

Bending the Dipole

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Abstract— This paper presents simulation results of bending the half-wave dipole antenna at different points of its length. Antenna under test is a center-fed dipole simulated at two different dimensions: half-wave length and resonant length. The bend angle is incremented by 5 degrees starting from 5 degrees to 90 degrees. The entire dipole is divided into 32 segments. There are 16 segments from one end of the dipole to its center. The bent length is incremented by one segment length per test point. Parameters such as impedance, and propagation pattern are simulated and presented. Analysis of results is done. Direction for further study is enumerated.

Keywords-dipole, simulation, EZNEC, bending, pattern

I. INTRODUCTION

Outdoor antennas were subject to nature's frivolity. After a storm or a tornado, bent antennas were common fixtures around an affected community. Needless to say, parameters (and, consequently, performance) were affected. Bending of antennas, though, were unintentional. A little curiosity led to formal inquiry. What if an antenna was intentional bent? What parameters are affected by the bending?

Like-minded researchers had asked the same questions. The study done in [1] intended to design a dipole antenna to fit in a limited space. Part of the length of the dipole at both ends was bent to a 90 degree angle. The current study intended to find the behavior of a number of parameters as the center-fed dipole antenna is bent at both ends by an increment of 5 degrees. These antenna parameters are the impedance and the propagation pattern.

II. LITERATURE REVIEW

The first mention of a similar antenna studied in [1] was in a book chapter written by J.A. Fleming [2] dated 1906. Yet, both works had provided little information on the particular performance of a bent dipole antenna. In 1970, a paper [3] on radiation characteristics of bent-wire antennas was published. The antenna was a dipole, but it was bent in circular and parabolic geometries. The current work bent the dipole at similar length from both ends and at the same angle. Fig. 1 showed the test configuration. BL stood for bent length, and θ is the bend angle.

In [4], the importance of properly characterizing antenna impedance and far-field propagation pattern of an antenna was noted for practical use. This work put emphasis on the same parameters for further inquiry on bent dipole. Recent

studies [5][6] tended to focus on the degradation effect of bending the dipole. This work meant to simulate the aforementioned antenna parameters and to characterize the effect of bending on a dipole.



Figure 1. Test Configuration of the Bent Dipole.

III. SETTINGS

A. Configuration of Antenna Under Test

The first configuration was at non-resonant length (i.e., a half-wave-long dipole). The second configuration was at resonant length (i.e., when impedance is purely resistive). Since the dipole antenna was center-fed, there was an equal length on both sides. Each side was divided into sixteen segments which served as test points for the bent length. Each test length was then bent at an increment of 5 degrees from 0 to 90 degrees.

B. Configuration of Simulation Software

The wire was defined as having resistivity of $3.2 \times 10^{-8} \Omega\text{-m}$ and a relative permittivity of 1.000022. The aluminum bars available locally had these particular characteristics. This was done to allow for future experiments using such wires. The software used was EZNEC+ v5.0 with the help of AutoEZ v2.0. Free space was used as the ground type. Test frequency was set at 434.482 MHz with a wavelength of 690 mm. Wire diameter was at 6.35 mm or 0.25 in.

IV. RESULTS AND ANALYSIS

There were two data set of interest: antenna impedance and propagation pattern. The antenna impedance was given in both rectangular (i.e., resistance and reactance) and polar (i.e., amplitude and argument) forms. Each quantity had data

set for both non-resonant and resonant lengths, and both were presented side by side here. For Fig. 2 to 7, the vertical axis was the magnitude of the quantity being shown. The axis leaning to the left was the bend angle and the values were in degrees. The axis leaning to the right was the bent length and the values were multiplied to the wavelength.

Fig. 2 and 3 showed the resistance of the bent dipole at non-resonant and resonant lengths, respectively.

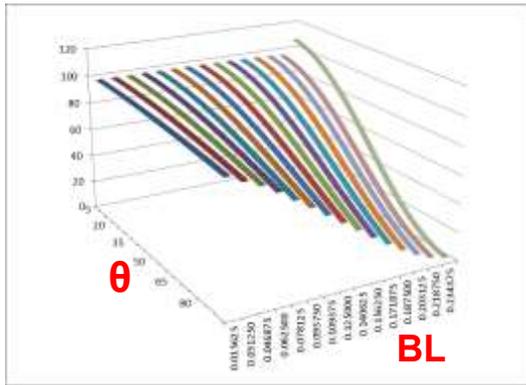


Figure 2. Resistance at Non-Resonant Length.

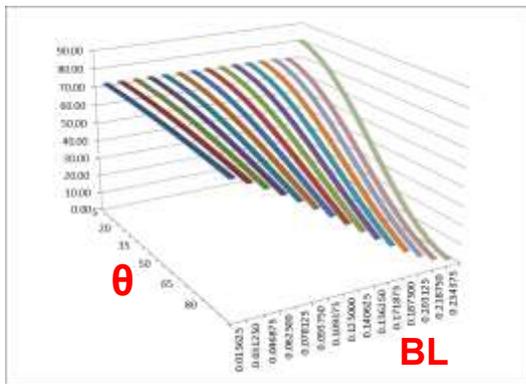


Figure 3. Resistance at Resonant Length.

The two data sets seemed to indicate that the variation of resistance was relatively the same. At non-resonant length, the resistance started off at around 98 Ω . At resonant length, the resistance started off at around 73 Ω .

Fig. 4 and 5 showed the reactance of the bent dipole at non-resonant and resonant lengths, respectively. The two data sets seemed to – again – indicate that the variation of reactance was relatively the same. At non-resonant length, the reactance started off at around 50 Ω . As expected, the reactance started off at 0 Ω at resonant length.

Generally, there was lowering of impedance as the bend angle was increased or the bent length was increased – or both.

Fig. 6 and 7 showed the impedance of the bent dipole at non-resonant and resonant lengths, respectively. The two data sets seemed to indicate that the variation of impedance between non-resonant and resonant lengths offered more contrast than the resistance and reactance data sets.

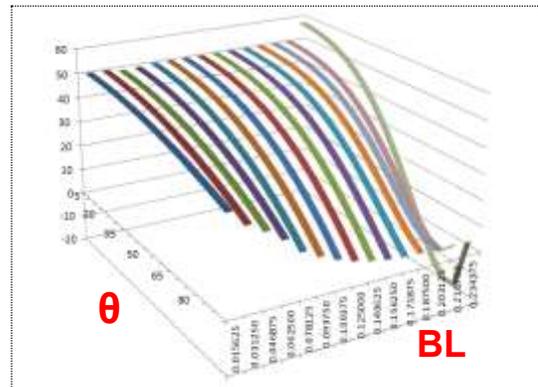


Figure 4. Reactance at Non-Resonant Length.

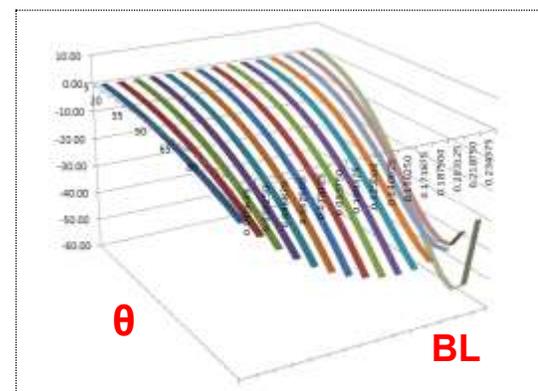


Figure 5. Reactance at Resonant Length.

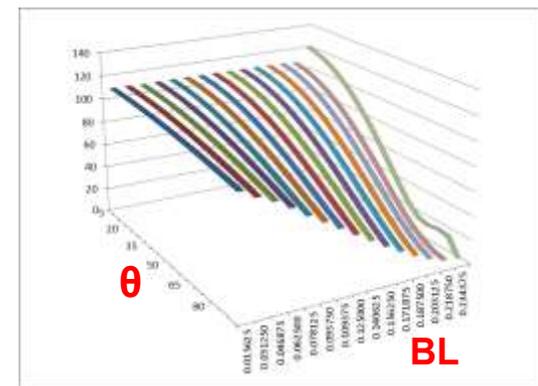


Figure 6. Impedance at Non-Resonant Length.

Fig. 7 seemed to suggest that impedance of resonant-length dipole was less susceptible to bending than its non-resonant counterpart.

Fig. 8 to 10 showed the propagation pattern of non-resonant antenna at different bent lengths. Fig. 8 showed the propagation pattern at the far field for bent length at $1/16 \lambda$. The pattern at the top-left corner was for a bend angle of 15 degrees. There was an increment of 15 degrees as one moved in a U-shaped pattern. The bottom-left corner then was at a bend angle of 45 degrees, bottom-right corner at 60

degrees, and top-right corner at 90 degrees. Every figure thereafter was arranged in the same manner.

For lack of space, only the 15, 30, 45, 60, 75 and 90 degrees were shown in each figure – and only the bent length of 0.0625, 0.125 and 0.1875 of the wavelength.

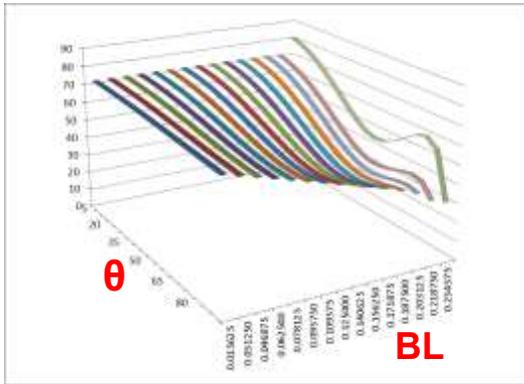


Figure 7. Impedance at Resonant Length.

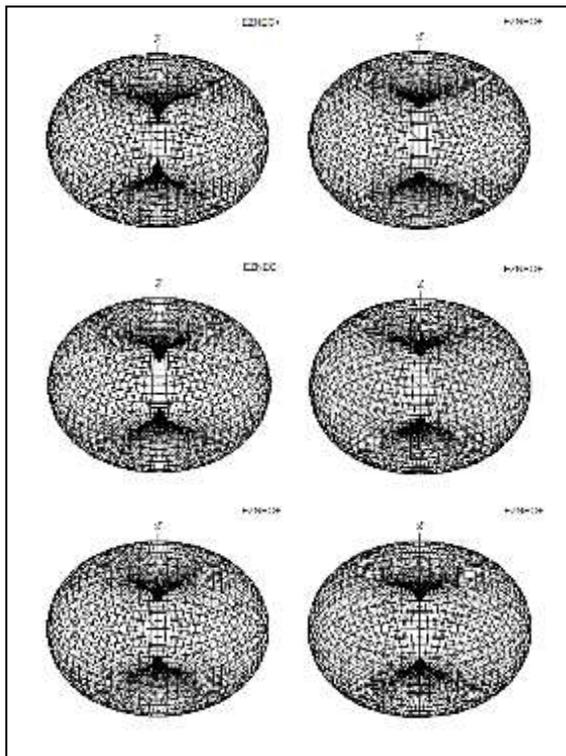


Figure 8. Propagation Pattern at Bent Length of 0.0625λ (Non-Resonant).

The maximum gain of the 3D pattern in Fig. 8 was between 2.05 and 2.20. There was an almost imperceptible change in the pattern as the bend angle was increased from 5 degrees to 90 degrees. For the current intent, this change was deemed negligible.

Fig. 9 showed the propagation pattern at the far field for bent length at 2/16 of λ. The maximum gain of the 3D pattern was between 1.62 and 2.21. There was still an almost imperceptible change in the pattern as the bend angle was

changed from 5 degrees to 90 degrees. Again, for the current intent, this change was deemed negligible.

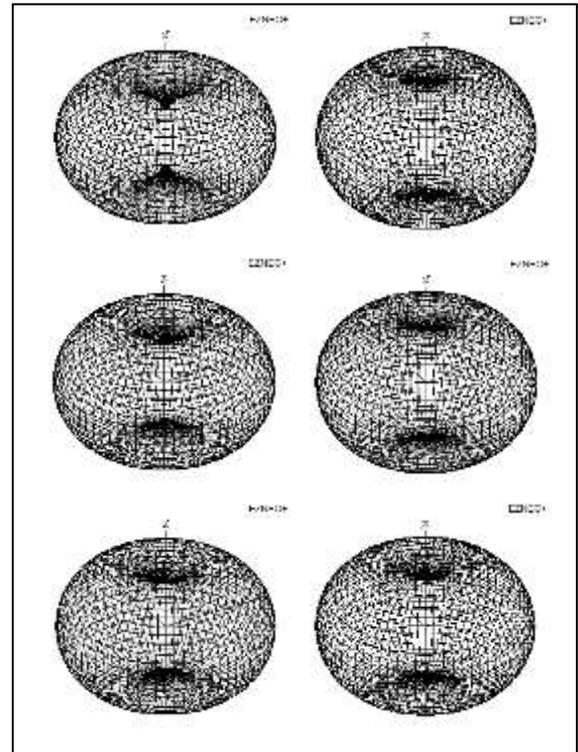


Figure 9. Propagation Pattern at Bent Length of 0.125λ (Non-Resonant).

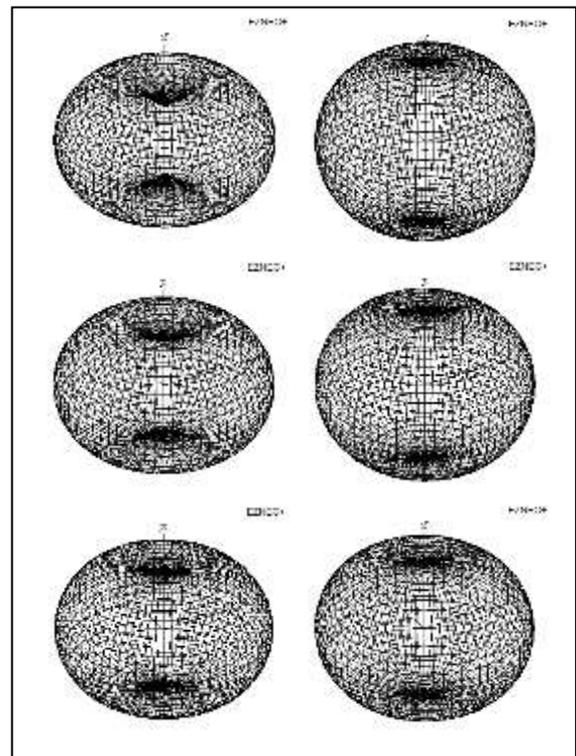


Figure 10. Propagation Pattern at Bent Length of 0.1875λ (Non-Resonant).

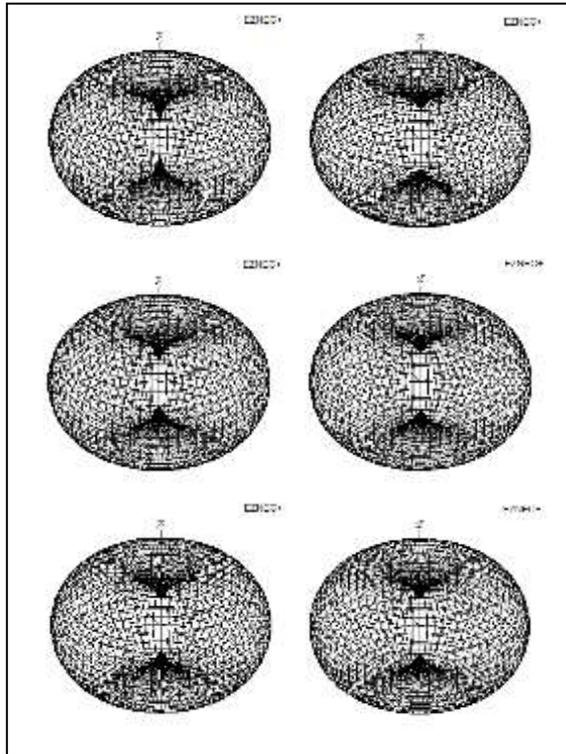


Figure 11. Propagation Pattern at Bent Length of 0.0625λ (Resonant).

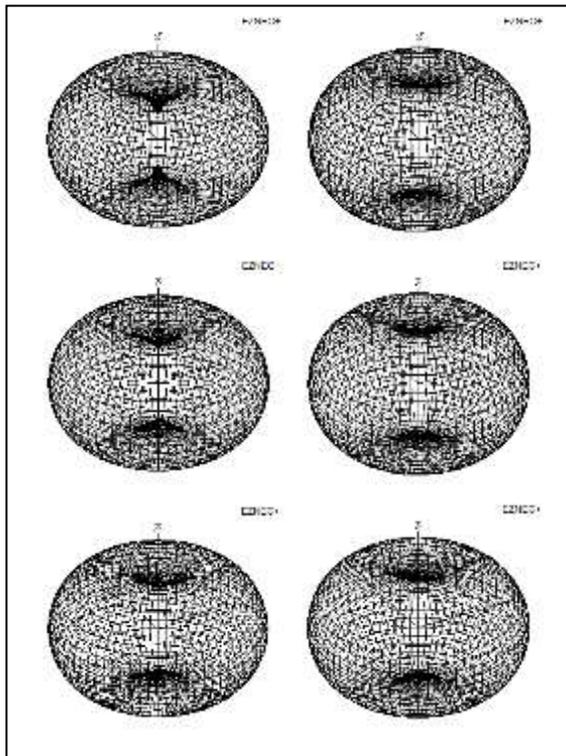


Figure 12. Propagation Pattern at Bent Length of 0.125λ (Resonant).

Fig. 10 showed the propagation pattern at the far field for bent length at $3/16$ of λ . The maximum gain of the 3D

pattern was between 0.85 and 2.21. There was an obvious change in the antenna pattern between bend angles of 5 and 90 degrees. At 90-degree bend angle, the pattern looked omni-directional – it was not, though.

Fig. 11 to 13 showed the propagation pattern of resonant antenna at different bent lengths. As with Fig. 8, Fig. 11 showed the propagation pattern at the far field for bent length at $1/8$ of the resonant length. The maximum gain of the 3D pattern was between 2 and 2.13. There was also an almost imperceptible change in the pattern as the bend angle was increased from 5 degrees to 90 degrees. This change was deemed negligible.

Fig. 12 also bared similarities to the propagation pattern at the far field for bent length at $2/8$ of the resonant length shown in Fig. 9. The maximum gain of the 3D pattern was between 1.66 and 2.13. There was now a perceptible change in the pattern as the bend angle was increased from 5 degrees to 90 degrees.

Fig. 13 showed the propagation pattern at the far field for bent length of $3/8$ of the resonant length. The maximum gain of the 3D pattern was between 1.04 and 2.13. As with Fig. 10, there was a now an obvious change in propagation pattern between bend angles 5 and 90 degrees.

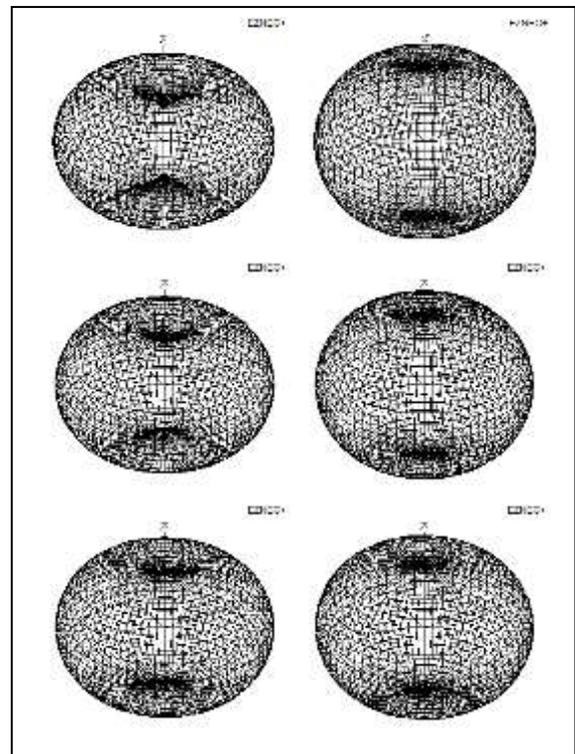


Figure 13. Propagation Pattern at Bent Length of 0.1875λ (Resonant).

Bending the dipole at resonant and non-resonant lengths provided a number of information. As bend angle changed, the antenna impedance of both non-resonant and resonant-length dipole changed relatively in the same manner. They started off at different values, but the variations are almost identical. The same relationship seemingly existed with the propagation pattern.

V. DISCUSSION

Fig. 14 showed the effect of bending to impedance at various bent lengths for non-resonant dipole. The vertical axis measured the change of impedance between bend angles of 5 and 90 degrees. The value was taken from the ratio of the antenna impedance at 90 degrees over the impedance at 5 degrees. The horizontal axis featured the different bent lengths being considered. It was obvious that the impedance significantly changed as the bent length was increased.

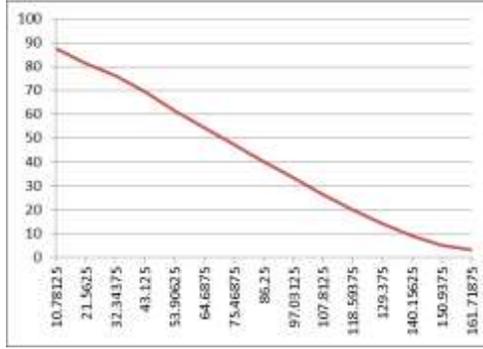


Figure 14. Impedance Change With Bend Angle (Non-Resonant).

Fig. 15 showed the effect of bending to impedance at various bent length for resonant dipole. The axes were the same as Fig. 14. The change of impedance, though, was not as sharp as the non-resonant data.

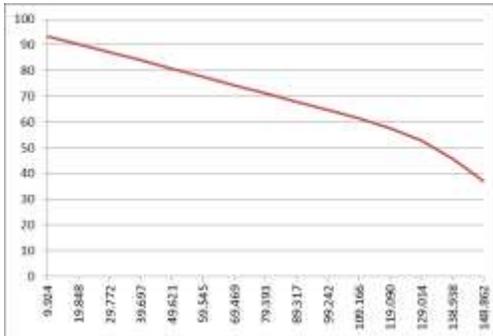


Figure 15. Impedance Change With Bend Angle (Resonant).

It was worth noting that the values indicated in Fig. 14 and 15 were ratios between the impedance at 90 degrees over the impedance at 5 degrees. The change of impedance as the bend angle was varied on a particular bent length was not linear but a higher-order polynomial curve.

It was observed that the impedances at 5, 10 and 15 degrees remained relatively the same (i.e., a difference of about 2Ω) for the first two-thirds of bent lengths being considered. It was also observed that the impedances at bend angles from 70 to 90 degrees remained relatively the same – again, a difference of 2Ω – for the first two-thirds of bent lengths being considered.

VI. CONCLUSION AND RECOMMENDATIONS

In conclusion, bending the dipole resulted to the same variation of impedance and propagation pattern whether non-resonant length or resonant length was used. Generally, a decrease in impedance and maximum gain happened when an increase in bend angle was implemented.

It is recommended that further study on the bandwidth of the bent dipole limited by a particular value of standing wave ratio is done. It is further recommended that bent dipoles are used in an array or a hybrid antenna.

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