Sidelobe level correction for parabolic
antennas radiation pattern measurements in

SIDELOBE LEVEL CORRECTION FOR PARABOLIC ANTENNAS RADIATION PATTERN MEASUREMENTS IN QUASI-FAR FIELD CONDITIONS

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A method and formulas for correction of the sidelobe level of the radiation pattern of high gain antenna when measured in the Fresnel region is presented. After a thorough analysis of a large number of different cases, trend curves have been computed and an empirical formula has been derived, which allows the correction of the measured values of the sidelobes when the effect of the phase error is significant.

Introduction: It is commonly known that antenna far field measurements require that the separation between the antenna under test (AUT) and the source/probe antenna (SRC) fulfills the condition

$$R > 2(D_t^2 + D_s^2)/\lambda \tag{1}$$

Where D_s and D_t are the (maximum) diameters of the SRC and AUT, respectively. For large AUTs, when D_t is significantly larger than D_s, equation (1) is usually approximated with

$$R > 2D_t^2/\lambda = R_F \tag{2}$$

and R_F is called the "Fraunhofer (or "Far Field") distance".

However this general rule has different validity depending on the quantity to be measured. In fact, the field variation on the axis maintains its dependence on the distance very near to $1/R$ also for R significantly less than R_F, so that the gain measured at distances somewhat less than R_F (e.g. down to 0.5) is affected by a small error (few tenths of dB) with respect to the Far Field condition and beyond. Conversely, the sidelobes level, in particular the first, may be affected by non negligible errors also when R fulfills conditions (1-2), or even if it is larger, especially when sidelobes are low. In [1] it was shown that a first sidelobe level of -30 dB rises to -28 dB when measured at R_F: to have a smaller error (e.g. 0.2 dB) the condition $R > 2R_F$ should be fulfilled. Note that the measured sidelobe level at reduced distances is always higher than in Far Field, so that the actual level of the sidelobes is always lower than the measured one.

The increasing demand, in recent years, for high data rate communications has led to a further development of satellite connections with new VSATs in various bands (from Ku to Ka) and new services (Tooway, Ka-sat, etc.) in areas not easily serviceable by terrestrial Wi-Fi or wired links. Consequently a new market is open for reflector antenna manufacturers, with new requirements for testing, considering that the radiation patterns must comply with relatively severe constraints on sidelobe level envelope and cross polarization (ETSI, FCC).

In general, pattern measurements for antennas of this type may be carried out in Far Field (FF) or Near Field (NF) conditions, and Near Field ranges may use either Compact Ranges or Near Field - Far Field transformations. However these latter methods require usually the acquisition of all data and the subsequent transformation to far field. Among the various scan possibilities (planar, spherical, cylindrical) the spherical one seems preferable because the results cover the whole sphere, while the planar one doesn't cover the back space, and the cylindrical one omits part of the side regions. However, if the antenna testing is also aimed to an improvement of the antenna performances by successive trials (e.g. by adjusting the feed position and angles) the NF testing may require a too long time: in this case a FF measurement can have advantages, because it doesn't require the complete scan of the antenna and subsequent processing, which may take many hours. For this type of antennas FF measurements are therefore preferable, on long (outdoor) ranges, of the order of about 100-200 m or more: but ranges of this size are not always available, especially in densely populated regions, so that the FF distance is not always attained, and the probe/source is in the Fresnel zone of the antenna under test.

This problem obviously is not new: one possible method for a correct measurement is to compensate the phase error by axially refocusing the feed [2]. However this is not so simple, in particular for offset reflectors, also because it implies modifications in the antenna feed structure and it is not easily applicable to final production samples.

Also the analysis or the radiation in the Fresnel zone has been a subject of several old and more recent studies ([3], [4], [5]) that have found methods of computing the field in the Fresnel region: an example of such patterns, for various values of the distance R, is shown in Fig.1, where an unblocked circular aperture is assumed, with illumination of the type "square parabola on pedestal", edge taper -9.1 dB: at R_F the first SLL increases by 1 dB with respect to an infinite distance, and by about another 1 dB if the distance is reduced to $0.7R_F$.

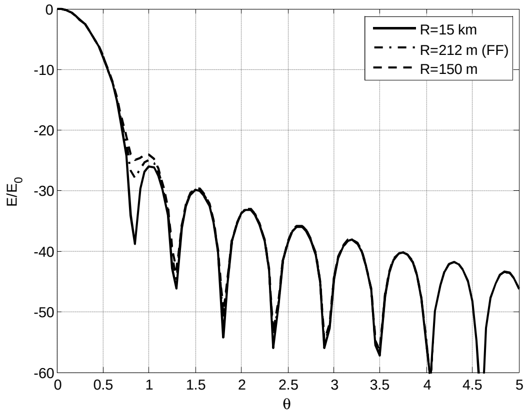

Fig. 1 *Circular aperture radiation patterns in Fresnel zone. Here $D = 1.03$ m, f=30 GHz, edge taper 9.1 dB.*

For the numerical compensation of the effect of the short distance, different correction methods have been proposed, e.g. in [6] and [7], but they require the knowledge of the field in amplitude and phase, and cannot be used in long outdoor ranges, especially because the phase (even if it is measured) suffers some jitter due to the propagation effects.

In this paper we will use a simpler approach, by determining, on the basis of simulations and measurements, and on a statistical analysis, the correction to be given to the first sidelobe (the most sensitive to the range reduction) and also (although less significant) to the second one, to obtain their correct level at far field. In fact, for the verification of the compliance of a reflector antenna to the sidelobe specification, only the knowledge of their peaks is necessary.

In this context a detailed analysis of Fresnel region fields of aperture antennas becomes very important to predict the error produced by the reduced range on the measured side lobe level as compared to the ideal side lobe level in FF. Some previous work on this subject exists, as e.g. [8], which however assumes ideal analytical aperture distributions, while in this work more realistic configurations have been considered.

Radiation pattern distortion analysis: In order to quantify the error on the first SLL and consequently the correction to be given, a very large number (a few hundreds) of simulations have been carried out, for aperture diameters normalized to λ and ranges normalized to the FF distance,for different types of aperture distribution and edge taper, both theoretical and derived by actual feeds, considering in particular the level of the first sidelobes, the most critical in fulfilling antenna specifications. For all different cases, in particular the first and second sidelobe levels have been compared with the ideal ones in FF, in order to compute the level differences for each case.

These differences have been plotted in dispersion diagrams vs. the sidelobe level using the distance as a parameter; the presence of blocking was also considered, for various values of the blocking ratio (from 0.6 to 0.10), to generalize the analysis to center-fed reflectors. Data points were picked for peak values wherever explicitly visible, otherwise levels at angles corresponding to ideal peak values at far field have been selected.

Actually, the results show that the error is significant for the first sidelobe only, while for the second and the others it is practically negligible in most cases, as it can also be seen in Fig.(1).

In Fig.2 two examples are shown of such dispersion curves, for $R/R_F = 1$ and $R/R_F = 0.59$, for the first sidelobe: here, as in all other cases, it can be seen that the statistical distribution of the points representing all the considered configurations is concentrated in a well defined region, and it can be interpolated with good approximation (within about ± 0.5 dB) by a line (as a polynomial or an exponential functions), regardless of the type of aperture distribution.

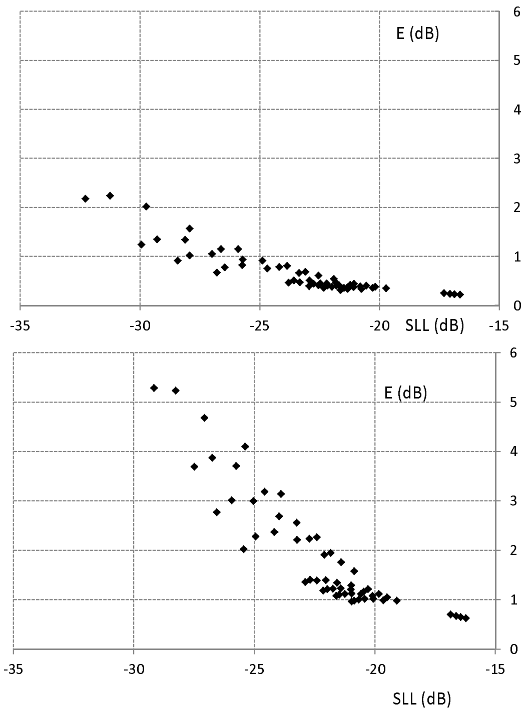

Fig. 2 *Examples of dispersion curves of the sidelobe correction factor, for $R/R_F = 1$ (above) and $R/R_F = 0.59$ (below).*

A closed form empirical formula has been found to be a good approximation of the distribution of the correction factor, by using different types of interpolations (linear and exponential) to represent the dependence upon R/R_F and on the measured SLL. First, exponential interpolations (the most suited for such data distributions) have been found for varying sidelobe level (in dB) S and and for all the fixed values of the logarithmic normalized distance $x = \log R/R_F$, each with a multiplicative factor A and an exponent coefficient C, so that for each x the error E (in dB) is

$$E(x, S) = A(x) \cdot e^{-C(x) \cdot S} \quad (3)$$

Then the values of $A(x)$ and $C(x)$ have been interpolated respectively with exponential and linear functions, obtaining

$$\begin{aligned} A(x) &= \alpha \, e^{\beta x} \\ C(x) &= \gamma + \delta x \end{aligned} \quad (4)$$

so that

$$E(x, S) = \alpha \cdot e^{\beta x - \gamma S - \delta x S} \quad (5)$$

with

$$\begin{aligned} \alpha &= 0.0153 \\ \beta &= 3.0174 \\ \gamma &= 0.1535 \\ \delta &= 0.1125 \end{aligned} \quad (6)$$

Equation (5) can be represented in various ways, and also using, instead of the variable x, directly the normalized distance R/R_F. A contour plot of the error E (in dB) is shown in Fig.(3).

Conclusion: In this letter the derivation of correction factors for a more accurate assessment of the first sidelobe of a parabolic reflector, offset or center fed, when measured in quasi-far field conditions (Fresnel zone) has been presented. Trend curves for all the different cases were computed and, on the basis of their analysis, an empirical formula has been derived allowing the correction of the measured values of the sidelobes when the measurement range is below or around the FF distance.

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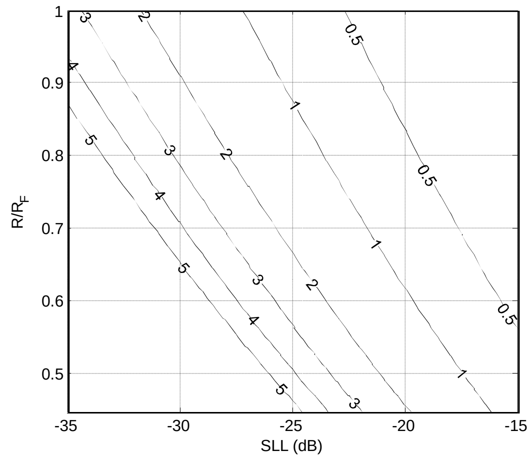

Fig. 3 *Contour plot of the sidelobe correction factor, vs. measured value and measurement distance.*

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