How It Works

BY DAVE INGRAM, K4TWJ

Theory 'n Practice

A Quick and Simple Study of Vertical Antennas

Do you ever look at modern "no ground system required" vertical antennas and wonder how their design or features differ from basic 1/4-wave verticals of past popularity? Are new 3/8- and 1/2-wave style radiators such as the Hy-Gain AV640 shown in photos A and B really better for transmitting and receiving DX-worthy signals than traditional verticals? Well, friends, that is our topic of discussion this time, and I feel sure you will find it beneficial for understanding how the new verticals work.

Although rarely recognized, verticals have always been a mainstay in amateur radio. Why? They are affordable, low-profile antennas, plus one person can install and maintain one without undue stress. Yes, and they really look attractive after you've struggled to lift a multi-element beam over your head atop a swaying tower! Unfortunately, however, some folks consider verticals poor signal radiators, mainly because they install them in cramped spots where their performance is severely stunted. Bear in mind that any antenna needs "breathing room"—at least 1/8 wavelength between it and signal-blocking obstructions such as garages, houses, etc.—in order for you to reap the best results. Ideally, a vertical should have a clear horizon view in at least two of four compass directions. If it is blocked by a house, consider mounting it on the roof. If necessary, use an Alpha Delta tilt mount to raise and lower it from view. Think creatively!

Trends in Vertical Antenna Design

In amateur radio's "younger days," 1/4-wave verticals were "worked against" a full ground radial system like the one shown in fig. 1. Technically speaking, it could be compared to half a dipole stood upright with its radials producing a mirror image of the "missing half." Some (many?) amateurs used only their vertical's mounting pipe as a ground rod rather than laying down radials, which reduced the antenna's overall efficiency at least 40 percent (more if the antenna's radiation was blocked by buildings). Hy-Gain addressed that pitfall during the 1950s and 1960s by encouraging amateurs to add 1/4-wave radial kits to the company's "AVQ" series verticals and to mount them above nearby objects. Both Cushcraft and Butternut echoed the same message in the '70s and '80s by reiterating the importance of using radials with their verticals. Folks listened. They began describing their verticals by radial lengths and counts.

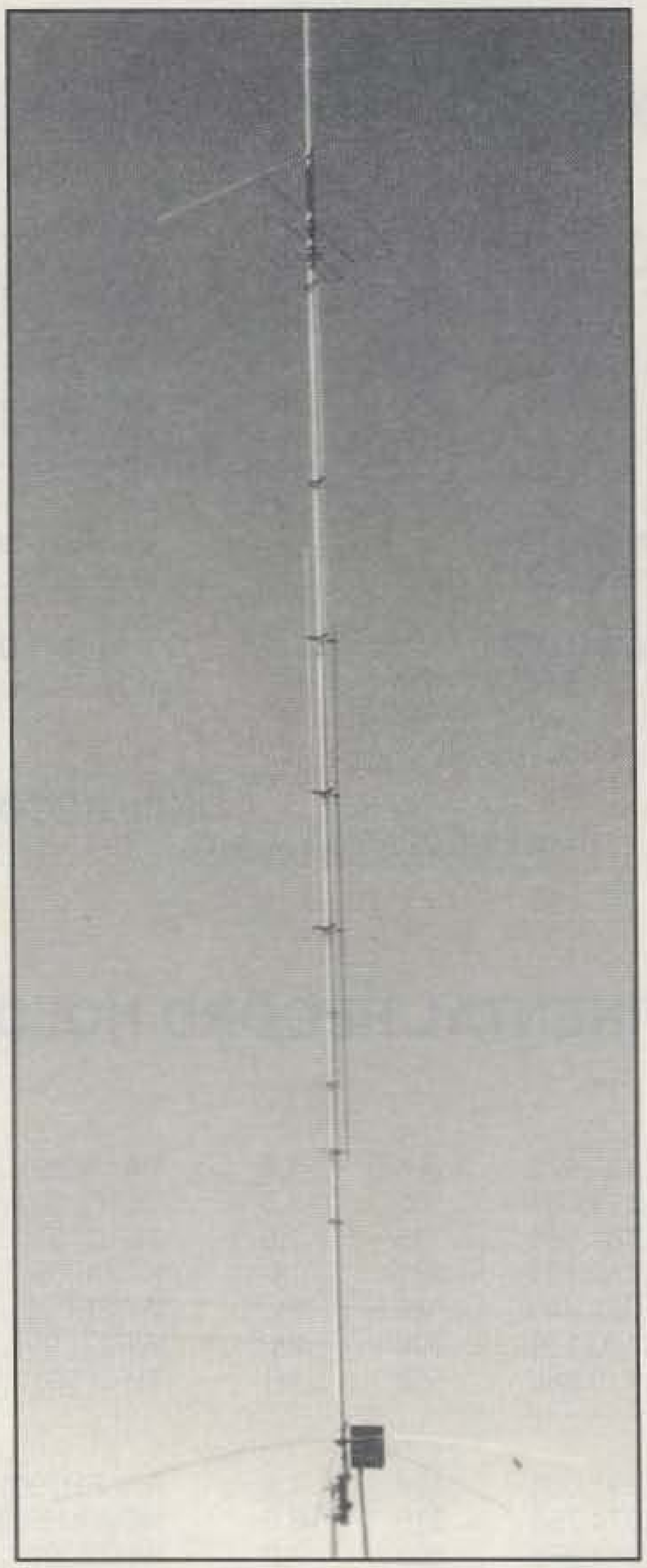

Photo A– Hy-Gain's recently introduced AV640 represents a fresh new approach to vertical antennas. It is easy to assemble and install, does not require an external ground system, and delivers mild signal gain for big-time radio fun on a budget. "How it works" is described in the text. (Photos courtesy Richard Stubbs of Hy-Gain/ MFJ Enterprises)

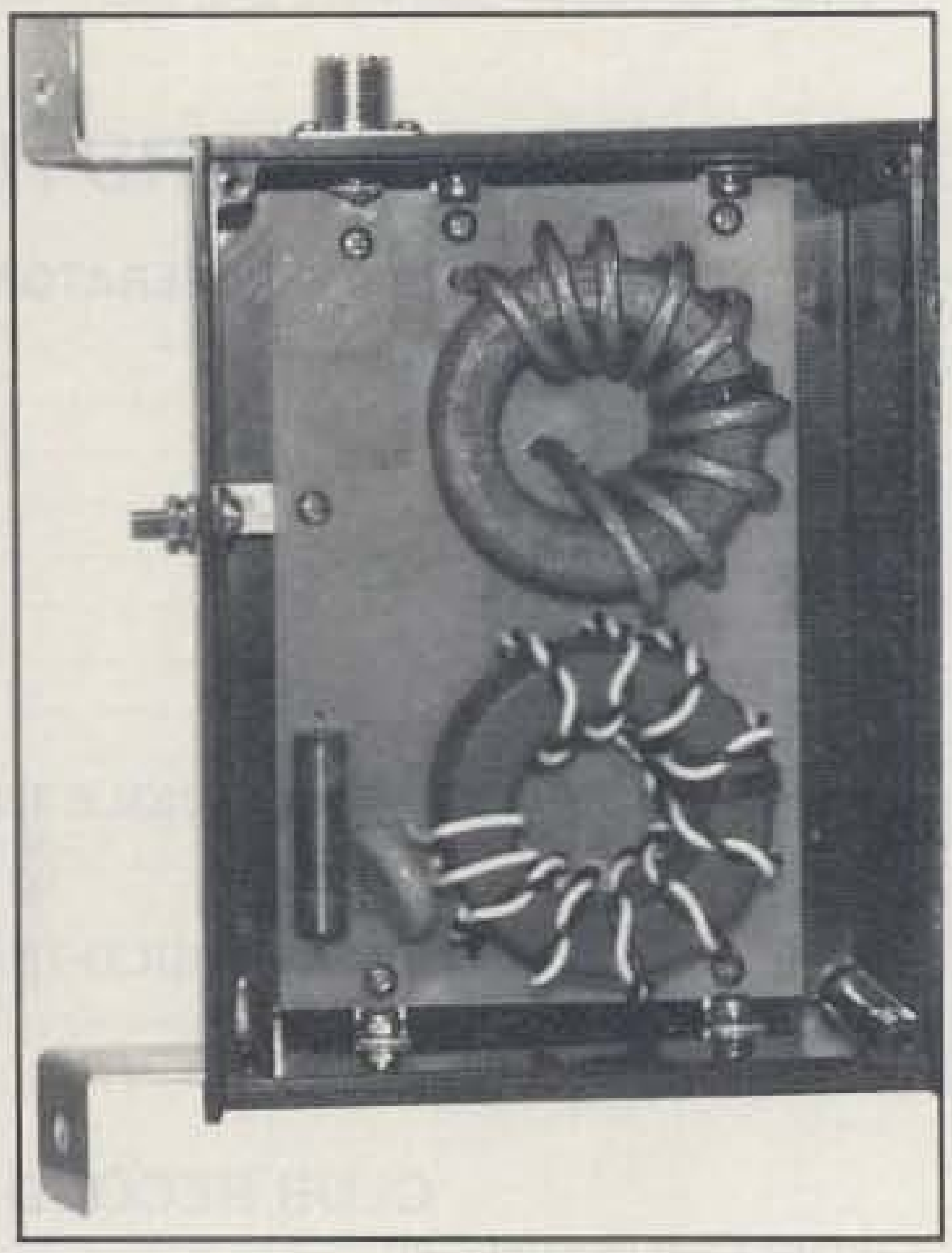

Photo B– Hy-Gain's AV640 utilizes 3/8-wave radiators for each band of operation. These radiators exhibit a high feedpoint impedance. Thus a toroidal RF transformer in a black box at the antenna's base steps up impedance. You are looking at the critter.

Multiband verticals also started gaining in popularity during the 1950s, first as multiple radiators sharing a common support and RF-fed in parallel, as illustrated in fig. 2(A). Next "trapped" verticals, like the one shown in fig. 2(B), gained favor. Then Gap and several other companies entered the antenna arena and longer length radiators plus capacity hats and linear-loading sections entered the picture. A new era dawned in vertical use and popularity.

How Trap Antennas Work

A significant amount of information regarding traps has been distributed, discussed, and debated in the past, yet they still remain a somewhat vague subject among many amateurs. I do not wish to join such debates, so the following information is presented only as my views.

Simply stated, a trap is a parallel-resonant circuit comprised of inductance (a

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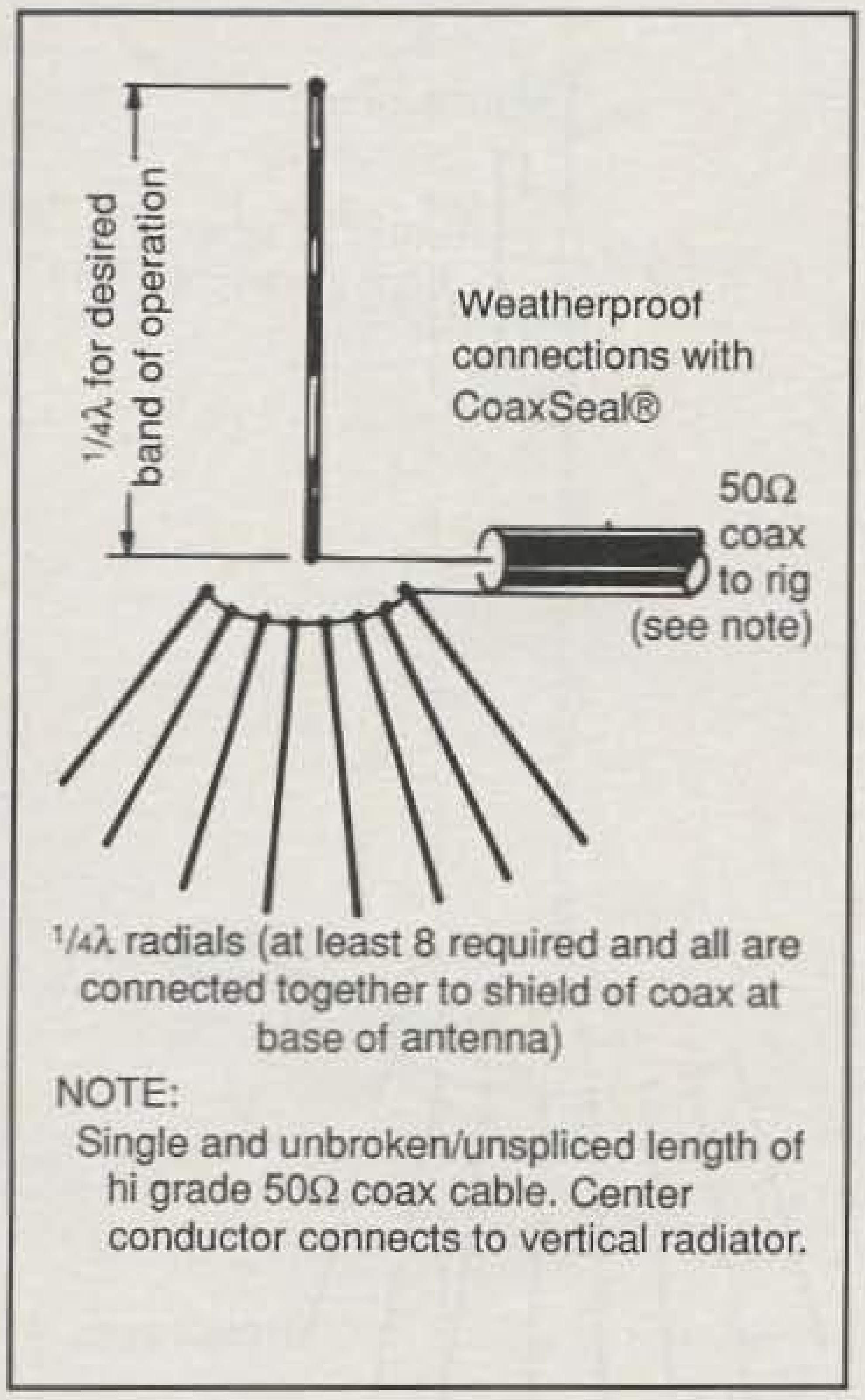

Fig. 1– Outline of a basic 1/4-wave vertical antenna and its associated ground system. Main radiation and reception is broadside to the vertical element. The antenna therefore should be mounted in an area clear of obstructions for best results.

coil of wire), capacitance (often made from concentric lengths of aluminum tubing), and resistance (of the coil). When placed in series with a vertical's main radiator, the trap passes all "outside of resonance" frequencies through it, but acts like a high impedance or "end of element point" to "within resonance" frequencies. With reference to fig. 2(B), that means only element section A would be in operation for 10 meters, and element sections A and B plus the coil in trap #1 would be used on the next lower frequency band. Element sections A, B, and C, plus the coils in traps #1 and 2 would be used on the next lowest frequency band, etc. In other words, the traps act like remote switches that automatically connect or "add in" various lengths to the vertical radiator to mate with a desired band of operation. There is a rather small loss of signal strength due to copper losses in a trap's coils, but it is an acceptable trade-off for the convenience of "hands free" multiband operation.

Capacity Hats and Linear Loading Sections

Two quite effective ways of increasing the electrical length of an antenna without extending its overall physical length (or height) are with *capacity hats* and *linear loading sections* like those illustrated in figs. 3(A) and (B). Both of these techniques have been incorporated in antenna designs for a number of years, and both have their merits.

Implemented in its most conventional form, a capacity hat consists of two thin rods crossed to make an "X" and mounted on the upper section of a vertical radiator (or even a mobile whip). Let's say we wish to make a "short version" 1/4-wave radiator for 20 meters (12 feet tall) or a 1/2-wave radiator for 10 meters (also 12 rather than 16 feet tall). In either case, we simply attach two 2 foot long rods to the top of the 12 foot tall mast/whip as shown in fig. 3(A). Each of the four rods extends outward one foot from the 12 foot section, producing a total electrical length of 16 feet. Clever, eh? Could even more rods of longer length be substituted to further extend electrical height? Sure, but remember that exceptionally large capacity hats increase wind loading and produce unwieldy antennas. Everything has its limits.

A linear loading section also increases a vertical's electrical rather than physical height, and it is usually less apparent to curious eyes than a capacity hat. Simply described, linear loading is achieved by "folding part of an antenna's radiating element back on itself" as shown in fig. 3(B). Since this section is "spread out in the open air," it exhibits better signal radiating and intercepting abilities than a loading coil. Also, linear loading sections are not as prone to copper losses as coils. Overall, we thus can say full-size radiators are the best performers, but their tall height for lower HF bands makes them an illogical choice. In such cases capacitive, linear, and inductive loading reduces their physical height to acceptable dimensions.

3/8- and 1/2-Wave Radiators

The entanglements of installing a full ground system for a 1/4-wave vertical inspired amateur radio's progression to

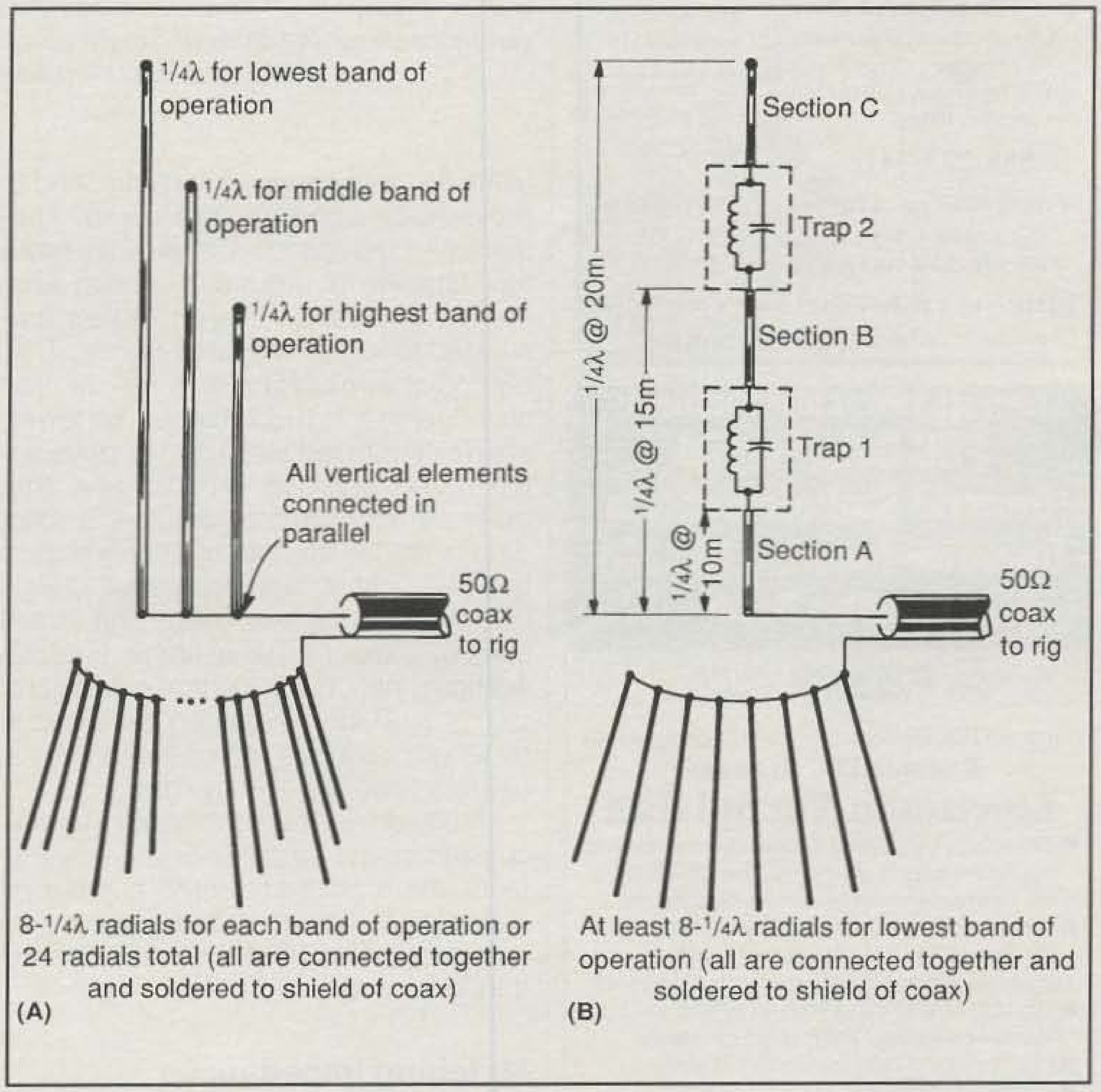

Fig. 2– Original versions of multiband verticals utilized separate 1/4-wave radiators with a common support as shown in (A). Later versions use a single radiator with traps isolating various sections for each band of operation, as shown in (B). (Discussion in text.)

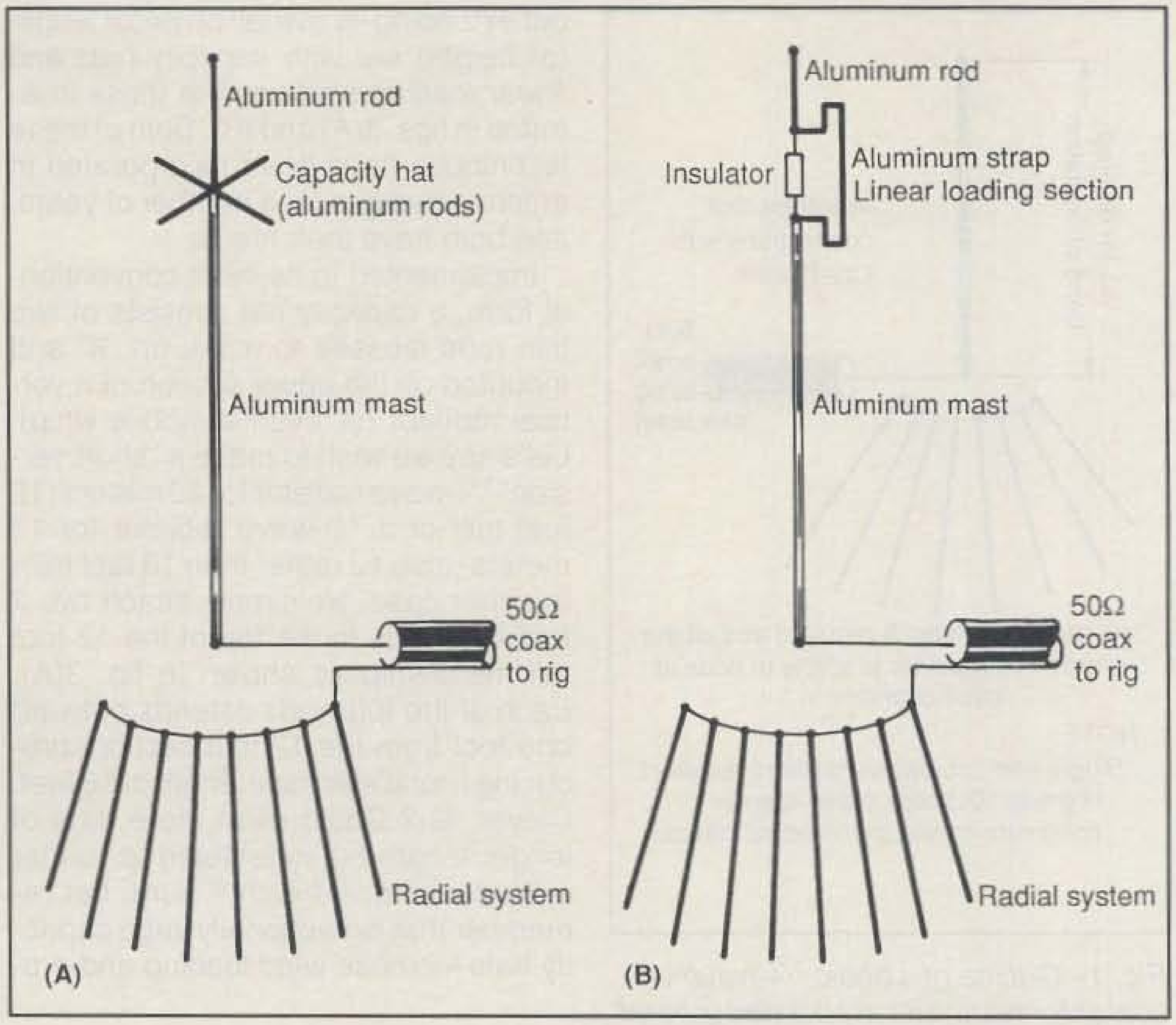

Fig. 3– Two quite effective methods of increasing a vertical's electrical height without increasing its physical height involve the use of a capacity hat as shown in (A) or a linear loading section as shown in (B).

using 3/8- and 1/2-wave verticals, and it proved to be a good move. How so? The feedpoint impedance of a 1/4-wave radiator typically is around 35 ohms, and many 1/4-wave (or longer) radials are needed to match that impedance. The feedpoint impedance of a 3/8- or 1/2-wave vertical is much higher, so fewer shorter length radials fill the bill, or serve the same purpose. Additionally, the taller vertical radiator delivers a mild gain in signal strength of approximately 3 dB—that is, assuming a full physical length radiator is used. The inclusion of capacity hats, linear loading sections, etc., can drop that gain figure to 1 or 2 dB, depending on the amount of length reduced for operation on a (usually lower frequency) band.

I really do not intend to make this discussion sound complex or repetitive in facts; there are just a large number of variables to consider and compare in antennas. Keep that thought in mind, and let's continue.

Matching Impedances

Since the feedpoint impedance of a 1/4-wave vertical antenna is low, it can be directly fed with 50 ohm coax cable. The feedpoint impedance of a 3/8- or 1/2-wave vertical is much higher and must be matched to its cable with a base-mounted transformer or base-located tuner. Let's consider the distribution of voltage and current along a full wavelength of wire as shown in fig. 4 and "plug in" some hypothetical values to illustrate that point.

Voltage (E) is maximum and current (I) is minimum at 1/2-wave points on the wire or conductor, while current is maximum and voltage is minimum at 1/4-wave points. The exact amount of measured voltage and current is directly proportional to the supplied RF power and is thus a "variable." The ratio between voltage and current is predictable, however, and always indicates a 1/4-wave impedance near 50 ohms and a 1/2-wave impedance near 2500 ohms. Since 3/8 wave is midway between 1/4 and 1/2 wave, its impedance is near 1200 ohms. If you study fig. 4 for a few minutes, you will see we can RF-feed any length of wire/conductor longer than 1/4 wave if we simply match its impedance at that point to its feedline. Could a regular antenna tuner fill that need, you ask? Probably, but reaching way out in the yard or atop the house to retune it when changing frequencies would be a tricky feat (we need "Plastic

Man"). Using a broadband toroidal transformer to match the two impedances definitely would be a better bet. Yes, and that RF transformer is what's in the mysterious black box at the base of a typical 1/2- or 3/8-wave vertical.

Applying Our Knowledge

Let's now return to the Hy-Gain AV640 vertical shown in the photos and use some of our acquired knowledge to understand "how it works." First notice, as advertisements of the AV640 state, quarter-wave stubs or radiators for 6, 10, 12, and 17 meters are full length and positioned around the center radiator. But wait, you say. This is supposed to be a 3/8-wave antenna, not a 1/4-wave antenna. How true indeed! Here is the key. Each quarter-wave stub is mounted or positioned up 1/8 wavelength (for its band) from the center radiator's base and connected to the center radiator at only that point. The other "X" type supports insulate the stubs from the center radiator (they are only supports). Add 1/8 wavelength for a given band to the 1/4 (or stated another way, 2/8 wavelength) stub for that band, and bingo: We have a 3/8-wave radiator. Slick, eh?

Now study the center radiator (that large aluminum tube with all the frills on top). Electrically, it must be 16.6 feet tall for 15 meters, 24.7 feet tall for 20 meters, 34.6 feet tall for 30 meters, and 49.6 feet tall for 40 meters. That requirement is filled by the loading coils and capacity hats on the center radiator's upper section (above the stubs). Loading coils alone could do the job, but inclusion of capacity hats minimizes the number of coil turns needed and lowers coil/copper losses.

Since feedpoint impedance is high, seven rods at the vertical's base make a more-than-adequate ground counterpoise. Toroidal cores in the base matching unit (photo B) act as impedance matching transformers, plus one toroid also acts as a current balun to help stop RF from traveling back along the feedline.

Now I wish to add one final note. If you invest in a shiny new vertical (or any type of antenna), connect it to your transceiver using new coax of the highest grade affordable. You should never degrade a good antenna with poor, old, or spliced coax.

We covered a lot of ground in a limited space! Included is a wealth of information you can use for many years. Now read it all again for maximum understanding and retention!

73, Dave, K4TWJ

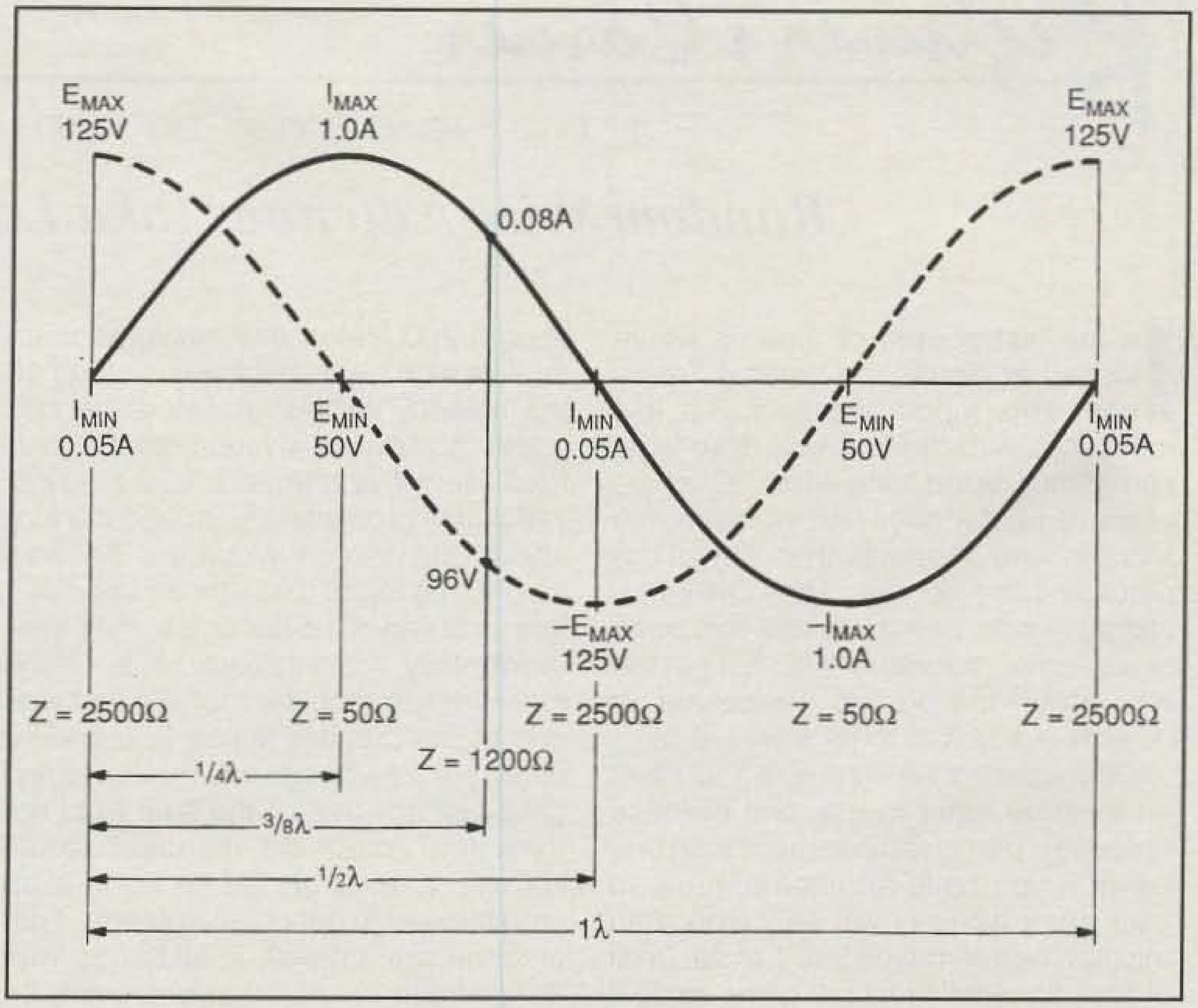

Fig. 4– Graphical study of voltage and current distribution along a wire or conductor of varying length. By inserting some hypothetical values to coincide with peaks and nulls, we can see how feedpoint impedance varies according to length of conductor, etc. (Full discussion in text.)