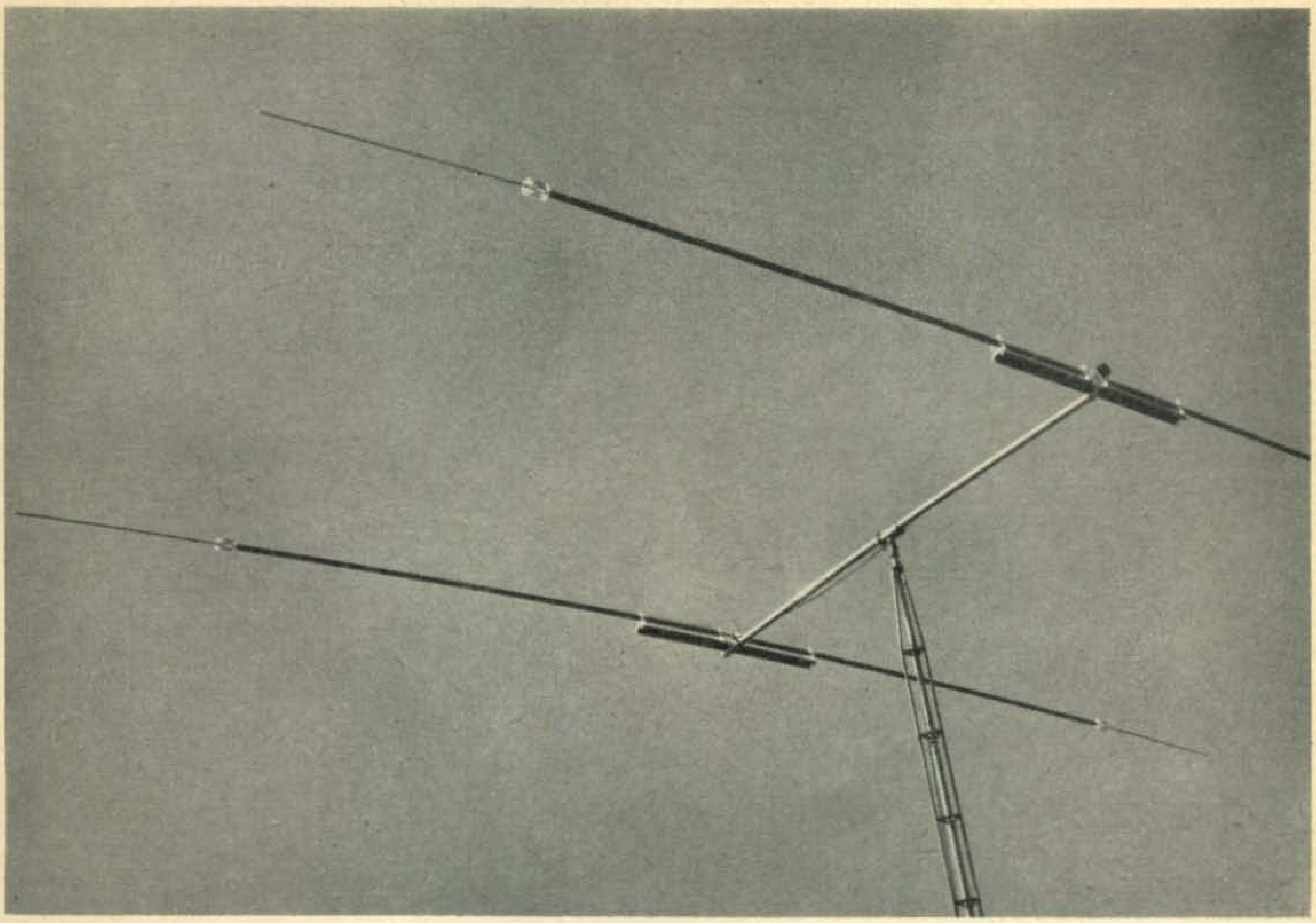

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A Rotary Beam for—75!

A majority of the current crop of amateurs had not yet been born when, in 1926, a couple of Japanese gentlemen named Hidetsugu Yagi and Shintaro Uda whipped up the idea of employing wave directors or reflectors with the dipole. In spite of the fact that their respective names were almost unpronounceable the results of their work eventually seeped through to America and, in May of 1927, the *Proceedings* of the IRE carried a paper by Uda on the subject. Right about here was where the "Hertz," "Zepp," and "Marconi" antennas started to become very unpopular, although it took nearly the next ten years for the amateur to find this out.

Amateur Acceptance

Beginning in 1928, and extending late into 1935, Hendricks[1], Hull[2], and Shanklin[3], published some excellent articles on the Yagi-Uda for amateur use, but all of these fell on deaf ears. In December 1935, Mims'[4] "Signal Squirter" article appeared and only after this did general acceptance of the Yagi-Uda for amateur use begin. There seems little doubt that Mims grandsired the amateur rotary beam from an acceptance viewpoint. His was the original whirlygig two-element Yagi-Uda. As it stands now in 1956, more than 20 years later, a great many of Mims' antennas are still in use and currently out-performing considerably more complicated arrays. One such two-element rotary, in daily use by W5EFC, has accounted for more than 200 countries on 20-meter phone and has established DX records that the double-stacked triple-element boys will be shooting at for many a moon.

With the advent of Yagi-Uda acceptance by the amateur nearly every inveterate experimenter went to work at once to improve the thing. These 20 years have seen innumerable writings describing modifications of the original. They include one by this writer[5] in May of 1939, covering the first 4-element monster. The amateur journals are full of others. The Yagi-Uda is now in general use, in some form, at 14 megacycles, and higher. Some are being used at 7 megacycles.

There are, to be sure, specific advantages to

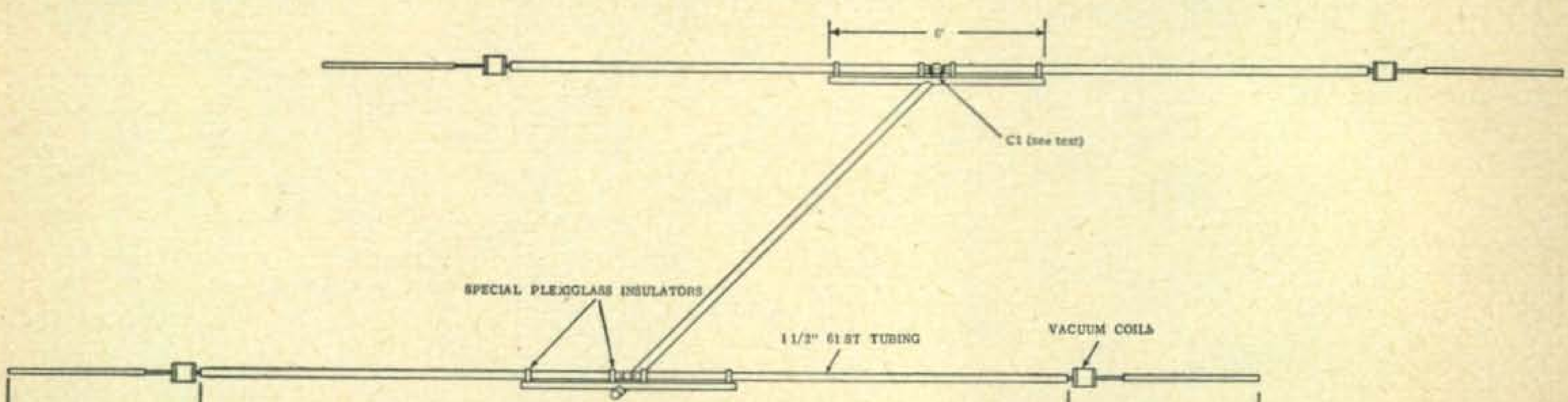
1. Hendricks, "High Angle Radiation," October 1928 *QST*.
2. Hull, "The Status of 28000 KC Communication," January 1929 *QST*.
3. Shanklin, "A 14 Mgc Rotary Beam for Transmitting and Receiving," July 1934 *QST*.
4. Mims, "All Around 14 Mgc Signal Squirter," December 1935 *QST*.
5. Bassett, "The 4 Element Rotary," May 1939 *Radio* (Now *CQ*).

be gained through the use of more than two elements when proper adjustment procedures are closely adhered to. The vast majority of amateurs, however, are not equipped to follow these procedures. A 3-element beam is about 100 times as hard to adjust to perfection as is a 2-element one. There is obviously nothing to be gained by simply installing more aluminum ahead of a good 2-element beam without also adjusting this aluminum. The additional aluminum will give you the doubtful privilege of being able to say that you now have 3 elements, or 4, or more, but it will also very likely result in lousing up an otherwise excellent 2-element beam. The last 20 years have definitely proven that a good 2-element Yagi-Uda will outperform, ten ways to Sunday, the usual "garden variety," or "factory pretuned," multi-element job. This subject has been covered recently, and well, by Orr.[6]

75 Meter Considerations

For as many years as this writer chooses to remember it has been apparent that a rotatable directional antenna would be most useful in the 75-meter band. The 20-meter band has never had a monopoly on heterodynes. While on 20 the QRM is consistent all during the daylight hours it is not until sundown that the banshees usually start wailing on 75. Unfortunately, from sundown on is the best period for 75-meter work. A rotary beam can alleviate this situation appreciably, particularly on receiving. It can also give the signal a desirable boost in the selected direction. When a beam is used on both ends of a communication circuit, the banshees begin to run for cover. These features, of course, are now well known and understood by those who have operated on the higher-frequency bands. One of the most important features of the beam, however, is that it also can lower the vertical angle of radiation considerably which makes for better contacts at greater distances. To date this sort of thing has been relatively unknown on the 75-meter band—the "brute force" method has predominated. And the "brute force" method is obviously a losing battle.

On 75 Meters it is mechanically impractical, if not impossible, to construct and operate a rotary beam having more than 2 elements. This *may be* fortunate. A full-size rotary beam for 3900 kc would have an approximate span of 125 feet and the elements would then be spaced about 25 feet apart at .1 wavelength spacing. When this is realized, it becomes obvious that unless you own a private circular railroad in your backyard, there will be great difficulty in rotating the beam. The first design step, therefore, is to suitably load the elements with inductance in order to achieve 75-meter resonance in a smaller span that can be rotated successfully while still maintaining high efficiency. This offers some problems. As an antenna is shortened and artifically made resonant, the loss resistance begins to add up and the terminal impedance goes down. If successful transmission line matching is to be had, the terminal impedance must be held high, and if radiation from the antenna is desirable, which it is, the loss resistance must be as low as possible. There are of course many known ways of matching a line to an antenna having a terminal impedance as high as 50 ohms. The "T," "Gamma," and the use of a folded driven element are all within the "satisfactory" category. Some sacrifice in efficiency, bandwidth, or convenience is usually discovered, however, in the use of any of these. Direct feeding of a split driven element simplifies the whole thing but first the terminal impedance must be such that this becomes possible. The Yagi herein described employs a split driven element having a high enough terminal impedance to feed directly. The loss resistance, furthermore, is low enough to enable a good portion of the stuff you buy from your local power company to end up in South Africa or in Australia.



Details of the 75-meter Yagi

Mechanical Design

The total span of this Yagi is slightly less than 34′ and one third of this is small-diameter material similar to that employed for mobile

6. Orr, "20-Meter DX With a 2-Element Beam," February 1955 *CQ*.

antenna use. The entire beam is light enough to be supported by any of the "crank up" TV towers. Even more important is the fact that it can be rotated by any of the better grade TV rotators. For loading to resonance at 75 Meters four of the recently developed[7] high-efficiency vacuum coils are employed. Two such coils are used in each element at optimum locations as shown in the accompanying photograph. In that these coils are filled with helium and then weather sealed, the effects of rain, dirt, and weathering are reduced to a minimum. The general mechanical design of the antenna is indicated in *Fig. 1*. It will be noted that relatively large-diameter center tubing is employed to maintain mechanical stability and to hold down the loss resistance of the current-carrying portion.

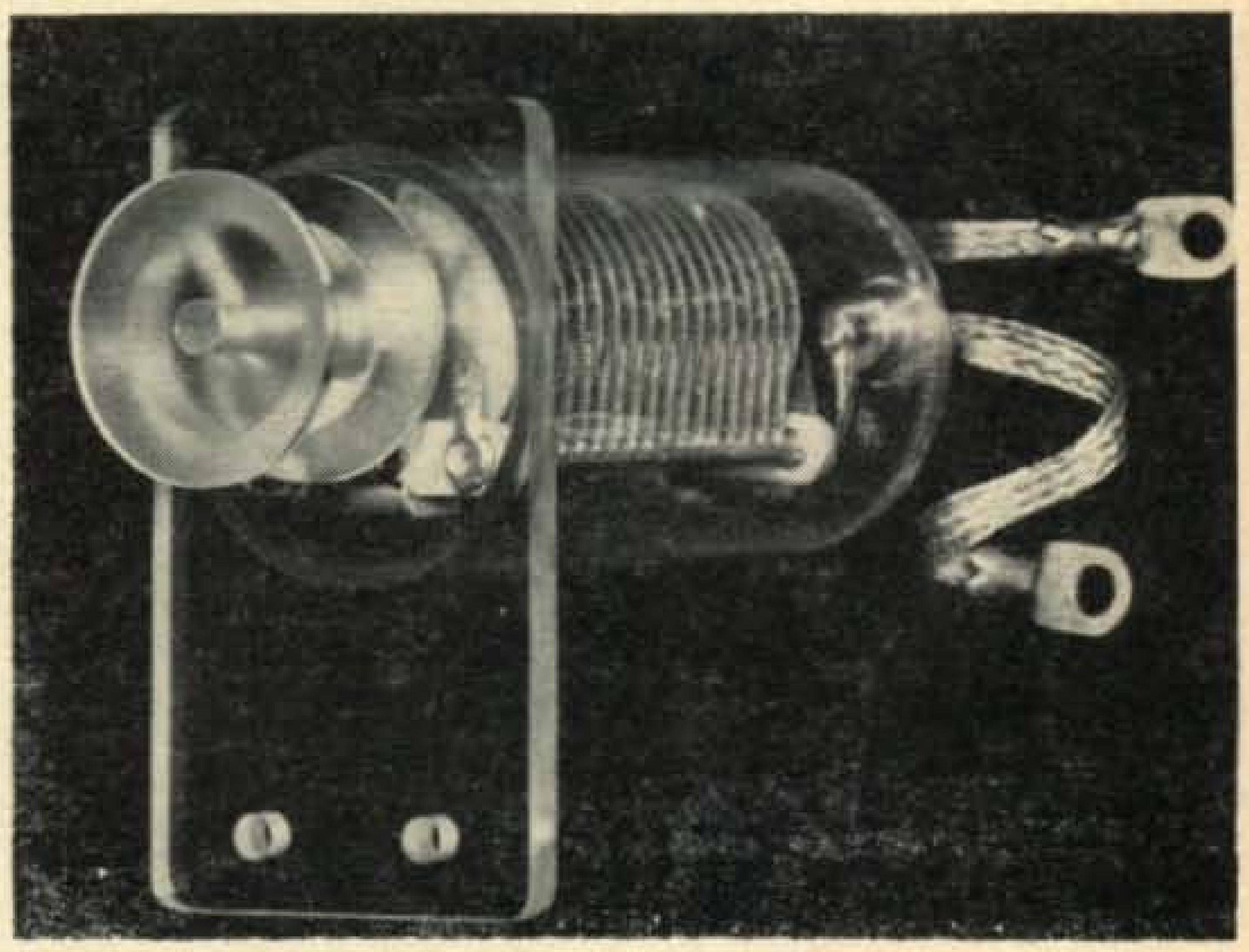
Mechanical stability in a Yagi is extremely important. Again it seems important that it be said that a beam *must* be adjusted, *after* installation, right down to the proverbial gnats' eyebrow, if good results are to be had. A flimsy beam that flops around in the slightest breeze simply cannot be adjusted. Motion of the assembly very greatly effects radiation resistance, terminal impedance, reactance and SWR, and completely obviates the necessity of putting the thing up in the first place. Unless you build one that will hold still during *and* after adjustment, it is better to stick to the old dipole. It will more than likely work better. This particular Yagi is built with a 2″-diameter boom which holds together a pair of very rigid element support channels. The elements are then mounted on solid plexiglas insulators that are securely bolted to the support channels. The loading coils are placed at a distance of 12′ from center and are carried by 1½″-diameter alloy tubing. This type of assembly is so strong that you can chin yourself on it without causing noticeable sag. A first attempt at making this Yagi in "plumber's delight" form met with little initial success from an electrical standpoint and it was quickly discarded in favor of the insulated-element design. The mechanical construction is straightforward and provides the greatest possible rigidity and strength consistent with minimum wind resistance and low weight.

Machined alloy plugs are permanently fixed in the outer ends of each element tube. In the center of each of these plugs is inserted a short length of ⅜-24 stainless steel threaded rod to accept the loading coils which are equipped with similarly threaded female fittings on each end. The adjustable end rods are threaded to screw into the other coil end. These end rods are 18″ in length over which is telescoped a 42″ length of alloy tubing. The tubing has a slotted end and a stainless steel clamp is used to bind the two sections together after adjustment to predetermined points. The end rods are mainly for the purpose of establishing resonance and contribute little in the way of radiation.

7. Bassett, "Mobile Antenna Perfection," September 1955 *CQ*.

Adjustment

During the last few years there has been noted within amateur ranks a growing tendency to shy away from adjusting a Yagi. This of course is false economy. Great numbers of amateurs seem to believe that they either do not have the technical qualifications necessary to do the job, or that nothing can be gained by adjustment. Some of this lazy thinking may have been encouraged by propaganda disseminated for sales promotion purposes. There is no miraculous built-in power whereby a "ready made" beam, by reason of "inherent design," requires no adjustment at all after installation. A Yagi is greatly effected by elevation, type of terrain, proximity to other objects, and even by the type of support on which it is mounted. The importance of adjustment after installation cannot be too strongly emphasized. This particular beam has been constructed from scratch with but one objective: to be able to quickly and easily "put it on the nose" after it was mounted on top of a supporting structure, and at the elevation at which it was to be used. In making final adjustments on this beam it is not necessary to emulate a human fly. It is not necessary to climb one ladder step above the ground. It makes no difference, therefore, whether or not your last insurance premium has been paid.



Hermetically sealed element-tuning condenser and pulley assembly

All initial adjustment of the beam is made by setting the telescoping end rods to predetermined positions while the whole assembly is still on the ground. After this has been accomplished, the antenna is then at about the "formula length," or "factory pretuned," stage of adjustment. This is as far as you can go until it is up in the air and in its operating location. The important adjustments are to be

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From the mail bag it is apparent that most of you fellows would much rather see RTTY technical information than a whole batch of station photos and pictures of people. We hope you like the present make-up of the column. Let's hear from you if you do. If you don't, let's hear from you anyway. Any suggestions will be well received.

75-METER BEAM

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made later and will be described further on. They can be completed in about five minutes and you will not require any fancy test equipment, expert knowledge, or a pilot's license. All you will need is about 100 feet of 20-pound fishline, a friendly nearby amateur, and your own receiver.

Radiation Pattern

The purpose, and necessity, of making final adjustment to any Yagi is to obtain the best possible radiation pattern. A beam antenna obviously is supposed to be so adjusted that it becomes undirectional, within design limits, and provides interfering signal reduction throughout a good portion of the azimuth while exhibiting some signal gain in a frontal direction. Signal reduction takes place off of the ends, and to the rear, while some gain over a reference dipole is evidenced from the front. The frontal signal, therefore, is termed a "beam" and the width of this beam depends on several factors including the type of Yagi, number of elements that are employed, and the final adjustment of the antenna. The beam-width of this Yagi is approximately 60° after final adjustments have been made.

The bandwidth of a beam antenna is normally considered as being that frequency range throughout which the antenna may be used while encountering a SWR of less than about 2:1. The average 20-meter beam will remain within this ratio throughout a bandwidth of about 100 kilocycles. When adjusted for best front to back ratio the 75-meter beam exhibits a bandwidth more closely approximating 75 kilocycles which, at this frequency, is understandable. It can be made to "load" well throughout the entire 75-meter phone band but "loading" is not an accurate yardstick of performance. Optimum performance can be obtained at the frequency of adjustment, just like any other Yagi, with reduced performance elsewhere.

On 75 Meters the phone portion of the band is a relatively large chunk of spectrum and the antenna should be adjusted for operation within the most generally used segment of the band according to individual taste. If you operate SSB on the high end, it should be centered there. If general coverage is desired, it should be set to center on the middle, or low, band end. It is not possible to cover this entire band efficiently even with a dipole, and so it is with the 75-meter Yagi.

Field-strength measurements made over an extended period were only in azimuth. At 75 Meters no satisfactory method has as yet been found whereby accurate vertical angle measurements can be made. Every conceivable method of running vertical-angle measurements was explored short of leasing a helicopter at $75.00 per hour and this seemed to be too expensive to justify the somewhat doubtful results. For the present then it has been found necessary to estimate the number of degrees by which the vertical angle has been lowered. Comparison indicates that the vertical angle has been lowered between 10° and 15° over a reference dipole. This follows closely the measurable difference to be expected from higher-frequency Yagi antennas of this type.

The forward gain obtained over a reference dipole is approximately 4 db. Front-to-back ratio is 15 db and the front-to-side ratio is about 35 db. The measured pattern is symmetrical within close limits. The antenna measured was mounted at an elevation of only 40′ above ground which height is considerably less than ¼ wavelength, but will no doubt be about average at other locations. An antenna should be elevated to at least ½ wavelength above ground if possible. There are few amateurs, however, who have 125′ high masts in their back yards. The fact of the matter is that, in spite of some early misgivings concerning the low altitude at 40′, the antenna has performed well.

This is a two-element Yagi employing a driven element and a reflector. For this reason it exhibits a somewhat higher terminal impedance and greater bandwidth than can be obtained by using a director instead of a reflector. In theory the use of a director would give about ½ db more forward gain but to really secure this gain the going gets rough. There is reasonable doubt that such small additional gain could be proven if it could be obtained. For those rugged individuals inclined to do things the hard way, it is a simple matter to shorten the parasitic element end rods and "experiment" to their heart's content.

Final Adjustment

After assembly of the antenna on the ground is completed the telescoping end rods are adjusted to predetermined positions. Three such positions were initially established by experiment for use with the particular coils employed. One position centered resonance at the middle of the phone band while the other two placed resonance at the low and high ends respectively. The three positions have been permanently marked on each telescoping rod for future reference. The important thing is that while the assembly is on the ground, each of the end

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rods is set for resonance within the desired segment of the band. Connection of the transmission line is then made and the assembly is raised and permanently fastened to the rotator at its operating level.

By reference to *Figure 1* it will be noted that *C1* is shown at the center of the parasitic element. This is a 100 μμfd double-spaced variable condenser weather-sealed in an acrylic housing as shown in the photograph. This is then mounted on the element support channel. The condenser is in series with each half of the parasitic element and has an acrylic drum fixed to its shaft which extends slightly beyond the end of the boom. The purpose of this condenser is to precisely tune the parasitic element to proper phase relationship with the driven element after the antenna has been completely installed. Before the array is raised, a length of fishline is wrapped several times around the drum on the condenser shaft and each half of the line is then allowed to fall from the drum to a position directly beneath the parasitic element. By holding each of these lines taut and alternately pulling one and the other, the condenser may be tuned as easily and as accurately as though you actually had the shaft itself in your hand.

All you now need is the friendly nearby amateur. The transmission line can be connected to your receiver which obviously must be located close enough so that the S-meter can be seen and accurately read. If this cannot be done, it is a simple job to build any of the germanium-diode field strength meters described in the amateur handbooks. The receiver is far better if it has a good S-meter.

Your friendly amateur, by the way, must be equipped with a dipole or a beam of his own, in order to be of service. His assistance consists of furnishing you with a signal on the frequency which you wish to use to enable you to adjust your beam. He cannot employ a vertical antenna for this purpose. The signal you adjust by must be horizontally polarized. In lieu of the friendly amateur, you can, if you wish, string up a dipole and drive it with a small portable transmitter of some sort to generate the signal. The dipole should be broadside to your beam and located about 500 feet away, or farther. Of course these things are technicalities with which you must contend before you can begin to make that final adjustment. Usually a friendly amateur can be found and it does not make too much difference how far away he may be as long as his signal does not fade.

With the reflector facing the incoming signal, carefully adjust the receiver so that the S-meter is at about center scale and the needle stands still. At this point the only remaining thing necessary is to pull the fishlines back and forth until the lowest possible S-meter reading occurs

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and you are finished. The antenna should then be rotated until the driven element directly faces the incoming signal and the S-meter rise will show you the front-to-back ratio. A number of stations should be worked at various distances in order to check this ratio accurately. Ground-wave from a local station can cause some error to appear in front to back measurements. This will not, however, effect the reading obtained by parasitic-element adjustment.

That's all there is to adjusting the 75-meter beam. Unfortunately there is one thing that has not yet been figured out. It now becomes necessary to remove the fishlines from around the tuning drum without disturbing the condenser. You may find some new way of your own to do this, but so far the only way found has been to lower the beam to a point where the drum can be reached and the line gently removed. In view of the things that can be gained by final adjustment this does not seem to be too high a price to pay for them.

Operation

The antenna herein described was initially designed for operation at 75 Meters, or at whatever frequency of resonance might be obtained by coil substitution. The same antenna has been constructed for operation below 2 megacycles, on commercial frequencies being used in Latin America. By substituting 40-meter coils it can readily become operative in this band. By placing jumpers around whatever coils might be installed, and readjusting, it can become operative in the 20-meter band. It was originally designed, however, for efficient operation in the 75-meter band where a beam antenna is most needed, and where, to our knowledge, none has ever before been tried (naturally Sam, W1FZJ, ex-W8UKS, exalted VHF Editor of *CQ* used to use a full-sized 3-element vertical rotary beam on 75, but this notable exception is the only one of which we know).

A number of the features of this antenna are quite applicable to any amateur-band beam that might be improved by accurate final adjustment. Down through the years nearly every other means of precisely resonating a parasitic element has been tried. None of these has equaled the smoothness and accuracy of the method herein described. This method is not new, nor was it invented yesterday. Some of the very first Mims antennas used it nearly 20 years ago.

If you are lucky enough to live near Chitlin Switch, Texas, where the wide open spaces abound, and where your backyard is measured in square miles, this may not be the beam for you. A rotary rhombic, if one can be built, might serve you better. This one is a rotating 75-meter beam for restricted space operation and is designed to keep some of the banshees out of your mixer stage. This it does quite well. ■