

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

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ABSTRACT

A previously developed method to place a quasi-null in a specified angular position of the near-field line source in sum patterns while, simultaneously, the far-field sidelobe level is maintained under a desired value, is shown to be applicable to linear Bayliss patterns as well. This method, as in the previous work, is performed through the use of the *Simulated Annealing* technique, which allows to perturb the complex roots of the pattern in order to achieve the desired specifications. An example developed below demonstrates this accomplishment.

1. INTRODUCTION

In a previous work [1], our research group has demonstrated that the near field pattern of a line source providing a far field sum pattern can be depressed in certain angular positions while maintaining the far field sidelobe level controlled to a desired value. In [2],

R.C. Hansen has studied the behavior of linear Bayliss difference patterns when the usual near field criterion $2D^2/\lambda$ is taken. Although in that work the pattern degradation due to the measurement distance change taking the first sidelobe level as fundamental parameter is analyzed, it also provides important conclusions. Specifically, it can be seen from that work that the progressive rising of the first null, and the subsequent development of the first sidelobe into a shoulder, becomes, finally, an increment of the first null beamwidth. Albeit the beamwidth can not be reduced in near field, we show in this letter, in a similar way that we have done for sum patterns in [1], that it is possible to choose some position in which the near field is as low as the designer determines. This quasi-null positioning allows the named minimization of the power pattern in a certain desired zone.

2. METHOD

For linear Bayliss difference patterns, the near field space factor is given by [2]:

$$F(u) = \sum_{n=0}^{\bar{n}-1} B_n \int_0^1 e^{-j\beta p^2} \sin\left[\pi\left(n + \frac{1}{2}\right)p\right] \cos(\pi u p) dp \quad (1)$$

Here, \bar{n} represents the coefficient that determines the control of the $\bar{n}-1$ first sidelobe levels in the far field pattern. $u = (D/\lambda) \sin \theta$ (being D the length of the line antenna, λ the wavelength and θ the angle measured from the broadside of the antenna), while p denotes the line source variable which is ± 1 at the ends and zero at the center.

The edge phase error β and the ratio γ of measurement distance R to far field distance are, respectively:

$$\beta = \pi/8\gamma \quad ; \quad \gamma = \frac{R}{2D^2/\lambda} \quad (2)$$

The coefficients B_n are defined as:

$$B_n = -(-1)^n (n - \frac{1}{2})^2 \frac{\prod_{m=1}^{\bar{n}-1} \left[1 - \left(\frac{n + \frac{1}{2}}{\sigma u_m} \right)^2 \right]}{\prod_{\substack{m=0 \\ m \neq n}}^{\bar{n}-1} \left[1 - \left(\frac{n + \frac{1}{2}}{m + \frac{1}{2}} \right)^2 \right]} \quad (3)$$

where u_m represents the zeros of the Bayliss space factor. The initial roots u_m of this B_n coefficients can be obtained from the tables given in [3], taking $m \leq 4$. For higher values of m , the formula applied is:

$$u_m = \sqrt{A^2 + m^2} \quad m > 4 \quad (4)$$

where $A = \cosh^{-1}(10^{-SLL/20})$, being SLL the desired sidelobe level in dB.

The dilation factor σ is given by:

$$\sigma = \frac{\bar{n} + \frac{1}{2}}{u_{\bar{n}}} \quad (5)$$

If the distance is selected with the aim of making $\gamma \geq 10$ (i.e. far field pattern), the equation (1) becomes the widely known Bayliss' formula [3].

The corresponding aperture distribution is given by a finite "sum" where the B_n coefficients are calculated using (3):

$$g(p) = \sum_{n=0}^{\bar{n}-1} B_n \sin \left[\pi \left(n + \frac{1}{2} \right) p \right] \quad (6)$$

For our requirements, the u_m real roots in (3) are replaced by the complex $u_m + jv_m$ values. This change allows to perturb both real u_m , and imaginary values v_m in order to ob-

tain the desired near and far field patterns. These perturbations are generated by the Simulated Annealing technique [4] that minimizes a cost function. This function contains all the useful parameters of the design characteristics, as shown in next example.

3. EXAMPLE

If we choose the desired level of the i -th far field side lobe $SLL_{FFd,i}$, the j -th desired maxima level of the far field filled null $Z_{FFd,j}$ and the desired level of the quasi-null QN_{NFd} -positioned at a freely preestablished angle-, 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 QN_{NFo} (far field side lobe levels, far field filling nulls and positioned quasi-null, respectively) and therefore applying next equation:

$$C = K_1 \sum_{i=1}^{\bar{n}-1} \Delta_i + K_2 \sum_{j=1}^{\bar{n}-1} A_j^2 H(A_j) + K_3 \Omega_2^2 H(\Omega_2) \quad (7)$$

where $\Delta_i = (SLL_{FFd,i} - SLL_{FFo,i})$, $A_j = (Z_{FFd,j} - Z_{FFd,o})$, $\Omega_2 = (QN_{NFd} - QN_{NFo})$ and H is the Heaviside step function (this function allows to maintain the obtained values under the desired ones). K_s ($s=1$ to 3) are adjustable constants controlling the relative importance of fixing far field side lobe levels, far field null filling levels, and second near field side lobe level, respectively.

Figure 1 shows the power patterns obtained after optimization, with $SLL_{FFd,i} = -20$ dB, $Z_{FFd,j} = -21$ dB, and the quasi-null depressed below $QN_{NFd} = -40$ dB and positioned at $u=3.22$ ($\bar{n} = 5$). Near field was taken considering $\gamma = 0.25$, which, for a $D=10\lambda$ antenna length, determines an $R = 50\lambda$ distance. Figures 2 and 3 show the amplitude excitation distribution and the phase distribution, respectively. Table 1 lists the obtained roots corresponding to this example.

4. CONCLUSIONS

It can be seen that for difference radiation diagrams, the aim of quasi-null positioning in near field, while the far field sidelobe level is kept under a certain value is perfectly realizable. The behavior of the difference diagram when the quasi-null is positioned too close to the main beam is similar to that of the sum pattern [1]: the far field sidelobe level can not be controlled easily, making impossible the maintenance of that parameter under a desired value.

We suggest that it is possible, in a further investigation, the application of this method working on line sources with shaped beams [5-7]. As final remark, the optimization presented here, took under 7 minutes time on a PC with an AMD-K7-ATHLON XP1800/266 processor running at 1.53 GHz.

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
1.8122	0.0000
2.5406	-0.1350
3.4187	0.3008
4.3867	0.0829

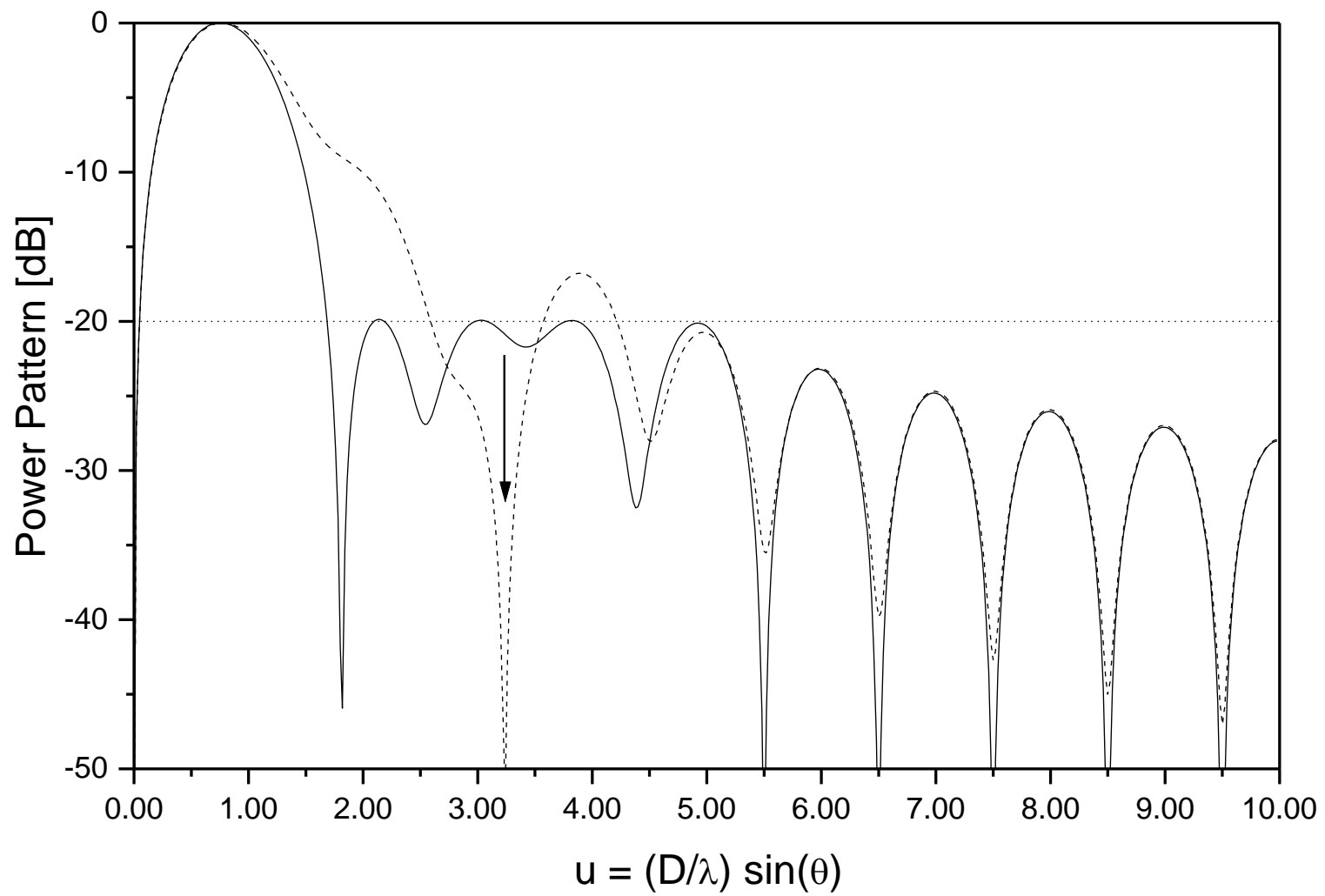


Fig. 1

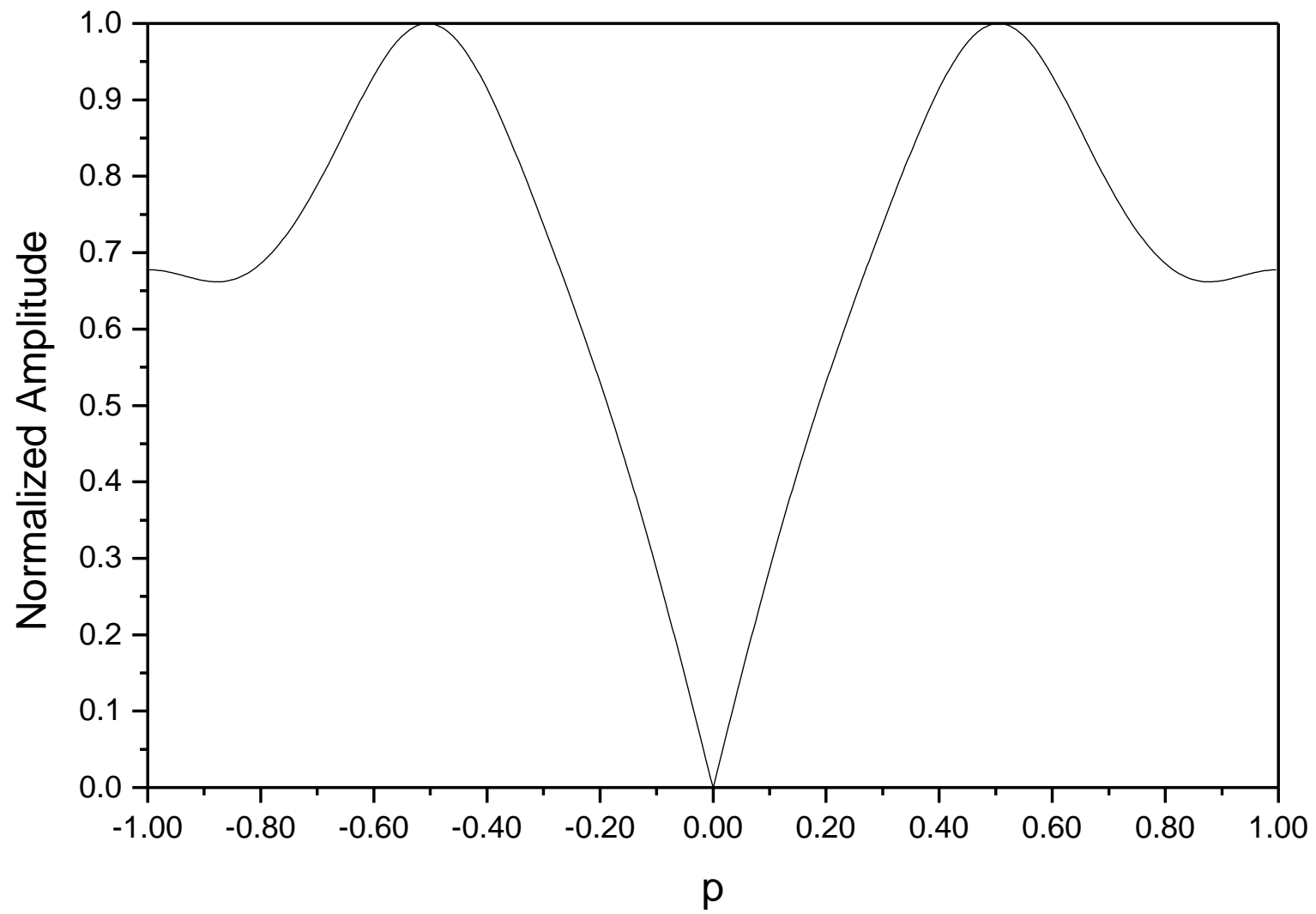


Fig. 2

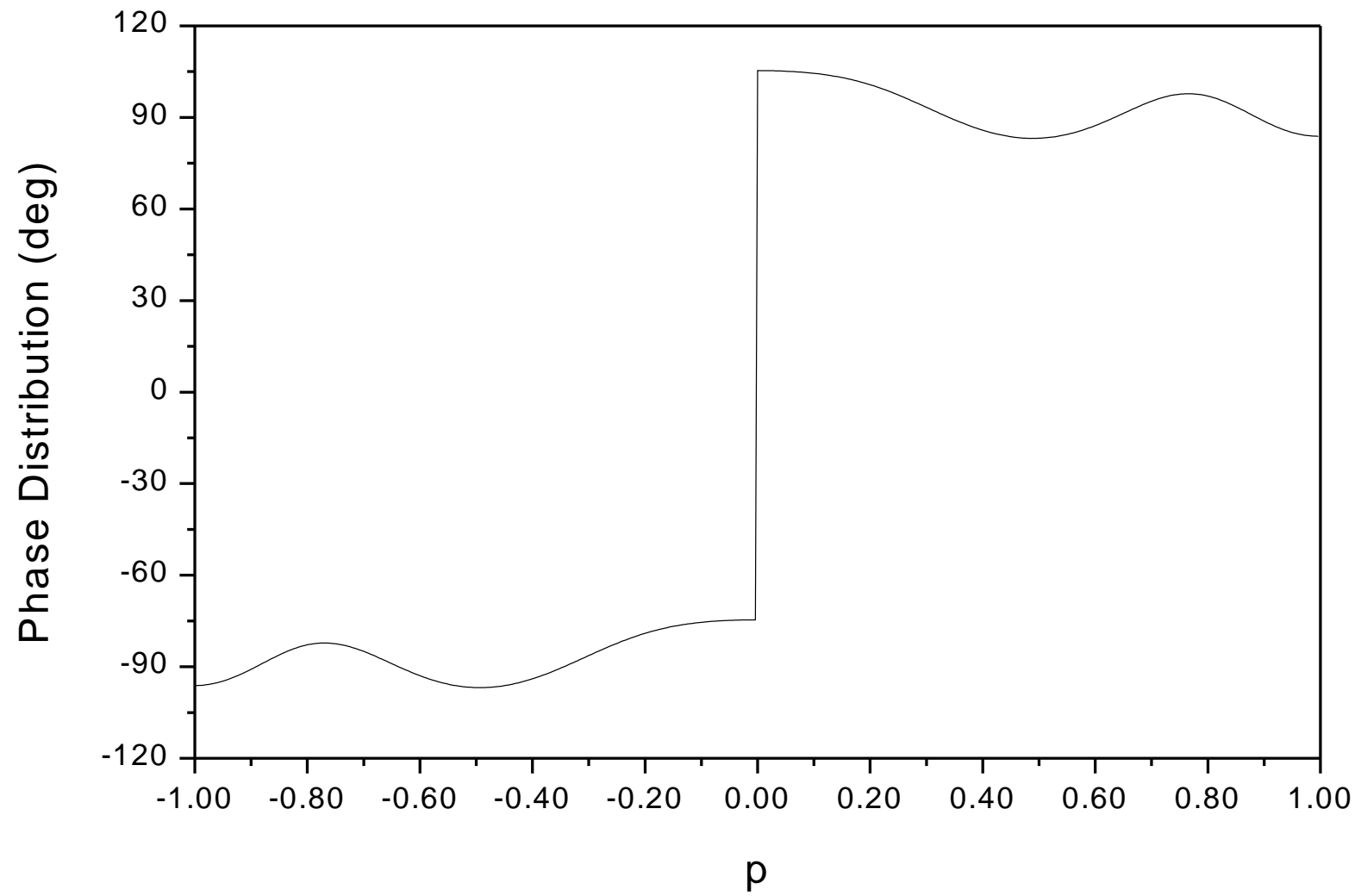


Fig. 3