how to design shunt-feed systems for grounded vertical radiators

A graphical design system for using your tower as a shunt-fed vertical antenna

John R. True, W4OQ, 10322 Georgetown Pike, Great Falls, Virginia 22066

Vertical antennas have several advantages over horizontal dipoles on the lower amateur bands, especially in those cases where the dipole cannot be raised at least one-half wavelength above ground. A recent article showed how to use a 54-foot (16.5m) tower, top loaded with a quad or Yagi, as a grounded vertical radiator on 40 and 80 meters.[1] However, to properly design the shunt-feed matching system for these two lower bands required the use of a good quality impedance bridge. Once the complex input impedance had been determined, a graphical method was used to calculate the components required to match that impedance to a 50-ohm transmission line.[2]

This antenna system generated a great deal of interest, but since few amateurs have access to an RX impedance bridge, they were unable to use this technique to adapt their own towers for use on the lower amateur bands. For this reason I decided to make a series of measurements which would be used to generate a set of graphs which would simplify the design of shunt-fed vertical radiators. These graphs are presented in this article.

First, a series of antenna tests were conducted by scale modeling to determine the electrical height of towers which are capacitance loaded by a typical Yagi beam or cubical quad. Further tests were conducted to determine how long the gamma-type shunt feed rod had to be to permit the use of a practical L-network for matching to 50-ohm coaxial cable.

All tests were made with an aluminum-tubing gamma rod about 1 inch (25mm) outside diameter, spaced 10 ±2 inches (20.3 to 30.5cm) from one leg of the tower. This size was chosen for maximum physical and electrical stability as well as high conductivity. The resultant design curves show the electrical height of the tower, required gamma rod length, and series capacitance, C_s, required to cancel the inductive reactance of the gamma rod. The parallel matching capacitance, C_p, is also given (**fig. 1**). The series and parallel capacitors should both be air variables so the matching system can be adjusted to provide as low vswr as possible.

using the curves

The graph of **fig. 2** shows the relationship of physical height to electrical height of a thin wire (calculated from

$234/f_{MHz}$), measured electrical height of a 1½-inch (38mm) diameter conductor (which coincides very closely with the predicted electrical height of a thin conductor), and a tower 1 to 2 feet (30 to 61cm) in cross section, top loaded with a Yagi or cubical quad. If you wish to use your present tower as a vertical antenna for the lower bands, you can determine its electrical height from the data presented in **fig. 2**.

The data in **fig. 3** is for use on the amateur 7-MHz band and shows the length of the gamma rod and required series capacitance for towers up to 90 feet (27 meters) high (about 3/4 wavelength on 40 meters). Towers which are taller than this will produce a large lobe of high-angle radiation that reduces the radiation at lower vertical angles. Some shorter towers may actually be shorter, physically, than the recommended gamma rod; in that case more parallel capacitance will be required to match the system to 50 ohms. **Fig. 4** shows the same type of data for the 80-meter band (towers higher than 180 feet [54 meters] exhibit the large, high-angle lobe).

The data in **fig. 5** is for use on the 160-meter band. Note that a tower which has an electrical height of 90 feet (27 meters) requires a gamma rod which is 60 feet (18 meters) long. Since a 43-foot (12m) tower with a Yagi represents an electrical height near 90 feet, a 60-foot gamma rod is obviously an impossibility. The use of a shorter gamma rod and more parallel capacitance *may* provide a match to 50 ohms, but in this case an rf bridge and graphical solution will save a lot of time.[3]

Note that for towers with electrical heights near 53 and 70 feet (16.2 and 21.3 meters), a gamma rod approximately 20 feet (6.1 meters) long will provide operation on both 80 *and* 40 meters (the rod is about a quarter-wavelength long on 80 meters, one-half wavelength long on 40). For operation on both 80 and 160 meters, a similar coincidence occurs for towers which are electrically near 110 and 135 feet (35.5 and 41.1 meters) high. In this case a gamma rod approximately 40 feet (12.2 meters) long will provide operation on both bands. In either of these dual-band systems adjustments of the parallel tuning capacitor, C_p, will compensate for differences from the specified gamma rod length.

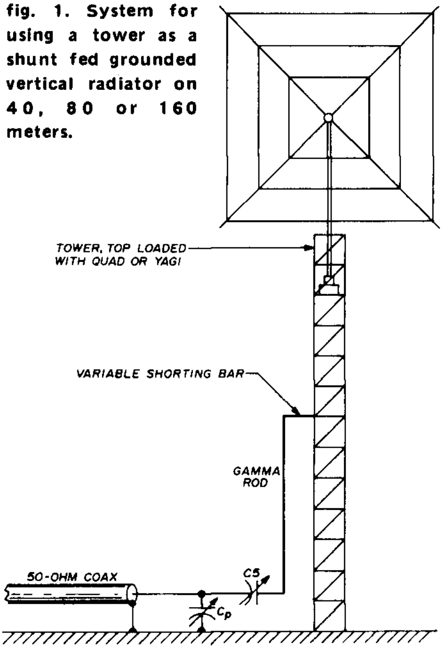


fig. 1. System for using a tower as a shunt fed grounded vertical radiator on 40, 80 or 160 meters.

The electrical height of towers higher than 120 feet (36 meters) can be extrapolated by adding about 35 feet (10 meters) for a three-element 20-meter Yagi with a quarter-wavelength boom (about 16 feet or 5 meters); add about 45 feet (13 meters) of electrical height for a multielement beam such as the Hy-Gain TH6DXX. A two-element 40-meter beam adds 50 to 60 feet (15 to 18 meters). Although cubical quads add about 25 feet (7.6 meters), multielement quad designs add little more because the elements are well away from the top of the tower and insulated from it.

matching capacitors

Since the reactance of the series capacitor, C_s, is quite large except in those cases where the tower is approximately a quarter-wavelength high, this capacitor should have a breakdown rating of about 1000 volts for transmitters up to about 200 watts output. For transmitter powers of 2000 watts this capacitor should have a breakdown rating of 5000 volts or more.

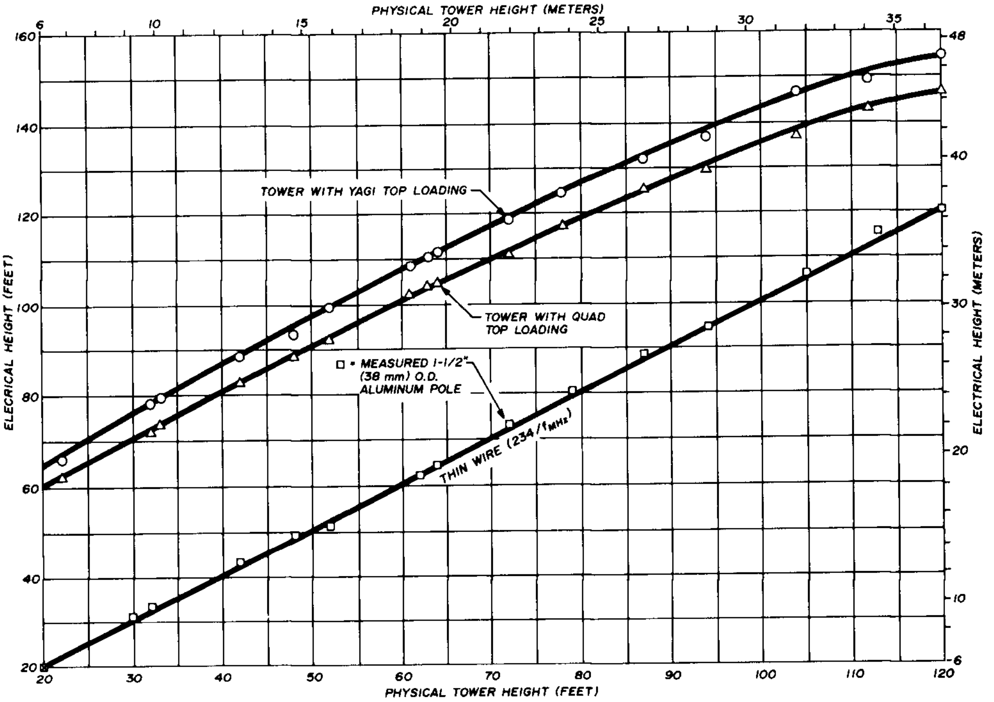


fig. 2. Physical vs electrical height of towers top loaded with Yagi beams or cubical quads.

The parallel matching capacitor, C_p, does not require such a high voltage rating unless excessively high vswr is expected at full power. For a 200-watt transmitter, an old style BC capacitor with 700 to 1000 pF maximum should work nicely. For 2000 watts PEP the parallel capacitor should have a rating of 1500 volts minimum with current-carrying capacity of seven amperes.

Where large capacitance values are recommended, it is suggested that at least half be variable with the rest made up with fixed padding. Note that *both* the stator and rotor of the series capacitor must be isolated from ground.

The ideal matching network for this antenna system would use two vacuum-variable capacitors. These capacitors are not seriously affected by humidity or changes in barometric pressure, and they can be connected to small geared motors so they can be controlled remotely from the operating position. A 300-pF vacuum variable rated at 7500 volts, and a 1000-pF vacuum variable with a 2000 volt rating should handle practically any legal amateur transmitter with low vswr.

A remote-control system that I have used for several years is shown in reference 1. It's obviously a lot easier to remotely control the matching system from your hamshack than it is to traipse out to the backyard in snow, sleet and rain each time you want to shift your operating frequency.

construction

A typical gamma rod installation is shown in **fig. 6**. On my vertical antenna the gamma rod is mounted with PVC insulators spaced about 10 feet (3 meters) apart. The insulators are made from 1-inch diameter (25mm) PVC water pipe. The movable shorting bar is made from the same material as the gamma rod.

To attach the PVC insulators to the gamma rod, first notch the ends so one end fits around one leg of your tower, the other end around the gamma rod. Then cut half-inch (13mm) long slits on each side of the PVC pipe, about 1 inch (25mm) in from each end (see **fig. 6**). Stainless-steel hose clamps are run through the slits in the PVC pipe and around the vertical member.*

If you wish, the same tower may be used on more than one lower-frequency band – simply install gamma rods on more than one leg of the tower. You can use separate capacitance matching systems or remotely controlled vacuum-variables, depending upon your operating requirements. A vertical tower antenna system which I use successfully on both 40 and 80 meters is described in reference 1.

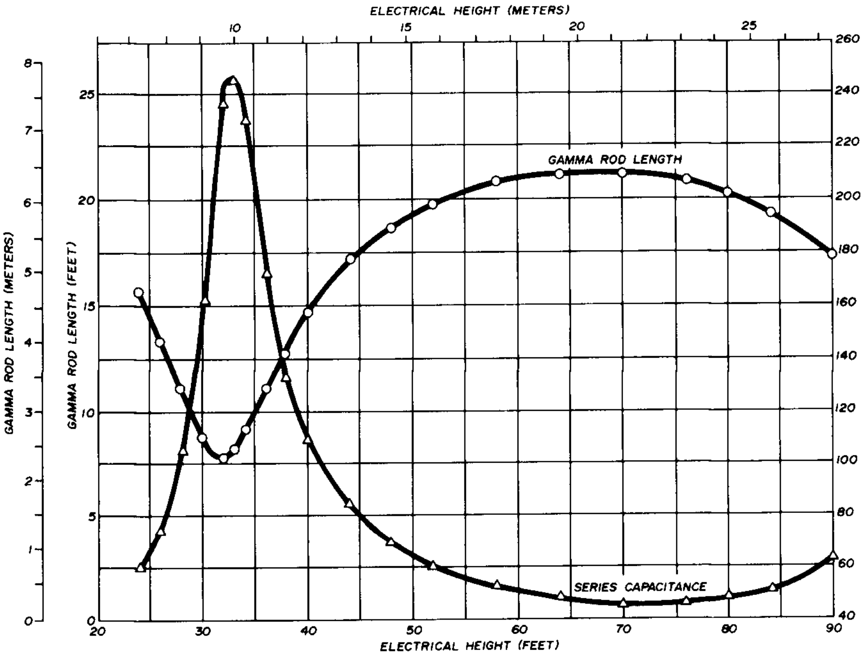


fig. 3. 40-meter vertical. Gamma rod length and series capacitance vs electrical height of tower. Recommended parallel capacitance to match 50-ohm transmission lines is 320 pF (at least 100 pF of which should be variable).

---

*The author has assembled several pages of how-to hints and additional constructional information which is available from him for the cost of printing and mailing. A self-addressed, stamped envelope to the author will bring a summary of contents and cost.

ground requirements

Remember that the vertical element is only one-half of a vertical antenna system – the vertical element must operate against a good ground plane or the ground losses will be so high that the antenna performs poorly. The so-called ideal ground system consists of 120 equally-spaced, quarter-wavelength radials, but even such an elaborate ground plane as this still introduces about 2 ohms of series loss resistance into the total radiation resistance. Since short vertical antennas are characterized by relatively low radiation resistance, ground resistance loss is higher, proportionately, than it is with vertical elements which are quarter-wavelength or more. A complete discussion of ground system requirements is contained in reference 4. For more information on short vertical antennas, consult the excellent series of articles by W2FMI.[5-8]

The tower which you use to support your higher frequency antennas can easily be used as a practical antenna system for 40, 80 and 160 meters. The graphs presented here will help you to design the necessary shunt-matching system, but note that since conditions vary from one location to another, some adjustments will be necessary to obtain a low vswr. However, with an swr bridge installed near the base of the vertical (very short leads), alternately adjust the series and parallel tuning capacitors until the reflected power approaches zero. If the amount of parallel capacitance for low vswr seems excessive, make the gamma rod slightly longer.

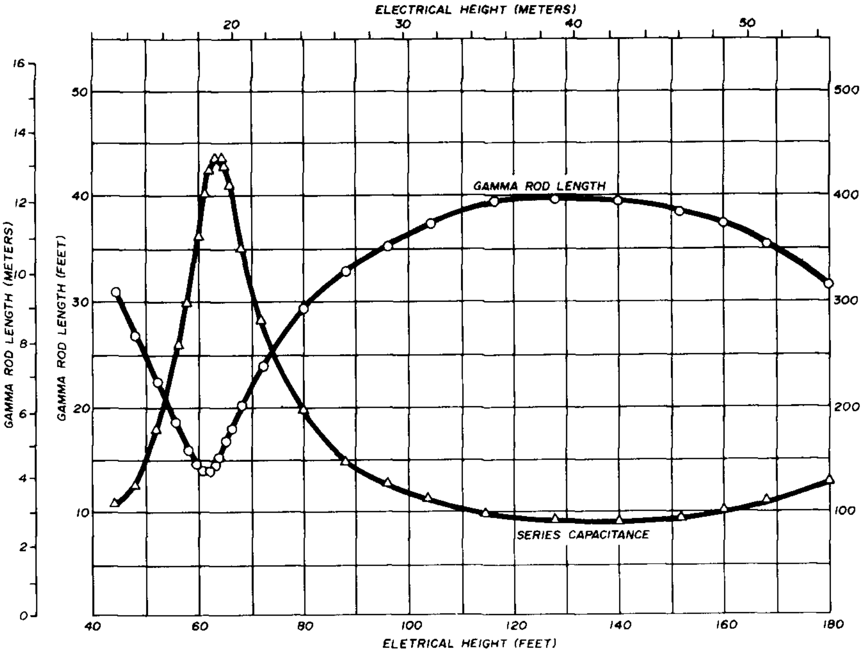


fig. 4. 80-meter vertical. Gamma rod length and series capacitance vs electrical height of tower. Recommended parallel capacitance to match 50-ohm transmission lines is 650 pF (at least half should be variable).

The setting of the series capacitor is rather critical because reactance changes

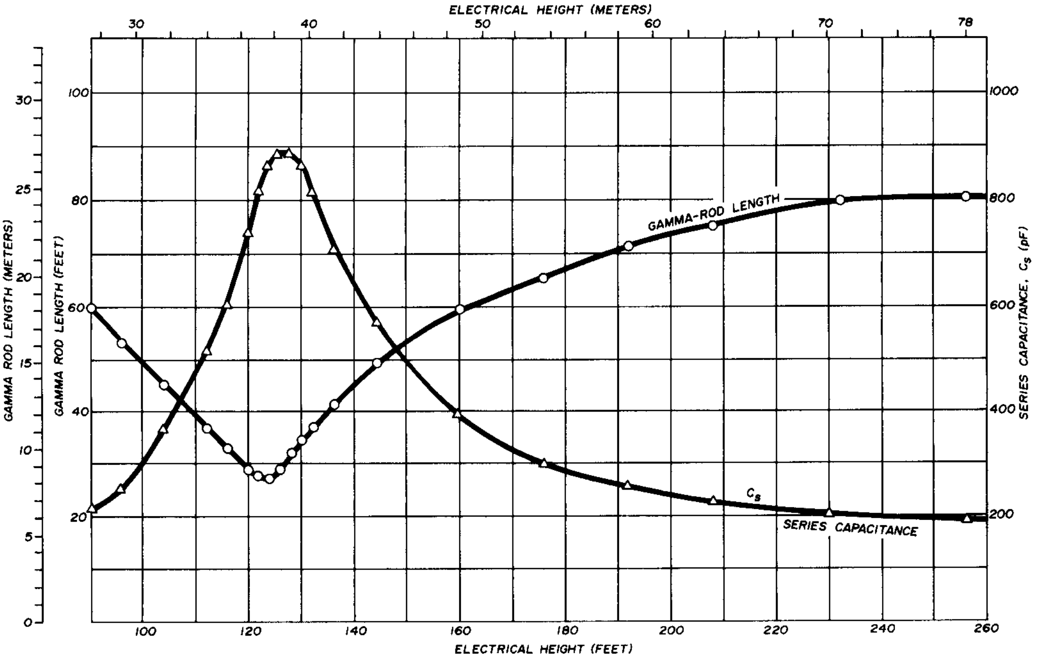
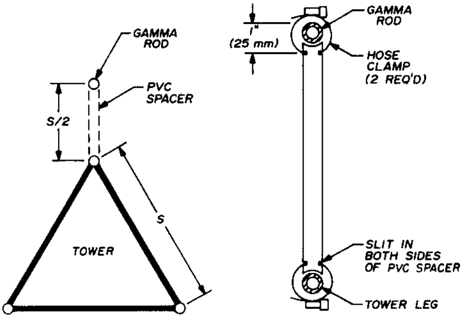


fig. 5. 160-meter vertical. Gamma rod length and series capacitance vs electrical height of tower. Parallel capacitance required to match 50-ohm transmission lines is approximately 1300 pF.

sharply near zero so it may take several tries before you can get the capacitor set exactly right. However, with a good ground system, the shunt-fed grounded tower can provide a very efficient antenna system for relatively little cost.



GAMMA ROD SPACING

PVC SPREADER

fig. 6. Construction of the shunt feed system for grounded vertical radiators. The spacers are made from PVC water pipe.

references

1. John R. True, W4OQ, "Vertical Antenna System," *ham radio*, April, 1973, page 16, and May, 1973, page 56.
2. I.L. McNally, W1NCK, and Henry S. Keen, W2CTK, "Graphical Solution of Impedance-Matching Problems," *ham radio*, December, 1969, page 26.
3. John R. True, W4OQ, "Measurement Techniques for Antennas and Transmission Lines," *ham radio*, May 1974, page 36.
4. Robert E. Leo, W7LR, "Vertical Antenna Ground Systems," *ham radio*, May, 1974, page 30.
5. Jerry Sevick, W2FMI, "The W2FMI 20-Meter Vertical Beam," *QST*, June, 1972, page 14.
6. Jerry Sevick, W2FMI, "The W2FMI Ground-Mounted Short Vertical," *QST*, March, 1973, page 13.
7. Jerry Sevick, W2FMI, "A High Performance 20-, 40- and 80-Meter Vertical System, *QST*, December, 1973, page 30.
8. Jerry Sevick, W2FMI, "The Constant-Impedance Trap Vertical, *QST*, March, 1974, page 29.

ham radio