ANNEX TO NPL CERTIFICATE FOR CONICAL LOG SPIRAL ANTENNAS

Antenna Factor

Where there is a sharp resonance in the antenna factor, at the bottom end of the frequency range, 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 resonance on the antenna factor graph.

If the antenna is used on an open field site in the height scan range 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 height above the ground plane is a larger fraction of one wavelength. The cable should extend horizontally behind the antenna for at least 2 m before dropping to ground in order to minimise parasitic reflections.

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.

The antenna factors are valid for any separation distance from the source exceeding one wavelength. For shorter distances the change in antenna factor with distance becomes significant and additional uncertainty would therefore be introduced.

Measurement of linearly polarised fields

Conical log spiral antennas are intended to measure circularly polarised fields with the same hand of polarisation as the spiral. If the field is known to be linearly polarised, the antenna factor must be increased by 3 dB in order to give the magnitude of the field. The uncertainty may need to be increased if the ellipticity of the spiral deviates from perfect circular.

Phase Centre

When a conical log spiral is receiving E-field radiation the phase centre is the active part of the antenna at any given 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, then a correction should be made to the measured field (at the phase centre position) in order to give the field at the required point. 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

The NPL certificate contains an expression which allows the approximate phase centre at any frequency to be calculated. The values for the constants, which are given in the NPL certificate are derived from the following equations :-

$$Z = \frac{Y \cdot L_H}{L_L - L_H} \qquad \mathrm{Cos}(\alpha) = \sqrt{1 - \left(\frac{L_L - L_H}{2 * Y}\right)^2}$$

$$X_F = \left\{\frac{(Y + Z) \cdot LF_{MHz}}{F_{MHz}} - Z\right\} \mathrm{Cos}(\alpha)$$

Where :- L_L and L_H = The diameters of the Low and High frequency (large and small respectively) ends of the spiral.
Y = The length of the spiral along the sloping edge.
LF_{MHz} = The specified low frequency limit of the antenna

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 ± 0.4 dB, assuming a receiver return loss of greater than 14 dB.

Adjusted Antenna Factor

For spiral antennas it is possible to calculate the result of an ARP958 1 m measurement rather than actually perform the measurement. We can do this because the conical log spiral antennas (CLSA) 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 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 CLSA 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 CLSA separation, and setting the reference point at the tip). However, for CLSA antennas operating down to 100 MHz, the difference between the two adjustments can be in the region of 1 dB.

A ARP958 calculation

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

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 CLSA.
R = Separation either from tip to tip (A), or from EUT to reference point on antenna (B).
X_F = Position of phase centre from antenna tip.
X_{REF} = Position of defined reference point from antenna tip.

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.

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 AF1m and conventional AF which enables absolute E-field strength to be obtained from the voltage output of the antenna. ARP958 describes AF1m as "apparent" antenna factor because it is derived from equations which do not take phase centre into account. When AF1m 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 AF1m 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.

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.