antennas

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Antenna Tuners . . .

Do they really tune your antenna?

Antenna tuners: They may be manual or fully automatic, balanced or unbalanced, for QRP operation or capable of handling full legal power; may be just a simple series capacitor or L network; may be found in the rather popular T configuration, or the less popular but highly effective PI ; some of the more sophisticated ones may offer full control of all the reactances involved, both capacitive and inductive, and be configured according to the requirements. What I can assure you, however, is that although they are all known as *antenna tuners,* those nowadays essential accessories of our amateur radio stations usually are *not* doing precisely what their name suggests.

From an engineering point of view, antenna tuners are defined as transmission-line sections, be they made from actual physical sections of feeders or from lumped circuits in the form of capacitors or inductors. What is most important of all to make this definition valid is that they must be located right next to the antenna itself. As a matter of fact, any attempts to place the device more than a very short distance away from the antenna in terms of wavelength at the operating frequency will disqualify it as a properly defined *antenna tuner.*

Let's face it: The box, usually with two or three knobs we can tweak, or in more recent times the fully automatic version placed right next to a typical transceiver, in most cases is not working as an antenna tuner as such, and could best be described as a transmission line to transmitter output matching system. However, I doubt that by now we can do anything realistic to change the name of such boxes, so in this column they will continue to be known as antenna tuning units, antenna tuners, or just tuners!

The first conclusion that you should draw from reading this month's "Antennas" Column is that whenever possible, the tuning unit should be located right next to the antenna in use. Doing this certainly will improve the performance of any radiation system, because power transfer from the transmission line to the antenna will be optimized, and the transmission line hopefully will "see" its characteristic impedance at both ends—that is, at the output of the transmitter and at the antenna. I may add, though, that recent careful measurements made to several popular amateur transceivers showed me that their output impedance wasn't the nominal 50 ohms specified by the manufacturers.

Locating the antenna tuning unit, which is the proper name of the accessory, right next to the antenna does bring into the picture one problem: the need to have a remote-control system to operate the system if one needs to change frequencies.

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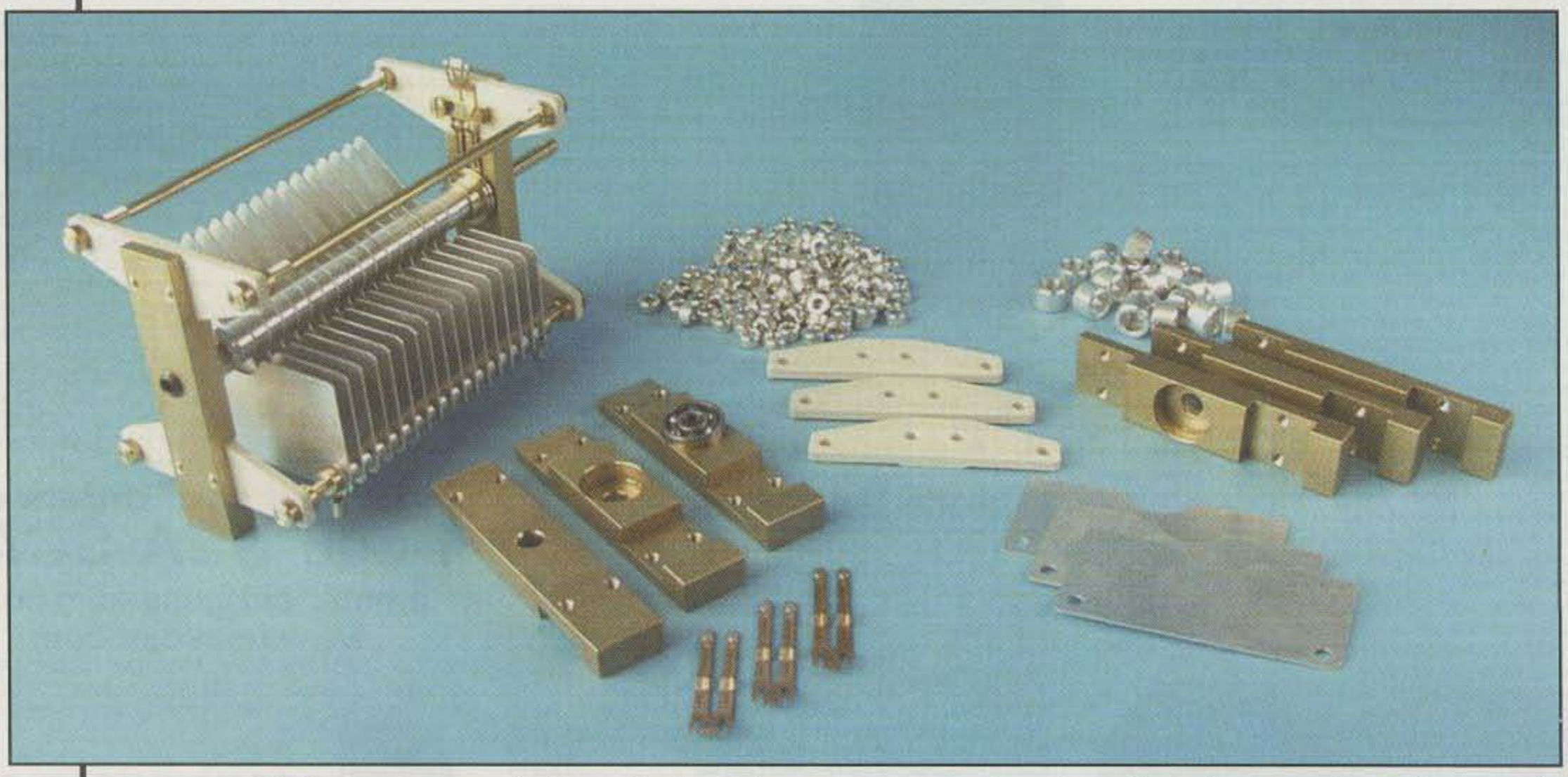

Photo A– Antenna tuning units for high-power use require using either air-spaced variable capacitors such as this one, or the more expensive vacuum variables to prevent flashovers arising from mismatch conditions.

With recent advances in microprocessor-controlled equipment, remotely tuned antennas are becoming more and more common, especially among professional users of the HF spectrum. Perhaps the best known cases nowadays are the "magnetic loop" antennas that are remotely tuned for resonance and minimum SWR and are helping so many amateurs enjoy the hobby despite having to face severe antenna installation restrictions. I will be presenting several easy-to-homebrew magnetic-loop antennas in an upcoming column.

So far, however, among radio amateurs even the automatically tuned equipment most of the time is located right next to the transmitter, with a variable length of transmission line connecting the antenna to the . . . *transmission-line tuner!*

Length of the Transmission Line

Playing with one of antenna engineers' favorite toys, the Smith Chart, you soon will find that the length of the transmission line between the antenna and the actual location of the antenna tuner, plus the length of line between the tuner and the equipment, have a very significant impact on the matching and efficiency of the system.

Single-band operation on the antenna makes things a lot simpler, because transmission-line theory will tell you that cutting the line to an exact multiple of half wavelengths makes it possible for the complex impedance seen at the antenna terminals to be almost exactly duplicated at the far end of the line, where your box will then attempt to achieve a match.

What to do when multiband operation is required? The answer to this important question will help you do a critical review of your station.

One good choice is to cut the transmission line, typically a coaxial cable run, to an exact number of wavelengths on your favorite band, and then be prepared to match whatever complex impedance is present at the end of the cable on other bands to the radio frequency amplifier output stage, be it a single transistor in a QRP rig, or two big metal-ceramic tetrodes that deliver high power for breaking those pile-ups!

The Right Name for Those Boxes

Let's call them, at least temporarily, by their proper name—*transmission-line matching devices*—and of course, let's also create yet another acronym . . . the *TLMD*.

Now that we have invented a good name for antenna tuners, as they have been known up until now, let's start to learn more about them.

In most cases involving the HF bands, from 80 meters all the way up to the upper edge of our widest band, 10 meters, extremely simple TLMDs will do a very good job indeed. What do I mean by simple? Well, just using the simplest possible matching network, formed by an inductor and a capacitor—the so-called L configuration.

A properly designed L tuning network will have lower losses than other arrangements such as the T or the PI, and it can be easily homebrewed if you can find the proper variable capacitors. Ideally, the L network should have both branches variable, but with antennas that are not resonant to the operating frequency, you can find the required inductance experimentally, then make a final version of the coil required, and only tune the variable capacitor for a proper match which can be approximated by measuring the voltage standing-wave ratio (VSWR).

One of the most prevalent myths, even among some old timers, is that antennas need to be resonant to the operating frequency if you really want them to be efficient. This is absolutely wrong. That's why the L antenna, used with a real antenna tuning unit and not a TLMD, has proven to be so effective.

The combination of an L antenna that starts very close to the station, with an L-network antenna tuning unit *plus* a good counterpoise, is an excellent multiband antenna if you are able to put up at least 0.15 wavelength of wire up in the air.

TLMDs to Avoid and Features to Look For

Transmission-line matching devices that use the T network are the ones you want to avoid using, if you also want good suppression of harmonics and other nonessential radiation. I must warn you, however, that opening up many of those antenna tuners will show that they use precisely the T circuit arrangement, a high-pass network, so it will provide almost no suppression of frequencies above the one on which you are operating.

Avoid the tuners that use very smallsize capacitors and very compact coils. RF watts that are so hard to generate should not be lost as heat.

TLMDs with built-in SWR meters are certainly advantageous, as they save lengths of interconnecting cables and connectors. However, don't think that you will gain a lot by having the SWR meter form part of the TLMD, because losses of the typical coaxial connectors and small lengths of cable are really minimal even all the way up to the VHF region of the spectrum.

TLMDs You Can Make Yourself

First things first: Yes, you can make your own high-performance TLMD or a *real* antenna tuner by following good design and construction practices. By now I am sure that you will avoid the T network for your homebrew TLMD or tuner. That decision will lead you to either the L , the PI, or the PI-L for typical unbalanced networks used with coaxial-cable feedlines.

The L, using high-quality capacitors such as the ones shown in photo A, may be used with the capacitor placed at

Photo B– The variometer was extremely popular among radio pioneers. Nowadays it is still used at high-power VLF stations for precise matching of very large antenna arrays. Variometers offer superior performance because the inductance can be changed without any mechanical contacts.

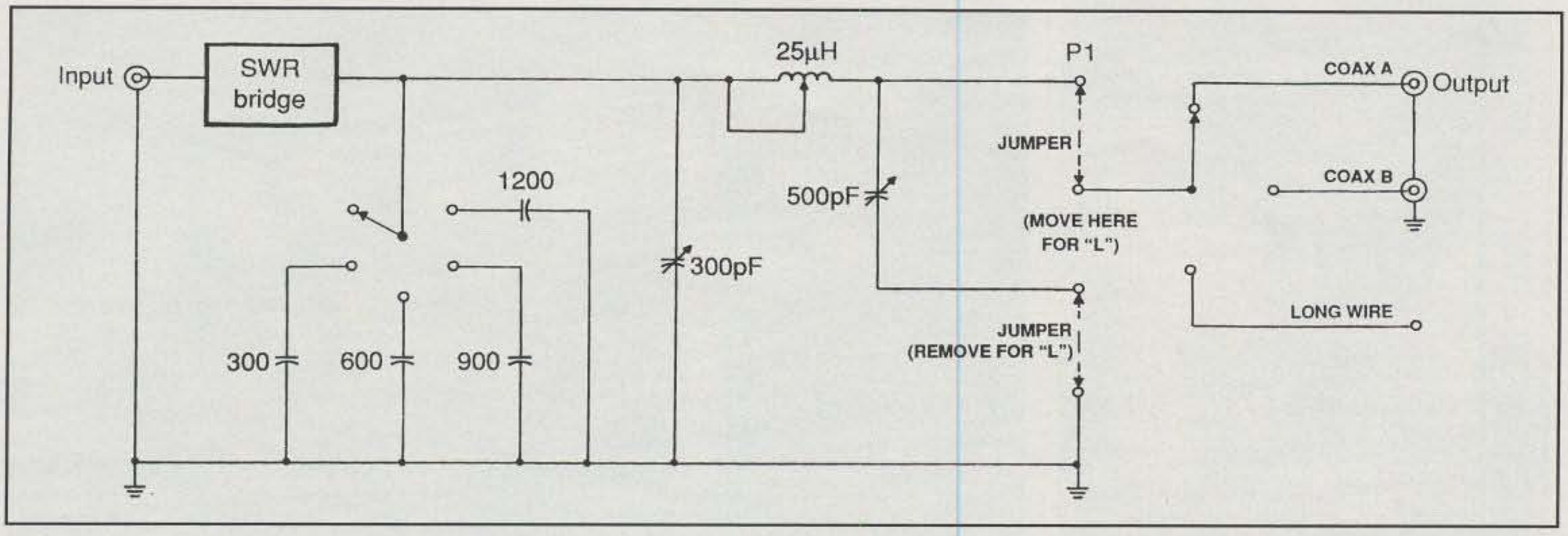

Fig 1– Circuit diagram of PI-L tuner. My favorite antenna tuner or TLMD, depending on where it is located, is the PI-L, which offers both a wide range of impedance matching and excellent low-pass action.

the antenna side or at the rig's output side. On some bands, using the L network to match, for example, an L or a T antenna will require that you have the capacitor connected to the antenna side, while on other bands the network has to be connected all the way around.

You can optimize the L network by making both the inductance and the capacitance variable. In that case, you have three choices for the variable inductance:

1. Use a fixed inductance (coil) with taps and a switch.
2. Use a roller inductor.
3. Use a *variometer* (see photo B).

Of the three above-mentioned options, the most efficient one is the variometer, as you can smoothly change the inductance without having to involve any metal-to-metal contacts. Variometers certainly are not popular in today's radio "art," and this may be due to the relatively high cost of making them, as compared to the simpler coils with switches or the continuously variable roller inductors.

After the ultra-simple L , the next easiest to build TLMD uses a PI network configuration that has the added advantage of much more low-pass filter action as well as providing a very wide range of matching.

Finally, if you really want the optimum, go for the PI-L network (see fig. 1), as this circuit arrangement will provide the widest matching range plus excellent low-pass filtering.

As you may realize by now, once you have the know how, TLMDs and real antenna tuning units are not that difficult to homebrew.

Actual losses due to the coaxial transmission line used at most amateur stations begin to be really significant when the SWR goes above 3 to 1 and the length of the cable is really long. This means that using the antenna tuner as a TLDM with relatively short cable runs —as most of us do—may not be that bad at all. Nevertheless, the highest

Tuners for VHF and UHF?

Sure . . . and I can't understand why they haven't become more popular among VHF and UHF operators. A PI-network 6 meter TLMD used at CO2KK practically eliminates any trace of TVI to local channel 2 , while my simple PI tuner used ahead of the 2 meter FM rig not only makes the rig look at a 1:1 SWR, it also dramatically reduces crossmodulation problems.

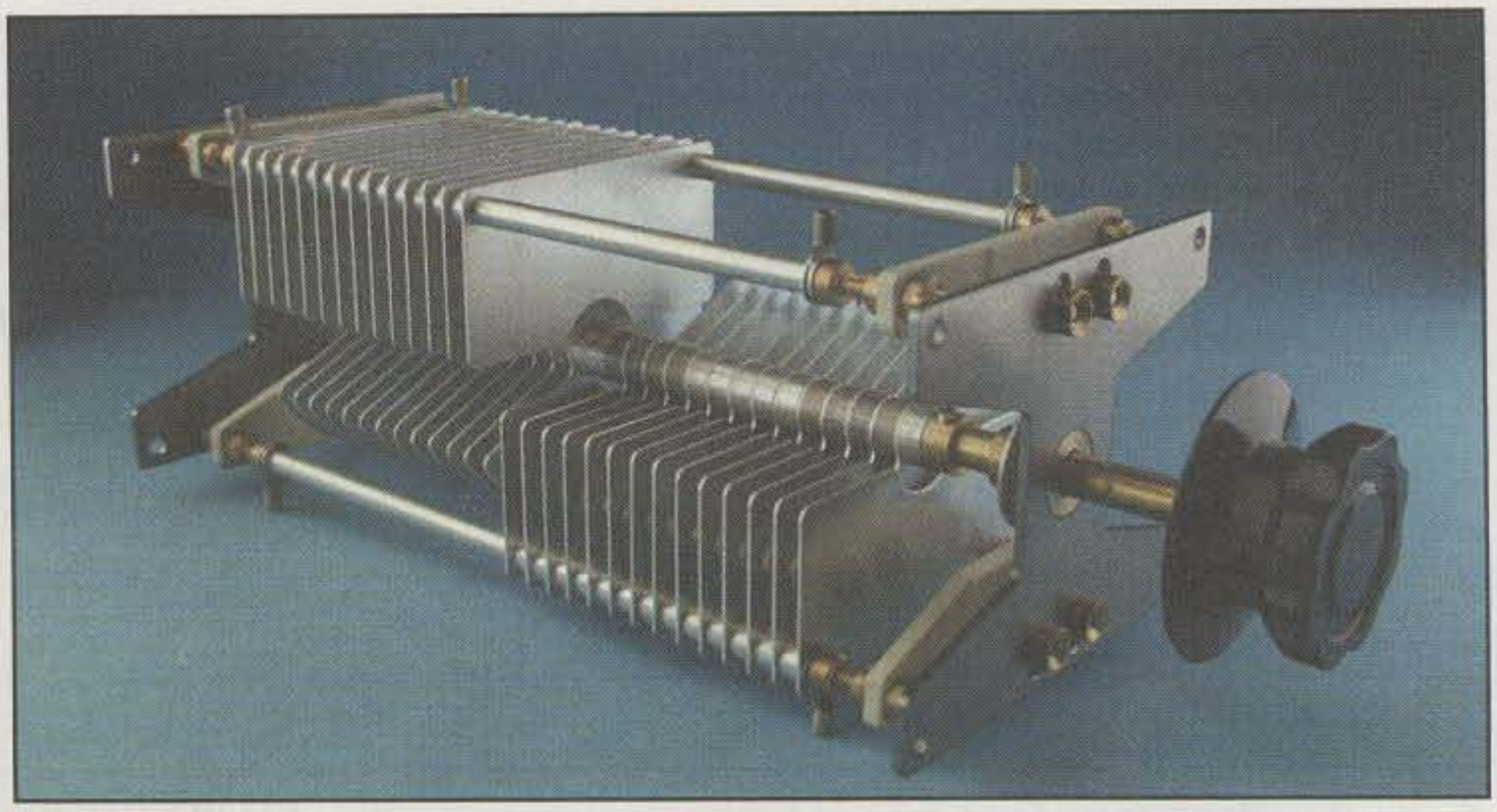

Photo C– Properly designed antenna tuning units will have optimum LC ratios, and the balanced units will use differential or split-stator capacitors such as this one to keep perfect balance between both sides of the transmission line.

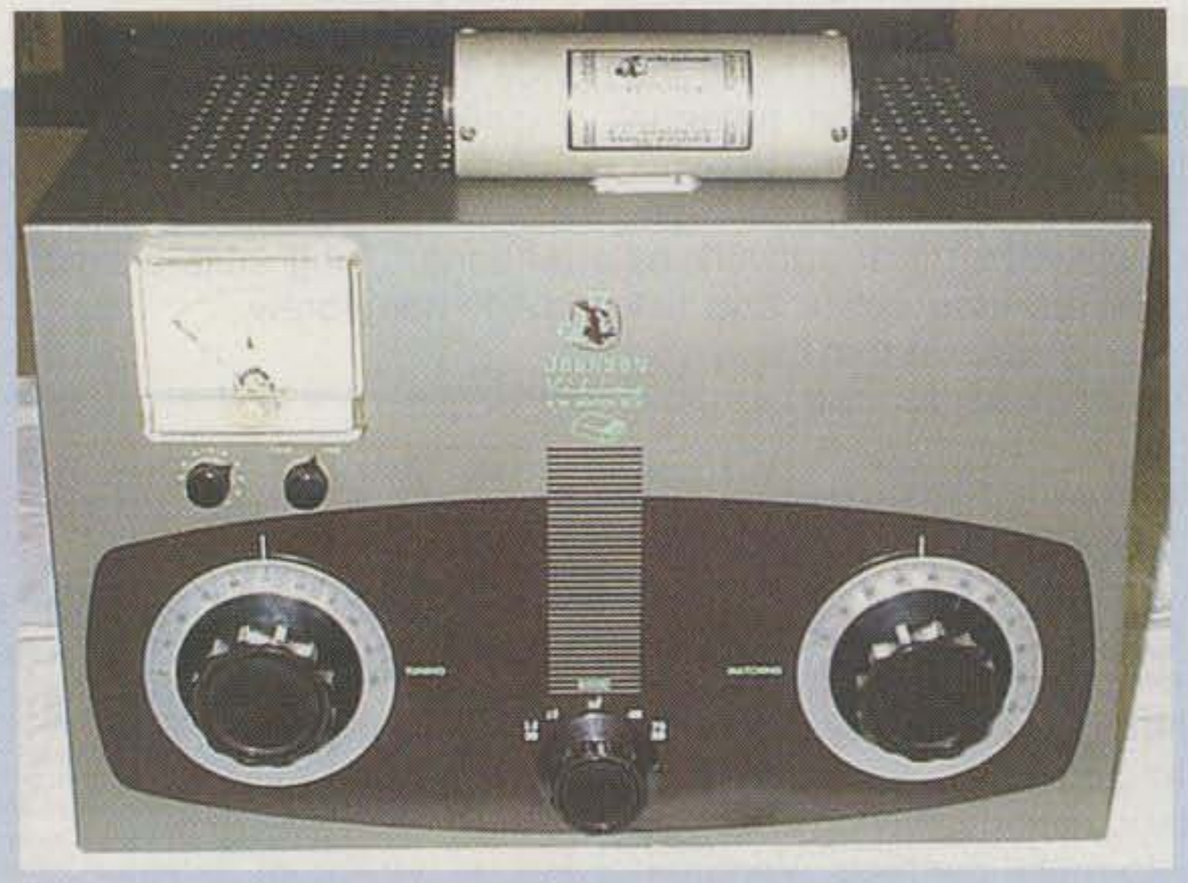

Photo D– Many years ago, the E.F. Johnson Company made the new-classic Kilowatt Matchbox. The engineers who designed it apparently convinced the sales people to use the appropriate name for the accessory, a "Matchbox," not an "antenna tuner."

possible efficiency certainly is achieved only when the matching unit is right next to the antenna to do its one and only job: *Matching* the antenna's complex impedance to the transmission line, *not tuning the antenna at all!*

TLDMs and Real Tuner Scenarios

If your tuner is right next to the antenna, for example at the base of a vertical, then it is a "real" tuner. However, if you simply connect a 50 ohm coaxial line to a half-wave wire dipole (even using a balun) and then trim the SWR to a minimum with the tuner located right next to the rig, you are using it as a TLMD!

Commercial antenna systems intended for wide frequency coverage in the HF spectrum use very sophisticated remotely controlled tuners with great effectiveness, but at very high cost, as extreme care must be taken to protect all the components from exposure to the weather.

My advice is that whenever possible, go for the real tuner function right next to the antenna, and match the antenna to the characteristic impedance of the transmission line right where it must be done! ■