Antennas for the Space Challenged©

Most urban amateur operators have space issues when it comes to antenna erection. Since I also fall into this group I have elected to design several antennas which mitigate the lack of sufficient space for full sized antennas on the lower HF bands. These antennas are constructed using 450 ladder line. Initial estimate of dimensions can be made from the following equations based on the diagram of Fig 1.

$$L = 159.75 / F_{MHz} + 0.43L1 \qquad \text{(Eq 1)}$$

or

$$L1 = \left[\frac{L - \frac{159.75}{F_{MHz}}}{0.43} \right] = 2.326 \times L - 371.58 / F_{MHz} \qquad \text{(Eq 2)}$$

Based on an antenna height of 30' these should give results that are slightly long allowing for easy trimming to frequency. Trimming is accomplished by lengthening L1 (i.e. shortening L2). Alternatively if the frequency is substantially off and low, L can be shortened. However, because this decreases L and L2 simultaneously care should be taken so as not to over compensate for offset.

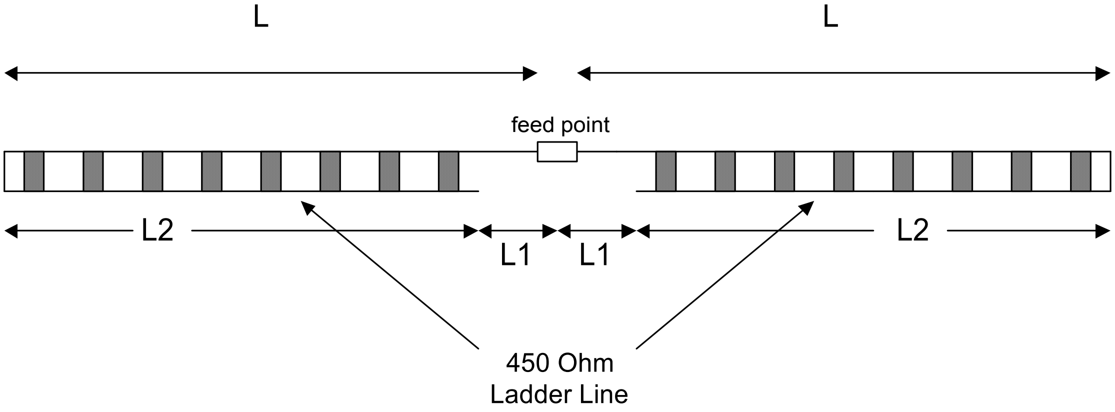
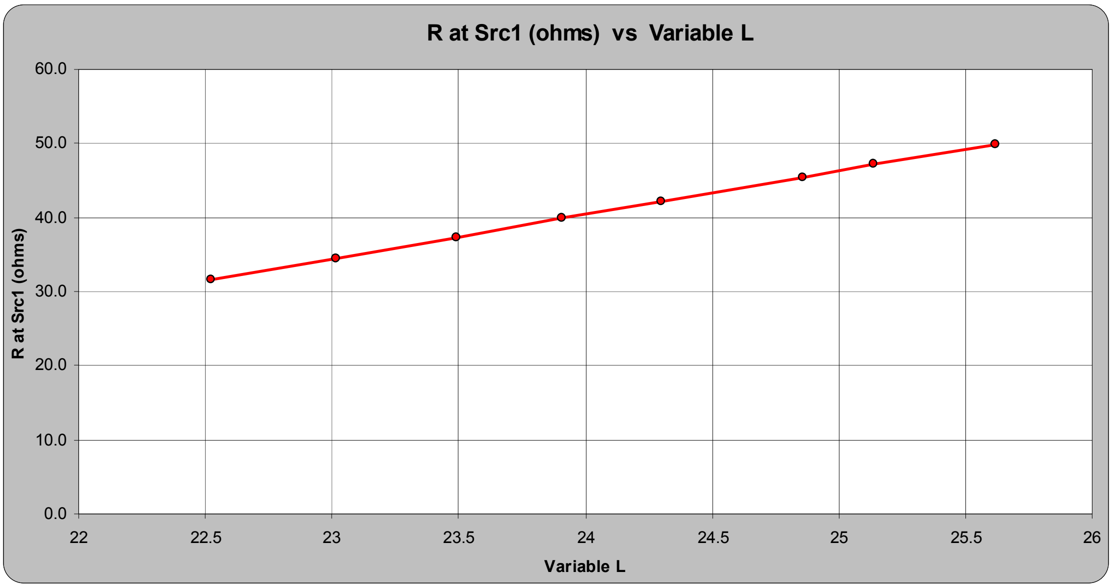


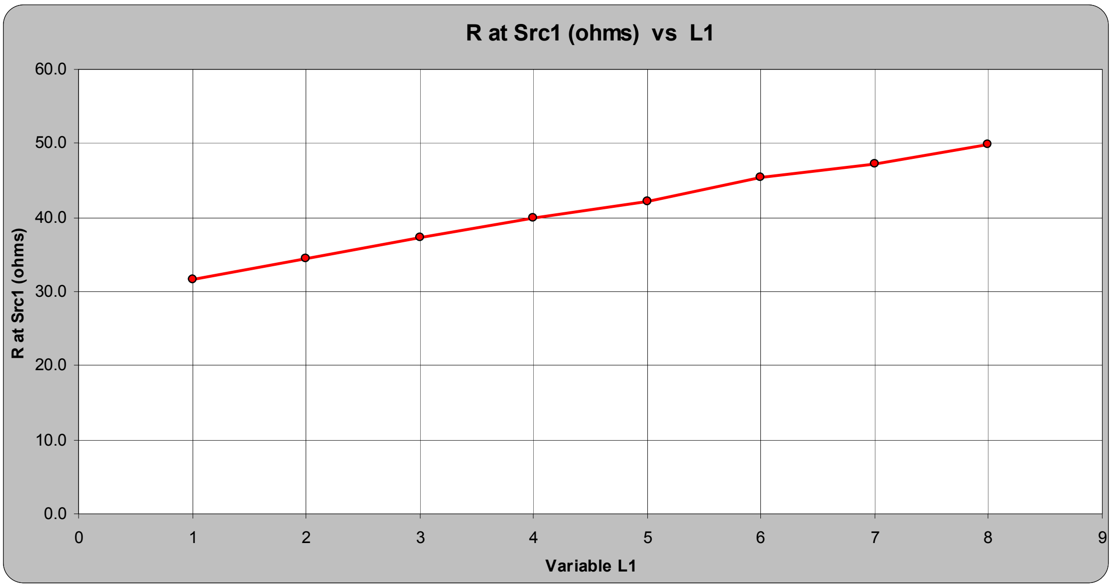
Fig 1

These designs can yield an antenna approximately 25% shorter than a full size dipole and will reduce the free space gain about 0.3 db below that of a full size dipole. The length of L1 determines the resonant feedpoint resistance (R). In the curves below one can see a gradual rising of the feedpoint resistance as the length of L1 is increased until R becomes nearly 50 ohms. As both L1 & L become larger eventually they reach the point where the antenna is simply a normal dipole with a value of R=72 ohms. For maximum shortening of the overall length the price paid is in VSWR where values of approximately 1.5:1 are seen. Even with this value, most present day transceivers will operate satisfactorily.

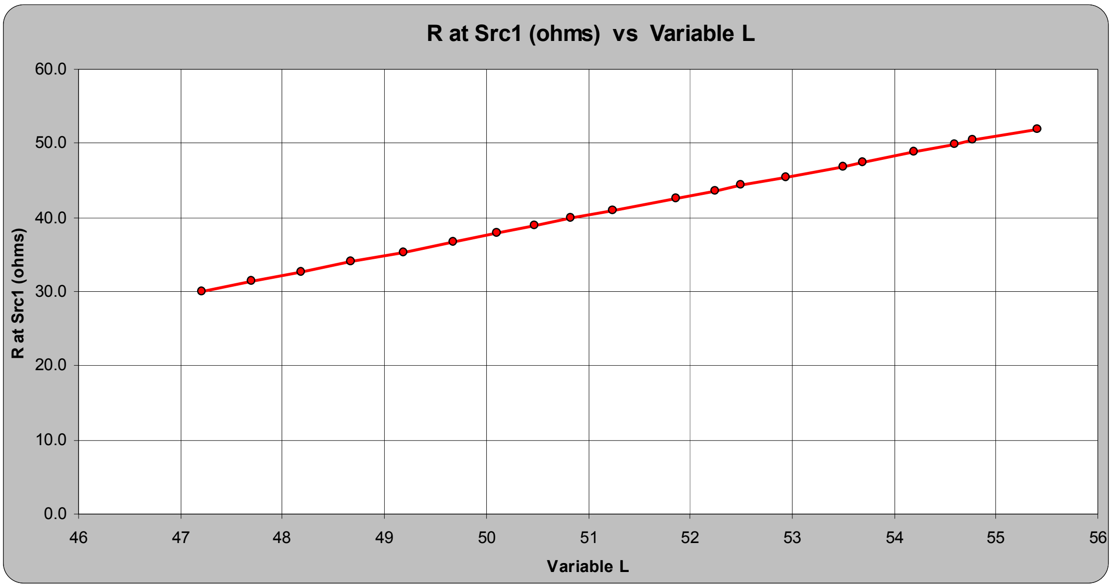
Each point on the curves below show the values of L and L1 required to achieve resonance at the respective frequencies. For example, with L approximately equal to 22.5 feet at 7.3 MHz then L1 must be approximately 1 foot for resonance to be achieved. Conversely, with L1 equal to 8 feet, then L must be just longer than 25.5 feet which results in a 50 ohm feed point impedance.



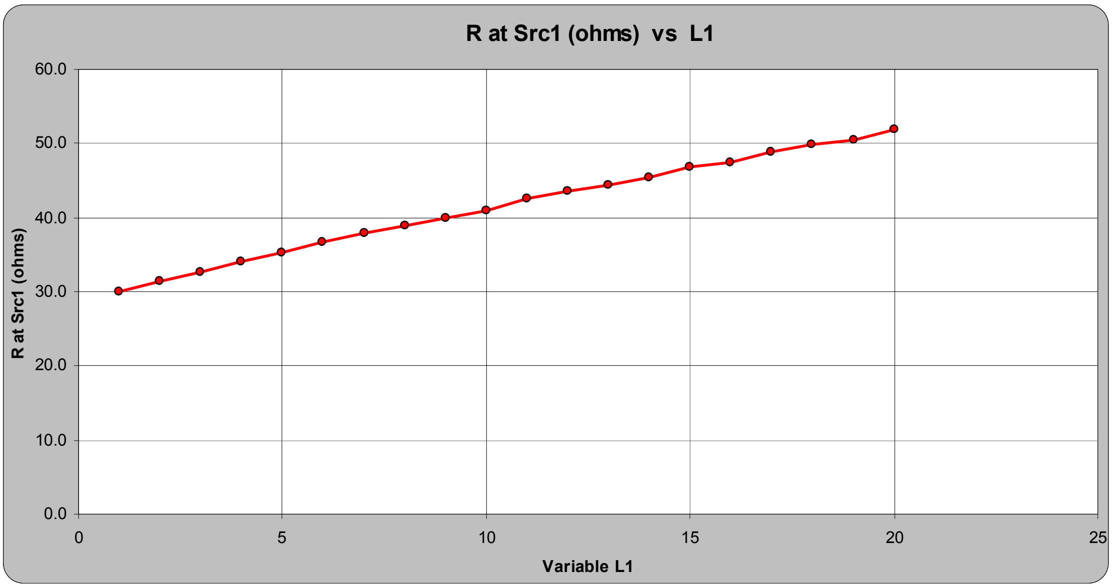
R vs L @ 7.3 MHz



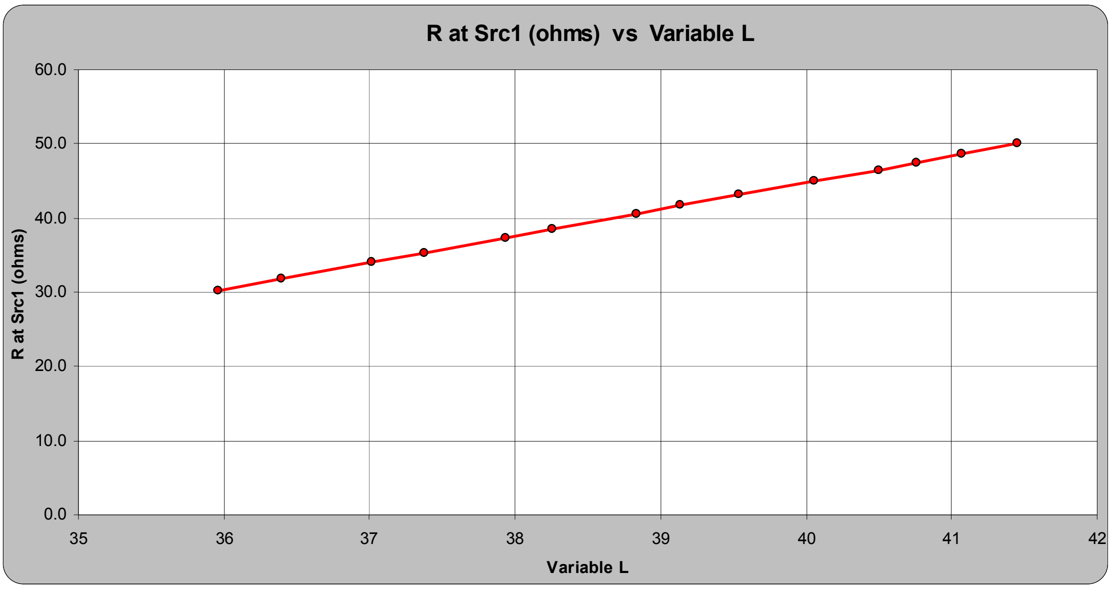
R vs L1 @ 7.3 MHz



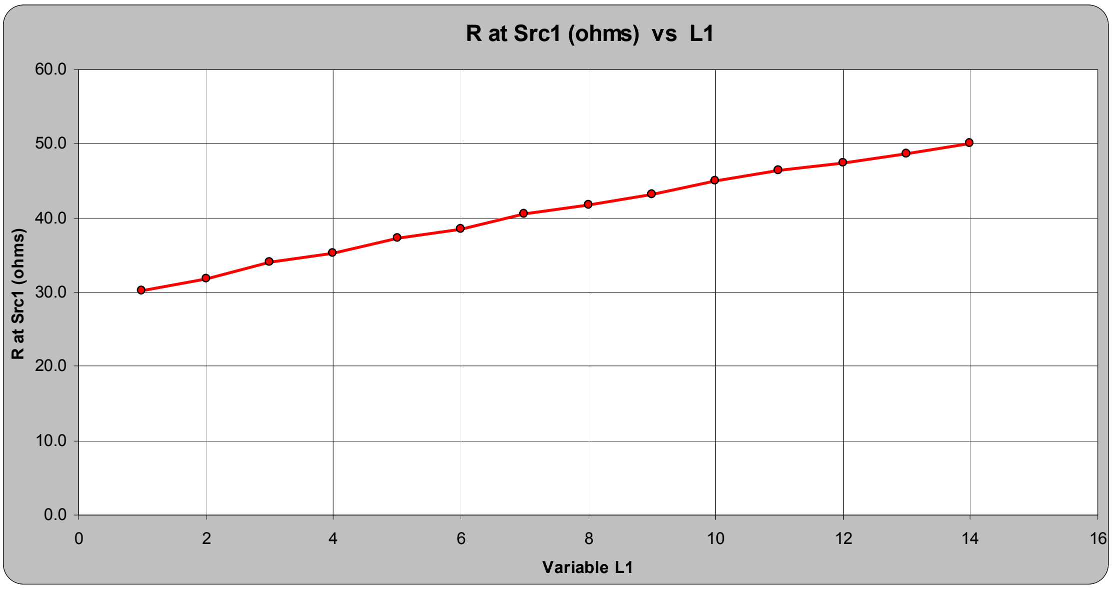
R vs L @ 3.37 MHz



R vs L1 @ 3.37 MHz



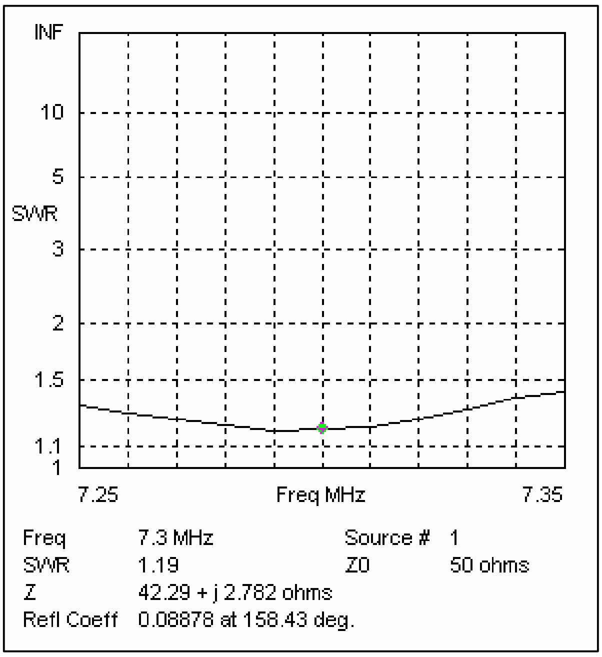
R vs L @ 4.46 MHz



R vs L1 @ 4.464 MHz

As can be seen from the above plots there is an optimum length for L and L1 to achieve the best match but at the cost of additional length of the antenna. Additionally as the antenna is lowered, the value of R and the resonate frequency will be lowered.

Typical VSWR performance is shown below in Fig 2. This plot is for an antenna in free space. At 30' over real average conductivity earth expect about 0.75 % lowering of the resonate frequency or about 50 KHz for this 7.3 MHz design. In this instance L would need to be shortened about 2" or L1 could be increased by 4".



Freq 7.3 MHz
SWR 1.19
Z 42.29 + j 2.782 ohms
Refl Coeff 0.08878 at 158.43 deg.
Source # 1
Z0 50 ohms

Fig 2

This antenna design for with L1=5’ at 7.3 MHz was constructed and performance was as predicted with length adjustments made for height. As is typical, your mileage may vary depending upon the installation.

Care and Feeding of the Antenna

Since the antenna is designed for 50 ohm impedance, the feedline should be the same characteristic impedance such as RG-8, RG-8x or RG-58. At shorter lengths, the antenna will exhibit impedances approaching 30 ohms and an antenna tuner will assist in the matching of the transmitter to the line. As stated earlier, most of the newer amateur transceivers with built in tuners should have no difficulty in matching the antenna feed. If space allows, the slightly longer designs will approach 50 ohms and thus be a better match to the feedline. The addition of a 1:1 balun or a current balun, while not necessary, will help in keeping the antenna balanced and/or radiation from the coax shield. Losses in the coaxial line should not be of major concern at these frequencies with reasonable (< 100 feet) of feedline. Antenna height should be as high as possible at the feedpoint. Feedpoint heights of less than 20 feet will show markedly lower impedances and VSWR (>2:1). Inverted Vee configurations with end heights of 10-15 feet should be acceptable but will be resonant at lower frequencies and will have to be trimmed to operating frequency.

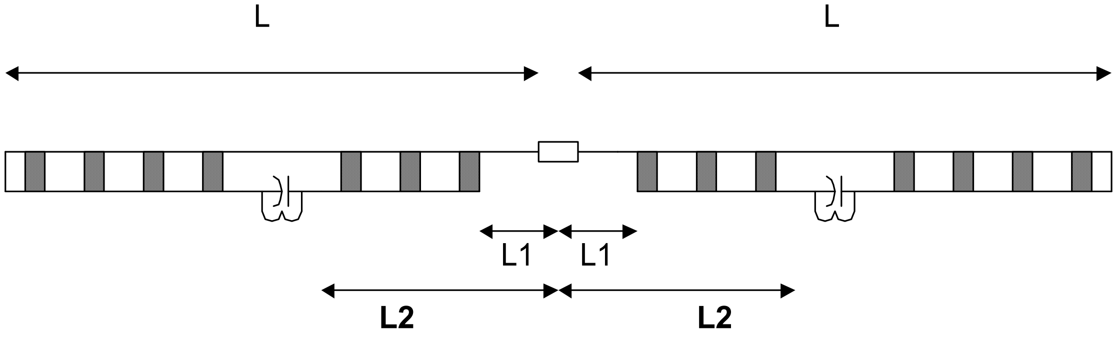
Design Process

If space is the major issue, determine how much length you have (2xL) and use Equation 2 to determine what the length of the cut-back L1 should be and then determine what the resultant radiation resistance R would nominally be from the appropriate figure. If space is less important and you desire to minimize mismatch then using the appropriate figure, determine either the cut-back length or one half antenna length L.

Other Designs

Multi-Frequency Linear/Lump Loaded Dipoles

It appears to be possible to integrate linear loads and lump loads in a common design to permit multiband operation. Two possible configurations are shown below.



Two Frequency Linear/Lump Loaded Dipole

The trap should resonate at the higher of the two frequencies desired. For AFMARS frequencies RK and RJ the suggested value of inductance is 12.7 uH. The capacitor should be 100 pf. Insertion of the trap alters the other dimensions to be as follows
For RK and RJ:

L = 43.5 ft, L1 = 6 ft, and L2 = 21 ft.

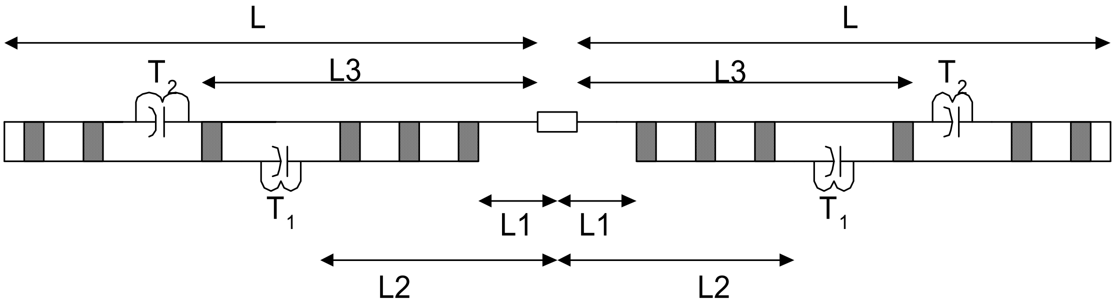
For powers to 100 watts, voltage rating of the capacitors should be at least 1 KV. Ceramic door knob type capacitors are ideal for this application. At 1 KW the voltage stress on the trap will approach 3 KV. Projected analyzed power loss in each trap will be significant at RJ and will approach 15 watts for a Q of 100 and a power input to the antenna of 100 watts.. Higher Q's will reduce this loss so care to design a coil of the highest Q possible is beneficial.

The following are possible inductor designs:

19 turns @ 10 turns per inch on 2 inch PVC or
12 turns @ 10 turns per inch on 3 inch PVC

Again, the trap should be adjusted for resonance as close as possible to RK. This antenna has not been constructed or tested but analysis indicates acceptable VSWR of under 1.5:1 when fed with 50 ohm coax.

For a 3 band design at RL, RK, and RJ the following design is proposed



Three Frequency Linear/Lump Loaded Dipole

Trap T_2 should be resonated at the highest frequency of the 3 and T_1 is resonated at the mid frequency of 3. For AFMARS RL, RK and RJ frequencies the following dimensions and lumped circuit values are suggested.

L1 = 37.8 ft, L1 = 9.75 ft, L2 = 21.7 ft and L3 = 31 ft.
T_1 = 12.7 uH in parallel with 100 pf (resonate at 4.46 MHz); same construction as above
T_2 = 8.5 uH in parallel with 56 pf (resonate at 7.3 MHz)

Voltage stress on the traps is greatest at 3.37 MHz and at 100 watts, the capacitors in T_1 and T_2 should be rated at 1 KV. As in all compromise antennas, there is no free lunch and the losses at 3.37 MHz will be nearly 50 watts with a Q in each trap of 100. On the plus side, you have an antenna the operates on RL, RK and RJ frequencies with VSWR's of less than 2:1 and in a space less than 80 ft total. A cautionary note, the placement of traps appears to be critical as is the length L1 which is adjusted to tune for best VSWR at RJ.

The antenna should be constructed and VSWR measured in the vicinity of each frequency and the adjusted in the following order

RL: Adjust T_2 placement
RK: Adjust T_1 placement
RJ: Adjust L1 length

As with the two frequency antenna, this antenna has not been constructed and measured but analysis at a height of 30 ft over medium conductivity earth indicates performance as described.