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Turnstile S-Shaped Dipole and Swastika Wire Antennas for VHF and UHF Applications

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ABSTRACT: *New wire antennas are proposed, namely turnstile S -Shaped dipole and Swastika wire antenna. The radiation characteristics are obtained using the method of moments (MoM) with one-volt delta gap source and suitable dimensions for these antennas. From the obtained characteristics these antenna are considered of wide bandwidth. The proposed Swastika antenna and turnstile S-Shaped dipole antenna radiate left circularly polarized (LCP) waves. Right circularly polarized (RCP) waves are obtained using the inverted Swastika antenna and inverted turnstile S-Shaped dipole antenna. Swastika antenna and turnstile S-Shaped dipole antenna with comparison with turnstile dipole with the same absolute length have superiority performance of radiation characteristics in addition to save up to 75% of the area that the antennas can occupy. The given discussions proved the feasibility of using such antennas in a wide range of applications in the VHF and UHF frequency ranges both in free space and with a perfect grounded conducting plane. In this paper commercial software (NEC-win professional) is used to obtain all the radiation characteristics of the proposed antennas.*

Keywords: *The method of moments (MoM), Turnstile arrangement, Wire antennas*

I. INTRODUCTION

Wire antennas are of spread use in the HF, VHF and UHF frequency ranges. They can be made from either solid wire or tubular conductors. They are relatively simple in concept, easy to construct and inexpensive. They are most widely used antennas for wireless mobile communication systems. Arrays of dipoles-the famous form of the wire antennas- are commonly used as base-station antennas in mobile systems. They have attractive features such as simple construction, relatively broadband characteristics, and small dimensions at high frequencies. The Loop antennas form another wire antenna type, which features simplicity, low cost and versatility. Loop antennas can have various shapes, namely circular, triangular, square, elliptical, etc. They are widely used in applications up to the UHF band. [1, 4]

The S-Shaped wire antenna-new form of wire antennas- which can radiate left elliptically polarized (LEP) waves. Right elliptically polarized (REP) waves are obtained using the inverted S-Shaped wire antenna. Also circular polarization of both senses is obtained using the turnstile arrangement and the Swastika antenna.

The MoM solution is a numerical procedure for solving the electric field integral equation. Basis functions are chosen to represent the unknown currents (i.e., triangular basis functions). Testing functions are chosen to enforce the integral equation on the surface of the wires. With the choice of basis and testing functions, a matrix approximating the integral equation is derived. If this matrix is inverted and multiplied by the local sources of electric field, the complex magnitudes of the current basis functions are derived. All antenna performance parameters can be determined from the derived current distribution. In this paper commercial software (NEC-win professional) is used to obtain all the radiation characteristics of the proposed S-shaped antennas and Swastika antenna. [5,6]

II. METHOD OF MOMENTS

The Method of Moments (MoM) is a well-known technique for solving linear equations. In antenna analysis, the MoM is used to convert the electric field integral equation into a matrix equation or system of linear equations. The matrix equation can then be solved for the current coefficients by LU decomposition, Gaussian elimination, or other techniques of linear algebra. The following development is based on the work by [5,6]

The basic form of the equation to be solved by the MoM is

$$L(u) = f \tag{1}$$

where L is the linear operator, u is the unknown function, and f is the source or forcing function. In order to create the matrix equation, the unknown function is defined to be the sum of a set of known independent functions, u_n called basis or expansion functions with unknown amplitudes α_n ,

$$u = \sum_n \alpha_n u_n \tag{2}$$

Using the linearity of the operator, L the unknown amplitudes can be brought out of the operator giving

$$\sum_n \alpha_n L(u_n) = f \tag{3}$$

The unknown amplitudes cannot yet be determined because there are n unknowns, but one functional equation. A fixed set of equations are found by defining independent weighting or testing functions, w_m , which are integrated with (3) to give m different linear equations. The integration of the weighting functions with (3) may be written symbolically as the inner product of the two functions, giving

$$\sum_n \alpha_n \langle w_m, L(u_n)\rangle = \langle w_m, f\rangle \ , \tag{4}$$

Where the inner product $\langle a,b\rangle$ is defined to be the integral of the two functions over the domain of the linear operator. Now there are an equal number of unknowns and independent equations, which allow for the solution of the unknown amplitudes α_n .

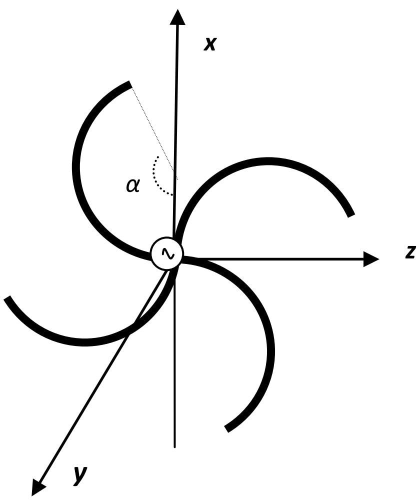
For antenna problems, the matrix equation of (4) is usually written in a form similar to Ohm's law as

$$\left[Z_{m,n}\right]\left[I_n\right] = \left[V_m\right]. \tag{5}$$

The generalized impedance matrix is given by $\left[Z_{m,n}\right] = \left[\langle w_m, L(u_n)\rangle\right]$, the generalized current matrix is given by $\left[I_n\right] = \left[\alpha_n\right]$, and the generalized voltage matrix is given by $\left[V_m\right] = \left[\langle w_m, f\rangle\right]$. The generalized matrices may need to be scaled to obtain the same units as the counterparts in Ohm's law.

III. TURNSTILE S-SHAPED ANTENNA

Antenna Description and Simulation Results: The turnstile arrangement of S-and inverted S-Shaped dipole antennas is energized with currents of equal magnitude but in phase quadrature. S-shaped dipole antenna was introduced in [7]. This arrangement, as shown in figures 1 and 2, are made of thin solid wire, and produce circular polarization wave of both senses.



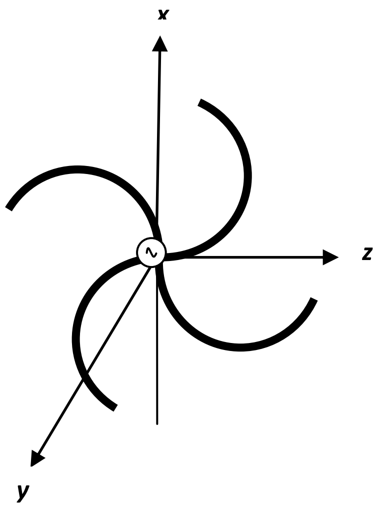


Figure2 : Turnstile S-shaped antenna Figure 2: Turnstile Inverted S-shaped antenna

The input impedance and the VSWR for α = 180°at different wire lengths (L_S =50 cm, 100 cm and 200 cm) are shown in figures 3, 4 and 5. It is clear that after 600 MHz the input resistances vary between small values and the antenna has capacitive reactance. The VSWR for L_S =50 cm is approximately $\leq$ 2 at f > 600 MHz.

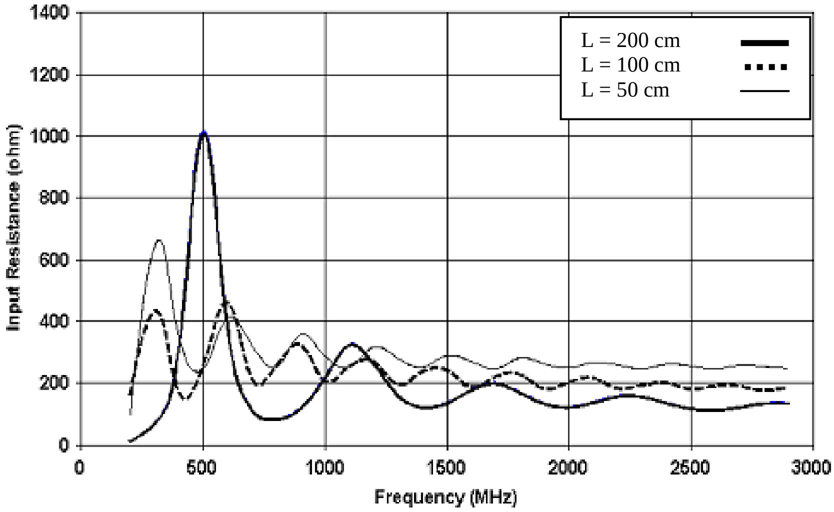


Figure 3: The input resistance at different values of wire length for S-Shaped turnstile antenna (α = 180°)

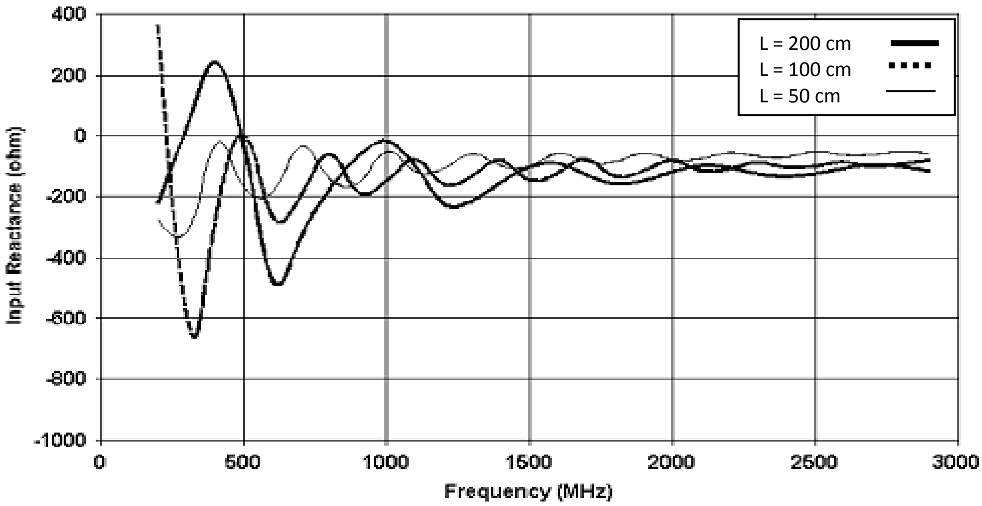


Figure 4: The input reactance at different values of wire length for S-Shaped turnstile antenna (α = 180°)

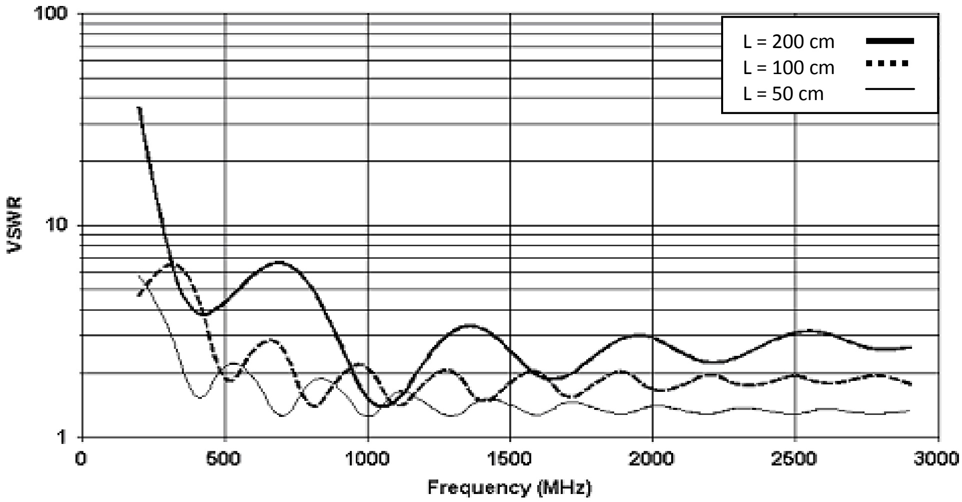


Figure 5: The VSWR at different values of wire length for S-Shaped turnstile antenna (α = 180°)

The gain in dB as a function of frequency for (L_S =50 cm and α = 180°) when it is located in free space and over PCGP is shown in figure 6.

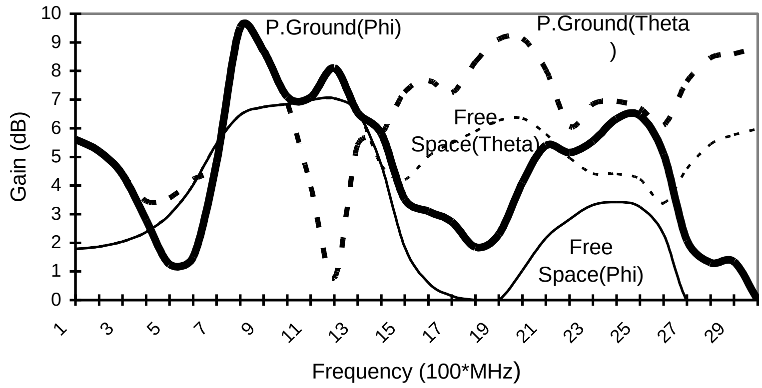


Figure 6: Gain relative to isotropic source for the turnstile S-Shaped dipole antenna (L_S =50 cm and α=180°)

Typical power radiation patterns at 800 MHz and 1400 MHz for normal and inverted turnstile S-Shaped dipole antenna (L_S , α) = (50 cm, 180°) in the free space and over a PCGP are given in figures 7 to 10.

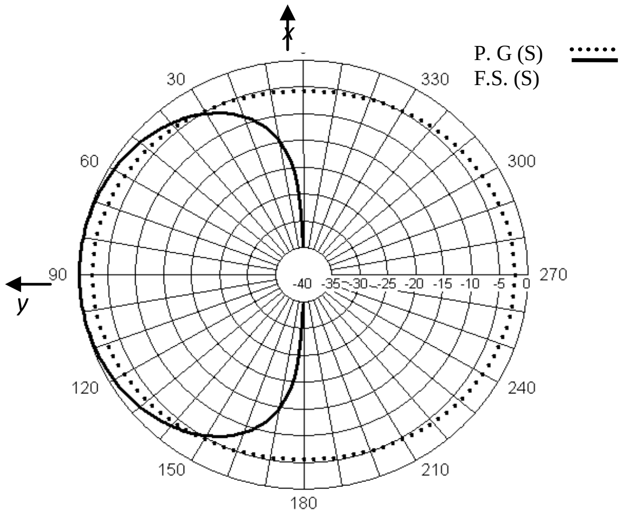


Figure 7: Total power radiation pattern in *yz*-plane at 800 MHz (L_S =50 cm and α =180°)

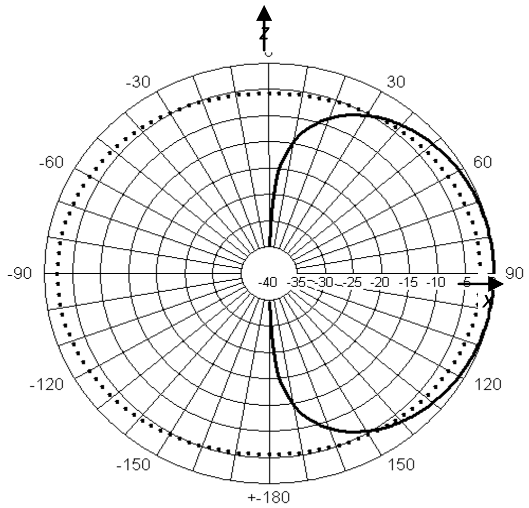
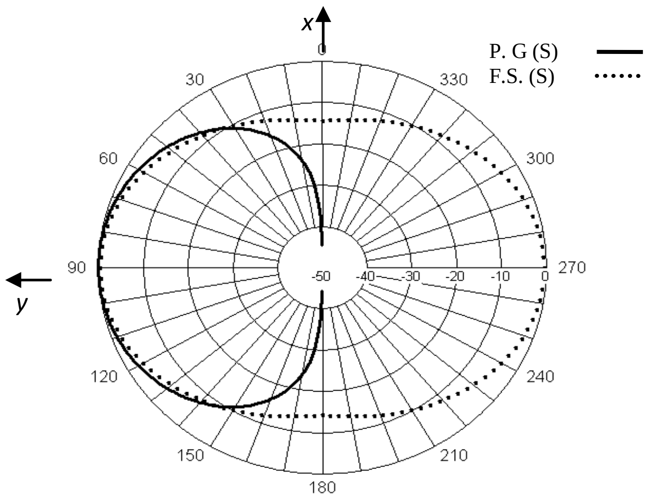


Figure 8: Total power radiation pattern in *xy*-plane at 800 MHz (L_S =50 cm and α =180°)



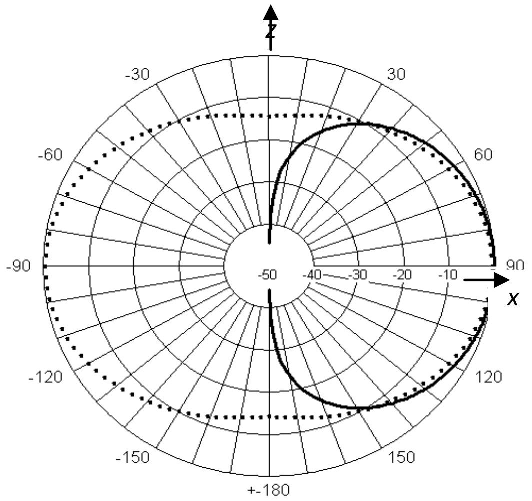


Figure 9: Total power radiation pattern in *yz*-plane 1400 MHz (L_S =50 cm and α =180°)

Figure 10: Total power radiation pattern in *xy*-plane at at 1400 MHz (L_S =50 cm and α =180°)

From figure 6 it is clear that the antenna over PCGP has high gain compared to that in free space case. For both cases the power radiation pattern becomes narrower as the frequency increase.

IV. SWASTIKA ANTENNA

The Swastika antennas which form by turnstile arrangement of clockwise and counter clockwise-Inverted swastika- 90° angle bent dipole antenna are energized with currents of equal magnitude but in phase quadrature. This arrangement, shown in Figures.11 and 12, made of thin solid wire, produce circular polarization wave of both senses. The antenna is located in the *xz*–plane. The MoM with one-volt delta gap source is applied to this antenna

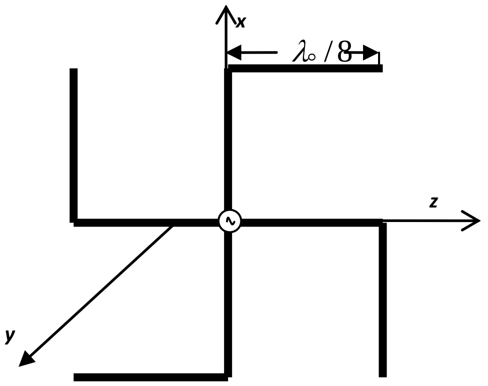


Figure 11: Swastika Antenna

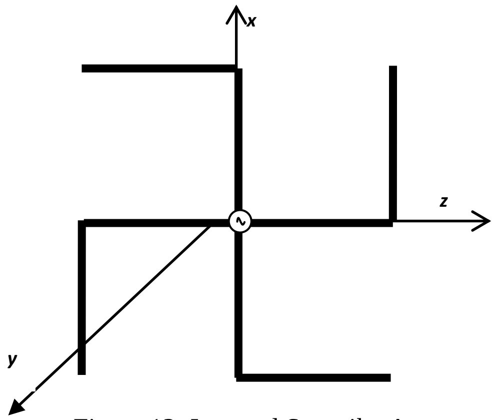


Figure 12: Inverted Swastika Antenna

The input resistance and reactance for the Swastika antenna with the same absolute length of turnstile half wavelength dipole ($\lambda_\circ/2$) are shown in Figures. 13 and 14. The variety of the input resistance of Swastika antenna after 2 $f_\circ$ is less than that of turnstile dipole and the input reactance is capacitive after this frequency.

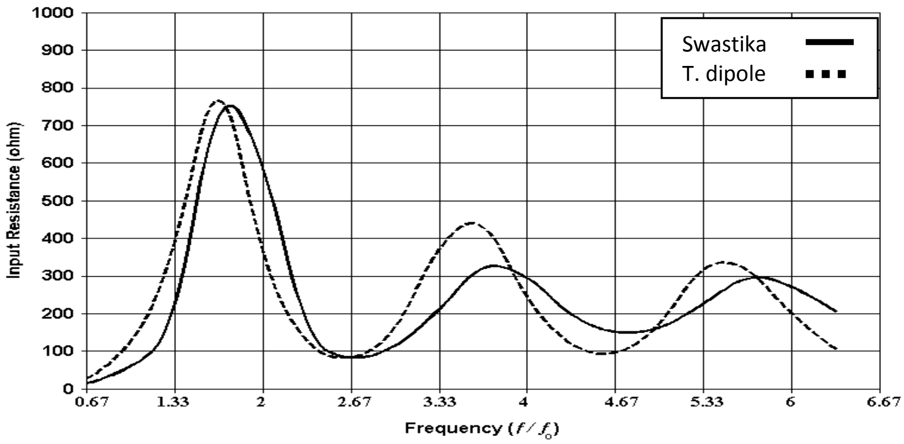


Figure 13: The input resistance as function of frequency for the Swastika antenna and the same length turnstile dipole

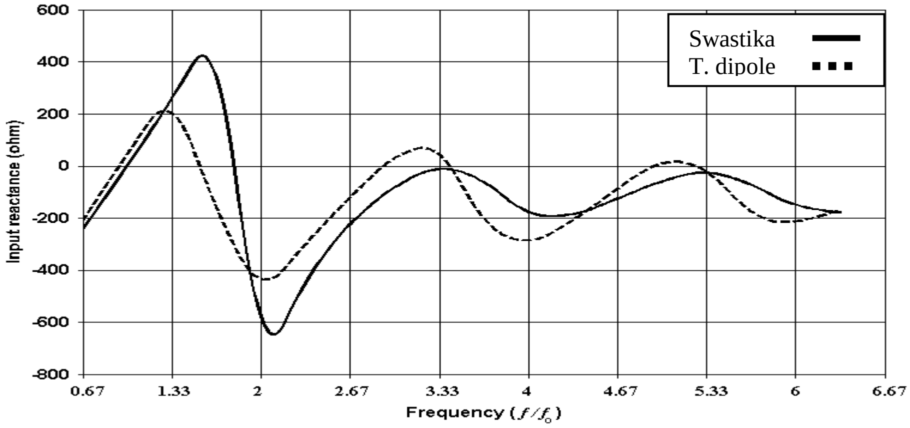


Figure 14: The input reactance as function of frequency for the swastika antenna and the same length turnstile dipole

The VSWR at $Z_\circ$ =300 Ω for the same previous antennas is shown in Figure 15. From Figure 15 it's clear that Swastika antenna has superiority performance on the turnstile dipole.

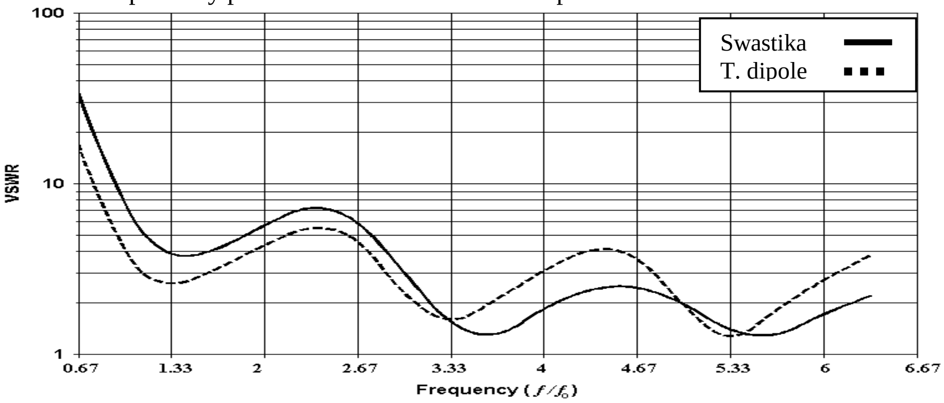


Figure 15: The VSWR as function of frequency for the Swastika antenna and the same length turnstile dipole

The current distribution over one side of the Swastika antenna and the current distribution over the same length dipole at the frequencies $f_\circ$, 2 $f_\circ$ and 3 $f_\circ$ are shown in Figures.16, 17 and 18.

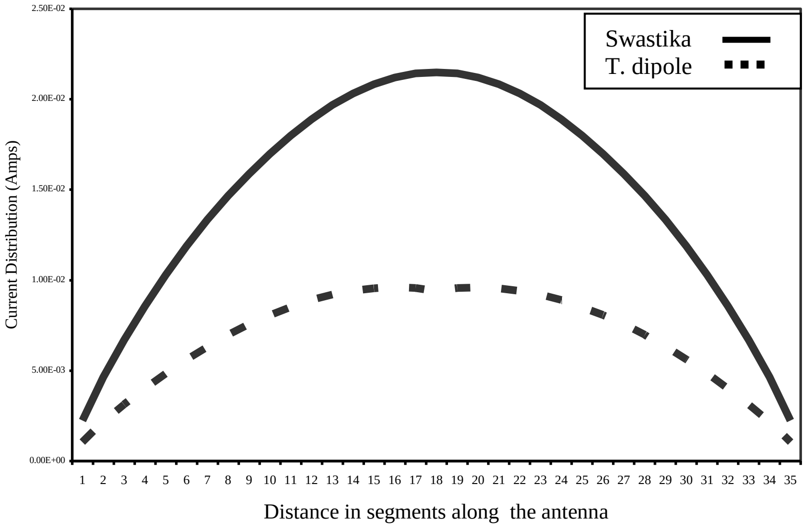


Figure 16: The Current distribution on the Swastika antenna and the same length turnstile dipole at $f_\circ$

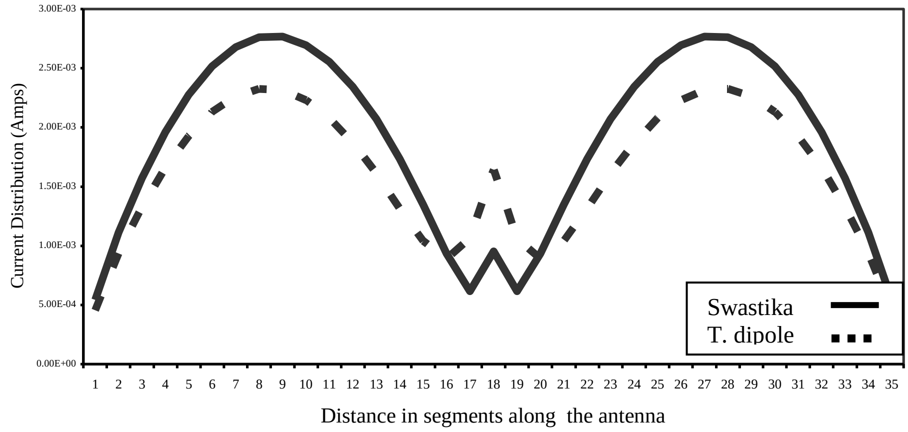


Figure 17: The Current distribution on the Swastika antenna and the same length turnstile dipole at 2 f_o

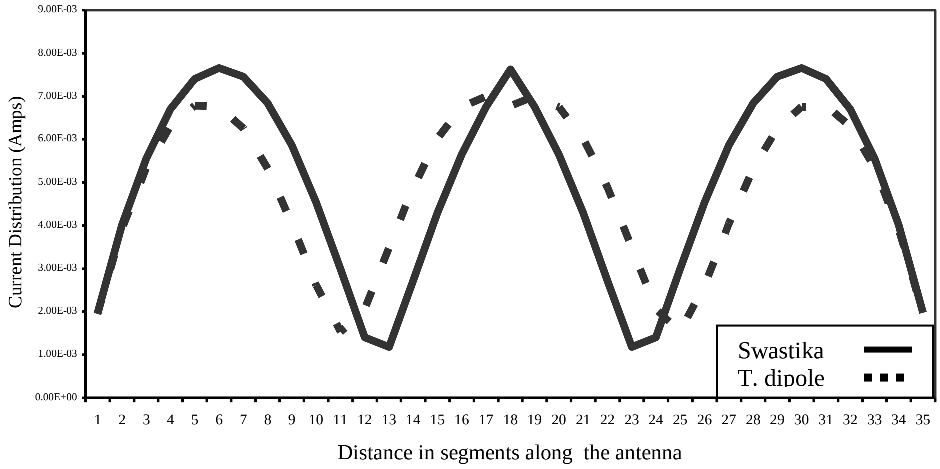


Figure 18: The Current distribution on the Swastika antenna and the same length turnstile dipole at 3 f_o

The gain in dB over an isotropic source as function of frequency for Swastika antenna when it is located in free space and over a perfectly conducting ground plane are shown in Figure 19. It is clear that the antenna over a perfectly conducting ground plane has superior performance.

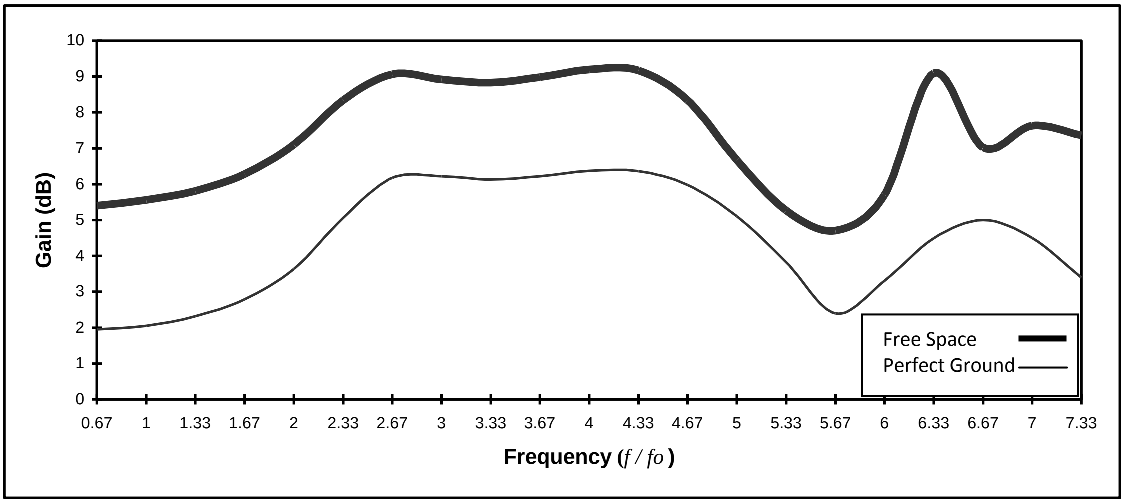


Figure 19: Gain relative to isotropic source for the Swastika antenna and the same length turnstile dipole

Typical power radiation patterns at $f_\circ$ and 3 $f_\circ$ for normal and inverted Swastika antenna in the free space and over perfectly conducting ground plane are given in Figures 20 and 21.

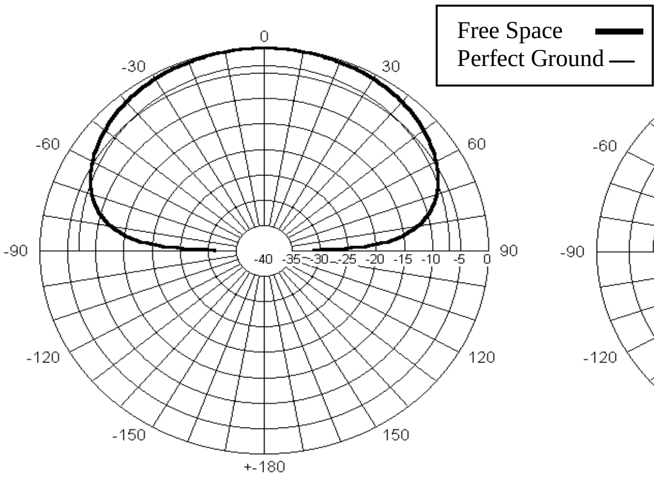


Figure 20: Power radiation pattern in at $f_\circ$

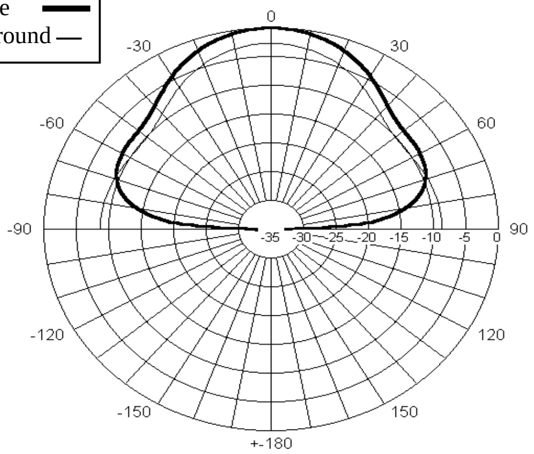


Figure 21: Power radiation Pattern in at 3 $f_\circ$

V. COMPARISON BETWEEN SWASTIKA ANTENNA AND THE TURNSTILE S-SHAPED DIPOLE ANTENNA

In fact the idea of construction of Swastika antenna arises after finishing simulation and testing the S-Shaped dipole antenna[7] and its turnstile arrangements (Figure1).

By choosing the turnstile S-Shaped dipole with (L_S = 50 cm and α = 180°) and Swastika antenna with length side also 50 cm, the input impedance and the VSWR are shown in Figures 22, 23 and 24.The previous radiation characteristics are nearly the same for both antennas.

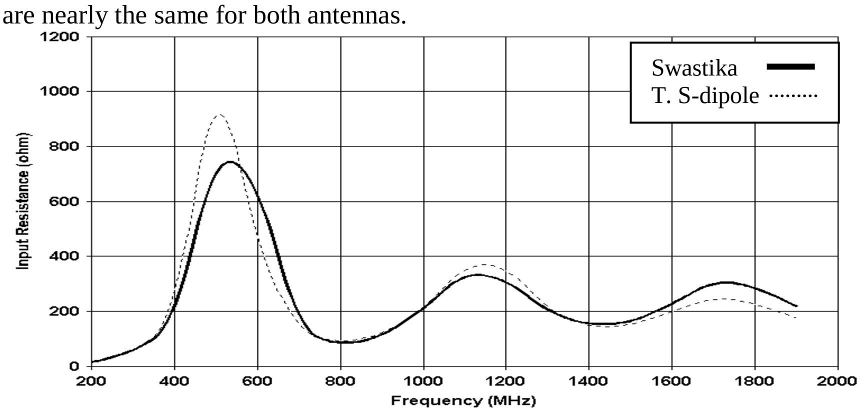


Figure 22: The input resistances for turnstile S-Shaped with L_S = 50 cm and α = 180° and the same length Swastika antenna

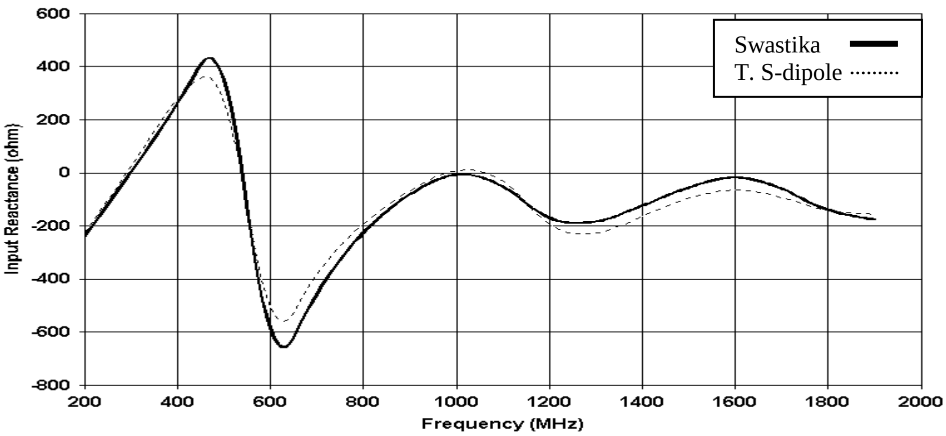


Figure 23: The input reactance for turnstile S-Shaped with L_S = 50 cm and α = 180° and the same length Swastika antenna

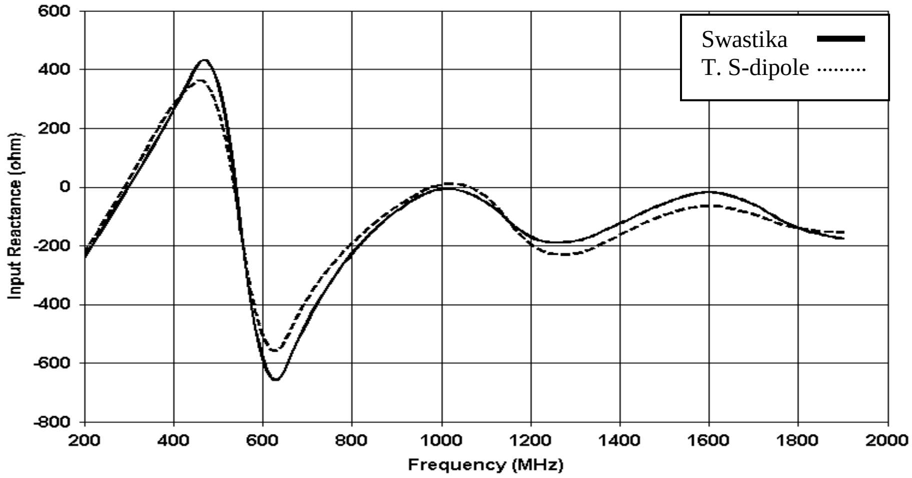
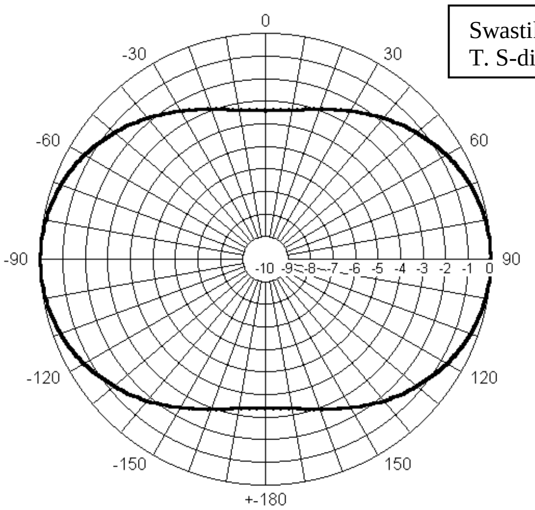


Figure 24: The VSWR for turnstile S-Shaped with L_S = 50 cm and α = 180° and the same length Swastika antenna

The radiation pattern at 300MHz and 900MHz are shown in the Figures 25 and 26 and the gain as function of frequency for both antennas is shown in Figure 27.



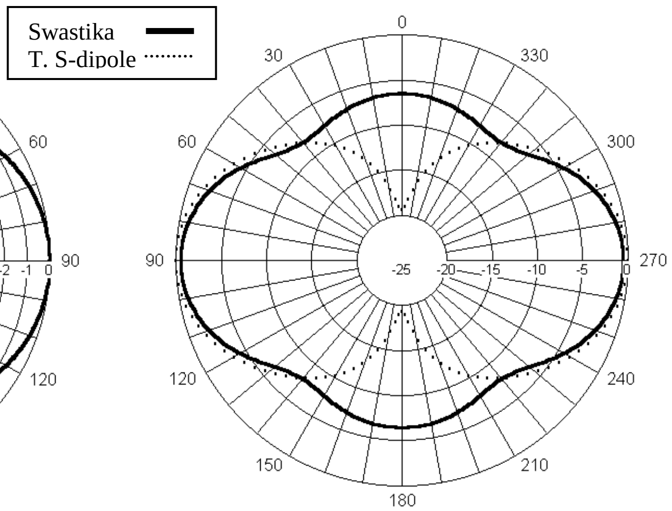


Figure 25: Power radiation pattern in at 300 MHz

Figure 26: Power radiation pattern in at 900 MHz

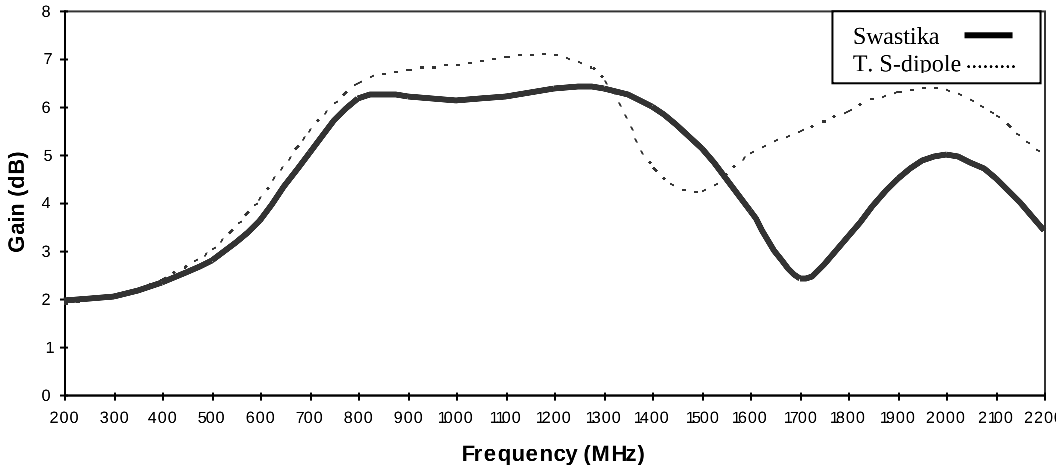


Figure 27: Gain relative to isotropic source for the turnstile S-Shaped with L_S = 50 cm and α = 180° and the same length Swastika antenna

The pattern at 300 MHz the same for both antennas but at the 900 MHz some differences in the pattern and from Figure44 cleared that after 600 MHz the gain has different shapes and values

VI. CONCLUSIONS

New simple wire antennas are proposed and analyzed, namely the S-Shaped and the inverted S-Shaped dipoles and its turnstile arrangements and Swastika antenna. The field patterns and gains in the principal planes over a range of frequencies are obtained for the mentioned arrangements. The other radiation characteristics such as input resistance, reactance and the VSWR as functions of frequency, for different antenna dimensions, are reported. The measurements of the power radiation patterns in the principal planes for the S-Shaped antenna are performed and proved theoretically. The results show that the proposed antennas can radiate linearly or circularly polarized waves and are promising to be used in the VHF and UHF frequency ranges. Wire antennas are still attractive due to their simple, rigid, cheap wide varieties and reliable constructions.

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