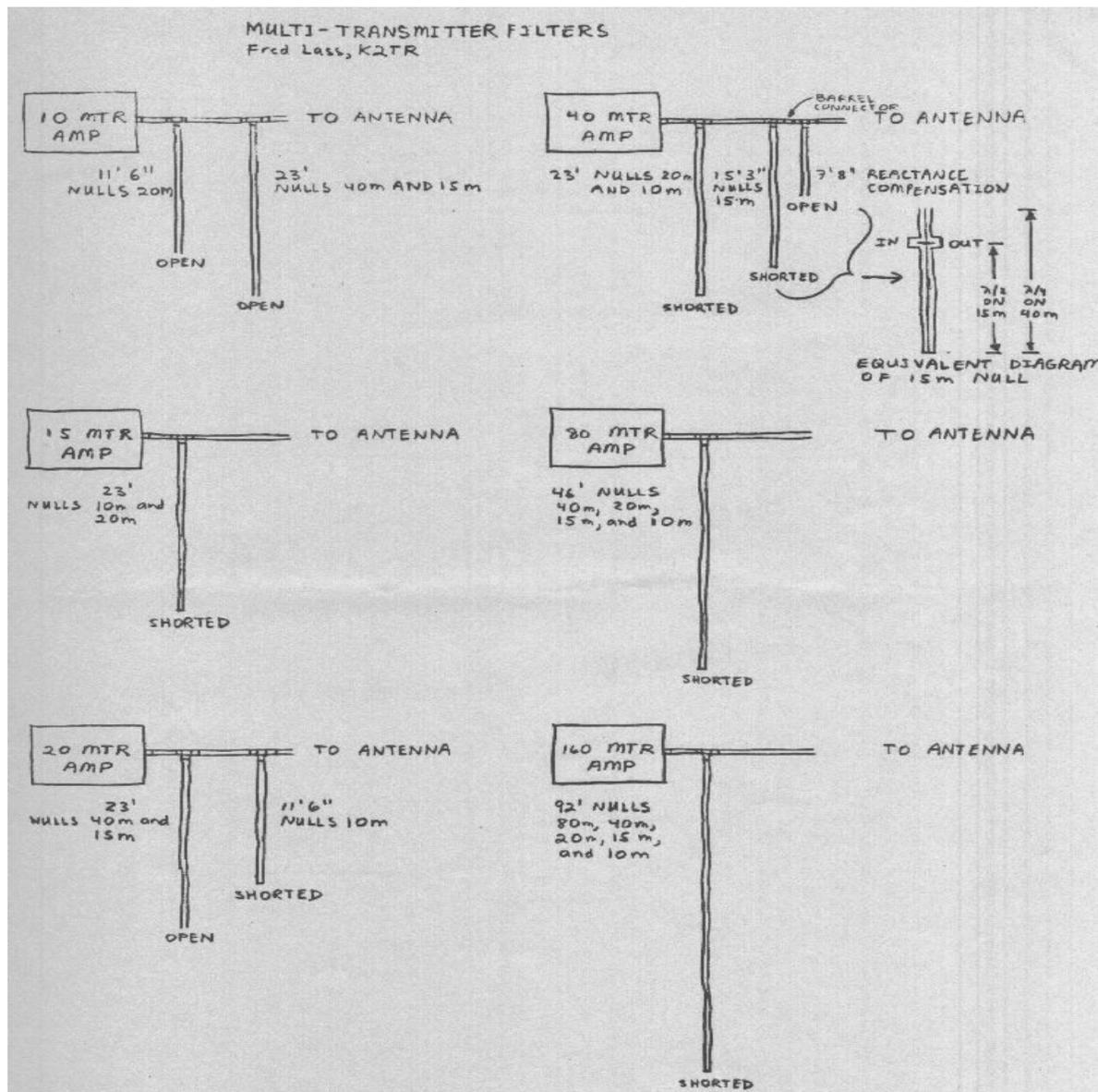


K2TR Coax Stub Filters



There are 1, 2, or 3 stubs as described below between the amp and the antenna. I like to keep them as close to the amp as possible, usually just a 'T' connector on the amp output or at the SWR meter.

The lengths below are for solid dielectric coax with a velocity factor of .66. I use RG-8, but you could also use RG-213 or RG-11. If you want to use a foam coax most of them have a velocity factor of .80. On the high bands (10, 15, 20) I use CATV hardline that has a velocity factor of between .81 and .83. The basic formula for a shorted 1/4 wave stub is $246 * V / f$. Where V is the velocity factor of the cable and f is the frequency in MHz.

Band by Band these are K2TR's stub plans. The copy of the article I have I think was from an old YCCC Scuttlebutt.

10 Meters. 2 Stubs

- 11' 6" OPEN nulls 20m
- 23' OPEN nulls 40m and 15m

15 Meters. 1 stub

- 23' SHORTED nulls 10m and 20m

20 Meters. 2 stubs

- 23' OPEN nulls 40m and 15m
- 11'6" SHORTED nulls 10m

40 Meters. 3 stubs

- 23' SHORTED nulls 20m and 10m
- 15'3" SHORTED nulls 15m
- 7'8" OPEN compensates for reactance from 15'3" stub. This pair of stubs works out to a 1/4 wave on 40m that is tapped at a point that results in a 1/2 shorted stub on 15m.

80 Meters. 1 stub

- 46' SHORTED nulls 40m, 20m, 15m, 10m

160 Meters. 1 stub

- 92' SHORTED nulls 80m, 40m, 20m, 15m, 10m

For more detailed analysis of stubs and pairs of stubs see my other notes:

- [Single Coax Stub Analysis](#)
- [Coax Stub Pair Analysis](#)

Analysis of Single Coax Stub

An article originally written for the YCCC Scuttlebutt

By David Robbins K1TTT

Since I started entering M/M contests I have been using Coax Stubs for filters to help separate stations. They have worked just fine and have provided around 30 to 40 dB of attenuation of harmonics. I have been curious about a few points of using them though, like:

1. How much attenuation should a stub provide?
2. What kind of bandwidth should a stub cover?
3. How does the cable loss affect attenuation?
4. How much power gets dissipated in the cable? (I didn't consider this until a stub made out of RG-59 melted down in one contest.)

This 'document' was created by using "MathCAD". "MathCAD" is a program for IBM PC's and compatibles (and also Unix workstations) that provide the capability to write formulas and then plug in numbers to calculate results, solve equations, and plot results. The original equations for this calculation were from the "MathCAD" electrical engineering applications pack.

In this initial example I will attempt to answer the first two questions using a 1/4 wave shorted stub of RG-8 for attenuating the second harmonic of 20 meters that would interfere on 10 meters.

To get the calculations started I have provided the following characteristics of the cable itself:

Impedance

$$Z_0 = 50\Omega$$

VelocityFactor

$$V = .66$$

Loss

$$\alpha = 1 \text{ dB}/100'$$

Length

$$d = 11.5'$$

TerminationImpedance

$$Z_L = 0\Omega$$

The frequency range I want to plot will cover the lower end of the 10 meter band that could be covered by a 20 meter harmonic.

Now the calculations begin, this is where "Math CAD" really does its job:

Define complex wave number.

$$\beta(f) = \alpha + 2i\pi f/Vc$$

Define impedance as a function of frequency and distance to termination:

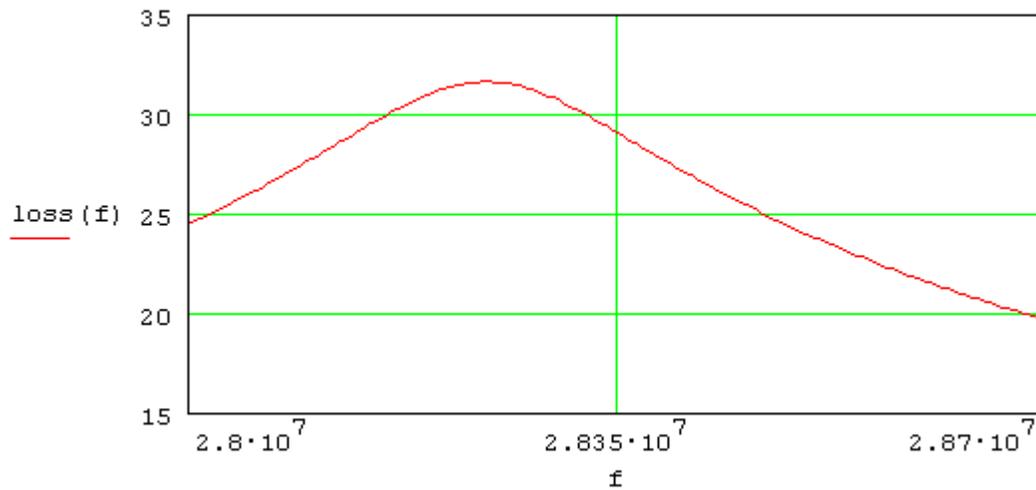
$$Z.\text{trans}(freq, len) =$$

$$Z.\text{line} \left(\frac{(Z.L + Z_0 \tanh(\beta(freq) len))}{(Z_0 + Z.L \tanh(\beta(freq) len))} \right)$$

$$\text{loss}(f) = 20 \log(1 + ((Z(f,d) - Z_0)/(Z(f,d) + Z_0)))$$

This is a plot of the attenuation provided by the stub. You can see that it provides about 32 dB of attenuation at 28.25 MHz. The bandwidth seems much narrower than I had expected, but I don't really have anything to measure it that accurately. I have seen about 30 dB of attenuation in some rather crude tests here so the overall result seems reasonable.

From these results I am considering making 2 sets of stubs, or providing a way to add or remove a few inches between CW and SSB contests since there could be over 10 dB attenuation difference across the band. Using a better cable would make the attenuation better, but would also make the bandwidth even narrower.



Analysis of pairs of Coax Stubs

An article originally written for the YCCC Scuttlebutt

By David Robbins, K1TTT

This is the second installment of my article about coaxial stubs for filters on transmitters. In the first installment I derived the basic attenuation features of a 1/4 wave length stub connected between a transmitter and an antenna. In this installment I will attempt to answer the question about using 2 stubs together to get better rejection. Before I start this time I must make one note about the previous article... I made an over simplification in the calculation of the loss function that added about 6 dB of attenuation, the max attenuation for the single stub should have been about 31 dB instead of 37 dB as plotted.

I am now using the new version of Mathcad for Windows 3.0, it is much nicer than the original and I highly recommend it for anyone seriously planning to work on anything like this. (for you legal eagles out there: Mathcad is a product of MathSoft, Windows 3.0 is from Microsoft)

In working on this document I changed it quite a bit from the last version, I added separate parameters for the cable for the stubs so I could look at using different cable for the stubs than for the transmission line. I also added the formulas to vary the distance between the two stubs as well as the length of each stub. This results in a much more complex problem and it becomes very difficult at times to visualize what is happening. I will attempt to show the various relationships by the use of plots of attenuation vs frequency and the distance between the stubs. First I will define the parameters for the feedline.

Z_0 is the characteristic impedance of the line

V is velocity factor,

α is loss in dB/100'

The values used here are:

$$Z_0 = 50\Omega$$

$$V = .66$$

$$\alpha = 1 \text{ dB/100'}$$

Now for the stubs.

Z_{stub} is the characteristic impedance of the stubs,

V_{stub} is the velocity factor and α_{stub} is the loss for the stub.

d_1 and d_2 are the lengths of the stubs and Z_L is the termination impedance. (0 ohms is of course a shorted stub).

$$Z_{\text{stub}} = 50\Omega$$

$$V = .66$$

$$\alpha.\text{stub} = 1 \text{ dB}/100'$$

$$d.1 = 11.5' \quad d.2 = 11.5' \quad Z.L = 0 \Omega$$

These values are for a pair of shorted 1/4 wave stubs on 20 meters. These will of course reject the second harmonic that would fall in the 10 meter band.

The formulas for Z.trans and Z.par are defined at the end of the document. What they do is simple, Z.trans just uses Smith Chart formulas to transform an impedance from one end of a line to the other. Then Z.par uses the basic formula for paralleling two impedances. The index values (n) and (m) added to some of the variables enable me to vary them over a range of frequencies (for (n)) or to change the gap between stubs (for (m)).

The basic flow of calculations is as follows:

- 1. Calculate Z.1 which is the impedance at the end of the first stub
- 2. Parallel first stub with main line = Z.a
- 3. Transform Z.a to connection point of other stub = Z.gap
- 4. Calculate Z.2 for impedance of second stub
- 5. Parallel second stub with Z.gap to get Z.net
- 6. Use Z.net to get reflection coefficient and then 'loss' value

$$Z.1(n) = Z.\text{trans}(Z.\text{stub}, V.\text{stub}, \alpha.\text{stub}, Z.L, f(n), d.1)$$

$$Z.a(n) = Z.\text{par}(Z.1(n), Z.0)$$

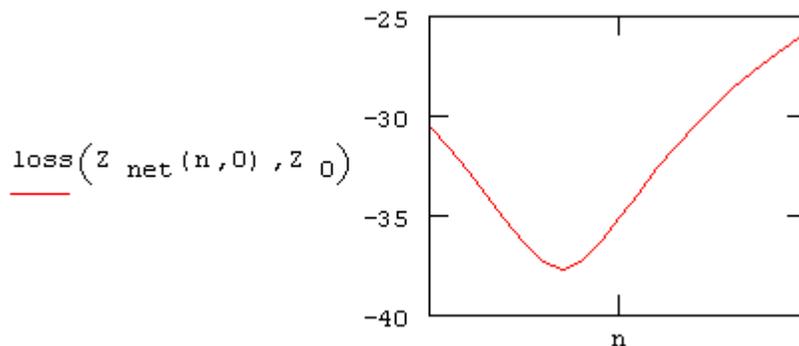
$$Z.\text{gap}(n, m) = Z.\text{trans}(Z.0, V, \alpha, Z.a(n), f(n), \text{gap}(m))$$

$$Z.2(n) = Z.\text{trans}(Z.\text{stub}, V.\text{stub}, \alpha.\text{stub}, Z.L, f(n), d.2)$$

$$Z.\text{net}(n, m) = Z.\text{par}(Z.2(n), Z.\text{gap}(n, m))$$

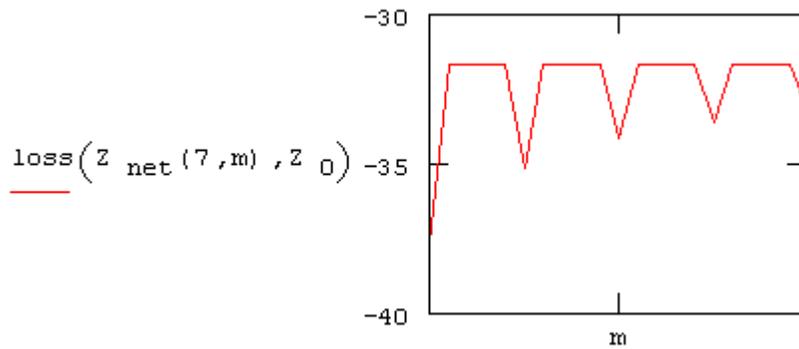
Now we can play with fancy graphs to see what we have. First lets plot attenuation vs frequency for a gap of 0' (i.e. the two stubs are connected to the same point).

This shows the attenuation as the frequency is swept across the 20m band. Note that the max attenuation is about 6 dB better than a single stub.



Now lets see what happens when the distance between the stubs changes. For this plot I will hold frequency constant and vary the spacing. This shows the change from a spacing of 0' to 46', or about 1

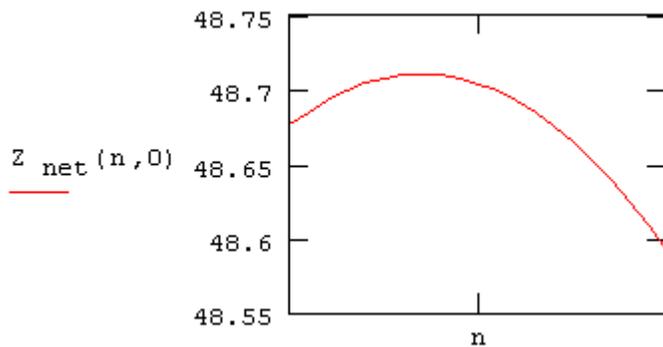
wave length at 14.1 MHz. Note the dips at 0, 1/4, 1/2, and 3/4 wavelengths.



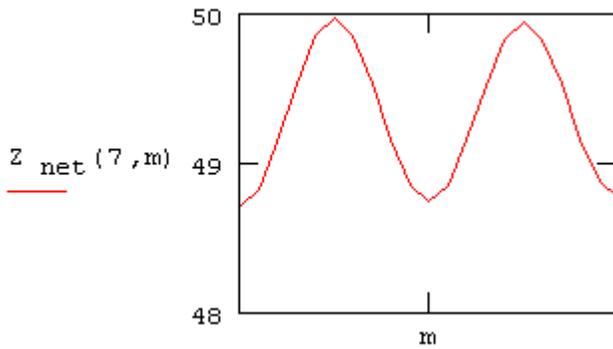
This is a very interesting result, nothing at all like I had expected. But after long contemplation it seems to make sense. Consider first the farthest stub from the transmitter. It presents a very low impedance to the harmonic that is trying to be rejected, this low impedance is then moved along the transmission line toward the second stub. As this impedance is transformed along the 50 ohm line it changes from low to high and back over each 1/2 wave of the line so that after each 1/2 wave it is back to the original low value. At a point 1/4 wave along the line it presents a very high impedance. When the second stub is added it also presents a low impedance, but the total impedance seen by the source is a parallel combination of the transformed impedance from the first stub and the impedance of the second one. If they are both low at the same time the net impedance is even lower and better rejection results. When the transformed impedance of the first stub is high at 1/4 wave from its connection then the 2 stubs are fighting each other and the rejection is lower.

Now lets take a look at the pass band characteristics, in particular the impedance presented to the radio.

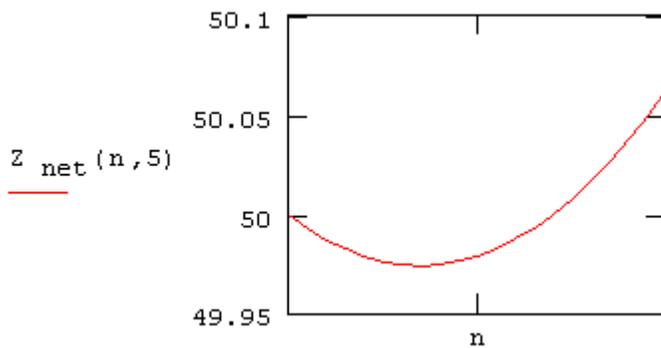
This shows the frequency dependence of the impedance at a spacing of 0' between stubs. Note how it changes over the width of the 20m band. It shouldn't be enough to affect most transmitters, but it does add another factor to tuning.



Now we take and hold frequency constant and vary spacing. Note that at 1/4 wave and 3/4 wave spacing the impedance is almost exactly 50 ohms.



And now lets sweep the frequency across the band at a spacing of 1/4 wave to see how this arrangement behaves. This change shouldn't bother any of todays transmitters or amps.



Now the trade off... For best rejection of harmonic, as I showed above, put the two stubs at the same point. For least effect on tuning of radio/amp put the two stubs 1/4 wave apart. Personally I put both stubs at the same point, it is easier to build, and I don't feel the change in impedance is severe enough to spend the extra time and effort to space them out.

Formula definitions for use above.

For parallel impedances x and y . This can be used to figure net impedance of stub connected to feed line

$$Z_{par}(x,y)=1/((1/x) + (1/y))$$

Reflection coefficient given impedance of transmission line Z_0 and impedance of load Z_{load} .

$$\rho=(z_{load} - z_0)/(z_{load} + z_0)$$

Complex wave number, given f =frequency, V =velocity factor, α =loss of line. Constant c =velocity of light

$$\beta(f,V,\alpha)=\alpha+2i\pi f/Vc$$

Formula for transformed impedance along length of coax cable.

Input values are:

Z_{line} = characteristic impedance of transmission line

V = velocity factor

α = loss of line

Z.start = impedance at starting point(far end of line)

freq = frequency

len = length of line (in feet)

Z.trans(Z.line,V, α ,Z.start,freq,len) =

$$Z.line \left(\frac{(Z.start + Z.line \tanh(\beta(\text{freq}, V, \alpha) \text{ len}))}{(Z.line + Z.start \tanh(\beta(\text{freq}, V, \alpha) \text{ len}))} \right)$$

This is formula for loss due to reflection from mismatched load. Used here to figure reflection from intersection of stub with main transmission line.

$$\text{loss}(Z.load,Z.line) = 20 \log(1 + \rho(Z.load,Z.line))$$

coax stub summary

To: cq-contest@tgv.com

A while ago I was looking for info on making/using coax stubs for filtering between two stations. Thanks to W1PH, VS6W0, KY1H, K3NA, K1VR, W0CP, K3LR, KR0Y, WA60TU, WM2C, ON6TT, N40GW, (and maybe a few others who got lost while cutting and pasting this together) for the hints and comments. Several cited the K2TR article in the May - June 1984 NCJ. Following is a collection of the various comments received (in no particular order) beginning with the original post.

Mike N0BSH
n0bsh@aol.com

I'm looking for information on using coax stubs for filtering between the two stations. Some questions that come to mind include:

- 1) Lengths required for nulling various bands - open/shorted?
- 2) Can stuff like RG58 be used or should we stick with RG8 (will be running about 1KW on each station?)
- 3) Do they need to be made with 50 ohm coax or can 75 ohm be used (have some of both laying around?)
- 4) Can we put these on a coax switch and switch in the ones we need depending on band?
- 5) Is it worth all this or should we just get out the MC/Visa and buy the Dunestar filters?

1. Lengths required: This depends on the velocity factor of the coax being used to make the stub. In addition, you will have to have an appropriate serial coax impedance transformer between the point where the stub and antenna feed attach and the radio. Otherwise the radio will see a wierd impedance and potentially high SWR. The lengths of the serial matching coax sections will be different for each combination of antenna and band-stub. (If you are getting the impression that this is complicated, you are correct!) Either shorted or open-ended stubs can be used. However, shorted stubs are easier to build properly. Open stubs tend to leak at high powers (remember, that will be a very high voltage point at the end of the open stub!)

2. The quality of the stub as a filter depends on the loss of the coax. RG58 coax has high losses and you will lose many 10s of dBs of filtering. Even RG-213 is pretty marginal... (This is another problem for the use of stubs in an expedition...)

3. Effective stubs can be designed using any impedance of cable, although the lengths of the matching sections will change.

4. Coax switching of stubs is very complicated because the matching sections must also be switched.

5. It is simpler to buy the filters. You will get similar performance to reasonable-quality stubs (altho not as good as excellent stubs, and not at 1500 W power levels). Switching is a breeze. And Dunestar or ICE filters are smaller and lighter to carry with you to the site.

The stubs are easy and cheap. I use RG62A/U that I bought by the pound from a metal salvage yard. Impedance of the stubs does not have to match the transmission line. RG62A/U is 93 ohm coaxial cable. Small cable is fine as it only has to carry the spurious signal. I use 6 dedicated feed lines for the 6 bands and have stubs permanently attached to each line. There is no reason not to use a switch to select the right stub. But if you forget to switch, the amplifier may be looking at a short circuit with the wrong stub. Stubs are not real high Q devices and seem to cover an entire band easily.

An effective combo of stubs and filters allows almost any band/antenna combo to be on the air at the same time.

Yes, stubs are worth it even if you use ICE or other tx filters I think. Most of the other filters are only exciter level so you put them between the exciter and amp, but they don't do anything for amp produced harmonics. In general the stubs are 1/4 wave shorted pieces of coax, except on 40m to null out 15m harmonics. If you are running kw's you want to use at least rg8x, preferably rg8 or rg-213. We melted down a stub using rg-59 here one contest. No, the impedance of the coax doesn't matter, but the lossiness of it does. Going from rg-58 to 3/4" hardline increases nulls from about 15 to about 40db. Using decent quality rg-8 gives good results. Yes, you can switch stubs, just remember that the size of the switch and any connecting coax pieces add to the length of the stub so shorten up the stub to compensate for it.

As most expeditions involve dragging too much stuff through reluctant airline channels, I'd recommend buying the DuneStars. Yes, you may bandswitch stubs in and out. Yes, you may make them out of 75 ohm cable. But to make stubs that work, you MUST have a testing machine that will read out frequency (AEA, MFJ, network analyzer, etc.) RG-58 vs. RG-213: The less loss, the better the stub performance. Remember, DuneStars go between xcvr and amp. Stubs of RG-213 can go after amp. I use ICE bn xcvr and amp, stubs of .750 inch diameter between amp and antenna.

Coax stubs are best at reducing broad band phase noise from nearby transmitters. They will provide about 20-25db attenuation on the next nearest band. The lower the loss of the coax used on the stub, the deeper and narrower the notch will be - take your pick from any coax that will handle the power. Note that stations have had stubs melt in the 'heat' of battle!. Better stick with 50 ohms... Many stations don't bother with stubs in multi-single - just good rx filters.

There is a middle way, which is to use an ant tuner as a "tunable stub". This doesn't work in a m/m operation, but for what you guys are doing, it might be the best approach. I have used MFJ 16010 tuners for this, which cost about \$30. I can get about 30 db of rejection on the offending band. Operationally, you simply switch to the offending band and tune the device for minimum band noise, and put little notation marks on it for reference during the contest.

RG-142BU which is that fancy, teflon-on-the-outside, the-size-

of-RG58-but-takes-5KW stuff that you find at swapmeets. Using small coax has it's drawbacks, however, because of it's higher loss. One thing to remember about coax stubs is: The greater the loss, the sloppier the skirts of the filter, and the shallower the null as you sweep it. In other words, hardline makes fabulous coax stub filters, and RG58 makes ones that only work so-so. RG213 or RG8 (same thing, really) have been found by practical experience to represent the best all around compromise.

Noise bridge: Start with the coax a little longer than you expect it to be after you've measured it to a 1/4 wave including the velocity factor, then you use this noise bridge gizmo and sweep the coax with your receiver. Where the hiss goes away is where the stub is cut for. It was one of those technical marvel things where everyone else in the room dropped their jaws and gasped with amazement.

We use 2 sets of ICE filters. They are cheap (\$30) and work well. there are some buts:
...1 physical filter per band= a lot of filter switching (we built all of them in a box)
...everywhere I went, someone always blew up the 20m filter. get a spare
...200w only.
... we tested them in a lab, they DO filter, but only if the SWR is good. The higher the swr, the worse the filtering

A comical note. At a multi/multi I know well, they did not follow my advise and insisted in making their own 2Kw band pass filters. They tested the filters with the boxes still open and they performed well. They filled the filters with foam and closed the boxes. First minutes of the contest: everyone blew the filters up: the foam did not dry!

1) All the stubs I have used are 1/4 wave in length...if you leave the end open, the other end will appear to be closed. If the end is closed, the other end will appear open. So for example, to put a 20m null on you 40 antenna, put on a 1/4 wave 20m stub, and leave the end open. Or you can put a 1/4 wave stub on your 20m antenna, and leave the end closed. One trick that I have used for open stubs is to put a small air-variable cap on the end, and make the stub just slightly shorter than 1/4 wave...then you can set the null exactly by twiddling the cap while listening to the receiver.

2) Don't use RG58...the better the coax, the deeper nulls you will get.

3) Doesn't matter...I'm currently using 75 ohm double-shielded RG-11 that was made for computer networks.

4) Yes, that is what I do...put a T connector on top of the switch. Be sure to account for the switch changing the length of the stub (use something like a noise bridge to cut them to length).

5) My current setup...I have 4 1/4 wave stubs on a coax switch to use with an all-band dipole. The stubs are closed on the end, so I switch in the one that is 1/4 wave on the band I'm operating on. There is some improvement, but not that impressive (my antennas

are very close together). We played around with some of the ICE band filters at FD, and they seemed much more effective. Probably would also be lighter to take filters than lots of coax stubs on a dxpedition!

If you wanna really do it right, you need bandpass filters and stubs!

1) Length is critical. Use a network analyser or other device to tune the stubs. Stubs are very frequency sensitive... you'll need one for SSB, and another for CW if you are trying to squeek out evry last dB.

2) Power was not the problem. RG58/RG8X did not (in my case) provide nearly the same attenuation per null as the RG8/213 did.

3) Suspect you can use 75 ohm. You will already have a small impeadence bump when you tap for the stub.

4) Yep. Be careful, for the coax switch adds enough length to the effective length of the stub to change the null outside your desired band segment!

5) Good question. All depends if you want to do the filtering before or after the amps. Amps are known for suprious emmissions. The stubs will help cure that, Dunstar/ICE won't. If you buy new RG213 for 160 thru 10, you come out about even with a set of ICE's.

Thanks again to all for the good info. CU from PJ8Z in CQ WW SSB 94!
Mike N0BSH
n0bsh@aol.com