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Evolution of the Beam Antenna

PART 1 **With the 90th anniversary of the RSGB being celebrated this month, it is an appropriate time to look back at the history of that most ubiquitous of radio antenna – the Yagi beam. *RadCom* 'Antennas' columnist Peter Dodd, G3LDO, takes an affectionate look at the development of the beam antenna over the last nine decades.**

When someone describes their antenna to you during an HF QSO it might be described as a "beam" having, say, four elements. At VHF or UHF it could be a "Yagi" with, say, 15 elements. From my office/shack window I can see around 10 or 11 houses all, without exception, sprouting TV and/or VHF radio Yagi antennas. This antenna, which is described in most literature as the 'Parasitic Array', has become the most familiar in our daily lives and the three-element beam has become an icon for HF amateur radio.

While the origins of many popular antennas are well known, the same cannot be said for the Yagi antenna. The purpose of this article is to explore how this antenna came into being and its development by radio amateurs.

EARLY DAYS

The parasitic beam antenna was the result of research carried out at Tohoku Imperial University in Japan in the early 1920s. The research team was headed by Professor Hidetsugu Yagi, who by that time had considerable experience of radio engineering, gained in Europe and the USA. Professor Yagi selected several students and co-researchers. Two of these were Kinjiro Okabe, who was to carry out research on the magnetron, and Shintaro Uda, who was to investigate the properties of antennas.

From the beginning of radio technology the frequencies of electromagnetic waves were defined in wavelengths and it is from these early days that classifications such as Long Wave (LW), Medium Wave (MW) and Short Wave (SW) were defined. Wavelengths shorter that 10m (frequencies higher than 30MHz) were classified as Ultra Short Waves. Although these frequencies had no practical use at the time they proved useful for investigating antennas because the small physical size of resonant lengths was convenient to handle.

Much of the work carried out Tohoku University concerned the generation of continuous electromagnetic waves, which followed on from Yagi's earlier research work with Flemming [1].

Shintaro Uda's early antenna work concerned the measurement of the single-wire resonant loop radiation pattern and he observed and recorded the effect of ground. He also noted that nearby unconnected resonant loops caused changes in directivity, and from this a directional antenna was created. Improved directivity was obtained when the loops were replaced with rods, then the driven element itself was replaced with a half-wave dipole [2]. The antenna design went from a loop to a dipole configuration, and the now familiar 'Yagi' antenna, with the dipole and parasitic rods vertically polarised emerged. Uda produced an in-depth analysis of the variables that controlled directivity such as parasitic element lengths, spacing and geometric arrangement of parasitic elements, and the effects of receiving antenna height and transmitting antenna height. All this research work appeared in a series of papers, first published in early 1926 [3]. This work was, of course, published in Japanese.

BEAM TRANSMISSION OF ULTRA SHORT WAVES IRE PAPER

In 1928, Professor Hidetsugu Yagi visited the USA, giving speeches to IRE members in New York City. He also contributed to the IRE a paper in English called *Beam Transmission of Ultra Short Waves* [4]. This two-part paper, which is now regarded as a classic, described the development of the beam antenna and the generation of ultra-short waves using the split anode magnetron. In summarising Shintaro Uda's work he said: "Suppose that a vertical antenna is radiating electromagnetic waves in all directions. If a straight oscillating system, whether it be a metal rod of finite length or an antenna with capacities at both ends and an inductance at the middle, is erected vertically in the field, the effect of this oscillator upon the wave will be as follows. If its natural frequency is equal to or lower than that of the incident wave, it will act as a 'wave reflector.' If, on the other hand, its natural frequency is higher than that of the incident wave, it will act as a 'wave director.' The field will converge upon this antenna, and radiation in a plane normal to it will be augmented. By utilising this wave-directing quality, a sharp beam may be produced.

"A triangle formed of three or five antennas erected behind the main or radiating antenna will act as a reflector. This system is called a 'trigonal reflector'. In front of the radiating antenna, a number of wave-directors may be arranged along the line of propagation. By properly adjusting the distance between the wave-directors and their natural frequencies, it is possible to transmit a larger part of the energy in the wave along the row of directors. Adjustment of the natural frequency of the directors is made by simply changing their length or by adjusting the inductance inserted at the middle of these antennas. The number of wave-directors has a very marked effect on the sharpness of the beam, the larger number of directors producing the sharper beam. It has been found convenient to designate such a row of directors as a 'wave canal... In general the effect of increasing the forming the canal is shown in **Fig 1**. The length of the directors must be accurately adjusted otherwise successful directing action will not be obtained. It has been found that the interval between the adjacent directors must be adjusted to a suitable value. The most advantageous value for this interval seems

Fig 1: The effect of varying the number and length of directors in wave canals on received current.

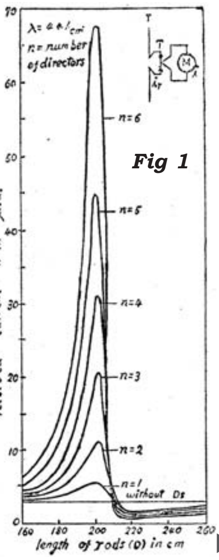


Fig 2: The beam radiation from a radiator utilising a wave canal.

Fig 3: The 1CCZ 28MHz antenna using a driven element, three reflector wires and two director wires.

Fig 4: Construction of the 1CCZ 28MHz antenna, showing the complexity required to support the wires (shown in Fig 3) and alter the elevation angle of the antenna.

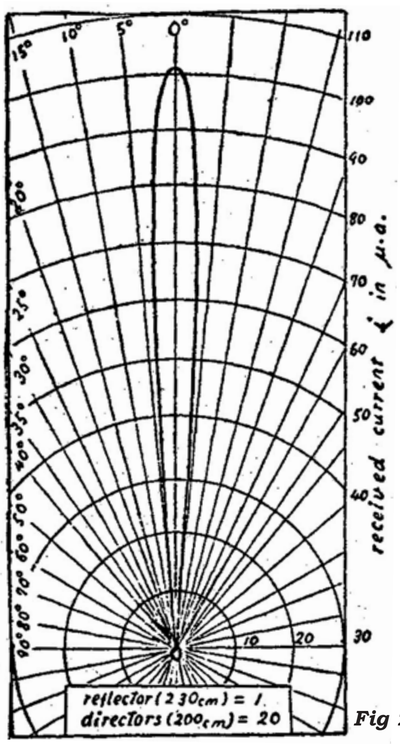
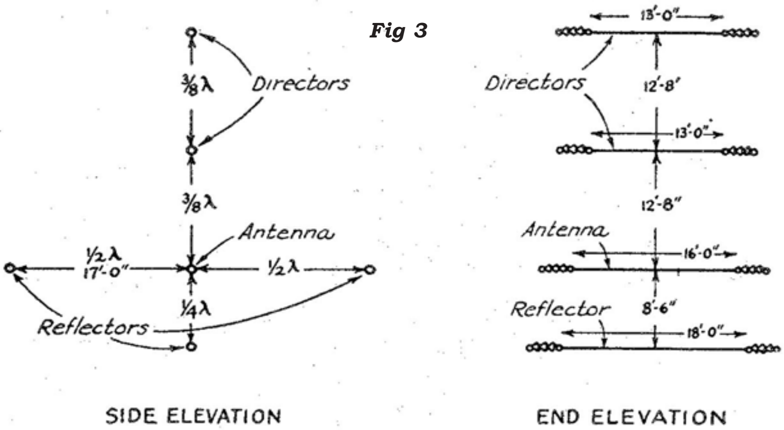


Fig 2

Fig 3



to be approximately 3/8 wavelength.

"A typical polar curve showing the beam radiation from such a projector is shown in is given in **Fig 2**. The measurements were taken on a horizontal plane near the earth's surface. It has been found that the power received increases nearly proportional to the square of the number of directors forming the canal".

FIRST AMATEUR YAGI ANTENNA, 1CCZ, 1928

In 1902 it was independently suggested by Heaviside and Kennelly [5] that a conducting layer existed in the upper atmosphere, which would allow radio waves to follow the earth's curvature. This layer was postulated to explain why Marconi's transmissions from Poldhu in Cornwall were received in Newfoundland.

The existence of a conductive, or ionised, layer was proved by Sir Edward Appleton in 1924 using the Bournemouth transmitter of the BBC. Radio pulses were transmitted vertically and by measuring the delay of the received pulses a layer, 60 miles high, was detected. By 1925, after many more experiments, it was found that the structure of this ionised layer was not as simple as might have been supposed. There were several ionised layers, which showed daily and seasonal variations and interacted differently at different frequencies.

This information would have been available at the time Uda was performing his experiments with antennas. It may have been the reason why he used a 'wave canal', described in [4], as follows: "A canal was arranged parallel to the surface of the earth in the first case and along the line inclined 30 deg to the horizontal in the second case… Thus, by the use of wave canals, high angle radiation may be propagated at various angles to the surface of the earth. This may find some practical application in long distance work".

In October 1928 the first documented amateur use of a parasitic beam appeared in *QST* [6]. It described the work of Mr E C Crossett, 1CCZ [note 1], who built a beam antenna for 28MHz [note 2] and operated from his summer home at Cape Cod. It was undertaken under the auspices of the ARRL Technical Development Program to explore the possibilities of long distance communication using the reflected signals from the ionosphere.

The antenna was built primarily to permit variable high angle radiation in somewhat the same manner as that described by Meissner in 1927 [6]. Because the presence of the ionosphere was detected using a vertically projected signal it was assumed, at the time, that communications using the ionosphere would require the signal to be projected at a high angle.

Meissner conducted experimental transmissions on 27.27MHz from Nauen in Germany to Buenos Aires. He used a beam antenna, which was

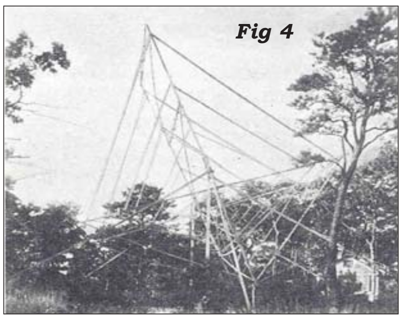


Fig 4

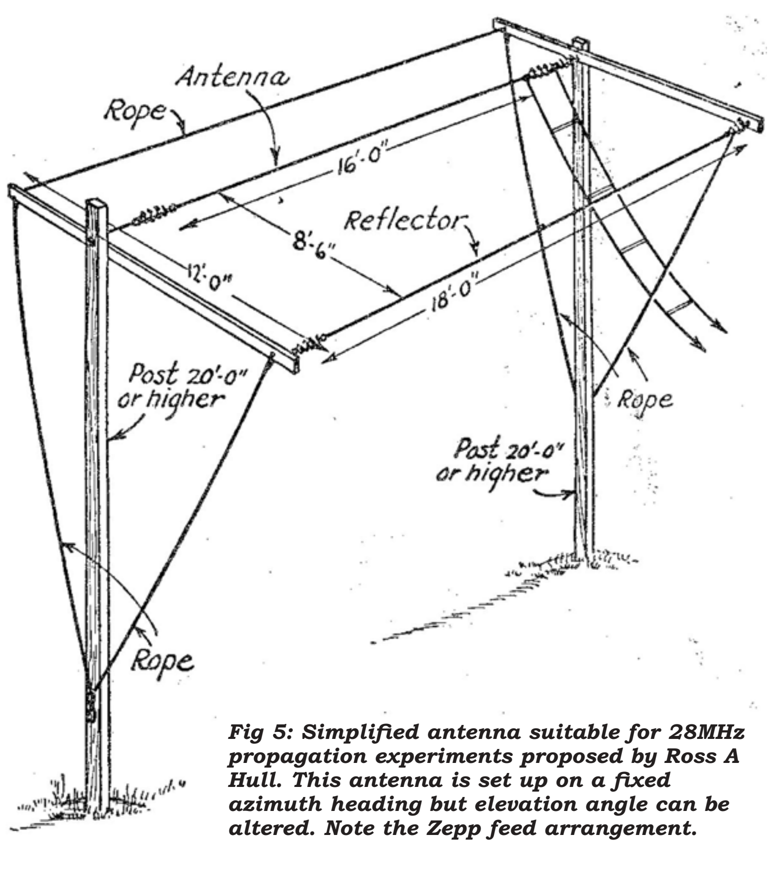


Fig 5: Simplified antenna suitable for 28MHz propagation experiments proposed by Ross A Hull. This antenna is set up on a fixed azimuth heading but elevation angle can be altered. Note the Zepp feed arrangement.

aligned on a fixed azimuth great circle path to Buenos Aires, although the elevation angle was adjustable. He noted, "Contrary to computations and theories, the 27,270kc [kHz] frequency was found to be highly effective in daylight between these two points providing the angle of the beam was adjusted to approximately 38 degrees or 80 degrees from the horizontal. With a simple vertical antenna in place of the beam, signals were rarely heard and then only at very low signal strength".

The experiments undertaken by 1CCZ were more ambitious. The objective was "...to endeavour to find the beam angle which would permit satisfactory contact with Australia – a distance over which one might expect 28,000kc to exhibit some of its useful characteristics". The antenna system, located at 1CCZ's QTH in Cape Cod, was arranged at a fixed azimuth angle 14 degrees north of west, on the great circle path to eastern Australia. The antenna could be tilted in the vertical plane by means of ropes. The antenna system consisted of a Yagi with a driven element, three reflector wires and two director wires, and described as: "...arranged in the manner suggested by Uda and Yagi [4]. The placing and dimensions of these wires is shown in **Fig 3**. The system is seen to be both complex and cumbersome and not particularly suited for the average amateur. The idea, however, was not to attempt to build a truly practical antenna for general amateur work on 28,000kc, but to put up a system strictly in accordance with the present understanding of the requirements. In this way, it was hoped, the work of developing a practical antenna would be, to some extent, facilitated".

The complexity of the structure can be seen in **Fig 4**. The method of feeding this antenna is neither illustrated nor described.

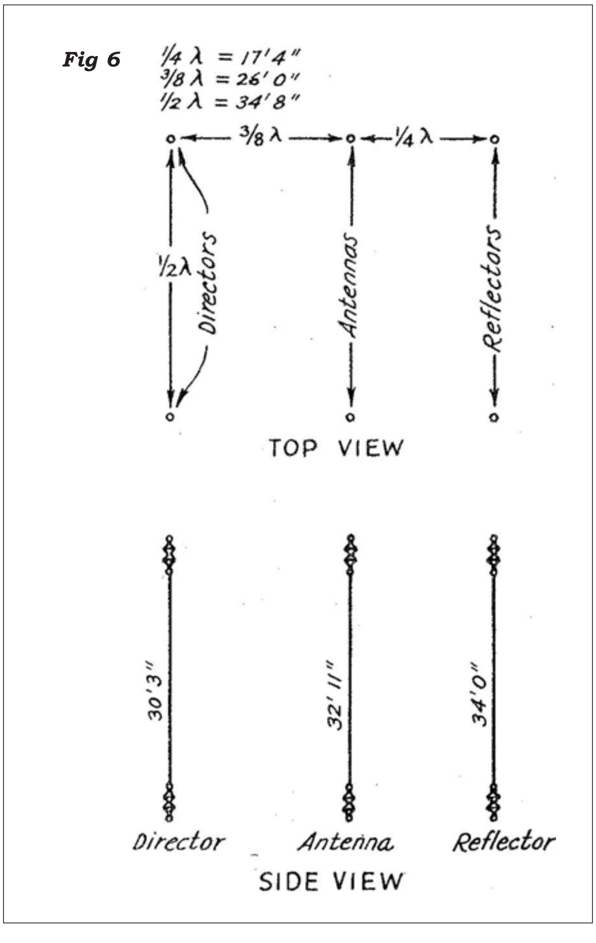
During the month of September the transmitter was operated on schedule with listeners in Australia but during the first two transmissions no reports from Australia were received. The signals, however, were reported R6 by 7ACS at Tacoma, Washington, on the West Coast of the USA.

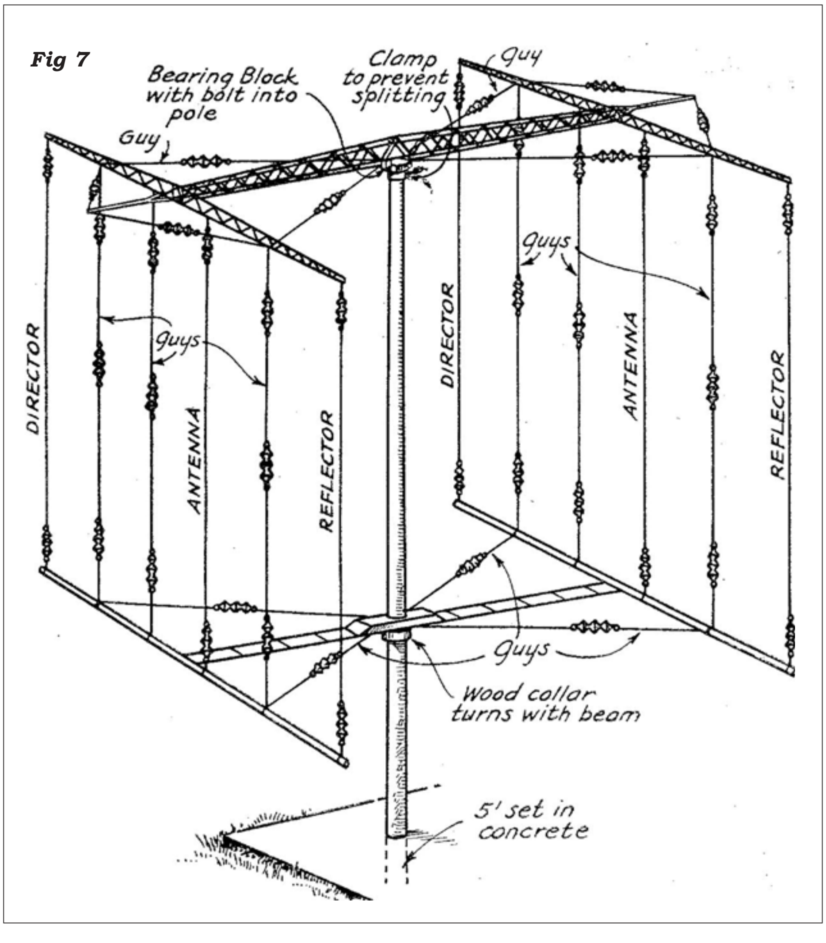
A report of experimental work done by amateurs in the 28MHz band appeared in January 1929, written by Ross A Hull [8], the Associate Technical Editor of *QST*, who was also in charge of the ARRL Technical Development Program. It outlined the USA coast to coast and transatlantic contacts that had been made to that date, plus other results from other parts of the world. The antenna and equipment used by 1CCZ, by now W1CCZ [see note 3], was made available for a week of experimental work by other members of the ARRL Technical Development Program. Hull describes the antenna experiments: "Experiments, with different beam angles and with the director and some or all of the reflectors removed, was made, extending over almost the entire hours when communication was possible. Code letters were sent to designate the different settings of the beam and in this way W6UF selected the most effective setting without knowledge of the angle. Many splendid checks were obtained of the improved signal intensity and greatly reduced fading at beam angles within a few degrees of 30 degrees. In contrast to Meissner's results no particularly effective angles above this were evidenced. The removal of the director made it clear that it was of very slight benefit. Also, experimental removal of the side reflectors made it appear that they were not of appreciable importance. The rear reflector, it seemed, was performing most of the work by itself. When it also was removed, leaving the antenna system as a simple horizontal fundamental Hertz approximately one wavelength above ground, the signal strength immediately dropped from the normal R5–R9 to R4–R5 and fading became pronounced.

"The experiences with the W1CCZ beam antenna have made it evident that any such system can be made much simpler than was first thought. In its most practical form the system would consist of a half-wave antenna mounted centrally between two reflector wires one wavelength apart. A quarter wave behind the antenna the third reflector would be mounted, the four wires being supported in some wooden structure which would permit the angle to be var-

Fig 6: Dimensions of element lengths and spacings for 14.2MHz.

Fig 7: Three dimensional view of the W3CIJ antenna. It is rotated by ropes fixed to the top main girder.





ied. The exact form of the supporting frame is not of particular importance and the amateur can be depended upon to design some assembly which is most suited to his facilities. Another highly satisfactory and still simpler system would consist of a horizontal half-wave antenna with a single reflector wire behind it. The reflector could be tied into place with ropes and made adjustable in the manner shown in **Fig 5**."

The simplified 28MHz antenna shown in Fig 5 is the first time that details were given of how the driven element was fed. This 'Zepp' feed arrangement was very popular with radio amateurs at the time and was used in larger antenna systems, to be described later.

THE W3CIJ 6-ELEMENT 14MHZ ROTARY BEAM

One of the earliest designs of an amateur DX beam was built by John P Shanklin, W3CIJ, and described in *QST* in July 1934 [9]. This antenna comprised two three-element vertical Yagis fed in phase. This is an excellent article and describes the antenna in detail. The dimensional arrangement of these elements is shown in **Fig 6**. The spacing between the elements are shown in fractions of a wavelength and in actual dimensions for a frequency of 14.2MHz. The complete beam assembly is shown in **Fig 7**.

W3CIJ describes the construction of the support structure in detail. The individual components are shown in **Fig 8**: "A good husky wooden pole of about 50-foot height carries the whole load. This is set in concrete, to ensure its remaining rigidly vertical. Pine flooring and plaster lath are the materials from which the main girder and end supports are made, the cost of the wood being about $115 and the whole works weighing only about 300 pounds. The tongue and groove were removed from the 1-inch by 3-inch pieces of flooring to make the 3-inch pieces, and those serving as the 1-inch by 2-inch pieces were cut down further to the latter dimension.

"With the bearing block on top and the collar at the bottom properly fitted, the beam is readily turned in any direction in a few minutes by means of a couple of rope stays. Once set at the desired position the ropes are pegged down to keep the beam from turning with the wind. To keep the feeders from becoming tangled up when the beam is turned, the line from the shack is anchored to the pole below the lower bearing point and flexible jumpers of sufficient length are connected between the line terminals and the quarter-wave coupling section of the beam. A pulley and weight arrangement keeps the line running to the shack taut under varying conditions of weather and temperature".

The Zepp method of feeding the driven elements is shown in **Fig 9.** Transposition of the feed line half way between the two radiators is necessary to excite the two antennas in phase. The feeders are extended a quarter-wave from one of the antennas; this quarter-wave section being shorted at its outer end to allow the antenna to be matched to the 520Ω feed line.

W3CIJ also describes a method of measuring the antenna's performance shown in **Fig 10**: "The intensity meter used in getting the experimental curve consisted of a Type 33 tube used as a diode rectifier, with both grids and the plate tied together, a 0 - 1 milliammeter connected in the output circuit giving the indications. Before taking the measurements it was calibrated on 60-cycle AC. In taking the measurements the intensity meter was set up 10 wavelengths from the beam and the beam was then revolved through 180 degrees, measurements being taken at a sufficient number of settings. The dotted portion of curve 'B' is approximate, the reading being too small in this region to be determined accurately.

"Theoretically the beam should boost the signal approximately 6dB over a non-directional antenna or, in other words, should give a power increase of four times, which means that the 50 watts here is effectively made equal to some several hundred watts with a non-directional antenna."

THE ZS1H 4-ELEMENT 14MHZ ROTARY BEAM

The antenna shown in **Fig 11** was constructed by ZS1H and a brief description of it appeared in the *T&R Bulletin* [10]. The antenna comprises two half-wave vertical driven elements, spaced a half-wavelength apart and fed in phase with 500Ω feeder (presumably using the Zepp end-fed arrangement). The two reflectors are half-waves, spaced a half-wavelength from the driven elements. The design appears to be a simplification of the W6CIJ beam.

The antenna support and mast were constructed of wood. The lattice mast was 54ft high and the top structure was 36ft long and 18ft wide and the whole support structure rotated on roller bearings. The antenna and construction is obviously influenced by earlier articles in *QST*.

THE G6CJ REVERSIBLE DIRECTION BEAM

By the early 1930s the Radio Society of Great Britain had a 'Research and Experimental Section' to the *T&R Bulletin*. Various individuals had specialised subjects and 'Aerial Design' was written by F ('Dud') Charman, G6CJ. In December 1935, G6CJ [11] described what appears to be a two-element reversible beam set up on a fixed (unquoted) azimuth angle. His edited description is as follows: "Some experiments recently carried out with a reflector system have shown that a considerable improvement in long-distance performance can be obtained fairly cheaply. Consider for a moment a horizontal half-wave aerial. This normally radiates in a broad direction at right angles to the wire with an angle to the horizon, which is determined by its height.

"…Now suppose that behind our horizontal dipole we can place a wire,

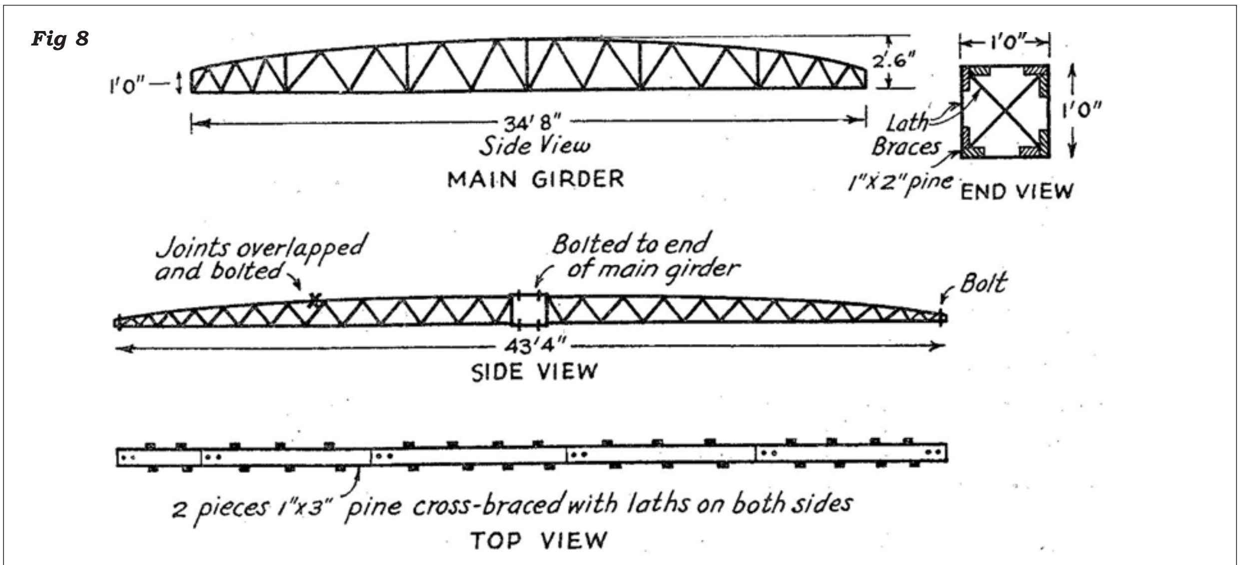


Fig 8: Construction details of the support structure of the W3CIJ antenna.

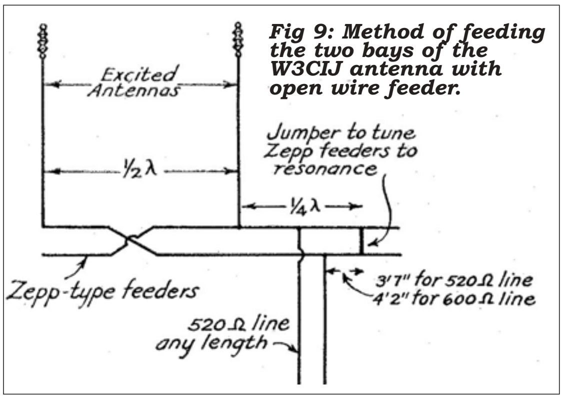


Fig 9: Method of feeding the two bays of the W3CIJ antenna with open wire feeder.

which is in resonance. At a quarter-wave spacing it will be seen, allowing a phase reversal for reflection, that the wave reflected back towards the dipole will be in phase with the next radiated cycle and will add in this direction; also in the opposite direction the two waves, the direct and the re-radiated, will be in opposition and tend to cancel. The system has become more directive and will, in addition to sending twice as much energy one way, also give lower angle propagation.

"The extra signal strength to be expected from doubled power is only 1.4, and is hardly perceptible, but the lower angle will allow of a long journey with less reflections between earth and F layer, and this will result in a reduction of attenuation which may be worth a hundredfold increase in power, and probably also a reduction in fading.

"…The experimental reflector was first tried on 14mc [MHz]. Theory showed that as there was a reactive coupling as well as resistive, the reflector might have to be longer than the usual 33ft, and 35ft was found to give best results. The radiation resistance of the radiator was increased somewhat by its presence, which means bringing the feeder tap or taps nearer the centre. The system was first faced west. Results were frankly astonishing. Signals in W6 rose from one to two points, and instead of getting through occasionally, stations were worked every time, and G6CJ became one of the best European signals over there. In Australia in the mornings signals went up two points and lasted out longer than any others.

"This was very encouraging, and the next thing was to make it easy to reverse direction. This was done by shortening the free wire to 31ft. This has the effect of trying to advance the phase of the re-radiated wave and so 'leading' the wave that way. Results were as before.

"…Turning to the practical side, the systems have so far been supported from one pair of poles by using 16ft spreaders. It is necessary to find the correct suspension point to allow for the weight of the feeders on one side, and the corners can be held back by cords to give stability. One and a quarter inch square pine will hold up a pair of 33ft wires, but it should be suspended from the middle as well as the ends in a sort of triangle. If full height is desired, 2 in x 1in may be used without the end triangle, but a rather stout halyard is necessary.

"A word of warning must be given regarding field strength measurements made with directive systems. In the horizontal system field strength measurements made locally mean practically nothing. The reflections from the ground at angles widely different from the direct ray completely spoil any attempts to find the directive properties of the system. If it is desired to carry out tests of this nature to determine the correct adjustment of the free wire, then the whole system must be made vertical and free from local reflecting objects. For convenience the design may be carried out on a scale model on 28 or 56mc, but the wire diameter should also be scaled down.

"…The writer wishes to register thanks to his fellow experimenter, 2ASP, for his enthusiastic assistance in connection with this experimental work".

There are no illustrations and the method of feeding is unclear. Furthermore there are no references so it has not been possible to ascertain if this was the first time a parasitic array had been used in the UK. The construction appears to be similar to that shown in Fig 5.

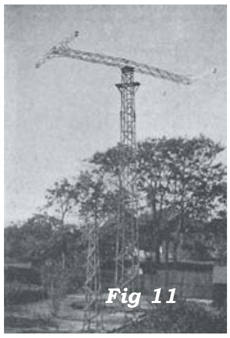


Fig 11

Fig 11: The ZS1H 14MHz four-element beam. A method for supporting the bottom ends of the vertical elements is not visible so it was probably done with ropes.

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In the concluding part next month, Peter Dodd looks at such interesting designs as the W5BDB 'Signal Squirter', GM6RG's massive 28MHz beam from the late 1930s, and the modern, all-metal, beam similar to those used today.

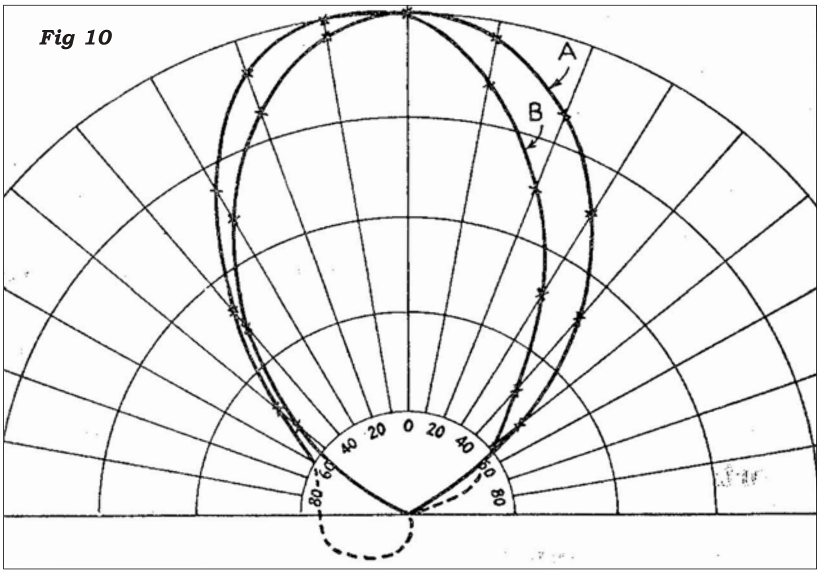

Fig 10

Fig. 10: (A) Calculated horizontal field pattern. (B) Measured field pattern.

NOTES

[Note 1] Although prefixes had been assigned to countries, amateur stations did not originally qualify for international callsigns. The USA was divided into nine call areas and amateurs were granted calls consisting of the call area number, followed by two or three letters, such as 1CCZ or 6MN. W and K prefixes started to be assigned to USA amateurs on 1 October 1928. [From http://www.ac6v.com/history.htm]

[Note 2] The 28MHz band become available to radio amateurs in March 1928.

[Note 3] The 28MHz experiments performed by 1CCZ ceased when he moved to his Chicago home in September. ◆

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Evolution of the Beam Antenna

PART 2 Peter Dodd, G3LDO, concludes his investigation into the development of the beam antenna, starting with the W5BDB 14MHz 'Signal Squirter' design of 1935.

W5BDB described details of his compact directional antenna in QST [12]. This antenna was, like G6CJ's design described in Part 1 last month, also a two-element 14MHz antenna that could be rotated, using a mechanical arrangement, from the shack. It was a lightweight design with a mixture of wood and aluminium tube used in the construction. The article is a clear unambiguous construction description with good diagrams, one of which is shown in Fig 12. It appears to be the first rotatable beam antenna design that could be reproduced by any radio amateur with the space to erect an antenna with a spread of 35 x 18ft.

W5BDB describes the construction: "The material used in the antenna in the final version is aluminium alloy tube 7/8in in diameter. Each side of the antenna consists of a 14ft section of this material with a 3 1/2ft section of a smaller tube that just telescopes inside the larger, providing the means of varying antenna length to the desired transmitting frequency. A small clamp is provided which allows a set screw to extend through a hole in the outer tubing, thus placing pressure against the inner tube and giving good contact between the two sections. The antenna is fed with EO1 transmission cable because of its extreme flexibility and ease with which it may be coupled to any final amplifier."

The reflector was mounted in a manner that space variations between the antenna and reflector might be made by moving the insulators supporting the reflector closer to or further away from the antenna. It was expected that the reflector would be further back from the centre than the antenna, which was desirable to provide a balance of weight since the antenna has the EO1 cable to support over a short distance. The reflector is of the same material as the antenna. W5BDB then describes how the performance was measured. It was the first time standing waves on a transmission line is mentioned: "Finally, after using the Signal Squirter on the air for some little time and becoming thoroughly convinced that the thing really did do the work, we went to work with the field-strength measuring equipment and started making final adjustments. There were several factors to be taken into consideration in doing this. First, the spacing between the two halves of the antenna; next, the exact length of the antenna; then, the spacing between the antenna and reflector; and finally, the length of the reflector.

". . . Element length change was easily made by sliding each end section of the antenna into or out of the larger section of tubing, the final adjustment being fastened firmly in place. A very critical point was the proper spacing between the two halves of the antenna itself, this adjustment being quite necessary to give the best match to the EO1 cable. This adjustment brought considerable improvement and eliminated a tendency for standing waves to appear on the feeder system. Final adjustment finally settled down at about 22in separation between the adjacent ends of the two halves of the antenna.

"Next came the location of the reflector back from the antenna. This spacing had been set arbitrarily at 17ft so that the reflector might be moved back further or up closer. The checks with the field-strength meter indicated very definitely that the spacing between the elements was important but not so critical as the actual length of the antenna and reflector. It was also found that the spacing between the two elements could be varied over a couple or three inches with little or no effect.

"After having found that the reflector seemed to do its best job when at about 16ft 10in instead of the usually recommended spacing of 17ft 4in, we started pruning the reflector length as the final step in adjustment. . . The final selection was 33ft 10.5in for our frequency of 14,215kc. The adjustments of reflector length were found to be quite effective and produced a noticeable difference as each change was made. In fact, it seemed at this stage of the game that the length of the reflector was fully as important as the antenna length, and that both of these were more important than the actual adjustment of space between the two elements in so far as critical and close adjustments were concerned".

G5PP 56MHz TWO-ELEMENT BEAM

Surprisingly, this is the first reference I can find of a parasitic antenna used for VHF, considering that the Yagi was designed for VHF in the first place. This two-element beam for 56MHz by G5PP [13] used a driven element and a reflector fixed to a wooden frame, which rotated within an outer supporting frame as shown in Fig 13. The elements were made

Fig 12

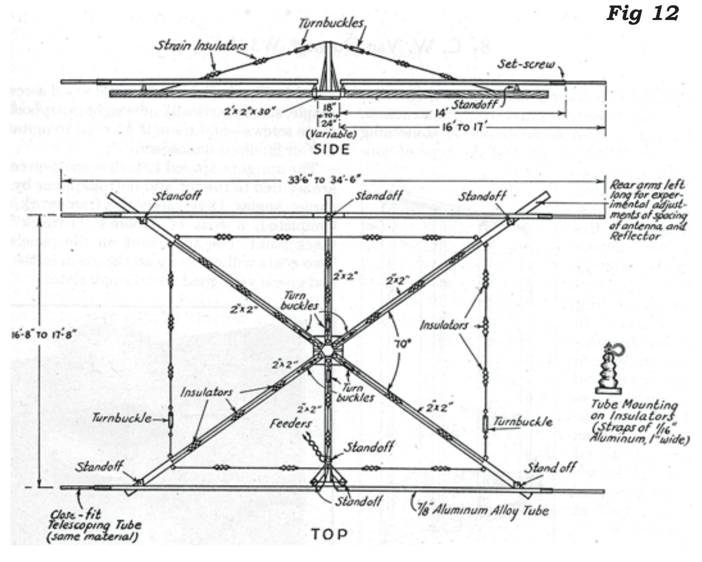

Fig 12: The W5BDB 14MHz two-element 'Signal Squirter'. This lightweight design uses a mixture of wood and aluminium tube in the construction. Note that the driven element is fed in the centre rather that the Zepp method in previous designs.

from 5/16in (8mm) copper tubing, which were fixed to the inner frame with 'midget stand-off insulators'.

The driven element was fed using a Zepp type feed. However, G5PP notes: ". . . but the single or double wire matched impedance type antennas can be used equally successfully, particularly as the feeder lines of the matched impedance aerial gives less trouble than the Zepp type during rotation." I am not sure what this alternative feed method is but I assume it is a centre fed arrangement. The antenna was rotated from the shack by a cord and pulley arrangement.

W1QP / W8CPC COMPACT BEAM

This compact version of a two-element beam was first suggested by John Reinartz, W1QP, and looks as though it was inspired by the W5BDB 14MHz as shown in Fig 12, where the strengthening wire could perhaps be the antenna element. A model was constructed for 14MHz by Burton Simson, W8CPC, and described in QST, October 1937[14].

This configuration is the same as the later VK2ABQ wire beam antenna and predates it by many years. A wooden frame was used to support the elements, which allows the element ends to be folded towards each other. The configuration and construction is shown in Fig 14. The elements were constructed from 1/4in copper tubing with brass tuning rods that fitted snugly into the ends of the elements. An additional brass rod was used as a shorting bar for the centre of the reflector.

The tuning procedure was interesting. The only test equipment available appeared to be an RF meter (0 - 5 amps), the transmitter PA current meter and the receiver S-meter. An RF meter was connected by short leads to the gap in the reflector and the driven element connected to the link coil of the transmitter by low-impedance twin transmission line. The brass rods at the ends of the driven element were adjusted for maximum transmitter PA current. The rods at the tips of the reflector were then adjusted for maximum RF current. These adjustments were interactive and would have had to be repeated. When the adjustments were complete the RF meter was removed and the gap closed with the brass rod. This tune-up procedure tunes the reflector to transmitter frequency.

A 14MHz CLOSE-SPACED ARRAY

By 1938 parasitic antenna designs were becoming more practical and efficient. A description of a two-element beam in the RSGB Handbook [15] is an example. It consists of a radiator and director spaced one-tenth wave with the radiator fed in the centre by means of a double Q matching section and an untuned line. The input Q consists of 72 ohm cable whilst the lower Q has a pair of No 14 SWG wires spaced 1.5in. The Zepp type of feeding is now regarded as not very satisfactory for these frequencies, as it is difficult to balance, and feeder radiation may be considerable.

The antenna is designed for 14.1MHz. The driven element is cut to 16ft 7in either side of the centre and the director slightly shorter, approximately 16ft 3in on either side with a small tuning stub in the centre. An inch gap is left between the two sections of the radiator (driven element).

Several construction methods are described for the centre arm of the rotating framework. The antenna elements are insulated from the wooden framework with ribbed type insulators with brass inserts.

A 28MHz ROTARY BEAM

For some years GM6RG had operated DX using wire beams. He wanted a rotatable beam and embarked on an ambitious project [16] to meet the following specifications: "The problem was to design an aerial having a gain of over 12dB which would give an angle of radiation not higher than 16 degrees. It had to be rotatable to cover all the world; further, remote operation was required with means provided to indicate at the remote controlling position the exact direction in which it was aiming. Finally it had to be strong enough to stand any gale up to 80mph, and yet be as light as reasonably possible".

GM6RG calculated that he would need two vertical phased parasitic antennas, each comprising a driven element, reflector and three directors to meet the above specification. A fairly large structure would be required to support these wire antennas and lattice beams. The construction method he chose was the same as used by W3CIJ, described earlier.

The large H centre of the top support structure was massive, with the centre section of the H being 45ft long and a local building contractor was employed to build it. He specified that the main supporting beam would have to be able to stand a steady weight of one ton!

The whole rotating aerial was supported on a Post Office pole, 50ft long and about 16in thick. This is set into the ground for about 8ft and is also stayed at a height of 20ft. The antenna is shown in Fig 15. The antenna had a couple of modern features. For a start the whole antenna was rotated using an electric motor and gearbox that weighed 360lb! It also had an azimuth position indicator described: "On top of the gearbox, but insulated from it, is a 16-contact commutator, with 15 of the contacts in use. Fixed to the drive shaft is a wiper, wide enough to touch two contacts at a time. A 16-core lead-covered cable runs from this point down to the controlling position, and is there suitably connected to 15 lamps, so arranged that as the beam is rotated the correct lamp is brought into circuit. The lamps are arranged to illuminate that part of a great-circle map at which the beam is aiming".

This large antenna did not live up to its expectations. GM6RG says, ". . . although the original design had been adopted with the intention of obtaining a very narrow angle of radiation, this condition had not quite been met. Results were very good, but

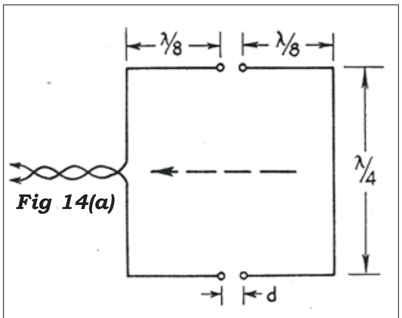

Fig 14(a)

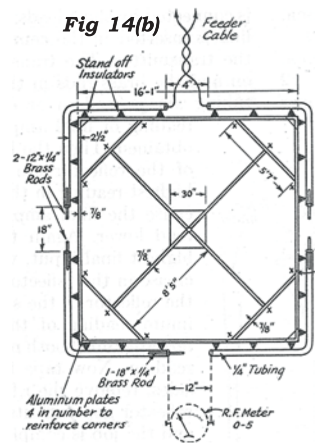

Fig 14(b)

Fig 14. The W8CPC two-element 14MHz 'signal squirter'. (a) Antenna configuration showing the bent elements. (b) Construction details showing method of using supported thin copper elements and method of tuning.

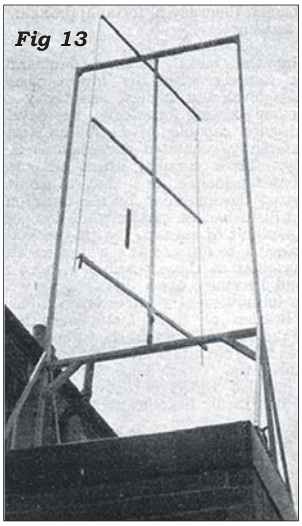
Fig 13

Fig 13: The two element beam for 56MHz by G5PP used a driven element and a reflector fixed to a wooden frame, fixed inside a support frame.

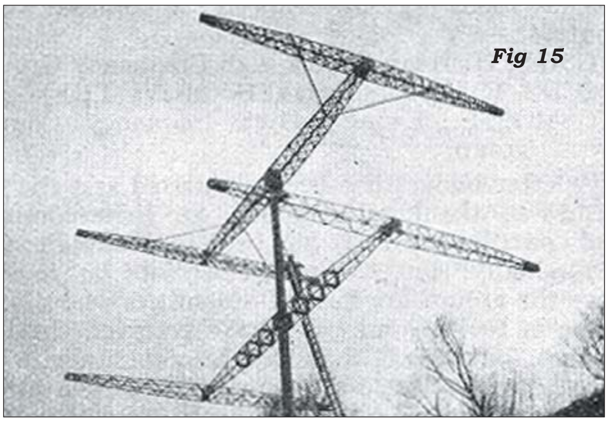
Fig 15

Fig 15: The GM6RG twin vertical phased parasitic antennas, each comprising a driven element, reflector and three directors. Some idea of the size of the structure can be seen compared with the figure at the top of the ladder.

since one of the (requirements was) to investigate the effect on fading of a restricted vertical coverage, such tests were not possible. Added to this, there was a severe storm in Galashiels, and although the rotary [beam] was not damaged, it offered such a large surface area to the gale that it was tossed about in the most violent manner. As a consequence it was decided forthwith to make alterations".

The new design [17] used the original heavy top central lattice structure as a boom to support a nine-element parasitic array using self-supporting tubular elements instead of wire elements, see Fig 16. It comprised one driven element, six directors, and two reflectors, all at a height above ground of 48ft. GM6RG describes it: "The lengths of the various elements for a working frequency of 28,460kc are as follows. Directors, 15ft 4in; driven element 16ft 6in; nearer reflector 17ft; further reflector 17ft 1in. The spacing is 3ft 6in between all directors and between the driven element and the first director, 7ft between driven element and nearer reflector, and 5ft between the near and more distant reflectors. The feed to the aerial is made by open 470 ohm line, and Y match, with a rather complicated system of wooden arms and insulators, which do, however, keep the line absolutely matched in whatever position the beam may be. It has been found much more satisfactory with very high-Q arrays, such as this one, to feed with a Y match and open line rather than by the more usual method of breaking the centre of the aerial. With the latter method it is impossible to keep the feed system clear of standing waves during tuning. . ."

I checked this antenna using EZNEC3 and found it had over 10dBi gain, which must have been very impressive for those days. It is difficult to know why GM6RG chose to use two reflectors - the second reflector contributes no improvement. If he had used one reflector and the director spacings (without changing his director lengths or numbers) closer to that recommended by Yagi [4] and 1CCZ [6] he could have increased the gain to over 13dBi with the long boom that he had at his disposal.

THE MODERN ALL-METAL BEAM

I spent some time trying to find the first instance of the all-metal construction that characterises the modern form of the parasitic beam antenna and was surprised at how late it made its appearance. The first instance of all metal constructed beams appears in the ARRL Handbook of 1947 [18]. The 'Antenna Systems' chapter has descriptions of parasitic beam support systems all constructed from wood, with stand-off insulators to hold the metal antenna elements in place. One design even uses a ladder for a parasitic antenna boom.

However, buried in a page of suggested antenna construction methods is the example shown in Fig 17. There is no description of it in the text but the caption reads "Pipe assembly three-element beam, 'Plumber's Delight' [note 4] with a folded-dipole driven element. Because all three elements are at the same RF potential at their centres it is possible to join them electrically as well as mechanically with no effect on the performance".

In the 'VHF Antennas' chapter of the same publication [18] there is a description of collapsible 50MHz two-element beam for portable use, which also uses this 'Plumber's Delight' construction and is illustrated in Fig 18. It comprises a radiator, which is fed with coaxial line by means of a T-match, and a reflector, which is spaced 0.15-wavelength behind the driven element. It is made entirely of 3/4in dural tubing, except for the vertical support, which is 1in tubing of the same material.

The fed section of the T-matching device is composed of two pieces of 3/4in dural tubing about 14in long. The two sections are held together mechanically, but insulated electrically by a piece of polystyrene rod, which is turned down just enough to make a tight fit in the tubing. The inner and outer conductors of the coaxial line are fastened to the two inside ends of the matching section. The positions of clips, which connect the T-match sections to the driven element, are adjusted for minimum standing wave ratio on the feeder. The idea for this antenna was suggested by W7OWX [19].

The W6SAI Beam Antenna Book [20], [1955], was one of the most comprehensive books on parasitic beam antenna construction and design ever published. I have an old well-thumbed copy, given to me by the late Eric Knowles, G2XK, who used it to design a six-element 10m Yagi on a 37ft long boom. This book helped me with many beam antenna construction projects and probably helped fashion the commercial and home-made designs of Yagi antenna that prevail today.

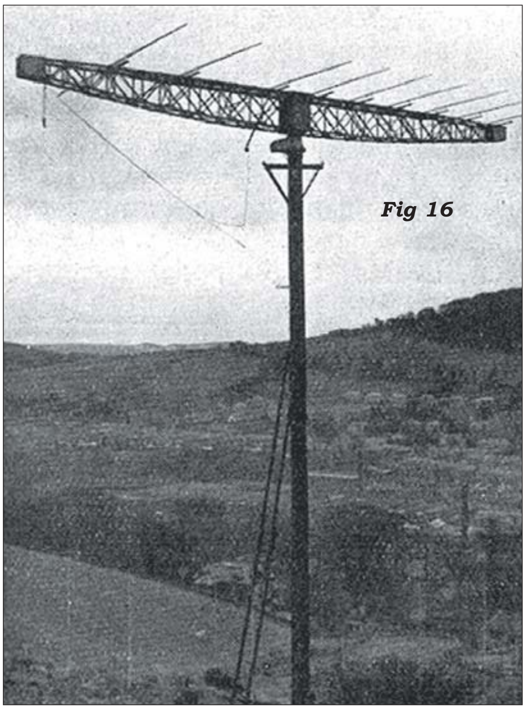

Fig 16

Fig 16: The new GM6RG design used the original heavy top central lattice structure as a boom to support a nine element parasitic array using self-supporting tubular elements instead of wire elements.

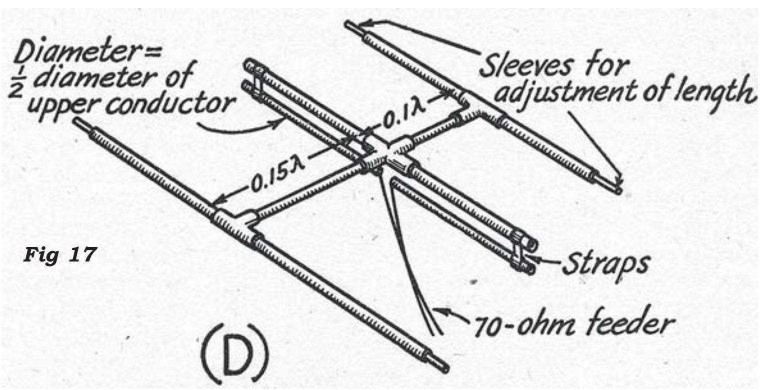

Fig 17

Fig 17: Pipe assembly three-element beam ('Plumber's Delight') with a folded-dipole driven element. The construction implies that it possibly came from the television industry.

ACKNOWLEDGMENTS

I wish to thank John Crabbe, G3WFM, curator of the RSGB Museum and Library, for all the effort he put into searches for relevant articles, papers and books; to Laurie Mayhead, G3AQC, for the Yagi IEE paper [4] and to Robert H Welsh, N3RW, for information via e-mail.

NOTES

[Note 4] 'Plumber's Delight' is a generally-accepted name for all-metal construction parasitic beams, where the antenna elements are fixed to a metal boom without insulators.

REFERENCES

[12] 'The All-Around 14-Mc Signal Squirter'. M P Mimms, W5BDB, QST, December 1935.

[13] 'A 56 Mc Rotating Beam Antenna', R Palmer, G5PP, The T & R Bulletin, December 1936.

[14] 'Concentrated Directional Antennas for Transmission and

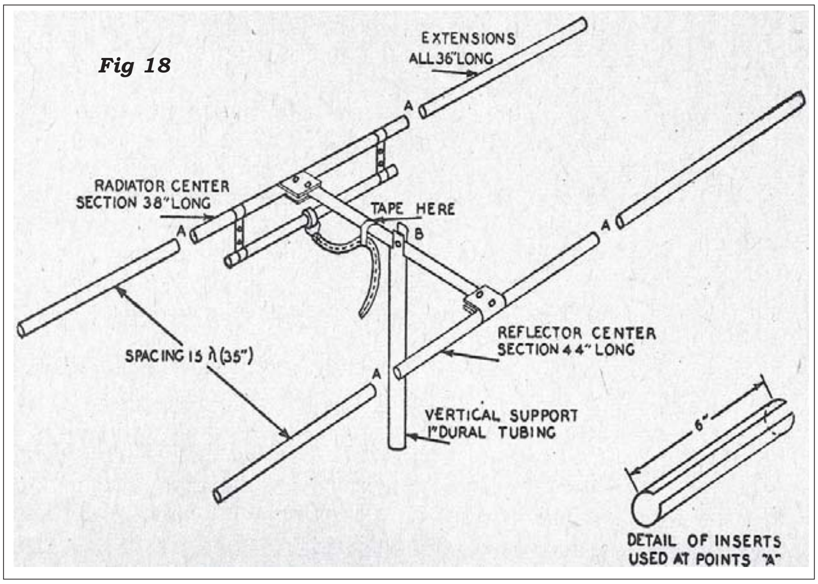

Fig. 18: Detail drawing of the collapsible 50MHz beam. For carrying purposes, it is taken apart at Points A and B, inserts of slotted dural tubing being used at Point A to hold the sections together. All extensions are the same length, the difference in element length being provided by the length of the centre sections.

Reception', John Reinartz, W1QP, and Burton Simson, W8CPC, QST October 1937.
[15] The Radio Amateur Handbook, RSGB, 1938.
[16] 'A 28 Mc Rotary Beam', Bryan Groom, GM6RG, The T & R Bulletin, June 1938.
[17] 'Rotatable Array Design', Bryan Groom, GM6RG, The T & R Bulletin, December 1938.
[18] The Radio Amateur's Handbook, 1947 edition, ARRL.
[19] 'Hints and Kinks', W7OWX, QST, April 1946, page 148.
[20] The Beam Antenna Handbook, William I Orr, W6SAI, and Stuart D Cowan, W2LX (1955). This book is now in its sixth reprint.

The drawings and photographs in both parts of this article are reproduced from the original publications dating from the 1920s to 1940s. ◆

'Party in the Park'

26–27 JULY 2003

To celebrate the RSGB's 90th birthday, the RSGB is holding a 'Party in the Park'. Each of the Society's 57 UK Districts has been invited to organise an event open to the general public. Each RSGB District will also have an opportunity to take part by putting on a special event station and operating the 'Special (Special)' callsign agreed by the RA for this commemorative occasion. The format of the callsign is GB90RSGB/*, where * is the RSGB district number, eg GB90RSGB/11. A complete list of the districts and district numbers can be found on page 14 of the June 2003 RadCom. A special 90th anniversary award certificate is available for those making contact with (or SWLs hearing) the GB90RSGB stations. Full details can be found on page 7 of the July *RadCom*.

The July *RadCom* contained a list of the 'Party in the Park' events notified to HQ at the time of going to press (pages 24 / 25). There is one correction to the details published last month - the correct telephone number for Paul Gaskin, G8AYY, the Solihull ARS contact for the GB90RSGB/52 station, is 0121 783 2996. Also, the Torbay Amateur Radio Society was scheduled to run the station GB90RSGB/112 from the Brixham area during the 'Party in the Park' event (see RadCom July 2003, pp24-25). Unfortunately, the club is no longer able to participate, and offers its regrets to prospective visitors.

The following six 'Party in the Park' events were notified too late to be included in the list published last month:

GB90RSGB/51

1. St Leonard's ARS (Stafford)
2. Stafford Castle, Castle Bank, Newport Road, Stafford ST16 1DJ (off the A518 just by the M6).
3. Derek Southey, G0EYX, tel: 01785 604 904; e-mail: g0eyx.derek@ntlworld.com
4. Sun 27/7.
5. Food 'n' socialising with a celebration of 25 years of archaeological digging at Stafford Castle from 11.00am, special event station on HF and 2m. The castle has a visitor's centre with a collection of artifacts from the digs and lots more. Plenty to do and see for all the family. Coverage and publicity from two counties (Staffordshire and Shropshire) with local papers, several radio stations and TV is likely.

GB90RSGB/51

1. Aldridge & Barr Beacon ARS
2. Aldridge Central Hall Community Centre, Middlemore Lane, Aldridge, Staffs (in the park)
3. Charles Baker, G0NOL, tel: 01922 636162; e-mail: catbaker@tiscali.co.uk
4. Sun 27/7
5. A joint club 'food, fun & games' day with the Cannock, Dudley & Wolverhampton Amateur Radio Societies, special event station on HF and 2m.

GB90RSGB/53

1. Stourbridge & DARS
2. Old Swinford Hospital School, Heath Lane, Stourbridge, Worcs DY8 1QX
3. John Clarke, tel: 01562 700 513; e-mail: john.clarke@iclway.co.uk
4. Sat 26/7
5. Demonstration and special event station operating on HF, 2m and Packet with celebrations, fun 'n' BBQ. Parents and pupils of the school are also invited. The school has a tradition of excellence dating back to its founding in 1667 and houses 593 pupils (boys) from 11 to 19 of which 365 are full or weekly boarders. The party is to be held within the grounds of the school.

GB90RSGB/104

1. Horndean ARC
2. Lovedean, Hants
3. Stuart Swain, G0FYX, e-mail: g0fyx@msn.com
4. Sat 26/7
5. Club barbeque.

GB90RSGB/104

1. Andover & DRC
2. TBA
3. T Cull, G8ALR, tel: 01980 629346.
4. Sat 26/7
5. Special event station.

GB90RSGB/105

1. Brickfields ARC
2. Riding Centre, Binstead, IoW
3. A Gardner
4. Sat 26/7
5. Special event station, displays.◆

KEY TO PARTY IN THE PARK EVENTS

1. Organising club
2. Location of 'Party in the Park' event
3. Contact person
4. Date of event (Sat 26/7, Sun 27/7, both days).
5. What is happening.