HF Meandered Line Dipoles Optimized with Simulated Annealing

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Electrically small meandered line dipoles for HF (28 MHz) are proposed. The antennas are less than 40% of the length of a conventional half wave dipole, and are self-resonant. The spacing and size of the meandered loops were optimized using simulated annealing, and a prototype was constructed to verify the design. Experimental results are consistent with numerical predictions.

Introduction

Full-sized antennas for the HF bands can be exceptionally large, and sometimes due to space limitations it is necessary to resort to the use of shortened antennas. Techniques for shortening the overall length of a dipole without having to utilize lumped loading include zigzagging the elements [1], or using a meandered line [2]. Recently, Marrocco proposed several meander line antennas for use in RFID applications, which were optimized with a genetic algorithm for maximum gain [3]. In this effort, simulated annealing was used to optimize meandered line dipoles for maximum efficiency, input resistance, and for self-resonance.

Antenna Optimization

The dimensions for the meandered line dipoles were optimized using a Simulated Annealing algorithm [4] combined with the Numerical Electromagnetics Code (NEC) source code [5]. The optimization parameters were: 1) the lengths of the meandered loops 2) the widths of the loops, and 3) the overall length of the antenna. The antennas were optimized for maximum radiation efficiency, and for maximum resistance and minimum reactance at a frequency of 28.6 MHz. The overall width was restricted to a maximum of 75 centimeters, and the overall length was restricted to no greater than 2 meters. Each arm of the dipole was required to make five alternating 90° turns, with both halves of the antenna being symmetrical. Four conductors were modeled, including ¾ inch (1.9 cm), ½ inch (1.25 cm), ¼ inch (0.64 cm) diameter tubing, as well as 14 gage wire. The conductivity of the conductors was assumed to be 5.7×10^7 S/m, and the antennas were modeled for the performance in free space. The accuracy of the dimensions in the simulations was limited to 1 mm, as constructing an antenna to smaller tolerances was deemed to be unfeasible. The execution time of the optimization runs was under an hour for each case.

The optimized dimensions of the antennas are given in Table 1, and the proposed antennas are illustrated in Figure 1. The predicted input resistances at resonance ranged from 15 ohms for the ¾ inch copper tubing antenna, to 23 ohms for the wire version.

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Experimental

A prototype of the ½ inch copper tubing design was constructed to verify the predicted performance. The copper pipes were cut with a precision of 1 mm, with care taken to account for the added length contributed by the 90° elbow joints. The structure was supported at the top by a PVC tubing frame, although the antenna was sufficiently rigid that this was probably unnecessary. A Plexiglas dowel was used to join the two halves of the dipole together, and short lengths of 14 gage wire were soldered in place at the feed point to facilitate coupling to a matching transformer. The antenna was mounted on a 0.6 wavelength high dielectric mast, over snow-covered terrain. An initial measurement of the driving point impedance indicated that actual resistance at resonance was slightly lower than predicted (12.61 ohms versus 18 ohms). Accordingly, a 12.5:50 ohm matching transformer was used to connect the antenna to a 50 ohm feed line. To prevent any scattering effects from the coaxial line from interfering with the measurements, snap-on ferrite beads were placed every 2 meters down the length of the coax [6].

Figure 2 shows the predicted and the measured VSWR assuming a 18:50 ohm matching transformer for the former case, and a 12.5:50 ohm transformer for the latter. The measured resonant frequency was 28.85 MHz, compared to the predicted free space frequency of 28.6 MHz. At present, efforts are underway to investigate the variation of the input impedance with the height above a lossy ground. Numerical simulations suggest that the gain for these antennas would be similar to that for a full-sized dipole (approximately 1.93 dBi versus 2.1 dBi). The normalized gain pattern for the ½ inch tubing antenna is shown in Figure 3.

Conclusions

A self-resonant meandered line dipole is proposed. The dimensions of the antenna were optimized using a simulated annealing algorithm used in conjunction with the NEC code. The antenna can easily be matched to a 50 ohm transmission line, and exhibits a 2:1 VSWR bandwidth of 650 kHz. Numerical simulations indicate the efficiency of the antenna is better than 98%, and the radiation patterns are similar to that of a half-wave dipole antenna.

References

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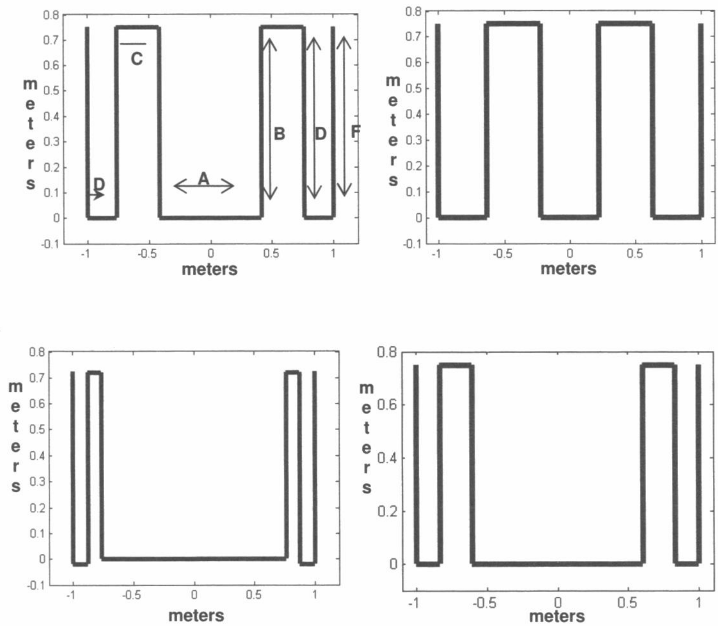

Figure 1. The optimized meandered length dipoles. The upper right plot is optimized for the 1.9 cm diameter tubing, the upper left is for 1.25 cm diameter tubing, the bottom right is for 0.64 cm diameter tubing, and the bottom left is for 14 gage wire.

Antenna Conductor	A (cm)	B (cm)	C (cm)	D (cm)	E (cm)	F (cm)	Predicted Resistance (Ω)
1.88 cm tubing	44.6	75.0	41.2	75.0	36.5	75.0	15.7
1.25 cm tubing	83.2	75.0	34.7	75.0	23.7	75.0	18.0
0.64 cm tubing	120.0	75.0	23.3	75.0	16.7	75.0	20.7
14 g wire	152.2	72.0	11.8	74.0	12.1	74.2	23.0

Table 1. The dimensions, in centimeters, of the meandered line dipoles

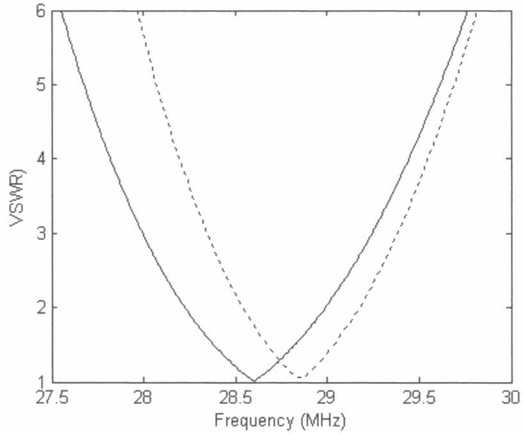

Figure 2. The predicted (solid line) and measured (dashed line) VSWR. The predicted line assumes a 18:50 ohm matching transformer is used, and the measured line was taken with a 12.5:50 ohm transformer at the feed point.

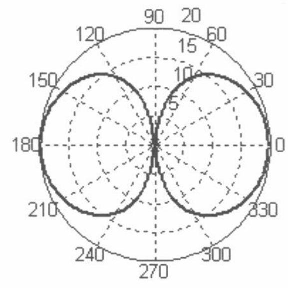

Figure 3. Normalized gain pattern