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Journal of Electrical and Computer Engineering Innovations

JECEI, Vol. 5, No. 1, 2017

Regular Paper

Design, Simulation and Implementation of an Active Dual-Band Dipole Antenna Using a Series Stub

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ARTICLE INFO

ARTICLE HISTORY:
Received 14 June 2017
Accepted 16 July 2017

KEYWORDS:
Dipole antenna
Dual-band antenna
Series stub
Military applications

ABSTRACT

In this paper, a new method for designing an active dual-band dipole antenna is proposed. The operating frequencies of the proposed antenna are 150 and 450 MHz that are usually used in military applications. Using a series stub is the main idea in the proposed dual-band antenna, where it makes an independent resonance frequency higher than the main resonance frequency of a conventional dipole. To make appropriate matching impedance in the two frequency bands, the technique of creating an internal coaxial cable is used. Furthermore, to improve the antenna gain, an amplifier is in series part connected to the proposed dipole antenna. The simulated and measured results of the return loss, radiation patterns and antenna gain show that this antenna has a good operation in both resonance frequencies.

1. Introduction

Today with advances in multi-band communication systems, applications in multi-band antennas capable of functioning independently are felt more than ever before [1] [2]. Dual band folded monopole loop antenna for terrestrial communication system [3], dual band hybrid vehicular telephone antenna [4], dual-Frequency strip-sleeve monopole antenna for laptop [5] and stubby monopole antenna for UMTS and WLAN dual-mode mobile phone [6] are referred to as multiband antennas.

This article aims to introduce a dual-band dipole antenna with frequencies at 150 and 450 MHz for use in military systems. In a conventional dipole antenna, antenna feed place is generally at the middle, exactly where it is going to be the maximum. But, the proposed antenna is a dipole antenna with a feed placed out from the center and it is asymmetric. The asymmetric dipole antenna has two resonance frequencies at 150 and 450 MHz. To create the appropriate matching impedance in the second frequency band, the technique of creating an internal coaxial cable in antenna is used.

The distance between cans, the location and type of feeding of dipole antenna that is asymmetric, based on the pattern required at different frequencies and impedance matching between the resonance frequencies is selected. To improve the antenna gain, a suitable amplifier as a series part with the proposed antenna is used. Then, the proposed antenna is checked in inactive mode and also in the presence of the amplifier.

2. Antenna Design

Figure 1 displays the general structure of the proposed dual-band dipole antenna. In general, antenna consists of two separate parts, the first part of the outer body of the antenna in accordance with Figure 1 contains 8 parts and the second part, the inner part of which contains connections to amplifiers and connectors

8 main components of the antenna outer body contain: 1- bottom can with a flat plate, 2- upper can with interconnection, 3- metal cylinder, 4- nut, 5-

teflon cylinder, 6- outer teflon cube, 7- inner teflon cube and 8- teflon cover. Material on the bottom can and the flat plate and the upper can are made up of aluminum. The lower cans with flat plate play the role of one of the two arms of the dipole antenna. Flat metal plate at the end of the antenna arm is used to form the antenna pattern at the desired frequency bands.

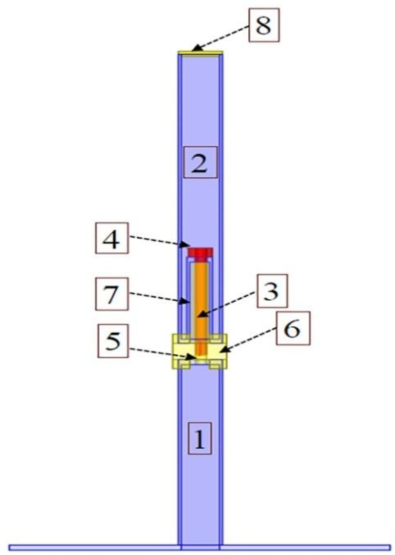
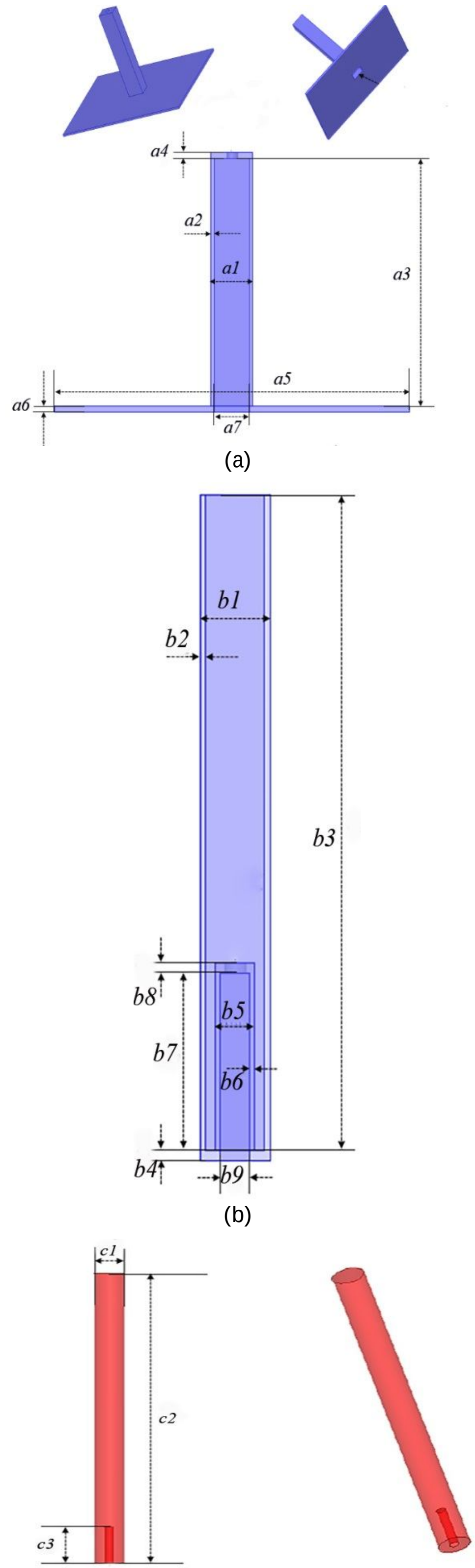


Figure 1: The outer body of the proposed antenna structure with its different components.

Figure 2(a) shows the bottom can with a flat plate with dimensions a1, a2, a3, a4, a5, a6. The top can with internal connection is the second piece of the proposed antenna body which includes internal and external sections as shown in Figure 2 (b). In fact, the inner part which has smaller dimensions has a major role in the creation of a second resonance frequency of the antenna. Metal cylinder shown in Figure 2 (c), has the task of connecting the cerebral connector to the upper can. As shown in Figure 2 (c), inside the cylinder, threads are used to connect the cerebral connector. The dimensions of the designed parts are listed in Table 1.

TABLE 1
THE DESIGNED PARTS DIMENSIONS OF THE ACTIVE DUAL-BAND DIPOLE ANTENNA (DIMENSIONS ARE IN MILLIMETERS)

a1	a2	a3	a4	a5	a6	a7
35	2.5	200	5	300	5	30
b1	b2	b3	b4	b5	b6	b7
35	2.5	315	5	20	2.5	85
b8	b9	c1	c2	c3		
5	15	10	18	15		



(c)
Figure 2: Dimensions of the active dual-band dipole antenna parts (mm) (a) bottom can with a flat plate, (b) top can with interconnection and (c) metal cylinder.

The overall dimensions of the antenna containing both the top and bottom cans are selected in such a way that they can tune the antenna resonance frequency to about 150 MHz (in the range of 30% of bandwidth). The length of the series stub in the top can is also selected in such a way that tune the second resonance frequency to about 450 MHz (in the range of 30% of the bandwidth. The flat bottom plate is used for forming an appropriate pattern at different frequencies. The distance between the cans and the location of the dipole antenna feeding, which is asymmetric, is selected based on the shape of the required pattern at different frequencies and the impedance matching at the two resonance frequencies.

As shown in Fig. 3, the feeding section of the proposed antenna includes a connector for connecting to the body, amplifier and antenna output connectors, all of which are located inside the bottom can (part 1). It should be noted that for the design of the active antenna in the band of 30-500 MHz, the ZKL-1R5 + amplifier is used which is made by Mini-circuits company. This has a wide-bandwidth between 10 to 1500 MHz. The amplifier has high gain of 40 dB throughout the bandwidth of 30 to 500 MHz. Moreover, the amplifier has small dimensions and low weight and low power consumption of 1.5 watts.

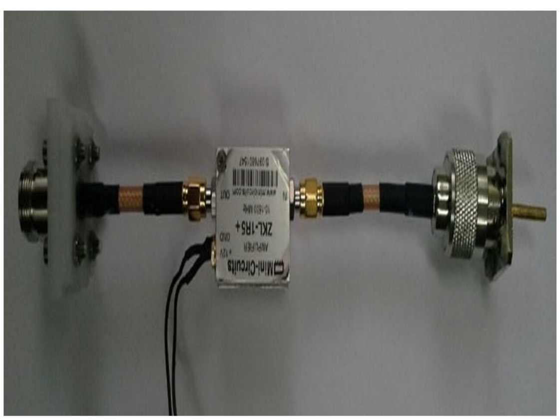


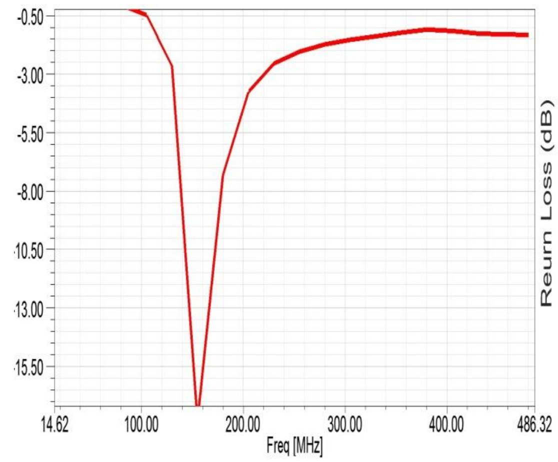
Figure 3: Feeding structure of the active antenna at 30-500 MHz band, which is placed within the bottom can.

The location of the antenna feeding connector is inside the bottom can and tangent to the bottom of it. As shown in Figure 2 (a), in order to optimize impedance matching for the proposed antenna at both frequency bands, a 50 ohm coaxial cable acts as the antenna feeding connector body part (1). Due to the diameter of the connector, the size of the feeding hole, in which a teflon loop is placed, is chosen in such a way to form an internal coaxial cable.

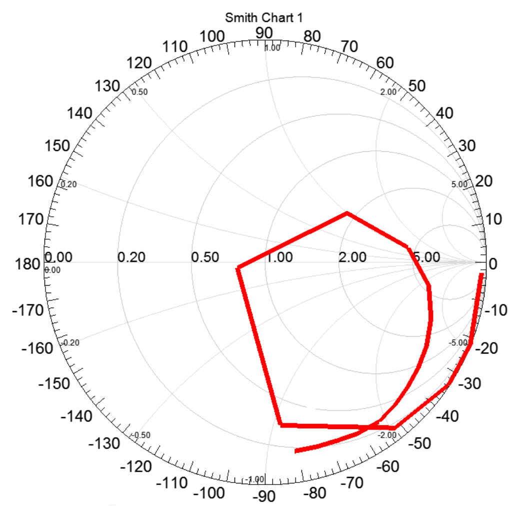
3. THE SIMULATION AND MEASUREMENT RESULTS

A. Return Loss

Simulated return loss and Smith chart of the proposed antenna without the series stub is displayed in Figure 4 (a) and 4 (b), respectively.



(a)



(b)

Figure 4: The simulation results of the antenna without the series stub (a) Return loss, (b) Smith chart graph.

This series stub creates a resonance in the conventional dipole antenna independent of the main resonance frequency of the antenna. This frequency is within a frequency range higher than the resonance frequency of the main antenna. The length can be controlled by using a series stub. Simulated and measured return losses of the active antenna are displayed in Figure 5 (a). Also, in Figure 5 (b), the Smith chart results can be seen in the presence of the series stub. As shown in Figure 5 (a), it can be seen that the dual-band antenna has two independent resonance frequencies at 150 and 450 MHz.

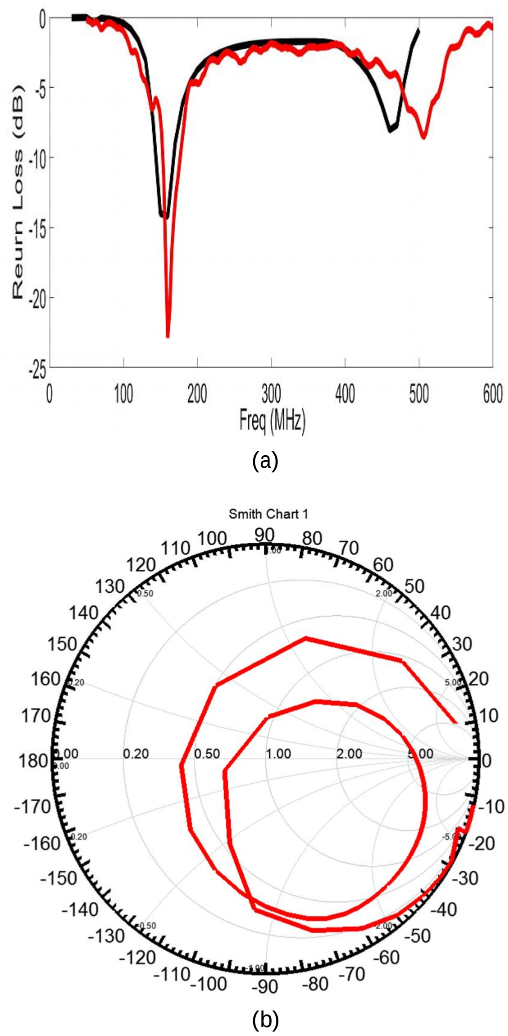


Figure 5: The simulation results of the antenna with a series stub. The return loss (measured results ▬▬ simulation results ▬▬) b. Smith chart graphs.

B. Radiation Pattern

As previously mentioned, the proposed antenna is a dipole antenna with an asymmetric feeding. Asymmetric dipole antenna at high frequencies because of phase changing current distribution on the antenna body as compared with the symmetrical dipole antenna feed, could result in shaped pattern [7]. However, in order to increase the degree of design freedom and have more control on the antenna pattern at different frequencies, the proposed antenna has a flat plate at the end of the bottom can (Figure 2 (a)). In fact, the flat edge can help us so that we can have appropriate patterns in the range of acceptable angles.

The proposed antenna targeted for the pattern angles in the range of 90 to 120 degrees. It should be noted that the pattern is a function of the geometry of the antenna and does not have any relationship with the amplifier gain. In order to better understand the results of the antenna patterns, Figs. 6 and 7, show both simulation curves and measured patterns. The curves in Figures 6 and 7 are not normalized to zero because different scales are used for the results of the simulations and measurements.

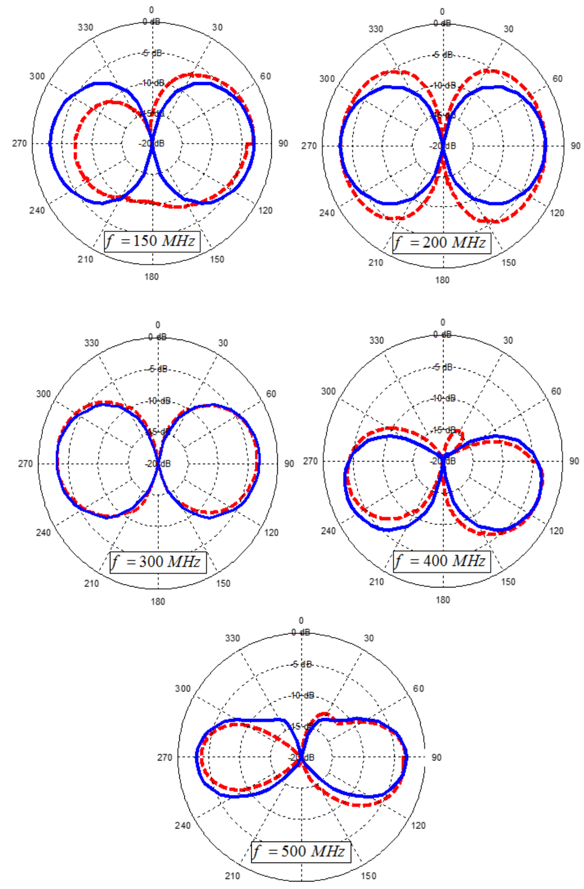


Figure 6: E-plane normalized pattern of the active antenna (measured results ▬ ▬ ▬ and simulation results ▬▬).

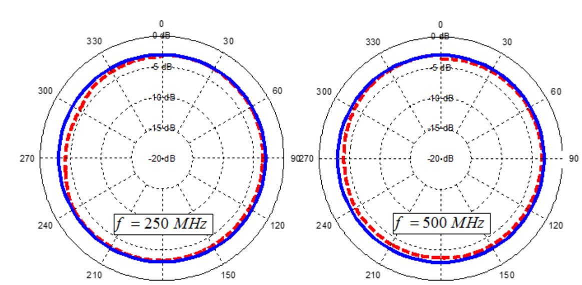


Figure 7: H-plane normalized pattern of the active antenna (measured results ▬ ▬ ▬ and simulation results ▬▬).

C. Gain

Figure 8 shows the proposed dipole antenna in the horizontal angle in the inactive mode (without amplifier). As expected, at low frequencies, the antenna gain is very small due to a low radiation resistance.

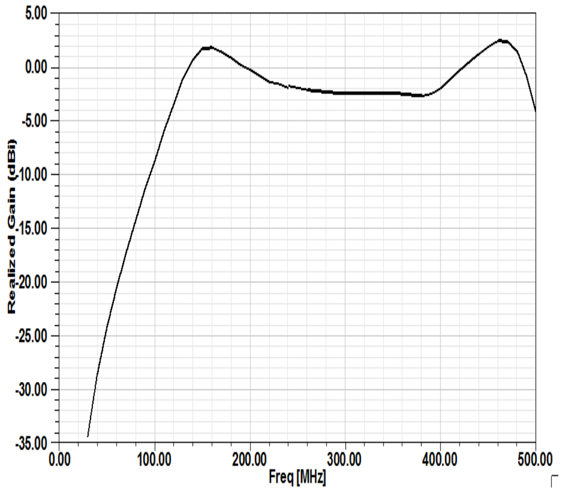


Figure 8: Simulation results of the horizontal angle gain of the dipole antenna without the amplifier designed by ANSYS HFSS.15 software.

An active antenna is simulated with the help of the ZKL-1R5 + S2P amplifier model available on the company's website. Figure 9 shows the simulation results of the proposed active antenna gain at the horizon angle ($\theta = 90^0$). As one can see in Figure 9, the minimum gain in the horizontal direction is 4.4 dB, which occurs at the frequency of 30 MHz. Refer to Table 2, to determine the real value of the gain. The measurement results of the gain of the active antenna at different angles are fully presented in Table 2.

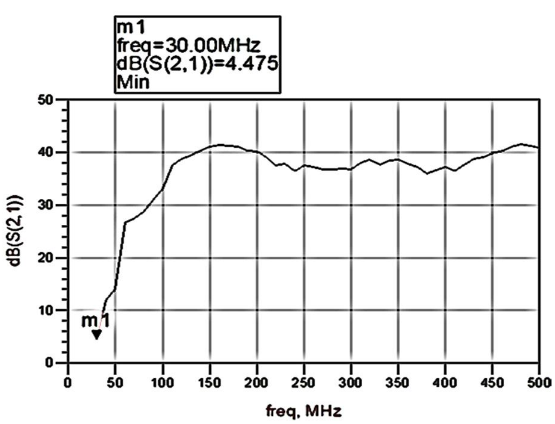


Figure 9: The simulation results on the horizon ($\theta = 90^0$) of the proposed active antennas in the presence of ZKL-1R5+ amplifier.

TABLE 2
THE MEASUREMENT RESULTS OF THE PROPOSED ACTIVE ANTENNA AT DIFFERENT ANGLES

Frequency (MHz)	150	200	300	400	500
Received power level of the reference antenna (dBm)	-77.8	-62.3	-63.7	-67.1	-64.5
Received power level of the active antenna (dBm)	-40.6	-28.7	-33.7	-35.9	-31.3
Gain of the reference antenna at the horizon angle (dBi)	0	6.35	6.75	6.5	6.6
Gain of the active antenna at the horizon angle (dBi)	37.26	39.5	36.79	37.66	39.79

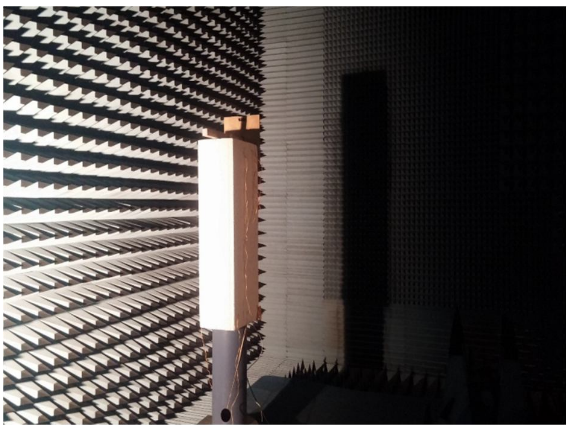
4. CONCLUSION

This paper presented a new method for dual-band dipole antenna design, based on using a series stub. In addition, antenna gain was increased by using an amplifier in series with the antenna. According to the simulation and measured results, it was demones trated that the proposed antenna has good efficiency of about 40 dB and an omnidirectional radiation pattern at the horizontal position.

Dual-band antenna at 150 and 450 MHz is an appropriate choice for military applications.

The measured and simulation return loss diagrams further confirmed the results. The fabricated active dual-band antenna is displayed in Figure 10.

(a)



(b)

Figure 10: The fabricated active antenna (a) the front view, (b) under test in a standard testing room.

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BIOGRAPHIES

Mojtaba Zahiry received the B.Sc. degree in Communications Engineering from Arak University (Arak-Iran) in 2015, M. Sc. degree from Shahid Rajaee Teacher Training University (Tehran-Iran) in 2017. His research interests include antenna theory, antenna design and simulation, microstrip antenna, multi-band antenna and wide-band antenna.

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How to cite this paper:

M. Zahiry, S. M. Hashemi, and Javad Ghalibafan “Design, Simulation and Implementation of an Active Dual-Band Dipole Antenna Using a Series Stub,” Journal of Electrical and Computer Engineering Innovations, vol. 5. no. 1, pp. 1-6, 2017.

DOI: 10.22061/JECEI.2017.622

URL: http://jecei.srttu.edu/article_622.html