



# **Mobile Radio Installations and RFI**

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**Flathead Valley Amateur Radio Club**

# What We'll Be Covering

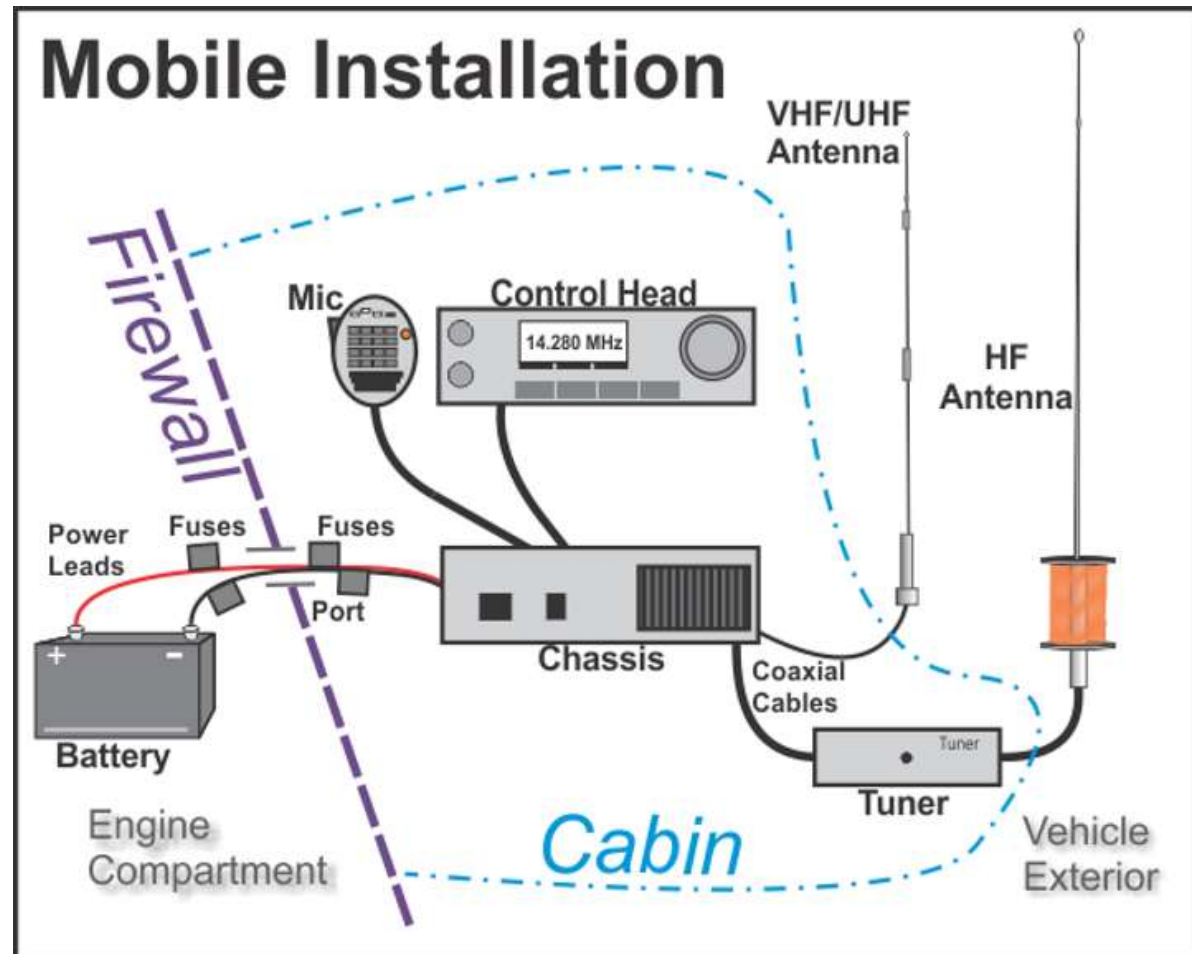
- Planning your mobile installation to minimize RFI
  - VHF/UHF only?
  - HF?
  - One piece vs. remote control head?
  - Amplifier?
  - Minimal permanent impact or scarring of your vehicle
  - Garage parking
  - Tips for minimizing RFI
  - **This presentation will NOT make vendor equipment recommendations**
  - **This is NOT a tutorial on how to do a mobile installation**
- Identifying and mitigating RFI after installation
  - Ingress RFI - mobile station RF getting into your vehicle's systems
  - Egress RFI – RF from your vehicle's systems getting into your radio
  - **DISCLAIMER: It is not possible to describe all kinds of RFI that might be encountered in a mobile installation in a brief presentation. This presentation only covers some of the most common types experienced.**

# Utility of a Mobile Installation

- Greatly expands the utility of Amateur Radio
  - Higher power and better antenna(s) allows much longer range communication than with an HT
  - No concerns about running down an HT's battery
    - APRS can significantly shorten operating time on an HT's battery
- Increases the opportunity for air time
- Does present some unique challenges compared to a base station installation or using an HT
  - Installation choices can be more limited than for a base station or HT
  - Routing of cables and coax can be more complicated

# Anatomy of a Mobile Installation

- Transceiver and related electronic devices usually reside within the passenger cabin
- Power cable will need to pass through the firewall and be connected at the vehicle's battery
- Coax will need to exit the passenger compartment somewhere to connect to one or more external antennas

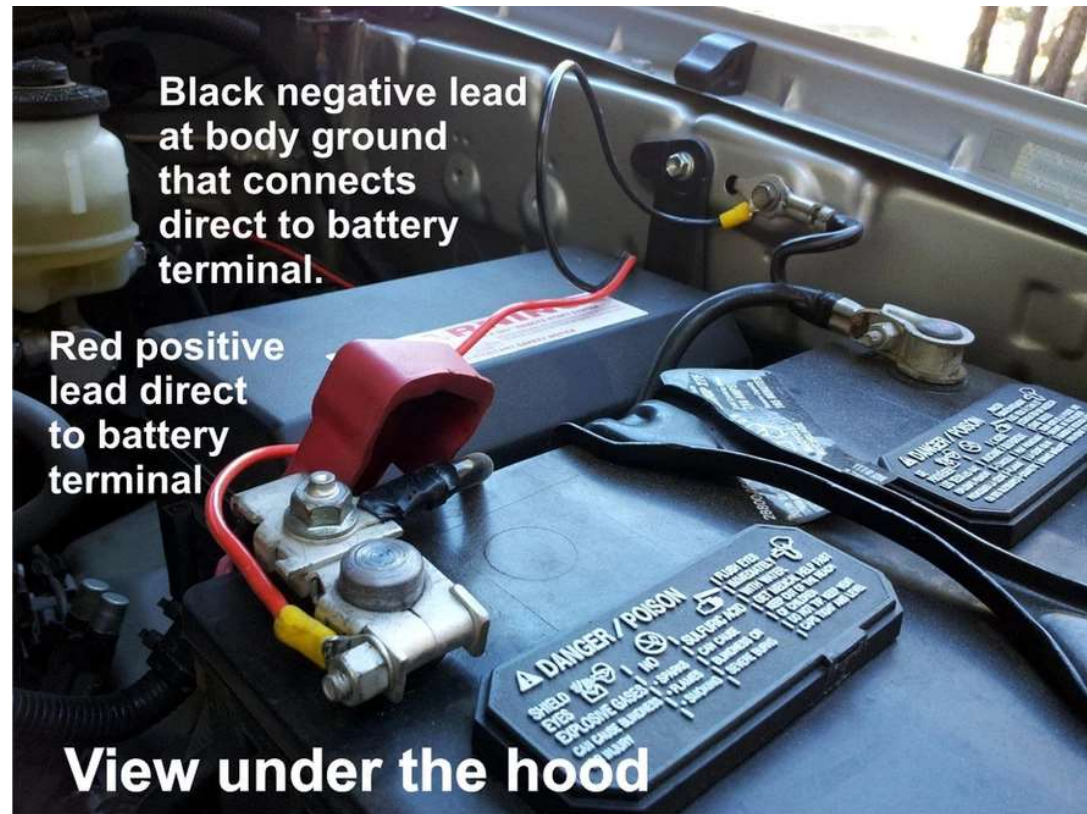


# Operating Choices

- VHF/UHF FM-only transceiver installations generally encounter fewer RFI issues
  - Most hams want this for simplex and repeater-based communications while on the road
- HF will allow much longer range communication
  - Useful if you find yourself beyond the range of VHF/UHF simplex, repeaters and cell service
    - Do you go with two separate transceivers or an “all mode, all band” transceiver?
    - A transceiver that can support digital modes with a smartphone/tablet/laptop can provide reliable comms, even email (WinLink) in very remote areas
    - Often presents more RFI and performance issues than a VHF/UHF FM-only installation

# Safety and RFI-avoidance Installation Tips

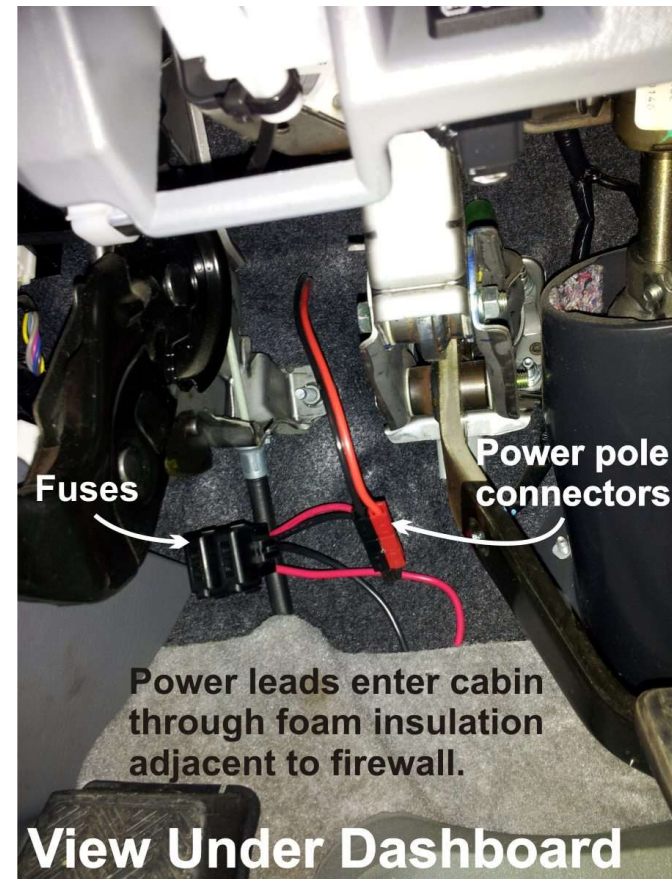
- Avoid trying to power your radio from vehicle wiring
  - Often a source of conducted RFI getting into the radio
  - Can present a safety issue/fire hazard
- Connect the power leads directly to or very close to the battery's terminals
  - Use an appropriate fuse in BOTH leads with fuses being located as close to the battery as possible





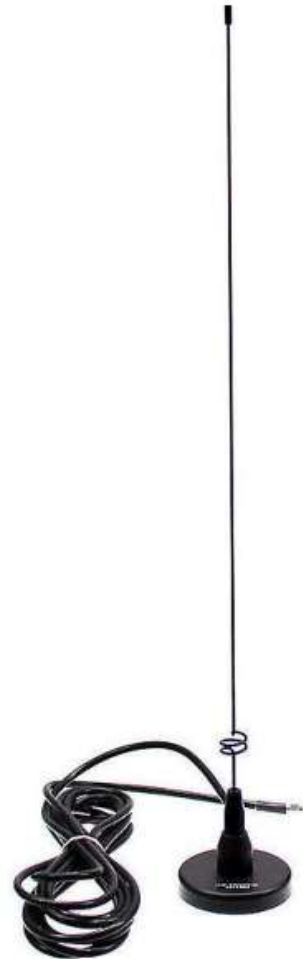
# Safety and RFI-avoidance Installation Tips (cont.)

- Always use a rubber grommet or heavy silicone tape insulation at the point where the power leads pass through the firewall
  - Most modern vehicles have passthrough ports
    - You might be able to share one of those and avoid any drilling and creating your own passthrough port
      - Might have to trim the existing grommet to share that port
- Avoid routing cables near hot engine components or points of friction



# Antenna RFI Considerations

- Ideally, antennas should have their ground side (coax shield) electrically connected to the vehicle's metal frame/body
  - Gives a return path for RF currents going to the antenna
    - Enhances performance
  - Helps to avoid common mode currents which are a frequent source of RFI
    - Initially test grounding with an ohmmeter, but a good DC ground could still present a high impedance to RF, especially HF frequencies
  - Magnetic mounted antennas, while avoiding 'scarring' of a vehicle, may be adequate for VHF/UHF-only applications, with some reduction in performance
- For improved performance, get antenna as high up on the vehicle as you can, maximizing the ground plane underneath it
  - Remember to allow for garaging





# Antenna RFI Considerations (cont.)

- Trunk/hood lip and hatchback mounts offer a more permanent and robust antenna installation
  - Offered with SO-239, NMO and  $\frac{3}{4}$  x 24 thread
    - The latter could be used for “ham stick” style HF antennas
  - Some electrically connect the set screws to the antenna ground
    - You will need to scratch off the paint where the set screws will contact the hood/hatchback sheet metal
      - Apply conductive “coax seal” paste to that area to prevent oxidation (Fe and Al oxides are insulators)
      - Apply a good weatherproof silicone sealer to the underside of the mount after installation to prevent rust
  - Quality mounts typically use thin RG-316 Teflon coax terminated in an SMA connector, making firewall passthrough easier
    - The small diameter coax also makes it possible for the vehicle’s soft rubber weather seals to tightly wrap the coax (e.g., hatchback installation)



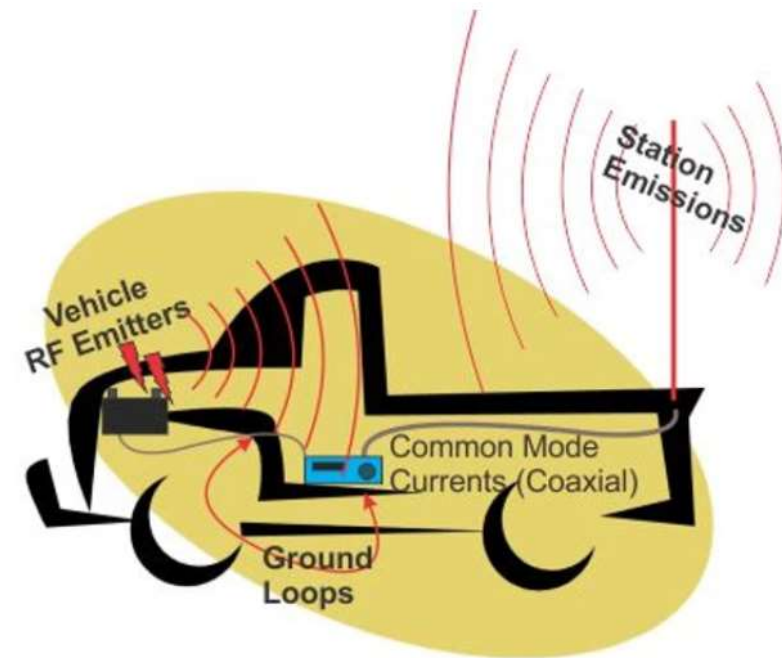
# Specialized Antenna Mounts

- The Antenna Farm (<https://theantennafarm.com/>)
  - Located in Rexford, MT
  - Offers NMO fender mounts for RAM pickups and some Ford Models
    - Uses one of the vehicle's under-the-hood fender bolts
      - Usually well-grounded mounts
- CB World (<https://www.wearecb.com/hood-mount/>)
  - Fender and bed rail mounts for many different vehicles
    - Supports mostly  $\frac{3}{4}$  x 24 thread mounts (standard in the CB world)
    - Most can be easily grounded
    - Will accept "ham stick" HF antennas



# Identifying and Mitigating RFI

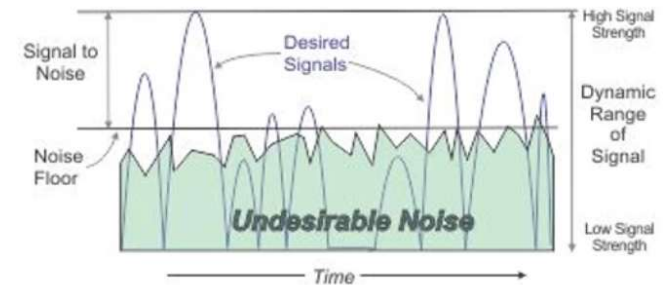
- Egress RFI – interference from your vehicle’s systems
  - Ignition system
  - Fuel pumps
  - Fans
  - Electric motors (e.g. windshield wipers)
  - Control modules
  - Entertainment system
  - Third party accessories
- Far more common than ingress RFI
- Generally appears as hissing, whining, crackling and popping in received audio
- Typically radiated (received by radio’s antenna)
  - Less commonly conducted through wires to the transceiver
- FAR more common on HF than VHF and above
  - Egress RFI on VHF/UHF is commonly conducted in nature



The mobile RFI environment is loaded with signals. Your station may receive signals from your vehicle’s noisy emitters such as ignition sparks, motors, or other electric devices. Your own transmissions, emitted very nearby from your mobile antenna, can also create RFI issues. Electrical ground loops and “common mode” currents can impose noise on your signals, both received and transmitted.

# Identifying and Mitigating RFI (cont.)

- Note what is running when the RFI appears
- Remove the antenna and see if the RFI is still there
  - May need to accelerate the engine to make the RFI more obvious
  - If the noise disappears or is greatly reduced with the antenna disconnected, the noise is radiated
    - If the noise is still prominent, you likely have a conduction issue which can be tougher to rectify
      - Remedied by grounding and use of chokes
- Reduce radiated egress RFI by improving SNR
  - Reduce the radiated noise at or near its source
  - Improve the signal strength of the desired signal



Noise of all types combine to produce a noise floor above which received signal strength must reach to be clearly detected by the receiver. Greater desired signal strength or lower noise levels make signals more discernible, with a greater resultant signal-to-noise ratio.

# Improving Desired Signal's Strength

- Improve the antenna's ground plane conditions (most mobile antennas are verticals, typically a half wave or less in length)
  - If possible, start with grounding the coax at the antenna
    - Losses introduced due to reduced current flow back to the transceiver can be significant
      - These losses are often compounded by the antenna being a "compromise" in itself (e.g., coil loaded, physically short)
      - Reducing or eliminating losses in the ground plane will often increase Signal-to-Noise Ratio (SNR)
  - Put as much metal under the antenna as possible
    - Reducing radiated egress RFI sometimes requires experimenting with antenna location on the vehicle

# Improving Desired Signal's Strength (cont.)

- Sometimes “bonding” the hood and trunk/hatch will improve SNR and reduce the effects of egress RFI by expanding the electrical ground plane
  - Their hinges often don't provide a good connection between them and the rest of the vehicle's body and frame
  - Attaching short lengths of flexible braid between the hood/trunk/hatch and the vehicle's body/frame will electrically include those items into the vehicle's overall ground plane
- The same approach between a PU bed and frame can sometimes improve its ground plane performance
- Braid is used to ensure a low impedance path for RF currents
- NOTE: If you don't have a good electrical ground at the antenna, you are mostly wasting your time with bonding



The hinges of trunks and hoods may not provide adequate electrical connectivity for effective ground plane integration. Photo courtesy KØBG.com.



# Reducing Egress RFI at its Source

- One common source of radiated RFI, especially on HF, is the exhaust system
  - Typically poorly connected electrically to the rest of the vehicle
    - Only connection is often at the engine, leaving the exhaust system to act as a radiator of egress RFI or to re-radiate/conduct your own TX signals
  - By making the exhaust system a part of the ground plane, we eliminate the problem
    - This process is often referred to as “bonding”; that is, making low impedance connections among conductive parts of the vehicle
      - Tinned braid is used to electrically connect the exhaust system to the frame at a minimum of 3 points along its length
        - Kits with braid and clamps are commonly available at ham supply stores



A sample of exhaust pipe bonding kit materials, courtesy DX Engineering.

# Ground Loops and Common Mode Currents

- Can cause noise on RX audio as well as your TX audio
  - The bonding and mounting methods previously described can help prevent/reduce problems in this area, but other measures may be necessary
- Ground loops can occur when there's a voltage differential between two points in a ground or power connection
  - One example of such noise is alternator whine on your TX signal
    - High pitch whine which increases with RPM
    - Magnetic mount antennas are prone to this
      - A power cable filter may help
        - 0.5V+ voltage drop
      - Need a good RF ground return
  - Go direct to the battery with both power leads
  - You may also need to ground your transceiver's chassis to the vehicle frame/body



Grounding station component chassis to the vehicle body can help alleviate ground loops and stray currents. A wide, low impedance conductor is best, and while copper strap may be used it can weaken over time from vibration and motion and may crack or break eventually. Here, a seat mounting bolt is used as a single ground point for multiple component ground straps.

# Ground Loops and Common Mode Currents (cont.)

- Common mode currents can also flow in coaxial and control connections
  - As in a base station installation, chokes would be used to suppress these currents
  - Snap-on ferrites are easy to work with
    - Be sure to use the right “Mix” for the frequencies of concern
    - Put ferrites on the power cable at the transceiver
  - Coaxial chokes should be placed as close to the antenna as possible
    - Sometimes additional improvement can be had by adding a choke at the antenna input on the transceiver



The Mix 31 ferrite bead, 6-loop choke for 10m – 80m HF operations, as advocated by Alan KØBG. The coax loops are about 3" in diameter, each loop through the bead orifice. Photo courtesy KØBG.com.

# Additional Considerations

- RFI from vehicle systems can sometimes be difficult to squelch and will require more involved corrections, especially for HF operation
  - Leaky ignition wires may need to be replaced with RF suppressive wires
    - Hissing sound which increases with engine RPM
    - Most modern engines use Coil-Over-Plug (COP) which usually isn't a problem
  - An alternator may need to be fixed/replaced
    - Cheap rebuilds can be a frequent source of RFI due to the use of cheap diodes
      - RFI from these may sound a lot like ignition or injector noise
  - An ECM may need replacing or be capacitively bypassed and ferrite choked
  - A fuel pump may need to be grounded (rare in vehicles made after 2004)
  - Inductive coil fuel injectors if bad or a bad wiring harness feeding them
    - Sounds like rapid clicking which increases with RPM
- Tracking down sources can be maddening and require multiple fixes
  - Be patient
  - Consider it a challenge and learning opportunity
  - Share what you learn with others – be someone else's elmer
- Don't overlook your transceiver's noise canceling features
  - Most transceivers are good at filtering out ignition noise

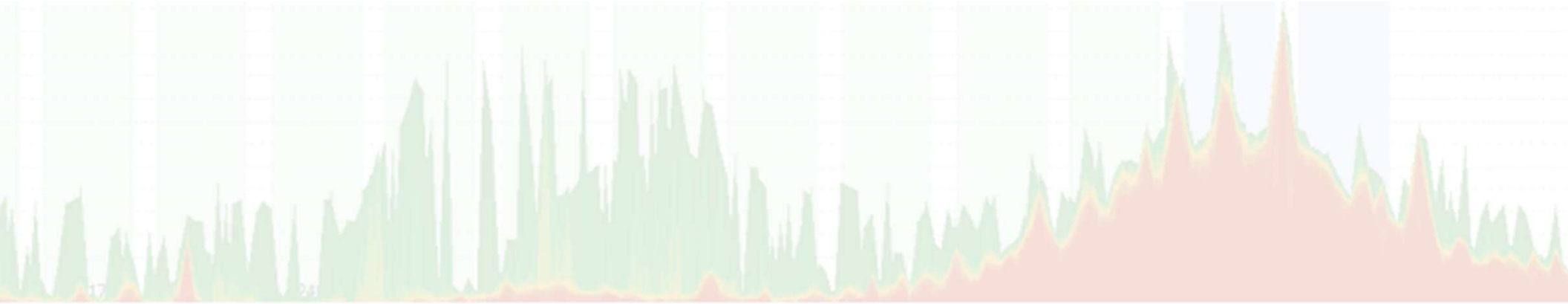
# Final Note on Ingress RFI

- Ingress RFI is much less common than egress RFI
  - Most commonly affected is AM/FM reception
    - Usually from HF transmissions
  - Use of an amplifier may increase the likelihood of ingress RFI
    - What might appear to be ingress RFI may actually be the amplifier drawing down the vehicle electrical system's operating voltage
      - Be sure that your alternator and battery can handle the addition of a transceiver and an amplifier and that battery connections are clean
- Very rare but sometimes problematic is the effect of transmitted RF on the ECU/ECM
  - Some operators have seen the "Check Engine" light come on after transmitting with random codes being 'thrown'
  - There have been a few reports of engine fuel-air mixture being affected during TX, with the engine stumbling or racing
  - Thus far these problems seem to have all been resolved by bonding the exhaust system
- Most problems I've seen reported affect third party add-ons rather than OEM equipment
  - Some third party GPS devices seem particularly prone
    - When problematic, it's often only VHF transmissions or above that affect the device
  - Some third party security systems also seem more susceptible than others or OEM systems
    - It can be embarrassing to be driving down the road and trigger the panic alarm when keying up
  - Strategically placed chokes can solve most of these issues

# Resources

- ARRL – Mobile Station Page
  - <http://www.arrl.org/mobile-stations>
- K0BG Mobile Amateur Radio Web Site
  - <http://www.k0bg.com>
  - Covers A-Z of every topic imaginable regarding mobile installations
  - Has many sound files which might help you identify the source of egress RFI





**Q & A**

