Bandwidth Enhancement of Dipole Antennas using Parasitic Elements

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Abstract **─** Dipole antennas have a limited bandwidth which restricts their use to narrow bandwidth applications. To improve the functionality of a dipole antenna, additional wire elements can be added to the dipole antenna to increase the impedance matching and bandwidth. A design for a modified dipole antenna is proposed and analyzed using multiple computational electromagnetic software to determine how the additional wire elements affect the input impedance bandwidth and radiated fields. The antenna was then fabricated and tested and compared to simulation results. The modified dipole antenna shows a bandwidth improvement of more than four times, approaching 31%, while maintaining radiation patterns similar to a traditional dipole antenna with slightly higher gain.

Index Terms **─** Antenna, bandwidth, dipole, far field, gain, impedance.

I. INTRODUCTION

Many modern wireless communication systems require antennas that can provide omnidirectional radiation coverage. As such, the classic half-wavelength dipole antenna which provides a uniform omnidirectional coverage is a popular candidate for these systems. The primary drawback for these antennas however is the fact that they operate in a very narrow bandwidth, which limits their application in modern communication systems. In this work, we propose a new configuration for the classic wire dipole antenna, to improve its bandwidth. The presented design is an extension of the configuration proposed in [1]. Four wire elements connected to the wire dipole antenna, as shown in Fig. 1. This essentially creates a quasi-log periodic wire antenna, which minimizes the reactive part of the impedance and improves the matching at the input port of the antenna, resulting in a wider bandwidth. It is shown that by proper tuning of these parasitic wires, the bandwidth of the classic dipole antenna can be increased by more than four times, while maintaining an omnidirectional radiation pattern and slightly increasing the gain.

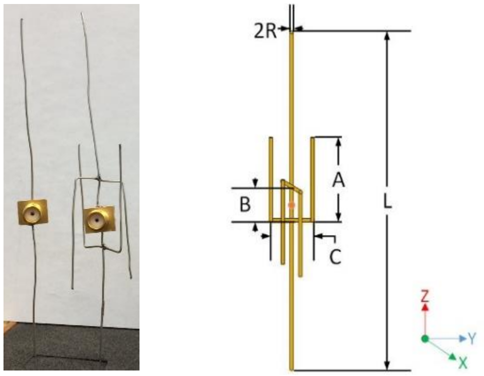

Fig. 1. Dipole antenna models: (left) dipole antenna, (center) modified dipole antenna, and (right) the modified dipole configuration along with design parameters.

II. DESIGN

The initial design for this study is based on the work reported in [1]-[3]. The objective of this study is to further the analysis of the modified dipole antenna configuration shown in Fig. 1. To this end, we compare the performance of the classic wire dipole antenna, with the modified dipole. The analysis is conducted using three computational electromagnetic software: FEKO [4], Ansys HFSS [5], and CEMS [6]. A parametric study for design parameters A, B, and C was conducted using HFSS to understand how the impedance matching of the antenna is effected by the additional wire elements. The parameters R and L were set to 0.2 mm and 128 mm respectively in all used software packages and for the parametric study.

Figures 2-4 show the result of the parametric study. Figure 2 shows the results when varying A with B=10 mm and C = 18 mm. As the length of A increases the real part of the input impedance decreases. The imaginary part of the input impedance curve straightens out as the length of A increases. From the results depicted here, it can be seen that the length of A that corresponds to a real input impedance close to 50 Ohms and an imaginary input impedance around zero, i.e., best matching over a broad frequency range, is for A = 33 mm.

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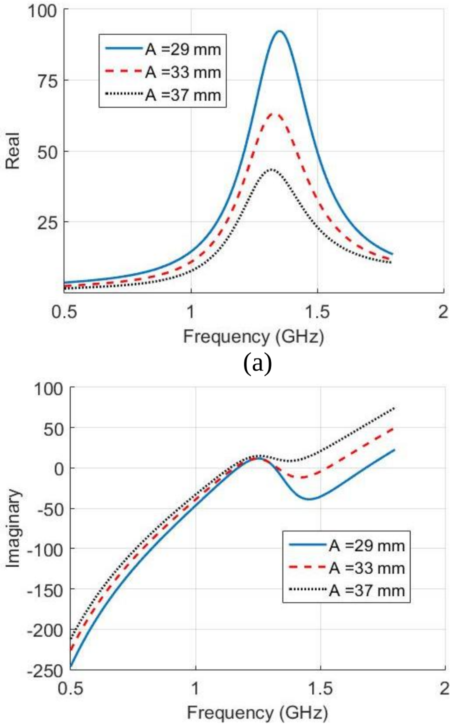
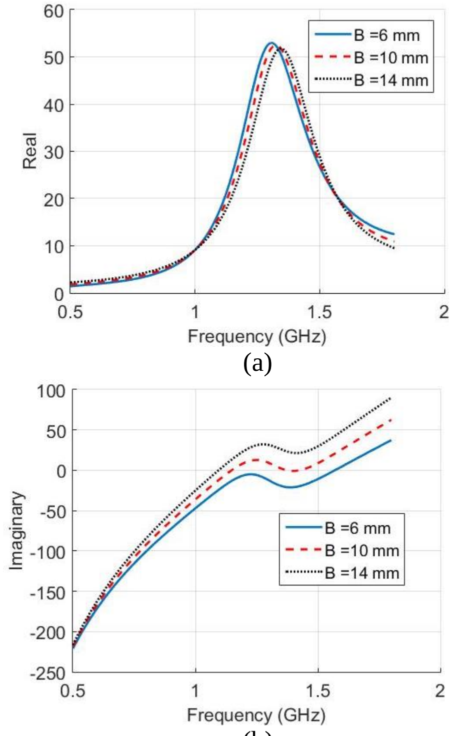


(a)

(b)

Fig. 2. Input impedance versus frequency: (a) real and (b) imaginary.



(a)

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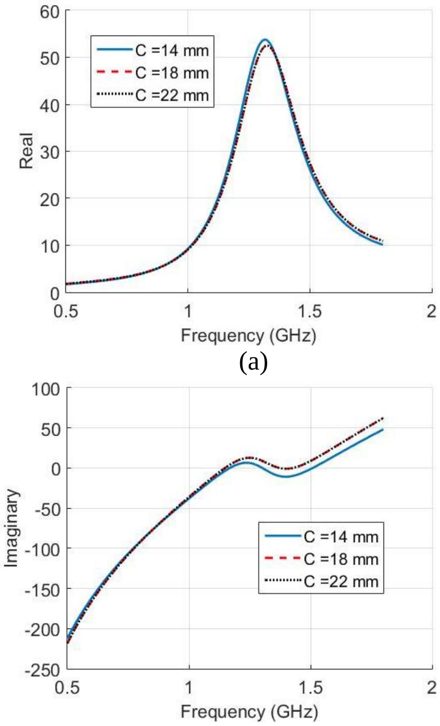
Fig. 3. Input impedance versus frequency: (a) real and (b) imaginary.



(a)

(b)

Fig. 4. Input impedance versus frequency: (a) real and (b) imaginary.

Figures 3 and 4 show the parametric study results for B and C. For the parametric study with B, A = 33 mm and C = 18 mm. For the parametric study with C, A = 33 mm and B = 10 mm. Parameters B and C show similar behaviors as for A, but to less extent. From the study reported here it can be seen that A is the main tuning parameter for impedance matching in this modified dipole configuration. The dimensions of the design parameters were chosen based on the results reported here and are A = 33 mm, B = 10 mm, C = 18 mm, L = 128 mm, and R = 0.2 mm.

III. RESULTS

Using the design dimensions determined in the previous section, the antenna was built and measured as well as simulated using three different computational electromagnetic software, namely: FEKO, Ansys HFSS, and CEMS. For comparison purposes a dipole antenna with the same length as the modified dipole antenna design is also simulated and tested. Figure 5 shows the magnitude of S_{11} versus frequency for the dipole antenna modeled in FEKO and the modified dipole configuration in the three different software packages.

Table 1 shows the original bandwidth and the corresponding improvement for each dipole simulation. The center frequency was determined by finding the -10 dB crossings and calculating the frequency in the middle. For the three modified dipole antennas results in

Fig. 5, the curves are different regions below -10 dB but exhibit a similar behavior. The slight differences can be due to the nature of the three different software packages and how they represent the antenna and the source of excitation. All of the modified dipole models operate at a higher frequency than the traditional dipole antenna and the reflection coefficient curves have two local minimums. The mean improvement in bandwidth is more than four times when comparted to the traditional dipole antennas as can be seen in Table 1. Figure 6 shows the measured reflection coefficient for the two models shown in Fig. 1. The curve does not closely resemble what was simulated, but the overall result is similar. The difference is due to the un-professional construction of the antenna, SMA connector, and from the solder joints which was not accounted for in simulations. The bandwidth of the fabricated modified dipole was improved by approximately four times when compared to the fabricated dipole antenna.

To study the effect of the additional wire elements FEKO was used to examine the radiated far-field patterns. The electric field was examined for the modified dipole antenna as well as a dipole antenna operating at the center frequency of the modified dipole antenna.

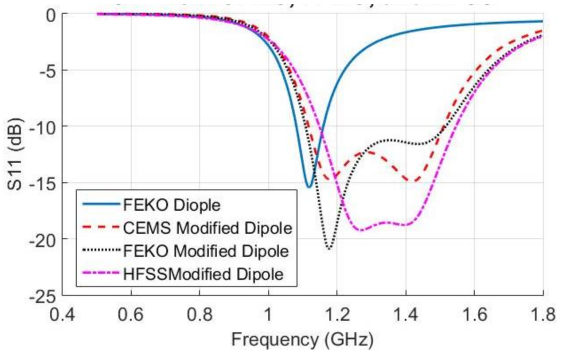


Fig. 5. Reflection coefficient for a regular dipole and the modified dipole using three different software packages.

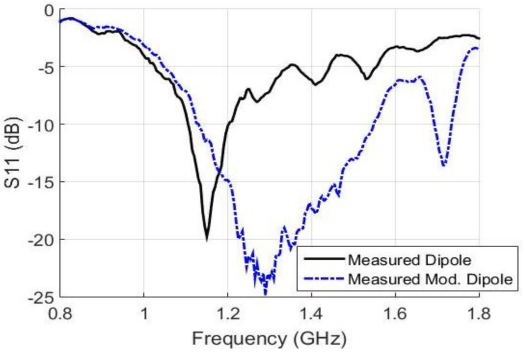


Fig. 6. Measured reflection coefficient for a regular dipole and the modified dipole.

Table 1: Bandwidths of the dipole antennas

Antenna	BW (%)	% BW Improvement
FEKO dipole	7.05	-
CEMS mod. dipole	30.37	23.32
FEKO mod. dipole	31.17	24.12
HFSS mod. dipole	30.35	25.36
Measured dipole	8.24	-
Measured mod. dipole	31.78	23.54

From Figs. 7 and 8 it is observed that the addition of the wire elements does not drastically change the magnitude of E_θ in all three planes across the frequency band. Table 2 shows the gain for both the modified antenna and dipole antenna at three different frequencies within the band.

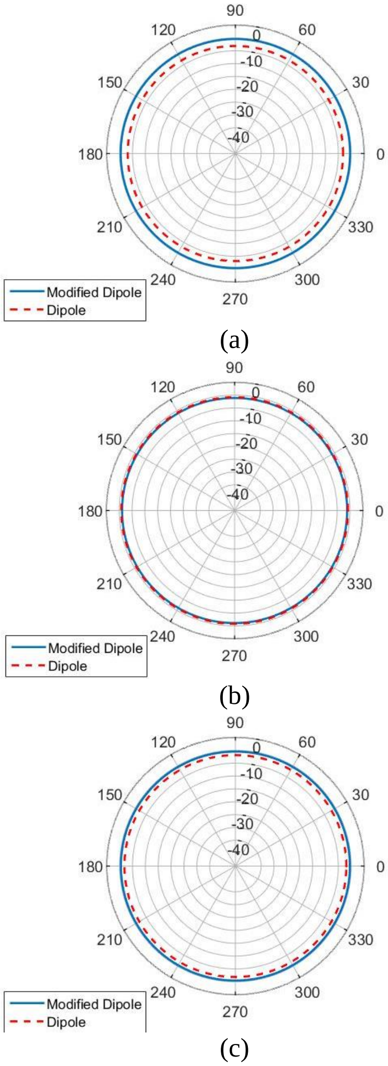
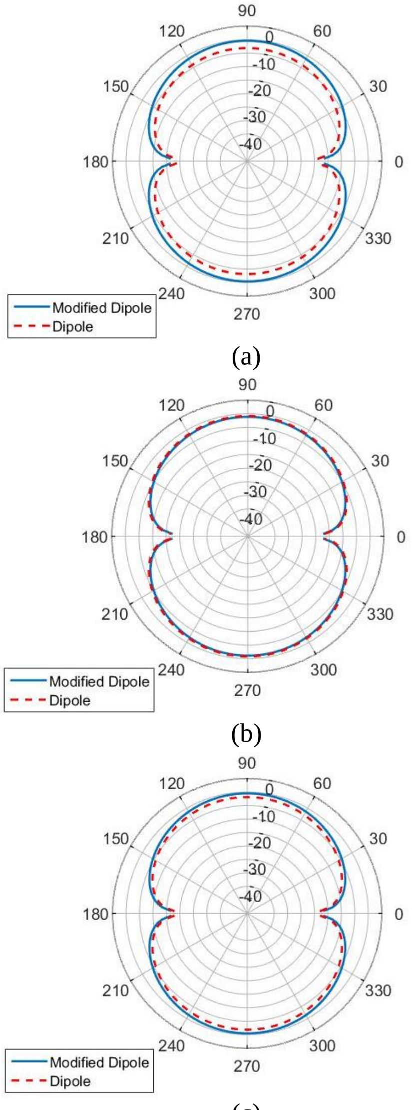


Fig. 7. Electric field in the XY-plane: (a) 1.202 GHz, (b) 1.306 GHz, and (c) 1.410 GHz.



(a)

(b)

(c)

Fig. 8. Electric field in the XZ-plane and YZ-plane: (a) 1.202 GHz, (b) 1.306 GHz, and (c) 1.410 GHz.

Table 2: Realized gain of modified dipole using FEKO

	Realized Gain (dBi)		
Antenna	1.202 GHz	1.31 GHz	1.41 GHz
Modified dipole	2.117	1.92	1.92

Due to the better matching at the input port of the modified dipole, the realized gain of the modified antenna remains around 2 dBi for all three frequencies. The calculated gain of the traditional dipole antenna is 1.94 dBi.

VI. CONCLUSION

A modified dipole antenna configuration is proposed and investigated using three different software packages as well as measured results from built antennas. Additional wire elements are added to a traditional half wave length antenna that enable impedance matching across the band. It is shown numerically and experimentally that this configuration can increase the input impedance bandwidth four times when compared to a traditional dipole antenna. The additional wires do not change the radiation characteristics of the dipole antenna as demonstrated using simulations. The resulting cross polarized electric field component E_ϕ is found to be less than 40 dB of the E_θ component. The gain of the modified antenna is close to 2 dBi over a broad range of frequencies. Based on this study, the proposed modified dipole antenna has the potential to expand the use of dipole antennas in a wide range of applications.

REFERENCES

[1] H.-T. Hsu, J. Rautio, and S.-W. Chang, “Novel planar wideband omni-directional quasi logperiodic antenna,” *Asia Pacific Microwave Conference (APMC)*, Suzhou, China, Dec. 2005.

[2] A. Z. Elsherbeni, P. Nayeri, and C.J. Reddy, *Wire Dipole and Monopole Antennas*, in Antenna Analysis and Design Using FEKO Electromagnetic Simulation Software, ACES Series on Computational Electromagnetics and Engineering, SciTech Publishing, an Imprint of IET, Edison, NJ, pp. 36-38, 2014.

[3] G. R. Hoch, P. Nayeri, and A. Z. Elsherbeni, “Bandwidth enhancement of dipole antennas using parasitic elements,” *The 31st International Review of Progress in Applied Computational Electromagnetics (ACES 2015)*, 2015.

[4] FEKO, EM Software & Systems Inc., Version 7.0.2. https://www.feko.info/

[5] HFSS, Ansys, Release 16.2.0. http://www.ansys.com

[6] CEMS, EM software package based on A. Elsherbeni and V. Demir, *The Finite-Difference Time-Domain Method for Electromagnetics with Matlab Simulations*, ACES Series on Computational Electromagnetics and Engineering, 2nd Edition, SciTech Publishing, an Imprint from IET, Edison, NJ, 2016.