OPTIMIZATION OF SHAPED WIRE ANTENNAS FOR ASYMMETRIC EXCITATION

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Abstract - In this paper, an approach to optimizing the shape of a wire antenna with symmetric and asymmetric feed with respect to maximum effective height is proposed. The optimization is achieved by using the method of steepest descent in conjunction with a line search algorithm suggested by R. Fletcher. It is found that for a given antenna length, the effective height of an asymmetrically driven antenna is larger, thus allowing the directivity to be higher than in the symmetrically driven case.

INTRODUCTION

The shapes or curvilinear wire antennas can be optimized in such a way that one parameter, e.g. the directivity, becomes maximum [1]. Therefore, these radiators can offer an attractive alternative to straight line antennas which has been demonstrated in [1-2] for symmetrically fed structures. In practice, however, the asymmetrically driven dipole is often used in order to obtain a special characteristic [3-6], and studies on the asymmetric counterpart of [1-2] have not been available to date.

This paper focuses on the optimization of shapes of linear antennas in order to achieve maximum effective height for a given antenna length. A maximum of radiating intensity in main-beam direction can be produced for asymmetric excitation. In this case, the effective height is larger than that of the symmetrically fed configuration.

THEORY

The effective height of a wire antenna is defined as $h_{eff}=V_o/E_i$ where E_i is the electric field strength of an incident plane wave, and V_o is the open circuit voltage induced by this field as shown in Fig. 1. For an asymmetrically driven structure, the resulting effective height reads

$$h_{eff} = V_0 / E_i = (V_1 + V_2) / E_i = h_{eff1} + h_{eff2} \tag{1}$$

The analysis of the shaped wire antenna is based on three assumptions: first, only a sinusoidal current distribution along the antenna is considered; second, the antenna is regarded as a series of conducting straight-line segments; and third, the wire diameter is much smaller than the antenna length.

In order to determine the current distribution of the antenna, usually three boundary conditions must be satisfied. First, the current must be zero at the ends of the antenna; second, the current distribution must be continuous at the driving point; and third, the electric field tangential to the wire antenna surface must vanish. Under these conditions, the effective height $h_{eff\,i}$ (i=1,2) is given by

$$h_{eff_i} = \sum_{n=1}^{N} \left\{ \exp\left[j\beta\Delta s_i \sum_{k=1}^{n-1} \sin\alpha_k^i \right] \cos\alpha_n^i \int_{z'=0}^{\Delta s_i} \frac{I(z_n')}{I(0)} \exp(j\beta z_n' \sin\alpha_k^i)\, dz_n' \right\} \tag{2}$$

where $\beta=2\pi/\lambda$ is the free-space propagation constant, z'_n is the arc-length coordinate, and $I(z'_n)$ is the current along the n-th segment. A maximum of h_{eff} is obtained by optimizing the parameter vector formed by inclination angles α^i_n

$$\underline{x}_{opt} = \left(\alpha^i_1, \alpha^i_2, \cdots \alpha^i_N\right)_{opt} \tag{3}$$

The optimization method used is a combination of the method of steepest descent and a line search algorithm proposed by Fletcher [7, ch.2].

RESULTS

First, the shape of a symmetrically driven wire antenna of total length $2h$ with $h=h_1=h_2=3/4\lambda_o$ optimized. Table 1 gives the numerical values for optimum inclination angles and the corresponding normalized effective height h_{eff}/λ_o. The results show that the effective height increases with increasing the number of sections N and approaches $h_{eff}/\lambda_o=0.634$.

Fig. 3 shows the shape of an optimized $h=3/2\lambda_o$ symmetric antenna with $N=30$ segments. A maximum effective height of $h_{eff}=0.669$ can be obtained which is a slight improvement of Landstorfer's result of $h_{eff}=0.654$ [1].

For the application of an asymmetrically driven structure, the shape of an optimized wire antenna of total height as in Fig. 2 but with $h_1=2.7/4\lambda_o$ and $h_2=3.3/4\lambda_o$ is shown in Fig. 4. Compared with the results of Fig. 2, it is found that the effective height of the asymmetrically driven antenna ($h_{eff}=0.751\lambda_o$ can be larger than that in the symmetrically driven case ($h_{eff}=0.669\lambda_o$).

CONCLUSION

The shape of symmetric as well as asymmetric wire antennas is optimized for maximum effective height. An optimization procedure utilizing the method of steepest descent in conjunction with a line search algorithm by Fletcher yields improved results as compared with previously published data. For a given wire length, the effective height of the asymmetrically driven antenna is larger than that of its symmetric counterpart, hence a higher directivity for off-center main-beam applications can be realized with asymmetric wire shapes.

REFERENCES

[1] F.M.Landstorfer and R.R. Sacher, *Optimization of wire antennas*. John Wiley & Sons: New York, 1985.

[2] D.K. Cheng and C.H. Liang, "Shaped wire antennas with maximum directivity", *Electronics Letters*, vol. 18, pp. 816-818, Sep. 1982.

[3] J. H. Pierluissi, "Some effects of asymmetric excitations on dipole radiators", *IEEE Trans. Antennas Propagat.*, vol. AP-19, pp.548-550, July 1971.

[4] R.W.P. King and B.H. Sandler, "Cylindrical antenna in a dissipative medium program", *IEEE Trans. Antennas Propagat.*, vol. AP-21, pp. 410-411, May 1973.

[5] N.P. Neff and C.A. Siller, "A trigonometric approximation to the current in the solution of Hallen's equation", *IEEE Trans. Antennas Propagat.*, vol. AP-18, pp. 805-806, Feb. 1970.

[6] B.D. Popovic, "On polynomial approximation of current along thin asymmetrical cylindrical dipoles", *IEEE Trans. Antennas Propagat.*, vol. AP-18, pp 117-120, July 1970.

[7] R. Fletcher, *Practical Methods of Optimization*, 2nd edition, Chichester, UK: John Wiley, 1990.

	α_1^1	α_2^1	α_1^2	α_2^2	α_1^3	α_2^3	α_1^4	α_2^4	h_{eff}/λ_0
N=2	34°	33.5°							0.5232
N=4	55.1°	56°	13.7°	12.4°					0.6121
N=8	34.3°	34.1°	73.5°	75.3°	21.9°	21.8°	7°	5.4°	0.6335

Table 1. Optimum inclination angles for maximum effective height

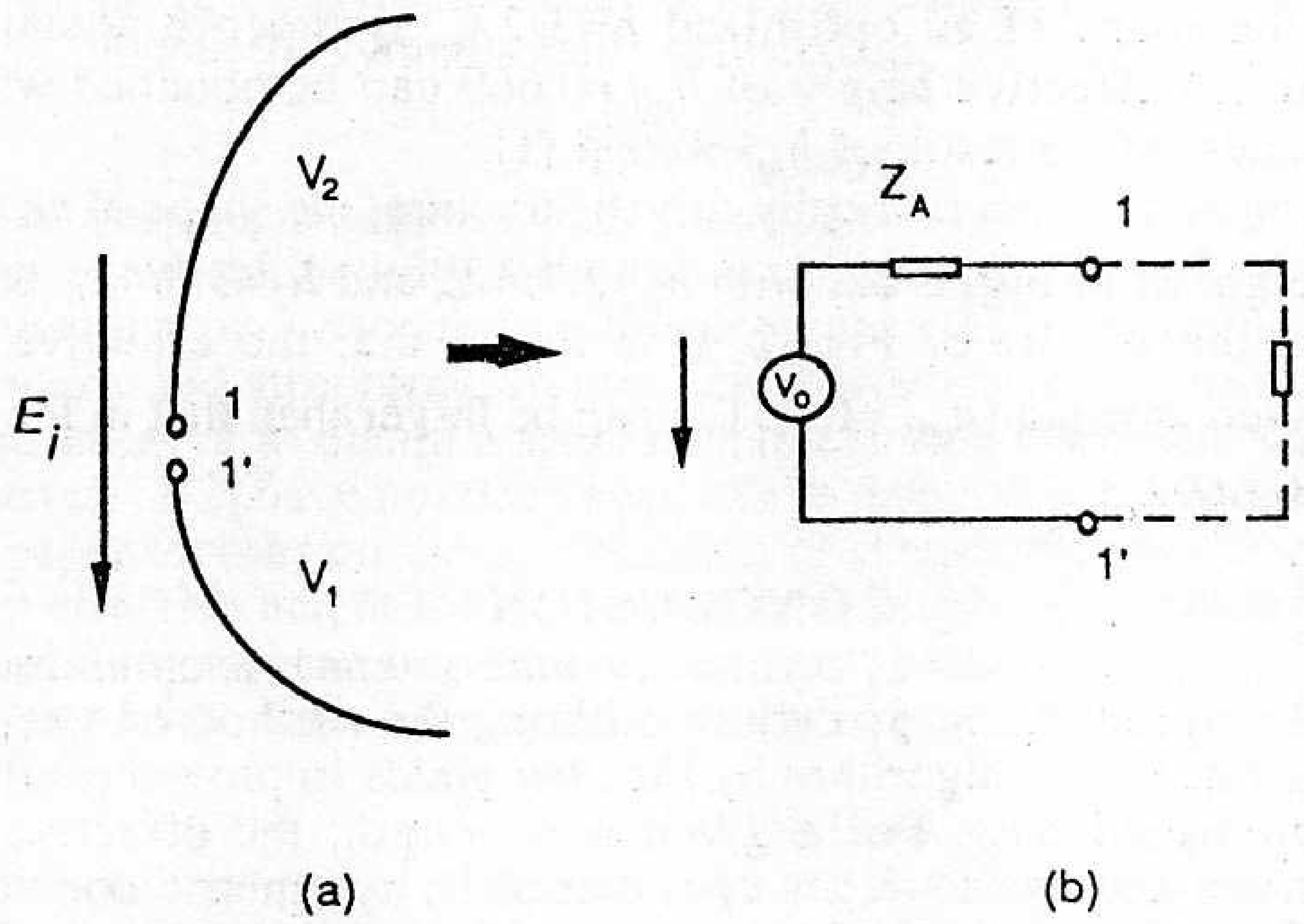

Fig. 1 Curvilinear receiving dipole with its equivalent circuit

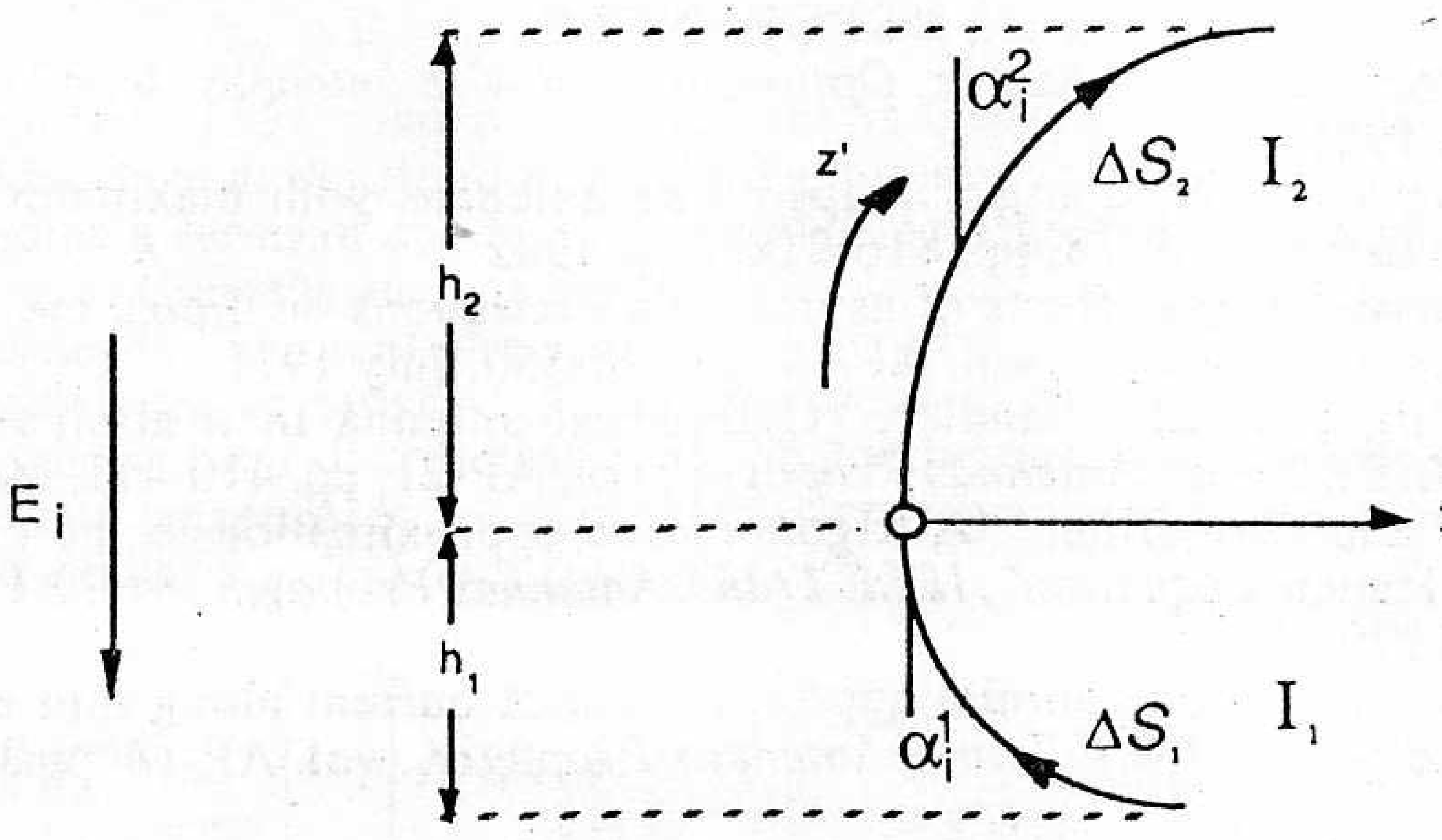

Fig. 2 Asymmetrical driven curvilinear wire antenna

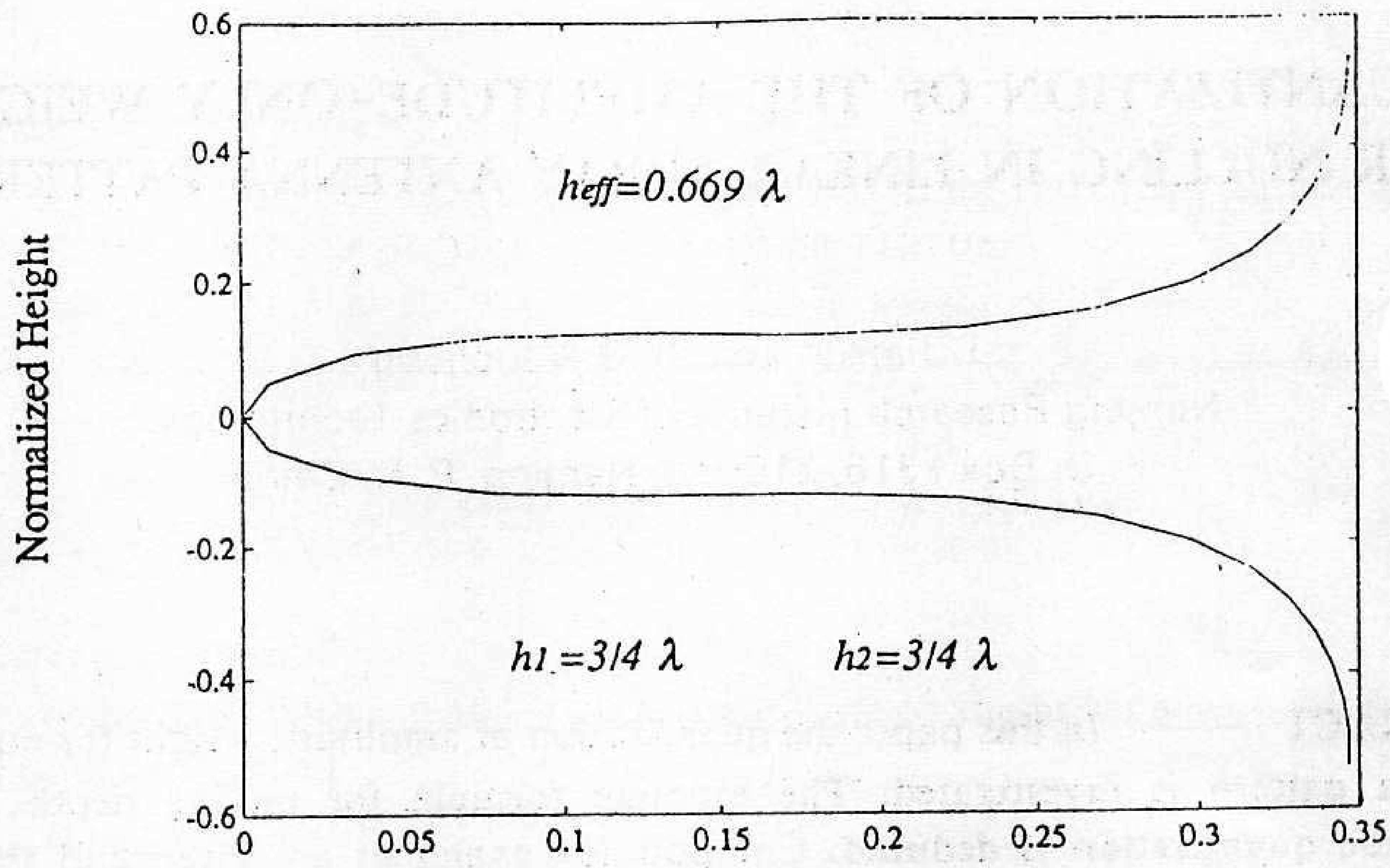

Fig. 3 Optimized Shape of Wire Antenna with Symmetrical Feed

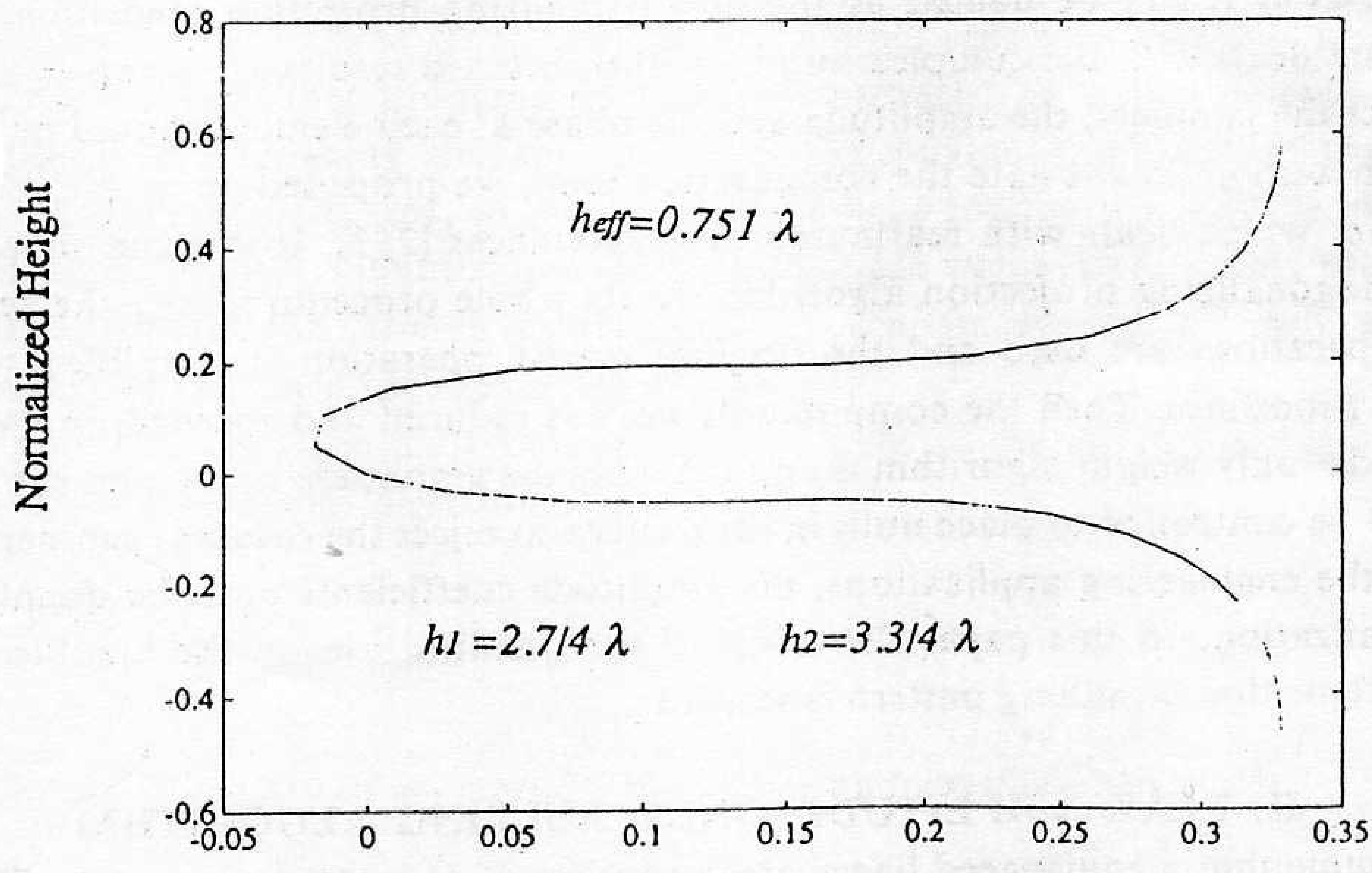

Fig. 4 Optimized Shape of Wire Antenna with Asymmetrical Feed