21 dB of gain on 2 meters with a new approach to the construction of VHF beams

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Introduction

Of all the components making up a VHF installation the antenna offers the most potential for improving a station's capability. For those who may have doubts it is pointed out that with the low-noise transistors available today, such as the MPF107 of the field-effect type, it is relatively easy to obtain a good noise figure; however, the overall noise figure of a VHF receiving installation is affected by the gain of the antenna. The improvement that can be obtained by increased antenna gain depends only upon the size of array that it is practical and economical to construct.

In recent months I have developed a suspension system for VHF antennas where the rigid booms and structural framework of the conventional high-gain antenna are replaced by ropes under tension. With this system it is easy to construct very long yagi antennas which individually have the same gain as stacked arrays of conventional design.

The 32-element yagi described in this article has a length of 73 ft, a theoretical gain of 21 dB, and can be constructed from all new materials for less than $10. Photo 1 shows a completed 32-element beam before it was raised onto its masts. Antennas of this form could properly be described as suspended long yagis and I suggest that they should be called "sly" beams, using initial letters to form the acronym.

Electrically the sly beam is identical to a rigid boom yagi of equivalent length except that the elements are slightly shortened to compensate for the removal of the usual metal boom.

Suspension Cords

Ordinary cotton or hemp rope is not satisfactory for the suspension cords as these materials absorb water into their fibers resulting in swelling and shrinking. Furthermore, the length of such ropes depends upon the period for which they have been subject to load, a phenomenon known as "creep." For any VHF antenna it is a fundamental requirement that elements must have the correct spacing at all times when the antenna is in use. Nylon cords generally do not absorb water into the fiber, but some types will hold water by capillary absorption between the fibers. A 120 lb breaking strain fishing line made of "Ulstron" fiber has been found to have adequate mechanical properties. (It is New Zealand made, so may not be readily available in all areas. But parachute cords, deep-sea-fishing lines, and other high-strength nonporous cords should be equally suitable.)

Elements

With yagi antennas the directors may be all of the same length or of decreasing length with distance from the driven element. In the former case the optimum length for all director elements depends upon their total number. When there are more than 12 in number, the length of directors becomes less than 36 in. for a design frequency of 144.2 MHz. Aluminum welding rod of 1/8 in. diameter is supplied in 36 in. lengths and is a ready source of elements. The low-cost, lightweight and high-conductivity characteristics of aluminum make it an ideal material. For the driven element and reflector which are necessarily greater than 36 in. long at 2 meters, solid brass rod of 1/8 in. diameter has been used. It is available in long lengths from suppliers of nonferrous metals. The lengths and spacings of all elements for the 32-element sly beam are given in Table I.

Matching

Most of the usual forms of impedance matching should be satisfactory with the sly beam. I used a 300Ω delta match at the driven element and a length of 300Ω slotted, balanced TV feeder to a fully adjustable balun at the transceiver. To some, this system may seem a bit crude but it does contribute to the overall simplicity of the antenna. Results using the delta match are very satisfactory and checks made with an impedance bridge confirm that a good match is obtained at the driven element. When using balanced line it is necessary to keep the line taut, otherwise some fluctuations in forward and reflected power may occur with movements of the feeder. Details of the delta match are given in Diagram 1.

All directors – cut from 1/8 in. diameter aluminum welding rod.
Driven Element and Reflector – cut from 1/8 in. diameter brass rod.
Spacing of Fiber Cords – 14 in.
Design Frequency – 144.2 MHz

Element Director	Length, in.	Spacing from Preceding Element	Spacing from Driven Element (in.)
1	35.2	6.6	6.6
2	35.2	7.4	14.0
3	35.2	7.4	21.4
4	35.2	16.4	37.8
5	35.2	31.9	69.7
6	35.2	31.9	101.6
7	35.2	31.9	133.5
8	35.2	31.9	165.4
9	35.2	31.9	197.3
10	35.2	31.9	229.2
11	35.2	31.9	261.1
12	35.2	31.9	293.0
13	35.2	31.9	324.9
14	35.2	31.9	356.8
15	35.2	31.9	388.7
16	35.2	31.9	420.6
17	35.2	31.9	452.5
18	35.2	31.9	484.4
19	35.2	31.9	516.3
20	35.2	31.9	548.2
21	35.2	31.9	580.1
22	35.2	31.9	612.0
23	35.2	31.9	643.9
24	35.2	31.9	675.8
25	35.2	31.9	707.7
26	35.2	31.9	739.6
27	35.2	31.9	771.5
28	35.2	31.9	803.4
29	35.2	31.9	835.3
30	35.2	31.9	867.2
Driven Element	38.4		
Reflector	43.0	12.3-20.5	

Note: The reflector spacing has a slight effect on the radiation resistance of the driven element.
If maximum front-to-back ratio is required the length of the reflector should be adjusted while making actual measurement.

Table I. Dimensions and spacing for 32-element sly beam.

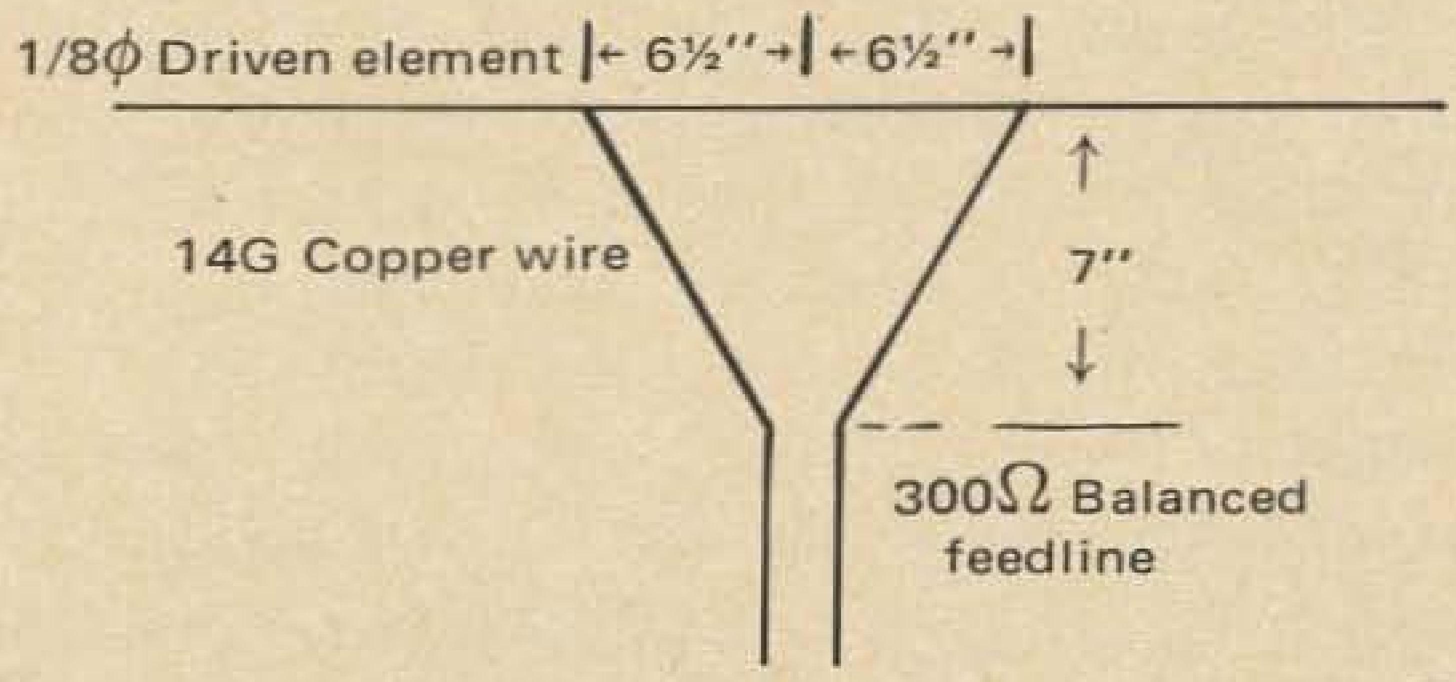

Diagram 1. Details of delta matching for 300Ω balanced feedline.

Fabrication

Even with the best artificial fiber cords available a small amount of creep inevitably occurs. A standard technique to minimize this is to prestretch the cords for 24 hours at about 90% of the breaking load. This is well worthwhile as about 80% of the ultimate creep will occur within the first few hours of loading, leaving only a small percentage to occur while the material is in service. The prestretching is conveniently done by placing two of the cords in parallel ready for the elements to be fixed and then tensioning between anchors as prescribed.

As an additional safeguard against creep it is recommended that when the sly beam is not in use the tension on its supporting cords be reduced to less than 50% of the working load. In practice, this is easy to do and only requires that the supporting cords pass through a pulley at the mast head and down to some convenient point from which adjustments can be made.

Two light wooden spacers about 15 in. long are used to maintain the cords at the correct spacing. These can be fixed to the fiber cords by passing the cords through small holes drilled near the ends of the spacers and then knotting the cords about the spacers.

It should be noted that the supporting cords are slightly elastic so that the spacing of the elements depends upon the tension applied. Also the sag of the array and susceptibility to lateral displacement in high winds is affected by the tension in the cords. It has been found that a total of 80–100 lb of tension in the antenna is satisfactory for a system employing two cords each of 120 lb breaking strain.

The elements should be cut to size and fitted to the supporting cords while they are subject to the intended working tension. Many methods of attaching the elements to the supporting cords are possible. However, wire ties should be avoided because of the risk of producing noise in the receiver due to the interaction of the unbonded metals. The simplest approach is to tie the elements firmly in place with a piece of cotton fishing line as shown in Fig. 2.

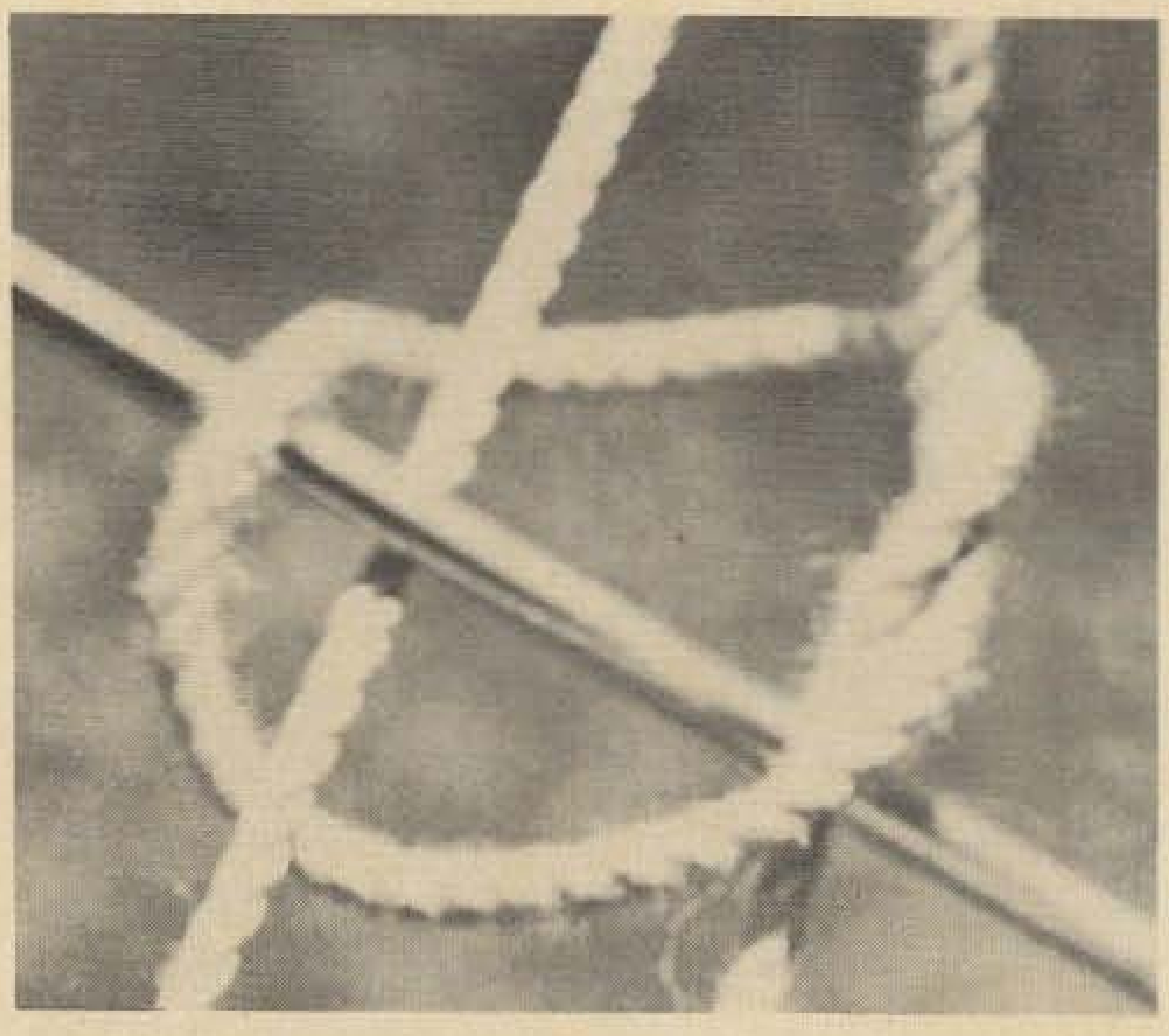

Fig. 2. Knot used to fix elements to suspension cords.

It is useful to arrange the knots so that they can be slid along the fiber supporting cords. The first step then is to tie all the elements in place and then working from one end slide each element into its exact position. A measuring stick with the leading dimensions marked on it simplifies this procedure. Knots are then trimmed and a drop of glue or varnish applied to hold them.

Masts

Two supporting points are required, one at each end of the array, and each of these must be capable of taking up to 100 lb of sideways loading. This sounds difficult but in practice is not really so. Use can be made of trees, chimneys and other natural objects although care is necessary to insure that the antenna's performance is not affected by objects within its effective aperture. If a tree is employed some arrangement is necessary to compensate for sway; otherwise the element spacing will vary. One solution is to use a pulley at the treetop and a counterweight which may rise and fall in a setup similar to that used for low-frequency longwire antennas. Even if two masts are required the cost need not be excessive. I used masts of 1½ in. galvanized pipe with three guy wires at every 10 ft of height. The guys used are

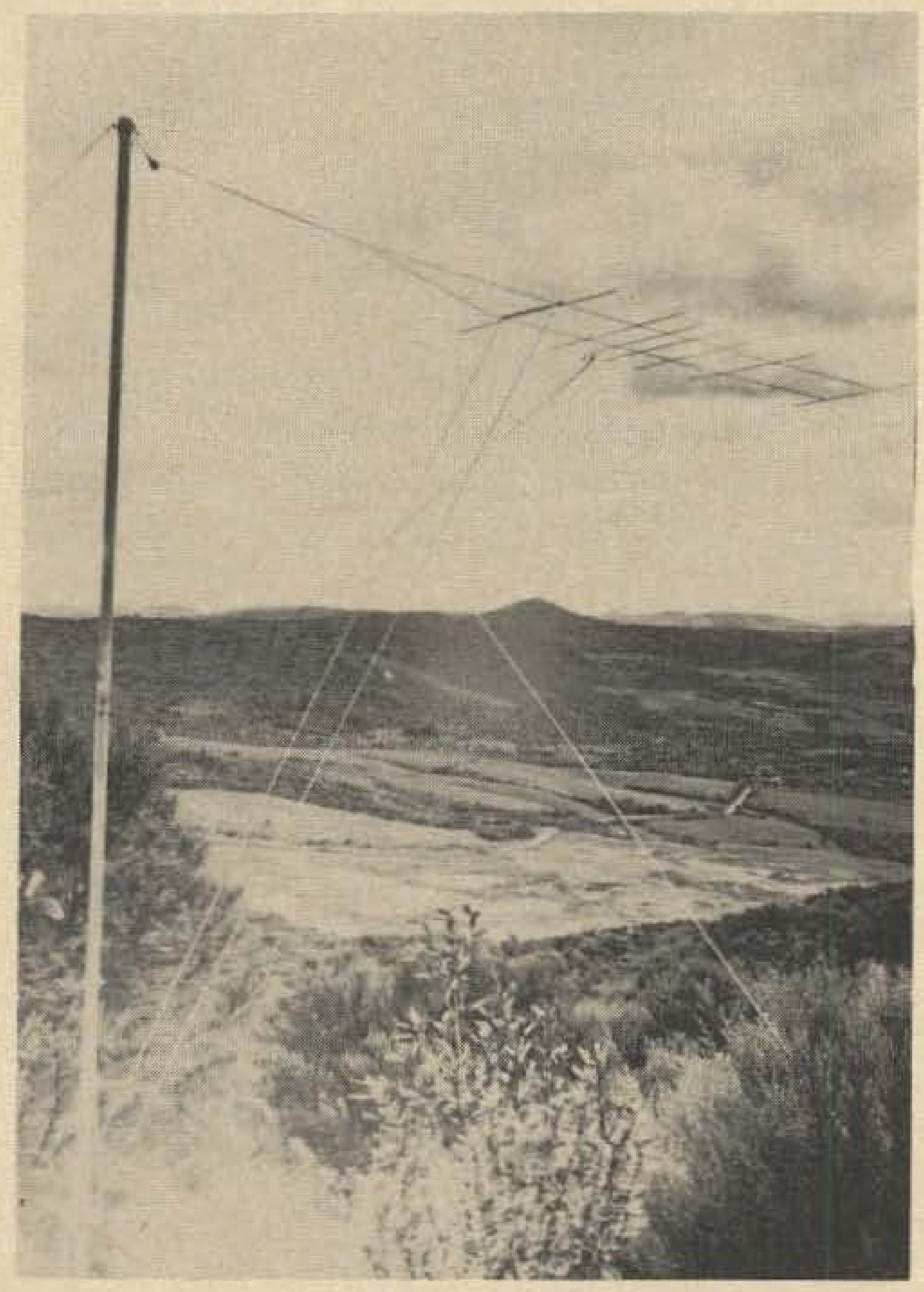

Fig. 3. The launching end of the "sly" beam.

10-gage fence wire, each fitted with a wire strainer for easy tensioning. With this arrangement there is no difficulty in obtaining the necessary 100 lb lateral load ability at 40 ft above ground, provided the guy anchors are firmly set.

Polarization

With the arrangement shown in Fig. 1 the two fiber cords are brought together to form a single cord at each end of the antenna. Generally the weight of the feeder is sufficient to keep the elements horizontal but in windy conditions the antenna may rotate, thus altering the plane of polarization. A simple solution is shown in Fig. 3. Two light cords are attached to the wooden spacer at the reflector element to maintain the desired plane of polarization of the array. A change from horizontal to vertical polarization or vice versa can be effected in a few moments by altering the relative positions of the two stabilizing cords thus rotating the array about its long axis.

Bandwidth

Generally speaking, the bandwidth of a yagi antenna is inversely proportional to the gain; for a 21 dB yagi, peak performance can only be expected over a narrow portion of the band. As normally defined, the bandwidth of the 32-element sly beam is probably about 0.5 MHz at 2 meters. Outside this range a noticeable drop in performance is expected. However, the sly beam has an unusual feature not found in conventional antennas: The supporting cords are quite elastic and by altering the tension on the beam it is possible to alter the spacing between adjacent elements. This *en masse* altering of element spacing tunes the array and has the effect of increasing the useful bandwidth of the antenna. It should be pointed out that to achieve maximum gain at a particular frequency the spacing between every element and the length of every element must be optimum.

Gain

Some authorities do not state performance figures for antenna arrays because of the uncertainties involved. However, I consider that an indication of the potential performance should be given so that different arrays may be tentatively compared. Provided the readers realize that many factors such as antenna height and multipath reflectors can markedly affect antenna performance, no serious disputes should arise.

The theoretical gain of the 32-element sly beam is close to 21 dB when compared with a dipole. Many weeks have been spent in attempting to verify this gain figure experimentally but a reliable and accurate figure has not been obtained. On-the-air comparative tests using a dipole and a 5-element yagi generally support the theoretical gain figure. The antennas used for comparisons were carefully checked for impedance matching and resonante frequency. Measurements were made with the aid of a reliable stepped alternator fitted between the converter and tunable i-f system. Tests were conducted from two sites under a variety of conditions with stations up to 180 miles distant. The improvement obtained with the sly beam over the 5-element yagi on receiving tests was typically 2 5-units, or 12 dB.

On the long path between Dunedin and Wellington (370 miles) the sly beam has shown its superiority. On December 14 when Bill (ZL2CD) was in contact with Peter (ZL4LV) and ZL4TAH (me), Bill's signals were barely perceptible on a 5-element yagi at my Pigeon Flat DX site. On the 32-element yagi Bill's signals were easily readable.

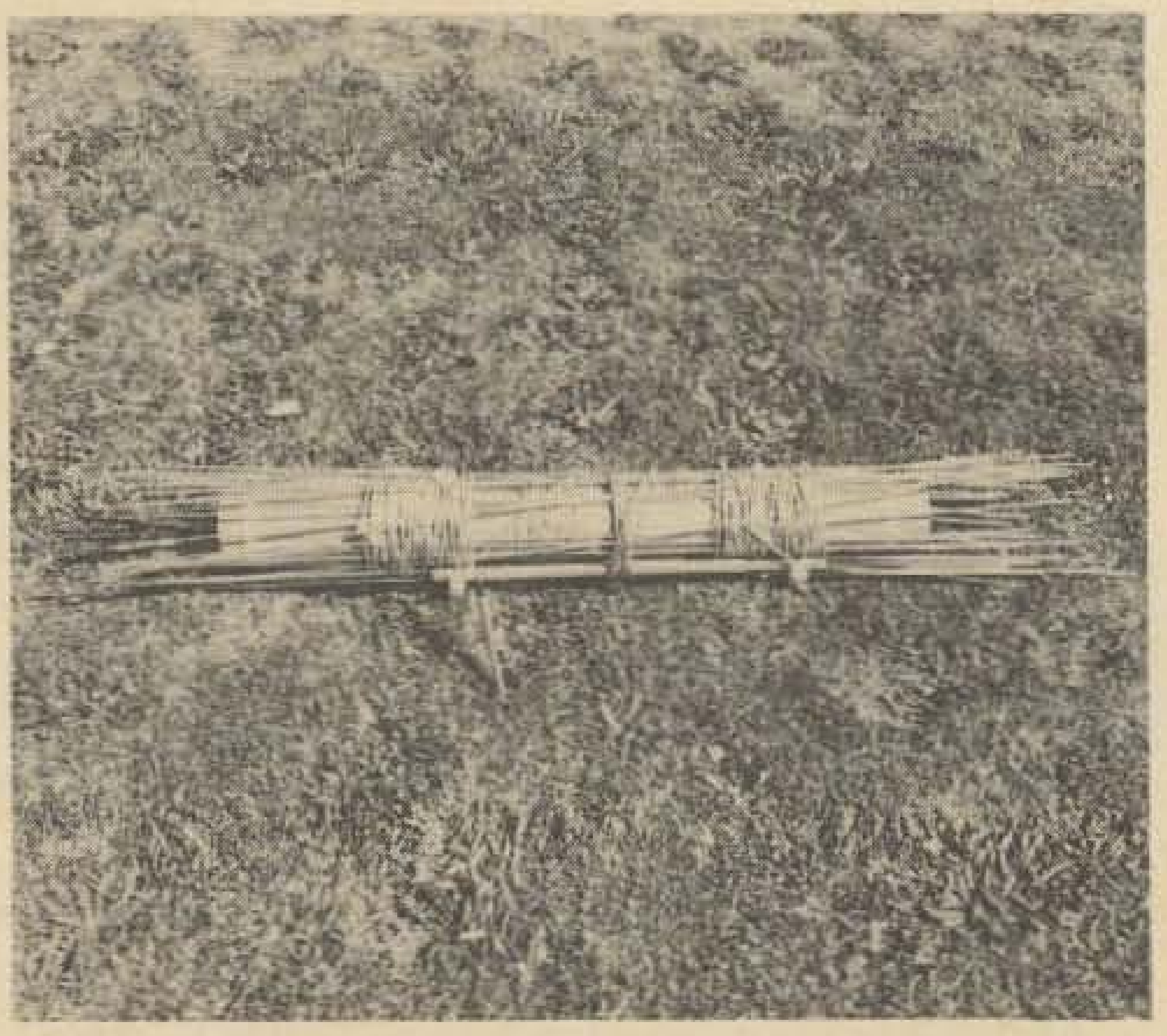

Fig. 4. A "sly" beam can be rolled on to a cardboard tube for transport.

Portable

Because the sly beam has no rigid boom, it can readily be rolled into a cardboard tube for transport to field day or DX sites. The total packed weight of the 32-element beam, excluding feedline, is about 2½ lb.

Usefulness

Obviously the sly beam is not intended for across-town contacts. With a simple antenna, such as a 5-element yagi, it should be possible to consistently work stations out to 100 miles or more, given average conditions and moderate transmitter power. If you cannot do this, fix your gear first or find yourself a good portable operating site, then think about building a sly beam.

For most DX purposes the fact that the array is fixed in direction may be of little importance. The 32-element beam described here has a beamwidth in the "E" plane of about 10° (at the half-power points). Thus at 200 miles the width of the main lobe is about 34 miles. My long yagi at Pigeon Flat near Dunedin has been carefully aligned so that the centerline of the main lobe passes close to Wanganui in the North Island. In the region of Wellington the main lobe (when it gets that far) would be 75 miles wide. Thus Christchurch, Wellington, and Auckland all lie close to the 10° solid angle enclosing the main lobe of the antenna on its present heading. In addition to the dispersion of a signal with distance, resulting from the diverging antenna beam, there is scatter due to topography and atmosphere. All this means that beyond 200 miles the area over which the transmitted signal will be heard and from which signals will be received is quite broad.

Future Development

Although the suspension system appears best suited to the yagi, it could readily be adapted for collinear or other types of array. Even with the yagi there is much scope for experimentation and development. An accurate measure of the gain of the sly beam and an assessment of the broadening of the bandwidth achieved by altering the tension of the suspension cords would be worthwhile projects.

A quick glance at Table I, which gives the length and spacing of elements, shows that apart from the reflector, the driven element, and the first four directors, the element length and spacing is constant. If a reflector, driven element, and set of launching directors were fitted to each end of the array, a switchable bidirectional antenna might result. This could prove handy for ZL2s who could then beam north or south simply by feeding the array at one end or the other.

Conclusion

The sly beam is an exceptionally high performance antenna which can be constructed in a single afternoon from all new materials for less than $10 (excluding feeder and masts). No special tools or fabrication techniques are required and anyone who can tie a knot could construct one. Unusual features of the suspended beam are its ability to be tuned by varying the tension on the supporting cords, its high gain resulting from its length, and its portable nature. It is best suited to fixed-direction communication beyond 100 miles and should make possible some rare DX communication on 2 meters and perhaps even a record-breaking contact between a first and fourth district station.

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