NEAR FIELD QUASI-NULL CONTROL WITH FAR FIELD SIDELOBE LEVEL MAINTENANCE IN LINE SOURCE DISTRIBUTIONS

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

An improving method -based on Taylor line source- that allocates a quasi-null in a specified angular position of near field pattern, and, simultaneously, controls the general topography of far-field sidelobe level -without significantly loss of directivity, compared with optimal efficiency Taylor distribution, of the latter- is presented in this article. The method is based on the application of the Simulated Annealing technique, by achieving the complex roots of the pattern distribution. An example developed below demonstrates this accomplishment.

1. INTRODUCTION

In some antenna applications it is necessary the reduction of the field magnitude in a particular angular position; either, for example, to avoid the radiation in a certain specific direction, or the reception of the signal in order to keep it away from some interference, null controlling is widely applied by antenna's designers. Previous papers [1-3] indicate that some authors have achieved null controlling or steering but only using far field patterns. These examples do not face the problem of near field radiation (or reception), so the named results have not the capability neither to avoid the perturbation caused by obstacles close to the antenna, nor radiating with undesired relatively high power in an certain angular position at the neighborhood of it.

In this article those problems are considered by taking into account both patterns, first, controlling a previously determined location and depth of a null in near field region and, second, maintaining the far-field pattern sidelobe level under a certain desired value.

2. METHOD

The near field space factor of a line source antenna can be written as [4]:

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

where $\bar{n}$, as in Taylor's pattern, represents the coefficient that determines the control of the $\bar{n}-1$ first sidelobe levels in the pattern topography, and $u = (D/\lambda) \sin\theta$ (being D the length of the line antenna, λ the wavelength and θ the usual angular spherical coordinate measured from the end-fire of the antenna). The edge phase error β is related to γ (ratio of measurement distance R to far field distance $2D^2/\lambda$) through:

$$\beta = \pi / 8\gamma \qquad (2)$$

The F_n coefficients are given by:

$$F_n = \frac{\left[(n-1)!\right]^2}{(\bar{n}+n-1)!\,(\bar{n}-n-1)!} \prod_{m=1}^{\bar{n}-1} \left(1 - \frac{n^2}{u_m^2}\right) \qquad (3)$$

where u_m represent the $\bar{n}-1$ first zeros of the space factor:

$$u_m = \frac{\bar{n}\sqrt{A^2 + (m-1/2)^2}}{\sqrt{A^2 + (\bar{n}-1/2)^2}} \tag{4}$$

Here, $A = \cosh^{-1}(10^{-SLL/20})$ is specified by the desired sidelobe level *SLL*, previously chosen by the antenna's designer.

When the distance is selected with the aim of making $\gamma \geq 10$, the pattern is reduced to Taylor's, as:

$$F(u) = \frac{\sin \pi u}{\pi u} \prod_{m=1}^{\bar{n}-1} \frac{1-u^2/u_m^2}{1-u^2/m^2} \tag{5}$$

The aperture distribution is given by:

$$g(p) = \frac{1}{2} \sum_{n=-\bar{n}+1}^{\bar{n}-1} F_n e^{j\pi n p} \tag{6}$$

where p is the line source variable that takes ±1 values at the ends and cero at the center.

The generalization of (3) for complex roots is immediate, replacing the u_m by the $u_m + jv_m$ values, as seen:

$$F_n = \frac{[(n-1)!]^2}{(\bar{n}+n-1)!\,(\bar{n}-n-1)!} \prod_{m=1}^{\bar{n}-1} \left(1 - \frac{n^2}{(u_m + jv_m)^2}\right) \tag{7}$$

This replacement allows the achievement required in this article, by perturbing the real values u_m, and the imaginary values v_m. These perturbations are generated by the Simulated Annealing technique [5] that minimizes a cost function containing all the useful parameters of the design characteristics, as next example indicates.

3. EXAMPLE

If we set the *i* desired levels of the far field side lobes $SLL_{FFd,i}$, the *j* desired levels of the far field filling nulls $Z_{FFd,j}$, and the desired level of the second near field sidelobe $SLL_{NFd,2}$, we get the cost function value after calculating in each iteration of the Simulated Annealing the obtained quantities $SLL_{FFo,i}$, $Z_{FFo,j}$ and $SLL_{NFo,2}$ (far field side lobe levels, far field filling nulls and second near field side lobe level, respectively) and therefore applying next equation (8). In order to avoid the "edge brightening" effect in the excitation amplitude distribution, a last term V is assigned to the "variability" of the continuous distribution, being $V = \max\{R_r\}$ (R_r is the difference between the r-th peak of the excitation amplitude distribution and the lower of its flanking minima). V_d is the desired value of V. Finally, K_s (s=1 to 4) are adjustable constants controlling the relative importance of fixing far field side lobe levels, far field null filling levels, second near field side lobe level, and the local variation of the aperture amplitude distribution. The cost function is:

$$C = K_1 \sum_{i=1}^{\bar{n}-1} \Delta_i^2 \, H(\Delta_i) + K_2 \sum_{j=1}^{\bar{n}-1} \Lambda_j^2 \, H(\Lambda_j) + K_3 \, \Omega_2^2 \, H(\Omega_2) + K_4 \left(V_d - V_o\right)^2 \qquad (8)$$

where $\Delta_i = (SLL_{FFd,i}\text{-}SLL_{FFo,i})$, $\Lambda_j = (Z_{FFd,j}\text{-}Z_{FFd,o})$, $\Omega_2 = (SLL_{NFd,2}\text{-}SLL_{NFd,2})$ and H is the Heaviside step function.

Figure 1 shows the power patterns obtained after optimization, with $SLL_{FFd,i}$ = -20 dB, $Z_{FFd,j}$ = -21 dB, $SLL_{NFd,2}$ = -40 dB and $V_d = 0.1$ in the cost function ($\bar{n}$ = 5). Near field was taken considering γ = 0.25, which, for a D=10λ antenna length, determines a R = 50λ distance. Figures 2 and 3 show the amplitude excitation distribution and the phase distribution, respectively. Table 1 lists the obtained roots. Comparing the peak directivity for a 10λ antenna length, with the $\bar{n}$ = 6 Taylor (far field) at –20 dB pattern (this value of $\bar{n}$ yields maximum efficiency of Taylor pattern at the considered sidelobe level) we have a loss of only 4.97%, as a result of being far field peak directivity of this optimized pattern equal to 18.54.

4. CONCLUSIONS

A design technique that allows fixing a near field quasi-null at prescribed locations while maintaining the near field sidelobe level under a desired value has been described. This technique allows low-loss directivity in antenna and variability reduction also. We suggest that is possible to apply this technique to Rhodes distributions [6], after generalization of its analogous near field space factor. The optimization presented here, took under 5 minutes time on a PC with an AMD-K7-ATHLON XP1800/266 processor running at 1.53 GHz. As a final remark, we advice that the reduction of γ values to minor orders than 0.25 reveals near field pattern degradation, and the optimization becomes too difficult.

5. ACKNOWLEDGEMENT

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6. REFERENCES

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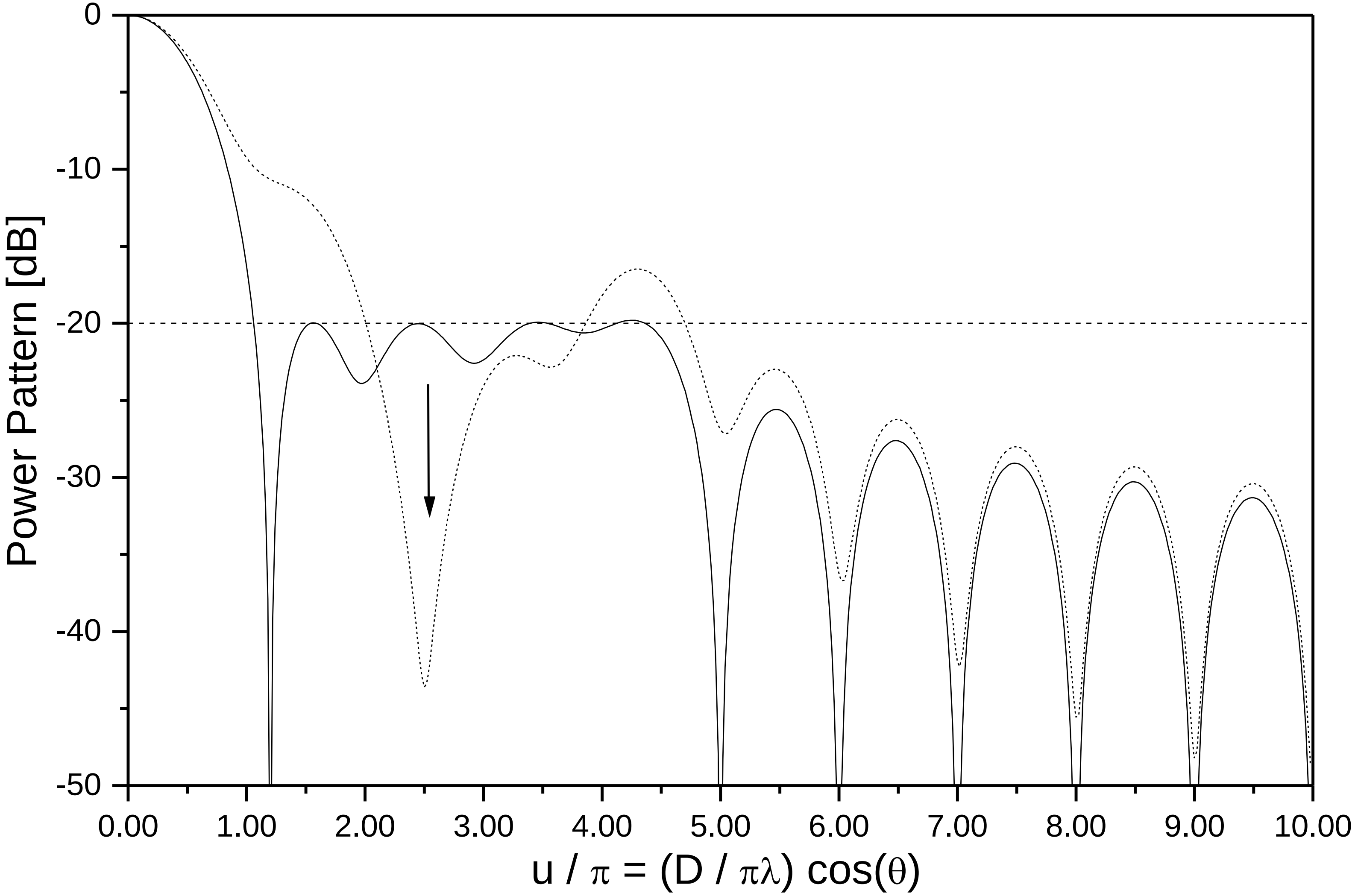
LEGENDS FOR FIGURES AND TABLES

- **Table 1.** Zeros of the radiation patterns of Fig.1.
- **Fig.1.** Near (-------) and far (——) field power patterns obtained after optimization.

  The arrow indicates the near field quasi-null position.
- **Fig.2.** Amplitude of the aperture distribution affording the radiation pattern of Fig.1.
- **Fig.3.** Phase of the aperture distribution affording the radiation pattern of Fig.1.

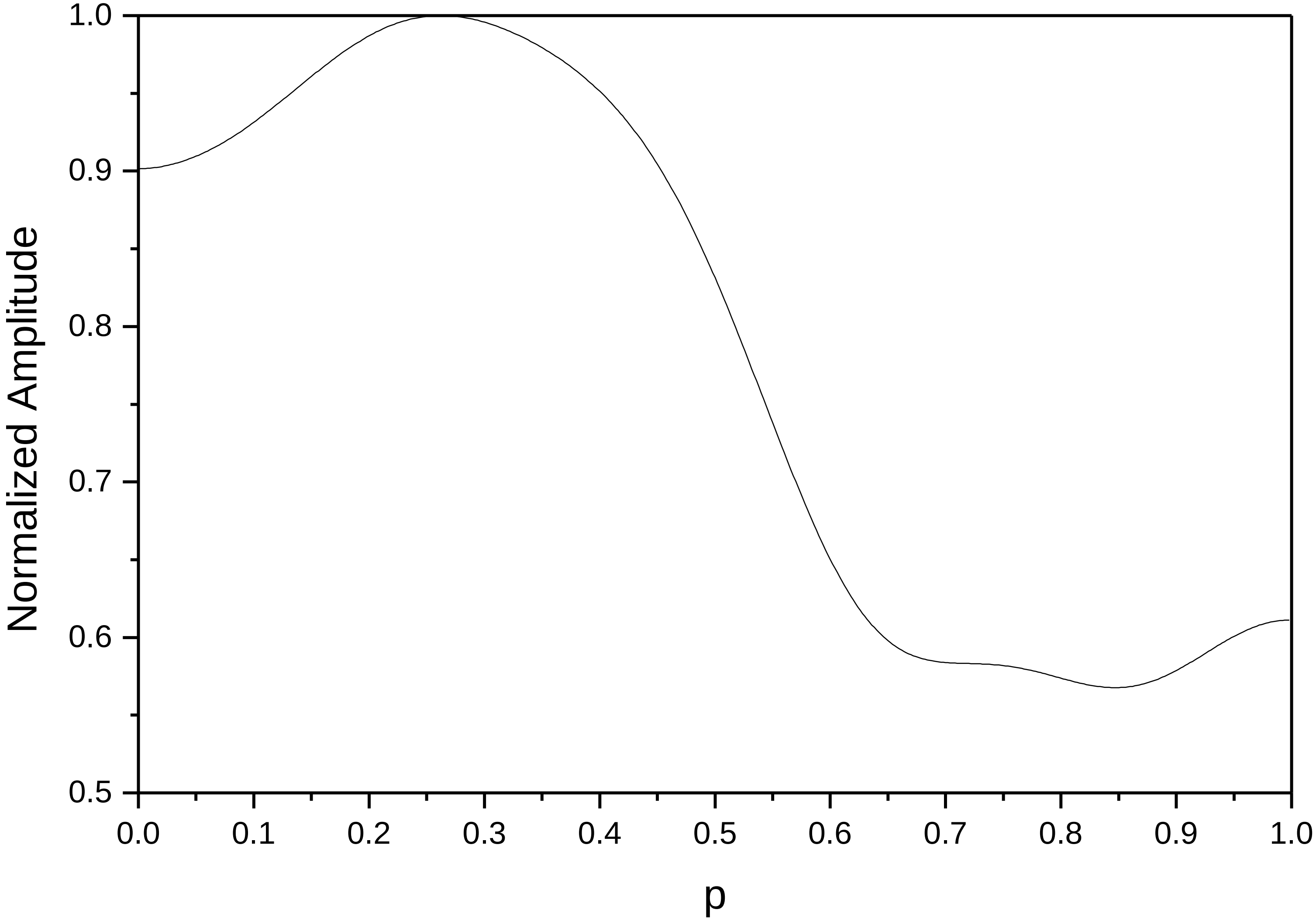
Table 1

u_n	v_n
1.2011	0.0000
1.9640	-0.2144
2.9138	0.3013
3.8564	0.4226



0
-10
-20
-30
-40
-50
Power Pattern [dB]
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
u / π = (D / πλ) cos(θ)

Fig. 1



Normalized Amplitude
1.0
0.9
0.8
0.7
0.6
0.5
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
p

Fig. 2

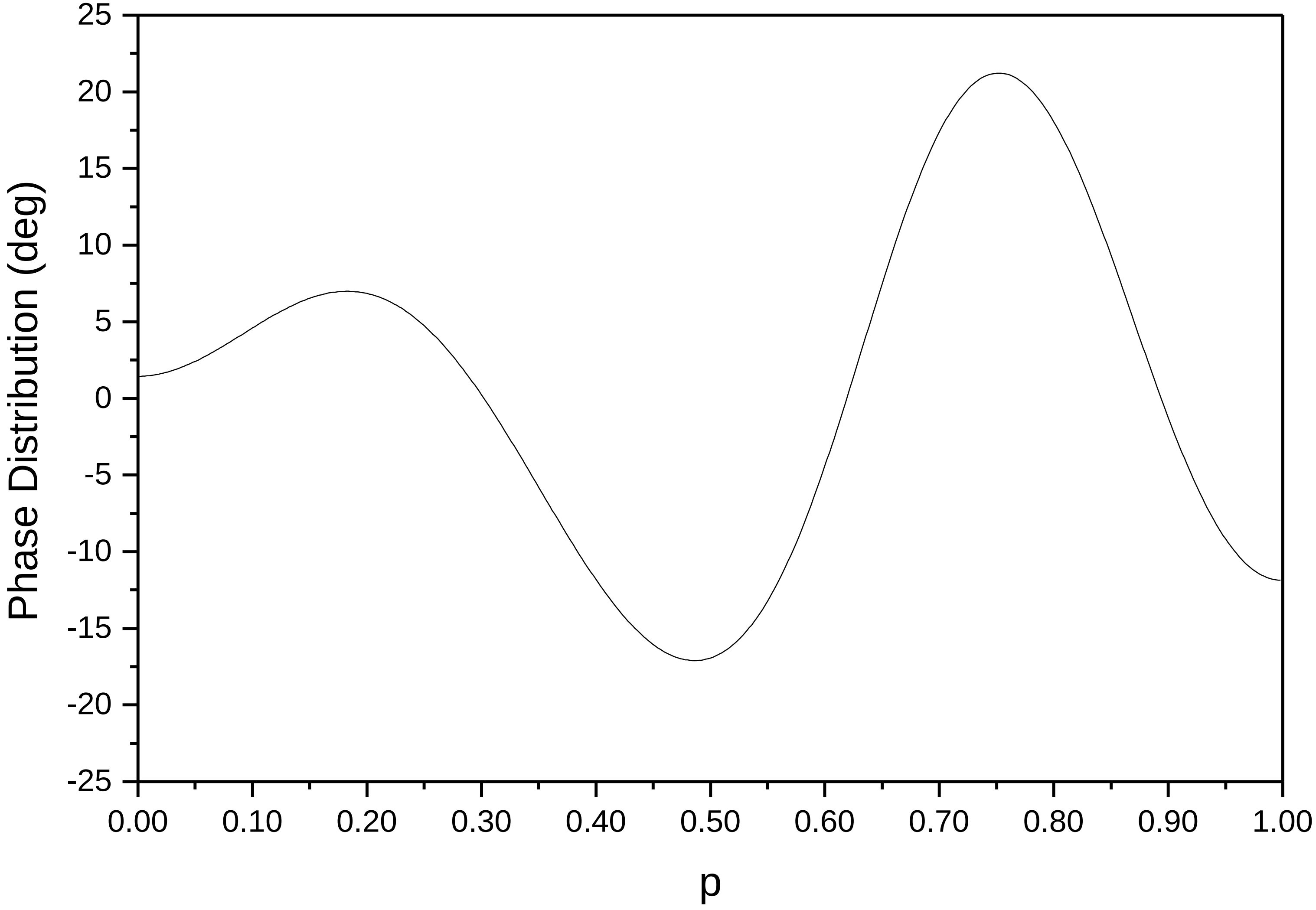

25
20
15
10
5
0
-5
-10
-15
-20
-25
Phase Distribution (deg)
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
p

Fig. 3