The development of the single coil Z match antenna tuner

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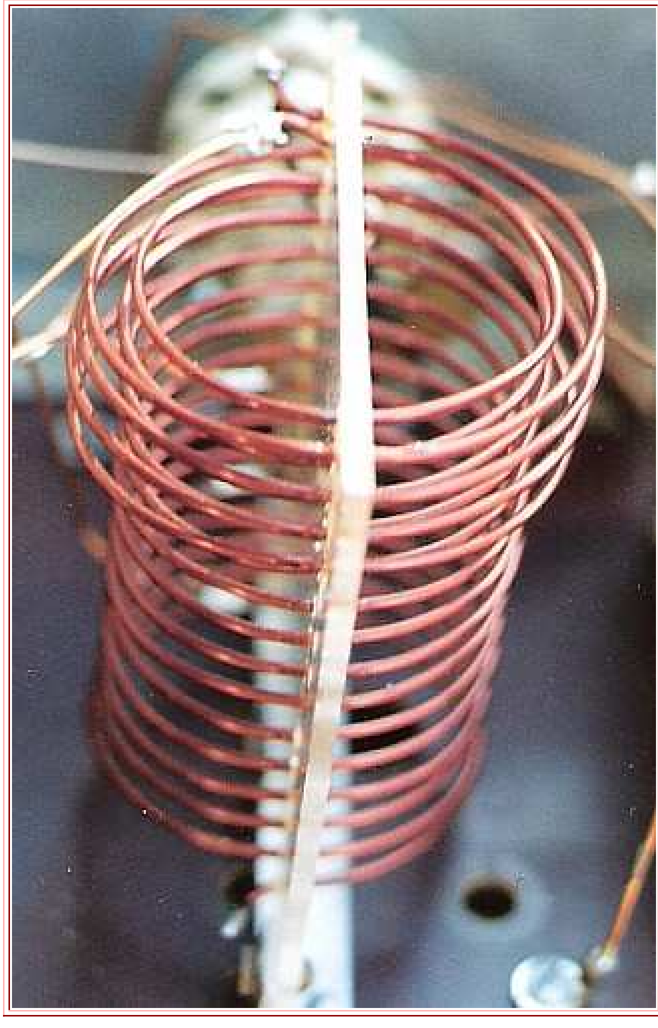
The single coil Z match antenna tuner is probably the simplest multi-band, multi-load range tuner one could make. This is the story of how its precise design was fine tuned to work without drop-out of load regions. It is also a story about the radio amateurs who helped make it work.

In the late 1980s and early 1990s I went through a phase of performance testing of various forms of Z match tuners. This was encouraged to a large extent by Reg Southwood, then VK3CCE, who had a interest in building different forms of these tuners. At the time, Reg liked to remain anonymous and the Southwood models were given anonymous publicity in the *Amateur Radio (AR)* column of *Random Radiators,* courtesy of Ron Fisher VK3OM. As part of the evaluation of the Reg's models, Ron sent some of them over to me and I carried out performance tests, particularly for load range.



The single coil used in the single coil Z match antenna tuner is wound with 16 SWG enamelled wire on a drilled Perspex sheet former.

Reg eventually assembled a model based on a circuit idea published in the March 1992 issue of New Zealand journal *Break In* and written by Tom Seed ZL3QQ (Reference 1). As far as I know, this was the first introduction to the circuit form we now recognise as the Single Coil Z Match.

With the one coil assembly, the circuit was able to resonate at two different frequencies and tune over two different adjacent frequency ranges. As I had done with the other models, I plotted load range curves and various gaps showed up in the range of load impedances that the single coil tuner could match. But this was something new and it needed only half the components of the well known two coil Z match. So I experimented with the number of turns on the coil and the coil taps until I achieved a reasonably universal load range on all the usual amateur bands. That settled the design and Ron promulgated it through *Random Radiators* as the AR Single Coil Z Match (Reference 2).

At this point I will introduce the late Graham Thornton VK3IY. Graham wrote an article published in the March/April 1995 issues of *AR* concerning how an antenna L match circuit worked (Reference 3). He did an excellent job of explaining a very simple principle which I will outline in the following paragraph.

The L match reactive components make up a tuned circuit. If you want to reflect a lower resistance to the transmitter than that presented by the series resistance component of the antenna load, you feed in series with the tuned circuit and take antenna output from it in parallel (let's call this Mode A.) If you want the reverse (for a very low load resistance), you feed the tuned circuit in parallel

and take the output in series (let's call this Mode B). A more detailed explanation is also given in Reference 4.

To explain the events which follow, I have to tell you that, if the antenna load is a pure resistance less than the resistance reflected to the transmitter (normally 50 ohms), only mode B can work. However, if a series reactance is part of the antenna load, the series circuit of resistance and reactance can be translated into a parallel equivalent of two different values of resistance and reactance. The equivalent resistance is much higher than the series value, allowing the L match mode A to work on both low and high resistance loads. All of the Z match tuners are a modified form of the L match operating in mode A. Also, they have inbuilt inductive reactance in series with the antenna load. That is how they work for both high and low resistance loads. All this I understood, except for one little thing I hadn't taken into account. Read on!

Graham clearly became very curious about how the Z match tuner worked and, in particular, this single coil version. This led to his assembly of a computer programme to simulate the performance of the single coil Z design. His results were a little disturbing as they indicated that there were drop-outs, or what he called black holes, in the ability of the tuner to match output loads with low resistance. None of these black holes showed up in the curves I had constructed from my own load tests and I questioned the results of the simulation.

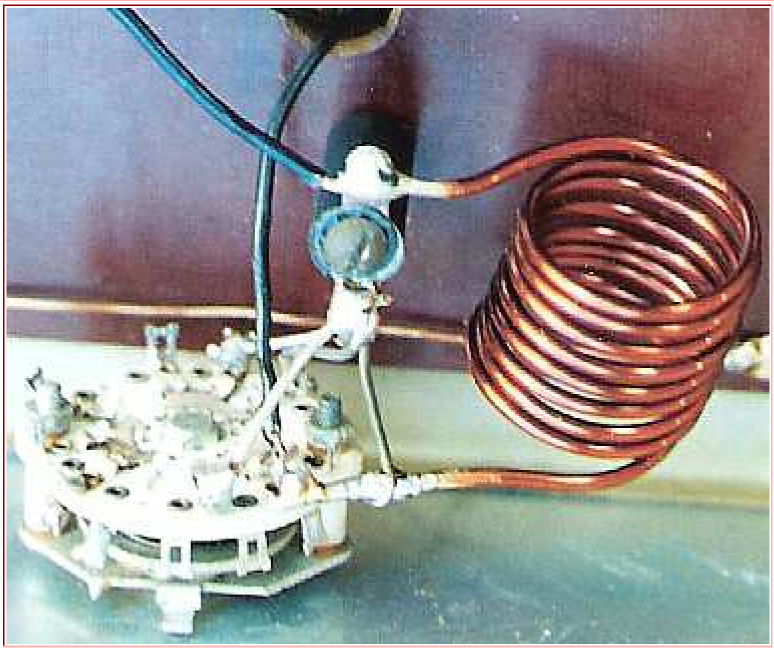
All this led to copious letters between Graham and I discussing the theory of how inductive reactance inserted in series with a low value of the resistive load enabled a match. (At that early frame of time we hadn't quite moved into the era of using email communication.)

Up to that point, in consequence of my own test results, I hadn't been prepared to accept that the circuit had these black holes. I guess you could say we were at loggerheads.

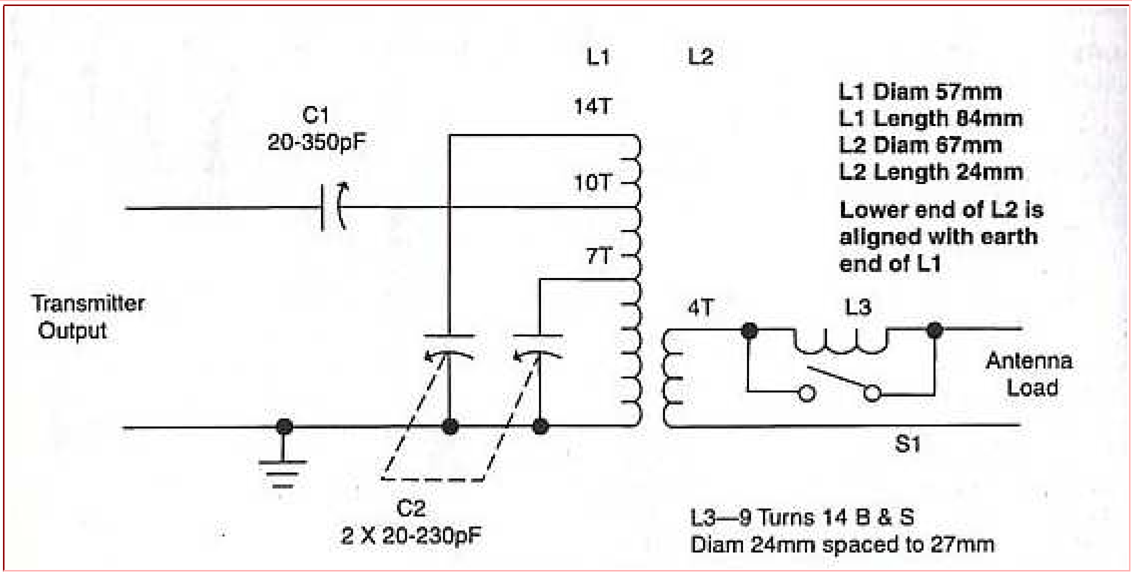
However, I eventually received a letter from Graham saying, in effect, "What if the antenna load has capacitive reactance and it is of such value as to balance the series inductive reactance inherent in the tuner output circuit?".And then, "Now eat humble pie Butler".

It took me only a few seconds to decide that he must be right and also to question why hadn't I thought previously of the possible condition he described. I tore out to the radio shack and set up the test gear again to look for these black holes. They were there all right! Now knowing what I was looking for, I was able to locate their precise locations on the load curves. The regions of drop-out were quite narrow and I had previously missed them in my measurement procedure. In that procedure I had taken numerous measurements at spot points and joined up the points to create continuous curves. This was the measurement fallacy! The narrow drop-out perturbations were hidden in between the spot points I had used.

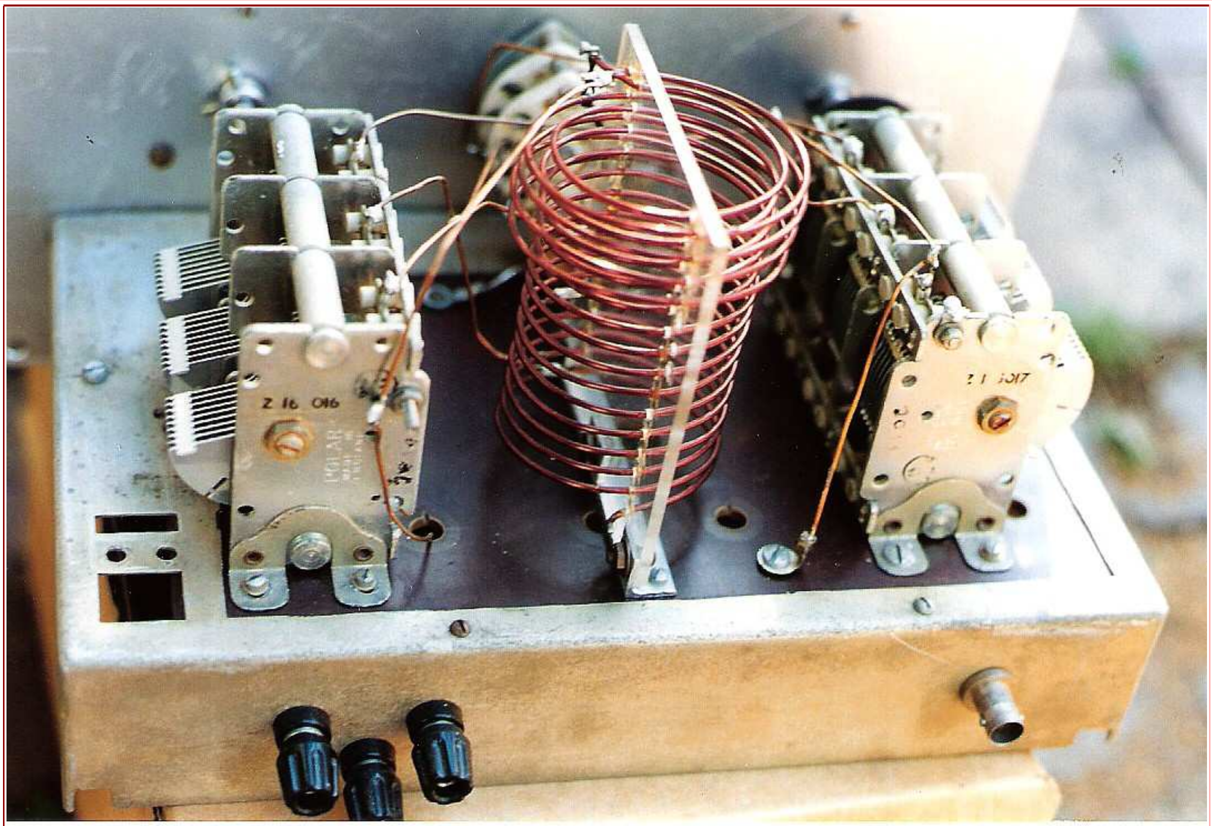
I am not sure whether I really ate Graham's humble pie but I certainly needed to find a way to cope with these unwanted tuning range drop-outs. As it turned out, there was a simple way. If a matching difficulty was experienced due to a drop-out region, a small reactance would be switched in series with the antenna load to shift the region away from that being used. Either a random value of series capacitor or a random value of series inductor could be used. But I figured out that a single value inductor would work out better for multi-band use. Hence the new circuit of the Single Coil Z Match included a small series inductor which could be switched in or out of the antenna output line (see Reference 5).



When a drop-out occurs, some extra reactance is simply switched in by the addition of L3. If a match cannot be found by adjustment of Cl and C2, then switch in L3 and try again



Schematic of the single coil Z match antenna tuner



A rear view of the single coil Z match made by Lloyd Butler VK5BR

Of course, by the time I had found out how to treat the inherent drop out regions, many amateurs had already built the previously published Single Coil Z Match unit. In general, it worked fine but there were some reports of difficulties.

Staunton (Mac) McNamara VK5ZH couldn't make his unit match his G5RV antenna on 40 metres. I visited Mac to see what I could do. I picked up the nearest small capacitor (of quite undefined value) and connected it in series with his antenna. An amazed Mac now observed that his G5RV loaded up beautifully. However, it was not really so amazing as I then knew how to deal with that 'black hole'.

My association with Graham Thornton was not finished. We both had a great deal of knowledge on how the Z match tuners operated (and in particular the single coil version). We had learned that there were drop-out regions in the ability of the original circuits to match certain load conditions and we knew how to shift these drop-out regions out of the way. A report was needed and we combined to write the article.

The interesting thing is that Graham and I never met in person and the article was co-ordinated via correspondence. I have been asked, "How could you do that?" Well, it wasn't that difficult! I started by writing a sample of what I thought we might say. The draft went back

and forth numerous times, each party adding or changing the content until we both were satisfied. The final draft was ultimately forwarded to *Amateur Radio* and was published in the March 1997 issue of the journal (Reference 6).

So, a new version of the Single Coil Z Match tuner was issued and this version has been adopted by radio amateurs worldwide.

To summarise, the development evolved via the efforts of various radio amateurs. Tom Seed ZL3QQ introduced in *Break-In* the concept of the circuit which could be tuned over two different tunable ranges with a single inductor. Reg Southwood built various forms of the Z match (including Tom Seed's idea) for experimentation. Ron Fisher VK3OM publicised the idea through *Amateur Radio* in the 'Two Rons' *Random Radiators* column. Ron sent Reg's models over to me for testing and performance assessment. Graham Thornton VK3IY did some theoretical study which led to the understanding of the nearly hidden drop-out regions of the Z Match performance. I came up with the simple idea of switching these regions out of the way.

And the result of all this experimentation, intercommunication and team work, was a great, simple antenna tuning unit.

Phil Williams VK5NN (SK), Lloyd Butler VK5BR and Rob Gurr VK5RG examining the author's single coil Z match unit at the Adelaide Hills Club Z Match Display Night in 1994

References

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3. Thornton VK3IY - An L of a Network - Amateur Radio, March, April and May 1995.

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