High Power Notch Filter

To make sure his 50MHz signal was as clean as possible, Nick Moldon G1BVI made himself an effective filter using stub techniques.

Since space limits the size of the antenna at my location, I've had to make do with a 3-ele antenna for 50MHz. To increase my outgoing signal further, I've built a full legal limit, semiconductor (f.e.t.) r.f. power amplifier to get over this low forward gain problem.

Built with a view to the future, the amplifier itself is a broadband unit, working from 1.6MHz upwards and its response doesn't start to 'fall off' until around 70MHz. It can also produce a full legal output right up through the 50MHz band, though I've not tested it at higher than 70MHz.

Major Problem

The major problem that affects users of the 50MHz band is, that second harmonic output from 50MHz transmissions are notorious for causing interference to Band II domestic f.m. radio. It's therefore most desirable that the various harmonic outputs are suppressed as much as possible.

When running full legal limit power it's also vital to ensure that only a clean harmonic free output is allowed to reach the antenna. By keeping the out-of-band signals to a minimum, neighbours should experience the fewest TVI/BCI problems.

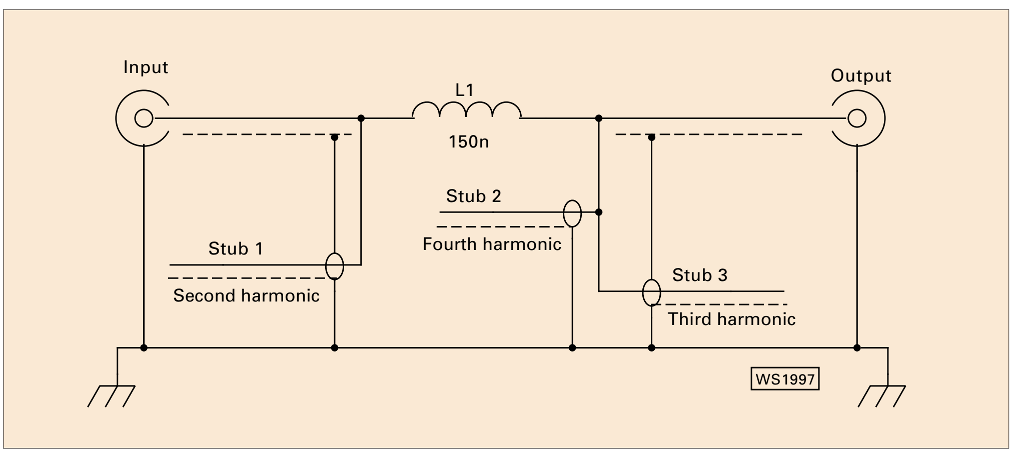
My amplifier being broadband, covering up to at least 70MHz, would seem to be a possible candidate for TVI/BCI problems. When it was designed, the specification was that it should have a frequency response that started to roll off from about 70MHz. Given this parameter, a signal at 100MHz, present at the input, should have very low gain through the amplifier.

Fig. 1: Looking very simple, this filter is capable of excellent rejection at harmonic frequencies. See text for more details.

External Filter

However, in spite of the amplifier's design specifications, some kind of external filter must be added to ensure that the signal has the minimum harmonics as possible (generated or amplified). So, I decided that a low-pass filter with a roll-off starting at about 55MHz should be constructed for the output of the amplifier.

The filter had to be a good suppressor of any potential second harmonic from 50MHz operation. But useful extra suppression can be brought about with the filter described here. I've incorporated other notch filters, designed to reduce the second, third and fourth



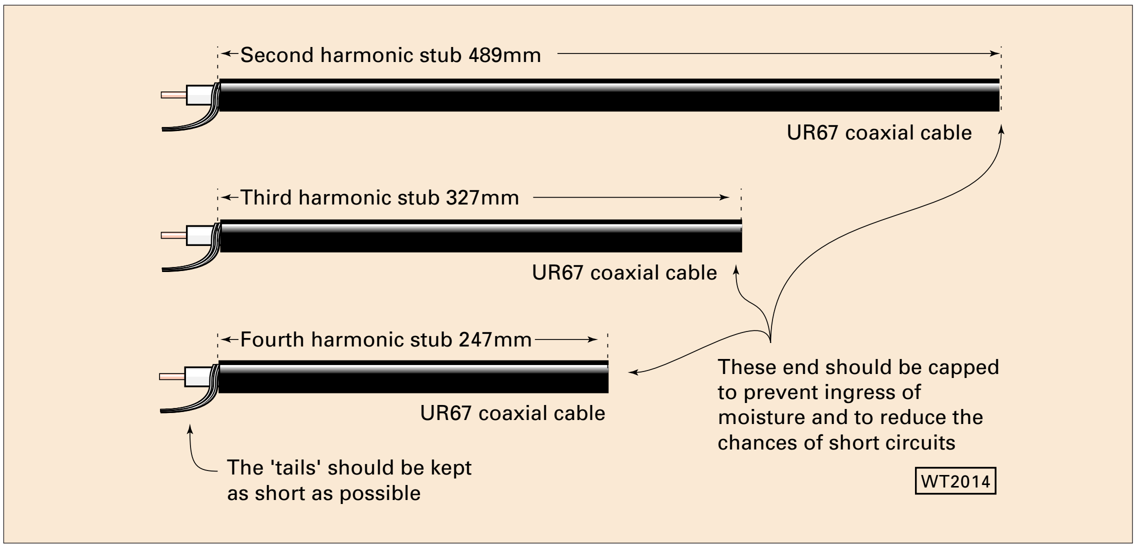


Fig. 2: The three quarter-wave stubs should have their open ends capped with insulating material to reduce the chance of shorting across.

harmonic of 50MHz output too.

The potential harmonics from 50MHz operation are at 100-104MHz, 150-156MHz, and 200-208MHz. Of course any second harmonic is likely to cause interference to Band II reception in your area (and don't forget, the 100-104MHz section is used for many local and low power radio stations).

Disastrous Effects

If you live near, or operate near coastal waters, then potentially disastrous effects, may be experienced, as the third harmonic of the 50MHz band occurs near the the v.h.f. marine band of 156MHz. There could also be problems with some rigs in the Amateur band at 144-146MHz too.

Higher in frequency, the fourth harmonic, at 200-208MHz might cause some problems for any official users of that band. So, I decided that the fourth harmonic had to go too!

As the amplifier is high powered, any harmonics generated could potentially still be at a fairly high level. So, I decided not to use discrete component filters, but to use tuned coaxial lines for each notch frequency. These filters were cut from good quality new, UR67 coaxial cable.

If you're only intending to use a less than full legal output, then thinner cable could be used. **But please choose good quality cable** even when 'low' power (up to 100W) is to be used. The quality of the cable will tend to control the effectiveness of the filter itself, as well as its power handling capabilities.

When you're considering making stub filters using coaxial cable, you must remember that the velocity factor of the cable has to be taken into account, especially if you intend to use different coaxial cable. See the separate panel for more information about making filters for other frequency bands.

Junk Sale

My filter is built in an aluminium box approximately 300×130×80mm that I bought at one of the club junk sales. I've used N-Type socket, one at each end for both input and output connections. To give a sufficiently good 'earth' connection between all the various components, a one millimetre thick, 30mm wide copper strip was added.

The copper strip was bent into a 'U' shape between the two input/outputs sockets. In my initial design, it was envisaged that the coaxial stubs, when fitted, the 'inner' end of the braid would be soldered direct to the copper strip. But since then I've found that the strip is not essential.

An insulating block is secured in the centre of the filter onto which is mounted the coil L1. As mentioned earlier, my original idea was to solder the braid to the copper strip, but in practice, due to the stiffness of the coaxial cable, this was not possible. So, I ended up adding solder tags at the points where the braid was to be secured.

So, enough of the design ideas, let's look at the circuit of the

Metallic Insulators

Stub lines or coaxial stubs can act rather like metallic insulators when used correctly in one band, or close to one design frequency. In fact λ\4 stubs are often used at high u.h.f. and microwave frequencies, where the lengths of quarter-wave stubs are quite short.

To design a quarter-wave (λ/4) stub is quite simple. Start by looking at the idealised current and voltage graph of an electrical quarter-wave **Fig. 4**. At point A, which would equate to the open end of the line, there's lots of voltage, but little, or no current. From Ohm's Law you will know that this represents a very high resistance.

And yet a quarter wave-length away at the point B, there's no voltage, but the current is now at a maximum. Again from Ohm's Law we can see that these conditions would only occur at a very low resistance point. If this is a very low resistance point, then shorting the the two conductors together at this point would not significantly alter anything.

Now if you bear in mind that we are dealing with physical distances then if we stick close to one frequency whose λ/4 is equal to the distance between A and B, then if one end is open circuit, the other appears, **at that one frequency**, to have a short circuit at the other point.

In feeder of any description, the electric wave travels slightly slower than in free-space. This has the effect of **shortening** the physical λ/4 (although it's still an electrical λ/4). The relationship between the speed of travel of an electric wave in the feeder to the speed of propagation in free space is called the Velocity Factor (often shown as V_f) which is always less than one.

For Unirad67 coaxial cable (UR67) the velocity factor is 0.67. So, to calculate a quarter-wave stub in UR67 we can use the formula:

$$\text{Stub } (\lambda/4) \text{ length} = \left\{ \frac{300}{f_{(MHz)} \times 4} \times V_f \right\} \text{m}$$

Now verify this, with say our second harmonic stub. Take the centre frequency of 102MHz, and fit into the above equation. The answer comes out to within one millimetre at 490mm. This answer is closer than one quarter of one percent. And as our band is almost four percent wide (50-52MHz), this is accurate enough.

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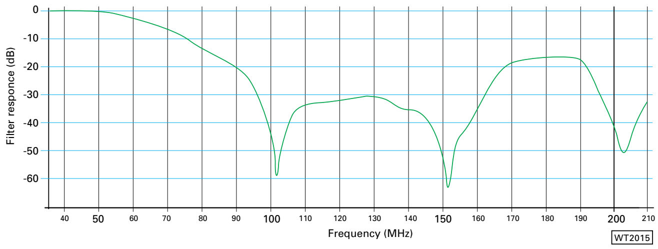

Fig. 3: Note the three deep rejection notches due to the open ended stubs.

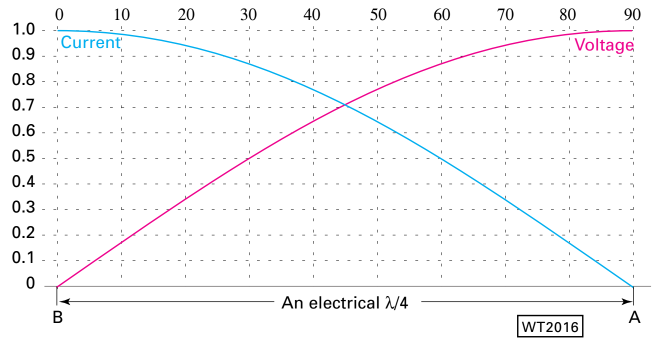

Fig. 4: Voltage and current curves on a quarter-wave section of unterminated feeder (see text for more details).

Notch Filter is shown in **Fig. 1**. the coil, L1 is a 150 nano Henry (nH) air-cored inductor, and was made using 1.5 mm diameter copper wire. As I intended this filter to handle a lot of power, I first threaded PVC sleeving over the wire before winding the coil.

Suitable Former

To wind the coil, I needed a suitable former and I found a twist drill shank rather handy for this. By luck more than judgement I found that four turns close wound on the shank of a 9.5mm drill gave me the required value coil.

Now to the stub filters themselves. All the Coaxial stubs are of the 'open circuit', λ/4 type. See the separate box for more details of how they work and how they may be constructed. The table, **Table 1**, and the illustration, **Fig. 2,** give the lengths and dimensions for the stub filters using UR67 coaxial cable.

Note: For safety reasons, the open ends of the coaxial cables should be capped or insulated to avoid shorting to the metal box.

As you will see if you read the separate panel about coaxial stub filters, the stubs should all be cut as accurately as you can. The 'tails' connections should all be made as short as possible. And all measurements are taken from open end of the cable, to the separation of the braid from the inner.

And although you could use other types of plugs and sockets, I'd advise anyone contemplating working with high power equipment up to and including u.h.f. to use N-Type connections rather than SO239/PL259 types.

Slightly Long

I think that I may have cut the third and fourth harmonic stubs slightly on the long side. This moved the third harmonic notch lower in frequency, nearer to the 144MHz Amateur band. Despite this, I was very impressed with the results from such a simple filter.

The measured filter parameters, agreed quite closely with the designed filter passband as shown in the graph of **Fig. 3**. If you have other bands or other frequencies that you need to filter out then see the separate panel.

The filter has been tested to 1kW with no problems, and does not get warm in normal use. So, if you work 50MHz then you should definitely consider one of these filters.

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