Progress In Electromagnetics Research Letters, Vol. 6, 75–82, 2009

COMPACT AND HIGH GAIN WIRE-STRUCTURED PENTAGONAL ANTENNA FOR HF COMMUNICATION

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Abstract—A novel V-shape wire-structured pentagonal HF antenna is developed. The parasitic guys and convex pentagon-shape arms are used to reduce the VSWR of the antenna at lower band. A computer model of the antenna is established to simulate the VSWR, gain and radiation pattern. The simulated and measured results show that the VSWR of this antenna is within 2.55:1 over 3∼30 MHz and the average power gain is about 11 dBi.

1. INTRODUCTION

Many widely used HF transmitting communication antennas such as curtain antenna, rhombic antenna and double-LPDA have amazing high gain and especially fit for long range communication. However, their requirements of large installation space have limited their usage. On the other hand, a whip antenna or a loaded dipole occupies quite small space but the typical gain of it is low, and usually become worse in lower HF band. Thus, it is significant to design a wideband antenna with small size and comparatively high gain.

Bowtie plate antenna is a widely used antenna in VHF/UHF band. It inherits broadband characteristic from biconical antenna. In addition it occupies a relatively small volume [1–6]. The shortcoming is that its gain is relatively low. In order to increase the gain, one can fold its two arms into a V-shape [1, 7, 8]. In this paper, two measures, pentagonal (or tapered bowtie) arms and parasitic guys, are incorporated to further improve the VSWR as well as power gain. The pentagonal antenna has been well-studied before [9, 10], but most of them belong to planar antennas. For HF application, planar structure is not practical, so wire structure is used instead.

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2. ANTENNA STRUCTURE

A horizontally-polarized V-shape wire-structured triangular HF antenna is depicted in Fig. 1. Its radiation arm is in the shape of a vertically arranged triangle and consists of many coplanar wires. One end of these wires is attached to a V-shape metal plate serving as feeding point and the other is fixed on a metal catenary. These two arms are no long coplanar. They are arranged in a V-shape, which can be formed by turning the two arms around a common vertical axis [1, 7, 8]. The angle between the arms is about 70°. The angles of the V-shape metal plate match the open angle of two arms. The structural parameters of this V-shape triangular antenna include the number of wires N, arm lengths L_1 and L, average height above ground H, apex angle θ, open angle α between two arms and feed gap width G_w between two feeding points.

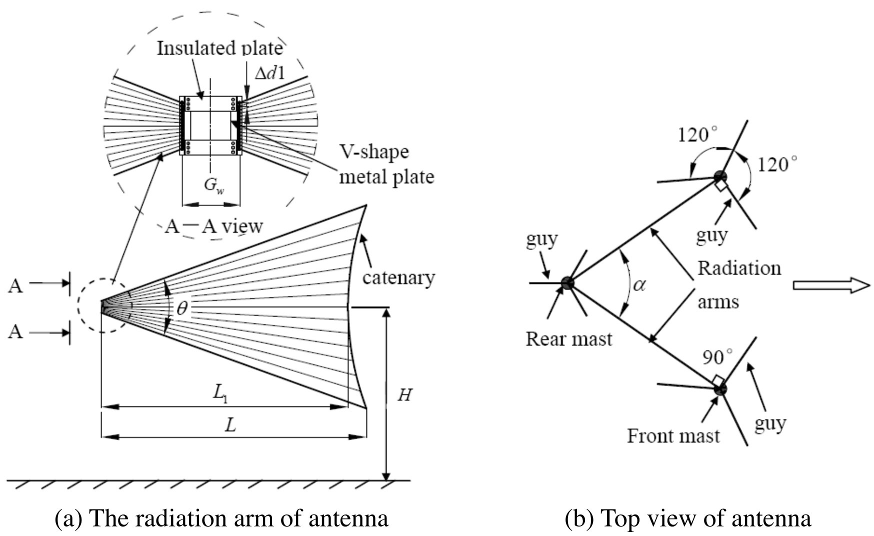


Figure 1. Structure of antenna.

3. WIDEBAND DESIGN

Software package NEC-2 (Numerical Electromagnetic Code Version 2) is used to analyse the characteristics of this V-shape triangular HF antenna. The influence of the parameter N, α and G_w to the performance of antenna are analysed in detail in [1]. The initial values of the parameters are: $L_1 = 25\,\mathrm{m}$, $L = 27\,\mathrm{m}$, $G_w = 0.5\,\mathrm{m}$,

$\alpha = 67.5°$, $N = 15$, $H = 15\,\mathrm{m}$, $\theta = 40°$. The resultant average gain is 13.39 dBi. The ground parameters are typical: $\varepsilon_r = 13$, $\sigma = 0.005\,\mathrm{S/m}$. VSWR is calculated based on an average impedance of $200\,\Omega$. The VSWR-limited operation frequency range of this antenna, namely VSWR < 2.5, is about 6–30 MHz. The lower end of this range can be further extended to 3 MHz if the size of the antenna is doubled. But this will lead to an unacceptable area requirement. Two methods are introduced to extend the bandwidth of this antenna without additional area requirement.

3.1. Guys as Parasitic Elements

Simulation results show that the VSWR with respect to $200\,\Omega$ exceed 4.6 at 4 MHz. Analysis shows that the impedance of antenna is very frequency sensitive at the lower HF band and the real part of the impedance is small at 3 MHz. This is because the electrical size of this antenna is small at lower band and the radiation ability is weak. We remove all the insulators on the guys for two front masts. It is found that these long wires induce strong currents and improve the VSWR property of antenna at the lower band. The VSWR and power gain with and without insulators on the front mast guys are shown in Fig. 2. It can be seen that the VSWR at lower band drops down obviously. With the increase of operating frequency, the radiation ability becomes stronger and the influence of the parasitic guys becomes weaker. No obvious improvement is observed when the frequency is higher than 6 MHz.

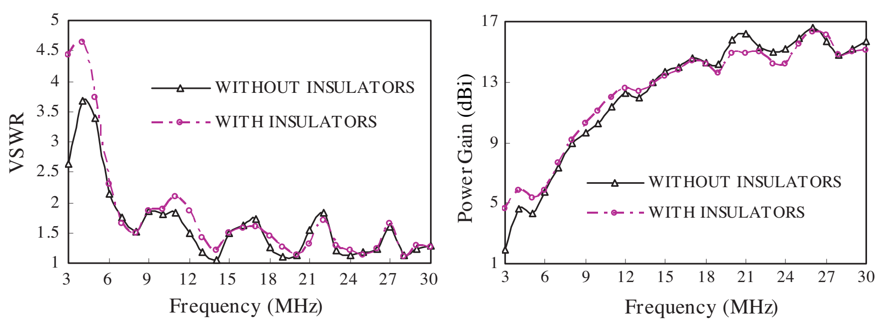


Figure 2. Comparisons of power gain and VSWR frequency responses with or without removing the insulators on the guys of front masts.

3.2. Using Pentagonal Arms

Although the VSWR can be obviously reduced by removing the insulators on the guys, it is still larger than the demand of 2.5. Other measures should be taken to further reduce the VSWR.

Research shows that a triangular dipole with larger apex angle has a wider band [2]. But larger apex angle means higher front masts. We solve this problem by reforming the triangular arm into a convex pentagonal one [9, 10], as shown in Fig. 3. A larger apex angle is realised, the horizontal length of which is l. A vertical non-conducting wire is used to fasten the conducting wires into position. In order to form the required shape, the upper end of this wire is attached to the top end of the rear mast and the lower end is attached to a grounding anchor. The vertical separations of conducting wires at the end of apex angle are equal and labelled as $\Delta d2$. We set $\Delta d2$ to 1 m to simplify the design and optimize parameter l. The properties of the antenna with different l are shown in Fig. 4. Other parameters are set to: $N = 15$, $H = 15\,\text{m}$, $\Delta d2 = 1\,\text{m}$, $G_w = 0.5\,\text{m}$, $\alpha = 70°$. It can be seen that the maximum value of VSWR can be reduced to 2.32 when $l = 8\,\text{m}$. By reforming the pentagonal arm into heptagonal or nonagonal one, a further optimized VSWR property may be obtained, but the structure becomes too complex to realize. Therefore, in this paper only pentagonal arm is considered. It can also be seen from Fig. 2 and Fig. 4, that the power gain of the antenna decreases too with the decrease of VSWR. This is because a large apex angle will introduce large vertical current component. It is well known that the

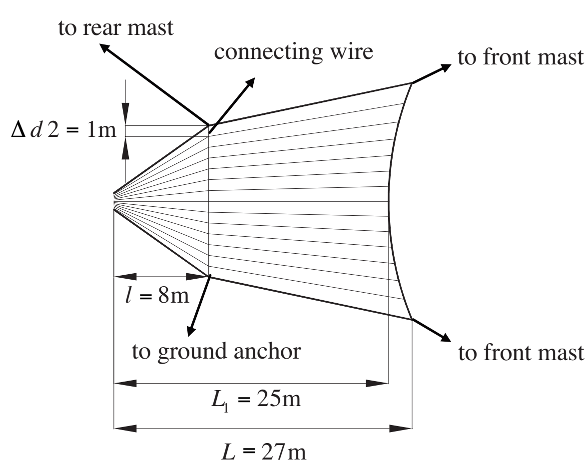


Figure 3. The improved design of antenna arms.

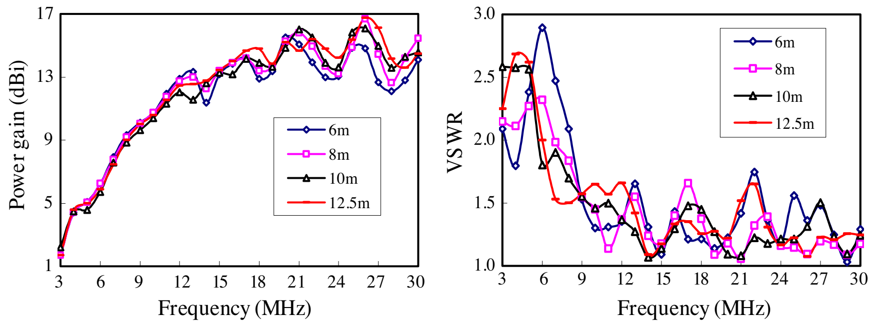


Figure 4. The frequency responses of power gain and VSWR with respect to different wire length l.

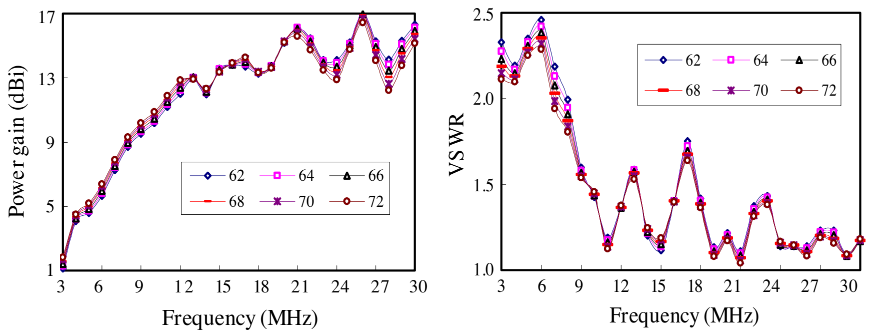


Figure 5. Comparisons of power gain and VSWR frequency responses with respect to the open angle α.

radiation of a vertical current is omnidirectional in horizontal plane. This will lead to the decrease of the gain. Comparisons of power gain and VSWR frequency responses with respect to the open angle α are shown in Fig. 5. The VSWR keeps below 2.5 when the open angle is between $62^\circ \sim 72^\circ$. With the increase of open angle, the power gain suffers a slight decrease at higher band and the VSWR of lower band decrease too. An open angle of 70° is thus picked up.

4. VSWR AND RADIATION PATTERN

A sample antenna is built based on simulation results. The measured and simulated VSWR are shown in Fig. 6. It can be seen that in general the simulation data agree well with the measurement data. The maximum value of VSWR is 2.55, just a bit higher than the demand of

2.5. The difference between them may be caused by the non-perfectness of terrain and a 4 : 1 balun located between the measuring cable and sample antenna.

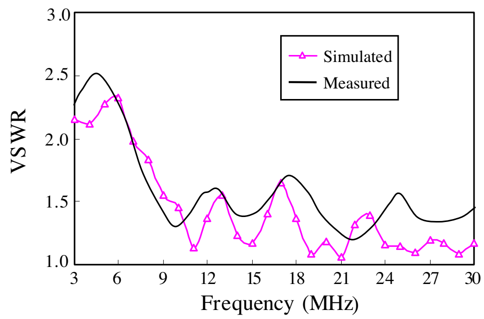
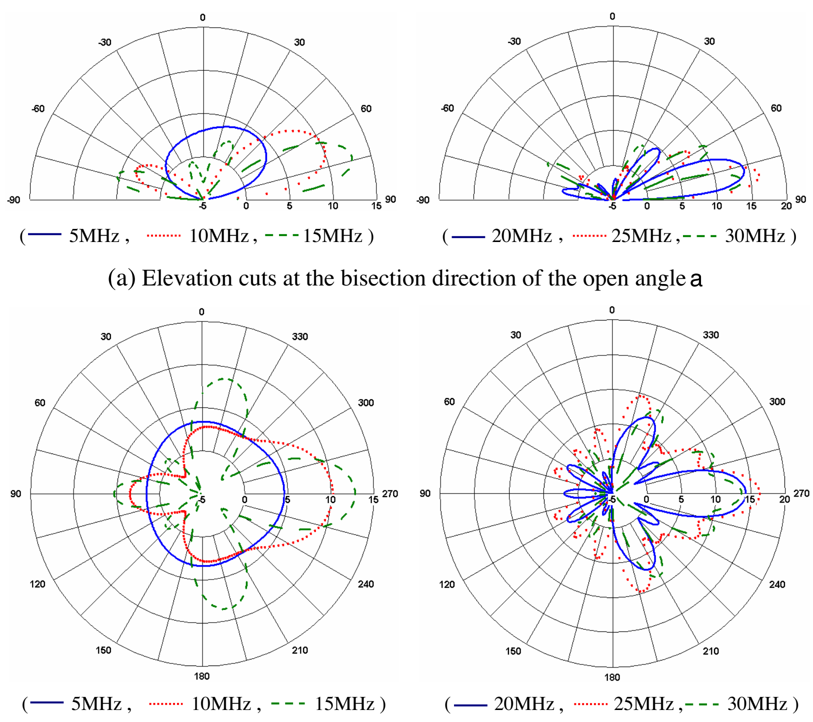


Figure 6. The simulated and measured VSWR.



(a) Elevation cuts at the bisection direction of the open angle a

(b) Azimuth cuts of main beam

Figure 7. Radiation pattern.

The antenna radiation patterns shown in Fig. 7 are elevation cuts at the bisection direction of the open angle α and azimuth cuts of main beam that contains the maximum gain. According to Fig. 7, it is observed that the designed V-shape wire-structured triangular antenna has a stable and also narrow main beam in the bisection direction of the open angle. The 3 dB width of the main beam is about 18° at 30 MHz. The horizontal radiation is nearly omnidirectional at lower band. This is expected since the electrical size is relatively small.

5. CONCLUSION

A horizontally-polarized, compact, wideband and high power gain V-shape wire-structured pentagonal antenna has been successfully developed. The high gain benefits from the V-shape structure. The whole HF band coverage is realized with a compact size by incorporating parasitic guys as well as a convex pentagonal shape of the arm. In virtue of a single, stable and narrow main beam, this antenna is particularly suitable for point to point communication circuit or narrow sector coverage application in medium or long distance.

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