On the Cross-Polarization Characteristics of Crooked Wire Antennas Designed by Genetic-Algorithms

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Introduction:

In recent years Genetic Algorithms have found numerous applications in the design and optimization of antennas. Altshuler and Linden have presented a crooked wire antenna made up of a few straight segments above a ground plane and fed by a coaxial line at the base [1,2]. The design of such an antenna was facilitated by the use of a genetic algorithm (GA) optimization. The input VSWR in a 50 Ω line and uniform right hand circular polarized (RHCP) radiation over nearly a hemispherical region were the parameters optimized in their design process. The cross polarization level was not specified in the cost function and it was not discussed in the analytical or experimental pattern data of the antennas designed in [1,2].

In many modern communication applications there is a need for simple circularly polarized antennas for hemispherical coverage with good axial ratio or low value of cross polarization. We revisited the crooked wire antenna because of its simplicity. This paper presents results of our investigation on the crooked wire antennas and other elements.

Methodology

Fig. 1 shows a sketch of a crooked wire antenna above a ground plane. It is fed at its base by a coaxial line. In the analytical model we used a delta gap source at the origin. We used an optimization process similar to that employed by Altshuler and Linden [1]. The numerical electromagnetic code (NEC 4) [3] was used in conjunction with a genetic algorithm [4], with slight modification of both codes. The numerical value of the cost function that was minimized was obtained as a weighted sum of the VSWR, the far field RHCP pattern fluctuation and the cross polarization level over a number of elevation and azimuth angles, (θ,ϕ).

We chose 5,6, or 7 straight segments for the crooked wire antenna. For each straight segment three parameters were assigned. These were the length, elevation and azimuth angles specified in a local coordinate system, e.g., (l_i, θ_i, ϕ_i) for the segment i. θ_i and ϕ_i are measured from the end point of segment i-1 in a plane parallel to the ground plane with respect to a local z-axis directed vertically. The range of values for ϕ and θ are given by $-\pi \le \phi \le \pi$ and $0 \le \theta \le \pi$ respectively, except for the first segment where θ value is limited to $\pi/2$. In the GA each chromosome consists of 105 binary genes for a 5-segment antenna with the use of 7 bits for each of the 15 parameters. Bigger chromosomes were used for 6 and 7 segment antennas.

The GA code initializes a random sample of 100 individuals with different parameters to be optimized. The elements in which wire segments intersected, touched the ground plane, or extended outside a cube of linear dimension equal to half wavelength were excluded from the population. The selection scheme used is tournament selection with a shuffling technique for choosing random pairs for mating. Jump mutation, Creep mutation, and uniform crossover were employed. GA input data were varied and as many as 1000 or more generations of computations were reached to make sure that near optimum results were obtained.

Results and Discussion

With a few straight segments such as 5,6, or 7, GA could not produce the required circularly polarized antenna for nearly hemispherical coverage with a low cross polarization.

Our subsequent investigations left the VSWR and pattern fluctuation specifications unconstrained. The axial ratio with the RHCP as the principal polarization was the only parameter that was optimized. Even in this case it was not possible to produce an antenna design with the worst case axial ratio better than 4 dB over $0 \le \theta \le 70^\circ$. The near optimum axial ratio was –5.6 dB for $0 \le \theta \le 25^\circ$. This value improved to a figure of –3.2 dB when the maximum value of θ was reduced to 10°. In all the computations mentioned above, pattern data were computed in 5° intervals for θ and 11.25° intervals for ϕ. Even for the case of a single evaluation at $\theta = 0^\circ$ the optimum value of the axial ratio was in the order of -2 dB. The pattern peaks were found to be outside the elevation angular region of interest. Thus our investigations showed that with a few straight segments and with a single feed it was not possible to produce circular polarization with good axial ratio.

GA optimization carried out without a constraint on axial ratio or cross polarization produced results similar to that of Altshular. In this case it was possible to design an antenna with an input impedance close to (50 + j 0) Ω. A near uniform pattern for the RHCP over the hemispherical region is possible. However, since the LHCP is not specified, its value is found to be as high as that of RHCP in some angular regions. An example of such a GA optimized pattern is shown for two azimuth values in Fig.2.

Conclusion:
From the results of our investigation it was found that with a few straight segments it was not possible to produce circular polarization with a low value of cross polarization over a wide angular region. If the number of segments is increased to a large value the antenna shape would approach that of a spiral or curl antenna [5]. Additional results on the crooked wire and other antennas will be presented in the symposium.

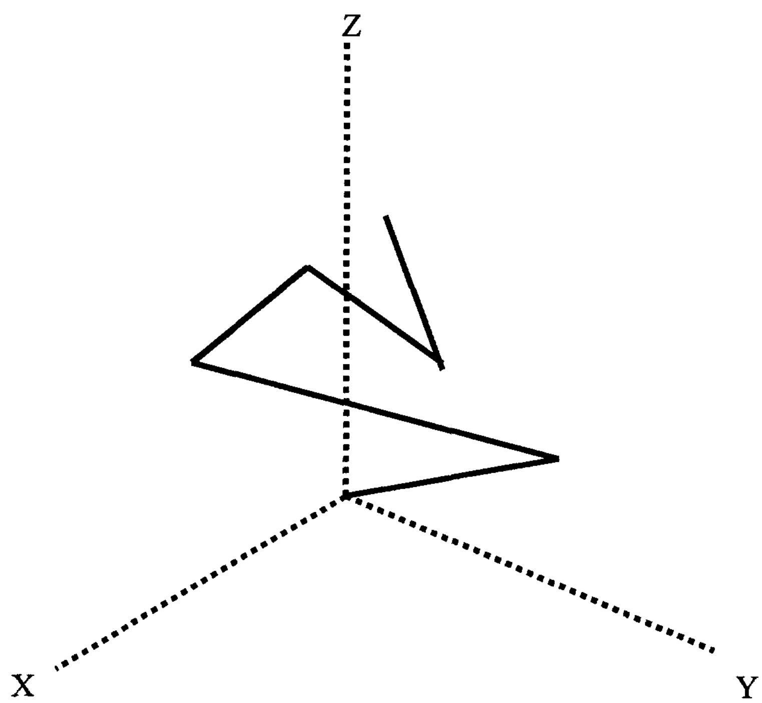

Fig. 1 A sketch of the crooked wire antenna

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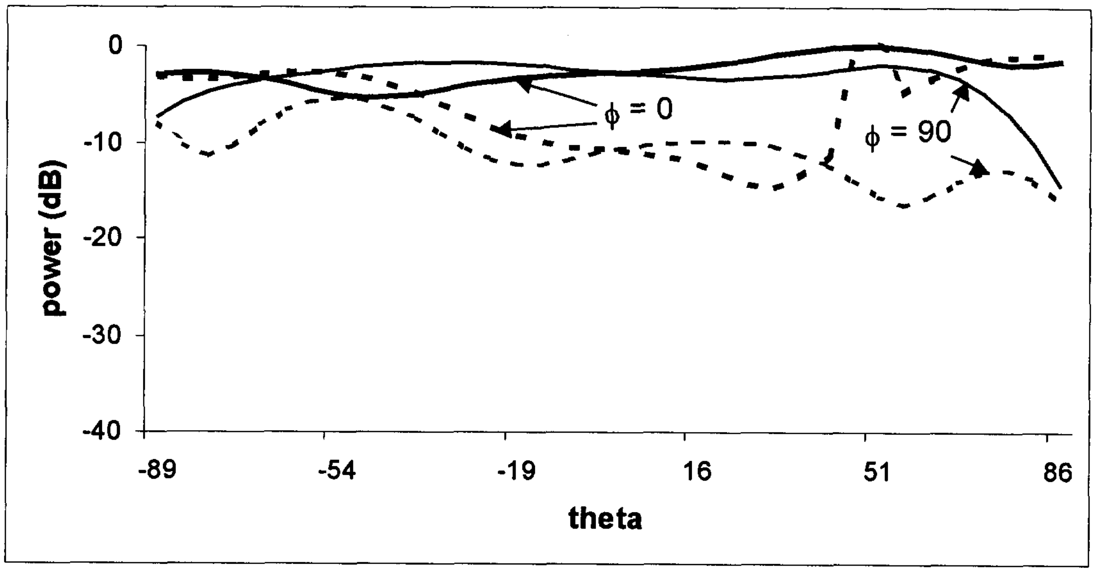

Fig. 2 Radiation pattern of a five-segment crooked wire antenna designed by GA with cross-pol unconstrained (solid line – rhcp, dashed line – lhcp)