A Tuning-Stub for the Chelsea Repeater

Wesley Cardone, N8QM

September 2022

WHAT IS A TUNING STUB?

A tuning stub is a dedicated and non-adjustable antenna tuner. The term "antenna tuner" is somewhat of a misnomer in that it is only the perception of tuning an antenna that is being realized. A less popular nomenclature calls it a "trans-match."

The actual function of a tuning stub is to transform an impedance looking into a device to the extent that the impedance will match the source impedance. With a matched impedance between source and load, a maximum power transfer may take place.

Please keep in mind, however, that impedance matching is only of significance when the physical length of the transmission cable is more than one-tenth of the wavelength of the signal being sent down the transmission line.

Let's consider an example of transmission cable length. Suppose our transmission signal has a wavelength of 2 meters. One-tenth of 2 meters is 20 cm or about 8 inches. A digital having a wavelength of 2 meters could therefore be dependably sent down ordinary hookup wire as long as the length of the wire was less than 8 inches. For an analog signal we would want to cut that distance in half for a maximum length of 4 inches. Obviously, for our amateur radio work it will always be necessary to match our impedances.

When source and load impedances are not matched there are reflections proportional to the magnitude of the mismatch. That portion of the energy reflected goes back to the signal generator where it is absorbed as thermal energy. But when the connector impedances are matched, there is no reflected power to the transmitter. It all goes to the load.

So, let us carry this one step further: Suppose the transmitter and feedline are matched but the other end of the feedline mating with the antenna has a slight mismatch. A proportional measure of energy will be reflected back to the transmitter connector but be reflected back again out to the antenna where some measure of that second-trip energy would be accepted by the antenna.

The feedline will spend some of the energy but in many cases the net effect is that an increase in e-field density produced by the antenna is increased.

Figure 1 The vector impedance measured looking into the transmitter feed line is shown as 32.6 + j5.90 Ohms

WHAT DO WE HAVE AT THE CHELSEA WATER TOWER?

At the Chelsea Water tower, the vector impedance measured looking into the feedline from the transmitter is illustrated in Figure 1. The objective of the plan proposed by this paper is to device a tuning stub that will allow the transmitter to see a perfect 50 + J0.0 Ohms. The net result will be that no

A Tuning-Stub for the Chelsea Repeater

Wesley Cardone, N8QM

September 2022

energy will be reflected back into the repeater owing to a mismatch of impedances. It is likely that more energy will find its way into the atmosphere increasing the e-field density.

But first, let's examine what Figure 1 is trying to tell us.

WHAT IS THE FIGURE ABOVE TELLING US?:

The subject frequency is that assigned to the Chelsea Amateur Radio Club by the Michigan Coordinated Repeater Council which is 145.450 MHz. The critical piece of information that Figure 1 is giving us relevant to the current assignment is the vector impedance of 32.6 + j5.90 Ohms.

The method of designing the tuning stub will be to use the Smith Chart via the computer application SimSmith. Refer to Figure 2 where the measured vector impedance has been plotted. Note that the impedance is very close to the ideal 50 Ohms with only a little net reactance. For ordinary amateur radio use, our antenna and feed line are close enough. However, this application is not simple amateur radio where transmitting will occur over a spread of frequencies. Repeaters operate on one frequency. It therefore makes sense to spend a little bit of time and elbow grease getting it right.

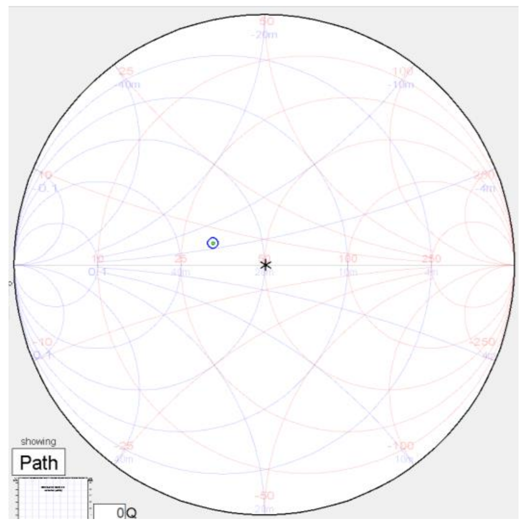

Figure 2 SimSmith is being used to plot the native vector impedance of the feed line leading from the transmitter to the antenna.

CONTROVERSEY:

There is some controversy within the amateur community regarding the usefulness of a tuning stub. But one thing is incontrovertible. A tuning stub allows the transmitter to see precisely 50 Ohms with no net reactance. The transmitter will therefore experience zero returned energy from a mismatch.

When the tuning stub is deployed, atmospheric measurements will be made to determine if there is a net increase in e-field density in the atmosphere. This is where the rubber meets the road.

Figure 3 illustrates the transmitter and antenna as if there were no feedline. We are not interested in the feedline contribution to the impedance but rather we are interested in the system

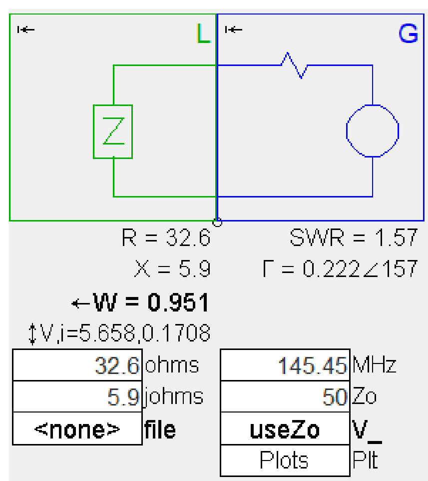

Figure 3 A circuit representation is shown for the system impedance.

A Tuning-Stub for the Chelsea Repeater

Wesley Cardone, N8QM
September 2022

impedance as a whole as seen by the transmitter. The important elements are the vector impedance as entered in the left cells.

But also significant is the relevant frequency (145.450 MHz) and system impedance (50 Ohms).

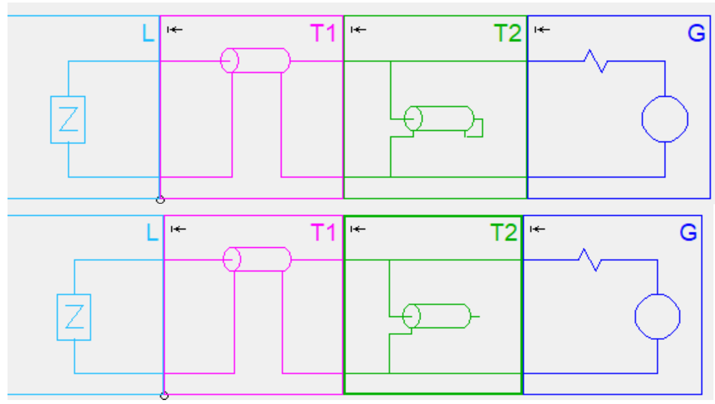

Figure 4 While there are many, many topologies for tuning-stub fabrication, there are only two convenient ways to fabricate a tuning stub for our purposes.

When we look at the Smith Chart of Figure 2, we see that the vector impedance is in the northern hemisphere meaning that the net reactance is inductive. In looking for a path to home plate, we also want to consider how we want to get there in terms of the easiest way.

An open-end stub is capacitive-conductive in nature. That is, an open-end stub will move a vector impedance in a southern direction. Further, it will move a vector impedance south following a conductive path rather than a resistive path. Therefore, we must add that amount of series coax such that the vector impedance will fall on a conductive path that leads home.

Consider the action of a shorted-end stub. This would have the same effect in terms of following a conductive path but in the opposite direction since a shorted-stub is inductive in nature.

There are probably well over a dozen different designs a tuning-stub can be fabricated from. However, it is in our interest to pick the easiest and cheapest way. This narrows down the selection pool to two topoligies as illustrated in Figure 4. We will be using a T-connector to patch a simple length of coax effectively lengthening the transmission slightly. On the other end of the T-connector will go a stub of coax. It will be either shorted or open at open or shorted will depend on where we move the phase to.

Therefore, if possible we will move the phase to a location which will facilitate an open-end stub. Of those two options, the easier of them is the open-end stub. Thus, we find as shown in Figure 6 that

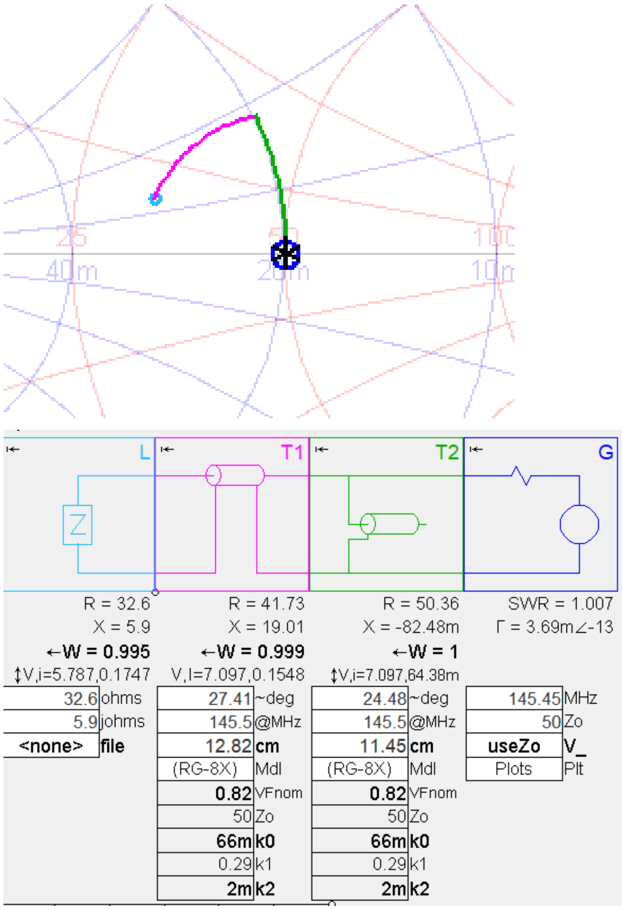

Figure 5 An open stub is added completing the tuning-stub.

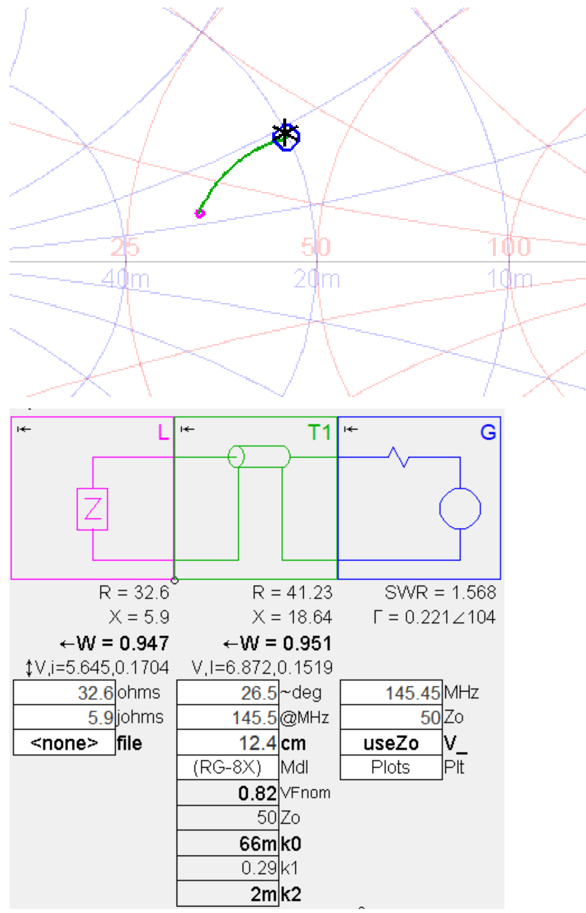

Figure 6 It is necessary to add sufficient phase to move the vector impedance to a conductive line which leads home.

12.4 cm of RG-8X coax placed in series with the existing feedline will add a relative phase such that the vector impedance now falls on 0.221 + j18.6 Ohms. This is particularly convenient in that the vector impedance now exists directly on a conductive path that leads home.

The next objective is to add an open-stub of sufficient length to neutralize the net inductance existing in the system. This is illustrated in Figure 5 where we have arrived at the final theoretical design.

Having arrived at the theoretical design, it is now necessary to design a practical implementation of that design. The first step in this process is to determine what parts are conveniently available. To that end

A Tuning-Stub for the Chelsea Repeater

Wesley Cardone, N8QM
September 2022

we explicitly call out any requirments dictated by what is already in place at the repeater. We leverage that against what is readily available or on-hand.

The only item of significance is the repeater and feedline connectors which are N-type. Our tuning-stub must properly interface with these.

Our next concern is to allow for connector distances integrating them into the design.

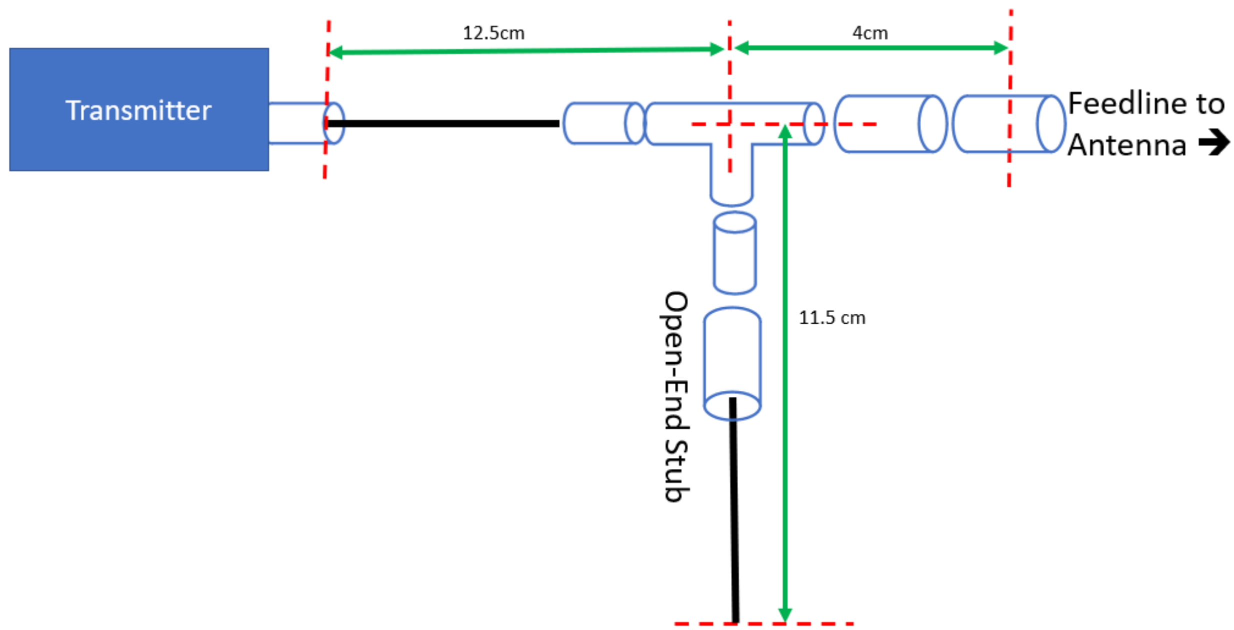

Figure 7 This is a sketch illustrating a proposed fabrication of the tuning-stub called for in this paper.

Referring to Figure 7 there are practical considerations allowed for. The T-connector is SO-239 on all sides but the transmitter connector is N-type. An adapter is therefore required. The length added by the hardware is considered in arriving at our design length.

One last practical consideration that cannot be ignored is the accuracy of cuts. It is only possible to cut coax to a precise length of plus or minus 0.1 cm. But a larger error source is the length we end up with after crimping together the coax with its connectors. All that we can do is try our best and then measure when the device is complete to see that reasonable expectations have been met.

A Tuning-Stub for the Chelsea Repeater

Wesley Cardone, N8QM

September 2022

A realization of our custom tuning-stub for the Chelsea Repeater is pictured in Figure 8.

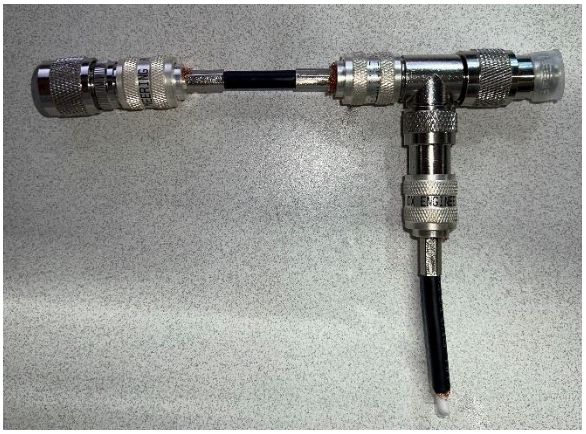

Figure 8 Shown is the realization of a tuning-stub.

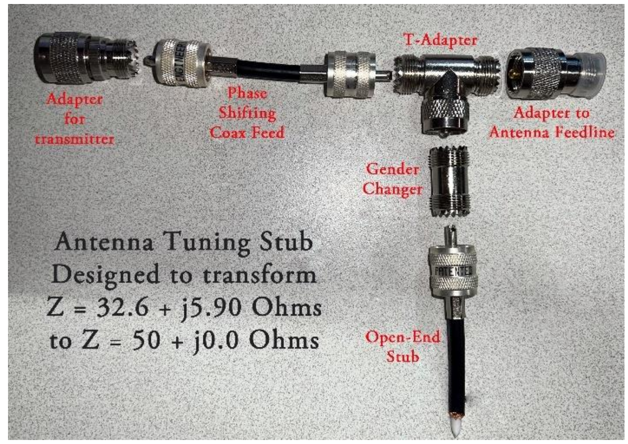

Figure 9 This is an illustrated parts breakdown showing the components of the tuning stub that was actually built

CONSIDERATIONS IN THE TUNING STUB FABRICATION:

.As noted earlier, there are many, many alternatives in the design of a tuning-stub. All of them will produce the same results. We therefore try to pick the easiest and cheapest way to build. Another consideration is, what parts are already on-hand.

The arrangement we ended up with is shown as an illustrated parts break down in Figure 9.

Once the tuning-stub was built, it was necessary to document the dimensions of what was actually built. There will always be trade-offs in the construction so we will measure the dimensions of the finished product to get a better idea of what to expect.

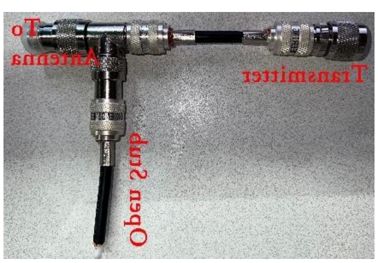

Figure 10 The antenna tuning stub is shown with labels indicating its intended connectivity

Figure 11 Shown here is the effective length of the open-end stub itself.

Figure 12 It might be easily missed, but there are 4mm of length added to the antenna feedline coming into the stub.

And finally we plug these “actual-measured” dimensions into the Smith Chart to see what the resulting impedance transformation is.

A Tuning-Stub for the Chelsea Repeater

Wesley Cardone, N8QM

September 2022

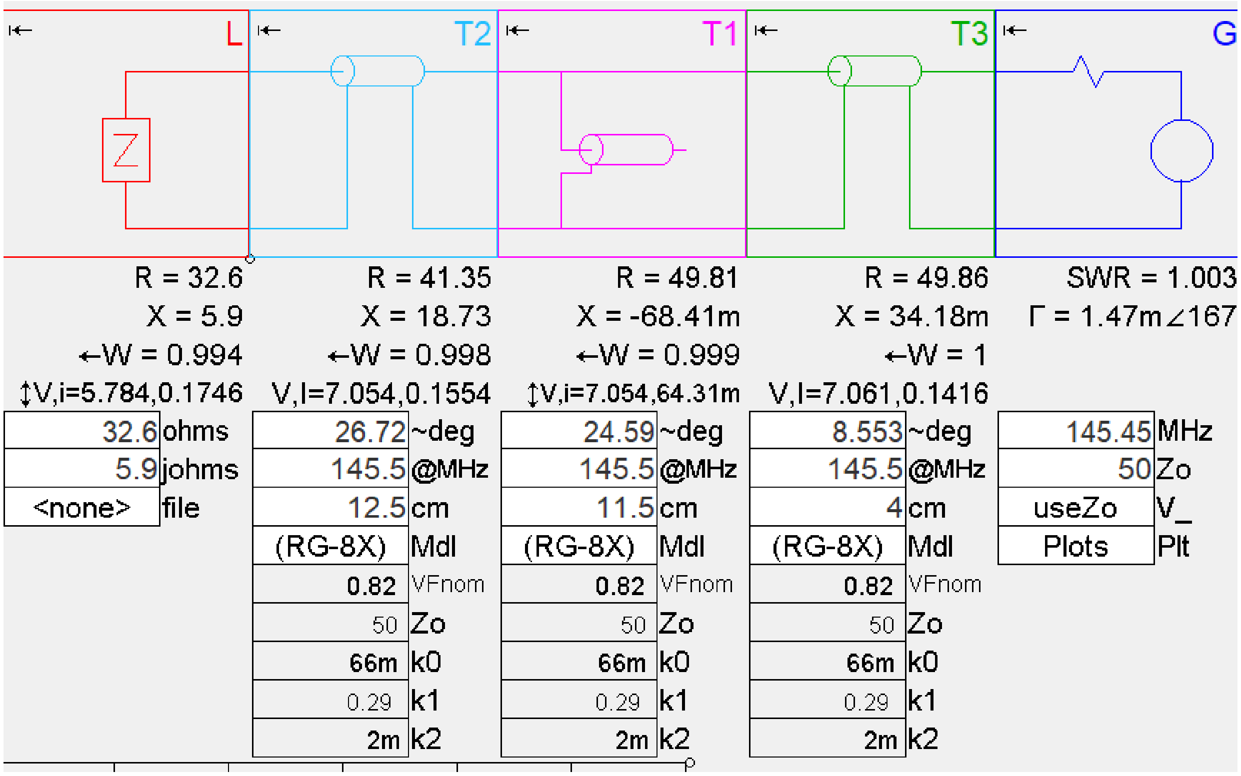

Figure 13 Working backwards, we have taken the actual measurements from the tuning stub that we built and put them into a Smith Chart representation to see how close we came to the Holy Grail. In this case, we hit it right on the money.

A Tuning-Stub for the Chelsea Repeater

Wesley Cardone, N8QM

September 2022