Shape Optimization of Curved Dipole Antennas

Juhani Kataja

Helsinki University of Technology, Department of Radio Science and Engineering
P.O. BOX 3000, 02015 TKK, Finland
Email:juhani.kataja@tkk.fi

Abstract

The dipole shape optimization problem is studied using discretized electric field integral equation as solution method for time-harmonic Maxwell's equations. A well justified shape representation method is presented. Finally, numerical solutions to the shape optimization problem are presented together with directivities and impedances of the resulting dipole antennas.

INTRODUCTION

Due to increase in computing power it has become feasible to optimize shapes of curved dipole antennas with high number of degrees of freedom for shape representation.

Despite increased computing power, the shape of the antenna should approximated with minimal number of degrees of freedom and the scattering problem associated with the shape approximant should be easy to solve numerically.

Solutions to the optimization problem are a new near-$1\frac{1}{2}$ wavelength curved dipole antenna and an antenna closely resembling the one in [1]. The latter shape resembles also the classic curved dipole antenna presented in [2].

ANTENNA MODEL AND DISCRETIZATION

The reference antenna is modelled as a perfect electric conductor (PEC) cylinder and the time harmonic Maxwell's field equations are solved using electric field integral equation for PEC [3] which is discretized using Galerkin's method and RWG basis functions [4].

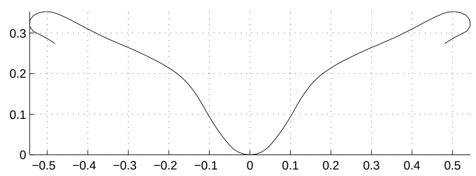
The PEC cylinder is meshed as a triangulated octagonal cylinder with circumference equal to cylinder with diameter of $\frac{\lambda}{100}$. Such a mesh has 972 faces and 1458 edges.

SHAPE REPRESENTATION

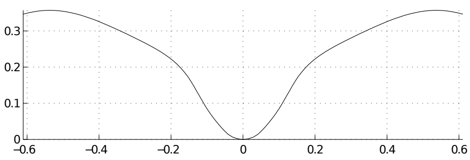
The shape of the antenna is sought as a symmetric arc-length parametrisable plane curve. Such curves can be approximated by curves with piecewise constant curvature function κ. Thus, the coordinates $\phi(t) = [\phi_1(t), \phi_2(t)]$ in $\mathbb{R}^2$ of the curve with parameter value t are given by

$$\begin{cases} \phi_1(t) = \int_0^t \cos(\int_0^s \kappa(\tau)d\tau)ds \\ \phi_2(t) = \int_0^t \sin(\int_0^s \kappa(\tau)d\tau)ds \end{cases} . \tag{1}$$

The best property of this method is that it can produce antennas that can curve "backwards" while still producing meshes where triangles are well shaped. Additionally, it turns out that any continuously differentiable arc-length parametrisable plane curve can be approximated with this method.



(a) The antenna shape with impedance target.



(b) The antenna shape without impedance target.

Figure 1: Optimization solution directivities and impedances. Length units are in wavelengths.

OPTIMIZATION AND RESULTS

The used optimization algorithm was BFGS (Broyden-Fletcher-Goldfarb-Shanno) with constraints to ensure that the curve does not bend too much and it's length stays bounded from above and below.

The new antenna shape was produced by optimizing directivity and impedance simultaneously while for the previously presented antenna [1], [2] only directivity was optimized.

For the antenna with impedance goal the length is constrained to $1.1\lambda \ldots 1.9\lambda$ which yields an antenna of length 1.554λ. The directivity and impedance of the resulting antenna are $7.165dB$ and 75Ω and its shape is presented in Fig. 1(a).

Without the impedance target the length of the antenna is constrained to $1\frac{1}{2}\lambda$. The directivity and impedance of the result are $7.198dB$ and $(105+i18)\Omega$ and its shape is presented in Fig. 1(b).

CONCLUSION

By using good antenna shape representation method, a wide class of smooth wire dipoles can be obtained and the impedance tuning of the antenna can be done by changing the shape and length of the antenna while still retaining the desired directivity properties.

References

[1] D. K. Cheng, C. H. Liang, "Shaped Wire Antennas with Maximum Directivity," *Electronics Letters*, Vol. 18, No. 19, pp. 816-818, 16. Sep. 1982.

[2] F. Landstorfer, "Zur optimalen form von linearantennen," *Frequenz*, vol. 30, no. 12, pp. 344-349, 1976.

[3] A.J. Poggio, E.K. Miller, "Integral equation solutions of three-dimensional scattering problems," In: Mittra R, editor, *Computer techniques for electromagnetics,* Oxford, UK: Pergamon Press; 1973.

[4] D. R. Wilton, S. M. Rao, A. W. Glisson, "Electromagnetic scattering by surfaces of arbitrary shape," *IEEE Transactions on Antennas and Propagation*, vol. 30, pp. 409-418, May 1982.