# A STUDY OF A PRINTED LOG-PERIODIC ANTENNA

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## SUMMARY
This paper describes investigations into the current distributions on a log periodic dipole antenna (LPDA) which was constructed on printed circuit board. The investigations involved measuring the magnetic field magnitude and phase at each point on the antenna. The wave nature of the current distribution could be readily observed and problems with the design such as standing waves on the feeder lines are highlighted for attention in a revised design. Measured current distributions are compared with predicted distributions obtained from Method of Moments (MoM) and Multiple Multipole (MMP) analyses of the LPDA structure. Measured and predicted far field radiation patterns are also compared.

## 1. INTRODUCTION
Log periodic dipoles are a common, linearly polarised, broadband type of antenna. The LPDA designed and constructed for this study was made using printed circuit technology. The use of the printed circuit board to support the radiating elements and to separate the two strips forming the parallel wire transmission feeder line created a mixed dielectric environment which modified the current distribution, the impedance and radiation patterns of the LPDA compared to those that would exist for a wire LPDA operating at the same frequencies in a free space environment. The study examines these differences and the ability of the available numerical analysis techniques could predict these differences.

The current distributions on the printed antenna were studied experimentally by scanning a probe to measure the magnetic field of the antenna at the surface of its radiating elements.

## 2. DESIGN AND CONSTRUCTION OF THE LPDA
The design principles of the LPDA are well established [1, 2]. The LPDA (as shown in Figure 1.) is an array of dipoles connected to a common transmission line fed from the apex of the array.

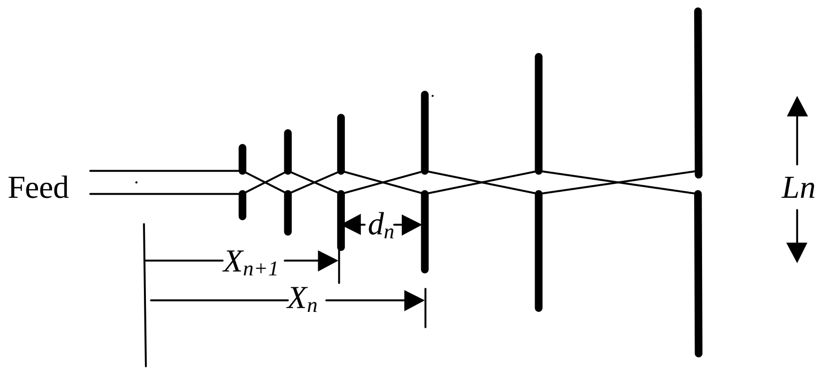



**Figure 1. A typical LPDA**

The transmission line from the feed must alternate which side of the line connects to which side of the dipole in order to get the correct phasing to create an antenna that radiates in the direction of the array apex. The transmission line consisted of two strip conductors, one on either side of the board. By putting one half of each dipole on either side of the board and connecting it to the transmission line strip, and alternating which half dipole went on which side of the board, the alternating feed connection was obtained (see Figure 2).

Fibre-glass board ($\varepsilon_r$ = 4.5) 1/16 inch thick was used to construct the LPDA. The required frequency range of the LPDA was 900 MHz to 3GHz which meant that the dipole elements, based on a free space wavelength could easily be accommodated on the 200 mm by 300 mm printed circuit board used.

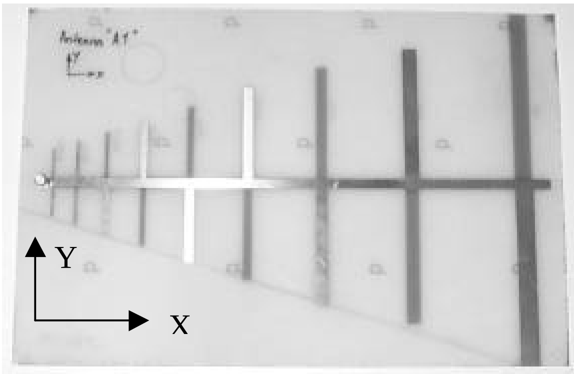



**Figure 2 The LPDA studied**

## 3. MAGNETIC FIELD DISTRIBUTION MEASUREMENTS

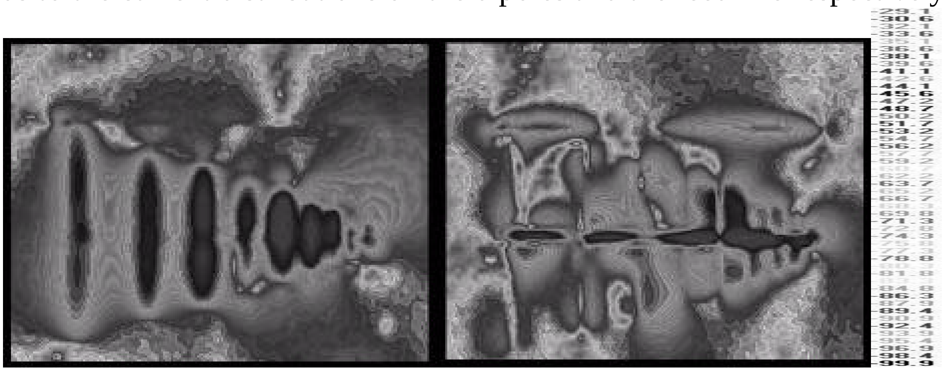
The magnetic field distribution on the LPDA was measured with the aid of a magnetic probe (a 1 cm. diameter shielded loop antenna), a coordinate table and a Vector Network Analyzer (VNA). The loop antenna was positioned close to the upper surface of the printed antenna and moved stepwise in a rectangular grid pattern. Because the coordinate table surface formed a metallic ground plane, the probe was attached to an extension arrangement making it possible to scan the antenna to the side of the table (see Figure 3). This arrangement reduced the influence of the ground plane.

**Figure 3. Scanning the LPDA using the coordinate table.**

The LPDA was connected to port 1 of the VNA, the loop antenna was connected to port 2 and the LPDA was excited with a CW signal. S21 was measured as the loop antenna was scanned in a raster pattern over the surface of the antenna with the loop being polarised to pick up either X or Y directed magnetic field. In Figure 3 the probe is polarized to be sensitive to currents along the dipole. Rotating the loop ninety degrees about the vertical axis enabled the probe to respond to currents on the transmission line joining the dipoles.

GPIB instruction files controlled the scanning table and the VNA making the entire measurement procedure automatic. At each positional step the magnitude or phase of the signal transmission from the antenna to the probe was measured. Two measurement scans per polarisation were necessary to obtain both magnitude and phase information (due to limitations in the control software). The procedure was repeated for each of the X and Y polarisations of the magnetic field and at each measurement frequency.

Figure 4 shows a two dimensional contour plot of the X and Y directed components of the surface magnetic field at 1132 MHz. Dark areas surround the strongest fields. This corresponds to the current distributions on the dipoles and the feed line respectively.



**The measured magnitude of magnetic field at 1.132 GHz**

**Figure 4(a) X Polarised** **Figure 4(b) Y Polarised**

## 4. METHOD OF MOMENTS MODELLING OF THE LPDA

MoM modelling of a wire LPDA in free space is straightforward but this technique does not easily handle mixed dielectrics (air and PC board substrate). In this antenna the current distributions on the dipoles are dependent on the near fields that exist in the mixed dielectric environment. An effective uniform dielectric constant was used with the MOM program to represent this mixed dielectric environment in order to calculate the current distributions. The value for this effective dielectric constant was determined from the magnetic scanning of the LPDA by observing which dipoles of what length went resonant at which frequency. This gave a value of $e_r = 1.84$

The current distributions determined by MoM analysis using this value for the effective dielectric constant were then used to calculate the radiation patterns assuming $e_r = 1.0$ (as the radiation takes place principally in free space). The match between the measured and predicted radiation patterns is shown in Figure 7.

## 5. MULTIPLE MULTIPOLE MODELLING COMPARED WITH METHOD OF MOMENTS

A Multiple Multipole analysis[3] package was used to better account for the effect of the dielectric board on the near field and far field distributions. The work done so far using this code shows that the dielectric board can be included in the model and the magnetic near field components can be derived. In Figure 5 the X-component of the magnetic field on the LPDA is shown when element 6 (from the left) is driven by a 1.4 GHz source.

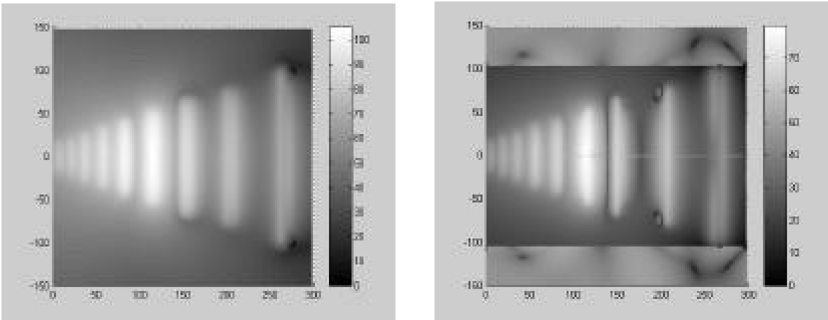


**Figure 5 Magnetic near field calculations using MMP.**
**LPDA elements without dielectric board (left) and with the board present (right).**

The X-component of the magnetic field over the antenna elements is mainly due to the current in that element and so can be used to determine the relative current magnitudes in each element. MMP analysis of the LPDA without the dielectric was used to determine the relative currents in each element. A comparison was then made of the corresponding normalised currents with those determined by the MOM analysis of the same LPDA.

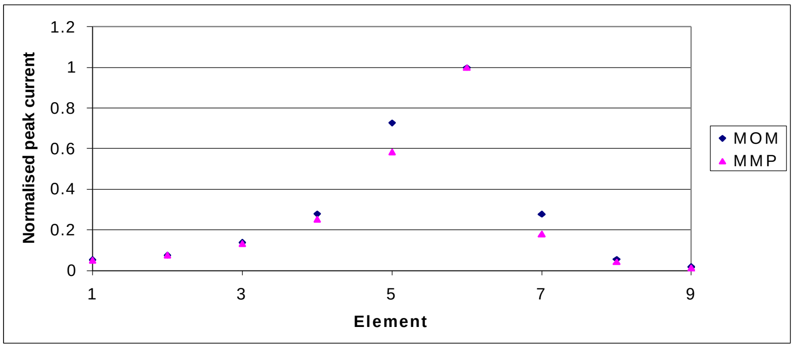



**Figure 6 A comparison was made of normalised peak currents on the antenna elements from the MOM and from the MMP analysis.**

This comparison gives us confidence that the MMP code may also give accurate results when the dielectric board is included in the model.

## 6. COMPARISON OF MEASURED AND PREDICTED RESULTS

### 6.1 Far Field Azimuth and Elevation Radiation Patterns

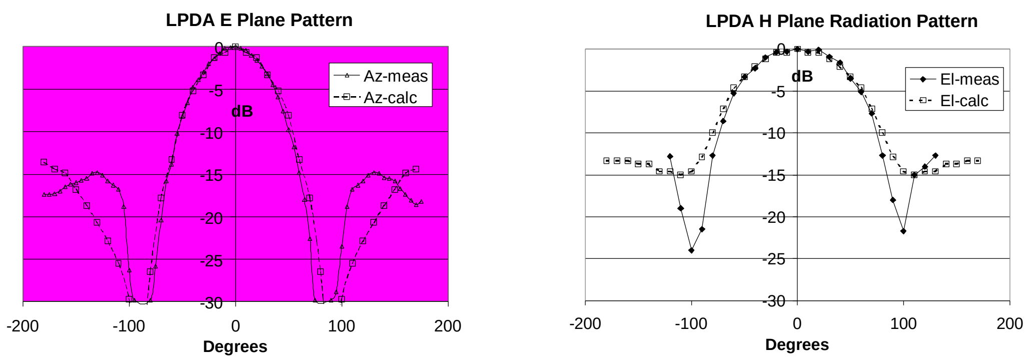



**Figure 7 E Plane and H Plane radiation patterns of the LPDA at 1132 MHz**

The computed and measured E plane and H plane radiation patterns of the LPDA are shown in Figure 7. There is good agreement between them for the main lobe of the pattern but some variance is seen between the back lobes. Differences between the actual current distribution and that derived from the MOM analysis must be resolved to improve this back lobe match.

### 6.2 Current Distribution on the Dipole Elements

The measured and MoM predicted currents on the individual dipoles are shown in Figure 8. The currents are plotted normalised and in dB as the surface magnetic fields were measured in relative levels expressed in dB.

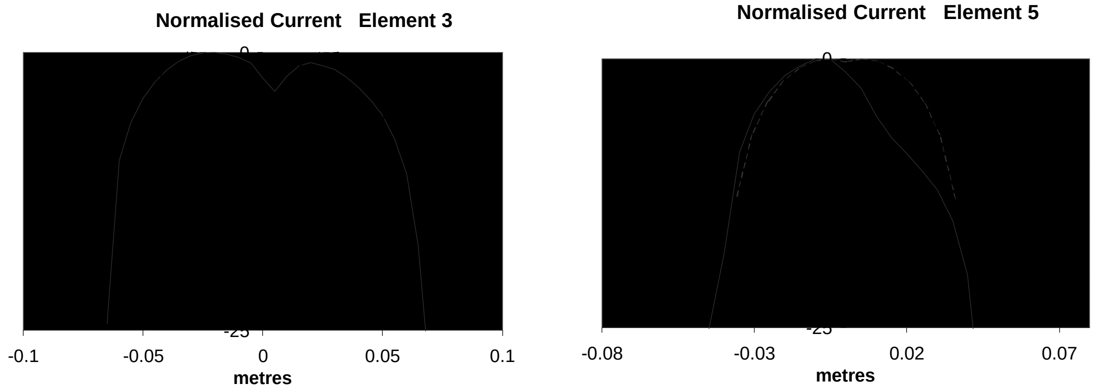



**Figure 8**
**Current distributions on two of the dipole elements (Solid-measured, broken-predicted)**

The shapes of the current distributions match except for an asymmetry in them which is assumed to be due to the presence of the co-ordinate table (see Figure 3). Some of the absolute levels of the individual dipole currents do not correspond well. This may be due to a non-proportional relationship between the magnetic field strength (measured with a finite sized loop antenna just above conductors of varying width) and the total current on that conductor. It is expected that ongoing investigations with scanning by a smaller loop antenna passed closer to the surface of the antenna and analysis with other numerical methods such as MMP will reveal the reason for this mismatch.

## 7. CONCLUSIONS

Magnetic scanning of the LPDA and MoM and MMP analysis packages has been used in order to get an understanding of the LPDA operation and its current distributions. The ability of the MMP method to overcome the limitations of the MoM and directly handle the mixed dielectrics used in the printed LPDA will be utilised in further studies of this antenna.

## 8. REFERENCES

1. R. C. Johnson and H. Jasik, *Antenna Engineering Handbook*, McGraw-Hill, 2nd Ed.,1984.
2. W. L. Stutzman and G. A. Thiele, *Antenna Theory and Design,* John Wiley and Sons, 2nd Ed.
3. R. Y. Tay and N. Kuster, *Performance of the Generalized Multipole Technique (GMT/MMP) in Antenna Design and Optimization,* ACES Journal, Dec 94