

ANALYSIS OF ELECTRICALLY SMALL SIZE CONICAL ANTENNAS

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Abstract—It has long been known that the conical antenna has broadband characteristics and good radiation efficiency. The design considerations in reducing the size of top loaded conical antenna by using posts with lumped resistive loading are presented. The resulting antenna can achieve a VSWR of better than 2.0 over 100–800 MHz frequency range. Results indicate that the addition of posts and lumped resistive loading has significant role in designing broadband antennas which are in small size.

1. INTRODUCTION

Electronic devices and communication equipment today are made so compact that miniaturization of components is critical, especially for small and broadband antennas. It is of immense need to miniaturize components which are resourceful for modern communication systems. Small antennas typically have characteristics of large input reactance and small radiation resistance. They also suffer from relatively high ohmic losses and narrow bandwidth [1]. Although the radiation pattern and directive gain of a small antenna remain almost constant as the size and frequency vary, its input impedance does not [2]. As the wavelength increases, the bandwidth of a small antenna decreases rapidly due to the very high quality factor Q of the antenna.

Generally the sizes of electrically small antennas in the low frequency range (VHF and UHF) are large. Various kinds of antennas have been studied based on the fundamental limitations of electrically small antennas. Although the former electrically small antennas are electrically small in size, they have narrow band characteristics. With a need for antennas with the characteristics of broad bandwidth and small electrical size, the conical antenna structures have been a focus

of research because of its broad bandwidth and good efficiency in the low frequency range [3–5]. Although the conical antenna with lumped element loading can shift the resonance to lower frequencies, the gain and the impedance bandwidth can be reduced. The conical structure has good performance if the dimension is infinite but practical antennas should be finite structure.

As the conical antenna has a traveling wave structure, lumped loads such as inductor or capacitor or the combination of both is used in the antenna in order to achieve small size configuration. In this study, small sized conical antennas with different loadings have been used to realize VSWR levels of less than 2 along with omnidirectional pattern [6]. The configuration of the conical antenna has the transformation nature like the gradually tapered lines [7–9]. Typically the conical antenna has a capacitive reactance at its low frequencies and the addition of two shorting posts to the antenna serves to provide inductive compensation at the lower frequencies with the broadband response [10, 11].

2. DESIGN CONSIDERATION AND RESULTS

The configuration of top-capped conical antenna with inductive post and resistive loading is first investigated and the geometry is shown in Fig. 1. The prototype of proposed conical antenna with inductive posts and resistive loading is fabricated (see Fig. 2) and measured with small ground plane in order to verify the small size and broadband performance of the proposed conical structures. The antenna is vertically mounted on a 50 cm square size ground plane and fed by a $50\ \Omega$ N-type connector. The Ansoft-HFSS software is used for modeling the entire structure of the conical shape design which is excited by a $50\ \Omega$ coaxial probe. The simulation and measured results of the conical antenna are shown in Fig. 3. There is good agreement between the measured and the numerical result of proposed conical antenna.

Based on the good agreement between the measured and the numerical result of proposed conical antenna, finite-size ground plane of dimensions $1\lambda \times 1\lambda$ at the resonant frequency is used to analyze all conical shaped antennas to obtain the characteristics of radiation patterns and input impedance. A new configuration of top-capped folded conical antenna with inductive post and resistive loading is also investigated (see Fig. 5).

Typically the simple conical antenna has capacitive reactance nature with decreasing radiation resistance at its lower frequencies. A possible approach to modify the current distribution on the conical antenna is to add capacitive loading at its ends, so as to obtain a more

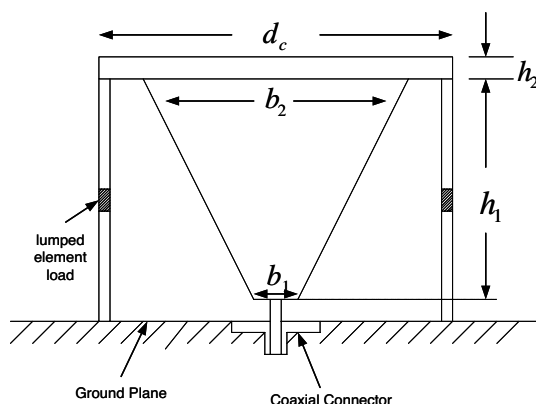


Figure 1. The structure of top capacitive loaded conical antenna with inductive post and resistive loading.

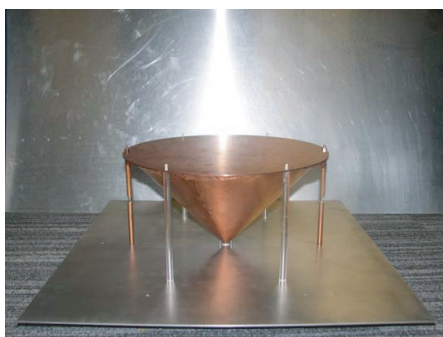


Figure 2. Photograph of the top capacitive loaded conical antenna with inductive post and resistive loading fabricated for measurement.

uniform distribution over the length of the antenna as the frequency varies. Throughout the frequency range of broadband antenna design, the lumped reactance elements such as coils and capacitors which are the functions of frequency were used for impedance-matching. The addition of two loading pins to the antenna performs inductive shunt compensation and it is made to achieve self resonance at the low frequencies for the small antenna. The resistive loading is then introduced at the two posts in order to cover the lower part of frequencies.

The dimensions of the top-capped antenna are: $b_1 = 1$ cm, $b_2 = 30$ cm, $h_1 = 15$ cm, $h_2 = 0.5$ cm, $d_c = 32$ cm and $dp = 8$ mm. Fig. 4 shows the frequency response of the VSWR of the antenna

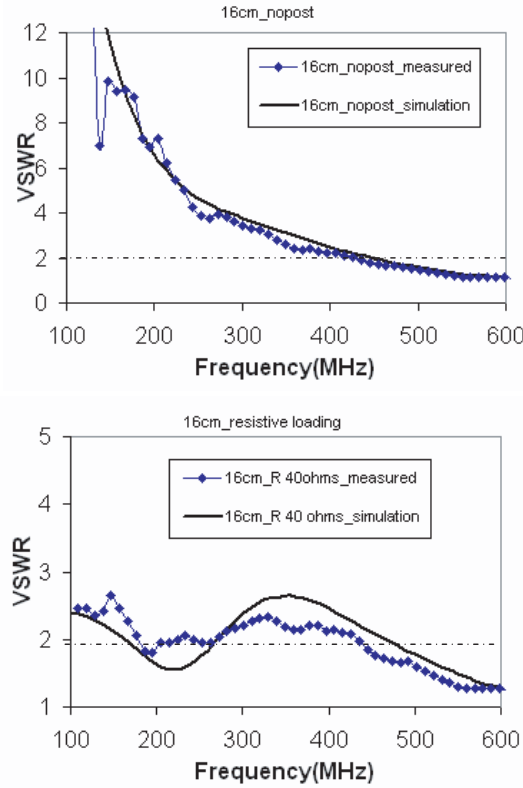


Figure 3. The comparison between the simulation and measurement results of the conical antenna with small ground plane.

with and without inductive post and resistive loading. The top-capped conical antenna with inductive post and resistive loading has a total height of 16 cm, and achieved a VSWR of better than 2 over 100–900 MHz.

In this study, we found that the height and diameter of the cone are critical to the functioning of the antenna bandwidth performance especially at the low frequencies. Thus the lowering in resonant frequency is a function of cone angle and the height of the cone. It is found that the input impedance of the conical antenna is also dominated by the flare angle at the feed point, which is varied from 30° to 90° . In order to obtain the resonance at the low frequency end, the flare angle of the conical antenna has to be increased and it was noted that the improvement in bandwidth can be obtained by the single

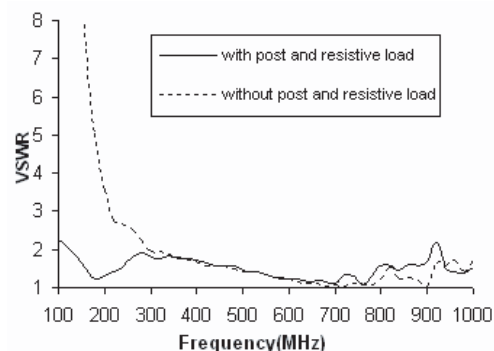


Figure 4. VSWR of top capacitive load conical antenna with inductive post and resistive loading.

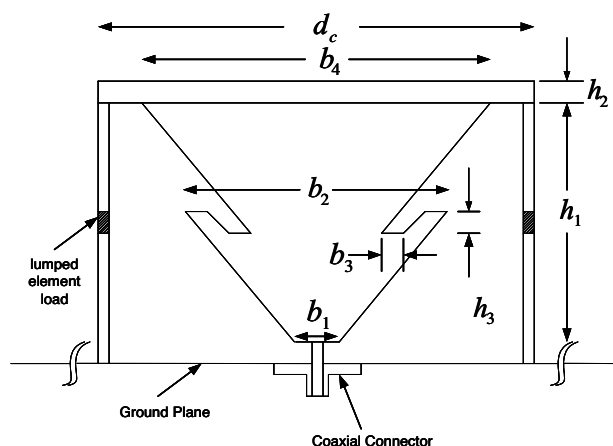


Figure 5. The structure of top capacitive load folded conical antenna with inductive post and resistive loading.

cone of 90° of the conical antenna. Thus the optimum half cone angle is a flare angle of 45° and the height of the conical antenna is chosen to be approximately equal to the radius at the base of the conical antenna for good impedance matching at low frequencies and broad bandwidth throughout the frequency span. Other design parameters, such as the height (h_1), cone base diameter (b_2), cone truncated apex diameter (b_1), and the top-cap diameter (d_c), the position of the resistive load can also be optimized for improved performance of the antenna.

In the second case, the top-capped folded conical antenna loaded by inductive posts and resistive loading was considered. The folding

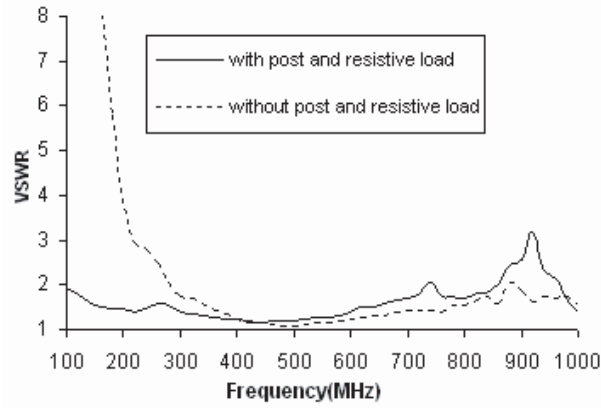


Figure 6. VSWR of top capacitive load folded conical antenna with inductive post and resistive loading.

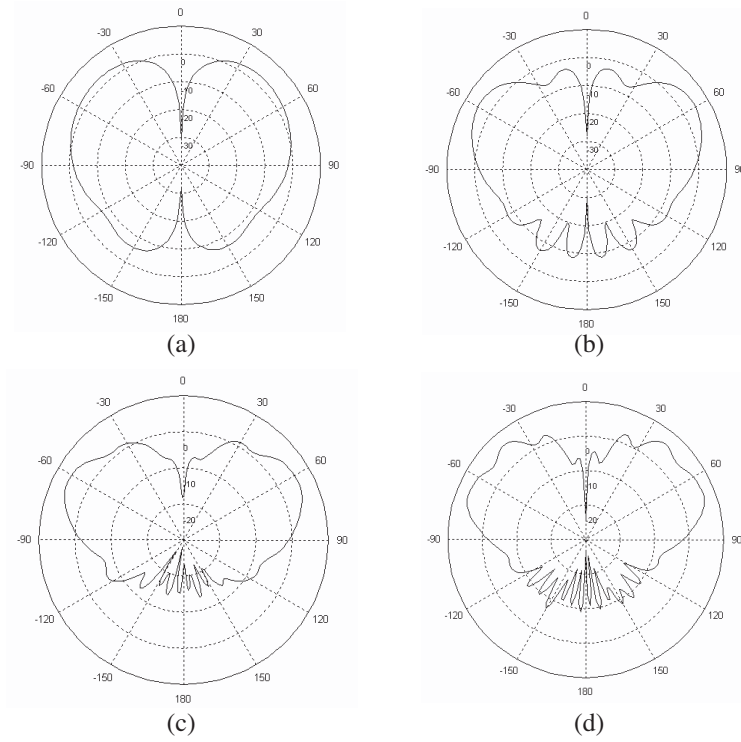


Figure 7. The radiation pattern of the folded conical antenna with inductive posts and resistive loading. (a) $f = 100$ MHz, (b) $f = 300$ MHz, (c) $f = 500$ MHz, (d) $f = 700$ MHz.

to the antenna is used to set up the radiation resistance to $50\ \Omega$, to impedance-matched to the characteristic impedance of transmission line. The top-capped folded conical antenna loaded with inductive posts and resistive loading has the following dimensions: $b_1 = 1\text{ cm}$, $b_2 = 24\text{ cm}$, $b_3 = 1\text{ cm}$, $b_4 = 30\text{ cm}$, $h_1 = 15\text{ cm}$, $h_2 = 0.5\text{ cm}$, $h_3 = 1\text{ cm}$, and $d_c = 32\text{ cm}$.

Figure 6 shows the frequency response of the VSWR, which is better than 2 over 100–800 MHz. The antenna has a total height of 16 cm. There are also other parameters such as the length of the cone, the spacing between each folded arm and the number of the folded arms to be optimized. When the length of the folded arm is increased, it is found that the resonant frequency is shifted to the low edge but it is limited to get the optimum wide bandwidth. Addition of the folded arm to conical antenna resulted with lower VSWR in the lower frequency range. With the proper folded arm length and the number of folded arms, the performance is almost similar to the first case, except the conical antenna is folded. Some radiation patterns of the antenna are shown in Fig. 7.

3. CONCLUSION

The small broadband top capacitive loaded conical antenna with two inductive posts and resistive loading with vertically polarized, omnidirectional field pattern in the operating frequency ranges from 100–900 MHz ($\text{VSWR} < 2$) and that of top capacitive loaded folded conical antenna with two inductive posts and resistive loading of the frequency ranges from 100–800 MHz ($\text{VSWR} < 2$) were studied. A combination of top-cap loading, low loss inductive loading and resistive loading is considered to obtain broadband small antenna design with good radiation efficiency. In practice, the folded conical antenna is difficult to fabricate but the 10 dB return loss result in the low frequencies is small compared to the normal conical design. Thus the folded conical antenna may be useful in some applications which demand small VSWR. The input impedance of the conical antenna varies according to the flare angle, as expected. It is observed that an optimum flare angle exists for $50\ \Omega$ matched impedance. From the above results, the influence of geometric parameters on impedance matching is noted. It is observed that the improvement in bandwidth can be obtained with the height of the conical antenna is approximately equal dimension to the base radius of the cone, i.e., a flare angle (i.e., half-angle of the cone) of 45° is optimal for all small conical antenna design considered here.

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