Lessons from
King George Amateur Radio Club 2015 Field Day
Tuned Stubs Experiment

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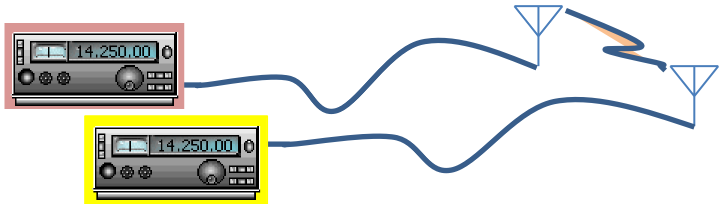
Problem Statement



- The energy from a typical HAM radio transmitter, when another radio's antenna is in close proximity, can couple into the second radio and cause interference even if they are widely separated in frequency.

- In the extreme, the front end of the victim radio can be seriously damaged.

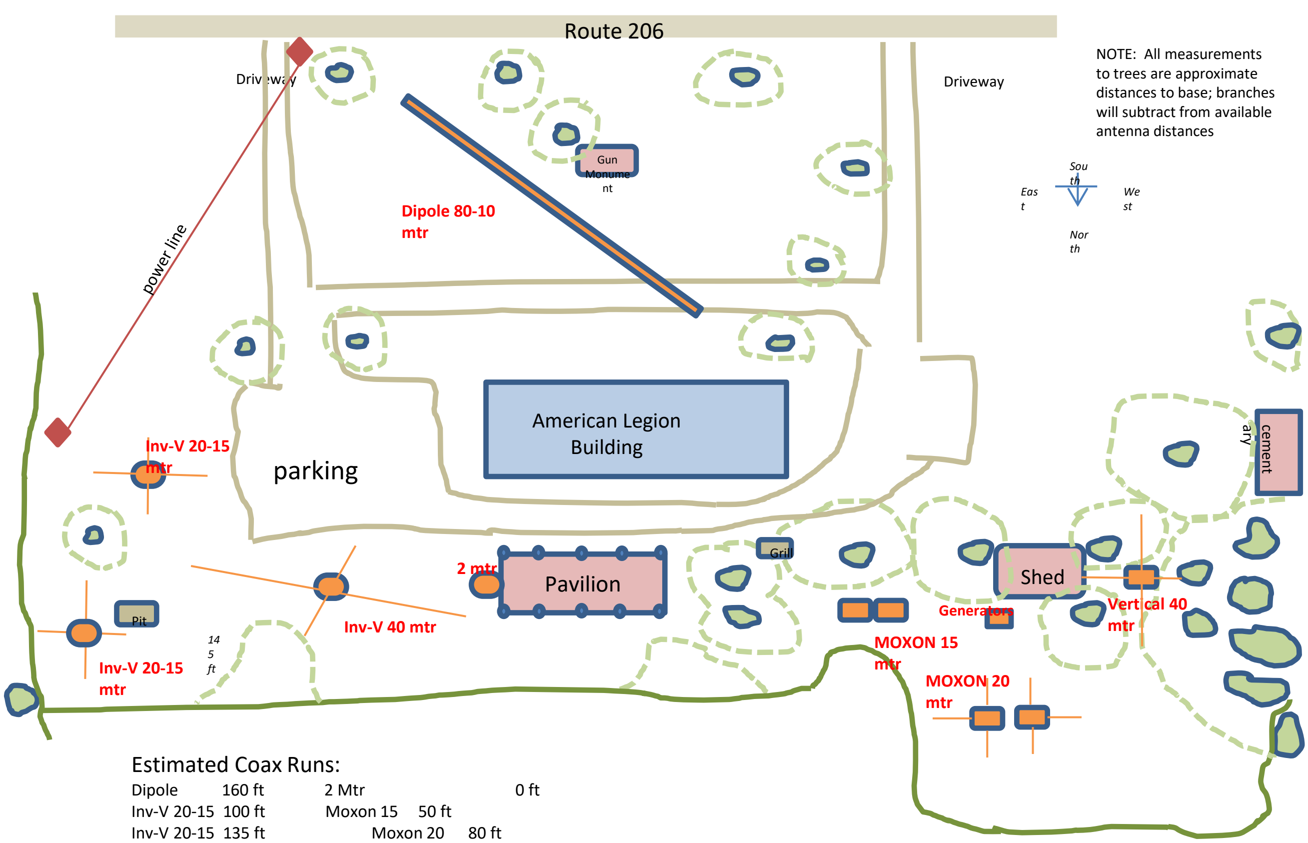
Ham radio receivers can be overdriven and damaged by EMI!

Our Field Day Interference Problem

- At our FD the last two years, we had severe cross band interference
  - We were working HF bands, CW and Voice on 10, 15, 20, 40, and 80 meter bands
  - We had disabling interference between 15 and 20 mtr CW
  - Power used was under 100 watts (50 typical)

- We decided to investigate RF filtering solutions for 20/15 mtr interference for this year's FD
  - Physically separating antennas had limited effectiveness because of FD site

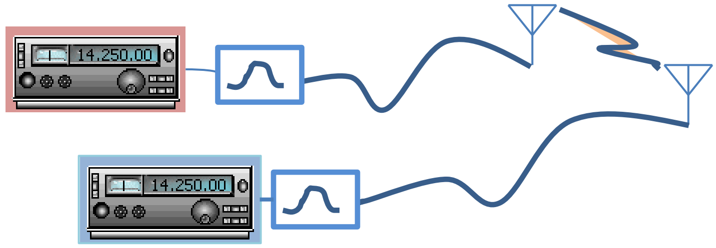
2015 Field Day Antenna Plan



Estimated Coax Runs:

Dipole 160 ft — 2 Mtr 0 ft
Inv-V 20-15 100 ft — Moxon 15 50 ft
Inv-V 20-15 135 ft — Moxon 20 80 ft
Inv-V 40 50 ft — Vertical 40 135 ft

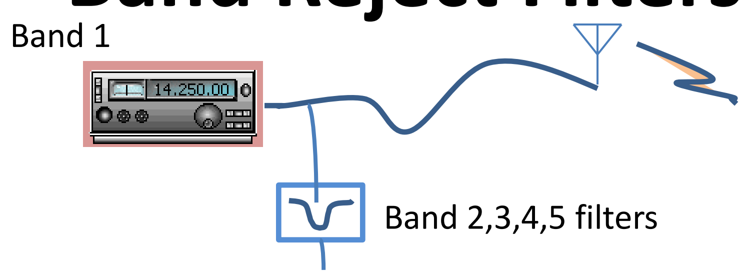
Should We Use Bandpass Filters?



- Issues:
  - Tuning external filters to match radio's frequency and adjusting filter bandwidth according to band being used is difficult over wide frequency ranges
  - It is difficult to match input and output impedances to 50 ohms over very wide frequency ranges
  - Bandpass filters' rejected signals will reflect back to the antenna and radio!

This is a difficult approach to implement

Solving the problem with Band Reject Filters



- Band Reject filters effectively short the feedline on HAM bands not being used; filters present "high impedance" to band in use

- Filters work for signals in both directions, ie, both transmitted and received signals are passed or rejected according to filter settings

- Requires a filter for each band rejected, but we can take advantage of the limited number of HF Field Day bands

Commercial Filter Products

- Single Band Lumped Component HF RF filters
  - Typically 25 db of suppression (4 + S Units)
  - Filters are fixed frequency, single Ham band filters
  - Internet user reviews very favorable

- Issues:
  - Manual band switching required
  - Filters made to order; lead time can be several months
  - Power limitations; filters can be destroyed by too much power
  - Cost is approximately $120 each band; one HF 5 band set can cost $600
  - "homebrew designs" available, but internet reviewers warned about difficulty to build and tune; parts availability is also a concern

Many Hams who purchased commercial filters were pleased with their purchase

¼ Wave Tuned Stub Alternative Approach

A RF filter can be built from common coax

A ¼ wave coax stub at the tuned frequency will invert the impedance at the opposite end of the cable.

Assume one end of a coax is open. Then the current at that end is nearly zero (less leakage); at the other end of the coax, ¼ wave away, the current must be very high.

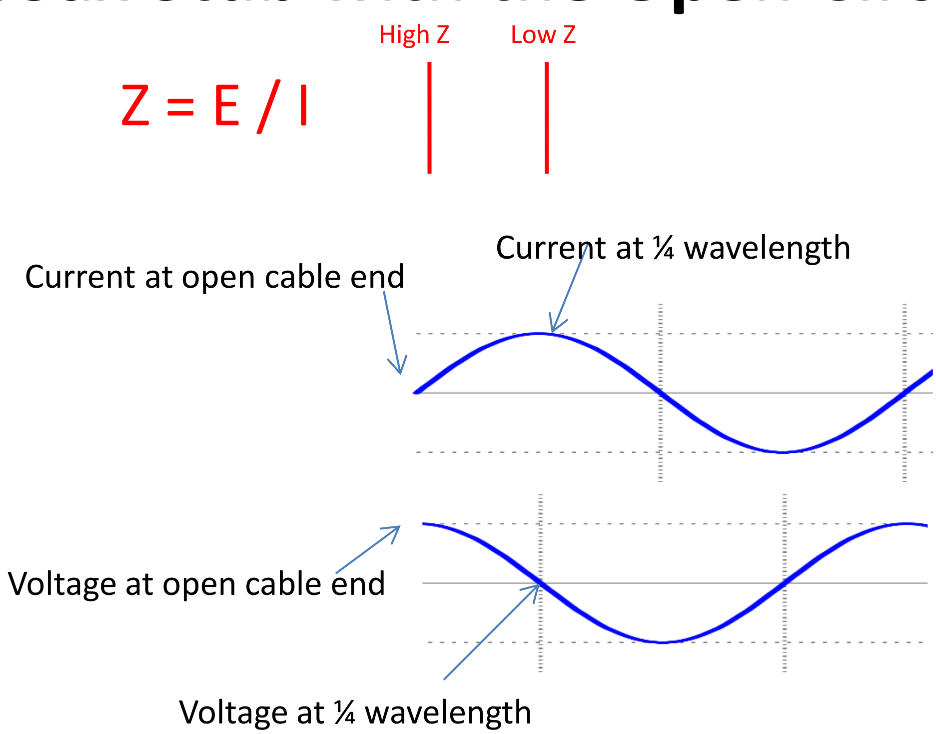
The inverse is true for the voltage.

THEREFORE:

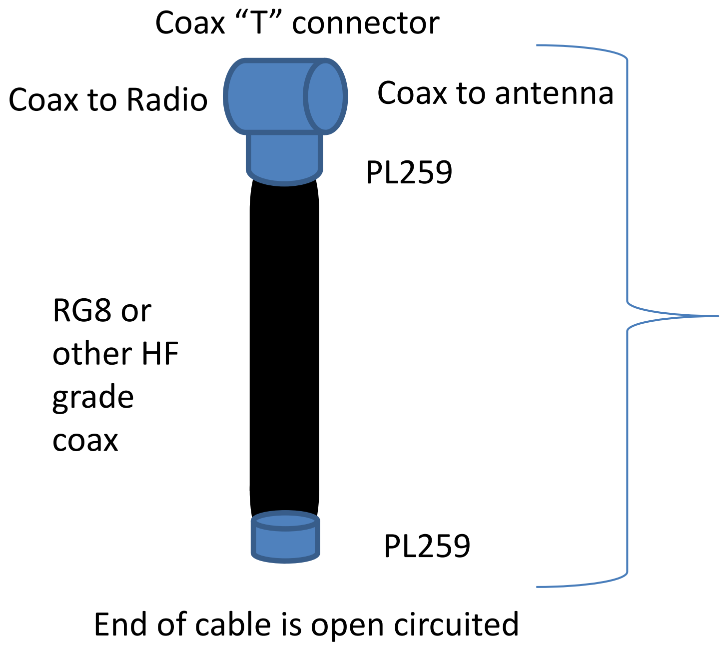
Since Z = E / I, the impedance at the open end must be very high and the ***impedance at the opposite end is very low at the tuned frequency***.

The inverse happens for a shorted coax stub, that is, the impedance at the opposite end is very high at the tuned frequency.

Impedance Transformation in a Coax Stub with the Open Circuit End



Tuned Stub Filter Design

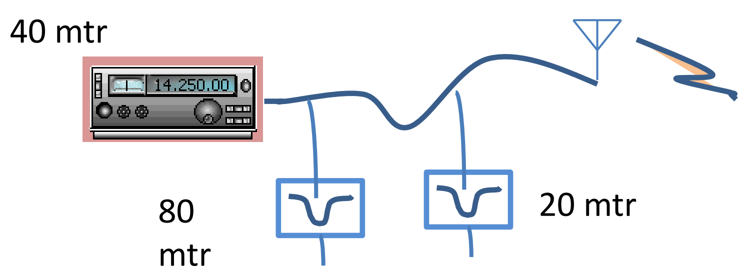


- Physical length of cable is calculated for ¼ wave as:
- Length $_{feet}$ = (Velocity Factor x 983.6) / 4 Freq $_{MHZ}$
- Length is approximate; cut longer and trim to resonance

Multiple Tuned Stub Filters Example

- Here is an example of two filters used to reduce interference from two adjacent bands

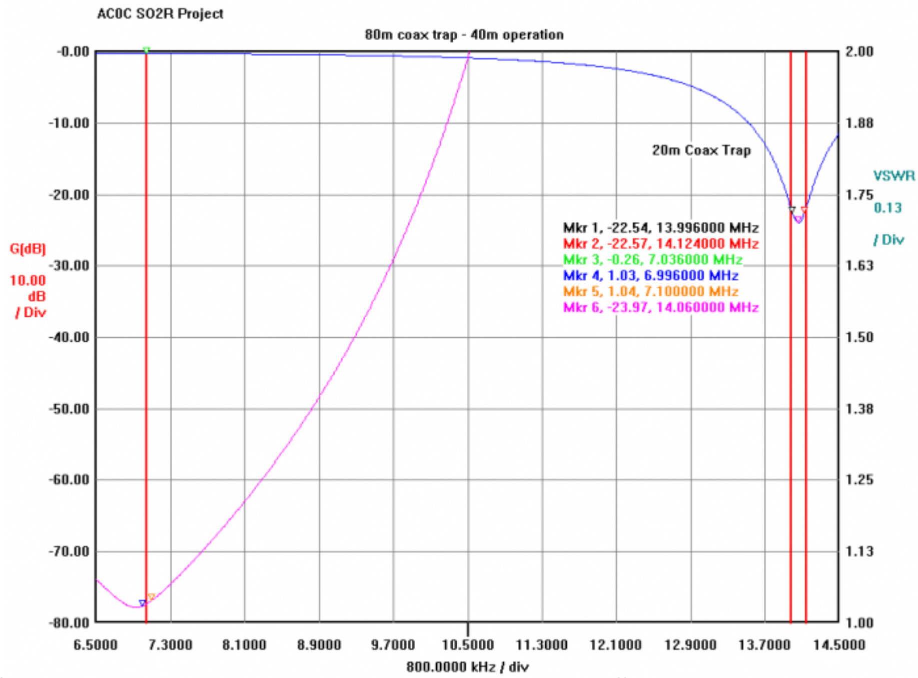
(NOTE: other radios may still have to install their own filters)



Example from AC0C Amateur Radio article on So2R "targeted Attenuation for Adjacent Bands" http://ac0c.com/main/page_so2r_coax_stub_intro.html

Two tuned stub filters at 80 and 20 meters for a radio operating on 40 meters

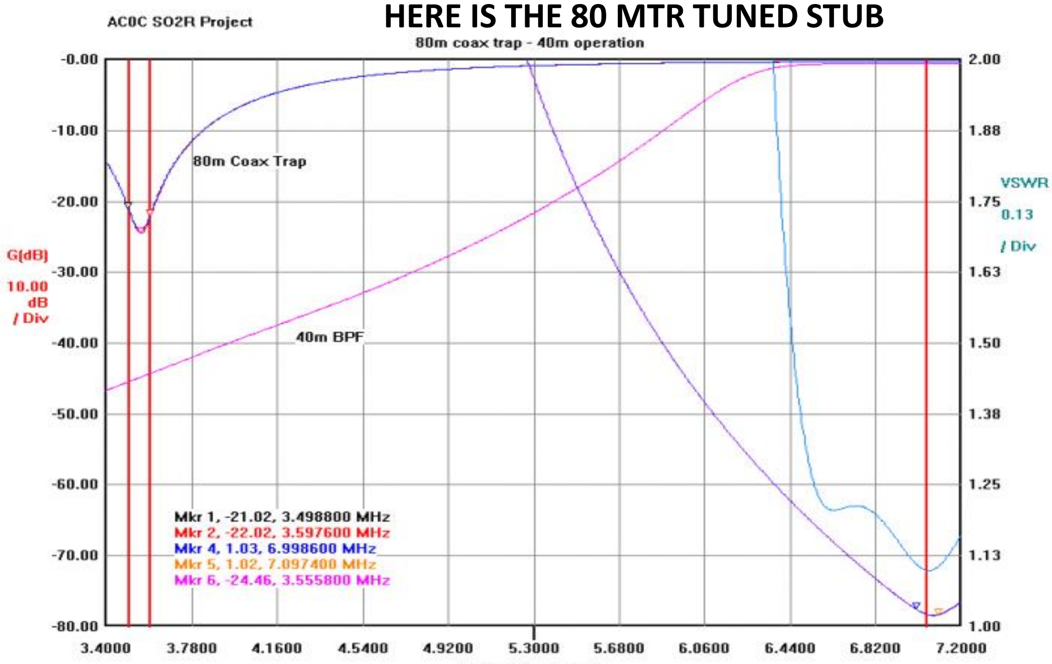
HERE IS THE 20 MTR TUNED STUB



Copied from AC0C Amateur Radio article on So2R “targeted Attenuation for Adjacent Bands” http://ac0c.com/main/page_so2r_coax_stub_intro.html

Two tuned stub filters at 80 and 20 meters for a radio operating on 40 meters

HERE IS THE 80 MTR TUNED STUB



Copied from AC0C Amateur Radio article on So2R “targeted Attenuation for Adjacent Bands” http://ac0c.com/main/page_so2r_coax_stub_intro.html

Our Field Day Experiment

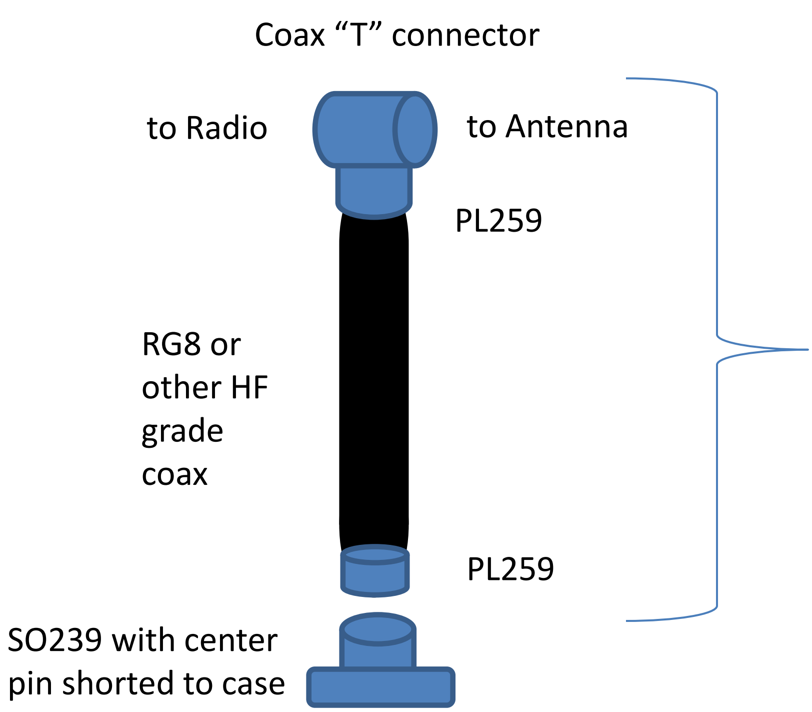
- We built three “40 mtr tuned stub” filters using “junkbox” parts and coax

- Cost was 25 feet of coax, a RF “T” connector , two PL259 and one SO239 connector per radio
  - Cost would be approximately $50 for each radio, if built with new components

  - Actuals were approximately $20 for each radio using old coax, toolbox connectors plus some new connectors

Bottom Line: our interference problem was solved at much less cost than purchasing commercial filters!

Our Field Day Tuned Stub Filter Design



- Physical length of cable is calculated for ¼ wave as:

$\text{Length}_{feet} = (VF \times 983.6) / 4\ \text{Freq}_{MHZ}$

- ¼ wave stub of RG 8 at 40 meters would be: (0.66x983.6) / (4 x 7MHZ) =23.2 feet

- When trimming, a change of approximately 4 inches in cable length corresponds to 100khz at 7 Mhz

Screw bulkhead connector into PL259 for “Open”
Remove connector for “short”

Coax Impedance Transformation

1. A ¼ wave coax at the tuned frequency will inverse the impedance present at the opposite end of the cable.

2. A ½ wave coax at the tuned frequency will have the same impedance as present on the opposite end of the cable.

3. A ¾ quarter wave coax at the tuned frequency will act like a ¼ wave coax, that is, it will inverse the impedance present at the opposite end of the cable.

4. A full wave coax at the tuned frequency will act like a half wave coax, that is, it will have the same impedance as present on the opposite end of the cable.

5. This pattern repeats beyond one wavelength

MEASURING ANTENNA IMPEDANCE

- Impedance varies with type of antenna, dipole, loop, ½ wave loop, vertical.
- Impedance varies with distance between earth and antenna:
  - Dipole at >½ wavelength = about 70 ohms.
  - Dipole at < ¼ wavelength = about 20 ohms
  - Dipole at 2 wavelengths = about 150 ohms
- Must measure SWR / TUNE at altitude. HOW

Half Wavelength COAX Feed

- Impedance at one end of a coax of ½ wavelength is equal (repeats) to the impedance at the other end but only at one frequency.
- SO, Trying to trim an antenna, get it up in the air at the place where you are going to use it.
- Then connect the center of the dipole to the antenna tuner with a ½ wavelength (at the center of your user band) coax.

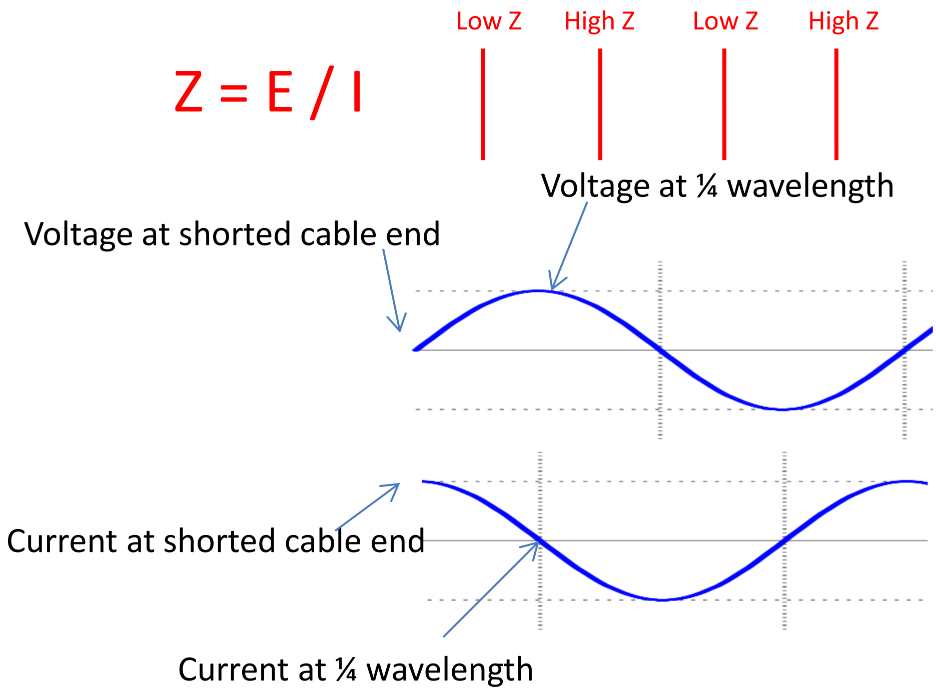
Making the 1/2λ Coax

- Calculate approximate length
  - Meters = 300/freq in MHz /2
- Cut at least 12” longer than calculated
- Put a PL 259 on one end.
- Attach to the Antenna Tuner and set to frequency.
- Use the “all” or #8 key
- Trim length (avoid shorts) by 1 inch
- Continue until the meter equals Z=50.0 ohms Resistance and X= 0 ohms (imaginary value).
- If the values reverse or go below 50 Ohms Z, you went too far. NOT TO WORRY!!
- Once you have the best length, CUT OFF ONE ADDITIONAL INCH.
  - That makes up for the connector length on the antenna tuner!

75 ohm to 50 ohm transmission line matching coax stub

- Coax Transmission line coax stubs are frequency dependent. Making a stub for one frequency means it **WILL NOT** work for another frequency. My example is for a 20m Resonant Feedline Dipole, sometimes called a Sleeve Dipole or Resonant Coax Dipole or Tuned Choked Coax Dipole.
- So you have an approx 75 ohm impedance antenna and you want to get the best match you can. Take the wavelength of the frequency, multiply it by the velocity factor of your 75 ohm matching coax and multiply again by 0.0815.

Impedance Transformation in a Coax Stub with the end shorted



Summary

Cable Length	Stub Impedance at Radio and Antenna cable end	Open cable end configuration
¼ wave	High Impedance	shorted
	Low Impedance	opened
1/2 wave	Low Impedance	shorted
	High Impedance	opened
¾ wave	High Impedance	shorted
	Low Impedance	opened
Full wave	Low Impedance	shorted
	High Impedance	opened

Our "Poor Man" Approach to Multiple Filters

- The amateur HF ham bands are harmonically related, so

  A quarter wave stub on 40 mtrs is a half wave stub on 20 mtrs!

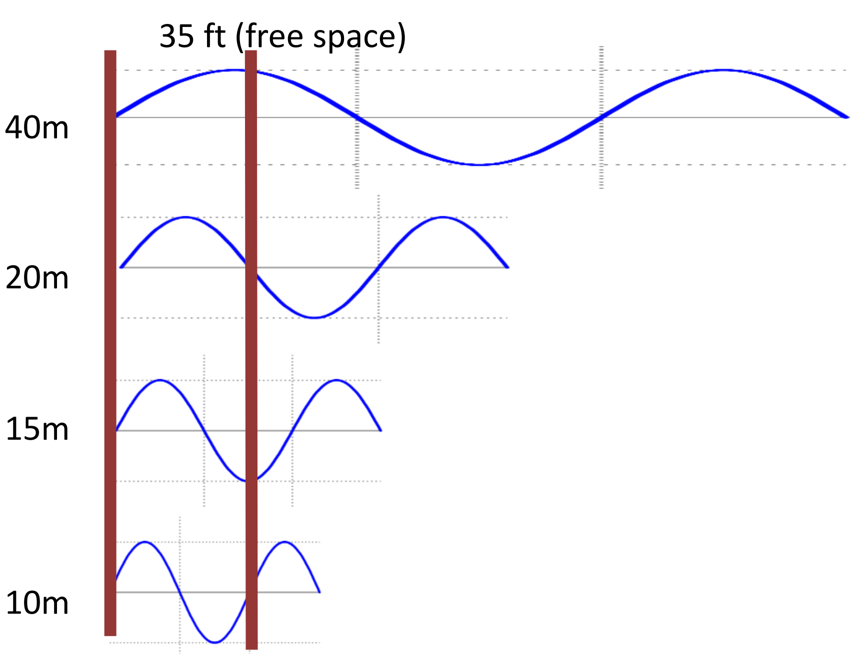
  Etc, etc, etc.

Therefore,

- A shorted ¼ wavelength stub on 40 meters appears as:
  - High Impedance on 40 and 15 mtrs
  - Low Impedance on 20 and 10 mtrs

- An open ended ¼ wavelength stub on 40 mtrs appears as:
  - Low Impedance on 40 and 15 mtrs
  - High Impedance on 20 and 10 mtrs

Harmonic Relationships of HF Bands



35 feet is:
¼ wavelength on 7.02 mhz

1/2 wavelength on 14.05 mhz

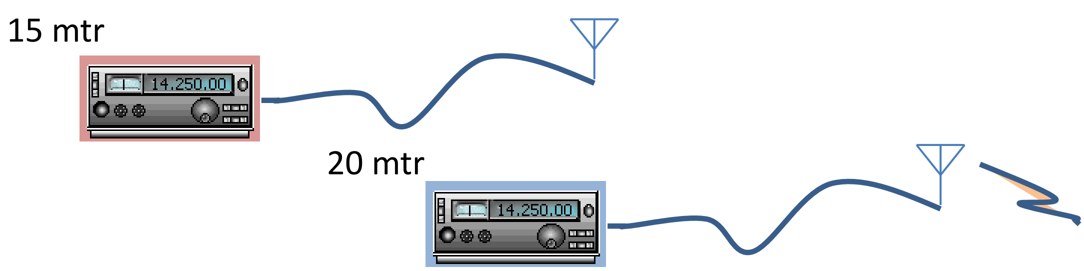
3/4 wavelength on 21.075 mhz

1 wavelength on 28.1 Mhz

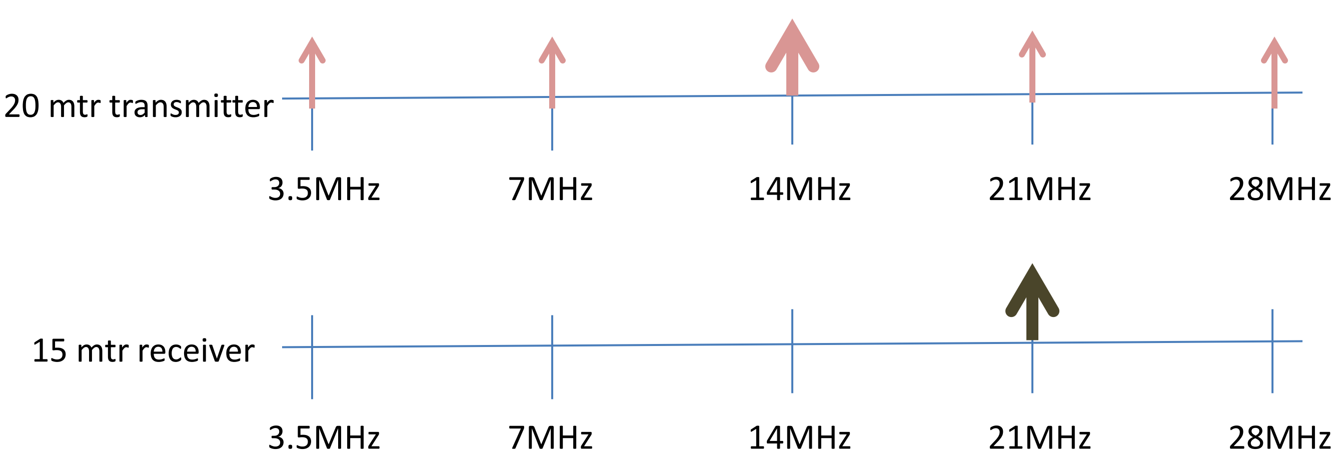
Effects on HF Ham Bands of a 40 mtr ¼ Wave Tuned Stub

Band	Shorted Stub	Open Stub
80	-------	------
40	pass	short
20	short	pass
15	pass	short
10	short	pass

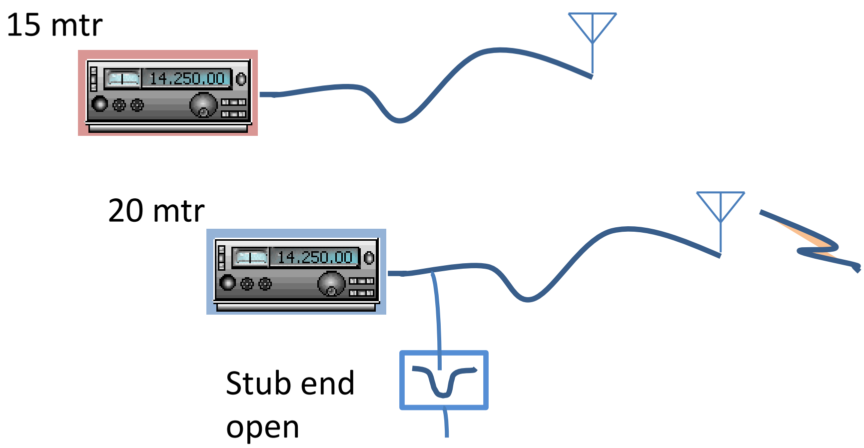
Our FD Interference Situation



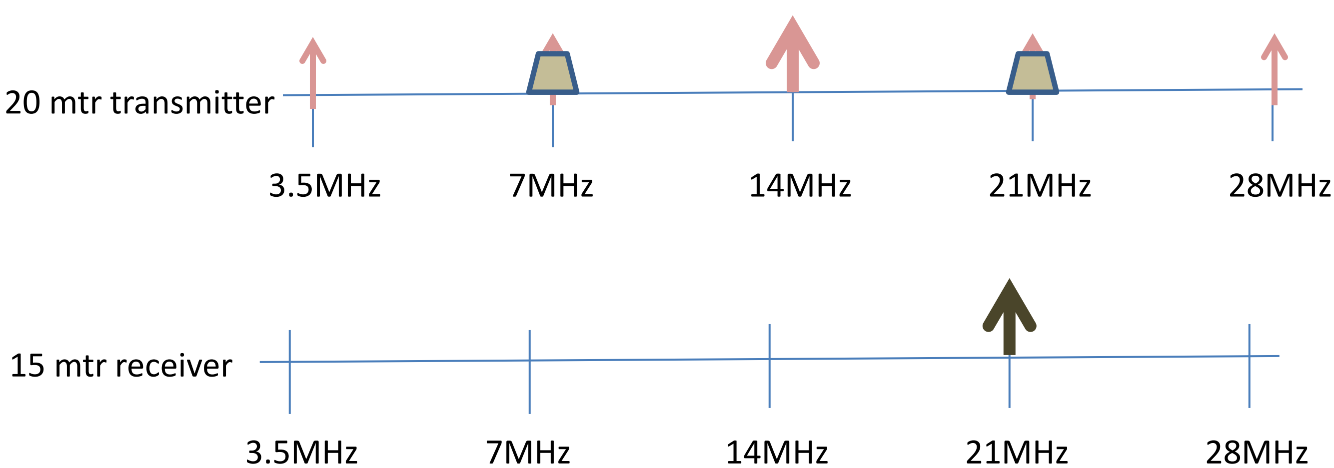
Assumed Interference Mechanism



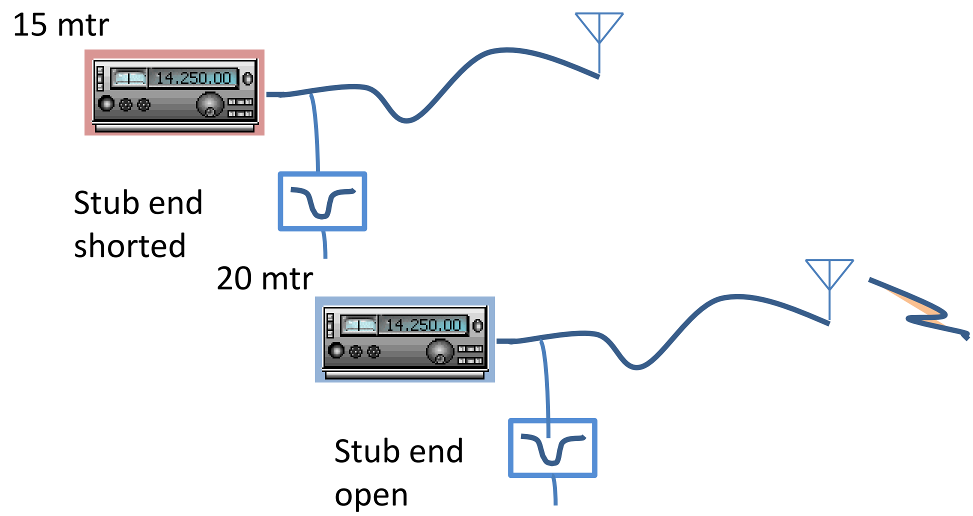
Our First FD Attempt at Filtering



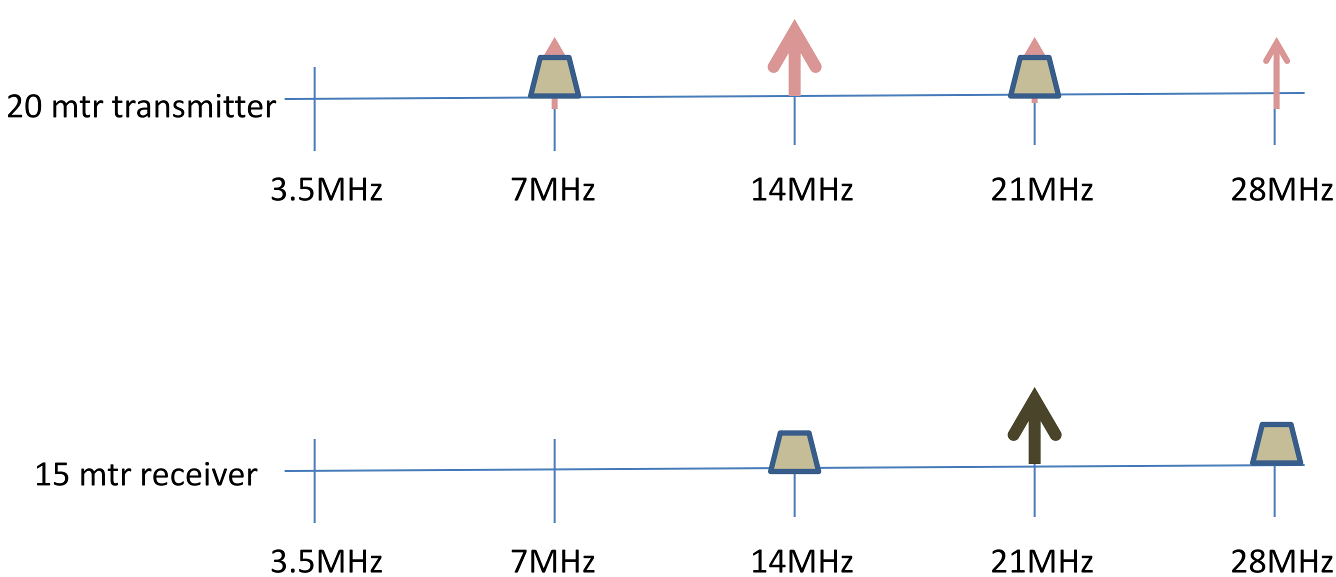
Effects of 40 mtr Tuned Stub on 20 mtr Transmitter



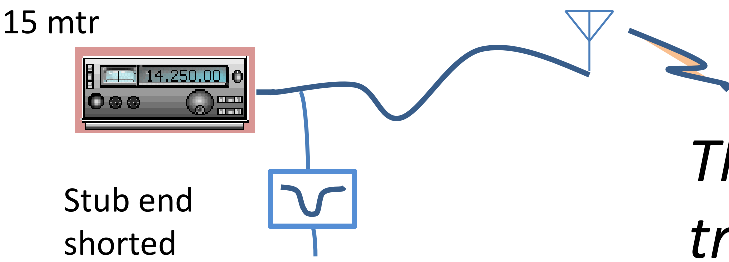
Our Second Attempt at FD Filtering



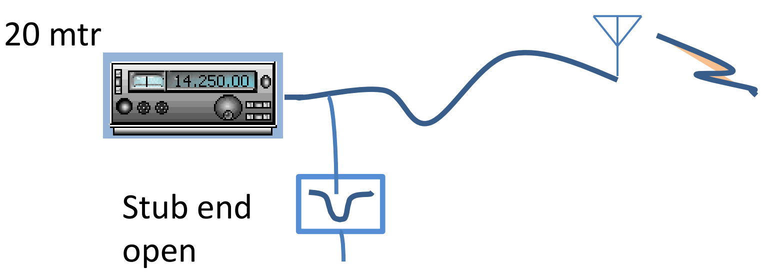
Effects of 40 mtr Tuned Stub on Transmitter and Receiver

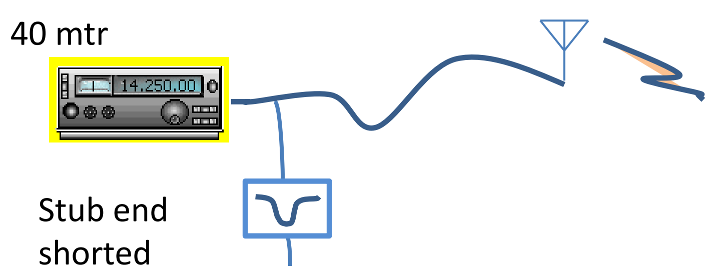


Our Field Day Tuned Stub Configuration



The offending 20 mtr transmitter was effectively isolated





Lessons Learned (1)

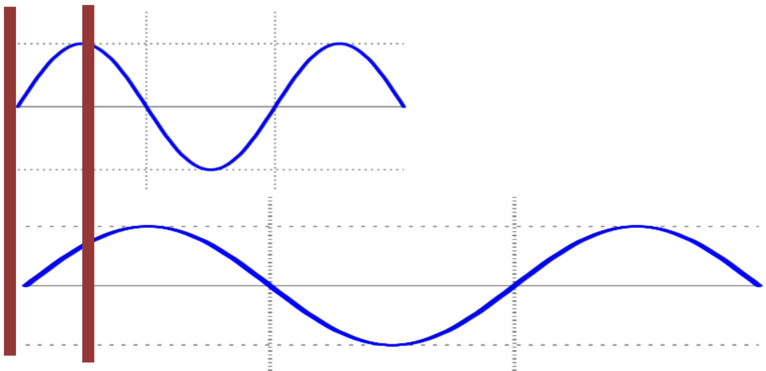
- Tuned Stub Filters are Easily Designed
  - Calculations are simple
  - Harmonic relationships must be considered in all designs, even single band filters
  - For multi-band single stub designs, band chosen must be at lowest affected frequency
- Tuned Stubs are Easily Built
  - Fast to build
  - Easy to tune with an antenna analyzer
  - Easy to test
  - Be careful about the quality of the coax; some old contaminated coax has very different velocity factors
  - Types of center insulation of coax limits loop sizes (avoid foam centers)

Lessons Learned (2)

- Tuned Stubs Require Thoughtful Hookups
  - Care must be taken to ensure correct configuration for band in use…don't short out your transmitter!
  - Danger! There is very high voltages on the open cable ends
  - ¼ wave stubs only work well on higher frequency bands
    - Our 40 mtr stubs would not work well with Interference on 80 or 160 mtr bands!

Why doesn't a 40 mtr stub work well on 80?

35 feet (free space)



35 feet is
¼ wavelength on 7.02 mhz

35 feet is
1/8 wavelength on 3.51 mhz

HOWEVER: ¼ wavelength on 80 is ½ wavelength on 40!

A 40 mtr stub will not work well on 80
but
A 80 mtr ¼ wave stub will work well on 40 and higher bands!

Lessons Learned (3)

- At field day
  - Using a filter on each of the interfering radios made some happy and pleasantly surprised operators
  - Using a single filter on one radio was insufficient
    - Two filters on the same radio during bench testing provided 3 dB additional suppression for one coupling mechanism, but overall effect was hardly noticeable!
    - Filter on the second radio was used to knock out second coupling
  - Filter Bandwidths covered our bands of interest with 4+ S units reduction per filter
  - As long as we stayed on a single band, the filters did not negatively affect our operations; switching bands required minor reconfigurations

Summary

- Our filter approach was effective for selected crossband combinations; not useful for all band interference combinations (we knew that going in)
- Tuned Stubs may not be the best EMI filter solution, but were very cost effective in our application!
  - Band harmonic relationships in tuned stubs can work for *and* against you
- At next FD, we may experiment with more tuned stub filters