THIS MONTH'S LEADING PROJECT

The VHF Log Periodic Yagi

by Mike Gibbings, G3FDW

MY INVOLVEMENT with VHF Log Periodic Yagis (LPYs) began as a result of problems with long boom high-gain VHF yagis. The severe weather at this northern QTH caused metal fatigue due to boom whip, which resulted in a loss of elements. Long booms are necessary for high performance VHF operation using yagis; it is common knowledge that you cannot get high gain from a short boom yagi. [1].

G3MY threw me a life-line in the form of an LPY for 6m, which was said to give a gain of at least 8dBd yet the boom was less than 6ft (1.83m) long (0.3λ). This antenna was constructed and its performance, compared to a 0.22λ two-element yagi, had to be heard to be believed. It also survived winds up to 115MPH (185km/h) and still remained in working order.

I then designed a bigger and better LPY for 70MHz. It was a complete failure. There was obviously more to Log Periodic Yagis than met the eye!

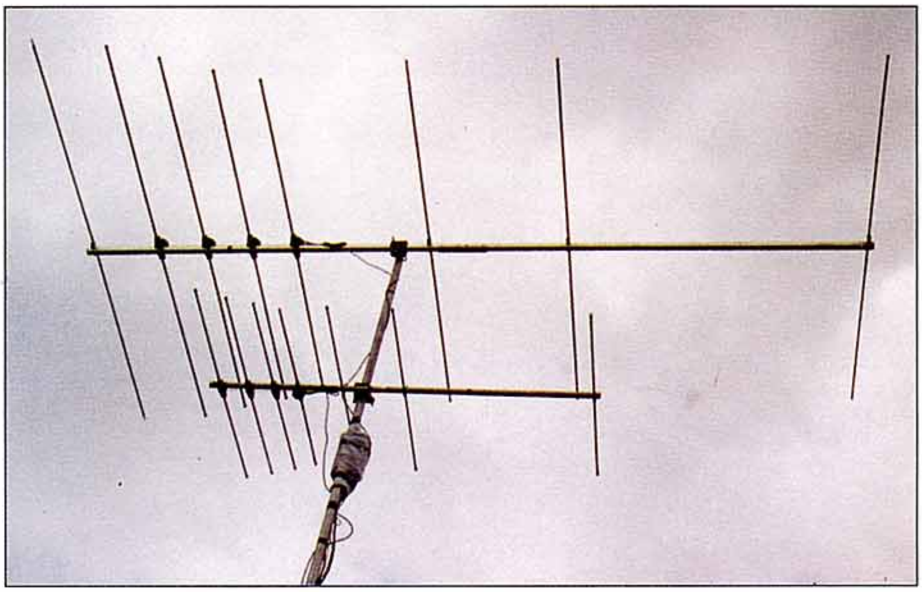
After many hours of work I figured out how the LPY can be adapted to other frequencies and other combinations of elements. Basically, the LPY is the amalgamation of two antenna systems which have complementary attributes, ie the log periodic and the yagi antennas.

THE LOG PERIODIC ANTENNA

THE LOG PERIODIC was designed to provide moderate gain but with a wide band width; six to eight elements can produce a gain of 4-5dBd over a 2:1 frequency range with an SWR better than 1.3:1 via a simple balun. Such an antenna has attractive features such as only one coax feed, driven elements connected via open line feeder and a gain better than many multi-band three element beams [2].

THE YAGI

THE YAGI PROVIDES high gain on a single band but the boom length becomes very large, the feed impedance becomes very low, the antenna becomes difficult to match and the more elements you use to get the high gain the more the polar diagram resembles the plan view of a hedgehog! Also, the SWR varies wildly over the design frequency band; the yagi is a narrow-band device. To obtain a gain of 9dBd on 50MHz you need a six-element yagi over 20ft (6m) long. On 70MHz it is over 14ft (4m) long.



LOG PERIODIC YAGI DESIGN

THE LOG PERIODIC YAGI design can be broken down into two parts: the log-periodic feed cell and the coupling of this feed cell to the yagi section. This arrangement results in both a high gain and efficient wide-band feed, all on a short boom, which gives lower wind resistance and greater strength than a yagi of similar gain.

Although a log periodic antenna can cover 50 – 70MHz using eight elements, only three to four elements are energised on each band, the others remaining passive.

With an LPY the single band log cell is optimized for maximum gain with the minimum number of elements.

To design an LPY for any frequency you require you have only to know how to operate an electronic calculator. All the design factors are given in this article.

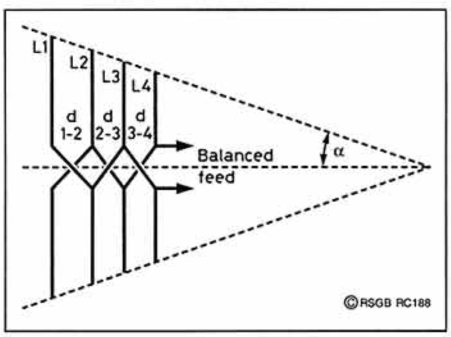


Fig 1: Basic log cell.

THE SINGLE-BAND LOG CELL

THE BASIC LOG CELL is illustrated in **Fig 1**. Certain design factors for a log cell need to be established.

Tau (τ) is a geometric constant smaller than 1, used to calculate the lengths of successive elements, L1, L2 etc and their spacing d1 – 2, d2 – 3, etc. If the lowest frequency for the log cell is f1, then the length of that element L1 is given by 492/f1 feet (150/f1 metres).

In the log cell, $L2 = \tau L1$, and $L3 = \tau L2$ etc. For a single band cell τ lies between the values of 0.85 and 0.94.

Rho (σ) is the relative spacing between elements. For single band log cells, σ lies between 0.05 and 0.06. From these values of τ and σ we can calculate other values for the log cell.

Alpha (α) is half the angle at the apex of the cell assembly. We need to know cotα to calculate other parameters for the log cell.

$$\cot\alpha = 4\sigma/(1 - \tau)$$

The spacing between cell elements is given by

$$d1 - 2 = \tfrac{1}{2}(L1 - L2)\cot\alpha \text{ and } d2 - 3 = \tau d1 - 2$$

It is useful to calculate the minimum number of elements which can be used to make a single band log cell for an LPY. The number of elements N is given by the formula:

$$N = 1 + (\text{Log } Bs/\text{Log}(1/\tau))$$

Bs is the structure bandwidth and is found from Bs = B x Bar where Bar is the array bandwidth, and B is the bandwidth required for the single band cell.

$$Bar = 1.1 + 7.7(1 - \tau)^2 \cot\alpha.$$

If we design our log cell with B = 1, ie for a single frequency, and we make $\tau = 0.9$, and $\sigma = 0.06$, then Bs = 1 x Bar.

$$\text{Now } Bar = 1.1 + 7.7(1 - 0.9)^2 \cot\alpha \text{ and}$$
$$\cot\alpha = 4 \times 0.06/(1 - 0.9) = 2.4.$$

$$\text{Therefore, } Bar = 1.1 + 7.7(1 - 0.9)^2 \times 2.4 = 1.2848, \text{ and } Bs = 1.2848.$$

The number of elements:

$$N = 1 + (\log 1.2848/\log(1/0.9)) = 1 + 2.38 = 3.38 \text{ elements.}$$

It would appear that the feed cell could be made with only three elements, but if the calculation gives an answer above 0.3 of an element, the result must be rounded up. In this case four elements are required for the basic log cell for a single band LPY. Optimum figures for a four element log cell are $\tau = 0.94$ and $\sigma = 0.06$, and this basic log cell gives a gain of 5.4dBd.

The gain increases with higher values of τ, or σ. This results in a longer boom to accommodate the extra elements. A modest increase of τ to 0.95 and σ to 0.08 increases the number of elements to six and the boom length increases by some 58%. The increase in gain however is only an extra 0.5dB.

THE LOG-PERIODIC YAGI

THE GAIN LIMITATION of the log cell can be overcome by marrying a log periodic to a yagi. Adding a director to the log cell does the same as adding a director to a dipole. If correctly spaced, and of the correct length, we increase the forward gain and lower the feed impedance of the array. The log cell provides a gain in its own right so putting a director in front of it will also increase the forward gain. From the available literature it appears that the addition of a single director increases the gain by at least 4dB.

Compare this to the gain realized when adding a single director to a two-element yagi. The approximate maximum figures quoted are 4.5dBd for the two element and 7dBd for a three-element yagi, an increase of 2.5dB [3].

So why is the LPY some 1.5dB better than a yagi? It is said to be due to the better illumination of the director by the log cell. There may be merit in using log cells with higher gain than my four elements but this has not been tried.

All directors are made of one continuous length for both strength and low resistance at the current maximum. They are cut and spaced as follows (except on 144MHz):

D1 is 0.45λ with 0.15λ spacing, and, if used,

D2 is 0.44λ with 0.15λ spacing and D3 is 0.43λ with 0.3λ spacing.

So the gain of the combined array is 5.36dBd from the log cell plus 4dB from a single director, a total of 9.36dBd; >2dB more than the best three-element yagi and yet the length is only 5ft 10in (1.78m) on 50MHz! The gains

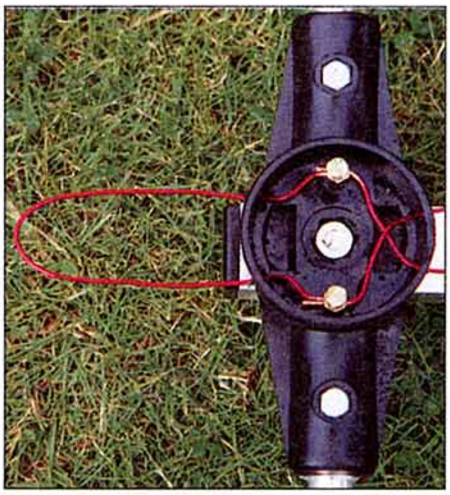


Photo 2: Connections in box L1. Shorting loop on 50MHz LPY shown.

from further directors are also impressive: D2 adds another 1.5dB, and D3 yet another 0.5dB [4].

The log cell has a 12 to 15dB front to back ratio. If you add a reflector, the F/B ratio is improved to a maximum of 25dB, but there is no measurable increase in forward gain.

As with a yagi, adding directors lowers the feed impedance but somewhat less dramatically. The feed impedance of a log cell is basically dependent on the construction and dimensions of the feed system and α. Impedance measurements indicate that an LPY is fairly broadband, unlike a yagi. The impedance is mainly resistive with very little reactance over the operating frequency.

THE LPY MATCHING SYSTEM

WITH DESIGN PARAMETERS of $\sigma = 0.055$ and $\tau = 0.94$, it has been found that, dependent on the characteristics of the open wire feedline, the feed impedance is between 200 and 300Ω for a multi-element LPY. Other σ and τ parameters seem to give impedances which are difficult to match. The feed impedance is only affected by director spacing if this spacing is close.

Most LPY designs rely for a match to coax cable on the use of very large diameter wires or tubes for the feed lines of the feed cell. I tried and found that they were difficult to assemble and were easily damaged. Also they needed to be supported and were not adjustable. On 50MHz the solution was to use 2mm diameter enamelled copper wire and to alter the spacing to control the impedance. These wires need no support, have never been damaged by wind (or birds!) and only

DIMENSIONS FOR THE 8-ELEMENT 70MHZ LPY

Log cell design frequency = 69.75MHz

L1 = 84.6in (2.15m)	d1-2 = 9.3in (236mm)
L2 = 79.5in (2.02m)	d2-3 = 8.8in (222mm)
L3 = 74.8in (1.90m)	d3-4 = 8.2in (209mm)
L4 = 70.3in (1.79m)	
D1 = 76.3in (1.94m)	s1 = 25.3in (641.m)
D2 = 74.3in (1.89m)	s2 = 25.3in (641.m)
D3 = 72.5in (1.84m)	s3 = 50.3in (1.28m)
Rfl = 86.5in(2.20m)	s4 = 14.3in (363mm)

Table 1a.

need straightening out if they have been bent in transit. For 70 and 144MHz LPYs, 1.6mm wire is recommended.

An adjustment range of the antenna feed impedance of 2:1 was achieved. It has been possible to adjust these feeders to a minimum of 1/8in (3mm) spacing without flash-over at 100W RF, even in the rain.

SAFETY NOTE:

Do not use more power than just sufficient to give FSD on the SWR meter when tuning for best SWR. Less than 1W is suggested.

Using a coaxial balun with a 4:1 impedance step-down, it was possible to obtain a 1.2:1 SWR using either 70 or 50Ω coaxial cable. That is a feedpoint impedance of 200 or 300Ω at the input of a seven or eight element 70 or 144MHz LPY.

The 50MHz five-element design with $\sigma = 0.05$ gives a feedpoint impedance of about 90Ω. The design works well with just the one director and the boom is only 6ft (1.83m) long.

THREE PRACTICAL LOG-PERIODIC YAGI DESIGNS

DETAILS ARE GIVEN of a 70MHz, eight-element and a 144MHz seven-element LPY with a calculated gains of 11.4dBd; and a 50MHz, five-element LPY with a calculated gain of 9dBd. All have been built, tested and used for some years and are of similar straightforward construction. The materials have been obtained from:

Sandpiper Communications, Aberdare, Glamorgan. 0685 870425.

TAR Communications, Stourbridge, West Midlands. 0384 390944.

MATERIALS FOR THE 70MHZ 8-ELEMENT LPY

Qty	Description
2	Boom, 1in (25.4mm) square-section, 6ft (1.83m) lengths
1	Boom coupling tube, 12in x 7/8in OD (305 x 22.2mm) and self-tapping screws
4	Insulated blocks, 1in square boom to ½in dipole fitting
8	Seamless tube, 3ft 6in x ½in OD (1.07m x 12.7mm)
2	Seamless tube, 6ft 6in x ½in OD (1.98m x 12.7mm) for D1 & D2
2	Seamless tube, 6ft 6in x 3/8in OD (1.98m x 9.5mm) for D3 and Rfl
2	Seamless tube, 6in x ¼in OD (152 x 6.3mm) secured in each end of reflector with a self-tapping screw.
4	Mounting clips, 1in square boom to ½in element
	5 UHF coax fitting with lightning arrester as illustrated in photo 5. As the feed elements are not earthed to the mast this is a safety precaution.
2	End caps for 1in square
2	End caps for 3/8in OD tubing.
12	End caps for ½in OD.
	12ft (3.66m) enamelled copper wire, 1.6mm dia.
	9ft (2.75m) UR47 coax for balun and feeder.

Table 1b.

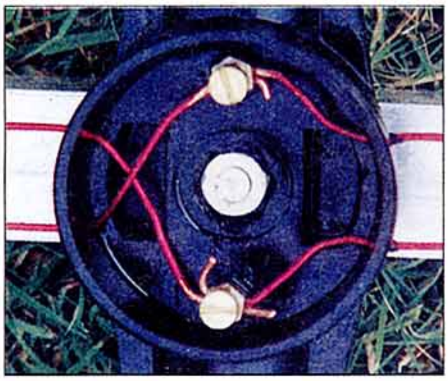


Photo 3: connections in boxes L2 and L3.

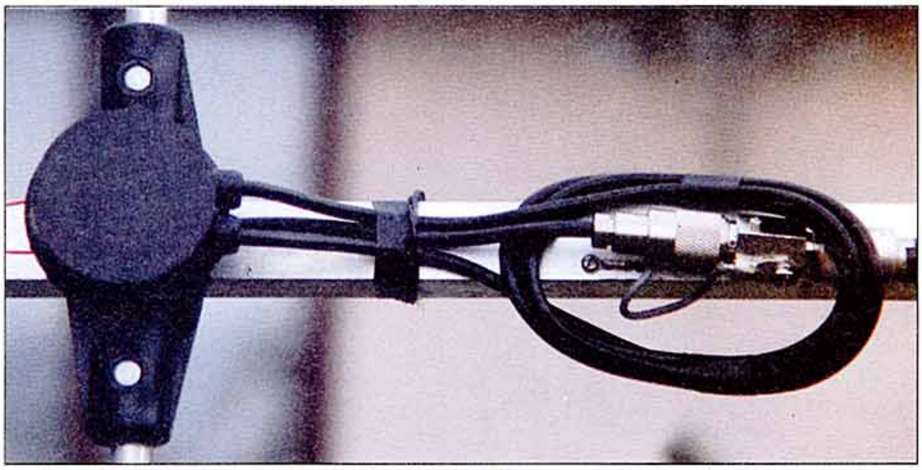


Photo 5: 4 to 1 coaxial balun and lightning arrester.

AN EIGHT-ELEMENT HIGH GAIN LPY FOR 70MHZ

THIS BEAM (**Fig 2, Photo 2, Tables 1a, 1b**) has been used for nearly four years, including VHF NFD 1991 and 1992 (first place in the low power section), and at home in Cumbria. Its all-up weight is below 7lb (about 3kg). The overall cost was under £50, using all new parts. The parameters are: τ = 0.94 and σ = 0.055 as recommended earlier. The log cell plus three wide-spaced directors and a close-spaced reflector on a 12ft (0.85λ) boom produce a calculated gain of 11.4dBd.

The feed impedance was measured to be about 300Ω. A 4:1 coaxial balun was used to give an unbalanced coax feed and the feedline spacing was then adjusted to give a 1:1.2 SWR at 70.2MHz using 50Ω coax. The beam was then raised to 22ft (6.70m) over sloping ground and tested using the GB3BUX beacon on 70.0MHz.

The F/B ratio was 25dB with a close-spaced (0.085λ) reflector and 12dB without the reflector. The side to front ratio was guessed to be over 30dB as the S9 signal from GB3BUX disappeared over a large angle off the side. The measured half-power (–3dB point) beam width was between 40 and 45°.

The gain of a beam can be calculated from the half power points (–3dB) in the following way:

$$\text{Gain (dBi)} = 10 \log (41253/\theta h \theta v)$$

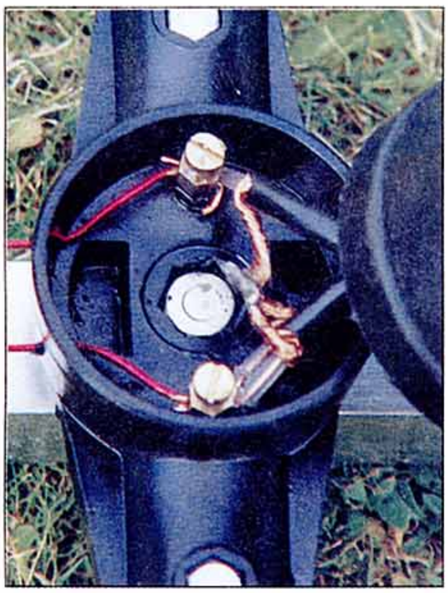


Photo 4: Connections in box L4 showing feedline, feeder and balun connections.

where θh and θv are the horizontal and vertical beam-width respectively. It was assumed that θh and θv were equal as the measurement was made over correctly sloping ground [5]. Therefore, the gain is between 13.1 and 14.1dBi, ie 11 to 12dBd. This is the closest correlation between calculated and measured gain I have ever seen.

It is thought that this beam is equivalent to a yagi over twice its size and constructed to the eight-element, NBS specification (1.75λ) boom.

Construction of the eight-element 70MHz LPY was as follows, (the construction of the other antennas is similar):

1. Join the two halves of the boom using a 1ft (30cm) length of 7/8in (22mm) OD tubing and self tapping screws.
2. Drill all the element locating holes in the boom.
3. Mount the four feed cell insulating boxes.
4. Drill two holes in the L1 and L4 insulating boxes and four holes in the L2 and L3 boxes, 3/4in (19mm) apart, for the 1.6mm wire feedline. The holes are best drilled from inside the boxes and will then have a slight downward angle to prevent water ingress (Photo 2).
5. Make sure that all the connecting posts in the insulating boxes are pulled down tight and are correctly aligned for the feedline connections.
6. Connect the enamelled copper wire feed line, making the crossover connections in boxes L1, L2 and L3; see **Photo 3**.
7. Connect the coaxial feeder in the L4 box; **Photo 4**. All outer braids will be soldered together but not earthed to the boom; see step 10 below and **Fig 3.**
8. Drill and fit the half elements L1, L2, L3 and L4 but make them all too long. Measure and mark elements L1 and L4, lay a straight edge between these marks and mark off L2 and L3. Cut elements to size. This ensures the correct taper of the log cell.
9. Make director and reflector elements and cut to length in situ. All directors and the reflector are of one continuous length, but the reflector has two 6in x ¼in OD (152 x 6.3mm) extensions, each fixed with a single self-tapping screw.
10. Make the 4:1 coaxial balun from exactly 55.5in (1.41m) of UR47 coax. The connections are as shown in Fig 3 and Photo 4 and **Photo 5** of the L4 connecting box. The balun is coiled up and strapped to the boom. The coax feed is via a UHF connector with lightning arrester

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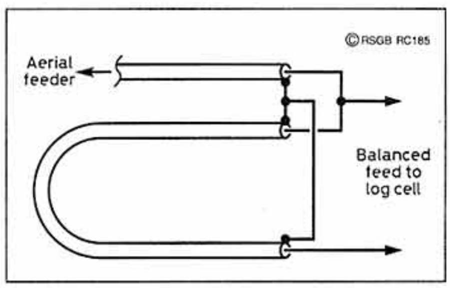

Fig 3: 4 to 1 coaxial balun, connections.

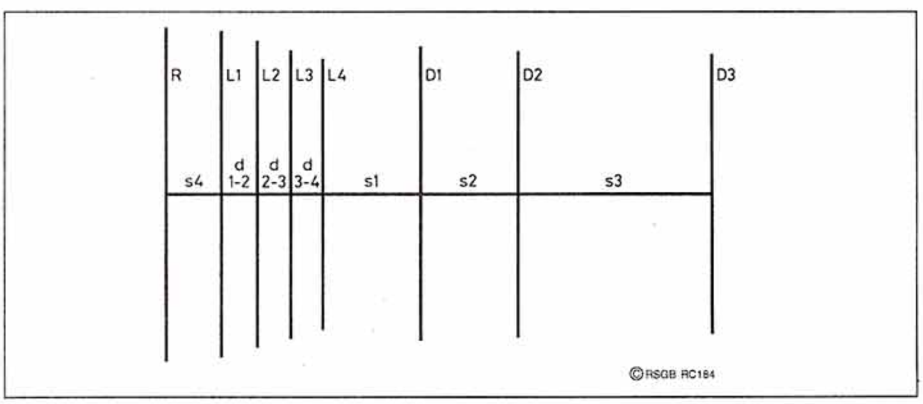

Fig 2: 70MHz 8-element LPY, dimensions.

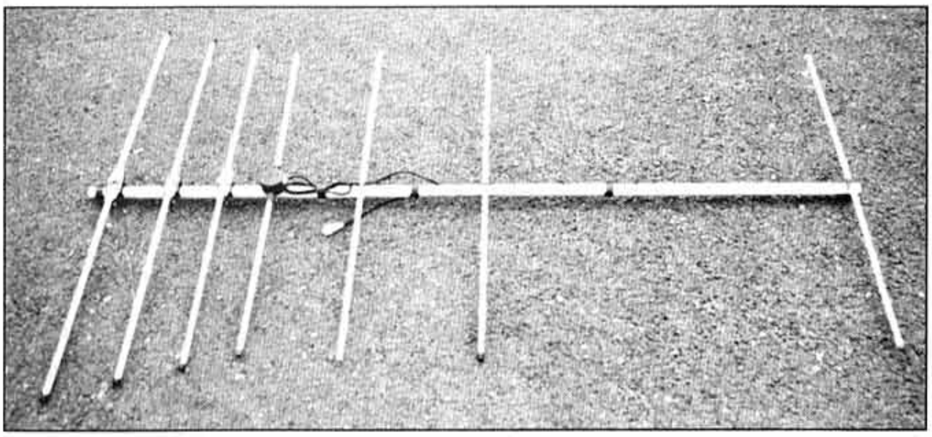

Photo 6: 50MHz 5-element LPY.

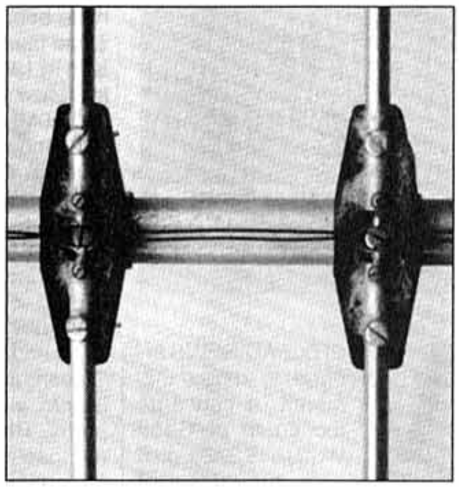

Photo 7: Close up of 144MHz log cell feedline.

DIMENSIONS FOR THE 50MHZ LPY FIG 4

L1 = 118.1in (3.00m)	d1-2 = 12.0in (305mm)	D1 = 108.3in (2.75m)
L2 = 111.1in (2.82m)	d2-3 = 11.3in (287mm)	s1 = 35.5in (902mm)
L3 = 104.8in (2.66m)	d3-4 = 10.6in (270mm)	L4 = 98.7in (2.51m)

Table 2.

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with its earth strap taken to a self-tapping screw into the boom.

On completion spray inside each dipole box with Finnigans Waxoyl (obtainable from Halfords) and refit lids.

THE ORIGINAL 50MHZ FIVE-ELEMENT LPY

THE CALCULATED GAIN was 9.36dBd using $\tau = 0.94$ and $\sigma = 0.05$. Total boom length was under 6ft (1.83m). See **Fig 4** and **Table 2**.

This antenna has been used for over four years both portable and at home. It stood up to very high winds and came through battered but in working order. I have worked all continents on 50MHz with it.

The feed to the log cell uses a short length of thin 70Ω coax wound in six turns on an RSGB ferrite core to form a choke balun. The coax ends are connected to the feed cell terminals.

The original was built with a 1in (25mm) OD round boom but a square boom, as in the eight-element 70MHz beam, could also be used. Construction for the log cell is as for the 70MHz LPY. Use 70Ω coax feeder. To improve the F/B ratio L1 is fitted with a 7in shorting loop (see Photo 2).

THE 144MHZ SEVEN-ELEMENT LPY

THE CALCULATED GAIN is 11.4dBd using $\tau = 0.94$ and $\sigma = 0.055$ and the boom length is 5ft (1.52m). This beam was designed for the low end of the 144MHz band. See **Fig 5**, **Photo 6** and **Tables 3a, 3b**.

The feed cell design frequency chosen was 141MHz to improve the F/B ratio to 15dB without the use of a reflector.

As on the 70MHz LPY, the feed cell feeder spacing was adjusted to give a SWR of 1.1:1 at 144.3MHz. At 145.5MHz the SWR was 1.5:1.

The connections to L1, L2 and L3 from the 1.6mm wire feeder are made using small solder tags attached to each element end by self tapping screws (**Photo 7**). All connections are soldered in situ.

ACKNOWLEDGMENTS

TO DR G M KING, G3MY, for all his help and encouragement and who inspired me to think that there must be something better than a Yagi. Also to Dr T H Wilmshurst, G3IBY, who gave me food for thought with his contribution to *Technical Topics* (Aug 1990) on the accurate measurement of 6m beam gain.

REFERENCES:

[1] *ARRL Antenna Book*, 1988, Chap.11 Figs 20 and 21 (see *Book Case* pages 94 and 95).

[2] *ARRL Antenna Book*, 1988, Chap.10

[3] *Yagi Antenna Design*, (Dr James L Lawson, W2PV), Chap 1, table 1.5

[4] 'LPY Gain' by Lea Johnson, *Ham Radio*, May 1983, pp78-82.

[5] 'Moxon Slopes', Les Moxon, G6XN, *RadCom*, June 1988.

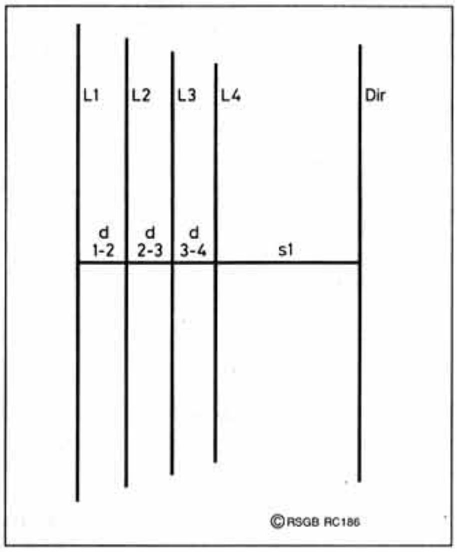

Fig 4: 50MHz five-element LPY, dimensions.

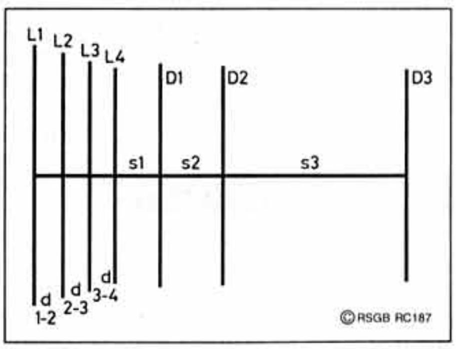

Fig 5: 144MHz seven-element LPY, dimensions.

DIMENSIONS FOR THE 144MHZ LPY

L1 = 41.9in (1064mm)	d1-2 = 4.6in (117mm)
L2 = 39.4in (1000mm)	d2-3 = 4.3in (110mm)
L3 = 37.0in (939mm)	d3-4 = 4.1in (104mm)
L4 = 34.7in (881mm)	
D1 = 35.9in (912mm)	sl = 7.3in (185mm)
D2 = 35.3in (895mm)	s2 = 10.0in (254mm)
D3 = 34.1in (866mm)	s3 = 29.5in (749mm)

Table 3a.

MATERIALS FOR THE 144MHZ 7-ELEMENT LPY

Qty	Description
1	Boom, 5ft (1.52m) x 1in OD tubing. Do not substitute a square boom.
3	open 1in boom to 3/8in dipole fittings
1	connecting box, 1in boom to 3/8in dipole fitting
3	1in boom to 3/8in ele mounting clamps
1	3ft enamelled copper wire, 1.6mm dia
1	27in (686mm) (exact length) UR47 coax for balun.

All elements: 3/8in (9.5mm) OD seamless tubing

Table 3b.