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Design and Development of Compact and Broadband Coaxially Fed Dipole Antenna Covering 500MHz to 2500MHz

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Abstract

In this paper a novel technique to enhance the bandwidth of 5:1 operating from 500MHz to 2500MHz for coaxially fed dipole antenna is presented with simulated and measured results. In modern scenario, Broadband Omni directional antennas are the preferred antennas for Electronic Warfare (EW) applications. Most of the communications especially for monitoring applications are carried out in HF, VHF and UHF bands. The antenna size reduction is achieved by shaping the antenna in a unique way without employing any matching circuits. The proposed antenna is well matched with VSWR ≤ 3:1 over the frequency band. Finally the antenna is optimized using CST Microwave Studio™ EM simulation software then practically implemented and evaluated for its characteristics. As the proposed antenna incorporates no matching and tuning networks, it can handle high power and is suited for Trans-Receive applications in communication.

Keywords: Broadband Antenna, Coaxial Feed Dipole, Compact Antenna

1. Introduction

Modern communication systems are being explored for diverse applications like telemetry, data, voice, video, multimedia, law enforcement, direction finding etc. Broadband antennas are at the forefront of Electronic Warfare. In Electronic Warfare (EW), disrupting communications is a daunting task because of the plethora of frequencies exploited by the enemy. Wideband antennas allow defence and intelligence customers to adapt to ever-increasing threats and changing requirements.

The proposed broadband and coaxial feed dipole antenna is best suited for monitoring and communication Electronic Warfare applications. Typically, conventional omni-directional antennas such as monopole or dipole are narrow band with bandwidth of the order of 5% to 10% at its center frequency. The narrowband antenna can be converted to a wideband antenna[1] employing the following techniques:

a. Reducing the λ(wavelength)/D(diameter)[2]
b. Angular dependent design or frequency independent concept[3]
c. Impedance matching or tuning devices[4]

By thickening a monopole or dipole antenna, impedance bandwidth of up to 20% at its centre frequency can be achieved. With sleeve configuration, an impedance bandwidth of 3:1 is achieved. Most of the matching circuits using R, L and C are loss in nature thereby the antenna efficiency is poor. In this proposed antenna, each radiating arm of dipole consists of conical section followed by cylindrical tube with different diameters. The dipole elements of antenna are fabricated using aluminium rod/tube and are fed coaxially to form a coaxial dipole. The outer conductor of the coaxial transmission line is connected to one end of the dipole and inner conductor to the other end of the dipole.

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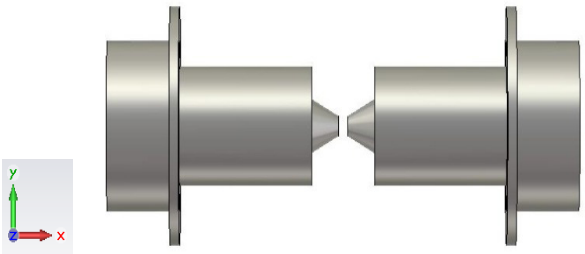
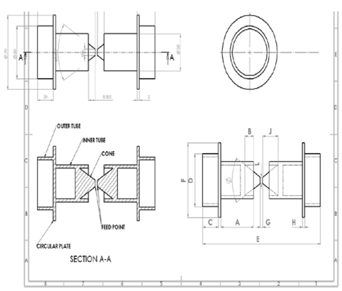
2. Design and Realisation

The time domain analysis of the desired model is done in the Electro-Magnetic (EM) Simulation software (CST Microwave Studio™)[5] where it provides a narrow pulse for excitation and takes less simulation time when compared to other EM simulation software's. The CST design model of the proposed antenna operating in 500-2500MHz band is as shown in Figure 1.



(a). Antenna model



(b). Sectional view of Antenna

Figure 1. CST design model of compact and broadband coaxially fed dipole antenna

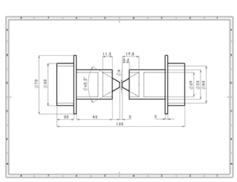


Figure 2. Geometrical representation of the proposed antenna with optimized values

For a conventional wideband dipole antenna to match the impedance at lower band edge, the minimum length required is $\lambda/2$ at the lowest frequency. The actual required length of dipole antenna to match the impedance at 500 MHz should be $\lambda/2_{\text{(at 500 MHz)}}$ = 300mm. However, in this paper by introducing unique antenna shaping and loading techniques, the size of antenna is reduced to half of that is required. Figure 2 shows the geometrical diagram of the antenna with various optimised dimensions. The length of the antenna is 150mm.

Each radiating arm of the proposed antenna is made up of four major sections. The antenna is fed at one end of the conical section. The full cone angle is 60.3°.The other end of the conical section is inserted to the inner tube followed by circular plate. Finally outer tube is attached to the circular plate.

With the above configurations a broadband antenna characteristics is achieved without using any matching or tuning networks. After optimising the various parameters of the antenna using CST Microwave Studio, the designed model is fabricated using aluminium tubes and plates. A choke type balun is designed by the using ferrite beads of various frequency responses to suppress the unbalanced current at the outer conductor of the feed cable. Figure 3 shows the photograph of fabricated antenna.

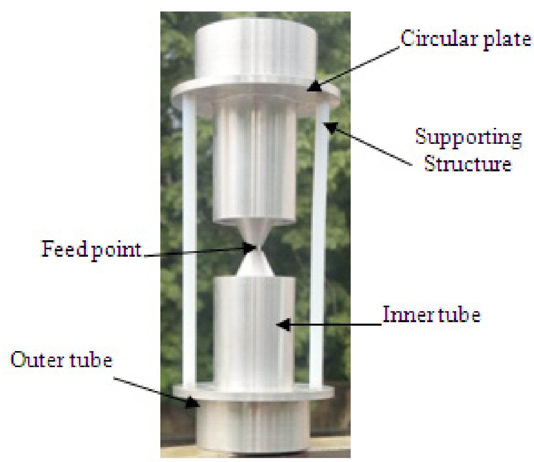


Figure 3. Photograph of Fabricated compact and broadband coaxial fed dipole antenna

When compared to other EW communication antennas such as Discone and Blade antennas, coaxial feed dipole antennas are mostly preferable because of its compact size, ease of fabrication and light weight.

3. Results and Discussion

Simulation studies is carried out by varying the various design parameters as shown in Figures 4(a), 5(a), 6(a), 7(a) and 8(a) respectively. The proposed dipole antenna is designed starting with basic fat dipole antenna configuration as shown in Figure 4(a). Later the capacitive loading elements namely circular plate and outer cylindrical tube are attached at the end of inner cylindrical tube are shown in Figure 5(a) and Figure 6(a) respectively.

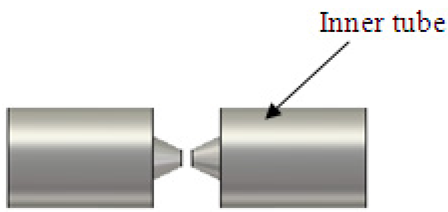


Figure 4 (a). Basic Fat dipole antenna.

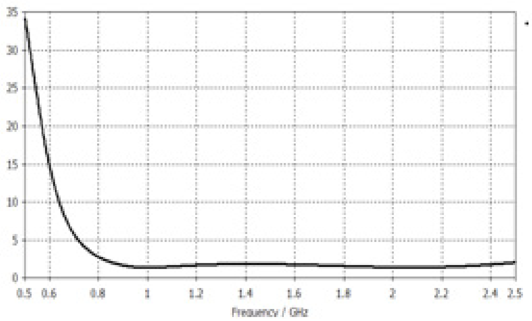


Figure 4 (b). VSWR of Basic Fat dipole antenna.

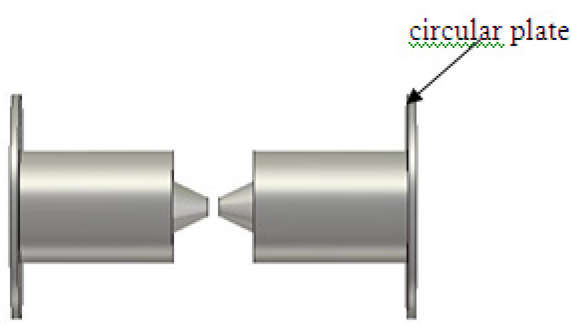


Figure 5 (a). Fat dipole antenna with circular plate

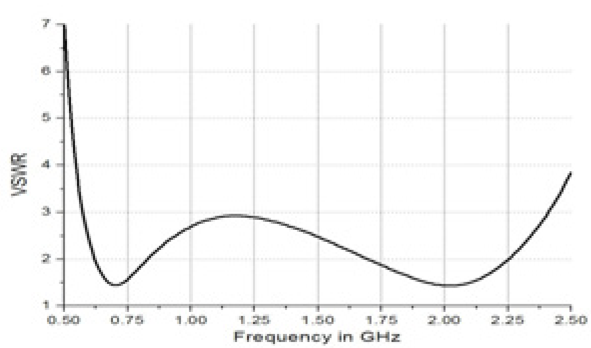


Figure 5 (b). VSWR of Fat dipole antenna with circular plate

Figure 4(a) and 4(b) shows the basic fat dipole antennas and its simulated VSWR. The antenna is matched with VSWR ≤ 3:1 from 800 MHz onwards. Further increasing the length, the antenna can be matched at lower frequencies too. However the radiation patterns at higher frequencies will get distorted due to larger length in terms of wavelength.

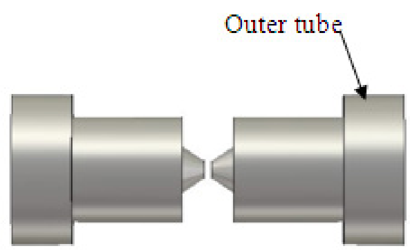


Figure 6 (a). Fat dipole with outer tube

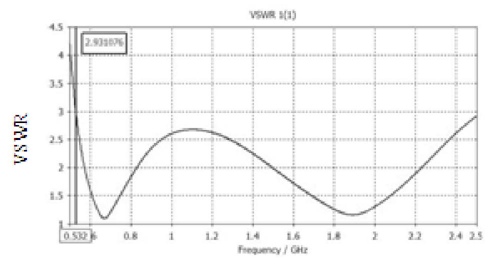


Figure 6 (b). VSWR of fat dipole with outer cylindrical tube.

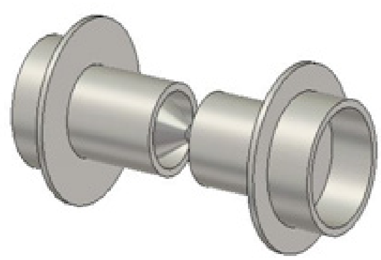


Figure 7 (a). Final proposed broadband dipole antenna.

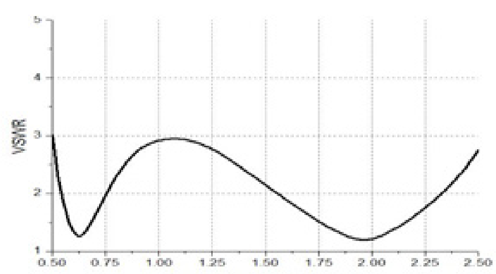


Figure 7 (b). VSWR of Final proposed broadband dipole antenna.

Thus, instead of continuingly increasing the length of fat dipole antenna, loading with various shaped structure is proposed in this paper. Figure 5(b) shows the simulated VSWR of fat dipole antenna with circular plate attached at the end of the inner cylindrical tube. From the figure it is seen that at both the edges of frequency band the VSWR is higher. It acts like band pass filter with limited bandwidth. Figure 6(b) shows the simulated VSWR of fat dipole antenna with outer cylindrical tube attached at the end of the inner cylindrical tube. Here the antenna is matched with VSWR ≤ 3:1 from 532 MHz onward. However the lower frequency band still has higher VSWR. Combining the above two configuration, the final proposed broadband dipole antenna was designed as shown in figure 7(a). Figure 7(b) shows the simulated VSWR of the proposed dipole antenna and it is less than 3:1 over the desired frequency band.

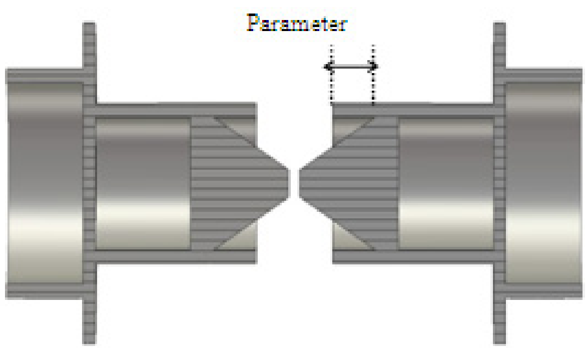


Figure 8 (a). Sectional view of proposed dipole with various length of inner tube extension towards feed point

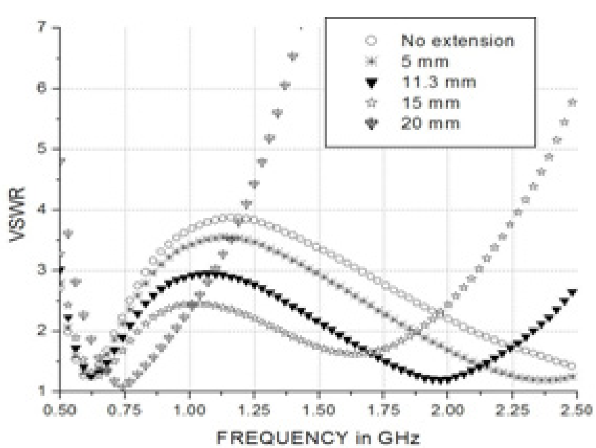


Figure 8 (b). VSWR for various length of inner tube extension towards feed point

The parametric study of inner tube extension toward feed point was also carried out as it played an important role in matching the input impedance of the antenna. The length of the extension is taken up to 20mm from the section where the cone is attached to the inner tube as shown in figure 8(a) and 8(b). The optimum extension is 11.3 mm towards the feed point which results in VSWR ≤ 3:1 over the frequency band 500 MHz to 2500 MHz.

After fabrication of the antenna, the VSWR was measured using Agilent ENA series Vector Network Analyzer (VNA) E5071C and was found to be less than 3.1:1 throughout the desired frequency band. Figure 9 shows the comparison of simulated and measured VSWR and they are in good agreement. The small variations in simulated and measured results may be due to free space environment assumption in simulation whereas in real scenario there are multiple reflections from the surrounding.

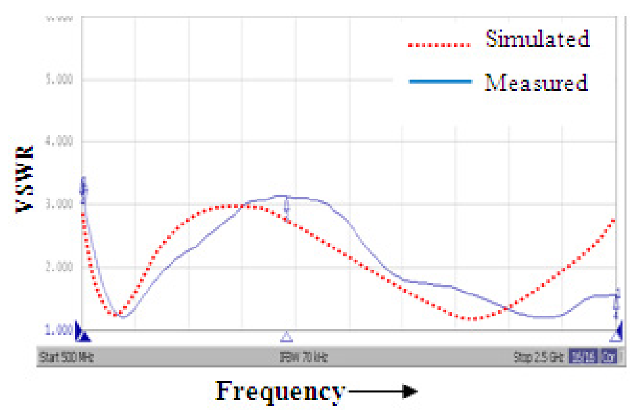
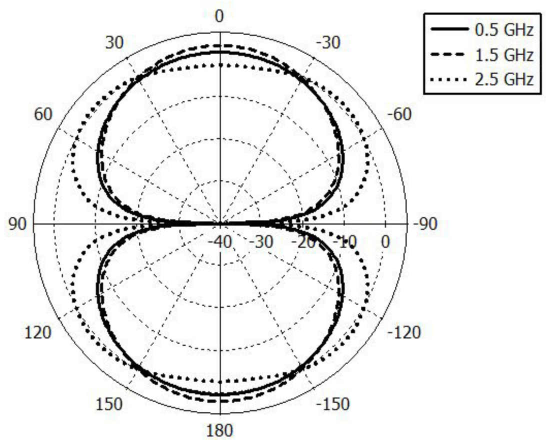


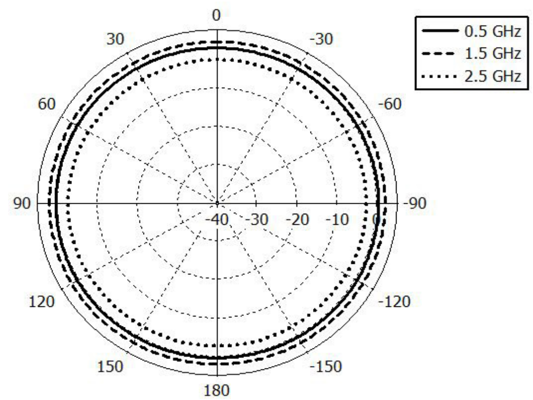
Figure 9. Simulated and Measured VSWR plots

The simulated radiation pattern of the proposed dipole antenna is shown in figure 10. From the figure it is observed that the proposed antenna has good elevation coverage and omni directionality which is one of the most important parameter for EW applications. At 2.5 GHz the E plane radiation pattern start bulging out, further increase in frequency the patterns will get split up. This shows the antenna overall bandwidth is restricted by radiation patterns at higher frequencies. Whereas at lower frequencies, is restricted by impedance matching.

The radiation pattern characteristics were measured in the rectangular anechoic chamber using PNA based antenna pattern recording system. Figure 11 shows the measured radiation patterns of the proposed dipole antenna.

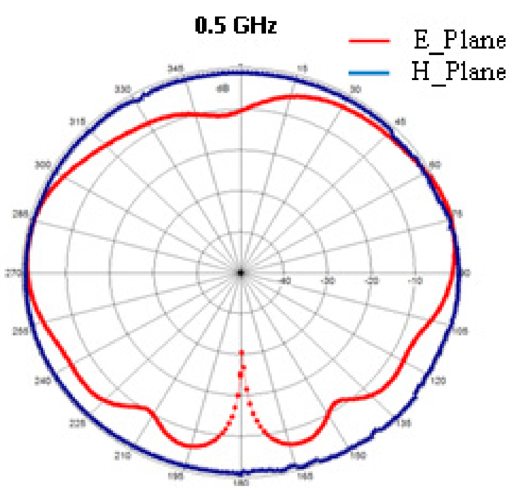


(a). E Plane at 0.5, 1.5 and 2.5GHz frequencies.

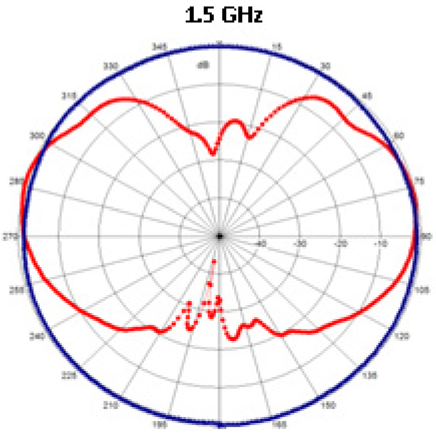


(b). H – Plane at 0.5, 1.5 and 2.5GHz frequencies.

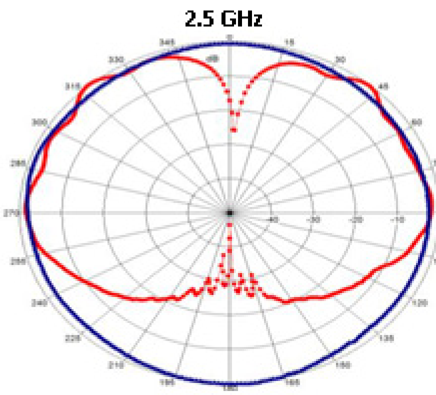
Figure 10. Simulated E and H Plane patterns.



(a). E and H plane at 0.5GHz



(b). E and H plane at 1.5GHz



(c). E and H plane at 2.5GHz

Figure 11. Measured E and H-Plane patterns at 0.5 GHz, 1.5 GHz and 2.5 GHz frequencies.

The theoretical gain of conventional tune dipole antenna is 2.15dBi[6]. In this proposed antenna, the gain values are varied from 1.5dBi to 2.4dBi throughout the frequency band. Gain is varied due to the variations in various parameters dimensions in terms of wavelength. The gain plot of the designed antenna is shown in figure 12.

4. Conclusion

The proposed compact and broadband coaxial feed dipole antenna is suitable for communication EW applications such as direction finding, surveillance and monitoring in defence and aerospace applications. Parametric studies of the proposed antenna are carried out and finally the antenna is successfully optimized, fabricated and tested.

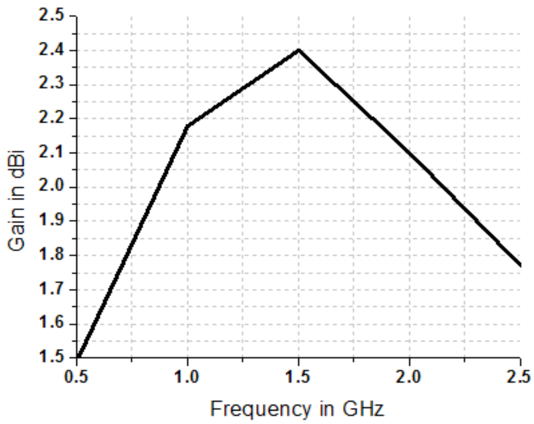


Figure 12. Gain plot of proposed dipole antenna

The antenna has simple structure, low cost, ease of fabrication, compact and light weight. Moreover, it can handle high power and best suited for Trans-receive applications.

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