My Experience Building a Broadband HF Antenna.

K6SQN - Ernest G. Wilson

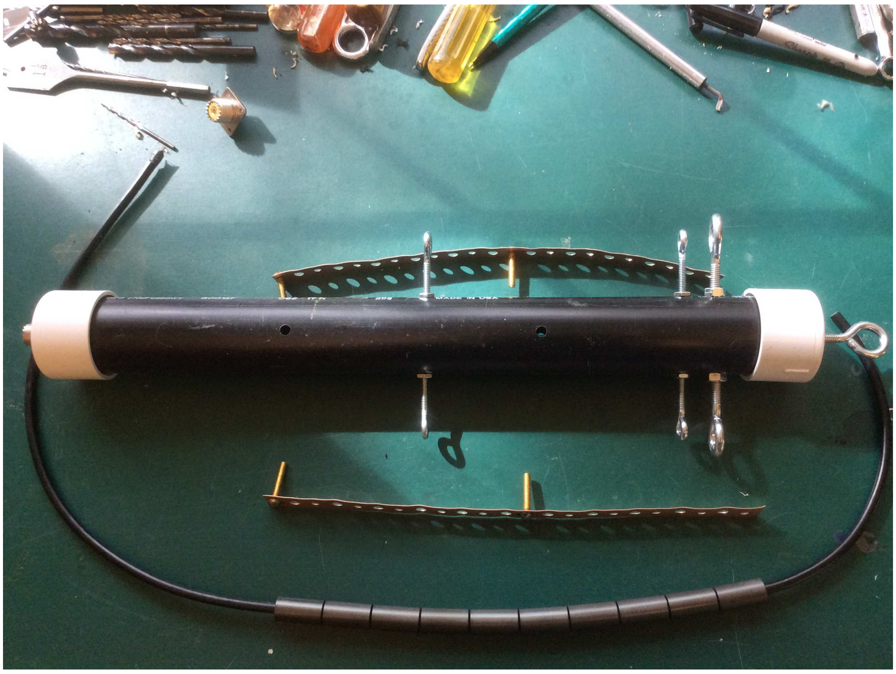
Here was an attempt to build an HF antenna with almost forgotten knowledge of the subject. It had been over 40 years since my last antenna build, and that was for 6 Meters. Indeed, some internet searches and an old ARRL Handbook proved invaluable. My son-in-law, gave encouragement, observational and labor support. I make this report for those persons interested in learning from my successes, mistakes and failures.

Being lazy, frugal and willing to give up some efficiency for convenience, these became my objectives: No tuner, broadband, acceptable VSWR, 80, 40 and 20 M voice bands, inexpensive.

First on the agenda was the Balun. Actually not a Balun but an RF choke made of Amidon Ferrite cores forced onto a piece of RG8x. This was housed in a section of ABS pipe which is a bit lighter in weight than PVC. The typical SO239 was soldered to one end of the coax and secured to the unit's bottom PVC cap. A small "weep" hole was drilled in the bottom of the cap in the event condensation might form inside the pipe.

Holes were predrilled for screws and eyebolts. The eyebolts were secured by placing a nut on two sided sticky tape on a narrow stick. The stick was inserted into the pipe until the nut aligned with a predrilled hole. The eyebolt, with locking nut on it, was threaded into the nut inside. Once the eyebolt had attained sufficient threads on the nut the stick was removed and the outside lock nut tightened.

Two pieces of copper "plumbers tape" had brass screws soldered to them. These two strips were then fitted into the pipe so the screws came through predrilled holes to the outside. Brass nuts held them in place. These would be the connection points for the antenna wires.



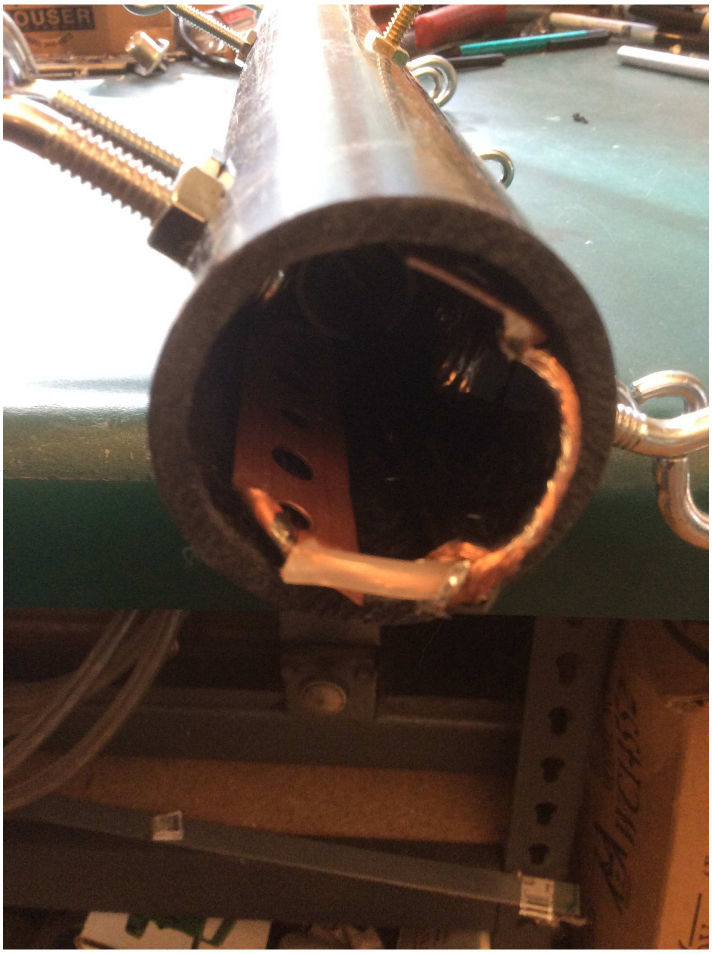
The RG8x and ferrite core assembly was then fed into the ABS pipe with the open end of the coax exiting at the top of the pipe. The bottom PVC cap was secured to the ABS pipe with 4 self-threading screws into predrilled starter holes.

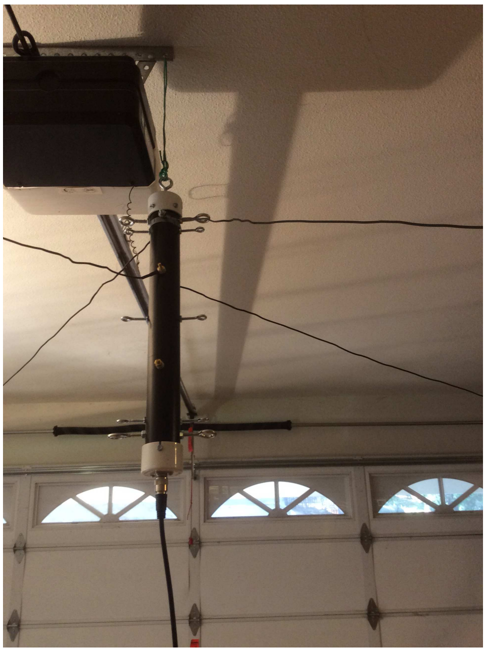
The RG8x was carefully stripped to expose the center conductor and the braided shield wires. The braided shield was tightly wound to form a smaller and stiffer wire. These were soldered to the tops of the copper strips.

It is true that these copper strips can be considered a short piece of open wire transmission line. Some thought had been given to spacing them apart in a manner which would approximate 50 Ohms. But, we decided to test this setup to see if that would be necessary. A test with a "RigExpert AA30" and a 51 Ohm resistor showed only a small reacatance appearing above 25 MHz. That was acceptable.

The top PVC cap included an eyebolt for a central rope if required. The cap was secured to the open end of the ABS pipe with 4 self-tapping screws into predrilled starter holes.

The finished unit, while hanging out in the garage, was given a quick test. Random wires were used just for an indication of resonance at any frequency on a "RigExpert" antenna analyzer.





We were determined to cover the 80 Meter band without loading coils. We had 125 feet between two tall trees to do it. It was also decided that some form of "cage" antenna or multiple stagger tuned elements would be used to increase bandwidth. This antenna would also qualify as a "fan" antenna since the 3 bands will be fed from a common feed point. A lot of separators are needed to cover 120 feet! Although this would be an experimental antenna, the stretching of wires by pulling on them did not seem like a good idea. Therefore, the separators included holes not only for #14 insulated wires but also 3/16th inch nylon support rope.

The 80 Meter wires were installed at opposing ends of the separators. The 40 Meter wires installed on the opposing ends of the other crossbars. The 20 Meter wire was installed through the cross-over point of the separator..

Pex was used for the separators due to its light weight. However, Pex was not entirely satisfactory because it tends to bow when the wires are made taught. Half-inch CPVC would have been a better choice. The separators are held together at the center with a plastic "Ziptie". These may deteriate in the weather, but after all, this was to be an "experimental" antenna.

AWG 16 wire would have been sufficient for the intended 100 W working power. A larger diameter wire would offer lower skin resistance. Some thought was given to using #12 but we found a good buy on #14 stranded and insulated wire and used that instead. The wire insulation also acts as a dialectric between the wire and surrounding objects including Earth ground. This adds more distributed capacity to the system than that attainable by bare wire. The overall effect of using two wires on each side of the dipole and the added capacity afforded by the insulation results in a shorter physical antenna.

This is the South-West half of the antenna showing wires and rope threaded through the separators.

The green wires on the horizontal plane of the separators are for the 80 Meter band. The 40 Meter blue wires are at the top and bottom of the separators. A single blue wire passing through a hole at the center of the separator is for 20 Meters.

The 80 Meter wires are the longest. They are kept taught by way of an "egg" insulator connected to the support ropes. There are suppoort ropes at both the top and bottom of the array to keep the whole system taught. The 40 Meter and 20 Meter wires being much shorter are terminated at separators respective to their wire lengths.

A pulley on an eyebolt was installed on the far tree at the 50 foot level. A single Nylon rope is fed through the pulley and attached to the array support ropes. The other end of the pulley rope is tied to an eyebolt and hook at the 4 foot level. The hook secures the rope when the antenna is raised to its working height. (The remnants of a previous antenna can be seen at the upper right)

This photo shows the North-East half of the antenna hanging low enough to work on it. The far end is connected to a rope whose pulley is secured at the 75 foot level. Needed or not, an attempt was made to keep the antenna in a more or less horizontal plane. The Earth slopes down 25 feet at this end of the antenna. Hence, the difference in height between the SW and NE pulleys.

A Halyard rope was attached to the top of the Balun in an effort to minmize center antenna sag.

The Nyon support ropes were tied directly to the Balun's eyebolts. They support the total weight of the antenna. The Antenna wires were also secured to eyebolts to avoid any pull on the connectors while keeping those wires taught.

The transmission line, an upgraded RG8U coax, travels horizontally and at right angles from the antenna to the second story of the house. Some of the Nylon rope is tied to the coax providing a "strain relief" for the connector. The connector was taped over to prevent moisture contamination after tests and tuning were completed.

This is a view of the whole antenna system. It is approximately 120 feet end to end. Shown here at a height a bit higher than it would be later for tensioning and tuned. The egg insulator has not yet been installed on the 80 Meter (green wires) which were purposely left long prior to tuning. The Halyard rope is supporting the center of the array.

The terrain also slopes downward on the South-East (broadside) of the array.

This is a view of the array at working height. The Halyard rope is supporting the Balun and antenna center. Two adjustment ropes allow for both vertical and horizontal placement of the antenna center to avoid possible snags with tree limbs.

This is a view of the North-East half of the antenna at its working height. The directions of propagation are at right angles to the array. That would be North-West and South-East.

The Fun Part - Tuning

Tuning the array had its ups and downs. Up for a resonance and VSWR reading, Down to adjust element length. Up again, etc. . This is where a little math and an antenna analyzer came in handy. We began with the longest wires first. In each case solving for the center frequency of the band.

Math definitions as used in this discussion:
k=234 K=new found k f=frequency in Mhz l=Length of wire in feet, one side of dipole

Find 80 M wire length: k/f = l 234/3.800 = 61.6 Ft. .6 Ft x 12 = 7.2 inches

Each half of the 80 M dipole was cut to 61 feet 7.2 inches and tested with the RigExpert analyzer. The resonant frequency was lower than desired at about 3.64 Mhz. Not surprising because the k value of 234 is based on a single uninsulated wire. This design used two insulated wires resulting in greater skin area plus distributed capacity. The value of k needed adjustment. The new value we'll call K.

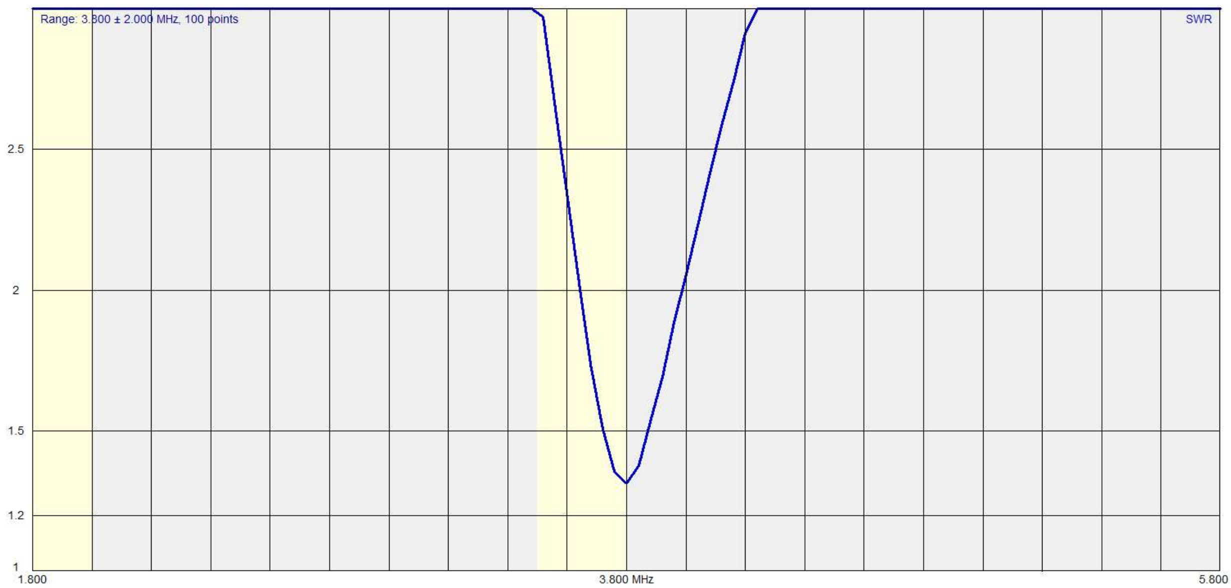
K=Original length times the measured frequency. K=61.6 x 3.64 = 224

Substituting K for k: K/f=l 224/3.800=58.94 Ft (round off to 59 Ft.)

Each side of the 80 M dipole was carefully adjusted to 59 feet in length with an excess of 6 inches to wind back on itself. Winding back on itself added a neglible amount of capacity at the dipole ends.

This methold of determing dipole wire length can be used for single wire antennae as well. It beats the "cut and and try" method. Note, however, at higher frequencies than shown in this example, the length changes are in smaller increments. If the first newfound value of k doesn't give the desired results, just repeat the procedure. Each time you'll be making smaller changes until you get the desired results.

RigExpert graph showing results of the 80 M dipole. Centered on 3.800 MHz with a VSWR of 1.27:1, 2.26:1 at 3.600 MHz and 2.02:1 at 4.000 MHz



Calculation of the 40 M wire was done in the same manner as done for 80 M.

Voice band center frequency = 7.20 MHz

k/f=l 234/7.2 = 32.5 Ft Starting length 32 Ft, 6 inches

Frequency measured = 7.025 Mhz

Solve for K Original length x mesured frequency 32.5 x 7.025 = 228

Substituting K for k K/f=l 228/7.2 = 31.7 Ft .7 x 12 = 8.4 inches

Corrected wire length = 31 Ft, 8.4 inches

New frequency was close to desired of 7.20 MHz at 7.22 MHz. Close enough for now.

40 M Graph

RigExpert graph showing results of the 40 M dipole. Centered on 7.22 MHz with a VSWR of 1.1:1, 1.95:1 at 7.100 MHz and 1.52:1 at 7.300 MHz

Lastly came the calculatiion for the 20 M dipole. Voice band center frequency = 14.250 MHz

k/f=l 234/14.250 = 16.4 Ft Starting length 16 Ft, 4.8 inches

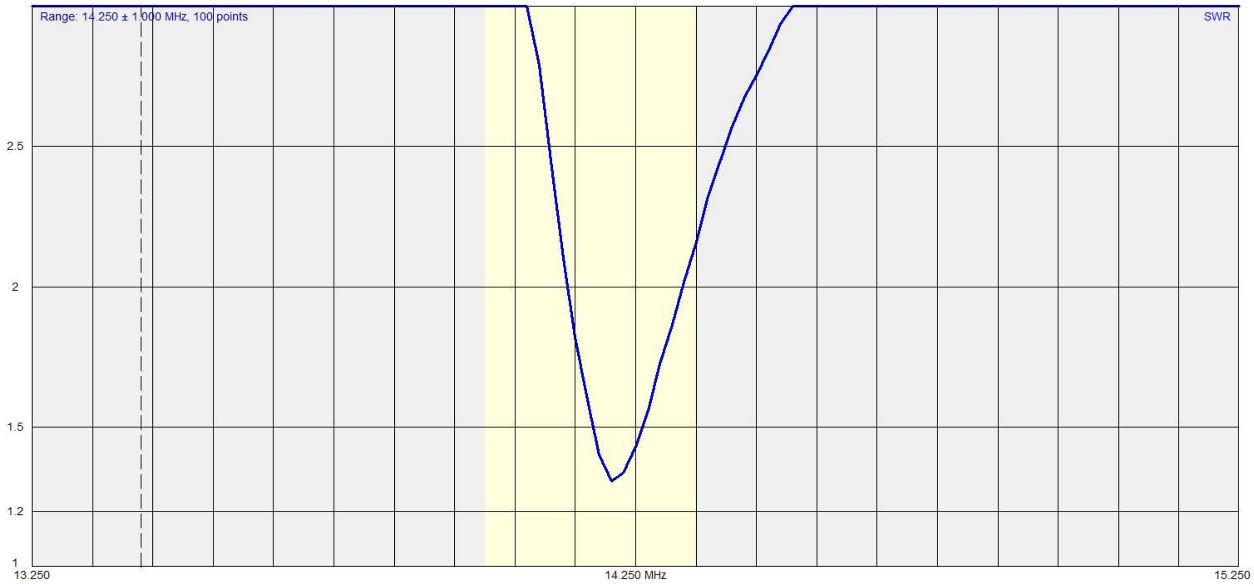
Frequency measured = 13.8 MHz

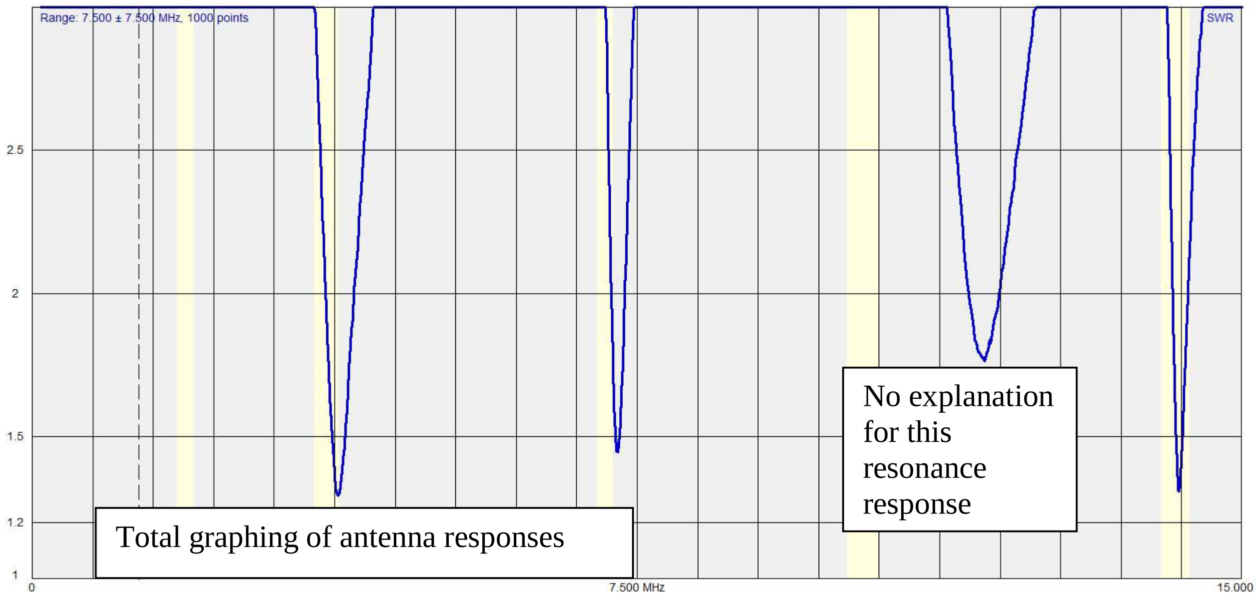
Solve for K Original length x measured frequency K=16.4 x 13.8 = 226

Substituting K for k K/f=l 226/14.250 = 15.85 Ft. .85 x 12 = 10.2 inches

Corrected wire length = 15 Ft, 10.2 inches. New frequency, 14.22 MHz. Close enough for now.

RigExpert graph showing results of the 20 M dipole. Centered on 14.22 MHz. 14.250 VSWR 1.43:1, 14.150 MHz VSWR of 1.82:1 and 14.350 MHz VSWR of 2.16





We wondered, what did we give up for the convenience of not using a tuner? Slightly more VSWR than could be obtained with a tuner, but does it matter?

To be most effective a tuner should be located at the antenna itself. Only the coax loss would then be considered. If no tuner is used then coax VSWR losses must also be considered.

We thought it might be interesting to see just how much VSWR and Coax Losses would effect the range of transmission. To find how much power would be delivered to the antenna we used an online calculator. We found it at:

https://www.qsl.net/co8tw/Coax_Calculator.htm

Parameters: 100 Watts output from transmitter
Use VSWR values for each band
100 feet of Belden 9913 (RG8U) transmission line

Frequency	% Power after Coax Loss Only	% Power after Coax and VSWR Loss
3.600	95	93
3.800	95	95
4.000	95	93
7.125	93	91
7.22	93	93
7.300	93	92
14.150	89	88
14.250	90	89
14.350	89	87

Theory refresher: Its the antenna current that produces the signal strength.

If power is reduced to 50% the voltage and current have both been reduced to 70.7%. The formula is the "square root" of the % of power. The square root of .5 is .707.

Range is determined by the amount of current flowing in the antenna.

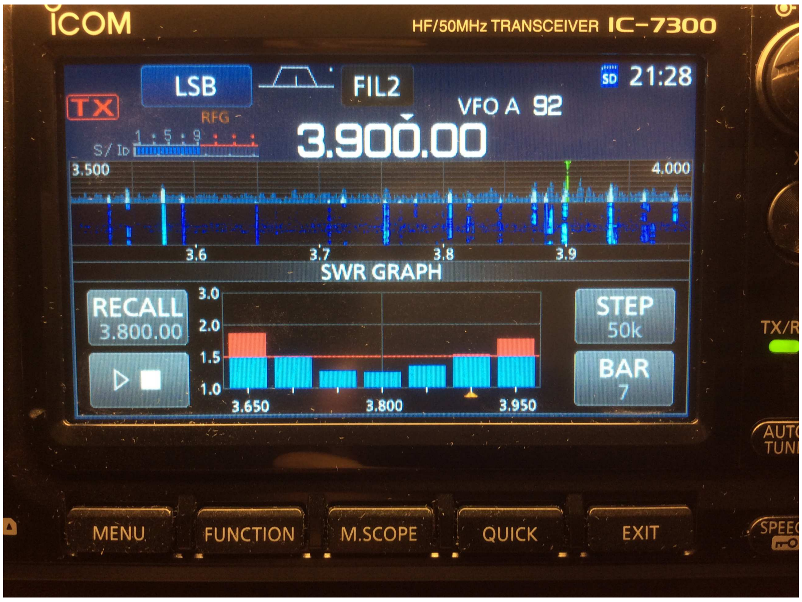
Example: If power is reduced to 80% then range is reduced to the square root of .80 = .89 = 89%.

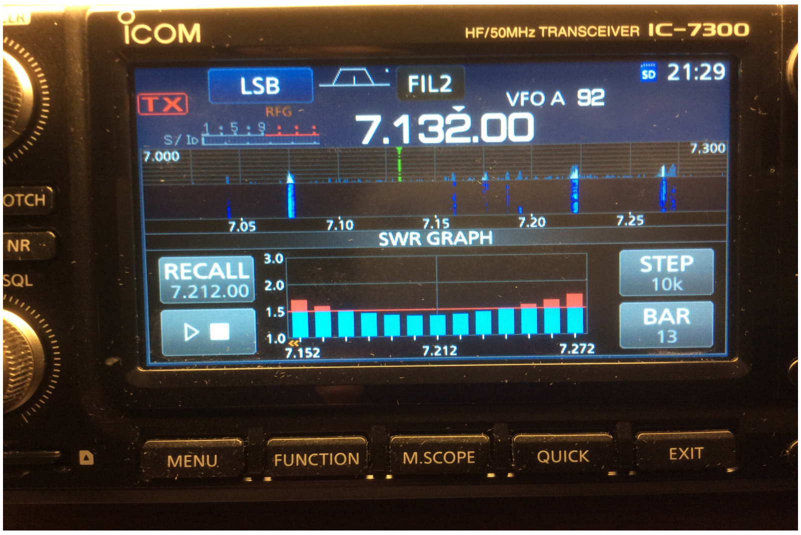
In other words: The square root of the of the percent power remaining equals the percent range.

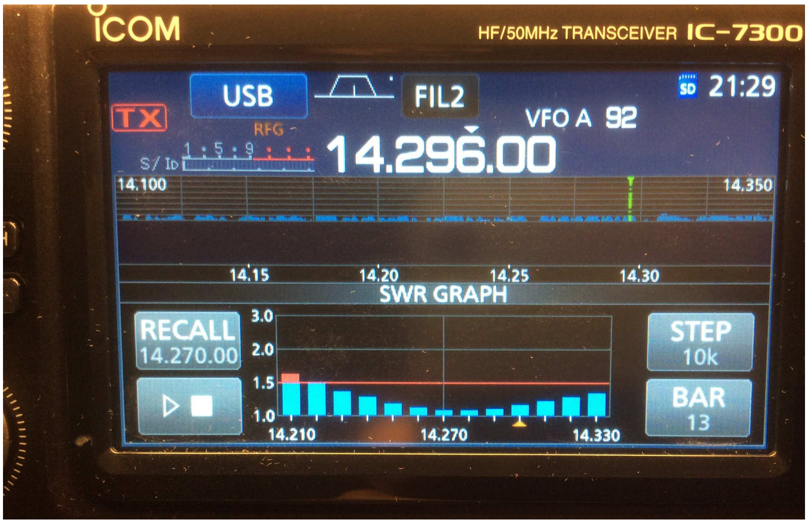
Example:
Worst case: 14.350 MHz % range with coax loss only (Sq root of .89) = 94.3%
% range with coax + VSWR loss (Sq root of .87) = 93.2%

Only a 1.1% decrease in range due to VSWR

Neglecting propagation and assuming any distance, say 1000 miles, then the worst case condition results in 1.1% reduction in range or just 11 miles per 1000 due to VSWR! That's not even 1 "S unit".







I'm happy with the results showing on my radio's SWR graphs.

What is surprising to me, and to others as well, is the received signal on 80 Meters. Contacts in the Santa Cruz mountains to Los Angeles have asked if I'm running power. Several have given me "20 over" reports and are amazed I'm running barefoot at 100 Watts

Perhaps power in the future but I see no need for it now. Contacts with Europe, South Africa and Central America have done well.

One may also consider how the square root of the power increase affects range.

Twice the power only increases range to 141 Percent.

Four times the power increases range to 200 Percent

Ten times the power only triples the range, 315 Percent.

Hopefully the reader will get something out of this experience. I did.