Radio FUNdamentals

BY BILL ORR, W6SAI

THINGS TO LEARN, PROJECTS TO BUILD, AND GEAR TO USE

Aloha, KH6SB

At the end of May 1994 NOAA closed down the Maui (Hawaii) Ionospheric Research Station. After running for years, all was finished. I pulled into the parking lot in early June to visit my friend Steve Barnes, KH6SB, who had supervised the station for decades.

At first glance all looked normal. The wideband antenna for the ionospheric sounder was in place. Steve's big tower was there, with the big Yagi antennas atop it. Inside the laboratory, however, things were different. The sounder, which had run continuously for many years, was silent. The rack of receivers and recorders was gone, as was a lot of the auxiliary support gear.

In Steve's home most of the furniture was missing. Some half-filled shipping cartons were awaiting final shipment. Most of KH6SB had been shipped, except for a transceiver sitting on a card table. The building was nearly deserted. By July 1st, if all went well, the remaining stuff would be packed and gone, and Steve would be flying home to the Denver, Colorado area.

As I shook hands and said goodbye to Steve, he handed me a last gift—the final ionospheric reading of the sounder, with a comparison to the previous sunspot cycle (fig. 1).

"It looks as if the cycle may bottom out sooner than expected," said Steve, "but you never can tell."

Aloha, Steve. We'll miss your big signal on the bands. We hope to hear KH6SB/Ø on the air one of these days. Mahalo.

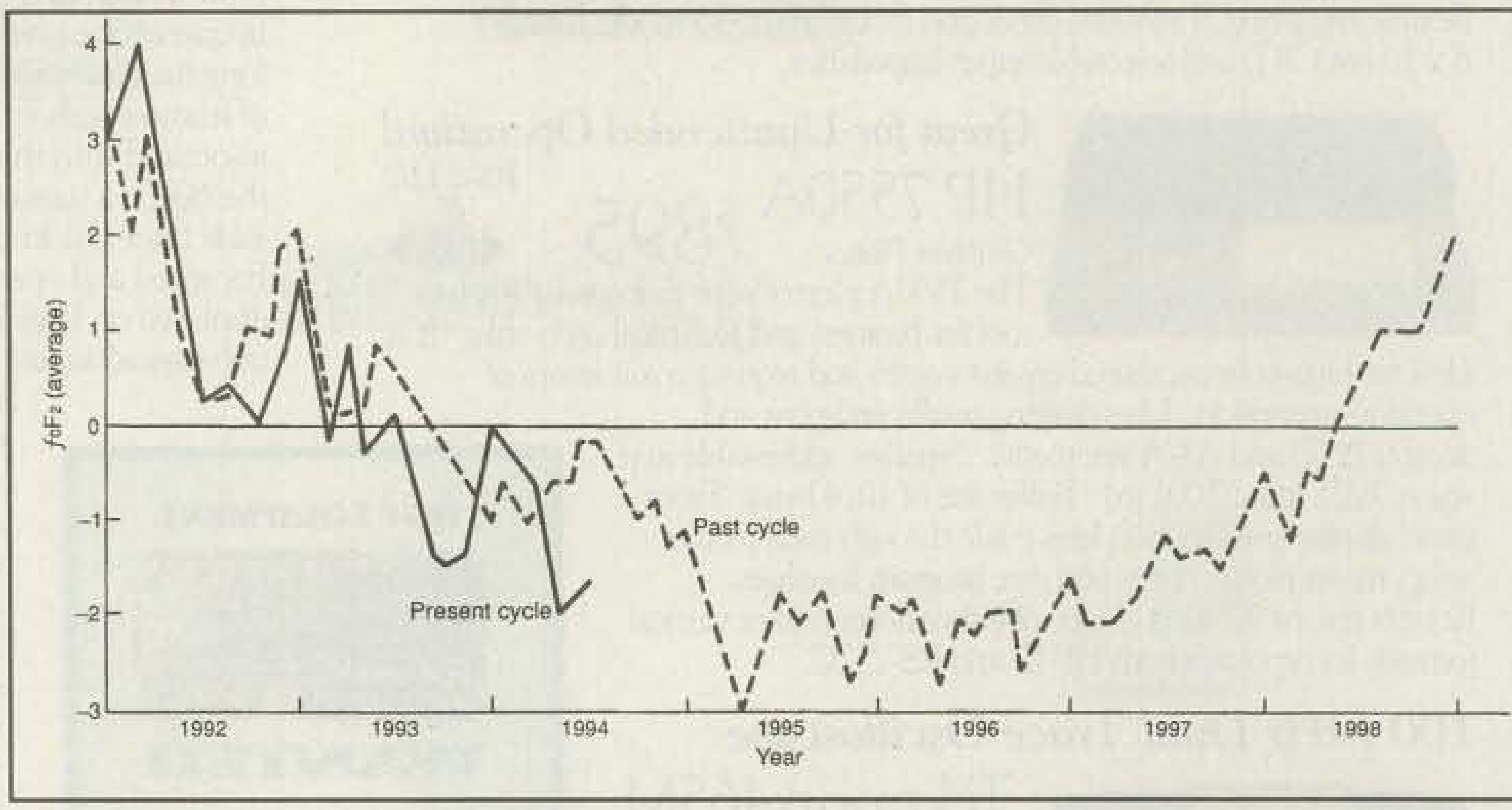

Fig. 1– A comparison of the present and past sunspot cycles hints that the forthcoming minimum may bottom out sooner than expected. It would be nice if the sunspot count started to climb in late 1996! Time will tell. Shown are the average ionospheric soundings taken at Maui, Hawaii.

The Log Periodic Dipole Array: Something For Nothing?

Ah, well. Even though the sunspot cycle is headed for the cellar and the bands are dry as dust, things will be looking up eventually. Perhaps by 1998. And that's only three years away. Time to start thinking about a new antenna system.

The spectrum of interest for a lot of DX-minded amateurs is the region between 14 and 30 MHz. Remember 10 meters in 1989–91 when the sunspot cycle was at its maximum? I do. The band was open from California to all of Europe, Africa, and Central Asia with booming signals. Fifteen and 20 meters were just as good, and both the 18 and 24 MHz bands had plenty of great DX signals on them.

So what about a multiband beam for the coming DX period when the sun once again cooperates with the eager amateurs? I've seen multiband Yagis advertised, but they either have a lot of aluminum up in the air or a multiplicity of traps. Or perhaps both. As far as I'm concerned, I like DX as well as the next guy, but I don't like an aluminum forest hanging over my head.

A lot of fellows think like I do on the subject of antennas. Some of them have turned to the log-periodic array, the beloved antenna of military and diplomatic communications. LPAs come in all sizes, and perhaps a modest one will suffice for the DX-minded amateur who is not enthusiastic about swinging a big multiband Yagi over his home.

Basic LPDA

The basic log-periodic dipole array (LPDA) physically resembles a truncated, multi-element Yagi. All elements are fed from a transmission line which runs along the center of the array. The line is transposed so that the proper phase shift occurs between each element.

The longest element is about a free-space half wavelength at the lowest operating frequency, and the shortest element is about 40 percent of a free-space half wavelength at the highest operating frequency. Spacing of the elements decreases as element length decreases. The feedpoint of the antenna is at the apex (fig. 2).

Since all elements are split at the center for the feedline, the mechanical assembly of the LPDA can get a bit messy. In some designs all elements are mounted above a single boom in insulated collars, in the manner of a Yagi driven element. The transmission line is transposed between elements as it runs along the boom.

Another scheme is to use two parallel booms, acting as a feedline, with the elements cross-connected to each boom, to maintain the proper phase relationship. Either idea provides mechanical problems for the builder.

Even though LPDA construction is complicated, the prospect of a multiband antenna, without traps or other gimmicks, is appealing, especially if the antenna assembly isn't too large, physically. How much gain and front-to-back ratio can a designer get from a modest LPDA?

The most modest LPDA design I have seen is in *The ARRL Antenna Book*, 16th edition, page 10-5. This array is shown in fig. 3. It is built on a 10 foot boom. A 4-to-1 balun is used to match the average input impedance of the antenna to a coax line. The term "average impedance" is used, as the input impedance varies with frequency.

The antenna parameters given in *The Handbook* indicate an average gain of

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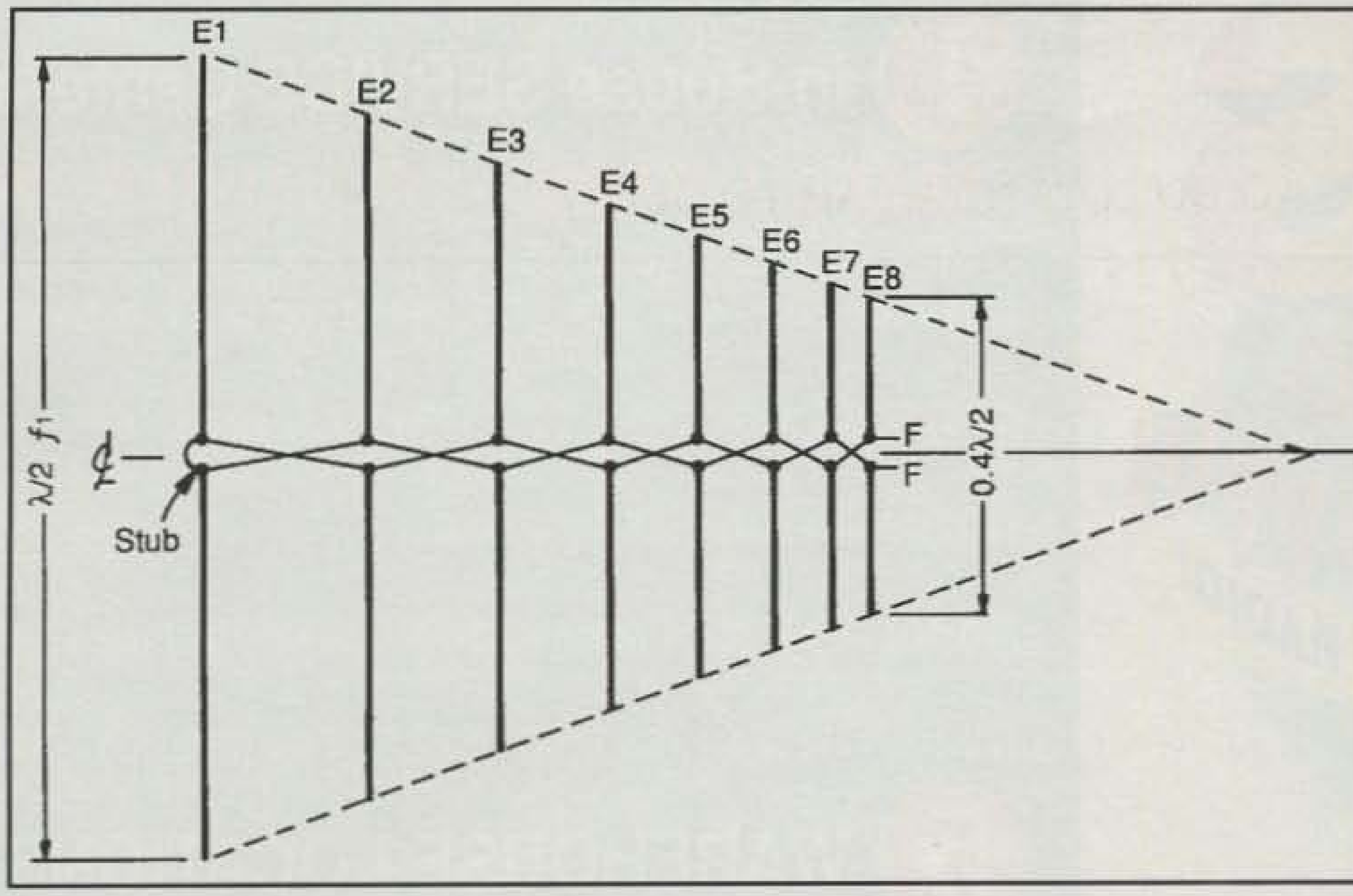


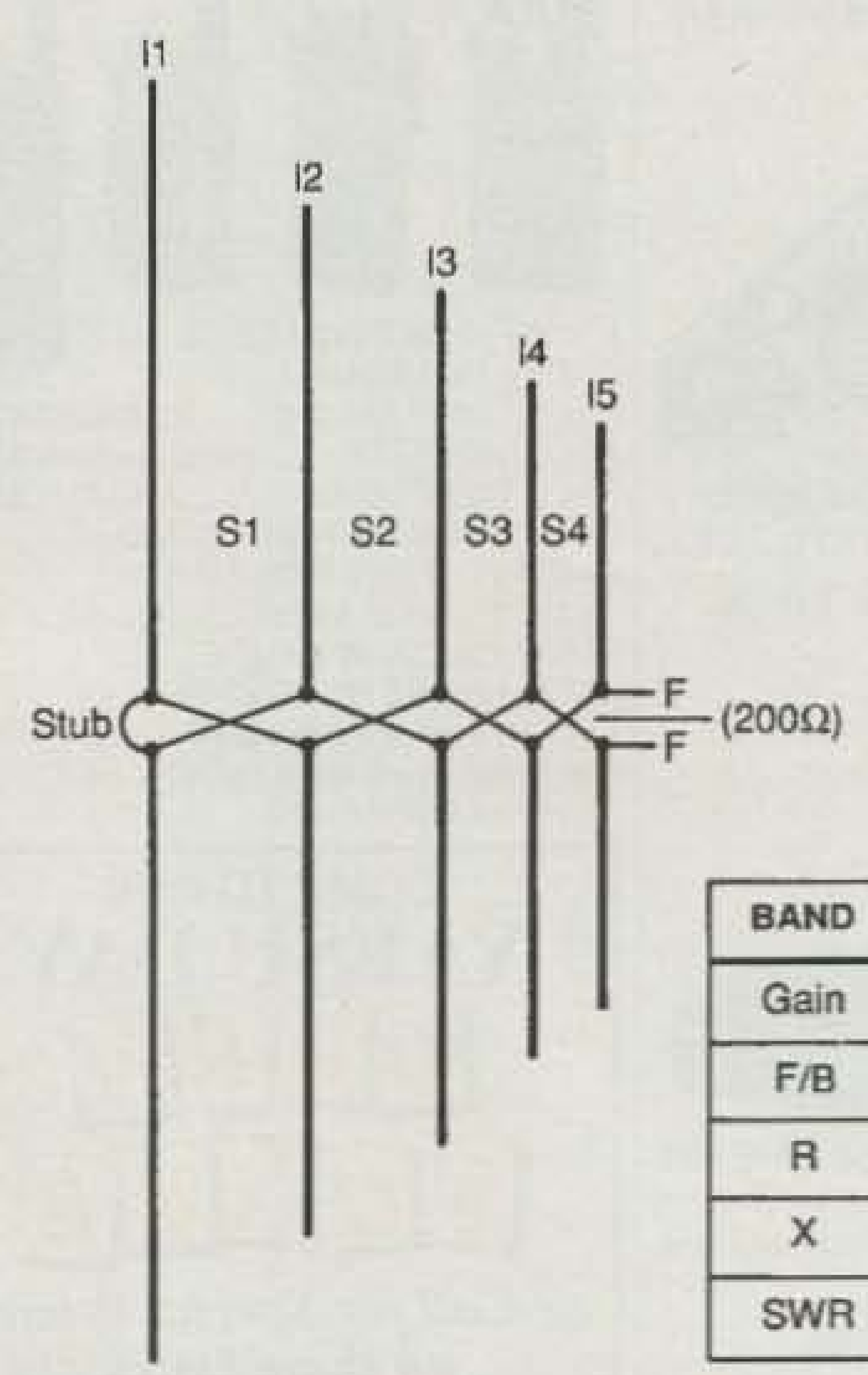
Fig. 2– Log periodic dipole array resembles a truncated triangle. Longest element is about a free-space half wavelength. Shortest element is about 40 percent of a half wavelength at highest operating frequency. Elements are split at the center and fed with a transposed transmission line at the apex. A short stub is placed across the feedpoint of the longest element.

3.2 dBd, with a "reasonable" front-to-back ratio.

That doesn't sound very encouraging, does it?

Computer Analysis Of The LPDA

This little antenna is a nice one to check out on an antenna analysis program.[1] The results are given in the table of fig. 3. Gain varies from 3.06 dBd at 14 MHz to 3.96 dBd at 28.5 MHz. Front-to-back varies from 6.71 dB at 14 MHz to 10.36 at 28.5 MHz. Not very impressive. The input impedance varies over a wide range, with the result that using a 4:1 balun the coax SWR on the four bands runs between 1.76 and 3.38. This indicates that an antenna tuning unit is probably required at the station for most solid-state transmitters. A tube-type rig, with a pi-network output



LEGEND:

I1 = 27.243'	S1 = 3.269'
I2 = 21.794'	S2 = 2.616'
I3 = 17.436'	S3 = 2.092'
I4 = 13.948'	S4 = 1.674'
I5 = 11.159'	

Stub at I1 = 6"

Gain = dBd
F/B = dB

BAND	18 MHz	21MHz	24 MHz	28 MHz
Gain	3.06	3.05	3.68	3.96
F/B	6.71	6.92	8.04	10.36
R	128	102	349	90
X	+194	–56	+22	–5.1
SWR	3.38	2.16	1.76	2.23

Fig. 3– Mini LPDA antenna for 18–28 MHz is built on a 12 foot boom. Operating characteristics are given in the table.

stage, probably would be able to compensate for these SWR values, and the tuning unit would then not be required. An azimuth pattern of the array at 24 MHz is shown in fig. 4.

Is A Little LPDA Worth The Effort?

Aha! That's a good question! One nice thing about the LPDA is that it radiates everything put into it. A trap dipole for these bands would have six traps of dubious efficiency. A real competitor of the little LPDA might be a 18 MHz dipole fed with an open-wire line—in other words, a center-fed "Zepp." Like the LPY, it would require a tuning unit. However, it is cheaper to build and less obtrusive in the air, but it has less gain and no front-to-back ratio at all.

Is it worthwhile then to have a 5-element LPDA beam on a 10 foot boom that will provide a modest amount of gain and "reasonable" front-to-back ratio for four bands? You'll have to be the judge of that! For more information, I refer you to *The ARRL Antenna Book*, Chapter 10.

Another Amateur's Thoughts

One day not long ago I was enjoying lunch with Hank Olson, W6GXN. It was a warm, lazy day and we sat under an umbrella in the courtyard of a small restaurant. Most of the other diners had left, and we were alone, chewing the fat, as amateurs do when they have a bit of spare time.

The talk eventually turned to early postwar receiver design and some of the popular devices that were thought to improve receiver performance, but in many instances did exactly the opposite. Hank had been through this period in a professional capacity, and I enjoyed listening to his thoughts. The following is a capsulation of his remarks.

R9ers & Other Devices To Degrade Receiver Performance

At a vintage radio swapmeet I encountered an old Millen R9er amongst the collection of junk the various purveyors were hawking. The old Millen job gave a tug at my covetous feelings, which I thought were long gone.

When I was young and broke, I'd have almost sold my little brother into slavery for such a unit. This was the magic preselector that "dug out the weak ones" on 10 and 6 meters. (It could also be used on 20 meters with the proper coils.)

Looking in a dog-eared *1949 ARRL Handbook*, I found the R9er was only $29.95. And the *Handbook* was a modest $2.00.

The R9er used a single 6AK5, which was the hot new amplifier tetrode developed during WW II, which amateurs came to love for gain and hate for instability.

Life was simple in those days. If a signal was too weak, amplify it. If signals were being QRMed, add another conversion to the receiver with a lower (sharper) IF. It seemed that the more front-end gain and the more conversions a receiver had, the better.

Amateur designs had plenty of both. And some commercial receivers followed the trend. One popular receiver covered 550 kHz through 54 MHz, plus the FM broadcast band (88–108 MHz)! It seemed to do everything, but it was prone to birdies and overload.

The R9er and other high-gain preselectors, such as the RME DB-20, were helpful in rejecting images and provided plenty of gain. This made the receiver S-meter very sensitive, and a signal that was, say, S2 could be boosted to a needle-pinning S9-plus. Of course, in most cases the background noise came up an equal amount. This was pretty impressive.

When the skip was absent on 10 or 6 meters, background noise was low and any boost in gain was helpful. A good preselector, such as the R9er, really helped in this situation.

However, once the band opened for DX, antenna noise was so great that almost any noise figure was acceptable in an amateur receiver. The additional gain of the preselector didn't improve receiver sensitivity since that was limited by the antenna noise. But it did decrease the dynamic range of the total receiving system!

Many high-gain receiver front-end designs appeared in the amateur magazines, but until the relationship between noise figure, antenna noise, and receiver overload were understood, a lot of fellows got into trouble with receivers having a poor balance between front-end gain, and gain distribution through the rest of the receiver.

The rush of noise contributed by two high-gain RF stages might have been comforting, but it wasn't much help when the receiver was burdened by many strong, local signals.

I agreed with what Hank said. In fact, I remember a local amateur who built a 20 meter DX receiver that had no RF stage at all. Antenna input went directly to a low-noise triode mixer, copied from the front-end of a radar receiver. I think it was a 6J4 VHF tube. He used a high-Q input circuit, with an air-wound 20 meter plug-in coil and adjustable link coupling to the antenna. He followed the mixer with an adjustable gain IF strip and plenty of audio gain. He shifted his gain as far back down the receiver chain as he could. He had a 455 kHz crystal lattice filter for selectivity. I listened to this set many times and always thought it was a winner.

We decided we still had a few moments before leaving this pleasant lunch, and our thoughts turned to the post-war amateur receiver. Hank had some interesting thoughts along this line:

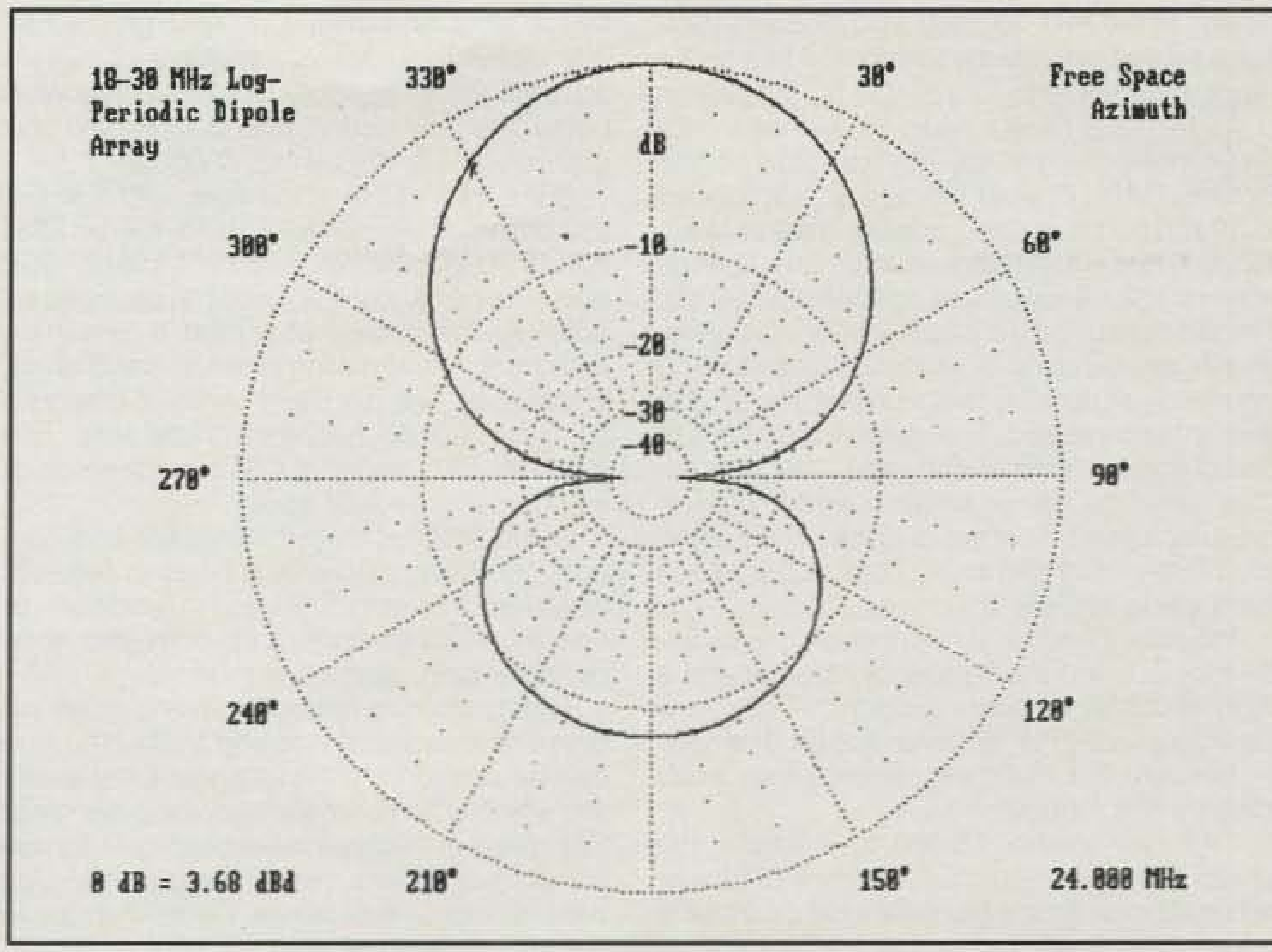


Fig. 4– Polar plot of short-boom LPDA at 24.9 MHz.

The God Father: The Collins 75A-1

During WW II, Collins Radio Co. revolutionized HF radio communication with a state-of-the-art military transmitter, their ART-13, designed for use in aircraft. This beautiful 200 watt phone/CW rig covered 2 MHz to 18.1 MHz and had multi-channel remote control and a radically new, high-stability VFO.

The multi-channel system wasn't much use for receivers designed for amateurs, but the new VFO allowed the design of a radically new receiver.

An early post-war military receiver, a companion to the ART-13, was the 51H-1, which used the permeability-tuned oscillator (PTO) design of the ART-13, plus a novel conversion scheme that provided a tuning dial that had a readout in kiloHertz.

As far as amateur radio was concerned, these new designs quickly resulted in the Collins 75A-1 receiver which was announced in 1947 and hit the HF receiver market like a rocket! Here was a receiver for amateur bands only. Image rejection was specified as 50 dB. The old-fashioned bandspread dial was gone, and in its place was a slide-rule dial, reading frequency accurately to about a kiloHertz! This was unprecedented. The effect at the plants of Hallicrafters, Hammarlund, and National (the "big three" traditional amateur-band receiver manufacturers) must have come like a lightning bolt out of the blue! They just couldn't compete in this arena!

The principles first shown in the Collins 75A-1—that is, accurate frequency readout and a high order of frequency stability—are now commonplace in HF receiver design. The newer transceivers have exceptional frequency stability and readout.

Take the Kenwood TS-950, for example. The specs call for a frequency accuracy of plus or minus 0.5 ppm (parts per million) at the 20 MHz reference frequency, over a temperature range of –10 to +50 Celcius. Digital readout is to 10 Hz. This beats the old 75A-1 specs by orders of magnitude. Still the 75A-1 led the way, and the modern receivers are direct descendants of that gigantic revolution in receiver design.

The principles underlying the 75A-1, over the decades, have led to even better receiver designs that are just beginning to surface. For instance, if one increases the IF frequency, say to 100 MHz, and uses a sharp IF crystal filter, it is possible to achieve multiple-conversion advantages in a single conversion receiver: better image rejection, plus bandwidths commensurate with SSB and CW operation.

Some new receiver designs use a VHF IF system with up-conversion to the amateur bands. This provides excellent image rejection. A second, low-frequency IF provides selectivity. The choice of a high IF eliminates many birdie and mixing problems and annoying images. The excellent series of articles by Dr. Ulrich Rohde, KA2WEU, in the May, June, and July, 1994 issues of *QST* provide an insight into modern receiver design.

Some state-of-the-art receivers use an IF near 100 MHz, plus crystal filters to provide a bandwidth of about 6 kHz. In addition, the design uses a parametric up-converter, which provides gain, as the first mixer.

This technique not only gives a mixer with gain and reasonable noise figure, but the mixer can be driven by a large-signal local oscillator, which affords enhanced dynamic range. Receivers of this type have been built for special projects where the HF receiver is in close proximity to a high-power transmitter, for example, on the same ship.

Voodoo Telephone Messages

I've been plagued with odd-ball telephone calls (usually around dinner time). The phone rings, I answer it, and nobody is there! Not a sound. No background noise, no heavy breathing. After ten seconds or so the connection is broken.

Before we left our extended lunch period, I mentioned this mystery to Hank. He had received the same sort of calls over the past months. What was going on?

After batting the problem back and forth, we decided that the mysterious calls are due to a form of telephone solicitation, such as somebody calling to sell you insurance, or an interest in a timeshare vacation home—or perhaps half-interest in the Brooklyn Bridge.

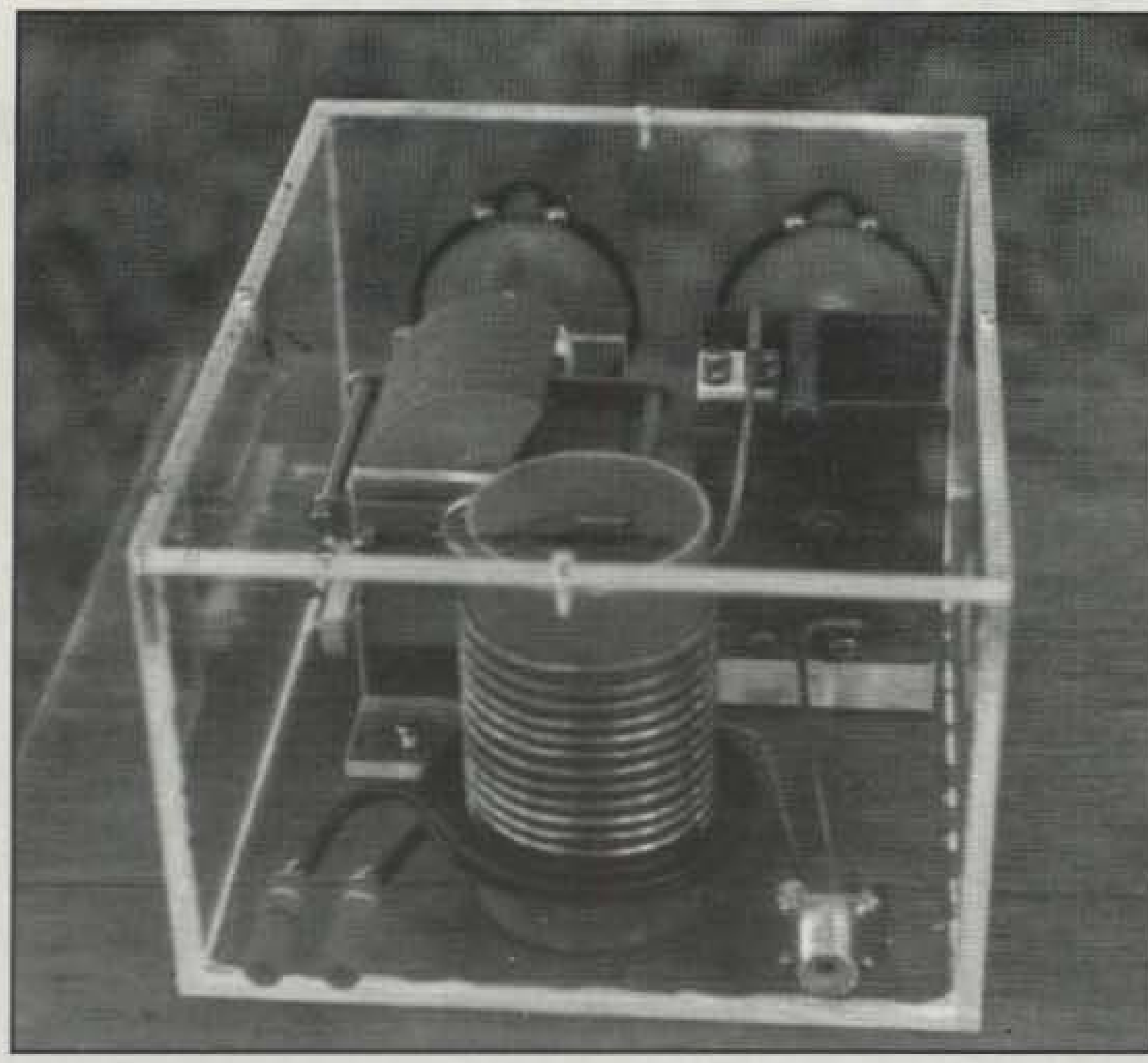
We think some of these "shot in the dark" phone calls are automated, and the calling device calls numbers in numerical sequence. If someone answers, the device switches the call to a live person, on the alert with a hard-sell spiel.

If this sequence gets out of sync, or the live person is busy with another call, the automated device simply breaks the connection, leaving the recipient frustrated and angry.

If there are any readers connected with the phone system, or who otherwise can verify this theory, we'd like to hear from them! Most of all, how do you turn the durned automated phone calls off? They are a pain.

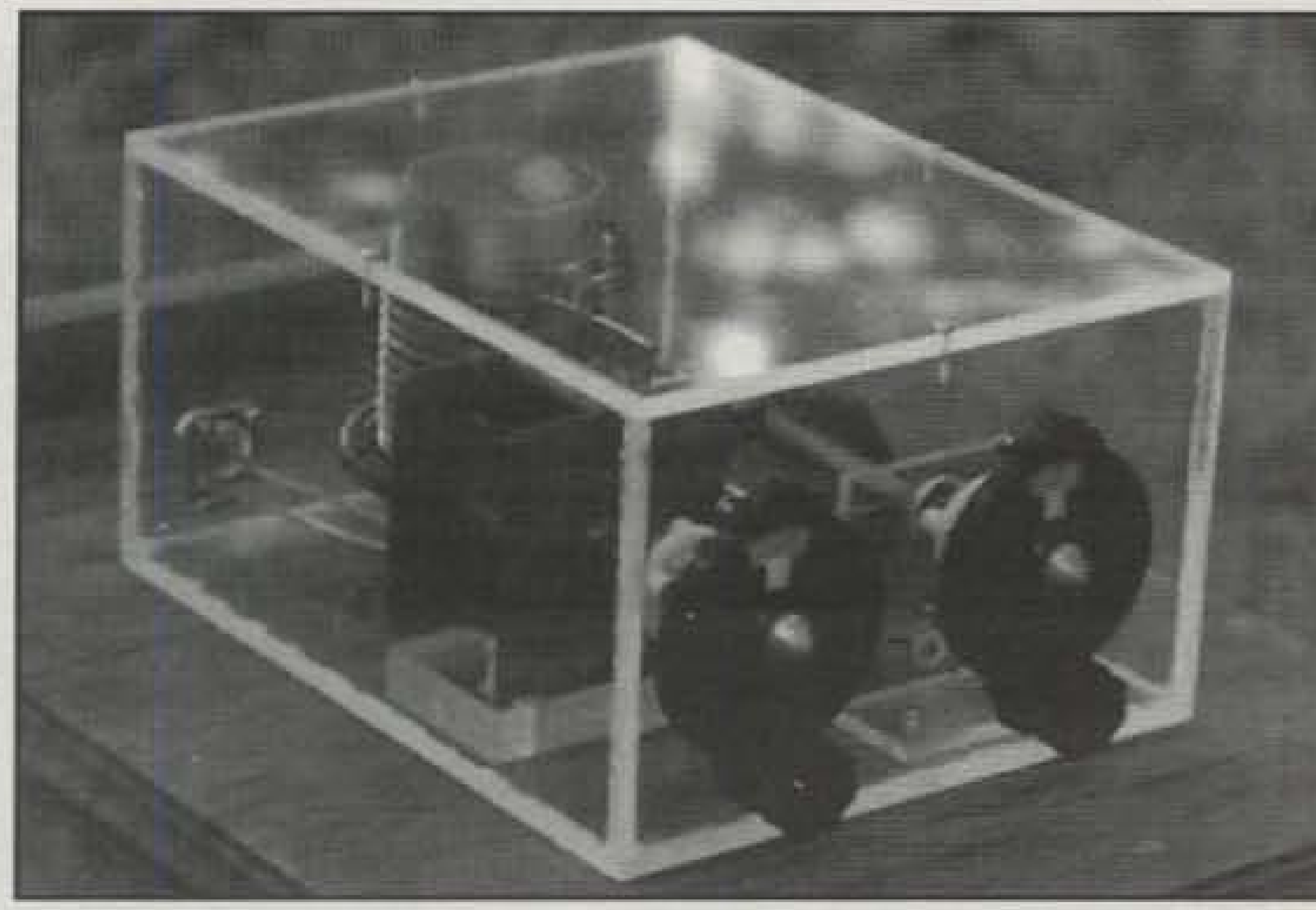
From the Mailbag

Richard, W1QWJ, reports excellent re-



The Z-match tuner of WD4NGG is built in a plastic box. Dials are National "Velvet Vernier." Two output links are used for coax and twin-line feed systems.

Front view of the WD4NGG Z-match tuner.



sults with the Z-match antenna tuner I described in recent columns. He says he wound the coil with No. 10 self-supporting wire. He found the capacitors at Fair Radio Sales, catalog #C-1003 for the single section, 400 pF, .02 airgap unit. The dual section capacitor, 600 pF, .02 gap is catalog #3G-600. Rich uses the Z-match with a 160 meter inverted-V fed with 400 ohm ladder line. He operates the antenna on all bands up to 10 meters. He also has a center-fed dipole, 102 feet long, with ladder-line feed for operation from 80 through 10 meters.

Todd, WD4NGG, also reports good luck with the Z-match and an inverted-V having 50 foot legs. He doesn't mention his feedline, but says the antenna works well on all bands, 80 through 10 meters. He is . . . "amazed at all the good signal reports I am getting."

Bob, K4CSV, sent me pictures of a Z-match tuner built in a plexiglass box by Todd, WD4NGG. It has two National "Velvet Vernier" dials for adjustment. Great job, Todd!

Bob also says he bought a Harvey-Wells "Bandmaster Z-matic" at a hamfest and says the circuit resembles the Z-match. He uses it with an inverted-V fed with 300 ohm line. Thanks to Bob and Todd for the interesting information.

Thanks to the following for their interesting letters. I really appreciate the input: VK2AU, W5INU, VE7MJY, WA3ZOR, K6BSU, WA5JCI, K6OPZ, and W5KFT. Good show!

73, Bill, W6SAI

Footnote

1. MN4.5 Antenna Analysis Program by Brian Beezley, K6STI, 507½ Taylor St., Vista, CA 92084.