Version 05: amended on 30 March 2006

ANNEX TO NPL CERTIFICATE FOR LOG-PERIODIC DIPOLE ARRAY ANTENNAS

Antenna Factor

The antenna factors are valid for any separation distance from the source exceeding one wavelength. For distances less than 10 m, the change in antenna factor with distance becomes significant when a fixed reference point on the antenna is assumed, and additional uncertainty would therefore be introduced. This is expanded in the section on Phase Centre.

Where there is a sharp resonance in the antenna factor the uncertainty given in the certificate does not apply. At the frequency where the resonance causes a deviation of greater than 1 dB from the overall trend of the data, the magnitude of the increased uncertainty can be estimated from the height of the spike on the antenna factor graph. The affected range can be taken as ± 1.5 % of the centre frequency. Because the data is sampled at discrete points the maximum error may be much larger than that shown in the antenna factor graph.

If the antenna is used horizontally polarised during a height scan from 1 m to 4 m above a ground plane, the antenna factors may differ from the values quoted by up to ± 0.5 dB. This is because the input impedance of the antenna changes due to coupling with its image in the ground plane. This coupling is greatest at the lower frequencies where the wavelength is a larger fraction of the height above the ground plane. When the antenna is used vertically polarised, there is no significant coupling with the ground plane, but the cable should extend horizontally behind the antenna for at least 2 m before dropping to ground in order to minimise parasitic reflections, particularly at the lowest frequency of operation of the antenna.

If the antenna is used in an unlined screened room the use of these antenna factors may not give the absolute value of field strengths, but a calibration provides an essential check that the antenna is working properly. The antenna factors can be used to compare measurements made in an identical setup using a different antenna of the same type.

There is a further error arising from the directive nature of the antenna radiation, which is greater at the higher frequencies. In a normal height scan up to 4 m, on a 10 m range, the signal maximum can be reduced by up to 0.5 dB compared with that for a uniform radiation pattern. For a 3 m range this error could be up to 2 dB (given that the signal maximum is normally achieved at a height of less than 2.5 m).

The majority of LPDA (log-periodic dipole array) antennas have elements in echelon, which causes sensitivity to cross-polarised fields. At the higher end of the operating frequency range of the antenna the elements are short and the step between each half of one dipole element is pronounced. In the extreme case this can cause greater sensitivity to cross-polarised fields than co-polarised fields. The uncertainty in the antenna factor in the certificate may have been increased to reflect poor cross-polar rejection of the LPDA.

Phase Centre

When a LPDA is receiving E-field radiation the phase centre is the active part of the antenna at any given frequency. The active part of the antenna corresponds approximately to the position of the element whose length is equal to that of the equivalent resonant half wave dipole for the received frequency.

The quoted uncertainty in antenna factor is only valid when the phase centre is placed at the point at which the field is required to be measured. If the antenna position is not adjusted with frequency to make this condition true, a correction should be made to the measured field (at the phase centre position). This is valid in free-space conditions but there is additional uncertainty when applied to a LPDA above a ground plane. For distances of greater than one wavelength from the antenna a reduction of the field proportional to the inverse of the distance can be assumed, which means that in an anechoic environment a linear extrapolation may be used to adjust the field strength. The adjustment of antenna factor to a fixed reference point on the antenna is described later in the annex. For measurements made over a ground plane this correction has to be calculated using the difference in E_{Dmax} [3].

The NPL certificate contains an expression which allows the phase centre at any frequency to be calculated. This approximation is derived from some equations which govern LPDA antennas with triangular profiles (i.e. where the element tips form a straight line). Hence larger errors in the predicted phase centre will occur when these expressions are used for tapered antennas. The values for the constants, which are given in the NPL certificate are derived from the following equations :-

$$\delta = \frac{X_L \cdot L_H - X_H \cdot L_L}{L_L - L_H} \qquad Tan\alpha = \frac{L_L}{2 * (X_L + \delta)}$$

$$X_F = \frac{71.2}{Tan\alpha} \cdot \frac{1}{F_{MHz}} - \delta$$

Where:

L_L and L_H =	The lengths of two well spaced elements which reside towards the Low and High frequency ends of the LPDA respectively.
X_L and X_H =	The distance from the tip to the same two elements.

If the above corrections are not feasible then an alternative strategy is available. This method, which may be applied in an anechoic chamber or near signal maxima during a height scan, uses a fixed phase centre, whose position is chosen in order to weight the incurred error evenly at either end of the operating frequency band. The fixed phase centre, X_{FIX}, is given by :-

$$X_{FIX} = \frac{1}{2} \cdot [X_{LOW} + X_{HIGH}]$$

The error incurred, U_E, at either end of the operating band is given by :-

$$U_E = \pm 20 * Log_{10}\left\{ \frac{R - \left[\frac{X_{LOW} - X_{HIGH}}{2} \right]}{R} \right\}$$

Where :- X_{LOW} = The phase centre of the low frequency operating limit.
X_{HIGH} = The phase centre of the high frequency operating limit.
R = The required separation to the EUT (i.e. 10 m or 3 m).

For most common LPDA designs the calculated fixed phase centre (X_{FIX}) will be approximately half way between the actual tip of the antenna and the longest element. Thus, for simplicity, the reference point is often obtained by halving the distance from the tip to the back element.

Return Loss

The antenna factors quoted apply when the mismatch between the antenna and the receiver is attenuated. A well matched 6 dB attenuator is recommended. For example, if no attenuator is used and the receiver front-end attenuation is set to zero, the antenna factor can change by typically ± 0.3 dB, assuming a receiver return loss of greater than 14 dB, an antenna return loss of 10 dB and a cable loss of 3 dB.

Adjusted Antenna Factor

For LPDA antennas it is possible to calculate (A), the result of an ARP958 1 m measurement rather than actually perform the measurement. We can do this because the LPDAs are in the far-field of each other. This calculated value does not take account of the small amount of coupling between the antennas which would occur during an actual ARP958 measurement, but this effect is included in the stated uncertainty.

We can also calculate (B), an adjustment to the antenna factor, which extrapolates the field measured at the phase centre of the antenna to a defined reference point. The separation to the EUT has to be specified and the reference point on the LPDA is often at the tip. This type of adjustment is not quite the same as the first type, but roughly similar results are generated (using a 1 m EUT to LPDA separation, and setting the reference point at the tip). However, for large LPDA antennas the difference between the two adjustments can be in the region of 1 dB.

The adjusted antenna factor is commonly given for 3 m and 10 m separation, measured from the marked reference position or the mechanical centre of the antenna. If these 3 m and 10 m antenna factors are used for measurements other than at 3 m and 10 m respectively, the uncertainty will be larger than if the free space antenna factors are used, with correction for phase centre. The latter can be used for any distance exceeding two wavelengths without the need to increase uncertainty.

A ARP958 calculation

$$AF_{1m} = AF_{FS} + 10 * Log_{10}\left[\frac{R + (2 * X_F)}{R}\right]$$

B Reference point adjustment

$$AF_{REF} = AF_{FS} + 20 * Log_{10}\left[\frac{R + X_F - X_{REF}}{R}\right]$$

Where :-

AF_{1m} = ARP958 antenna factor, usually with R = 1 m.
AF_{FS} = Measured free space antenna factor.
AF_{REF} = Antenna factor referenced to defined point on LPDA.
R = Separation either from tip to tip (A) or from EUT to reference point on LPDA (B).
X_F = Position of phase centre from LPDA tip.
X_{REF} = Position of defined reference point from LPDA tip.

Note

For R = 1 m and X_{REF} = 0 m, both expressions give similar answers for small values of X_F.

Use of ARP958 Antenna Factor

Measurement at 1 m distance from an emitter is called for in MIL-STD-461D[1], which stipulates that procedure ARP958[2] is to be used for 1 m calibrations. It is necessary to distinguish between AF_{1m} and conventional AF which enables absolute E-field strength to be obtained from the voltage output of the antenna. ARP958 describes AF_{1m} as "apparent" antenna factor because it is derived from equations which do not take phase centre into account. When AF_{1m} is used to measure absolute field strength (at position of the active element at the frequency of measurement, ie the phase centre) an additional uncertainty term of ± 4 dB must be included at 200 MHz, and this diminishes to ± 0.5 dB at 1 GHz. This is because AF_{1m} extrapolates the field strength from the position it is measured by the active element, to a distance of 1 m from the emitter. The extrapolation assumes a fall off in field inversely proportional to distance and does not take into account an imperfect measurement environment, such as a partially lined screened room, in which the field may not fall off linearly with distance.

ANSI Height Scan Method

The ANSI C63.5[3] procedure describes how the antenna factor may be measured over a ground plane by a height scanning three antenna method. For each measurement pair, one antenna is at a fixed height and polarisation, and the other is height scanned. The receiver is set to record the maximum measured signal during the scan. In the three pairings each antenna is measured twice, and if the customer supplies two antennas then one of the antennas is always allocated to the height scanning mount, and the other to the fixed mount. An NPL antenna is used for the third antenna which height scans for one pair and is fixed for the other pair. If the customer supplies one antenna it will be placed at the fixed height.

Where standards call for an ANSI calibration (e.g. for NSA measurements), NPL recommends the use of free-space antenna factors for measurements at 10 m separation because they agree well with 10 m ANSI antenna factors. However, at 3 m separation the ANSI antenna factors differ significantly from the free-space values, so for an emission measurement made by height scanning the uncertainties may be less using the ANSI 3 m AFs. Where the NSA of a 3 m site is being measured by the NSA method described in ANSI C63.4:1992 and CISPR 16-1:1999, [4], the ANSI 3 m AFs should be used for best results (the ANSI method ignores near-field terms, but this cancels out if the AFs and NSA are both calculated using the formulas given in the ANSI standards).

References

[1] MIL-STD-461D, Requirements for the control of electromagnetic interference emissions and susceptibility, 1993, Department of Defence, USA.

[2] SAE ARP958:1992, Electromagnetic interference measurement antennas; standard calibration method. Society of Automotive Engineers.

[3] ANSI C63.5-1998, American National Standard: Calibration of antennas used for radiation emission measurements in Electromagnetic Interference (EMI) control.

[4] CISPR 16-1:1999, CISPR publication 16. Specification for radio disturbance and immunity measuring apparatus and methods, Part 1:1999 Apparatus, Central office of the IEC, 3 rue de Varembé, Geneva, Switzerland.