ham radio TECHNIQUES

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We are happy to introduce a new department in ***ham radio*** *by one of the most respected and knowledgeable Amateurs in the world. Bill Orr started his Amateur career in 1934, when he obtained his first license, W2HCE. He has been a prolific contributor to the Amateur literature, having authored more than 100 magazine articles and many books. Perhaps his most famous works are* ***The Beam Antenna Handbook*** *and* ***Radio Handbook,*** *of which he is the editor. Bill's literary style is friendly and easy to read and understand. We hope our readers will enjoy this series of articles, which will contain technical topics of general interest to Radio Amateurs.* ***Editor***

BY WILLIAM I. ORR, W6SAI

Happy New Year 1981! What will the New Year bring to Amateur Radio? We have the prospect of the new 10-MHz band in the near future and the probability that the 160-meter band will be expanded as the Loran-A equipment is deactivated. And, the sunspot cycle will continue its inexorable decline.

You probably won't notice much deterioration in DX conditions on the high-frequency bands this spring, but you might find that 10 meters is noticeably less "DX-y" this coming fall. And by spring, 1982, the slump in 10-meter openings should be quite apparent. So enjoy 10 while you have the chance. Pay attention to 6 meters, too; it might be a long time before 6 meters shows the long-distance communications that seem to be almost a daily occurrence these past years.

the popular triband Yagi beam

This column discusses the triband Yagi beam for 20, 15, and 10 meters. This well-known design is used (with impressive results) by many DXers, and it's an inexpensive and effective antenna that's not too big.

The modern triband Yagi was developed from a multifrequency dipole invented and perfected by Howard K. Morgan, Superintendent of Communications, Transcontinental and Western Airline, Inc. The requirement of the airline (the grandfather of the modern TWA) was for a simple, multifrequency antenna that would provide good reception of various aircraft frequencies at ground communication stations. The multifrequency dipole devised by Morgan was described in the August, 1940, issue of *Electronics*, and the original drawing from that article appears in **fig. 1**.

The Morgan antenna consisted of a center-fed dipole with the end insulators replaced by parallel-tuned circuits. Extra wire sections were added beyond the circuits so that the dipole was again resonant at a lower frequency.

For example, if the center dipole section is cut for 21.2 MHz and the parallel-tuned circuits (commonly called *traps*) are tuned to 21.2 MHz, the dipole works in a normal manner; the very high impedance of the resosulator. Wires that have been added after the traps have little, if any, effect on antenna operation at, or near, 21.2 MHz.

If wire sections are added after the traps are cut to the proper length, the overall antenna system will resonate at a lower frequency, say, 14.0 MHz. The presence of the tuned circuits affects the length of the antenna, so resonance is obtained at 14.0 MHz with an overall antenna length somewhat shorter than normal. A typical antenna is shown in **fig. 2C**. The traps act as electrical switches that are either open or closed, depending on the frequency of operation of the antenna.

Morgan's article pointed out that antennas for operation on as many as four different frequencies had been built successfully. Finally, the article provided detailed information concerning adjustment of the traps for proper antenna operation.

resurrection of the multiband dipole

Morgan's multifrequency antenna died a quick death. Here was the perfect antenna for operation on the various Amateur high-frequency bands; the traps were easy to build and adjust, low-impedance transmission line was readily available, yet nobody carried the idea forward. With the coming of World War II and the ban on Amateur Radio, the multiband-antenna principle fell by the wayside.

It was not until after the war that the concept of multiband operation surfaced again, in a design by Chester Buchanan, W3DZZ, described in the December, 1950, issue of *Radio and Television News*. Buchanan described a dual-band beam for 10 and 20 meters using trapped elements. He also provided the first complete description of how the trapped antenna worked. His final beam design, known to many DXers as the "W3DZZ beam," was fully described in *QST*, for March, 1955.

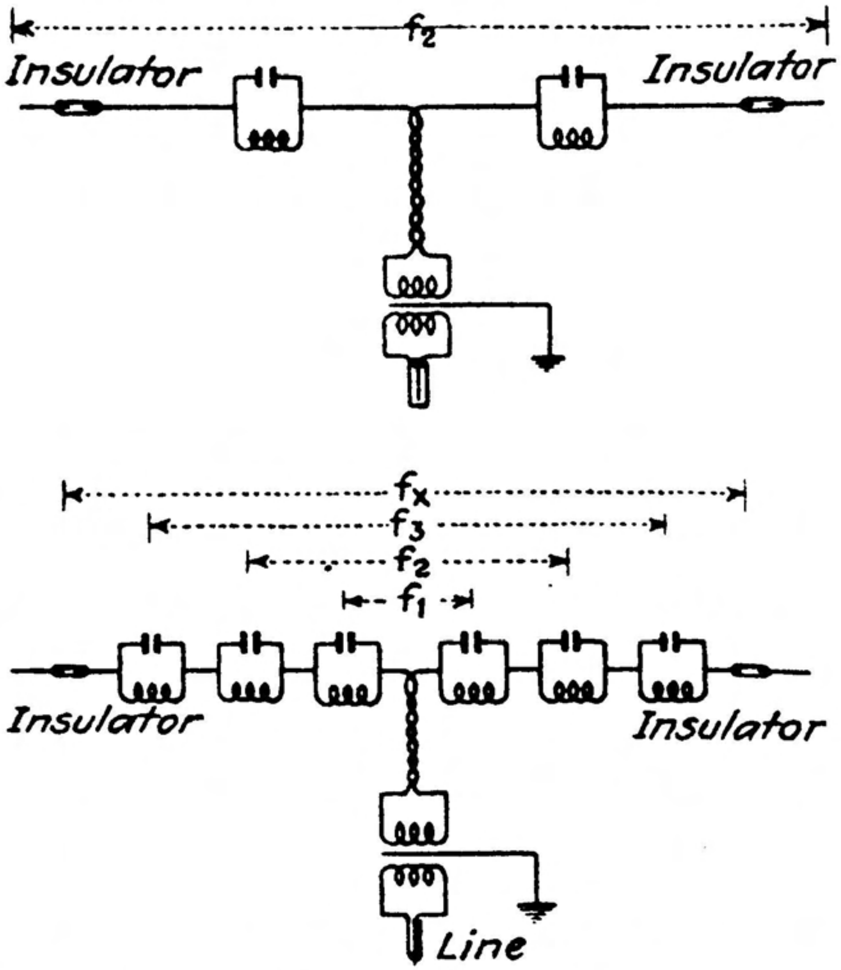

fig. 1. The original illustration in the issue of *Electronics* magazine depicting the trap dipole scheme evolved by Howard K. Morgan. The multifrequency antenna was originally designed for ground-station reception in the aeronautical service. Parallel-tuned trap circuits served as insulators at the resonant frequency of trap and antenna.

how the triband beam operates

Frequency-sensitive "switches" are the operating secret of the triband beam. The switches consist of a capacitor and inductance connected in parallel. This is a simple parallel-tuned circuit, which provides a very high impedance across the terminals at the resonant frequency.

The actual value of the impedance is the reactance of the coil times its Q, ($Q \times Q_L$). If the value of Q is high (Q being the electrical excellence of the coil), the circuit works as a high-impedance insulator at the circuit resonant frequency.

The curve in **fig. 2D** shows that the off-frequency reactance of the circuit is quite small: inductive at frequencies lower than resonance and capacitive at frequencies higher than resonance.

When the trap is placed in an antenna, the equivalent circuit of the antenna above and below resonance is shown in **fig. 2C**.

On 15 meters the center portion of the antenna works as a dipole with trap "insulators" tuned to 15 meters. When the antenna is used on 20 meters, the inductive reactance of the traps is quite low, and they act as loading coils. The wire length between the traps is cut so that the wire, plus the loading coils, is resonant at 20 meters, in conjunction with the center section.

Thus, on 20 meters, the trap dipole

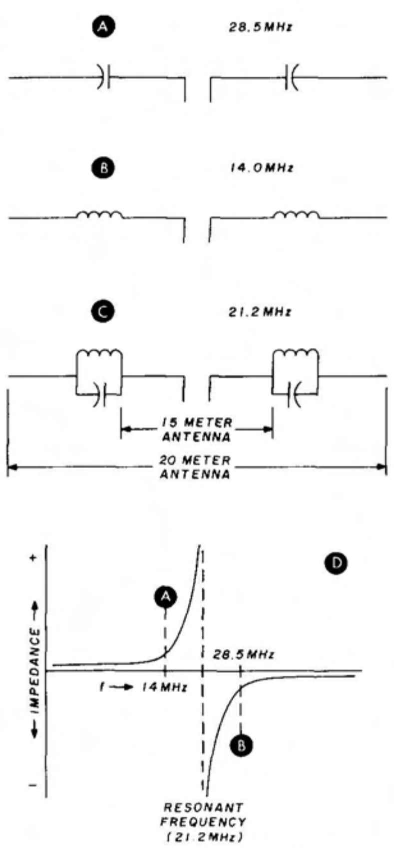

fig. 2. Operation of tuned trap for 20-15 meter, two-band dipole antenna. A: Equivalent circuit of antenna and trap at some frequency above resonant frequency of trap. Trap "looks like" a series capacitance. B: Circuit of antenna and trap at some frequency below resonant frequency trap. Trap "looks like" series inductance. C: At trap resonance, trap acts as a very high-impedance — the equivalent of an insulator. Examples given are for a trap tuned to 21.2 MHz (15 meters). D: Impedance chart of 15-meter trap showing reactance curve through the 14-28 MHz region. At 14 MHz the coil is the dominant component of the trap, and at 28.5 MHz the capacitor is the dominant component. Antenna is resonant at 14 MHz but is not resonant at 28.5 MHz. An extra set of traps is required for 10-meter operation, as shown in fig. 3.

is considerably shorter than normal due to a portion of the antenna being duplicated by the series inductance of the traps — the antenna is *nonresonant* on 10 meters unless extra traps are added.

To put it all together, in a triband element, the inner section and inner traps are resonant at 10 meters, the middle portion of the antenna and associated traps are resonant at 15 meters, and the whole antenna assembly is resonant at 20 meters (**fig. 3**).

trap performance

The trap is the heart of the triband antenna. A good trap will have reasonably high Q and must be waterproof. Many Amateurs make their own traps for triband dipoles[1] from an airwound inductance and a transmitting-type ceramic capacitor. The trap is placed in a waterproof housing.

Commercially made traps for triband beams are more sophisticated and are designed for mass production. The two traps in one section of an element may be combined into one structure, as shown in **fig. 4**. This arrangement provides a compact and rugged assembly.

No reliable information exists, as far as I know, as to the actual gain of a triband beam compared to a full-size antenna. Admittedly, the perfect trap has not yet been built, so some power is lost in each trap. In addition, on the two lowest bands, the antenna elements are not full size, so additional power is lost because of the reduced element length. This power is lost in the trap, which acts as a loading coil.

On the whole, the tribander design is good. The triband Yagi beams on the market *work*, and work well, judging from the number of DXers who use them and the robust signals they put out.

triband-beam bandwidth

One specification in which the triband beam suffers is bandwidth. On 10 meters, where the inner set of traps act as insulators, the bandwidth of the triband Yagi compares favorably with that of a conventional 10-meter Yagi beam. On 15 and 20 meters, operational bandwidth is somewhat restricted, because a portion of the element on each band is made up of the trap (or traps) for the higher-frequency band.

Then, too, some triband beams are built on shorter-than-normal booms to conserve space. This compromise further reduces operating bandwidth (and gain) — especially on 20 meters.

A set of representative SWR curves for a triband Yagi and a full size 20-meter Yagi is shown in **fig. 5**. Both beams are built on 20-foot (6-meter) booms. Observe that the 20-meter bandwidth of the tribander suffers in comparison with the full-size 20-meter beam, but bandwidth improves on 15 meters, and is equal for both antenna designs on 10 meters. This is of little consequence to the Amateur having a tube-type final-amplifier stage with an adjustable output network, but it poses a problem to those who have a solid-state output stage that requires an antenna with a low standing wave ratio.

One way around this problem is to build an SWR "flattener" that will reduce the SWR on the line at the transmitter end of the line (**fig. 6**). This simple matching network is placed between the coaxial line to the antenna and the station SWR meter. The capacitors and number of coil turns are adjusted for lowest SWR on the operating band. It can be easily adjusted for near-zero SWR at any point in the 10, 15, or 20-meter bands by tuning the controls for minimum SWR as observed on the meter. The settings can be logged for future use.

is a triband Yagi beam practical?

Based on personal observations over the years, the answer to this question is *yes*. If you have a well-made tribander, you have the tremendous advantage of three-band operation with one relatively small antenna. I've used a triband Yagi for years, alternating with a full-size 20-meter beam, on occasion. As far as working DX goes, I can do equally well with either antenna, and I notice no difference between the three-band design and the single-band beam.

Common sense and measurements made on the triband Yagi tell me that it isn't as efficient as the full-size beam. The bandwidth is somewhat restricted, and the front-to-back ratio isn't quite up to snuff, particularly on 15 and 10 meters. But these complaints fade away when I consider the convenience of working *three bands*, and the fact that I can compete in DX work and get reports that are just about equal to those of others in the area.

Tests. Before I installed the tribander, I wouldn't have believed this, as I took the traps into the company laboratory and measured the *Q* on a precision meter. A trap that I made out of the best materials available (air-wound, silver-plated, copper coil and a transmitting-type ceramic capacitor) provided a *Q* of over 300 at 30 MHz.

The *Q* of the commercial trap, measured at 30 MHz, was only about 180. This so discouraged me that the triband beam sat in my garage in the original box for about a year. Finally, deciding to see for myself how the antenna performed, the 20-meter Yagi came down, and the tribander went up in its place. Despite my misgivings, the triband worked, and worked well.

Some of my engineering colleagues sniffed in disdain at my unscientific test and were unmoved when I beat them out in a DX pileup. "Pure luck," was their conclusion.

Well, I don't know about that. Luck and operating skill surely are factors to be reckoned with. But if the antenna doesn't work, all the luck and operating skill in the world are to no avail.

table 1. Data for the G3LDO wire-beam antenna. All dimensions are in inches and are for insulated wire; multiply by 1.04 for uninsulated wire. Dimension C is approximate.

band	reflector	driven element	A	B	C	D
20	452	417	245	263	180	33
15	302	279	154	166	113	22
10	225	208	114	122	85	15

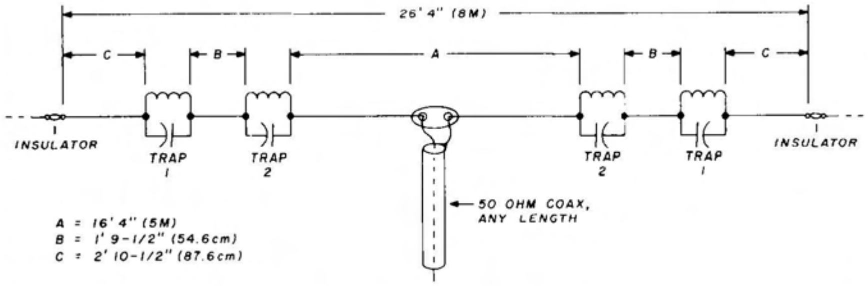

fig. 3. A triband element for 20, 15, and 10-meters. Dimensions are given for no. 16 (1.3mm) antenna wire size (not critical). Each trap is resonated to the design frequency before it is installed in the antenna. Length of each trap is about 2 inches (51 mm). Small ceramic or mica capacitors, rated at 3 kV, are used, which should have zero temperature coefficient.

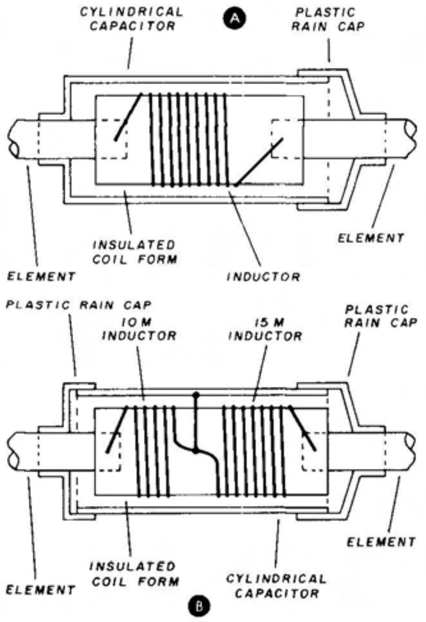

fig. 4. Typical trap construction. A: Single trap composed of inductor connected in parallel with cylindrical capacitor. The capacitor serves as an outer shield for the inductor and provides capacitance between cylinder and coil. End of assembly is sealed against weather with a plastic rain cap. B: Dual, two-band trap composed of two coils mounted within a single cylindrical capacitor. Number of turns on coils and placement within cylinder determines effective capacitance. Ends of assembly are sealed with plastic rain caps. Connection between coils and cylinder is made at center junction of inductors.

Power transfer. It's true that some transmitting power is lost in the traps. I have a telescoping tower and can reach the traps in my antenna from the garage roof when the tower is retracted. Running a kilowatt input for 10 minutes, key down (when the band is dead!) results in the traps being slightly warm to the touch. Obviously, some rf power is being converted to heat in the traps. Other hams (having more ego than common sense) have attempted running excess power to a trap Yagi beam and have damaged the traps.

In conclusion, then, a good trap Yagi beam is an acceptable compromise for the Amateur who wants

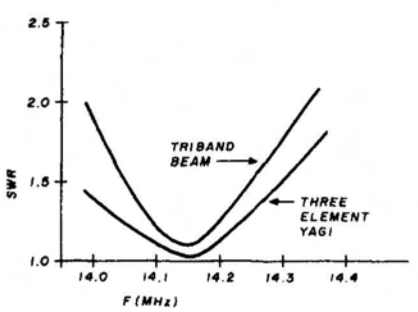

fig. 5. SWR bandwidth curve of typical triband Yagi beam is quite sharp on 20 meters, approaching 2 at band edges. A three-element, full-size Yagi exhibits a more moderate SWR curve for the same frequency span. On 15 meters, tribander bandwidth is somewhat improved and is essentially equal to full-size Yagi on the 10-meter band.

three-band operation. If a solid-state transmitter is used, an SWR "flattener" will prove helpful in making the transmitter perform at top efficiency.

the G3LDO wire

While on the subject of Yagi antennas, the interesting design by G3LDO is worth considering.[2] Experiments were run on 144 MHz with wire beams, and G3LDO came up with the interesting observation that the resonant length of a wire element depended upon the insulation on the wire. Uninsulated copper wire and enamel-coated copper wire provided "normal" dimensions, whereas insulated copper wire (hookup wire) had a velocity factor of about 0.965. The insulation on the tested wire was PVC (polyvinyl chloride).

Based on this information, G3LDO built a test beam on 2 meters, and then a larger model for 10 meters (**fig. 7**). He found that bending the elements back in the plane of the antenna caused an increase in the resonant frequency of the bent element and also resulted in a drop in gain. The solution was to fold the elements back in umbrella fashion, with the ends of the elements forming guys for the bamboo or fiberglass support structure. Dimensions for the beam are given in **table 1**. The performance of this simple and inexpensive wire beam was equal in every way to a standard equivalent design using full-size elements. This looks like a good antenna design for the ham who has a problem locating aluminum tubing.

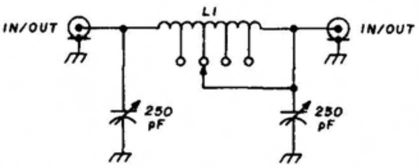

fig. 6. Simple SWR "flattener" for coaxial line. Capacitors are single-spaced receiving types for powers to 250 watts. Mica compression units can be used for low power. Inductor consists of 15 turns, 1-inch (25.4mm) diameter and 2 inches (51mm) long. Tap to coil is through a ceramic, single-pole rotary switch, such as Centralab 2501 (two to six positions, nonshorting). The coil is tapped about every other turn. Wire tap can easily be soldered to coil by depressing turn on either side of tap with screwdriver to allow tap wire to pass around a turn of the coil (coil may be a B&W miniductor or equivalent). Network is symmetrical; either terminal may be used for input or output.

a TVI filter for the 6-meter operator

Do you have a problem with 6-meter operation? It's a tough deal, what with TV channel 2 only a few megahertz away. Filters that can protect channels 2 and 3 (and provide attenuation of TV garbage in the 6-meter receiver) are hard to find.

My attention has just been directed to a new filter that will be of interest to all 6-meter operators. It is the *Unadilla/Reyco* Interfilter, specifically designed for 6 meters. It's rated for full Amateur power over the range 50-52 MHz and provides over 63 dB attenuation at TV channel 3. (Attenuation at channel 2 is somewhat less.) For full information on this interesting filter, write Unadilla/Reyco, 6743 Kinne St., East Syracuse, New York 13057.

references

1. Design and construction of trap antennas is covered in detail in *Simple Low-cost Wire Antennas*, by the author of this column. Available from Ham Radio's Bookstore for $6.95.
2. This material is abstracted from *Radio Communications*, a publication of the Radio Society of Great Britain, 35 Doughty Street, London WC1N 2AE, England.

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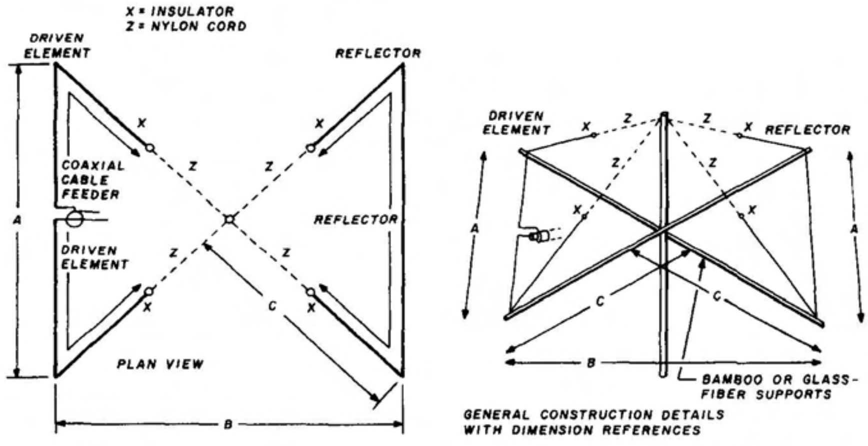

fig. 7. The G3LDO wire beam antenna for 10, 15, or 20 meters. Framework consists only of vertical mast and four bamboo or glass fiber support rods. Antenna is fed with coaxial line at midsection of driven element. Dimensions are given in table 1.