission of signals out of an HFC network (Egress)**

# Signal Leakage (Egress)

## Background

- ✓ Two reported interference incidents got the FCC involved
- ✓ Only prior complaints were HAM operators and occasional FM radio
- ✓ Cable network RF signals do not cause interference when the system complies with Federal Communications Commission (FCC) rules for limiting interference

# Signal Leakage (Egress)

## Background

- ✓ Occasionally, however, cable television system signals can “leak”
- ✓ Cable signal leaks occur when the RF signals transmitted within a cable system are not properly contained within the cable plant
- ✓ Cable signal leaks can be caused by a number of things, including loose connectors, damaged plant and cracked or unterminated cables

## Signal Leakage (Egress)

### Why Is Signal Leakage Monitoring Important?

- ✓ **The FCC requires that we control signal leakage**
- ✓ Prevents interference to authorized users of the spectrum
- ✓ Eliminates ingress into our networks, which can interfere with our video and data services
- ✓ Improves the physical condition of our system

## Signal Leakage (Egress)

### Regulatory Requirements

- ✓ The FCC has set maximum leakage limits that apply to ALL parts of the cable telecommunications network
- ✓ FCC 47 CFR 76.605 (a) 12 defines leakage limits

Frequency	Limits
54 – 216 MHz	20 $\mu\text{V}/\text{m}$ @ 3 meters
> 216 MHz	15 $\mu\text{V}/\text{m}$ @ 30 meters

- ✓ FCC 47 CFR 76.613 requires elimination of “harmful interference”, irrespective of the level of signal leakage

# Signal Leakage (Egress)

## Regulatory Requirements

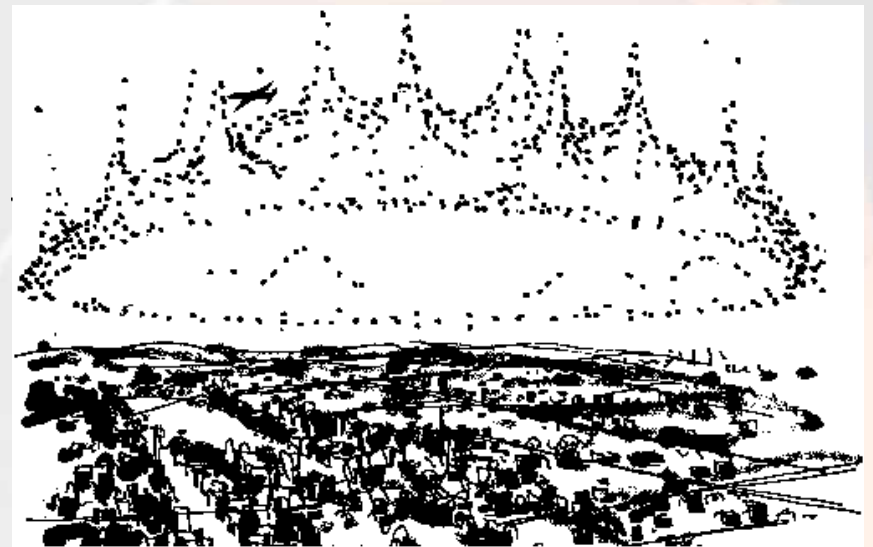
- ✓ To ensure compliance, the FCC has instituted several methods of testing that cable operators are required to perform:
  - Quarterly leakage monitoring (continuous monitoring)
  - Annual ground based Cumulative Leakage Index (CLI), or
  - Annual aerial based Cumulative Leakage Index (CLI)



## Signal Leakage (Egress)

### Cumulative Leakage Index (CLI)

- ✓ CLI is the combined field strength of all the leaks in the system added together
- ✓ The combination of all the leaks form an invisible cloud of unwanted RF energy over the cable system



## Signal Leakage (Egress)

### Why Is Signal Leakage Monitoring Important?

- ✓ The FCC requires we control signal leakage
- ✓ **Prevents interference to authorized users of the spectrum**
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## Signal Leakage (Egress)

### Shared Frequencies

- ✓ The cable industry uses RF frequencies that are shared with Over-The-Air (OTA) broadcasters:
  - Government
  - Military
  - Ham (amateur radio)
  - TV
  - Broadcast radio
  - Aeronautical radio
  - Cell phones
  - Among other users

# Signal Leakage (Egress)

## Shared Frequency Bands

- ✓ There are many licensed users of the same frequencies that are used in cable networks.

User	Channels	Frequency Range(s)
FM Band	95, 96, 97	88 – 108 MHz
Aircraft & Aeronautical	98, 99, 14, 15, 16	108 – 137 MHz
Ham Operators	17, 18 57, 58, 59, 60, 61	144 – 148 MHz 420 – 450 MHz
Government Mobile	21, 22	162 – 174 MHz
Military Air Voice	24 - 53	225 – 400 MHz
Cell Phone 4G LTE	109, 110, 111 114, 115, 116, 117 121, 122, 123	702 – 720 MHz 732 – 756 MHz 774 – 792 MHz

## Signal Leakage (Egress)

### What Problems Can Signal Leakage Cause?

- ✓ It can endanger the lives or hamper the rescue efforts of safety personnel
- ✓ This interference, especially on the emergency channels, can interfere with the communications of safety personnel or airplane pilots
- ✓ Cable signal leakage can interfere with any of the over-the-air services that happen to be using the same frequencies as the cable operator and that are within the vicinity of the cable system

## Signal Leakage (Egress)

### Why Is It Important to Control Leakage?

- ✓ Cable operators are considered the secondary users of these frequencies; therefore they must not interfere with the licensed over-the-air users who are the protected (primary) users of these frequencies

## Signal Leakage (Egress)

### Why Is Signal Leakage Monitoring Important?

- ✓ The FCC requires we control signal leakage
- ✓ Prevents interference to authorized users of the spectrum
- ✓ **Improves the physical condition of our system**
- ✓ Eliminates ingress into our networks, which can interfere with our video and data services

# Signal Leakage (Egress)

## Common Causes

- ✓ The majority of all leakage is caused by problems between the tap and the customer premises equipment (CPE)
- ✓ The following is a small list of items that cause signal leakage:
  - Loose drop connectors
  - Improper installation of connectors, coax, passives and splices
  - Poor quality coaxial cable, passives, or connectors
  - Corroded connectors, dampness or the presence of water
  - Physical damage to cables or connectors

## Signal Leakage (Egress)

### Common Causes *Continued*

- Product aging due to environmental conditions
- Bad/loose port terminator
- Unterminated ports on taps, passives and actives
- Broken tap ports
- CPE or shielding of equipment (e.g., faulty VCR or poorly shielded TV set)
- Squirrel/Rodent chews
- Customer installed equipment
- Loose hard line connectors
- Damaged amplifier housings and loose housing lids

## Signal Leakage (Egress)

### Aging Cables

✓ Large amounts of drop wires are 15 to 20 years old at this point (major upgrades from the early '90s)

- Stress points include the connector interface
- Attachment interface
- Animal damage
- Seasonal changes – weight, contraction, expansion
- UV damage – jacket damage, corrosion, moisture migration



# Signal Leakage (Egress)

## Coaxial Drop Cable

### ✓ Standard Tri-Shield Drop Cable

0 rotations



10,000 rotations



20,000 rotations



# Signal Leakage (Egress)

## S – Bend Testing

### ✓ 50 Times

- Conduits
- Prewired homes tight bends
- Wall plate tight turns
- Home entry points



## Signal Leakage (Egress)

### Why Is Signal Leakage Monitoring Important?

- ✓ The FCC requires we control signal leakage
- ✓ Prevents interference to authorized users of the spectrum
- ✓ Improves the physical condition of our system
- ✓ **Eliminates ingress into our networks, which can interfere with our video and data services**

## What is Signal Ingress?

**Undesired entry of signals into an HFC network  
(Ingress)**

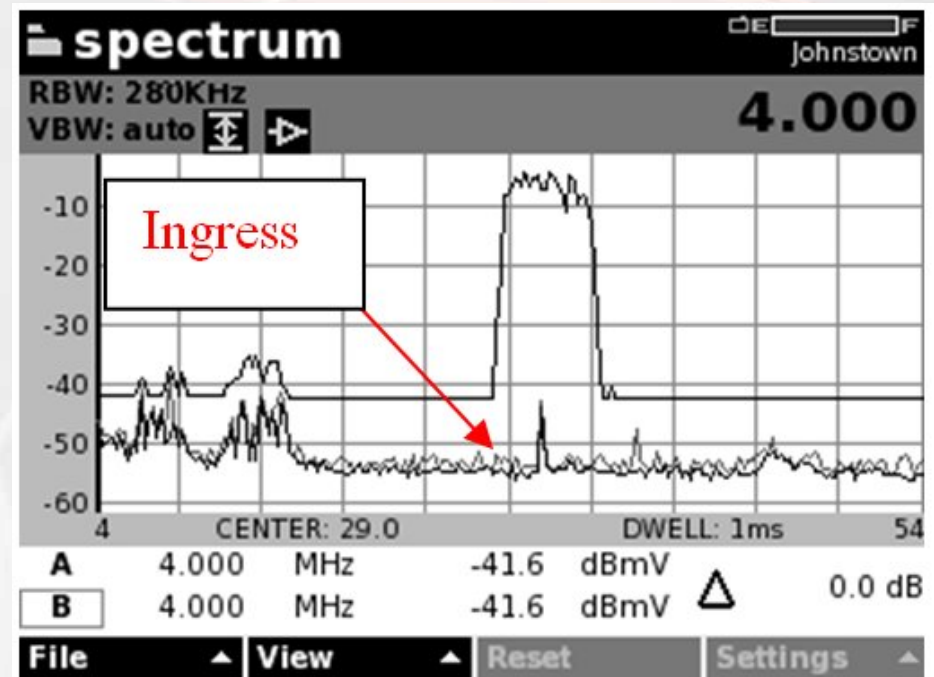
## Ingress

- ✓ It is possible that OTA signals can leak into a drop (ingress) and cause problems on both the forward and reverse signals
- ✓ The interference is often bursty or impulsive in nature, although it can also be a continuous increase in the system noise floor
- ✓ To locate the place where signal is leaking in, use the "divide and conquer" method
- ✓ The mostly likely cause of the problem will be a bad or loose F-connector, a break in the drop cable's shield, an old push-on jumper or bad wiring

## Reverse Path

### Reverse Ingress

- ✓ It is extremely important to understand ingress in reverse systems
- ✓ With increased implementation of services requiring return path activation, ingress brings the viability of two-way services into question
- ✓ VoIP demands high network reliability



## Reverse Path

### Reverse Ingress

- ✓ **Ingress is a significant issue at the lower frequencies**
  - Lower frequencies travel farther through the air with less loss than high frequencies
  - Many interference sources (electric motors, welders, etc.) generate more RF energy at the low frequencies
- ✓ **Prevention of ingress problems can save time and costs involved with later "truck rolls"**
- ✓ **95% of the ingress on the return path occurs from the tap through the customers premise - over 75% of the ingress occurs within the house**

## Reverse Path

### Reverse Ingress

- ✓ Ingress is a major concern in cable networks due to what is referred to as “funneling”
- ✓ Funneling is the result of sources of ingress and other interference harmful to reliable operation being picked up at multiple locations and funneled back to the receiver at the headend/hub, similar to noise in the reverse network

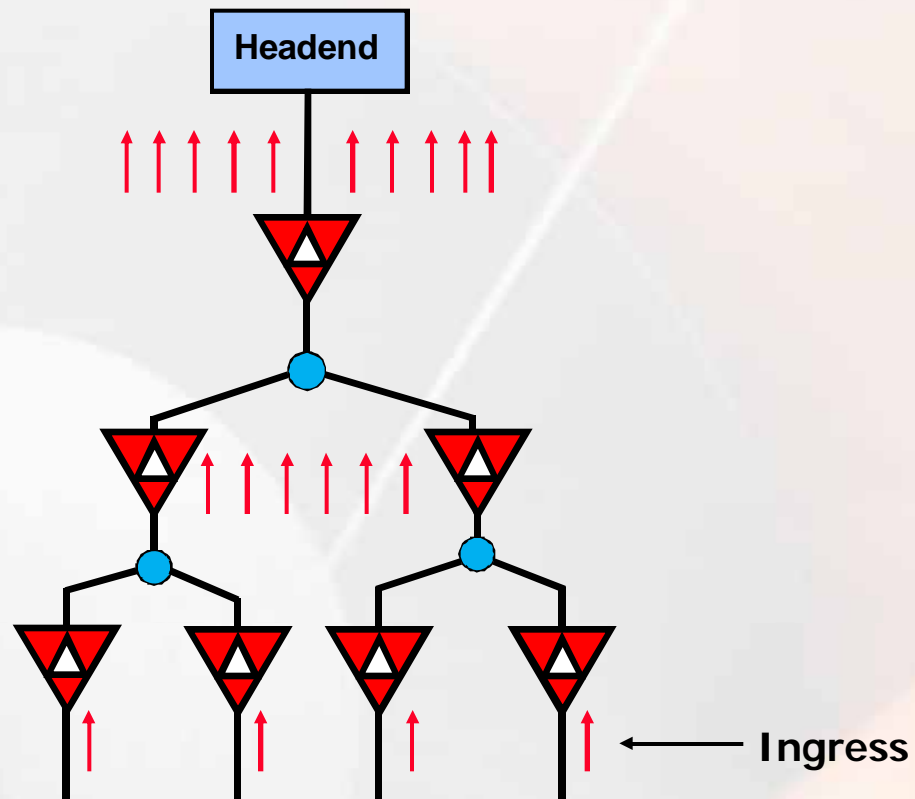
## Reverse Path

### Reverse Ingress

- ✓ Ingress on the return path is summed together - it only takes one bad house to corrupt an entire node!
- ✓ Each home's ingress is combined together and increases the total ingress noise level received at the hub, which affects all homes serviced by a node
- ✓ Therefore, it is important to minimize and control the ingress at each individual home

# Upstream Ingress Addition

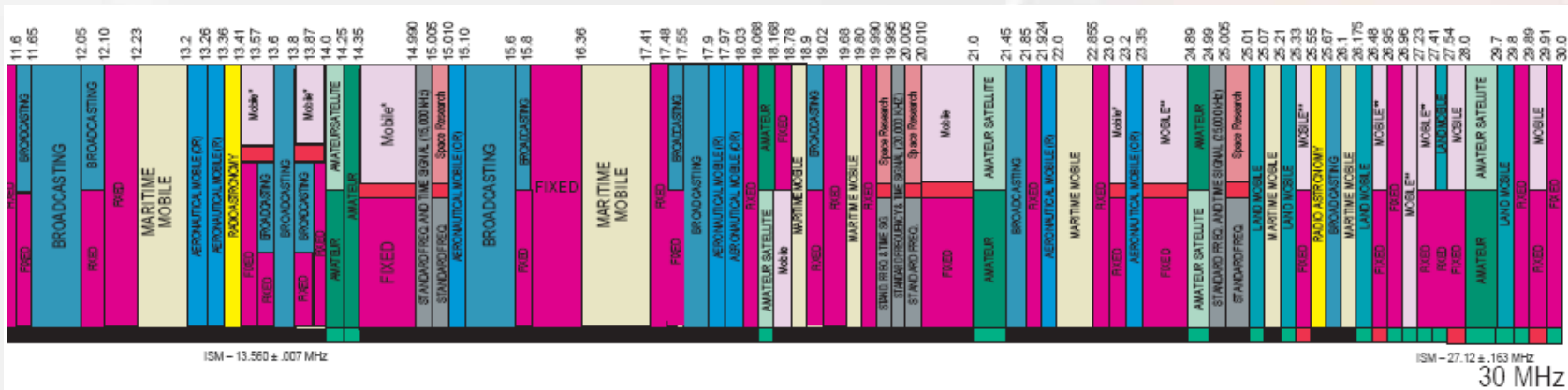
Reverse System  
"Ingress  
Funneling"



# Reverse Path Impairments

## RF Ingress

- ✓ The 5-42 MHz reverse spectrum is shared with numerous over-the-air users.

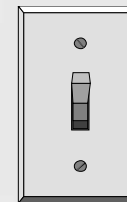
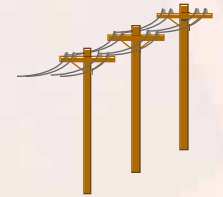
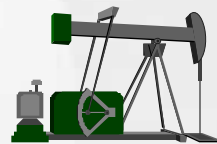


- ✓ Signals in the over-the-air environment include high power shortwave broadcasts, amateur radio, citizens band, government, and other two-way radio communications.

# Reverse Path Impairments

## Impulse noise

- ✓ Most reverse data transmission errors have been found to be caused by bursts of impulse noise
- ✓ Impulse noise is characterized by its fast rise-time and short duration
- ✓ Common sources include:
  - Vehicle ignitions
  - Neon signs
  - Static from lightning
  - Power line switches
  - Electric motors
  - Electronic switches
  - Household appliances



## LTE (Long-Term Evolution)

### Today's Issue is actually two issues

#### ✓ Ingress – Cellular signals interfering with the cable signals

- Not just a 5MHz to 42MHz issue anymore...
- LTE interference issues can cause problems affecting the downstream signals

#### ✓ Egress - Cable leakage interfering with the cellular signals

- The FCC said to check for leakage in the aeronautical band
  - This is a Narrow area – 108MHz to 137MHz
  - No one was checking other frequencies for the most part!

## LTE (Long-Term Evolution)

### Today's Issue is actually two issues

- ✓ **Ingress – Cellular signals interfering with the cable signals**
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## LTE (Long-Term Evolution)

### Cellular Signal Interferes with Cable (Ingress)

- ✓ Cellular signals get into the cable interfering with SD, HD, Data, Voice, VOD
  - Keep in mind a typical 6MHz cable QAM can carry:
    - 6 to 10 channels of Standard definition TV
    - 2 to 3 HD TV signals
    - Several hundred cable modem customers
    - Several hundred more telephony customers

# Ingress

## Ingress on Analog Channels

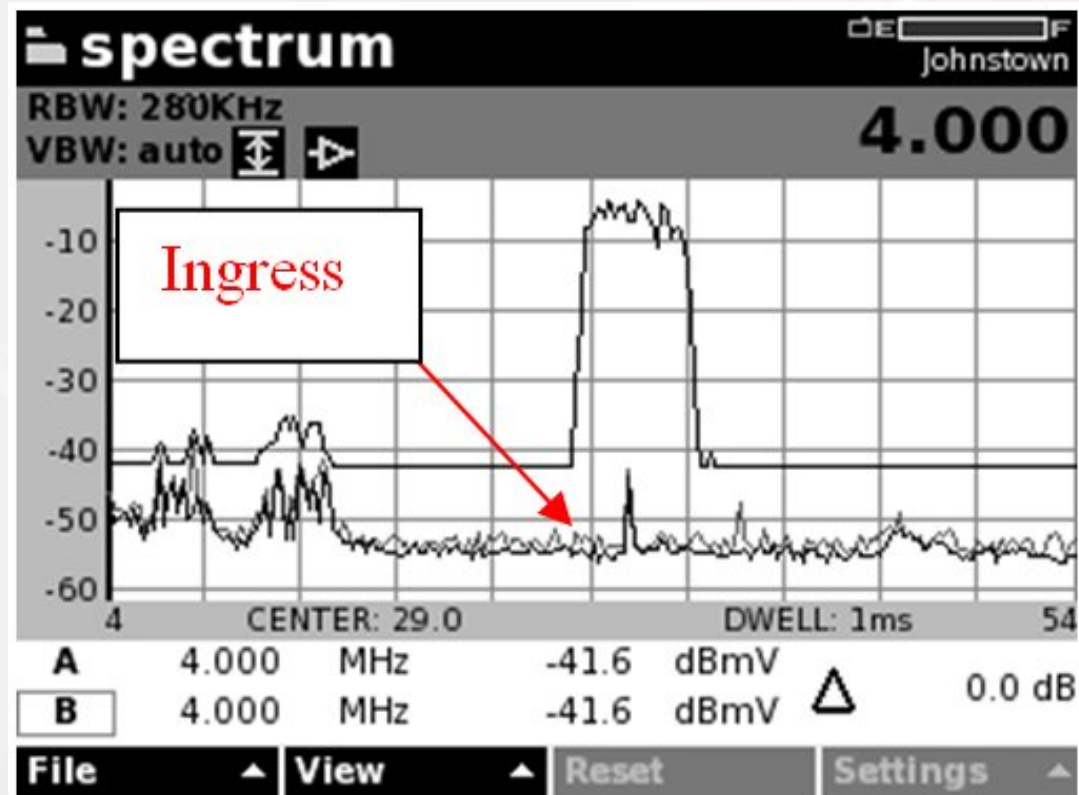
- ✓ Lines in picture
- ✓ Ghosting
- ✓ Interference from two-way radio services using the same frequencies
- ✓ Repeat Service Calls



## Digital Video Impairments From Ingress

- ✓ The same problems in the coax network that have been described (bad cable, fittings, etc.) have different symptoms or artifacts on digital television channels. Although the "fix" is the same, for digital channels, MER/BER can be used to isolate the cause.

# Ingress Under Digital



# Digital Video Impairments From Ingress

## Ingress on Digital Channels

- ✓ Pixelation
- ✓ Macroblocking
- ✓ Image Freezing
- ✓ Object Retention
- ✓ Blue/Black Screen



## LTE (Long-Term Evolution)

### Today's Issue is actually two issues (2)

- ✓ **Ingress** – Cellular signals interfering with the cable signals
  - Not just a 5MHz to 42MHz issue anymore...
  - Ingress issues can now cause problems affecting the downstream signals
- ✓ **Egress** - **Cable leakage interfering with the cellular signals**
  - The FCC said to check for leakage in the aeronautical band
    - This is a narrow range – 108 MHz to 137 MHz
    - No one was checking other frequencies for the most part!

## LTE (Long-Term Evolution)

### Cable QAMs Interfere with Cellular (Egress)

- ✓ QAM signals leaking out of the cable network
  - Interfere with cellular reception
    - How? Cable QAM signals might be stronger or equal to cell device signal
  - Interfere with cellular transmission
    - How? Low power transmissions from cell device may be equal to local leakage

# LTE (Long-Term Evolution)

## Industry Findings

- ✓ SCTE has published a technical report outlining many of the LTE interference issues
  - SCTE 209 2015
  - Discusses causes and solutions
  - Outlines testing options
  - Describes test equipment vendors' methods for finding LTE-related leakage
  - Report can be downloaded from:  
[http://www.scte.org/standards/Standards\\_Available.aspx](http://www.scte.org/standards/Standards_Available.aspx)



ENGINEERING COMMITTEE  
Network Operations Subcommittee

SCTE Technical Report

SCTE 209 2015

Technical Report  
UHF Leakage, Ingress, Direct Pickup

# LTE (Long-Term Evolution)

## Industry Findings

- ✓ A lot of work is being done by both operators and test equipment manufacturers to help better identify what is going on with LTE interference
- ✓ The following slides describe some of the industry findings regarding this issue

# LTE (Long-Term Evolution)

## Industry Findings

- ✓ **Leaks can be frequency specific**
  - A leak at 700 MHz can occur when no leak is measured in the aeronautical band (108 – 137 MHz)
- ✓ **The shape and dimensions of the leak source are significant**
  - Determines how it acts as an antenna
  - Impacts the way the leak propagates at different frequencies
  - Affects the level of the leak

# LTE (Long-Term Evolution)

## Industry Findings

- ✓ **Leaks are more likely at higher frequencies than at lower frequencies**
  - Smaller breaks in shielding allow shorter wavelengths to propagate out of the network
  - Testing performed by Rohde & Schwarz shows the following:
    - ~30% of all leaks found are in the VHF range
    - ~50% of all leaks found are in the 700 MHz range
    - ~20% of all leaks occur over a wide frequency range (100 MHz to 800 MHz)

# LTE (Long-Term Evolution)

## Industry Findings

- ✓ **Leaks are more likely at higher frequencies than at lower frequencies**
  - Smaller breaks in shielding allow shorter wavelengths to propagate out of the network
  - Testing performed by Arcom Digital shows the following:
    - ~13% of all leaks found are in the VHF range
    - ~67% of all leaks found are in the 700 MHz range
    - ~20% of all leaks occur over a wide frequency range (139 MHz and 735 MHz)

# LTE (Long-Term Evolution)

## Industry Findings

- ✓ **Leaks can occur at different levels at different frequencies**
  - One documented case found a 10  $\mu\text{V}/\text{M}$  leak at 137 MHz from a bad tap that was measured 40 dB higher, or 1000  $\mu\text{V}/\text{M}$ , at 700MHz!
  - Several studies by MSOs and test equipment manufacturers have found less extreme cases, but  $<10 \mu\text{V}/\text{M}$  leaks at 137 MHz are commonly found to be leaking at  $>150 \mu\text{V}/\text{M}$  at 700MHz
  - No correlation can be made between VHF and UHF leakage levels

# LTE (Long-Term Evolution)

## Industry Findings

- ✓ **Ingress/Egress levels are not always linear**
  - Field testing is showing that a high level leak does not always mean a high level of ingress at the same location, and vice versa
  - The shape of the leak source will impact both the ingress and egress potential of the fault in the network
  - Lower signal levels on the network mean smaller leaks when compared to potential ingress signal levels

# LTE (Long-Term Evolution)

## Industry Findings

- ✓ **A major source of LTE Ingress and Egress is the drop**
  - Same causes as in the aeronautical band (108 – 137 MHz)
    - Loose connectors
    - Age & Stress
    - Physical trauma
    - Poor coax, passives, or connectors
    - Customer premises equipment

# LTE (Long-Term Evolution)

## Industry Findings

- ✓ **The outside plant is also a major source of LTE Ingress and Egress**
  - Higher signal levels in the OSP have the potential to create higher level leaks
  - Loose or warped tap faceplates make an excellent UHF slot antenna
    - Free space quarter wavelength at 750 MHz = 3.93"
  - Loose hardline connectors make an excellent UHF slot antenna
    - Threaded nut on the back of a .500 connector is approximately 3" diameter
  - Other OSP faults can be UHF leakage sources
    - Radial cracks in expansion loops
    - Animal chews
  - Again, the shape and the dimensions of the leak source and how they act as an antenna will all impact leaks at different frequencies

# LTE (Long-Term Evolution)

## Industry Findings

- ✓ **Set Top Boxes and Cable Modems are not immune**
  - An independent study showed that 7 out of 9 STBs showed the effects of ingress from LTE signals
  - The same study showed that 12 out of 12 CMs showed the effects of ingress from LTE signals

## LTE (Long-Term Evolution)

### Shielding Effectiveness Performance

- ✓ **To prevent both ingress and egress, the shielding effectiveness of all components must be maintained**
  - 4G/LTE cell phones transmit at up to 200 mW
  - With 256 QAM, shielding effectiveness must be better than 84 dB to ensure 35 dB CNR performance in the presence of cell phone signals
  - This means all components in the network must maintain shielding effectiveness of greater than 84 dB to ensure handheld cell phones don't interfere with the cable signals, and that the signals in the network don't interfere with the handheld cell phone

# LTE (Long-Term Evolution)

## Shielding Effectiveness Performance

### ✓ Typical drop product shielding effectiveness

- Splitters: 110 dB
- Drop amplifiers: 110 dB
- F Connectors (when tight!): 110 dB
- Standard coaxial cable (new):
  - Bi-Shield 60%: 85 dB
  - Bi-Shield 90%: 88 dB
  - Tri-Shield 60%: 100 dB
  - Tri-Shield 77%: 107 dB
  - Quad-Shield 60/40%: 111 dB

# LTE (Long-Term Evolution)

## Interference Manifestation on LTE Networks

### ✓ LTE Networks

- Give up noise performance to get more data
- Require a S/N as much as 20dB higher (compared to 2G/3G)
- Non – linear effects expected
  - Slow data speeds – or erratic speeds
  - Drop outs in data, long loading times for pages
  - Slower transmission times (My 3G was faster than this)
  - Audio drop outs in Videos; Freezing of video
  - Range of effects of the above from minor to severe up to cliff effect

# LTE (Long-Term Evolution)

## Interference Manifestation on LTE Networks

### ✓ LTE Network Cliff Effect

- Data faults are corrected up to a point like a cliff
- At a certain point it is no longer successful in correcting corrupted data
- Data then just plain quits or goes “off the cliff” so to speak
- Working, working, working, then is just plain OFF!

## LTE (Long-Term Evolution)

### Interference Manifestation on Cable Networks

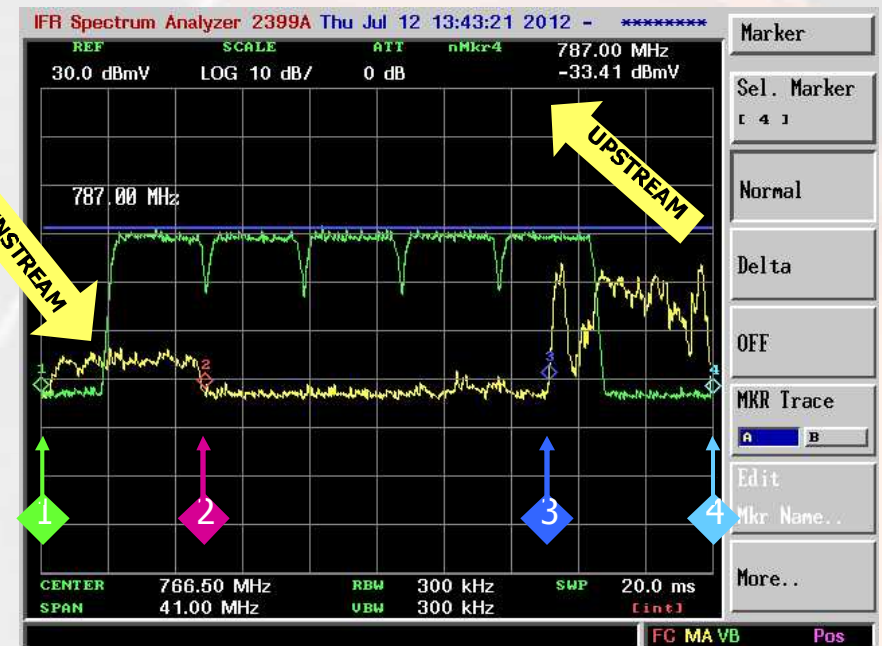
- ✓ **Similar behavior could be expected of Cable QAM signals when interference is present**
  - Slowing of data rates, brief interruptions
  - Pixelization
  - Freezing Video
  - Audio drop outs
  - Cliff effect - working, working, working, OFF!

# LTE (Long-Term Evolution)

## PCT Lab Tests

### ✓ Overlay of Issues

- Live QAM signals
- Live Receive LTE
- Live Transmit LTE (QAM Levels emphasized for clarity)
  - LTE signal levels from folded dipole
  - Antenna tuned to 720 MHz
  - Building with reinforced concrete walls
  - Metal roof, interior lab



# LTE (Long-Term Evolution)

## Egress

### ✓ Egress of Cable QAM

- Cable QAM interfering with LTE download

Loose F Connector



# LTE (Long-Term Evolution)

## Egress Cable Leakage Affecting LTE Reception

### ✓ Egress of Cable QAM

- Simple lab test correlates loss of 4G BW with QAM egress present

Speedtest.net



Tight F Connector  
Connector



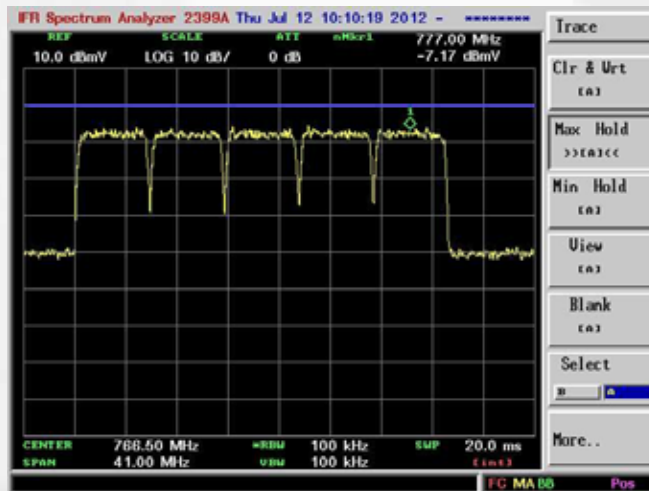
Loose F

# LTE (Long-Term Evolution)

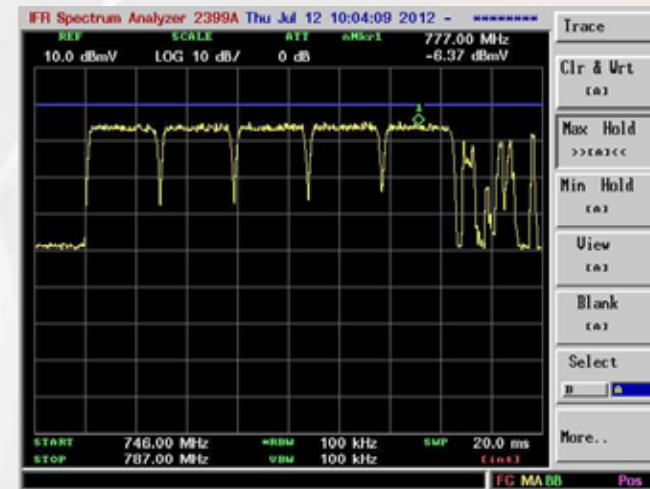
## Ingress

- ✓ Local handheld upload of video

Tight F Connector



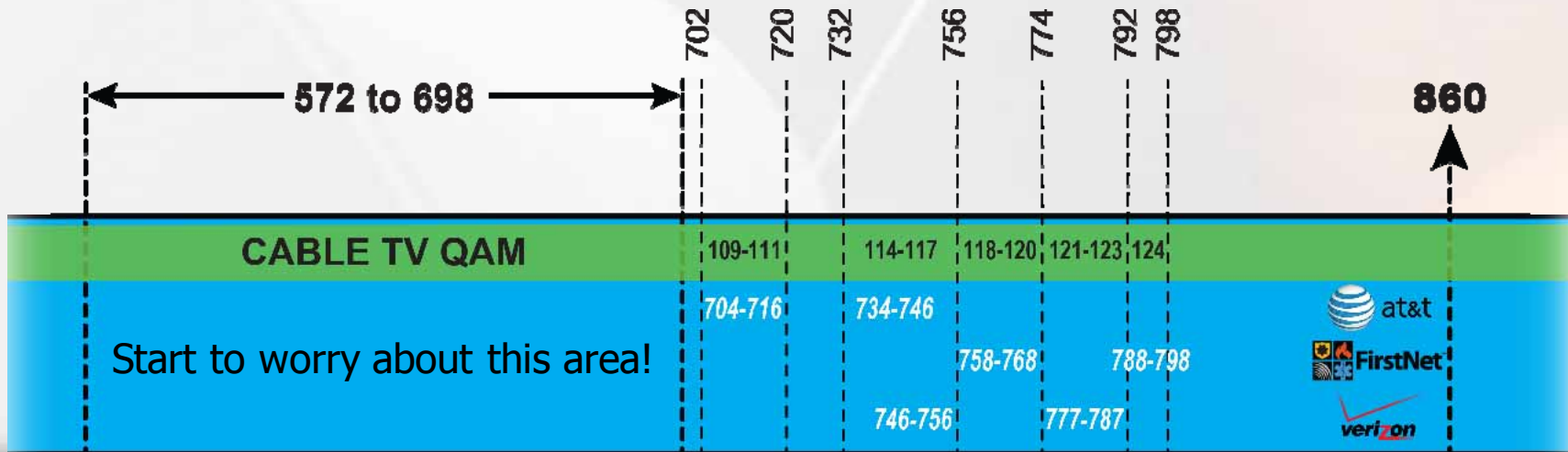
Loose F Connector



# LTE (Long-Term Evolution)

## Future Issues? 5G?

- ✓ The appetite for bandwidth is voracious
  - Off-air UHF 31-51?



# LTE (Long-Term Evolution)

## Round 2? Is it possible?

### ✓ FCC 600 MHz Incentive Auction in early 2016

- Part of the National Broadband Plan
- Will be auctioned off for LTE type services or similar wireless services through a two tiered process
  - Reverse auction to determine prices at which broadcasters are prepared to give up channel space and to determine the amount of spectrum to be auctioned
  - Forward auction to determine how much cellular operators are willing to pay to acquire the spectrum
  - Maximum range of 548MHz – 698MHz (TV Ch. 27-51) to be vacated
  - Minimum range of 656MHz – 698 MHz (TV Ch. 45-51) to be vacated

## LTE (Long-Term Evolution)

### Round 2? Is it possible?

#### ✓ FCC 600 MHz Incentive Auction in early 2016

- FCC to “repack” the remaining spectrum to accommodate broadcasters that don’t participate
- Broadcasters that do participate share in the auction proceeds
  - Vacate the broadcast spectrum altogether
  - Share spectrum with other broadcasters
- The result of the “refarming” of this spectrum would create a greater overlap between the cable industry and cellular systems

# Television White Spaces (TVWS)

## Another Concern

### ✓ TVWS

- NLOS (non-line-of-sight) fixed wireless broadband system
- Unlicensed transmission in “unused” frequencies between existing TV channels
- Designed to detect and protect off-air television service (cognitive radio technology)
- Automatically logs into national database to activate/authorize service and download local channel plans
- Can operate anywhere in the TV broadcast VHF/UHF spectrum (54 to 698 MHz)

# Television White Spaces (TVWS)

## Another Concern

### ✓ TVWS

- Two standards have been approved
  - IEEE 802.22 (WRAN – up to 100 km – long term/permanent service)
  - IEEE 802.11af (Super Wi-Fi or WLAN – up to 5 km – temporary service)
- Incorporates channel bonding (2 to 4 channels)
- Initially intended for rural deployments (802.22)
- Can be used anywhere (802.11af)

# Leakage Mitigation

## Finding Leaks at 700 MHz

- ✓ **Current leakage equipment isn't designed for 700 MHz**
  - Current equipment is generally just for the aeronautical band (108 – 137 MHz)
  - New methods under development by test equipment manufacturers
- ✓ **DIY methods can be used**
  - Most reliable method uses a spectrum analyzer, high-gain directional antenna, preamplifier, and bandpass filter

# Leakage Mitigation

## Finding Leaks at 700 MHz

### ✓ DIY methods can be used

- Field Strength Meter method
  - Effective for high level leaks and when close to leaks
  - Uses the spectrum analysis mode
  - Only indicates the existence of leakage and does not provide exact measurements of the leak
  - Requires an antenna designed for 700 MHz

# Leakage Mitigation

## Finding Leaks at 700 MHz

- ✓ **Cox Communications in Phoenix has been using the following antenna design to successfully find leakage at 700 MHz**
  - Cut a 26" piece of RG-6 cable
  - Install an F connector on one end of the cable
  - Carefully remove 1/2" of the jacket ONLY approximately 6" from the connector, leaving the braid and tape intact
  - At the opposite end of the cable, remove the braid and dielectric to expose 2" of center conductor

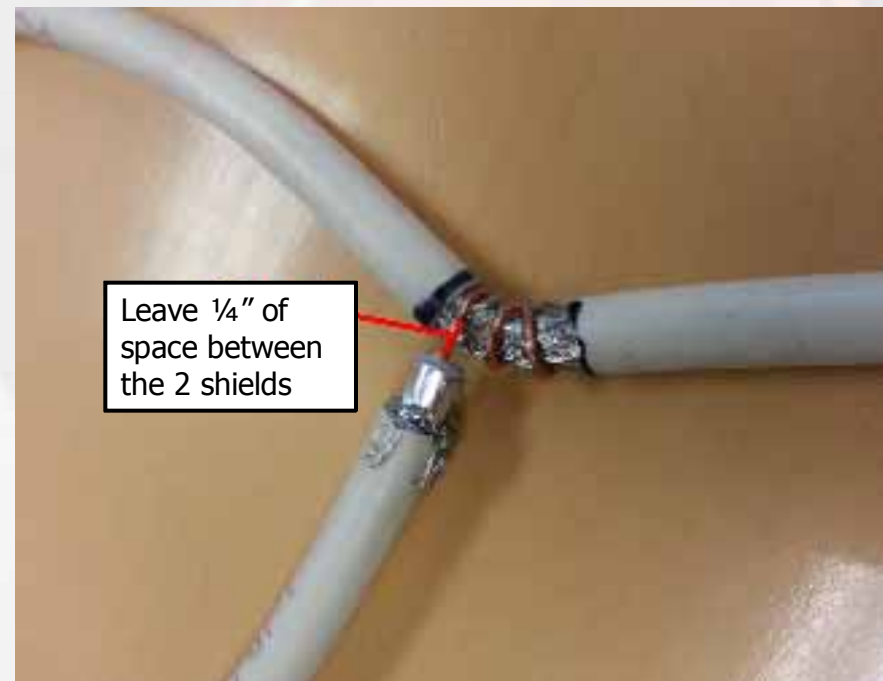
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# Leakage Mitigation

## Finding Leaks at 700 MHz

- Wrap the center conductor around the exposed shielding of the cable, leaving  $\frac{1}{4}$ " space between the shielding and dielectric as shown in the picture to the right

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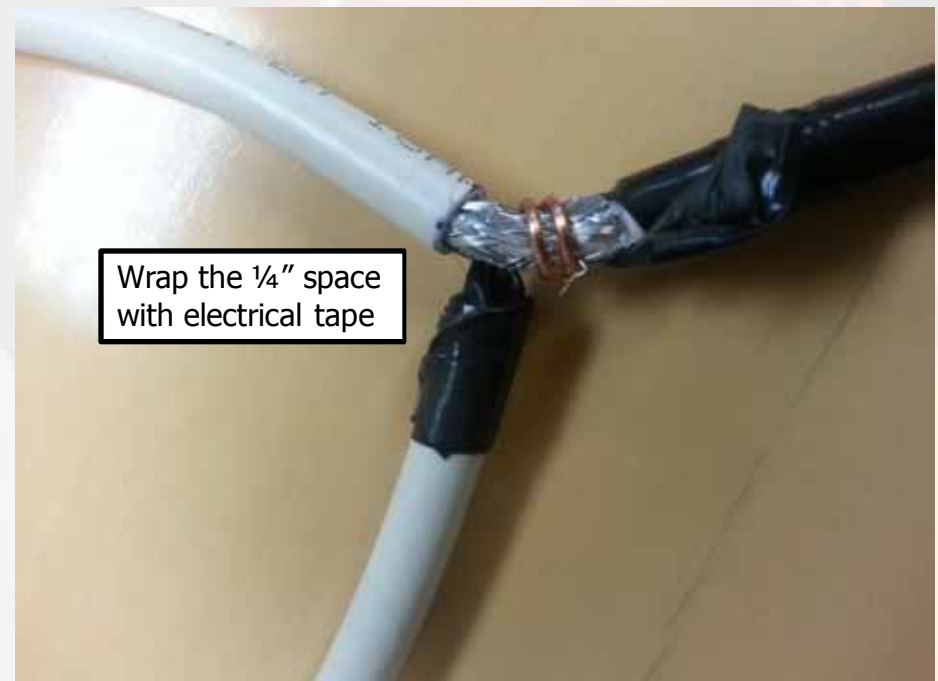


# Leakage Mitigation

## Finding Leaks at 700 MHz

- Wrap the exposed dielectric and shielding with black electrical tape as shown in the picture to the right, making sure it does not touch the shielding on the cable where the center conductor is wrapped.

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## Leakage Mitigation

### Finding Leaks at 700 MHz

- Finish wrapping the exposed center connector and braid with black electrical tape. The resulting loop should be approximately 5" to 6" in diameter.

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# Leakage Mitigation

## Finding Leaks at 700 MHz

- The loop antenna can be used to look for leaks at 700 MHz
- If a preamplifier function is available on the field strength meter, it will be helpful to use it
- Signal loss over distance (free space loss) in the 700 MHz range is much higher than in the aeronautical band
- The loop antenna is very effective as a near field probe when trying to find the specific location of the leak

# LTE (Long-Term Evolution)

## Finding, Fixing, Benefits

- ✓ **Controlling signal ingress and egress is one of the most effective tools to use in maintaining a high performance network**
  - Low level leaks will eventually become high level leaks if not fixed
  - Minimal signal leakage means minimal signal ingress to interfere with return path DOCSIS signals
  - Minimal signal leakage means minimal interference to and from LTE networks
  - A plant with better physical integrity will generally last longer, and require less emergency maintenance as potential faults are repaired prior to becoming a major problem

# LTE Interference



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**Innovation for the Last Mile™**