Minimizing Inter-Station Interference

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http://k9yc.com/publish.htm

Don’t Bother Taking Notes

These slides are at k9yc.com

Two Kinds Of Interference

- Same band
  - Field Day
  - CQP, other QSO parties
- Different bands
  - Most major contests

For Both Kinds

- Clean transmitter (and power amp)
  - Key clicks
  - Phase noise
- Very good receiver
  - Low phase noise
  - Ability to handle strong signals
- Serious bonding of all equipment
- Proper grounding and bonding

For Both Kinds

- Antenna separation
- Antenna location and orientation
  - In line with each other
- Ferrite choke at every feedpoint
  - k9yc.com/2018Cookbook.pdf
- Coax with very good shielding
  - Beefy copper braid shield

For Both Kinds

- Use the best available radios and power amps
- To minimize clicks and splatter
  - Carefully tune tube power amps
  - Use a good tuner with solid state amps
  - NEVER use ALC between rig and amp to set drive power

Auto-Tune Amps and Tuners

- Some only detect frequency and select “memorized” settings
  - Match to output stage may be too poor for a clean signal
- A few detect frequency, select memorized settings, and auto-tune as you transmit at full power
- Most antenna tuners must be tuned with power amp on idle

Auto-Tune Amps and Tuners

- **Study the manual for your amp or tuner to make sure you know how it works**

Power Amps and ALC

- **The ONLY good reason for ALC between rig and amp is to protect the amp when:**
  - **Something “breaks” in the antenna system**
  - **The operator goofs and selects an antenna for the wrong band**

Power Amps and ALC

- **Always use ONLY the Power control on the rig to set drive power to the amp**
- **If you want to use ALC to protect the amp, carefully set the ALC level so that it doesn't take effect until something goes wrong!**

Good Contesting Radios

- Top line
  - Elecraft K3, K3S
  - Flex 6000 series
- A small step down
  - Elecraft KX3
  - Kenwood TS-590S, SG

Not So Good Contesting Radios

- Mid-line, even the most expensive
  - Some have very good receivers
  - BUT:
  - Transmit clicks, phase noise
  - Most Yaesu, Icom rigs with good receivers are clicky on CW are OK on SSB
  - If keying rise time is adjustable, always set for longest time

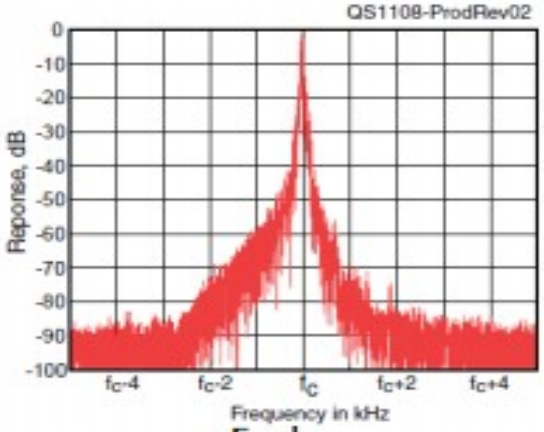
Telling the Good From the Bad

- http://k9yc.com/TXNoise.pdf
  - Compares ARRL Labs data for phase noise and clicks
- http://k9yc.com/P3_Spectrum_Measurements.pdf
  - My own occupied spectrum measurements of selected radios

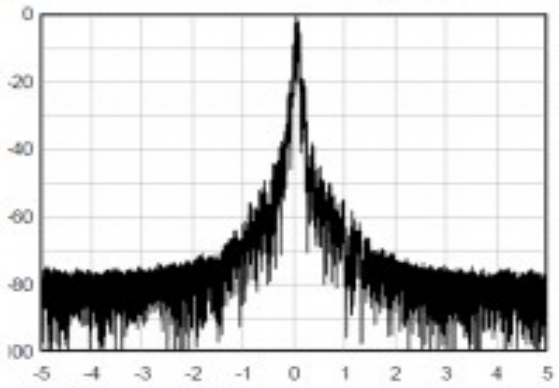
Telling the Good From the Bad

- Here's ARRL data for CW bandwidth of 9 rigs
  - What I can fit on a slide you can see
- I did this work in 2014
  - ARRL had not tested Flex 6000 series
  - Firmware they tested not very good, so occupied CW bandwidth was poor
  - Next release was greatly improved

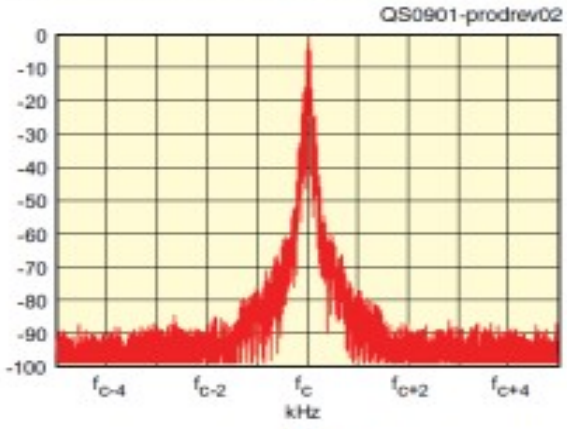
Raw Data -- Spectra With CW Keying – Clicks + IMD + Phase Noise



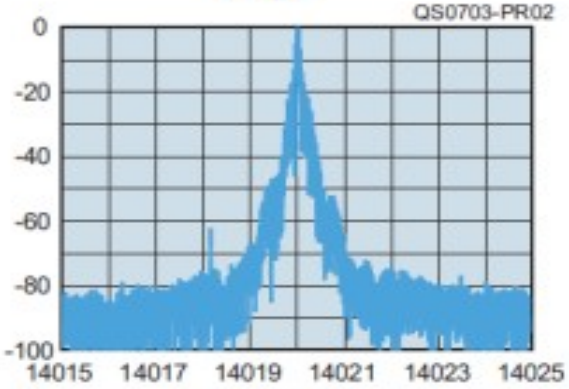
Eagle



Orion II



K3



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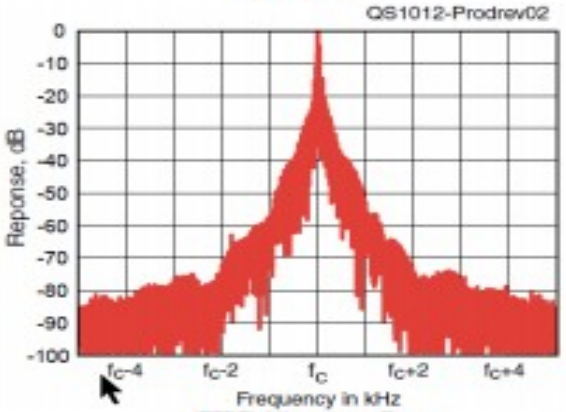
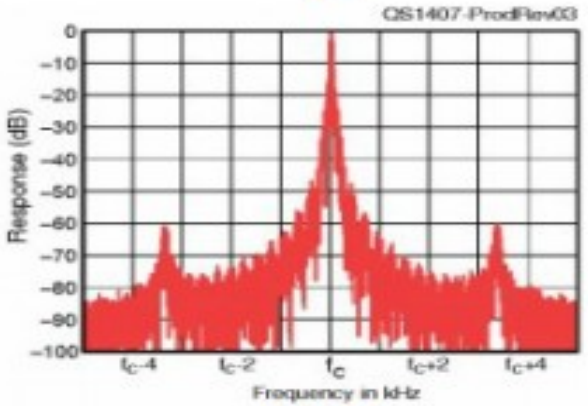


FTDX5000D



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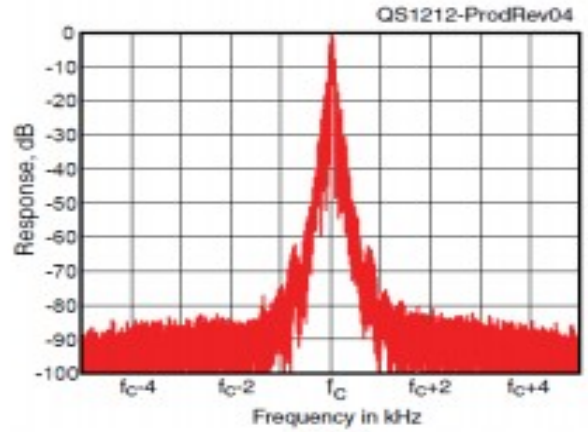
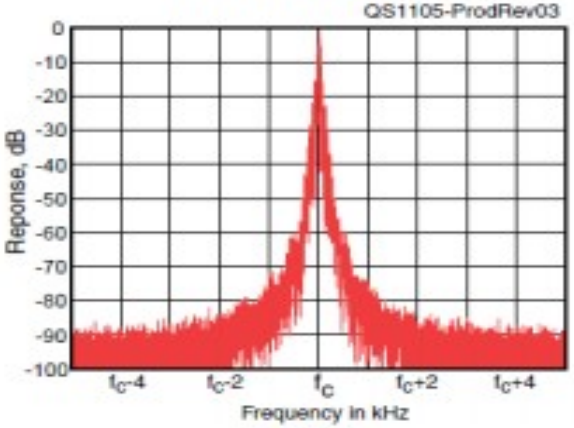
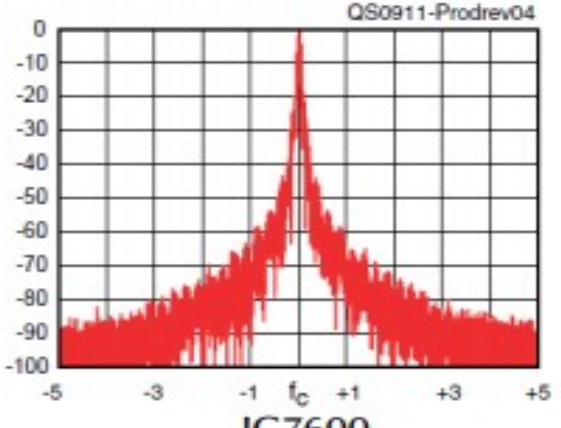


KX3



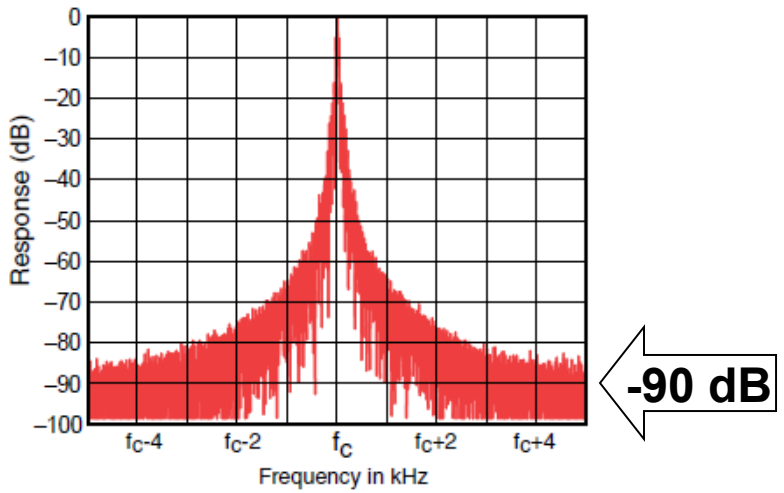
TS590



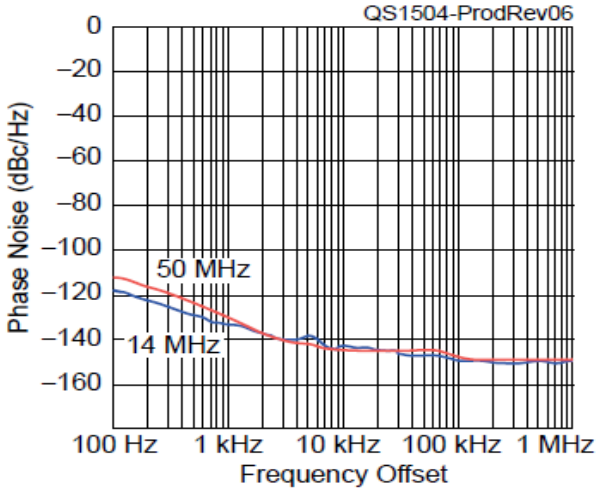
IC7600

Flex 6500

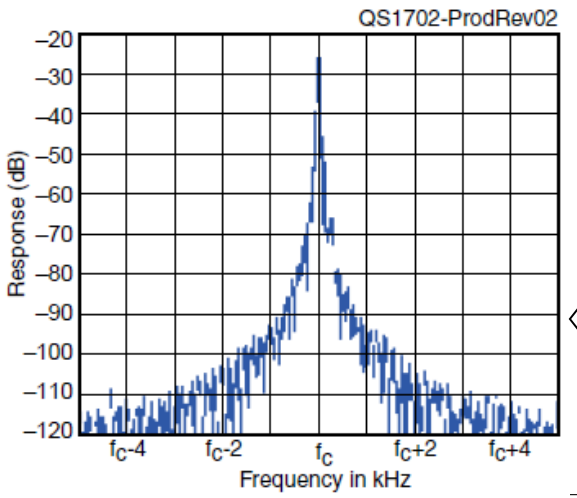
2015



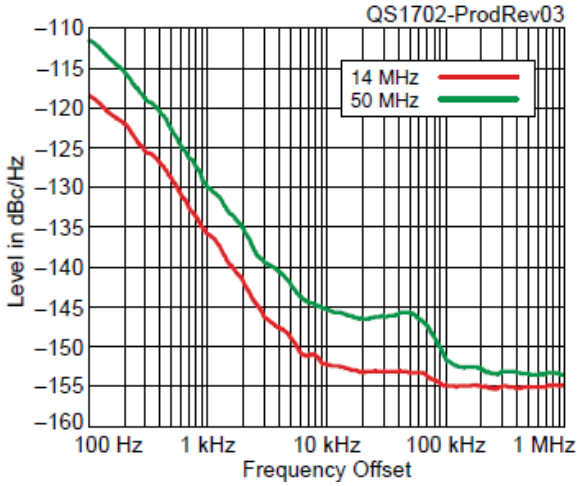
-90 dB



2017



-90 dB



Good Contesting Radios

- Differences matter most when two transmitters are on the same band
  - Field Day, state QSO parties
  - Bigger multi-multi stations
- And when two neighbors are on the same band at the same time
  - Depending on power, antennas, and propagation, “neighbors” can be tens or thousands of miles away!

Be A Good Neighbor

- Try to choose one of the top line radios
  - Buy a top line radio or amp used
- Tune your amp carefully
- Use antenna tuner with solid state power amps
- NEVER use ALC with a power amp to set drive power

Terrible Contesting Radios

- **Nearly all HF + 2M + 440 MHz rigs**
  - **Clicks, splatter, phase noise**
  - **Receivers easily overloaded**
  - **A disaster on Field Day**
- **Design compromises to:**
  - **cover all of these bands**
  - **low cost**

Cross-band Interference

- Why filters and stubs?
- Protect receiver from damage by the RF from another transmitter
- Protect receiver from overload by another transmitter
- Prevent radiation of harmonics produced by the transmitter

Power Amp Harmonics

- Power amps generate harmonics
  - 2nd harmonic typically -6 dBC
- Output stage filters the harmonics
  - In tube amps, transform impedance too
- This is true of both the rig itself and any outboard power amp

Power Amp Harmonics

- **Bandpass filter between rig and power amp can't filter power amp**
- **High power bandpass filter after the amp does filter power amp harmonics**
- **Stubs do too, and are a lot cheaper**

Power Amp Harmonics

- On CW and RTTY, harmonics often land on the next-highest CW and RTTY sections of the band
  - 3,530 kHz >> 7,060 kHz
  - 7,030 kHz >> 14,060 kHz

Power Amp Filters/Stubs

- **Most important for:**
  - **80M CW/RTTY to 40M CW/RTTY**
  - **40M CW/RTTY to 20M CW/RTTY**
- **<u>May</u> be needed for:**
  - **80M CW to 20M CW**
  - **40M CW to 15M CW, 10M CW, SSB**
  - **20M CW to 10M CW, SSB**

Cross-Band Interference

- **Low Power Bandpass filters**
  - **Between rig and power amp**
  - **Protects receiver**
  - **Can't kill harmonics from power amp**
- **High Power Bandpass Filters**
  - **On output of power amp**
  - **Protects receiver**
  - **Kill harmonics and intermod from rig and power amp**

How Stubs Kill Harmonics

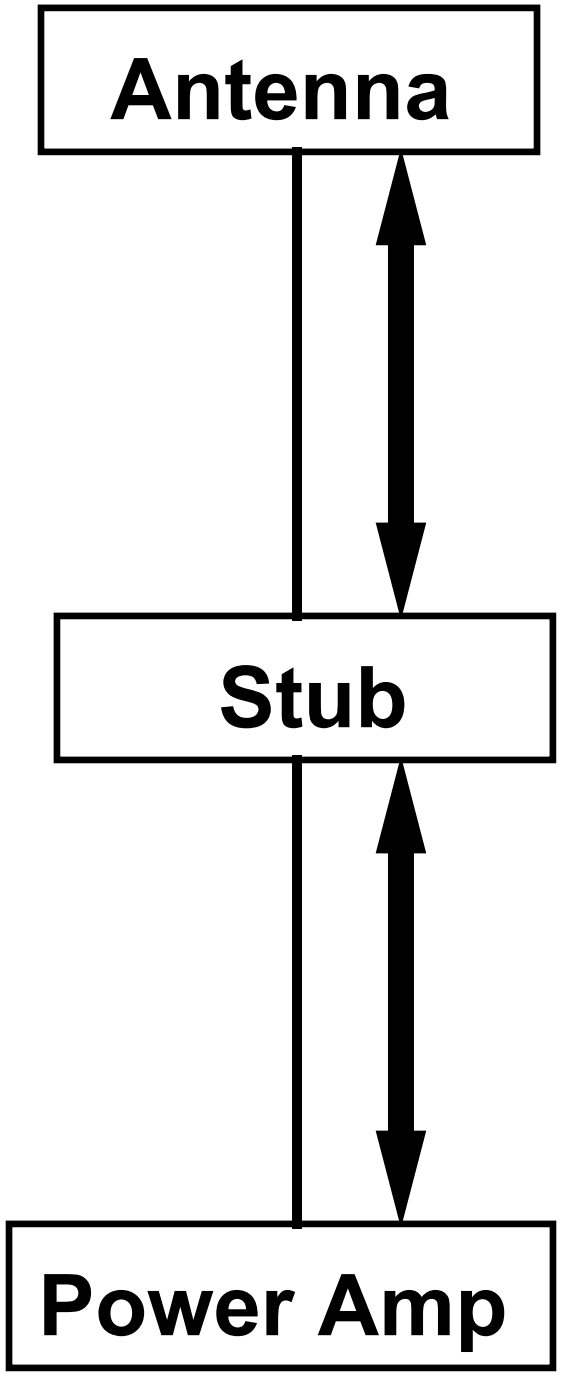
- A harmonic stub acts like a series resonant circuit across the line
- A λ/4 shorted stub cut for the transmit frequency
  - Is an open circuit at the transmit frequency
  - Places a short across the line at the 2nd harmonic frequency

Using Stubs

- Location along the feedline critical
- Spacing to power amp
  - "Right" yields 15-20 dB suppression
  - "Wrong" provides no suppression
- Spacing to antenna
  - "Right" adds ~30 dB suppression
  - "Wrong" adds no suppression
- Low loss coax for stub gives most suppression

Stub Location Matters

-



Stub Placement and Amplifiers

- Amplifier output networks suppress the 2nd harmonic (typically 30+ dB)
- A stub with “good” spacing to the power amp adds to that suppression
- A stub with “bad” spacing does not add much (if any) suppression
- “Good” and “bad” spacing depends on the amplifier’s output network

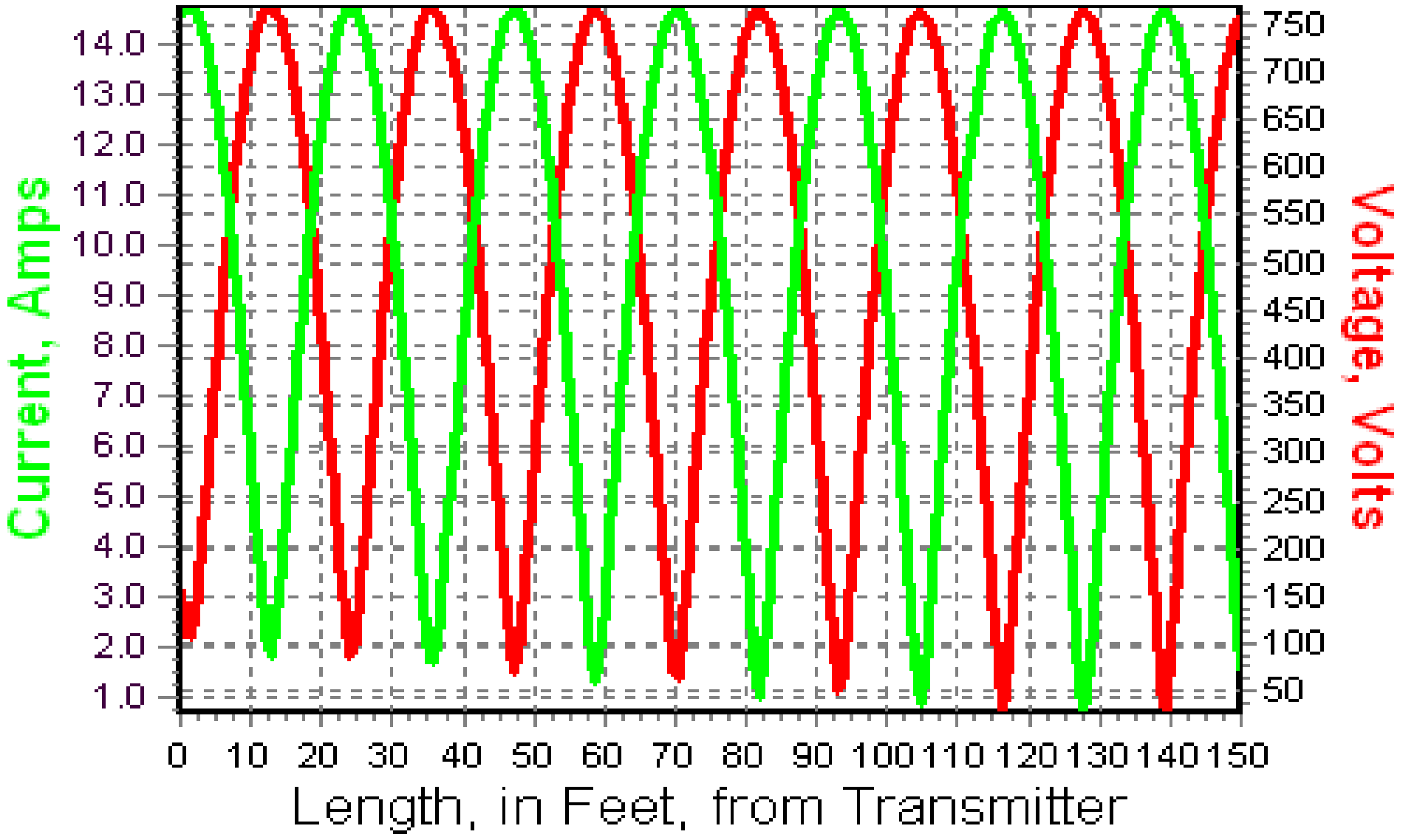
Spacing to Power Amp

- **Power amp with Pi-L output:**
  - **Multiple of λ/2 from amp to stub at harmonic frequency**
- **Power amp with capacitor output:**
  - **Odd number multiple of λ/4 from amp to stub at harmonic frequency**
- **RG8, RG213 stub**
  - **Right place = 15-20 dB suppression**
  - **Wrong place = 0 dB suppression**

Spacing to Antenna Matters

- **Most single-band resonant antennas have high SWR for 2nd and 4th harmonics**
- **Impedance along the line will vary from very high to very low, repeating in half wave intervals**

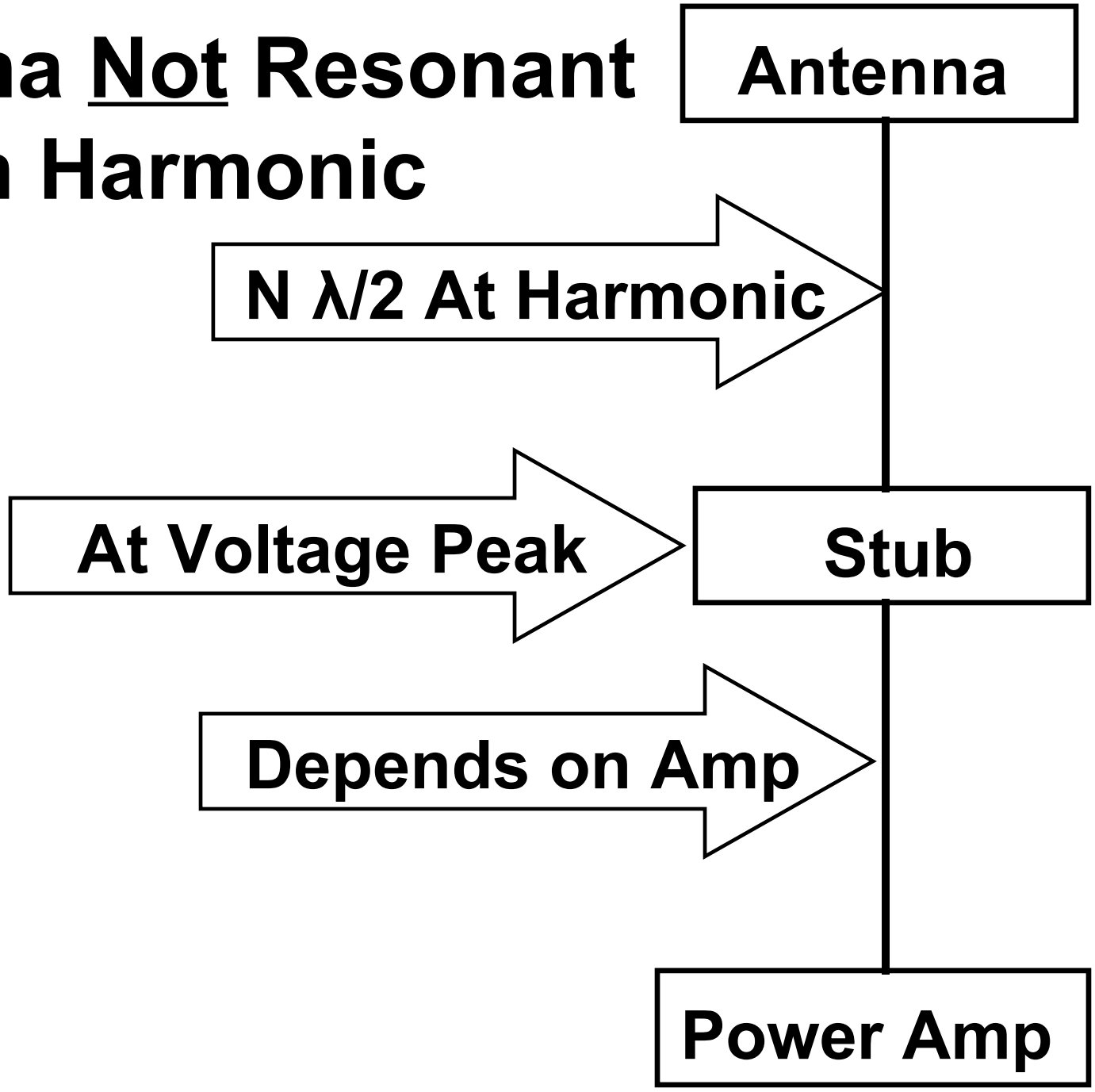
Voltage (Impedance) and Current Along the Transmission Line



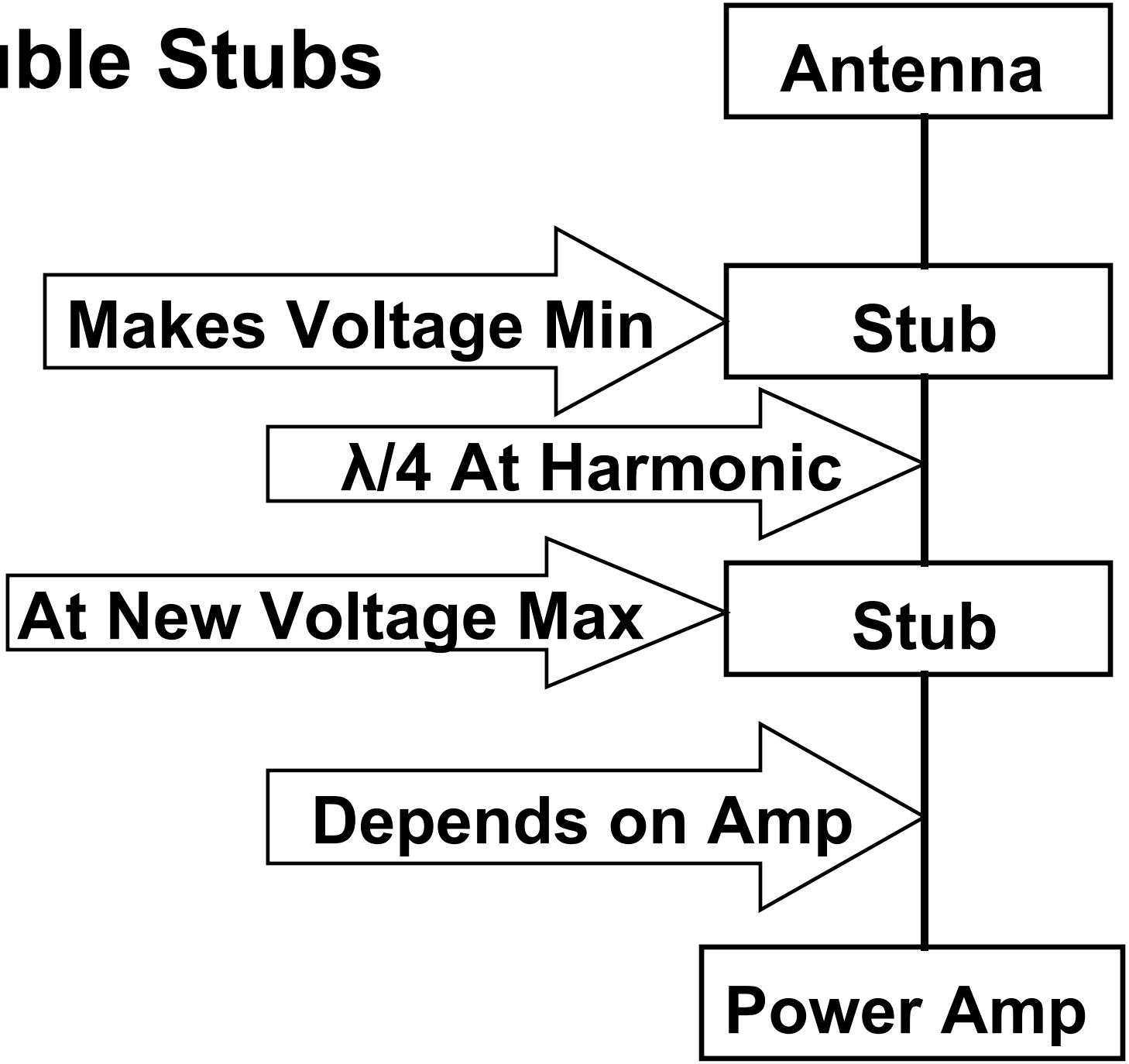
Spacing To Antenna

- Antenna not resonant at harmonic
  - Place stub at a voltage (impedance) maxima at the harmonic frequency
  - Multiple of λ/2 at the harmonic
  - Also proper spacing from power amp
  - It may be necessary to shorten or lengthen the feedline to satisfy both amplifier and antenna spacing

Antenna Not Resonant on Harmonic



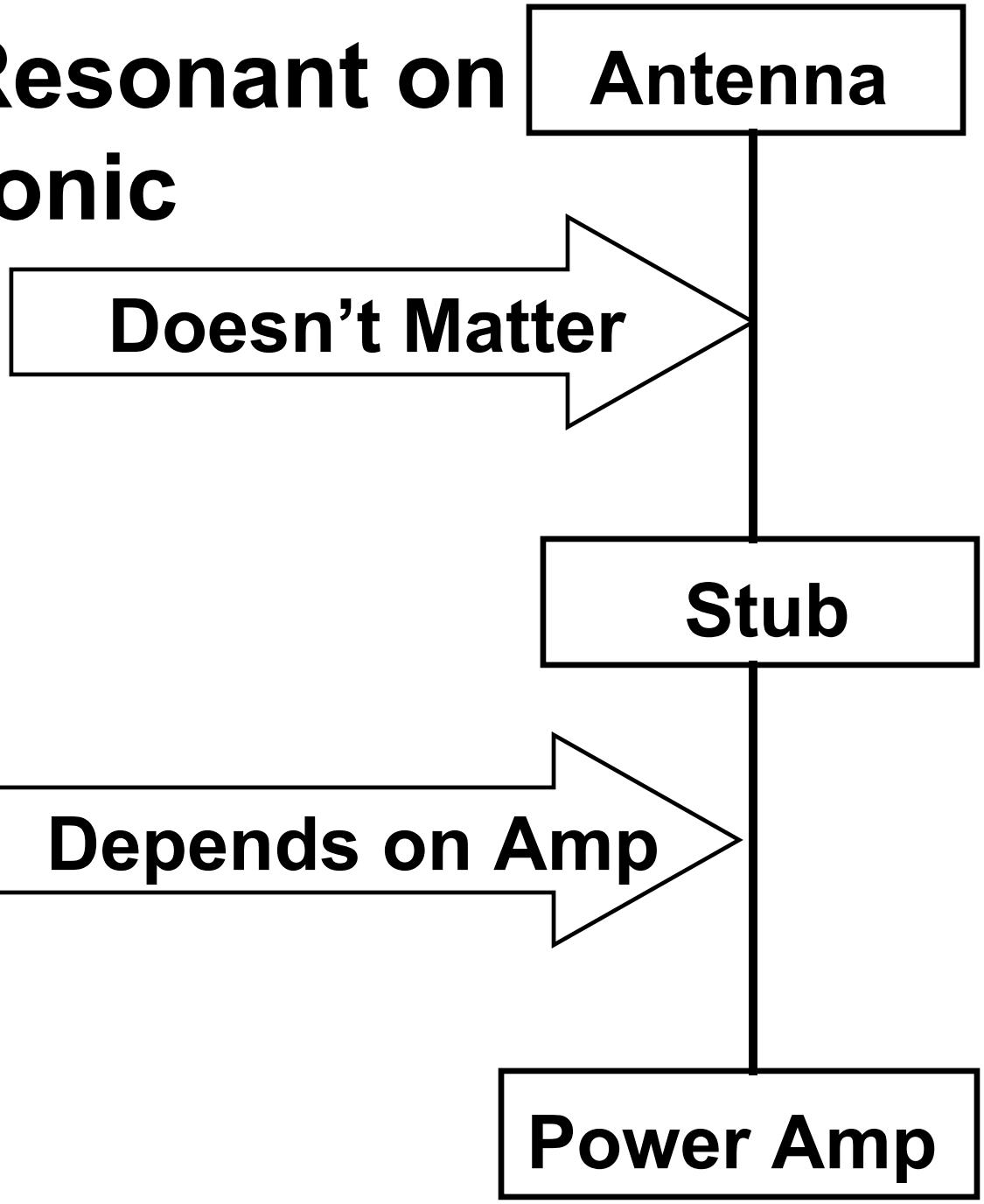
Double Stubs



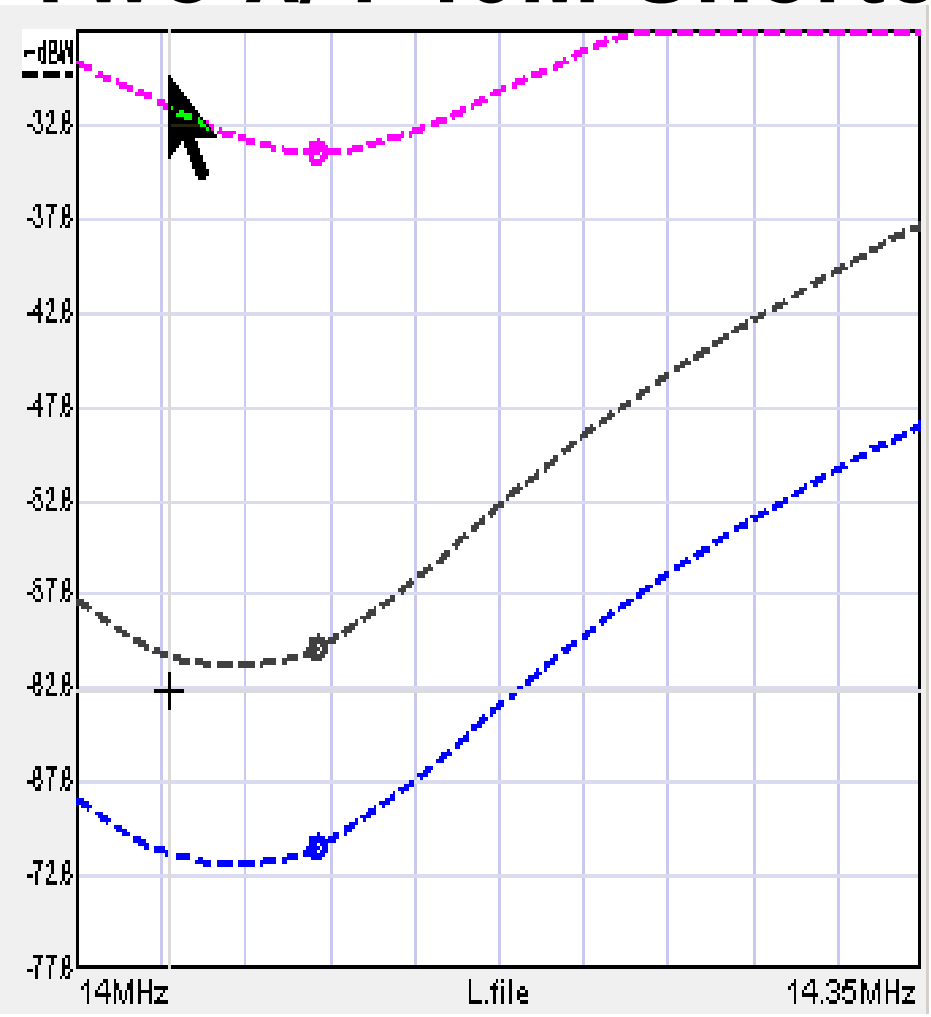
Double Stubs

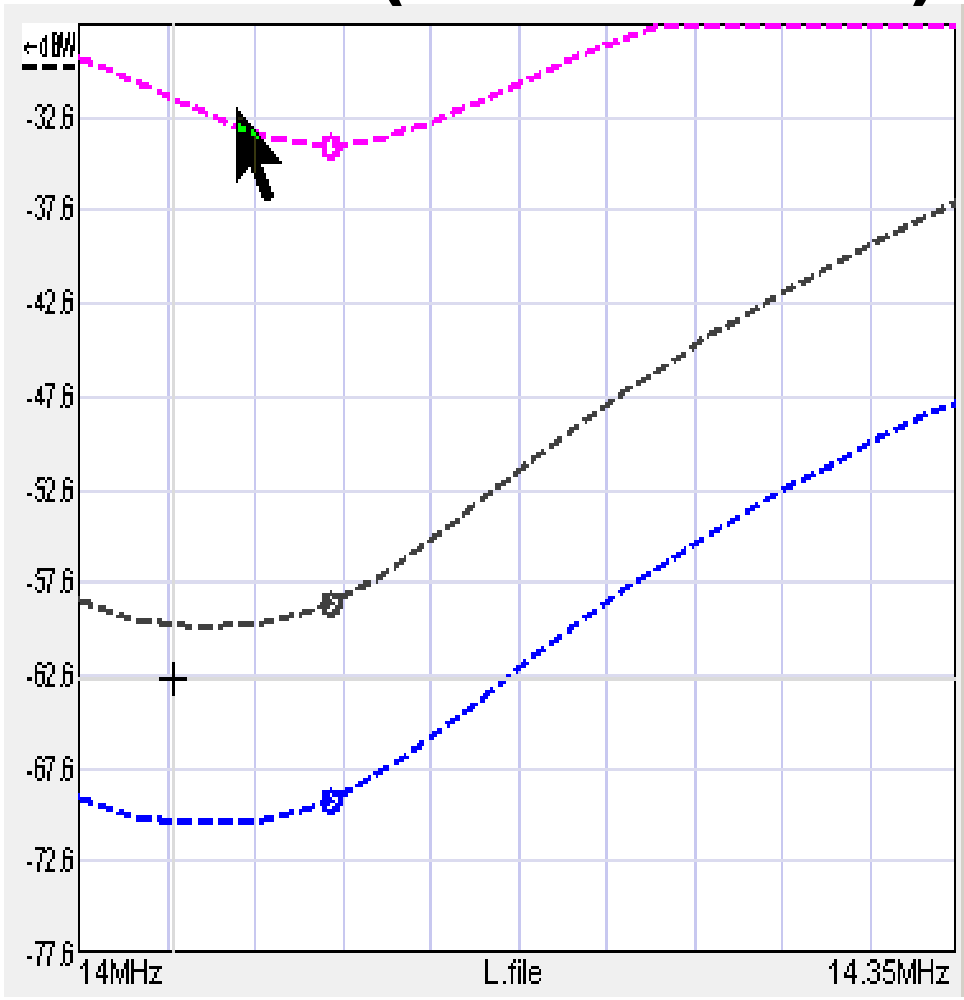
- A second stub adds ~30 dB more suppression
  - The first stub shorts the line at the harmonic frequency, setting a voltage minima
  - A second stub, λ/4 closer to the power amp will be at a voltage maxima
  - Spacing of second stub to the amp as before

Antenna Is Resonant on Harmonic



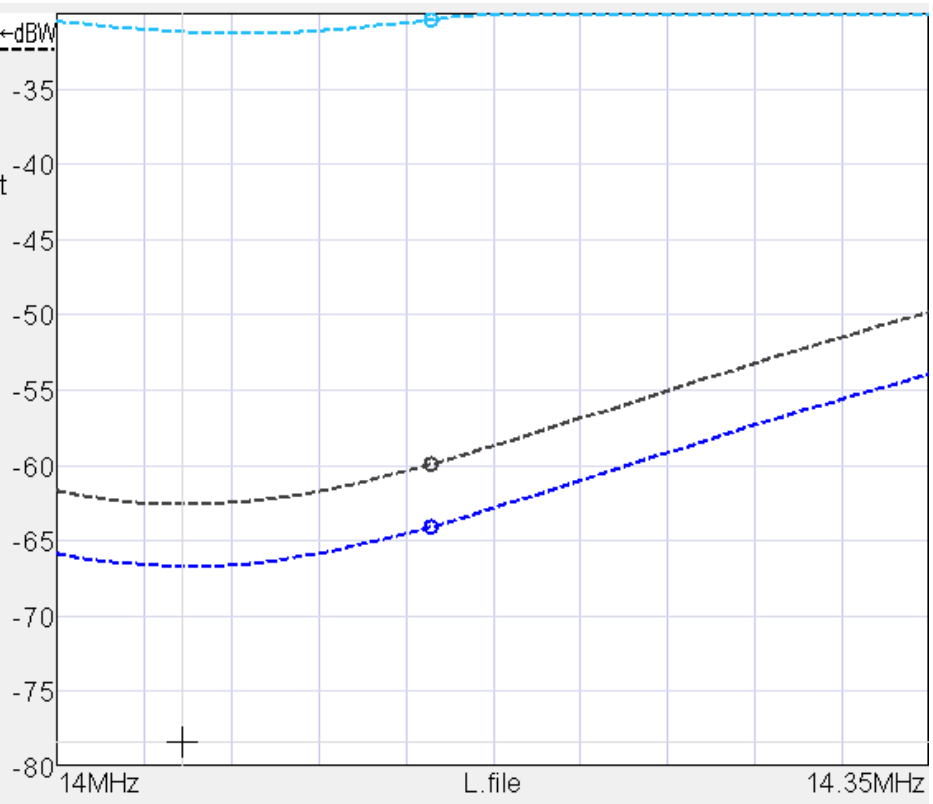
Two λ/4 40M Shorted Stubs (λ/2 on 20M)

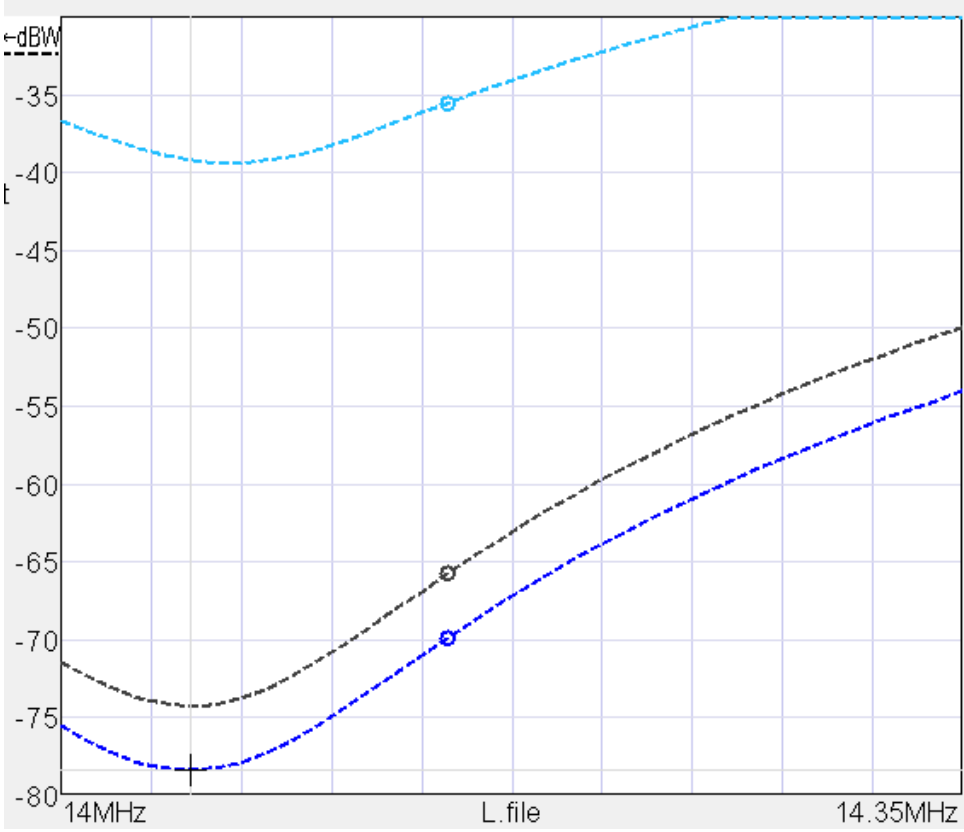




Both Stubs 14.1 MHz

Stagger-Tuned 14.072, 14.1 MHz





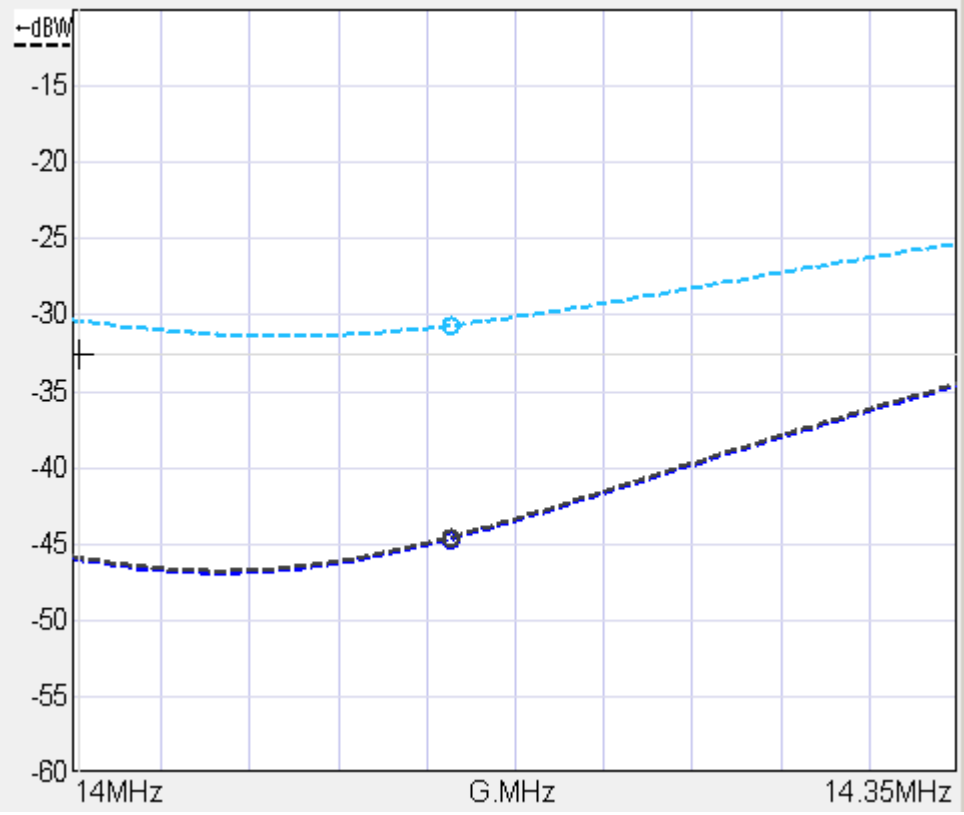
RG8X on 40M Dipole

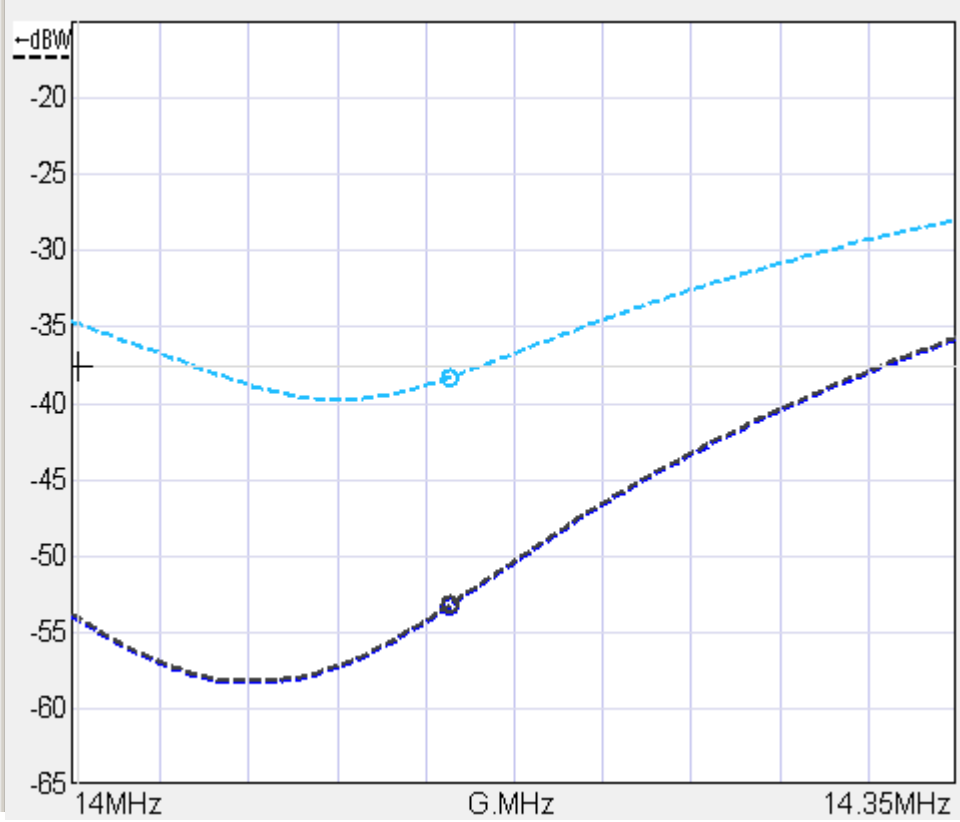
RG8 on 40M Dipole

Smaller coax for stubs gives less suppression but greater bandwidth

Antenna is resonant at harmonic

- Spacing from antenna doesn't matter
- Only spacing from power amp to stub nearest amp matters
- One stub gives ~25dB suppression
- Second stub spaced λ/4 at harmonic frequency adds ~30dB





Two RG8X Stubs

Two RG8 Stubs

When the antenna is resonant at the harmonic frequency

Suppression From Stubs

- **Antenna not resonant at harmonic:**
  - **10-12 dB if properly spaced from power amp**
  - **30 dB more for ideal spacing to antenna (40-42 dB)**
  - **Additional 30 dB for second stub optimally placed (70-72 dB)**

Suppression From Stubs

- **Antenna is resonant at harmonic:**
  - **~35 dB if properly spaced from power amp**
  - **~30 dB more for second stub (65dB)**

How To Use Stubs

- Detailed tutorial in text form
  - http://k9yc.com/LocatingStubs.pdf
- Detailed tutorial as a slide show
  - http://k9yc.com/StubPlacement.pdf
- Includes
  - Listing of power amps and their output networks
  - Three different ways to find the high impedance point depending on your tools

Stubs and Filters Can Not Fix

- Harmonics generated outside our station in non-linear devices or circuits
  - Switch-mode power supplies
  - Antenna rotators
  - Rectifying junctions (corrosion, etc.)
- Fundamental is picked up on wiring connected to non-linear device
- Harmonics (and IMD) are re-radiated by the same wiring

Stubs and Filters Can Not Fix

- These harmonics often have a "growl-like" sound, thanks to the presence of 60 Hz (Thanks W3LPL)
- Source can be in our home/shack or in neighbor homes, buildings, vehicles
- Trace like any other RFI problem
  - Rotate TX antenna
  - Rotate RX antenna
  - Chase it with portable RX during TX
- http://k9yc.com/KillingReceiveNoise.pdf

Killing Re-Radiated Harmonics

- Cannot be filtered in our station
- Must be killed at the rectifying source
  - Use chokes on wiring that acts as their antenna
  - Select chokes for TX frequency
  - Fix mechanical issues that set up the rectifying junctions

Killing Re-Radiated Harmonics

- Antenna rotators
  - Rectification at junction of rotating parts
  - Kill by bonding around the rotator (from boom to mast)
- Other non-linear junctions
  - Downspouts, building flashing, etc.
  - Kill by bonding around them (if you can find them and access them)

Killing Re-Radiated Harmonics

- Electronics of all sorts with poor isolation from external wiring
  - Switch-mode power supplies
  - Other electronics
- This stuff also puts noise in our receivers
  - Replace, or disconnect wires, or add ferrite chokes to wires connected to the culprits

Switch-Mode Power Supplies

- Replace with linear supplies
  - Buy at second hand stores, ham flea markets
  - Arrow, Newark, Digikey, etc.
  - Cut DC cable to equipment being powered, splice to DC cable from linear supply

Switch-Mode Power Supplies

- Replacement linear supply is usually unregulated, so output voltage depends on current
  - I add PowerPoles, so I can insert DC volt-ammeter inline to verify voltage
  - Not critical for most equipment

Using Low Power Bandpass Filters

- Should be used where SWR is low
  - Between rig and power amp
  - Between 100W rig and antenna tuner
- SWR stresses the components
  - Reduced power handling
  - Components fail (capacitors)
  - Filter must be retuned when components are replaced, requiring a Vector Network Analyzer (VNA)

How To Fry a Low Power Filter

- Use it during a 100W contest feeding an antenna that isn't well matched
- Use it on the wrong band
- Use it outside of it's design bandwidth

Low Power Bandpass Filters

- Prices are for a set of filters for the contesting bands
- Very good, higher isolation, 200W
  - Hamation Filtermax 4 ~$1,000
  - W3NQN ~ $900
  - 5B4AGN Kits ~ $500
- Good, less isolation, 100W
  - Hamation AS-419 ~ $700

Other Low Power Bandpass Filters

- Not so good
  - Dunestar ~ $500
  - Too narrow, poor power handling, SWR tolerance
- Poor design, performance, power handling, SWR tolerance, hard to repair
  - ICE 419 series

You Get What You Pay For

- **The better filters:**
  - **Use higher quality and more conservatively rated capacitors, so can handle more power and tolerate some mismatch without failure**
  - **Provide greater stop-band suppression**
  - **Have lower SWR and loss in the passband**

Bandpass Filters and Stubs

- If we're using low power bandpass filters, we still need stubs on the output side of the power amp to kill harmonics

High Power Bandpass Filters

- **4O3A**
  - **40 dB ~ $300 per band**
  - **55 dB ~ $460 per band**
- **VA6AM**
  - **4th order ~ $275 per band**
  - **5th order ~ $300 - $360 per band**
- **Switching system also needed to select filters by band ~ $300**

High Power Bandpass Filters

- Use at output of power amp
- Kills amplifier harmonics and intermod
- Protects receiver
- If you use these, you don’t need stubs to kill harmonics

RF Connectors

- Never use unbranded connectors or adapters
- Amphenol 83-1SP (silver plated)
  - Shield very carefully soldered
- Amphenol or MIL-stamped adapters
- All connectors wrench-tight
- Poor connectors generate IMD, harmonics

Tightening Connectors In Tight Spaces

W6GJB found this neat tool on amazon. It's a Tekton 34233

Crosstalk In Antenna Switches

- Some are FAR better than others
- The 4O3A 8x2 Antenna Genius is the best I've measured
  - Better than 100 dB isolation
  - His lower cost unit is about 75 dB
- The classic Array Solutions Six-Pak is only about 55 dB

Crosstalk In Antenna Switches

- There must be a continuous signal return in close proximity to the path of the switched conductor
  - A continuous "ground" layer on a two-sided board forms a transmission line with the trace above it (Microstrip)
  - EM field confined to region below trace
- But <u>not</u> if "ground layer" broken under trace!
  - Current takes roundabout path (chassis) so EM field goes everywhere!

Crosstalk In Antenna Switches

- Microstrip may be impractical at high power levels
- Can be approximated at MF and HF with switching on a circuit board mounted with very short stand-offs to a continuous chassis
- Connectors mounted to chassis

Proper Bonding

- Chassis-to-chassis of all equipment
  - Radios, amps, computers
- Every ground on premises
  - Power entry
  - Telco, CATV, cold water, antenna entry
  - Driven rods
- Operating desk to premises ground

Power Distribution

- Get power for all station equipment from outlets that share the same "green wire"
  - This includes computers, audio gear
  - If multiple outlets required, bond their green wires
- With proper bonding and power distribution, there's no need for audio transformers

Audio and Computer Interface

- Use top quality cables
  - Most cables you can buy are poorly shielded
- Build your own audio cables
  - Small diameter coax (RG58, RG174)
  - Switchcraft or Neutrik connectors
  - Part numbers and sources in k9yc.com/GroundingAndAudio.pdf

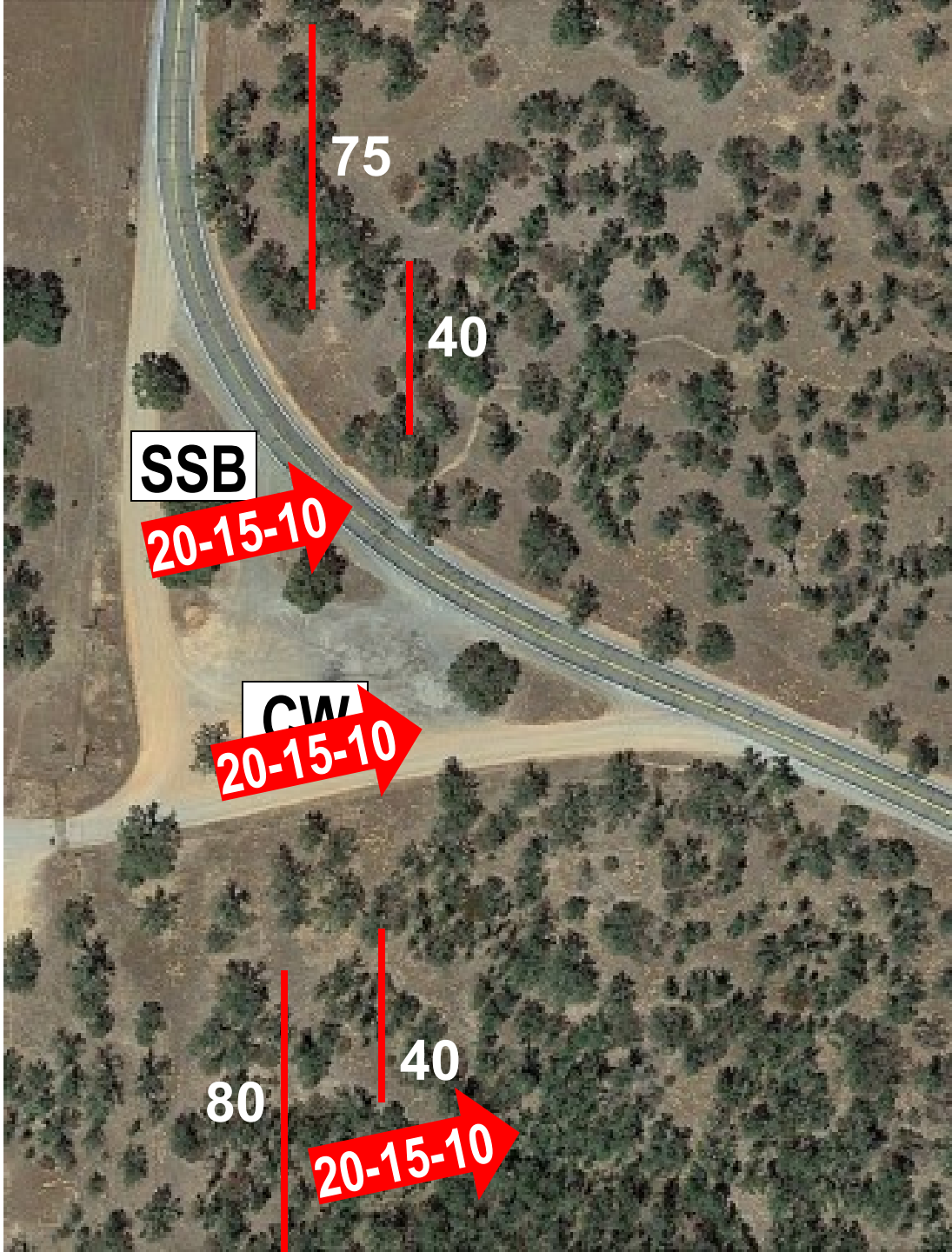
Antenna Layout and Separation

- Matters most with two stations on the same band
- For domestic contests, most of our long haul QSOs are to the east
  - Fixed Yagi aimed to 70º
  - Dipole broadside to 70º
- Place antennas for same band so that their driven elements are colinear, and greatest possible spacing

A Site Plan Designed For 500W CW and SSB On the Same and Different Bands

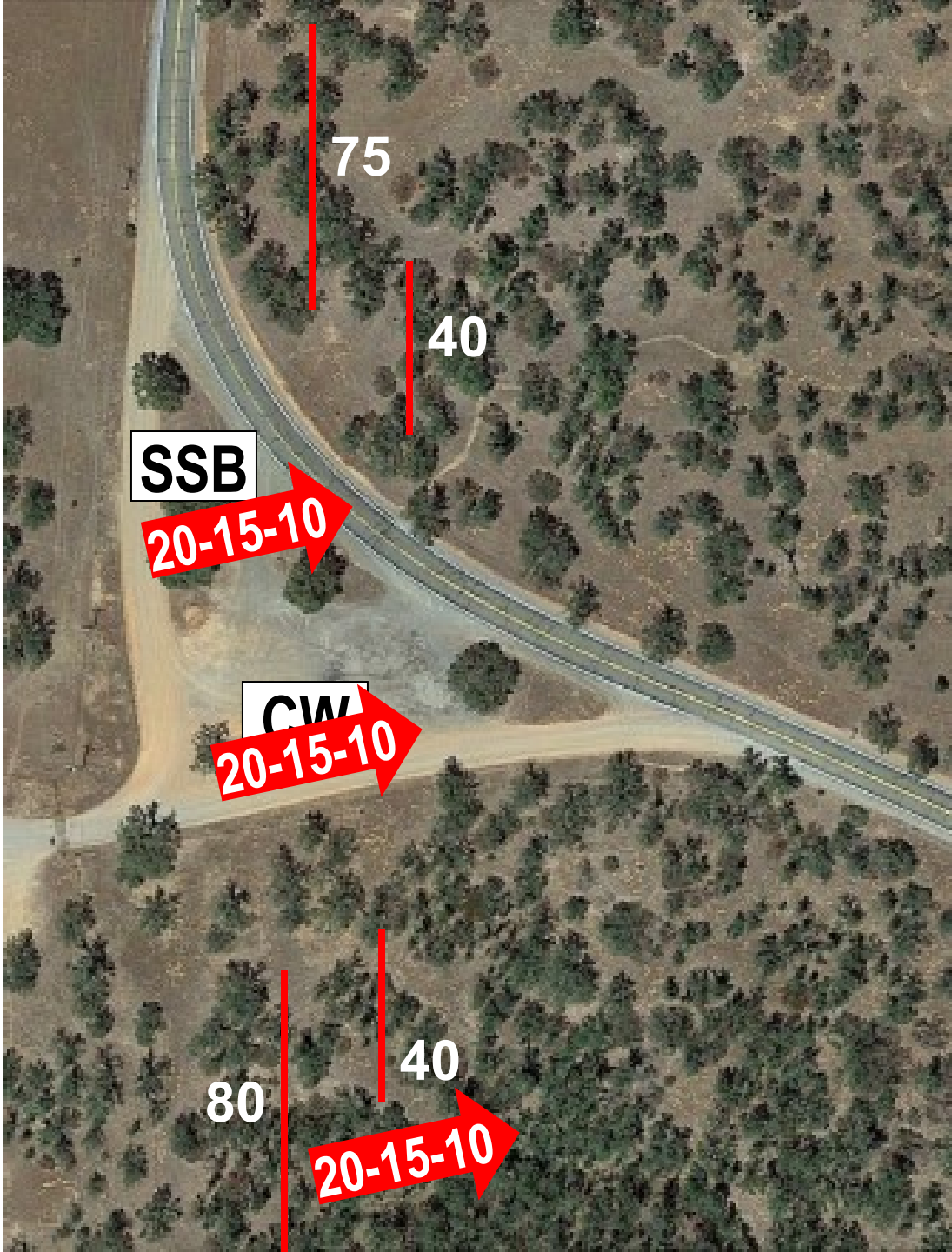
A CQP Site Plan

- 2-CW + 1 SSB
- Separation of CW and SSB antennas
- Antennas are co-linear
- Coax through culvert under highway to SSB dipoles
- Coax crosses dirt road on messenger between trees to CW antennas



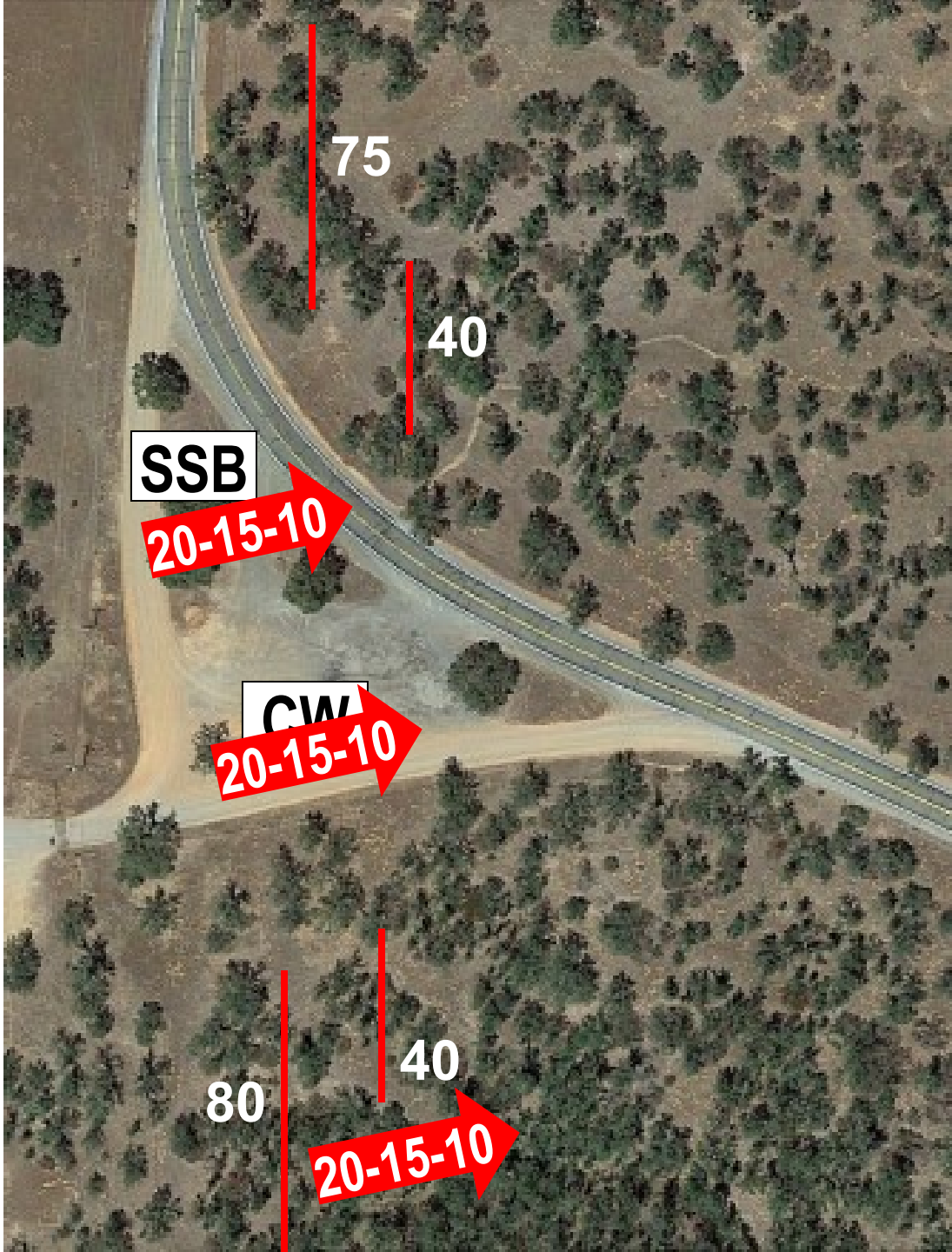
The Stations

- K3/P3/KPA500 KAT500
- W3NQN low-power bandpass filters
- Double stubs on 80M and 40M CW



The Antennas

- Dipoles on 80/75, 40
- RG8, RG11
- Serious ferrite choke at each antenna feedpoint
- Dipoles rigged between trees

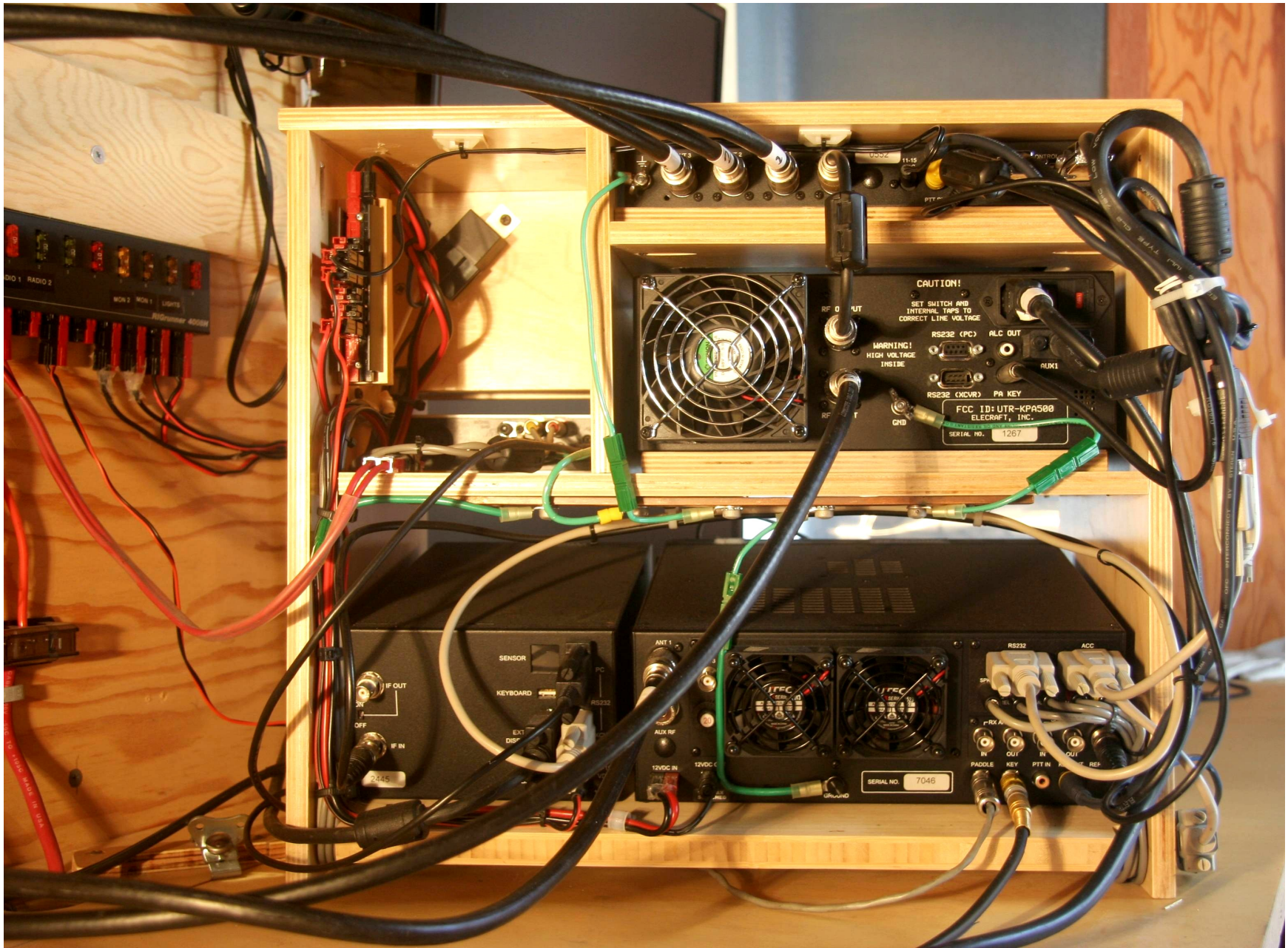


A Setup For Two Stations On Different Bands

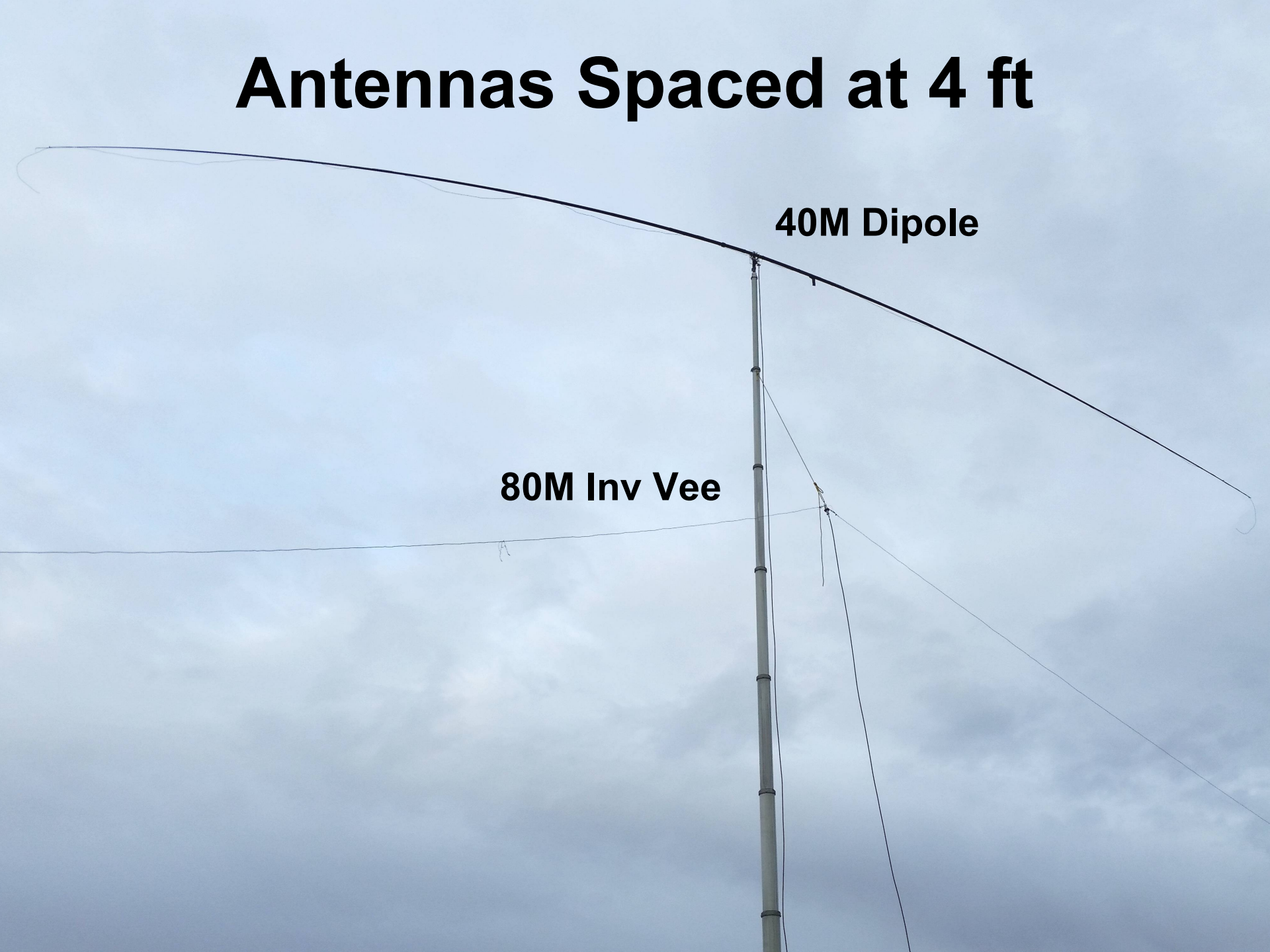
By Colorado River in Utah for Seventh Area QSO Party

One Of The Stations

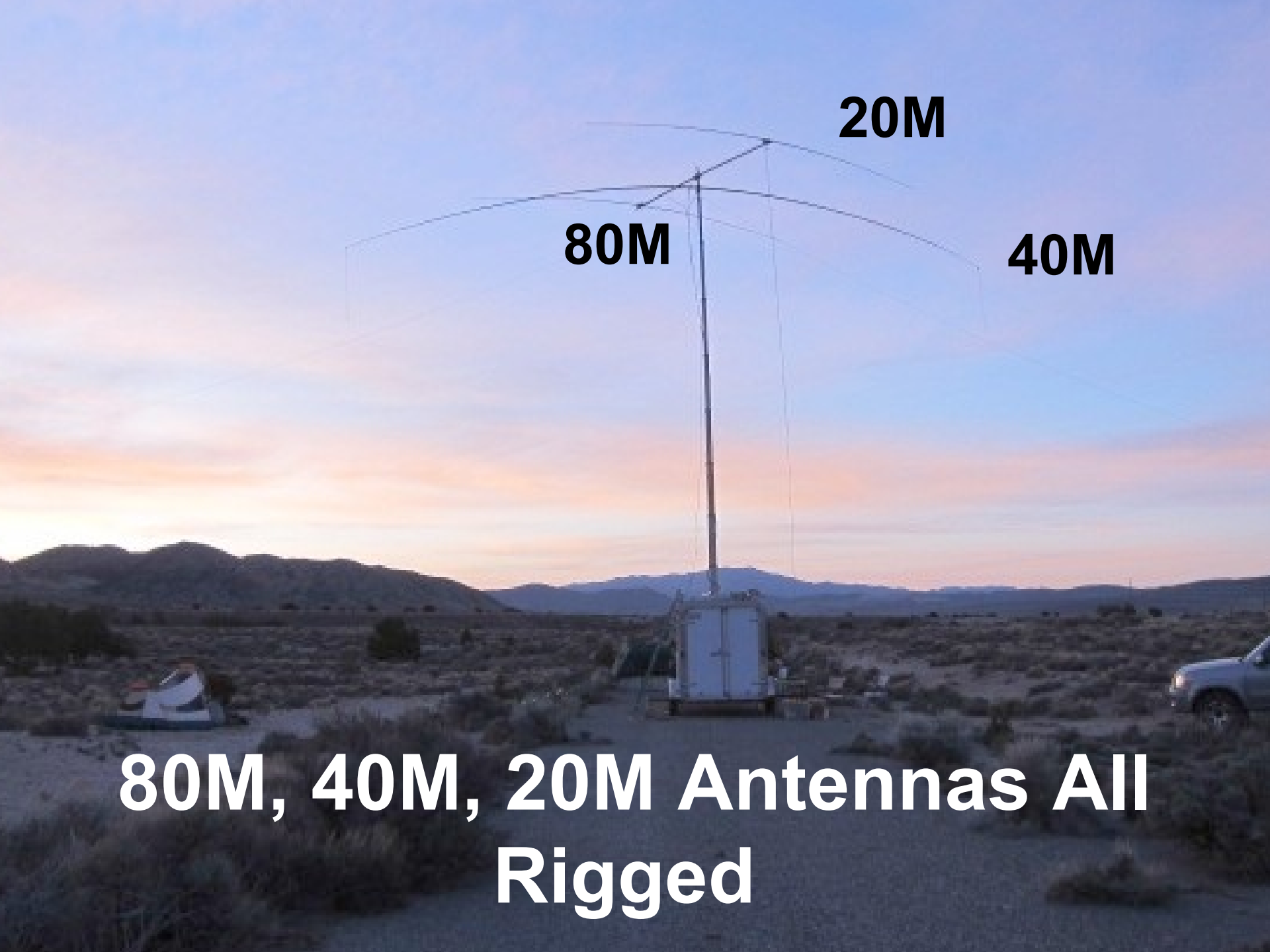
Rear View Of Station



Antennas Spaced at 4 ft




Double Stub Kills
2nd Harmonic of
80M



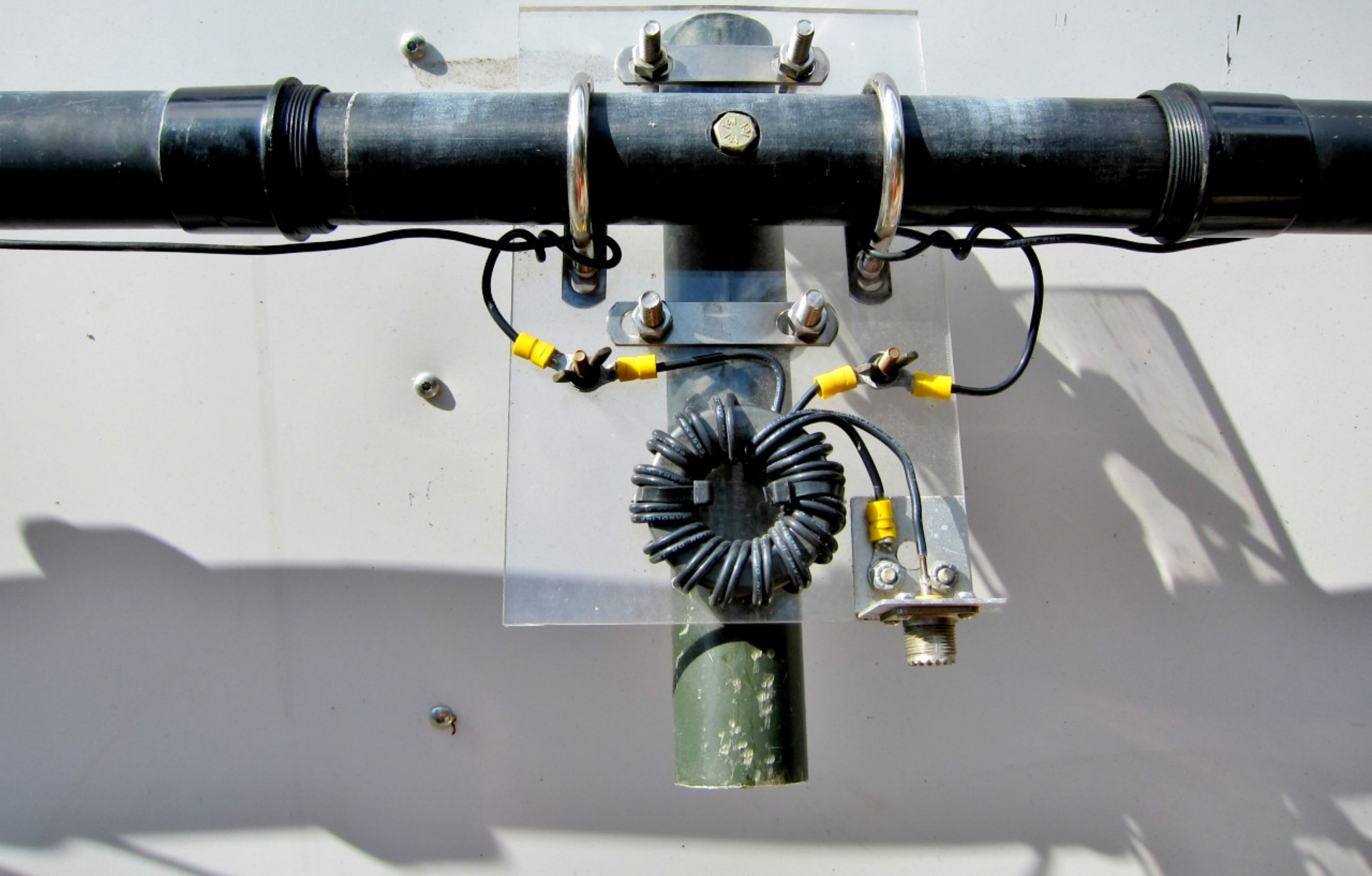
80M, 40M, 20M Antennas All Rigged

Double Stub Kills 2nd Harmonic of 40M

A Choke At Every Feedpoint

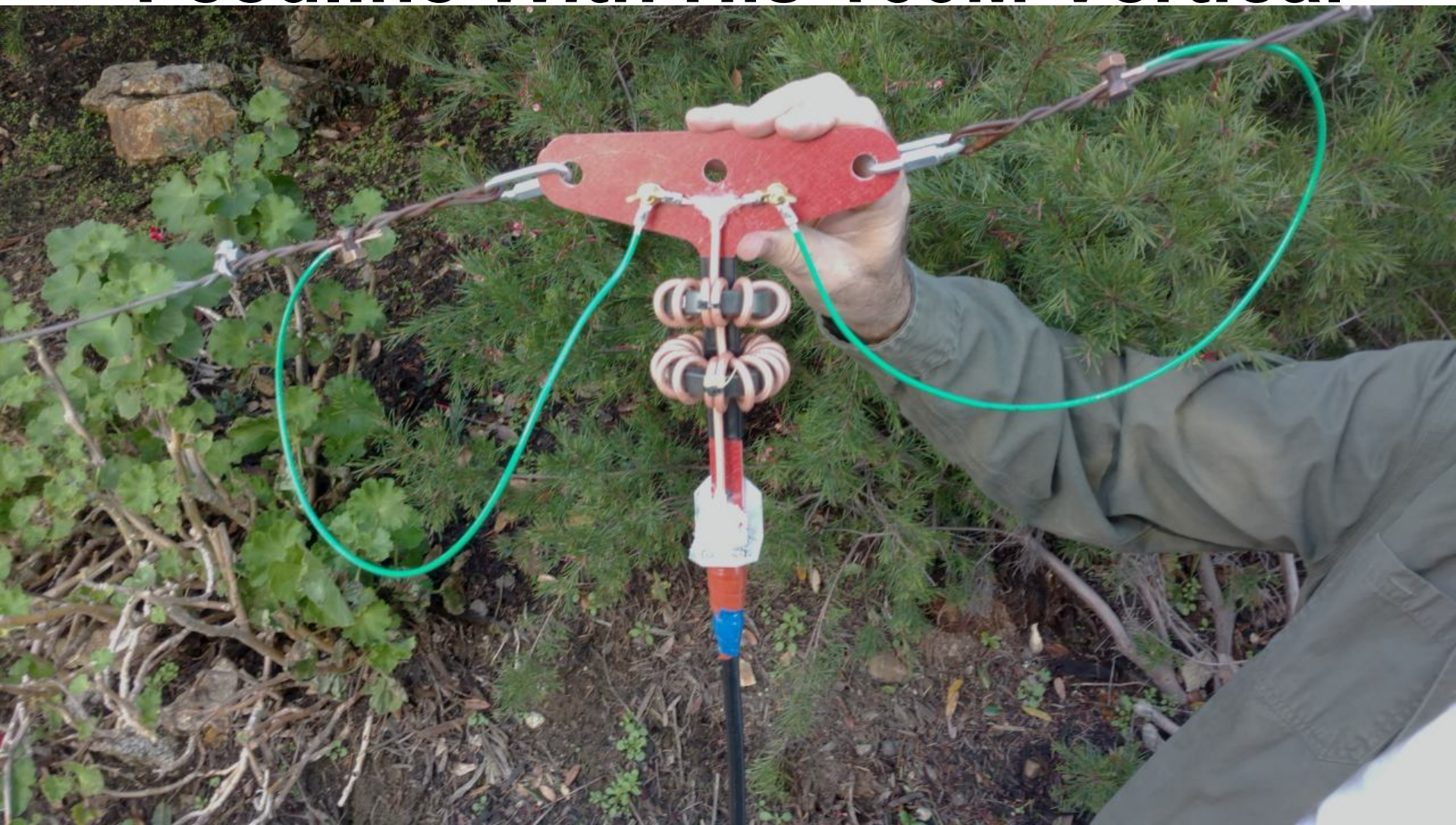
- Prevents radiation/reception by feedline
- Minimizes noise on receive
- Use a serious choke
- You can build MUCH better than you can buy, and for much less money
- k9yc.com/2018Cookbook.pdf

Choke on 40M Dipole



W6GJB's Dipole Insulator with K9YC's Choke Used on 80M Inv Vee

W6GJB's Latest Dipole Insulator Dual Chokes Prevent Interaction of Feedline With His 160M Vertical



In-Line Chokes in Long Lines

- **The coax shield is an antenna**
- **Shield current couples inside the coax by a mechanism quantified as it's *Transfer Impedance***
- $Z_T = \dfrac{\text{Voltage Induced Inside Coax}}{\text{Current on Outside of Shield}}$
- **Add choke in line to minimize antenna action**

Shield Quality and Z_T

- A lower value is better
- Shield resistance is the lower limit
- Z_T Is minimized by
  - Low shield resistance
  - Very good shield uniformity
  - Very high shield density
- Hard line with heavy solid shield material is near ideal, no inline choke needed

Coax Shielding Matters

- Never play cheap on coax
- Dense copper braid shield
- First quality RG8, RG213, RG11
- Hard line is best
- RG142, RG400 are good for short jumpers
  - Dense double shields of silver-coated copper braid
  - Loss like RG58, so use only short lengths
  - Use silver-plated reducers with 83-1SP

Poorly shielded coax and poor shield contact at connectors are a major cause of inter-station interference! (And flaky antenna performance)

W6GJB's Latest Designs

- RG400
- Teflon #12

Summary

We can’t give anything away!
Getting a lot of little things right adds up to minimize interference.

Things We Can't Give Away

- Chokes inline and at feedpoints
- Proper bonding
- Quality connectors and adapters, wrench-tight, very well terminated
- Cables with high quality shield
- Antenna layout and orientation
- Avoid passive intermod
- Low crosstalk in antenna switches

Things We Can't Give Away

- Clean transmitters – phase noise, clicks
- Very good receivers – phase noise, strong signal handling
- Keep tube amps well tuned
- Use tuner with solid state amps
- Optimize stub placement
- Bandpass filters

References

- **ARRL Handbook**
- **ARRL Antenna Book**
- **Managing Interstation Interference** ***George Custogeorge, W2VJN (buy direct from George)***
- **k9yc.com/2018Cookbook.pdf**
- **k9yc.com/RFI-Ham.pdf**
- **k9yc.com/GroundingAndAudio.pdf**


Please
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Minimizing Inter-Station Interference

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http://k9yc.com/publish.htm