EFFECTS OF MEASUREMENT DISTANCE ON MEASUREMENTS OF SYMMETRIC SHAPED PATTERNS GENERATED BY LINE SOURCES

J. C. Brégains, F. Ares, and E. Moreno

Grupo de Sistemas Radiantes, Departamento de Física Aplicada,

Facultad de Física, Universidad de Santiago de Compostela.

15782 - Santiago de Compostela – Spain

faares@usc.es

ABSTRACT

Symmetric shaped patterns generated by real continuous linear apertures derived from Taylor distributions resemble Taylor sum patterns as regards the distance-dependence of their side lobe heights, and their ripple shows negligible near-field degradation. If the aperture distribution is complex, however, ripple and sidelobe level show previously unreported degradation behaviour, including a lowering of first side lobe level.

1. INTRODUCTION

It is well known that at finite distances from a line source generating a sum or difference pattern the first one or two side lobes of the pattern are higher than at infinity, the first side lobe eventually merging with the main beam. R. C. Hansen showed that for Taylor [1] and Bayliss [2] patterns log(ΔSLL) depends linearly on the logarithm of the distance, where ΔSLL is the increase in side lobe height in dB. In this paper we extend his analysis to symmetric shaped patterns generated by continuous linear apertures synthesized by substituting complex roots for the first few roots of Taylor distributions [3,4].

2. METHOD

The Taylor line source symmetric near field space factor is given by the equation [1]:

$$F(u) = \frac{1}{2} \sum_{n=-\bar{n}+1}^{\bar{n}-1} F_n \int_{-1}^{1} e^{-j\left[\beta p^2 - \pi(n+u)p\right]} dp \tag{1}$$

where $u = (D/\lambda)\sin\theta$ (D being the aperture length, λ the wavelength and θ the angle from broadside), $p = 2x/D$ (x being algebraic distance along the aperture from its centre), $\beta = \pi/(8\gamma)$ (where $\gamma = R / R_0$, R being distance from the antenna and R_0 the traditional far-field measurement distance, $2D^2 / \lambda$), $\bar{n}$ -1 is the number of pattern roots that are controlled to depress side lobes on each side of the Taylor pattern, and

$$F_n = \frac{\left[(n-1)!\right]^2}{(\bar{n}+n-1)!\ (\bar{n}-n-1)!} \prod_{m=1}^{\bar{n}-1} \left(1 - \frac{n^2}{z_m^2}\right) \tag{2}$$

where z_m is the m-th root of the Taylor pattern [1]. Shaped beams can be generated by replacing the real z_m of the Taylor pattern by appropriate complex roots $u_m + v_m$ [3-5]. If the set of complex roots consists entirely of conjugate pairs, then the aperture distribution is real [4]. In this work we used our previously published methods to optimise real and complex apertures affording shaped beams with controlled far-field ripple and side lobe levels [3,4], and then investigated the dependence of the ripple and side lobe levels of the patterns generated by these apertures on distance from the aperture in the near field.

3. RESULTS

3.1. COMPLEX EXCITATIONS

Starting from Taylor patterns with $\bar{n}$ = 6 and side lobe levels of -15, -20, -30 and -40 dB, and considering an aperture length of 12λ, we proceeded as in Ref. 3 to fill the first two nulls so as to synthesize apertures generating shaped far-field patterns with ± 0.25 or ± 0.5 dB of ripple. Since changing the sign of the imaginary part of a complex pattern root does not alter the far-field power pattern, this afforded four aperture distributions for each combination of side lobe level and ripple. The four corresponding near-field power patterns do not differ significantly as regards the amplitude of the ripple, but do differ as regards morphological details of the ripple and side lobe level; Fig.1 illustrates this for patterns at $\gamma = 0.5$ corresponding to a far-field pattern with ± 0.5 dB of ripple and -20 dB side lobes.

Plots of log(ripple, in dB) and log(ΔSLL) against log(γ) do not exhibit the linear behaviour shown by the first side lobe levels of Taylor and Bayliss patterns [1,2]. Fig.2 shows this for ripple in the case in which the imaginary part of both complex pattern roots is positive. Log(ΔSLL) can only be plotted for a limited γ interval, because although the first side lobe level is higher in the very near field than in the far field, for sidelobe levels under –30 dB, there is in all cases a distance γ_c beyond which it is lower than in the far field, approaching the far field value from below as distance increases (Fig. 3). Similar ripple and ΔSLL behaviour obtains for the other three combinations of complex pattern root imaginary part sign, and for ± 0.25 dB ripple.

3.2. REAL EXCITATIONS

Starting from Taylor patterns with $\bar{n} = 8$, and considering the same aperture length and far-field side lobe levels and ripple as above, we proceeded as in Ref. 4 to fill the first four nulls so as to synthesize real apertures generating shaped patterns. In this case, the ripple of the near-field pattern is almost the same as that of the far-field pattern for all distances γ, and the first side lobe level behaves in the same way as that of Taylor and Bayliss patterns [1,2].

4. CONCLUSIONS

The ripple and first side lobe level of shaped symmetric power patterns generated by complex line sources exhibit marked distance dependence. Pattern measurements should either be corrected on the basis of studies analogous to those described here, or should be made far enough away (at least $10R_0$) to ensure relatively small deviation from the far-field pattern. By contrast, the ripple of shaped symmetric power patterns generated by real line sources hardly changes with distance. In this real aperture case, the first side lobe level exhibits the same kind of distance dependence as that of Taylor and Bayliss patterns, log(side lobe level in dB) depending linearly on log(distance).

5. ACKNOWLEDGEMENT

This work was supported by the Spanish Ministry of Science and Technology under project TIC 2002-04084-C03-02

6. REFERENCES

[1] R. C. Hansen, "Measurement Distance Effects On Low Sidelobe Patterns", *IEEE Trans. On Antennas And Propagat.*, **32**, 1984, pp. 591-594.

[2] R. C. Hansen, "Measurement Distance Effects On Bayliss Difference Patterns", *IEEE Trans. On Antennas And Propagat.*,**40**, 1992, pp. 1211-1214.

[3] F. Ares, R. S. Elliott, and E. Moreno, "Optimised Synthesis Of Shaped Line Source Antenna Beams", *Electronics Letters*, **29**, 1993, pp. 1136-1137.

[4] F. Ares, R. S. Elliott, and E. Moreno, "Synthesis Of Shaped Line Source Antenna Beams Using Pure Real Distributions", *Electronics Letters,* **30**, 1994, pp. 280-281.

[5] J. C. Brégains, F. Ares, and E. Moreno, “Near-Field Quasi-Null Control With Far-Field Sidelobe Level Maintenance In Line Source Distributions”, *Electronics Letters*, **38**, 2002, pp. 540-541.

LEGENDS FOR THE FIGURES

Figure 1. Power patterns afforded at a distance of γ = 0.5 by complex line sources synthesized to generate the indicated shaped symmetric far-field pattern. Patterns A, B, C and D correspond to different combinations of the signs of the imaginary parts of the two complex roots of the pattern (A, ++; B, --; C, +-; D, -+).

Figure 2. Distance-dependence of the ripple of shaped symmetric patterns generated by complex line sources synthesized to afford far-field patterns with ± 0.5 or ± 0.25 dB of ripple and -15, -20, -30 or -40 dB first side lobes. Patterns shown are for case A of Fig.1.

Figure 3. Distance-dependence of the first side lobe level (relative to the far-field first side lobe level) of shaped symmetric patterns generated by complex line sources synthesized to afford far-field patterns with ± 0.5 of ripple and -15, -20, -30 or -40 dB first side lobes. Patterns shown are for case A of Fig.1. The arrows indicate shoulders.

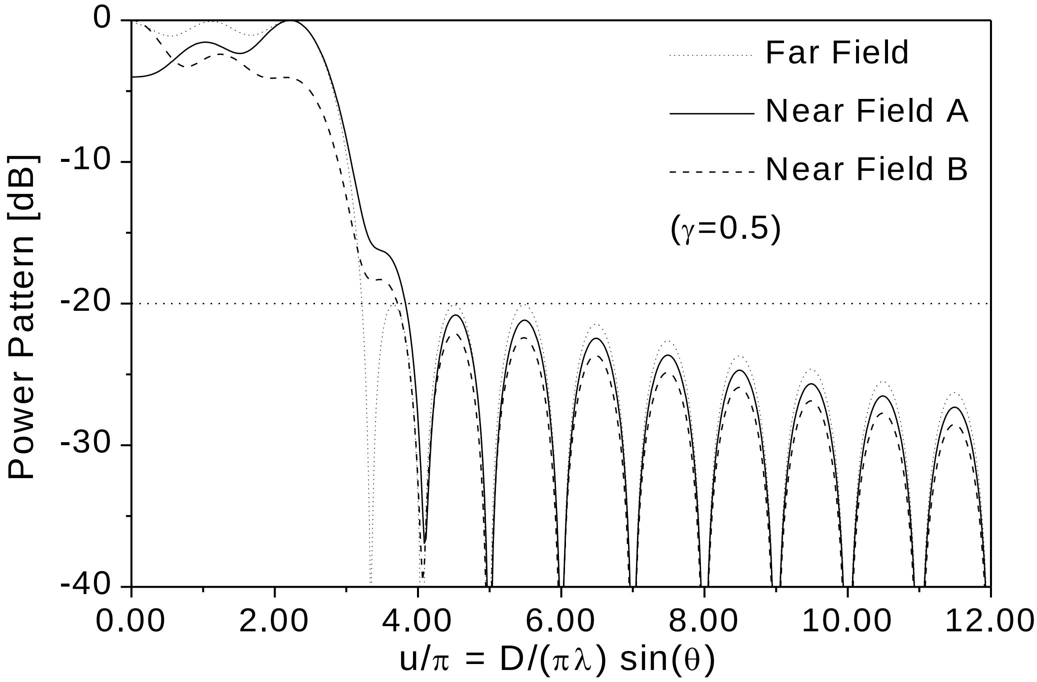
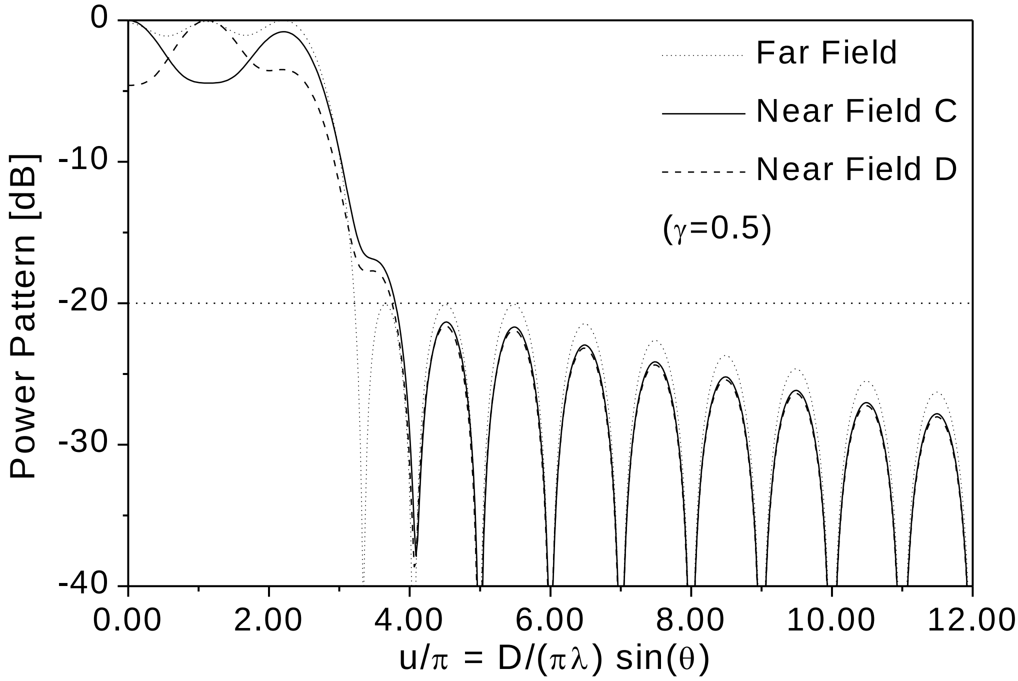
<table>
<tr><th>CASE</th><th>POWER
PATTERN</th></tr>
<tr><td>A, B</td><td>
</td></tr>
<tr><td>C, D</td><td>
</td></tr>
</table>

Figure 1

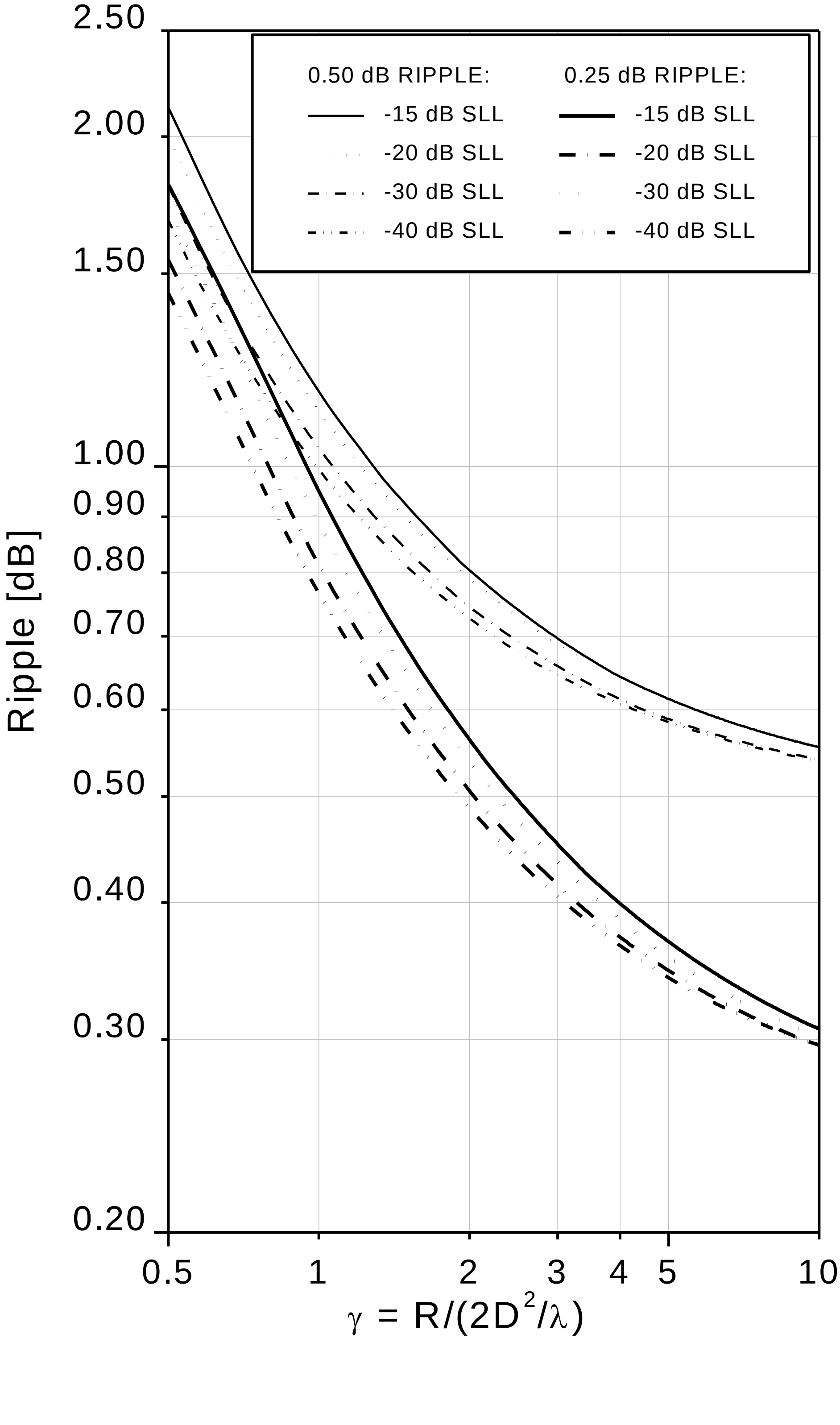
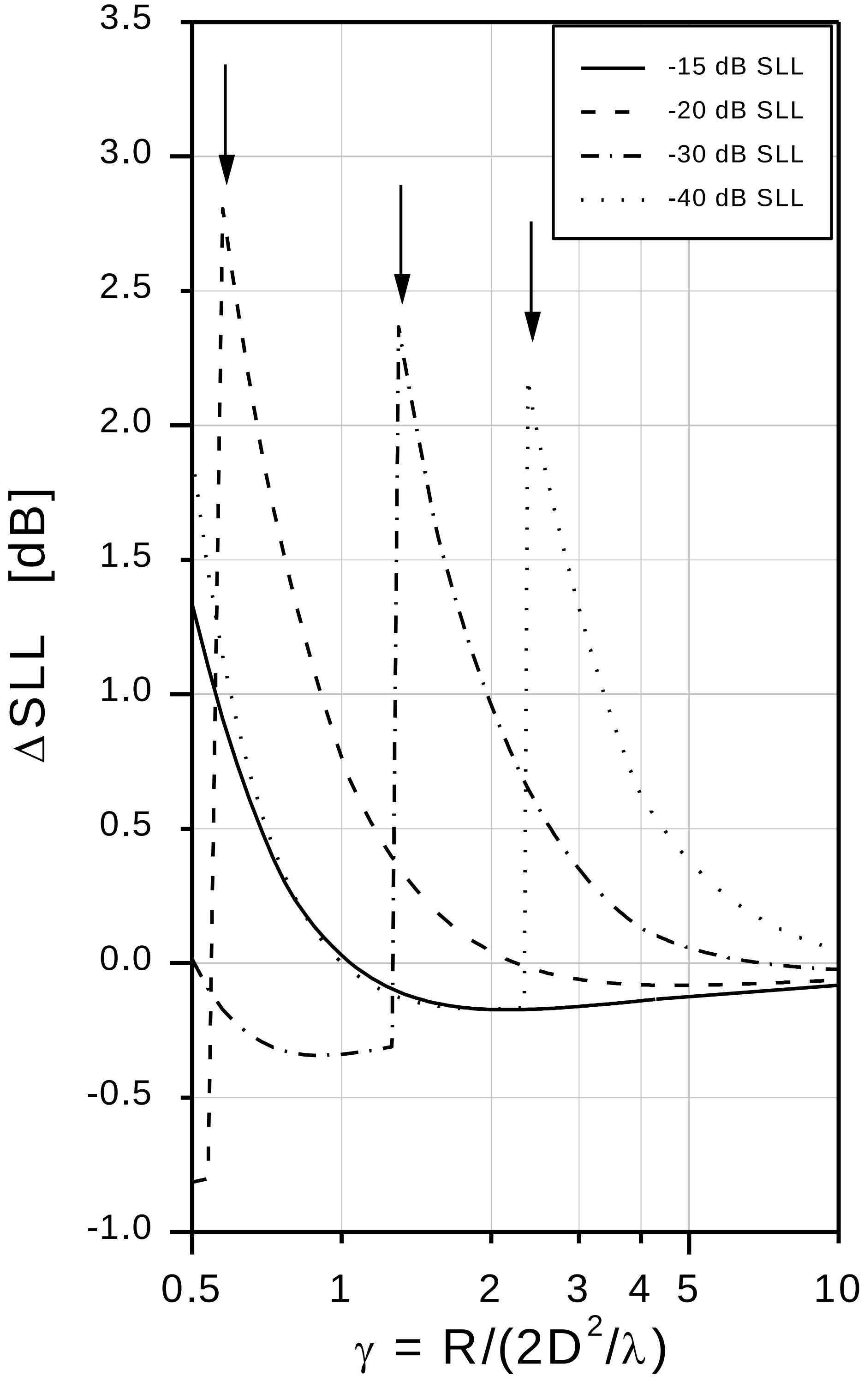

0.50 dB RIPPLE:
-15 dB SLL
-20 dB SLL
-30 dB SLL
-40 dB SLL
0.25 dB RIPPLE:
-15 dB SLL
-20 dB SLL
-30 dB SLL
-40 dB SLL
Ripple [dB]
2.50
2.00
1.50
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.5
1
2
3
4
5
10
γ = R/(2D²/λ)

Figure 2



3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
ΔSLL [dB]
-15 dB SLL
-20 dB SLL
-30 dB SLL
-40 dB SLL
0.5
1
2
3
4
5
10
γ = R/(2D²/λ)

Figure 3