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A NOVEL HIGH-GAIN AND BROAD-BEAM ANTENNA CONFIGURATION IN VHF BAND

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Abstract—A novel wire antenna configuration is proposed to achieve a 90 degree azimuthal beamwidth in the VHF band. The antenna has been manufactured and the measurement results are presented.

1. INTRODUCTION

In many radar applications, such as search radars, it is required that the transmitting antenna has a broad beamwidth to cover the designated area [1–4]. The aim is to design a transmitting antenna which has a 90 degree azimuthal beamwidth in the VHF band.

According to the frequency of operation which is within the VHF spectrum wire antennas are good candidates to be utilized. The first configuration which may occur to the mind is of course Yagi antenna [5, 6]. However, it will be shown that Yagi antennas can never construct a beamwidth up to 90-degrees in the E-plane. Another

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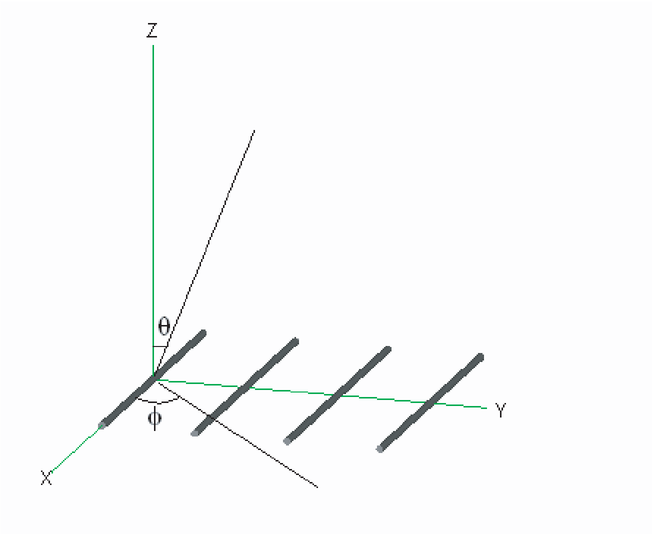

Figure 1. Yagi antenna as an array of dipoles.

solution is to use two Yagi antennas with 45 degree beamwidth for each one. This solution in turn has its own drawbacks such as demanding a huge structure, the need for splitting the power into two ways and finally the problem of interactions between two antennas which may cause another challenge in the radiation pattern.

To show the design procedure of the proposed antenna, first we need to investigate the radiation characteristics of Yagi antennas.

2. RADIATION CHARACTERISTICS OF YAGI ANTENNAS

Assume a Yagi antenna as an array which its element factor is a dipole antenna, as depicted in Figure 1. The radiation pattern of such structure is obtained by multiplying its element factor by its array factor.

The well known pattern of the element factor i.e., the half-wave dipole when the antenna is parallel to z axis is [7]

$$F(\theta) = \frac{\left[\cos\left(\frac{\pi}{2}\right)\cos\theta\right]}{\sin\theta} \tag{1}$$

The half-power beamwidth is 78°. To obtain the radiation pattern of the array antenna, provided that all elements of the array are similar, the array factor should be multiplied by the element factor and it is

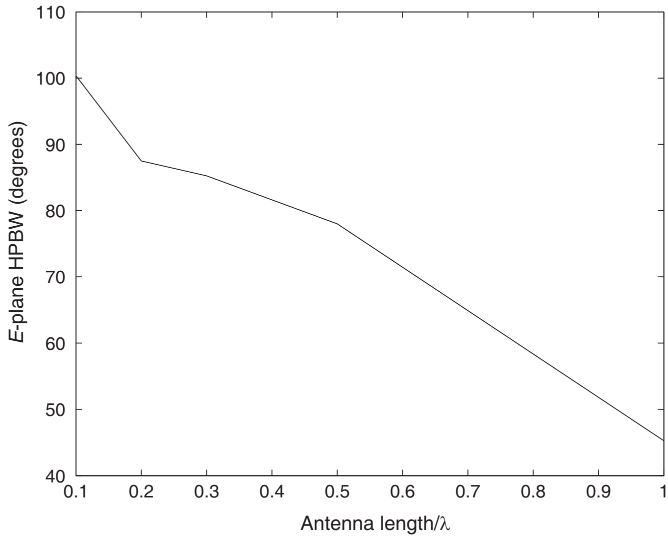

Figure 2. HPBW of a dipole antenna vs. its length (simulated with FEKO software).

obvious that the HPBM of the entire configuration is indeed less than 78°. Therefore, we can not obtain a HPBW about 90° using a Yagi antenna. By increasing the length of dipole, the HPBW decreases and by decreasing it, the HPBW increases. The dependence of HPBW to the antenna length is demonstrated in Figure 2. It should be mentioned that the VSWR of the antenna deteriorates if the length of the antenna changes from its resonant length. To alleviate such difficulties, a new structure is proposed.

3. THE PROPOSED ANTENNA STRUCTURE

The proposed antenna is illustrated in Figure 3.

3.1. The Feeding Structure

As it can be seen in Figure 3, the feeding structure is a vee-shaped dipole. It is observed that each wire rod is parallel to x-axis and arranged in the y-z plane. Unlike classical vee-antennas [8–10] which their length are much longer than the wavelength, this feed is a sort of resonant-vee antenna. The feed is separately plotted in Figure 4.

In a resonant vee-antenna, the effective electrical length of the antenna is such that the VSWR of this structure is desirable, while

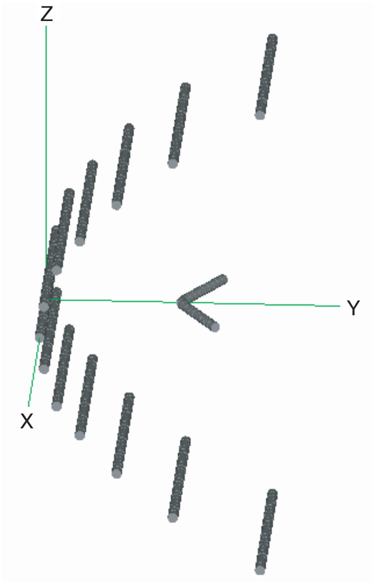

Figure 3. Schematic of the proposed antenna.

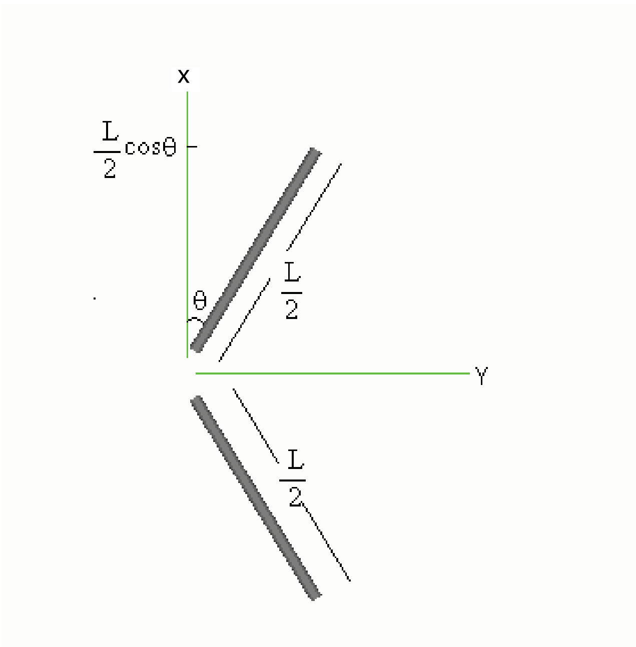

Figure 4. Detailed view of feeding structure of the proposed antenna.

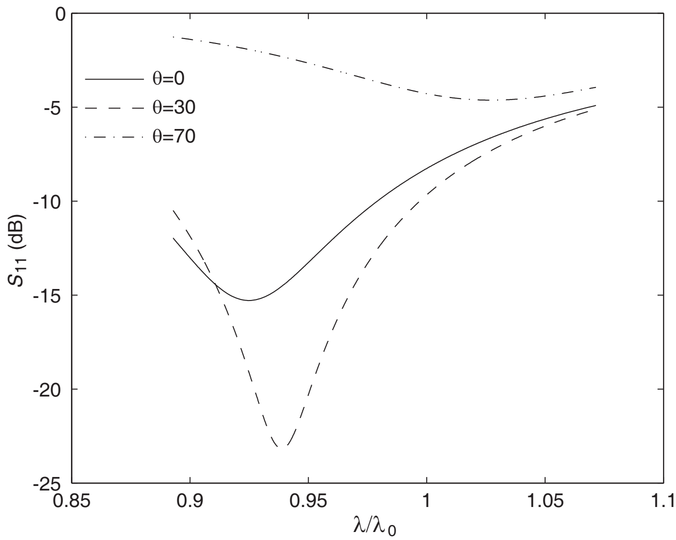

Figure 5. Simulated return loss of vee-antenna vs. frequency for different slope angles (θ).

the effective radiative length of it i.e., $2L\cos\theta$, is less than that of a half-wave dipole. Therefore according to the discussion of the previous section, the HPBW of it in the E-plane is wider than that of a half-wave dipole. Hence, a resonant-vee antenna can simultaneously hold both advantages of a half-wave dipole and a small dipole.

Figures 5–7 shed some light in the behavior of resonant-vee antennas.

Figure 5 shows the simulated return loss of the vee-antenna displayed in Figure 4, vs. frequency with different slope angles i.e., θ.

It is seen that the S_{11} antenna of the depends on the slope angle of the antenna and it is obvious that by increasing θ, the resonant point moves toward higher frequencies. Figures 6(a) and 6(b) illustrate the imaginary and real part of the antenna vs. frequency for different slope angles.

It is inferred from Figure 6 that for high slope angles, the input impedance decreases and to match the antenna, an impedance transformer may be needed.

The radiation patterns of the vee-antenna for different θ are depicted in Figure 7. As it was expected, the more the angle θ, the broader the beam in the E-plane.

It is also inferred that the radiation pattern has the deepest null when $\theta = 0$ and by increasing θ, the null becomes slightly shallow.

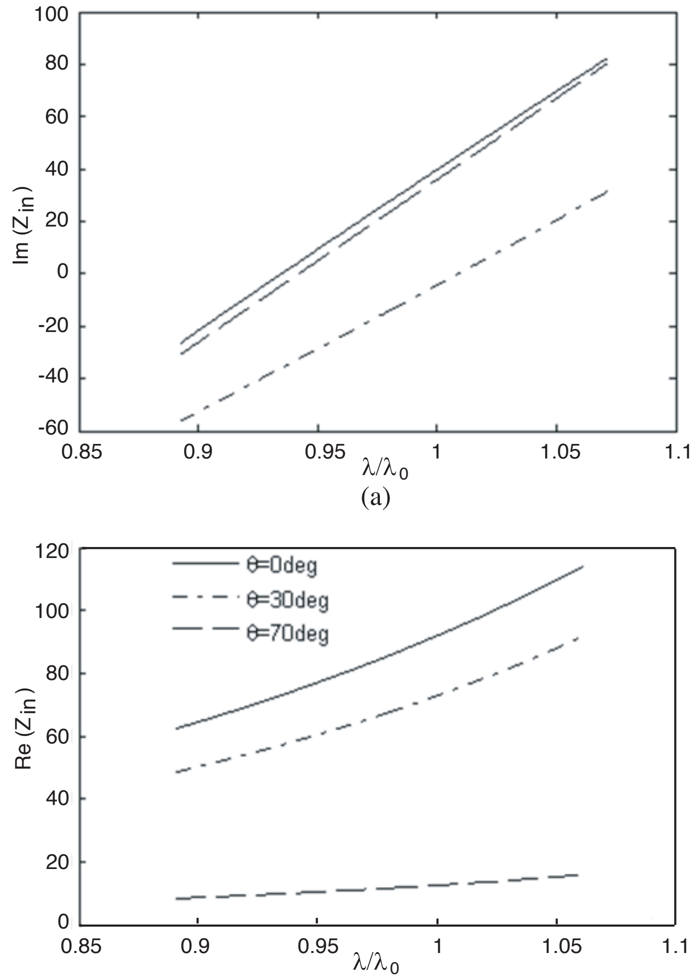

Figure 6. Imaginary (a) and real (b) part of the input impedance of resonant vee-antenna vs. frequency (simulated with FEKO software).

3.2. The Reflectors

Figure 8 is the side view of Figure 3 which exhibits the wire rods used as reflectors for the feeding structure i.e., the resonant vee-antenna.

The location of wire reflectors are

$$r_i = \frac{2f}{1 + \cos \varphi_i} \tag{2}$$

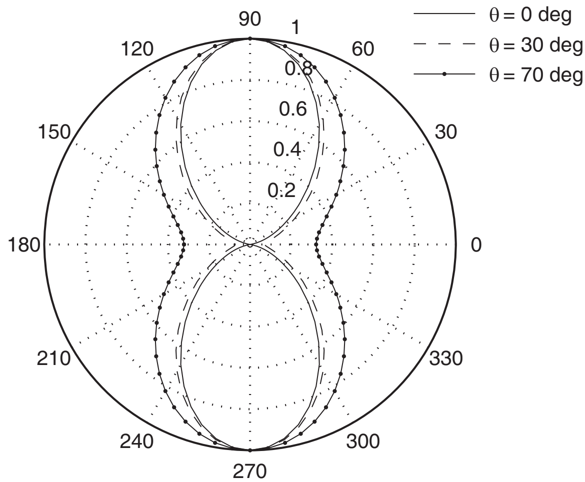

Figure 7. Radiation pattern of the resonant vee-antenna for different slope angles θ.

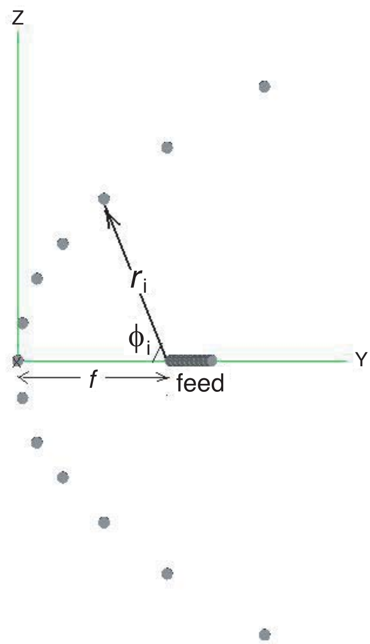

Figure 8. Side view of the proposed antenna structure.

which is a well-known curve of a parabola.

Since the reflectors are wire rods, the placement of these reflectors forms a cylindrical parabolic reflector and renders the H-plane (yz-plane) beamwidth of the antenna to decrease while the E-plane beamwidth remains unchanged. This is desirable because in addition to attain a high gain antenna, its broad-beam characteristic is also preserved.

3.3. The Fabricated Antenna

The fabricated antenna is shown in Figure 9. The optimized antenna parameters are: Number of reflectors = 13, focal distance $f = 0.43\lambda_0$, length of reflectors = $0.67\lambda_0$ and feed slope angle $\theta = 30\,\text{deg}$.

Figure 9. The fabricated antenna.

The measured VSWR of the antenna is shown in Figure 10. It should be mentioned that there is a slight difference between measured and simulated VSWR of the antenna. This is due to the fact that we have used a folded coax balun in practice while this is not included in the simulation. However, only by a small tuning of the feed length, the frequency performance of the antenna can be tuned to the desirable frequency of operation.

The radiation pattern of the antenna through the operational frequency is depicted in Figure 11. It should be mentioned that due to the low frequency of operation, it is not possible to test the pattern of such antenna in an anechoic chamber. It is also both time-consuming and money-taking to examine the antenna in an open range. Hence, the radiation pattern of the antenna is just simulated with MOM based EM simulator softwares i.e., FEKO and NEC. It is observed that both

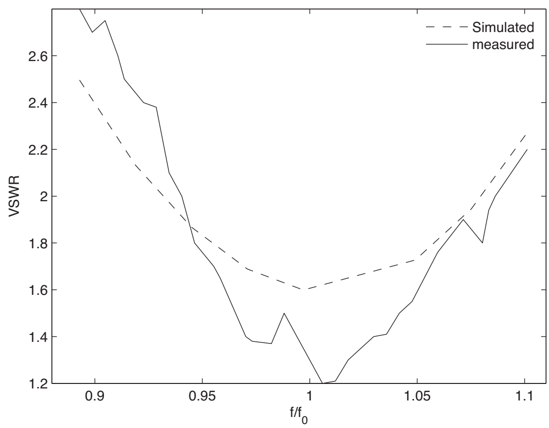

Figure 10. Simulated and measured VSWR of the fabricated antenna.

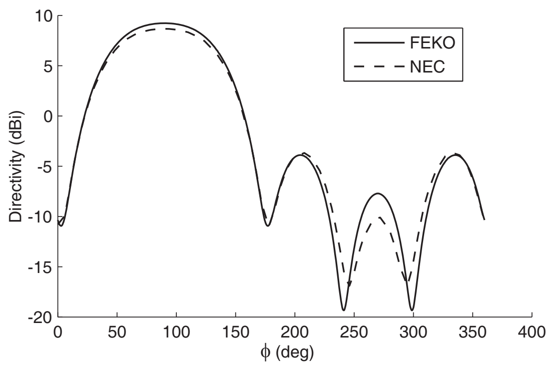

Figure 11. Simulated radiation pattern of the proposed antenna at $f = f_0$.

simulations do agree with each other. It is also worth noting that since the calculation of the antenna patterns is performed via integration, the numerical errors are much smoother than that of the VSWR of the antenna which depends only on some specific points.

4. CONCLUSION

According to the pattern requirements for search radars applications, a new antenna structure has been proposed which in addition to a high gain (near 10 dBi) has a broad beam (about 90 degrees) in the E-plane. The design procedure to achieve the designated characteristics has been illustrated. The antenna has been fabricated and the results have been discussed. It should be mentioned that using the proposed geometry, other radiational characteristics may be achieved provided that more sophisticated optimization techniques such as genetic algorithm are utilized.

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