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S-Shaped Dipole And Swastika Antennas

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الملخص

الهوائي ثنائي القطبية على هيئة حرف (S) والهوائي المسمى سواستيكا

يقدم في هذا البحث أنواع جديدة من الهوائيات المصنوعة من اسـلاك موصـلة . هـذه الهوائيات تسمى الهوائي الثنائي القطبية على هيئة حـرف S والتـشكيل المـسمى (turnstile) المشكل منه بالاضافة للهوائي المسمى(سواستيكا) . الخواص الاشعاعية لهذه الهوائيات حـسبت باستعمال احدى الطرق العددية لحل مسائل الكهرومغناطيسة وتسمى طرقة العـزوم وباسـتعمل برنامج محاكاة تجاري يعتمد على هذه الطريقة. من هذه النتائج الحسابية نجد ان هذه الهوائيـات من الممكن اعتبارها انها ذات نطاق ترددي واسع.

الهوائي الثنائي القطبية على هيئة شكل حرف S يطلـق موجـات اشـعاعية اهليجيـة (بيضاوية) القطبية يسارية الاتجاه ويمينية الاتجاه اذا استعملنا الشكل المعكوس منه.كذلك الهوائي السواستيكا و والتشكيل المسمى (turnstile) من الهوائي الثنائي القطبية على هيئة شكل حرف S يطلق موجات اشعاعية دائرية القطبية في كلا الاتجاهين .

الهوائي السواستيكا و والتشكيل المسمى (turnstile) من الهوائي الثنائي القطبيـة علـى هيئة شكل حرف S -بالمقارنة مع الهوائي الثنائي القطبية المتعارف عليه سابقا- يمتلكان خواص اشعاعية افضل بالاضافة لصغر المساحة التي يشغلها الهوائي التي تصل لأقل مـن 75% مـن المساحة التي يشغلها الهوائي ثنائي القطبية .

هذه الهوائيات المقترحة من الممكن استعمالها في تطبيقات متعددة وخاصة في النطـاقين العالي والفائق التردد من خلال استعمالهم في الفراغ أو فوق سطح موصل.

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ABSTRACT

New wire antennas are proposed, namely S-Shaped dipole antenna and its turnstile arrangements and Swastika 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 antennas are considered of wide bandwidth. The proposed S-Shaped antenna radiates left elliptically polarized (LEP) waves. Right elliptically polarized (REP) waves are obtained using the inverted S-Shaped dipole antenna. Also 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: Wire antennas, Turnstile arrangement dipoles, Elliptically polarized waves, The method of moments (MoM).

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, 2]

The S-Shaped dipole antenna -new form of wire antennas- radiates LEP waves. REP waves are obtained using the inverted S-Shaped dipole antenna. Also circular polarization of both senses is obtained using the turnstile arrangement and the Swastika antenna.

The Method of Moments (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. [3]

This paper consists of eight sections. Section I gives an introduction. Section II presents the MoM. The S-Shaped dipole antenna and the turnstile arrangements are presented in sections III and IV. The Swastika and its inverse antenna are given in section V. The comparison between the Swastika antenna and turnstile S-Shaped dipole antenna presents in section VI. Measured radiation patterns for S-Shaped dipole antenna are reported in section VII. A conclusion is given in section VIII.

II. The Method of Moments (MoM):

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 given by [4]

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 are 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,

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

where the inner product $\left\langle a,b \right\rangle$ 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. The S-Shaped Dipole Antenna:

This antenna is made of an S-Shaped thin solid wire as shown in figure 1 and it is fed symmetrically. The Inverted S-Shaped dipole antenna is shown in figure 2. The antenna is located in the *xz*–plane. The MoM with one-volt delta gap source is applied to this antenna.

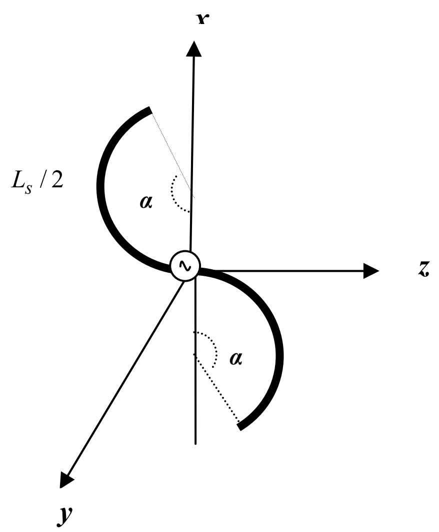

Fig. 1: S-Shaped dipole antenna

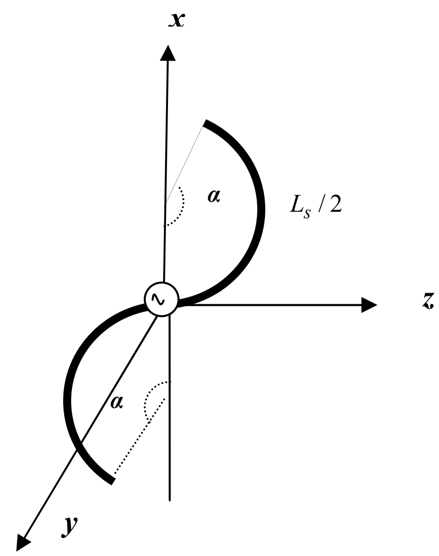

Fig. 2: Inverted S-Shaped dipole antenna

The radiation characteristics of the antennas can be obtained by straight forwarded procedure if we know the current distribution on the antenna [1,2]. The current distribution on the S-Shaped dipole antenna with L_s = 50 cm and α = 180° and 270°, (L_s is the length of the wire which the antenna is made), and a linear dipole antenna of the same length at 300, 500, and 1000 MHz are presented in figures 3 to 5.

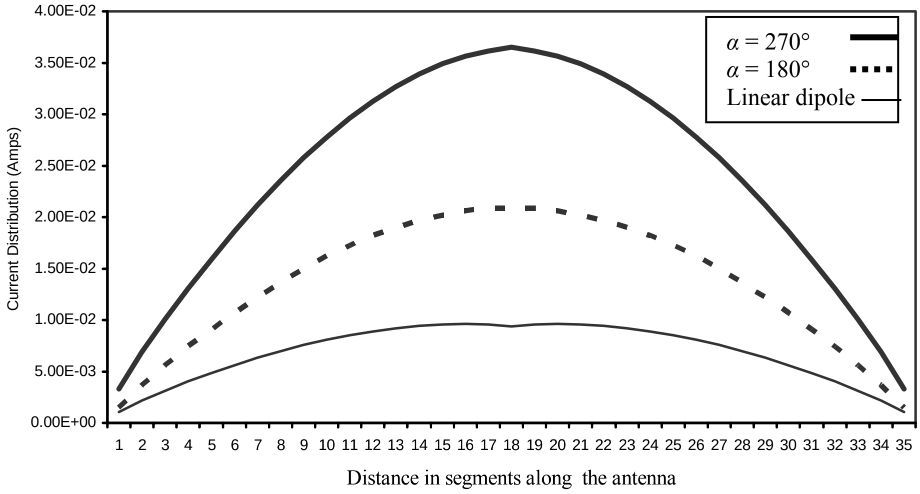

Fig 3: Current distribution at 300 MHz on the S-Shaped dipole antenna of L_s =50cm (α = 180° and 270°) and on a linear dipole

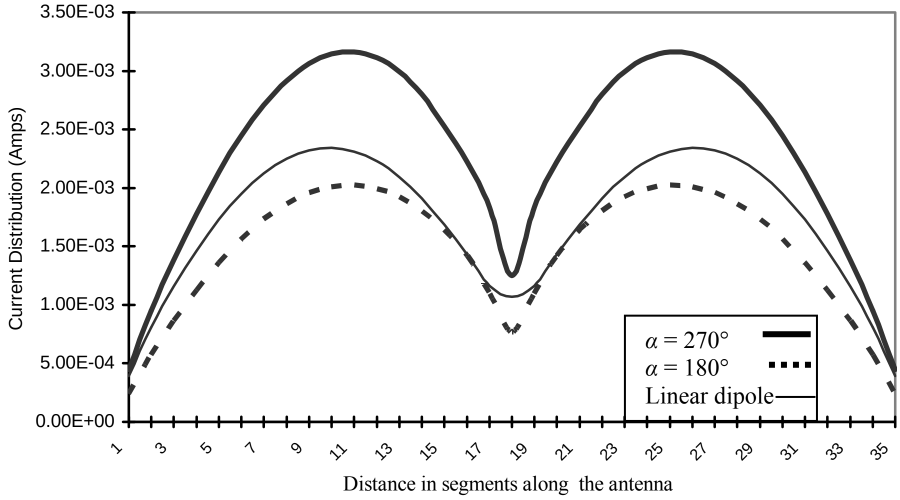

Fig 4: Current distribution at 500 MHz on the S-Shaped dipole antenna of L_s =50cm (α = 180° and 270°) and on a linear dipole

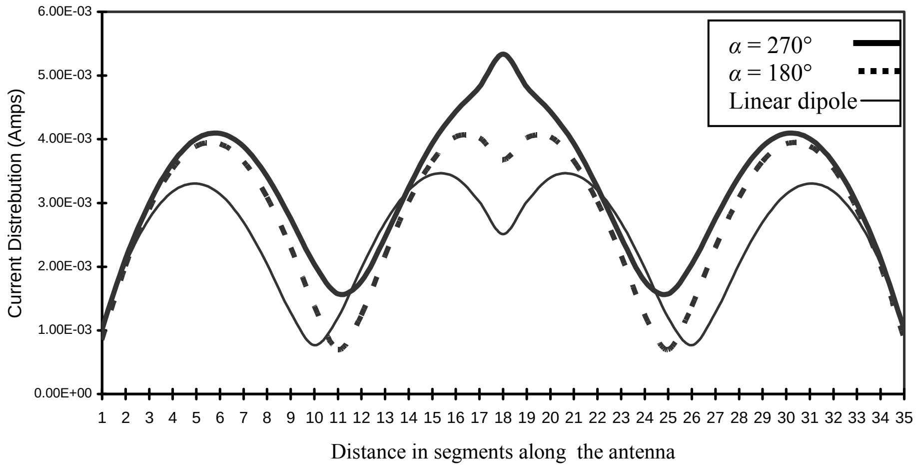

Fig 5: Current distribution at 1000 MHz on the S-Shaped dipole antenna of L_s =50cm (α = 180° and 270°) and on a linear dipole

From the previous figures it is clear that the current distribution becomes better when re-shaped the linear antenna in radial configuration. The input impedance as a function of frequency for L_S = 50 cm and different values of α (90°, 180° and 270°), together with a linear dipole of same length, and wire radius of 0.3 cm for S-and inverted S-Shaped antennas are represented in figures 6 and 7.

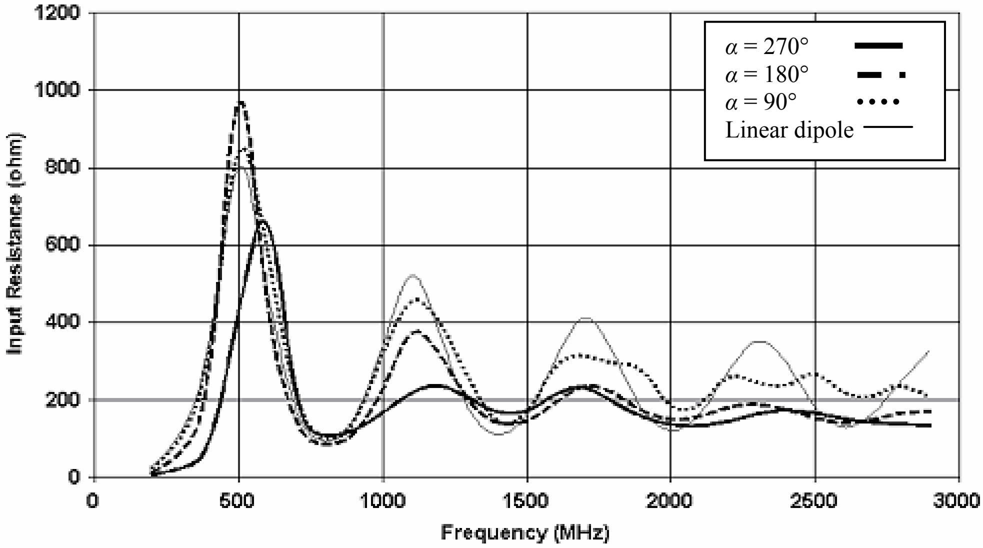

Fig. 6: The input resistances for L_S = 50 cm wire length and 0.3 cm radius as a function of frequency for the different configuration

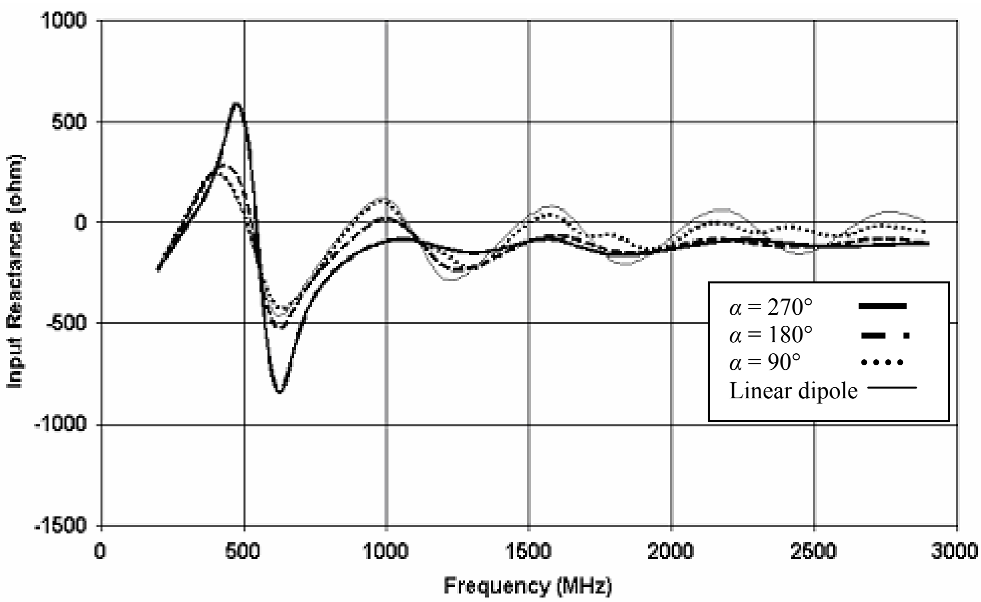

Fig. 7: The input reactance for L_S = 50 cm wire length and 0.3 cm radius as a function of frequency for the different configuration

It is clear from figure 6 that the variation of the input resistance, after 600 MHz, for α = 180° and 270° is relatively small. Also at these angles the reactive part of the input impedance is capacitive. For α = 90° and for the case of linear dipole the reactive part of the input impedance fluctuate between capacitive and inductive values. The VSWR at Z_o=300 Ω for the previous mentioned antennas is indicated in figure 8 as a function of frequency. VSWR at Z_o= 300 Ω for the S-and inverted S-Shaped dipole antennas of α = 180° is shown in figure 9, for different L_S, (L_S= 50, 100 and 200 cm).

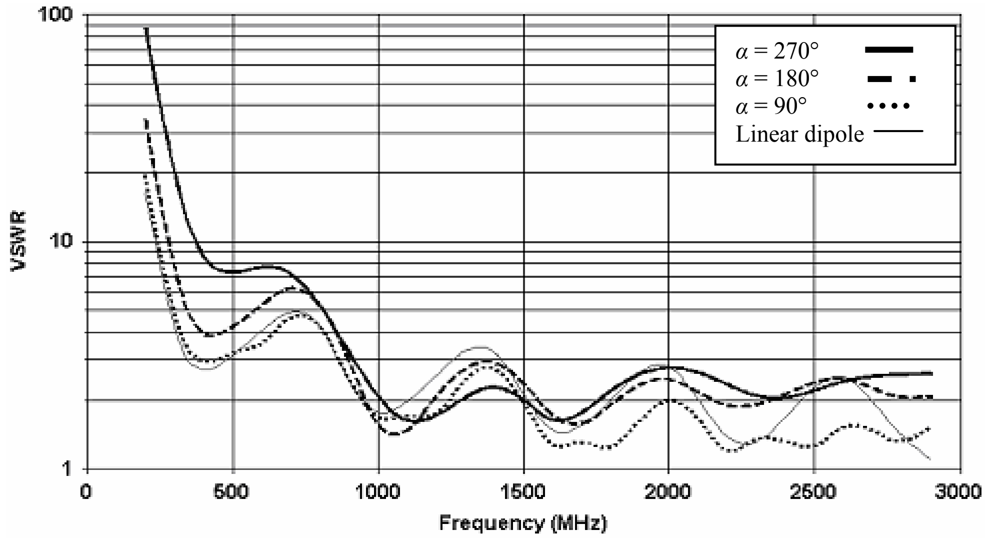

Fig. 8: The VSWR for L_S = 50 cm wire length and radius 0.30 cm for different angles α (90°, 180° and 270°) and a linear dipole for the same length

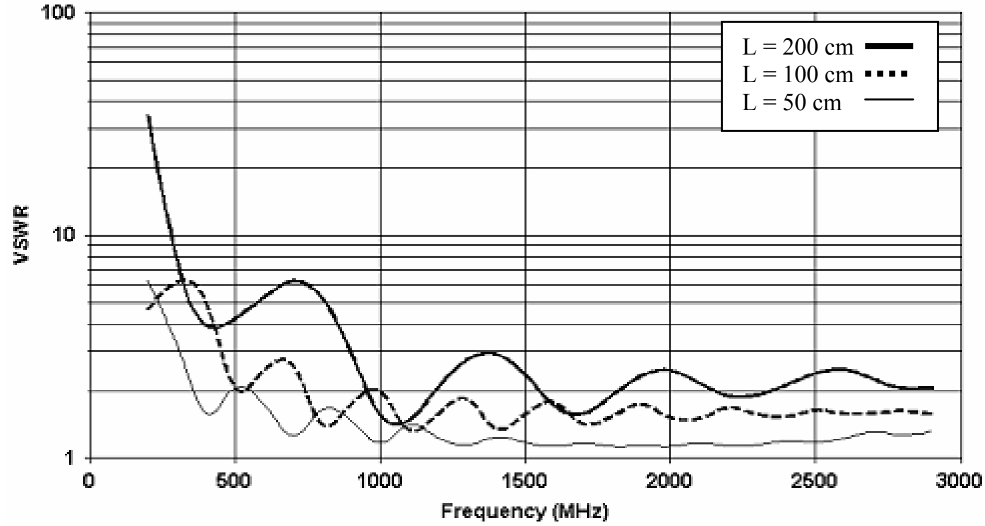

Fig. 9: The VSWR at different values of wire length and radius 0.30cm for S and inverted S- Shaped dipole antenna (α = 180°)

From figure 9 it is clear that the coupling between the antenna components improved the VSWR behavior. The antenna gain in dB relative to an isotropic source as a function of frequency for L_S = 50 cm and α = 180° when is located in free space and over a perfect conducting ground plane (PCGP) for S-and inverted S-Shaped antennas is shown in figure 10. It is clear that the antenna over a PCGP has superior performance.

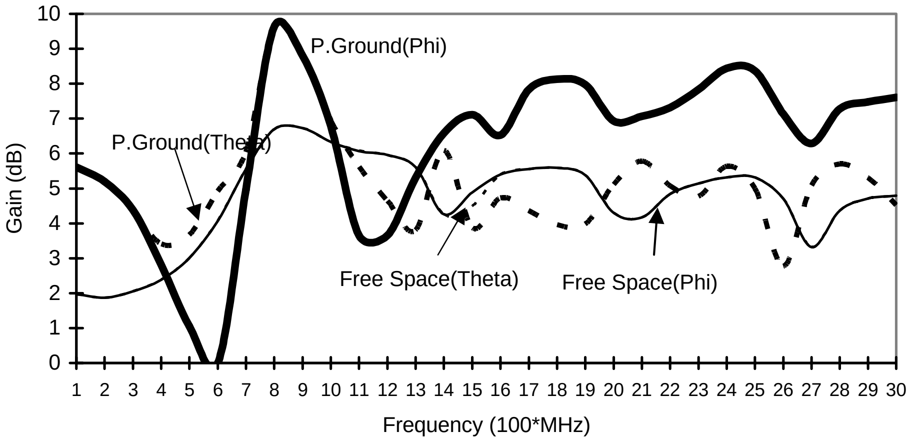

Fig. 10: Gain relative to an isotropic source for the S-and inverted S-Shaped dipole antenna (L_S = 50 cm and α = 180°)

The antenna gain in dB as a function of α at different frequencies (500, 800 and 1600 MHz) for L_S=50 cm is shown in figure 11. It is clear from the calculated results that the gain for α = 180° optimum.

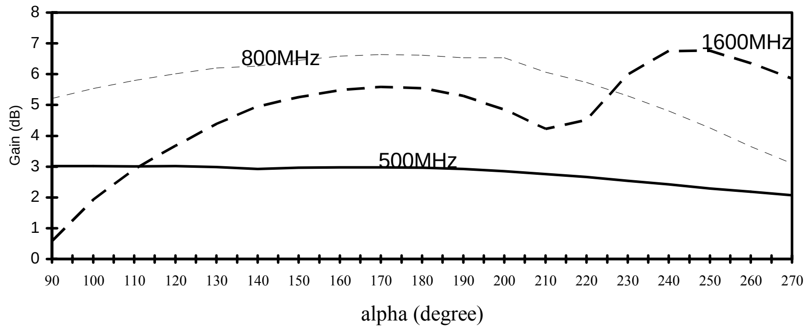

Fig. 11: Gain relative to an isotropic source as function of α for the S- and inverted S-Shaped dipole antenna (L_S =50 cm and *f* =500, 800 and 1600MHz)

Typical power radiation patterns at 300 MHz and 800 MHz for normal and inverted S-Shaped dipole antennas (L_S, α) = (50 cm, 180°) in free space (FS) and over a PCGP are given in figures 12 to 15.

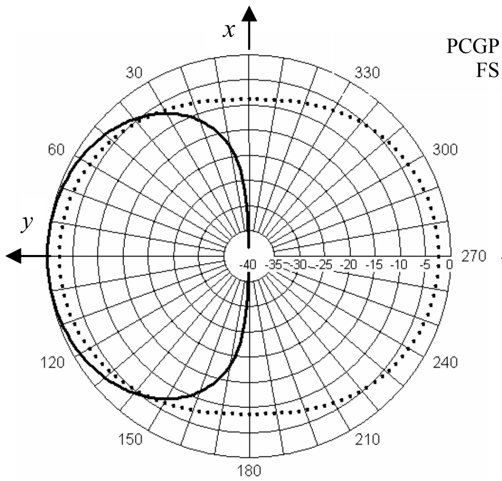

Fig.12: Total power radiation pattern in *xy*-plane at 300 MHz (L_S = 50 cm and α = 180°)

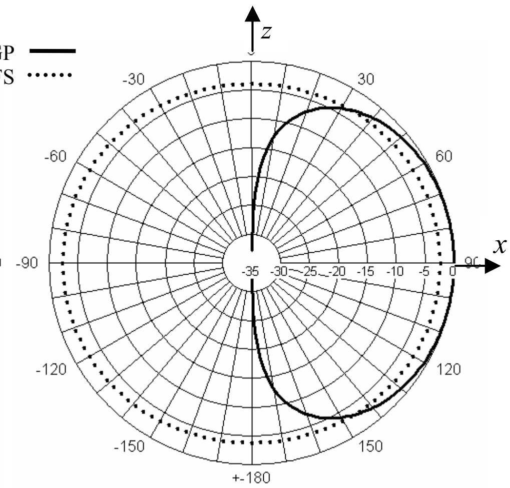

Fig.13: Total power radiation pattern in *zx*-plane at 300 MHz (L_S = 50 cm and α = 180°)

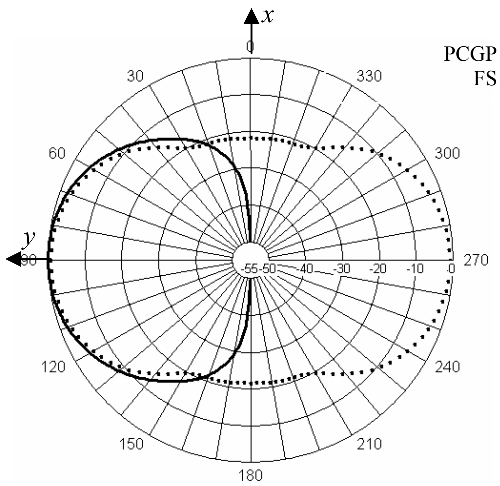

Fig14: Total power radiation pattern in *xy*-plane at 800 MHz (L_S = 50 cm and α = 180°)

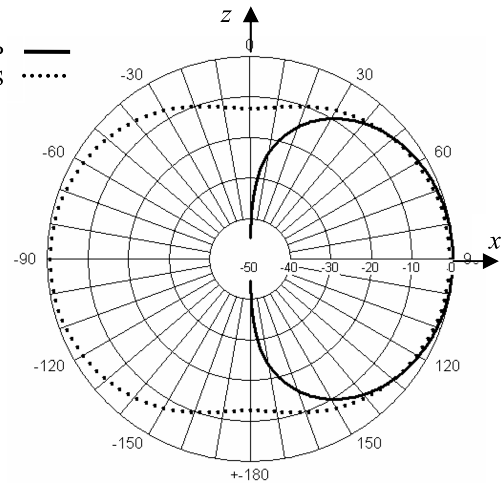

Fig.15: Total power radiation pattern in *zx*-plane at 800 MHz (L_S = 50 cm and α = 180°)

The axial ratio, AR, (the ratio between the minor axis and the major axis of the polarization ellipse) of the S-and inverted S-Shaped dipole antennas as a function of frequency for α = 180° and as function of α at 800 MHz are shown in figures 16 and 17, L_S = 50 cm

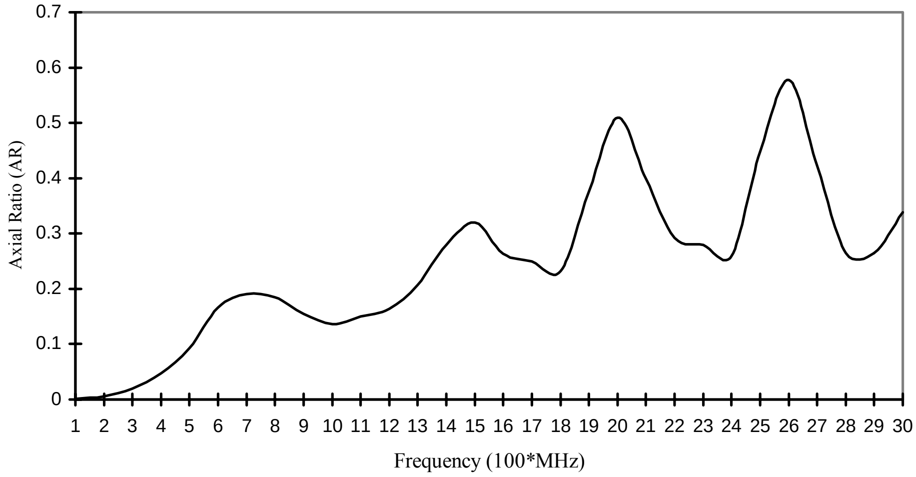

Fig.16: The Axial ratio as a function of frequency for the S and inverted S-Shaped dipole antenna (L_S = 50 cm and α = 180°)

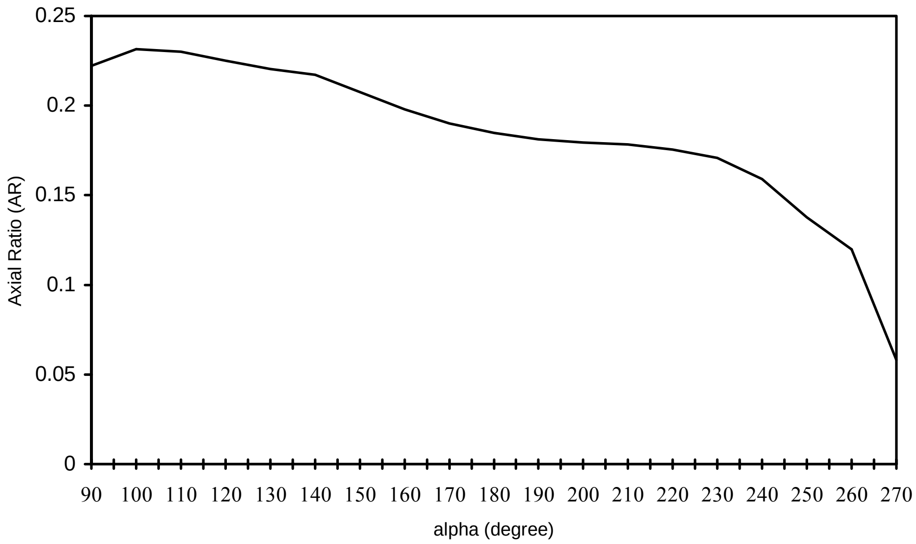

Fig.17: The Axial ratio as a function of α for the S and inverted S-Shaped dipole antenna (L_S =50 cm and f = 800MHz)

It is clear that the S-and inverted S-Shaped dipole antennas radiate elliptically polarized waves with left polarization for the S-shaped antennas and right polarization for the inverted S-Shaped antenna.

IV. S-Shaped turnstile antenna:

The turnstile arrangement of S-and inverted S-Shaped dipole antennas is energized with currents of equal magnitude but in phase quadrature. This arrangement, as shown in figures 18 and 19, are made of thin solid wire, and produce circular polarization wave of both senses.

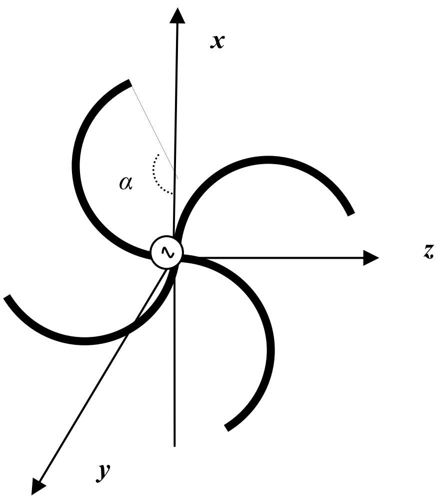

Fig.18: Turnstile S-shaped antenna

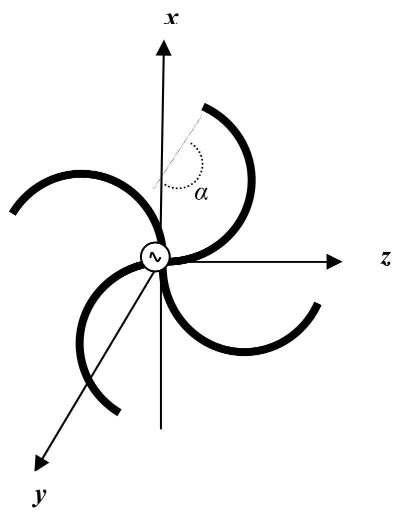

Fig. 19: Turnstile Inverted S-shaped antenna

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 20, 21 and 22 as a function of frequency. It is clear that at frequencies higher than 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.

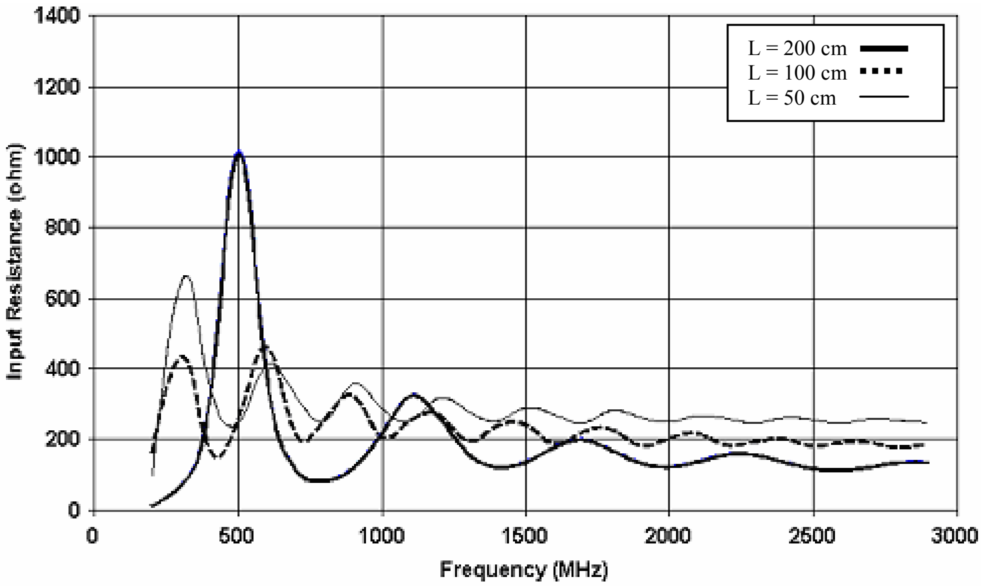

Fig. 20: The input resistance as a function of frequency for different values of wire length of S-Shaped turnstile antenna (α = 180°)

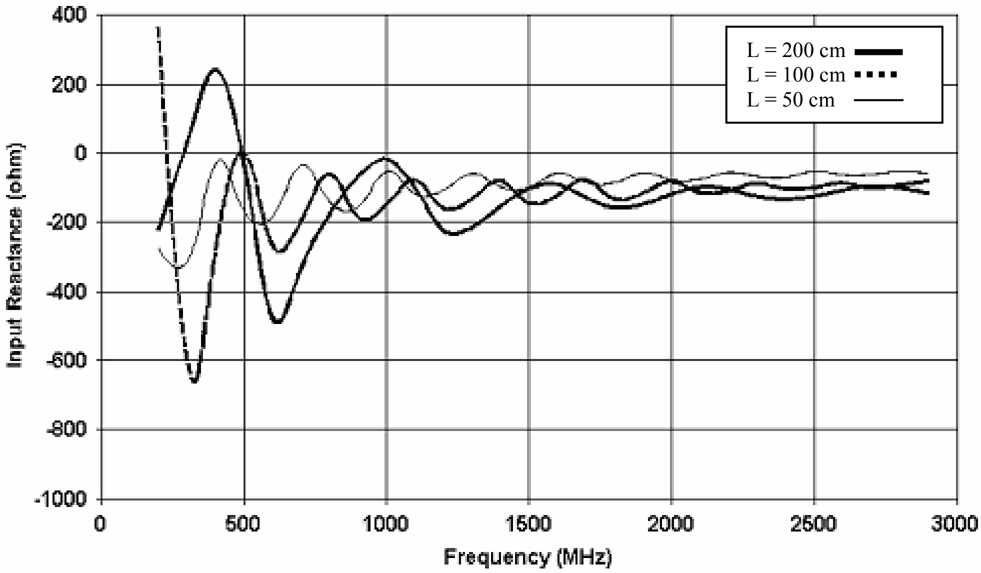

Fig. 21: The input reactance as a function of frequency for different values of wire length of S-Shaped turnstile antenna (α = 180°)

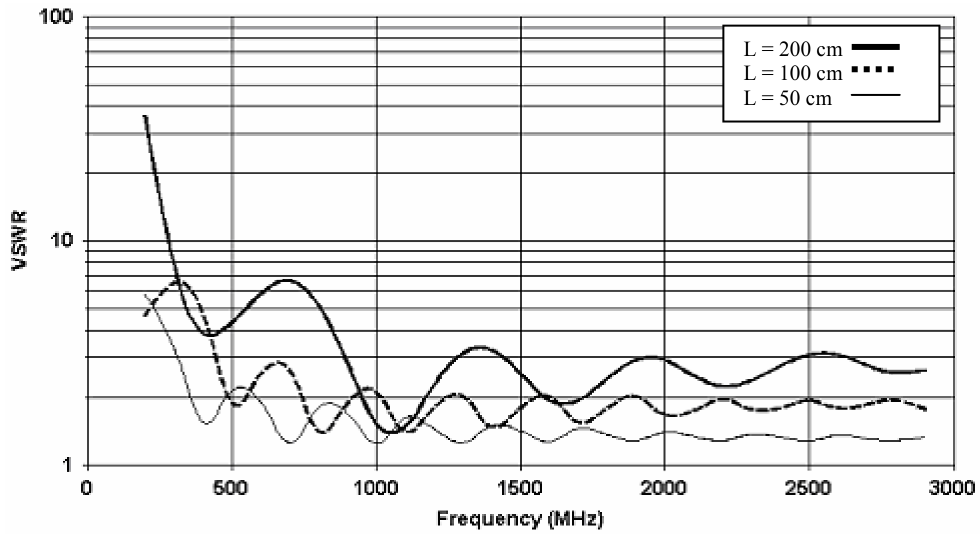

Fig. 22: The VSWR as a function of frequency for S-Shaped turnstile antenna (α = 180°) and for different values of L_S.

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 23.

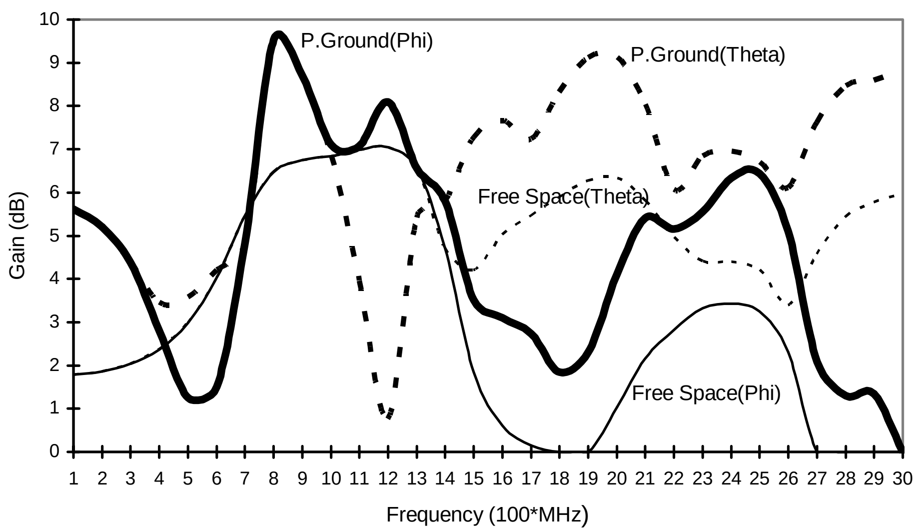

Fig.23: Gain relative to an isotropic source for the turnstile S-Shaped dipole antenna (L_S =50 cm and α=180°)

Typical power radiation patterns at 800 MHz and 1400 MHz for normal and inverted turnstile S-Shaped dipole antenna, (L_S =50 cm, α =180°) in free space and over a PCGP are given in figures 24 to 27.

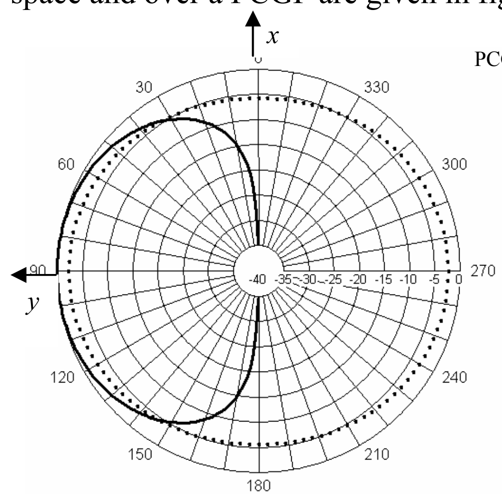

Fig.24: Total power radiation pattern in *xy*-plane at 800 MHz (L_S =50 cm and α =180°)

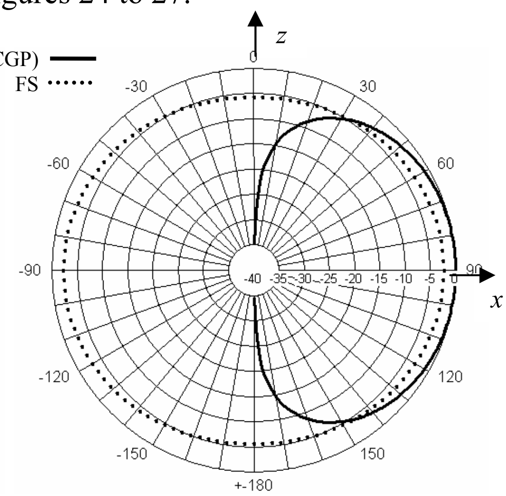

Fig. 25: Total power radiation pattern in *zx*-plane at 800 MHz (L_S =50 cm and α =180°)

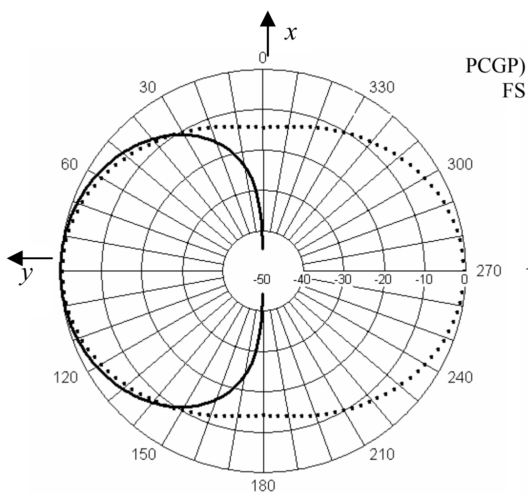

Fig.26: Total power radiation pattern in *xy*-plane 1400 MHz (L_S =50 cm and α =180°)

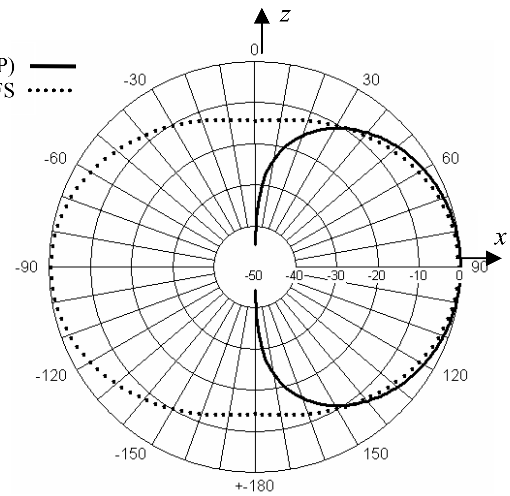

Fig.27: Total power radiation pattern in *zx*-plane at 1400 MHz (L_S =50 cm and α =180°)

From figure 23 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 increases.

V. Swastika antenna:

The Swastika antenna is formed from turnstile arrangement of clockwise and counter clockwise-Inverted swastika- 90° angle bent dipole antenna. The antennas energized with currents of equal amplitude but in phase quadrature. This arrangement, shown in figures 28 and 29, made of thin solid wire. The antenna consists of four equal sides of $\frac{\lambda_o}{8}$ each, where λ_o is the operating wavelength. These antennas 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.

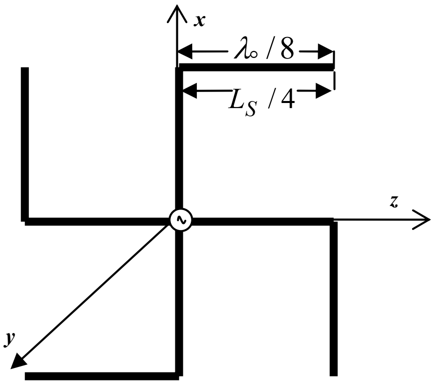

Fig.28: Swastika Antenna

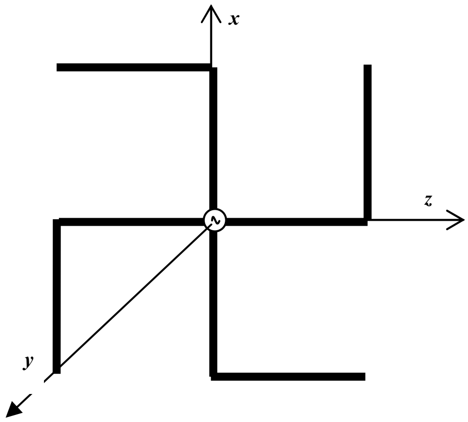

Fig.29: Inverted Swastika Antenna

The input resistance and reactance for the Swastika antenna with the same length of turnstile half wavelength dipole ($\lambda_o/2$) are shown in figures 30 and 31. The variation of the input resistance of Swastika antenna after $2f_o$, where f_o is the operating frequency is less than that of turnstile dipole and the input reactance is capacitive after this frequency.

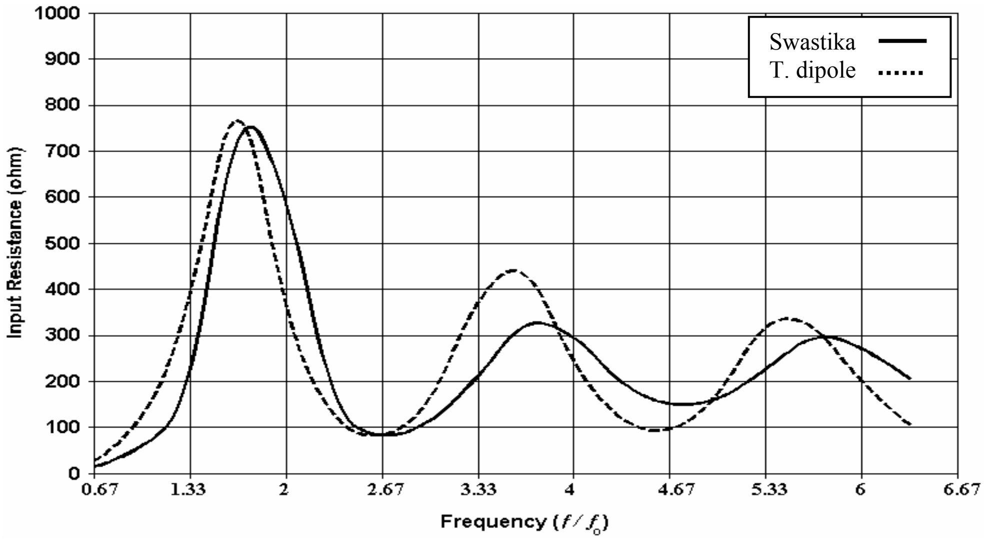

Fig.30: The input resistance as function of frequency for the Swastika antenna and a turnstile dipole of the same length

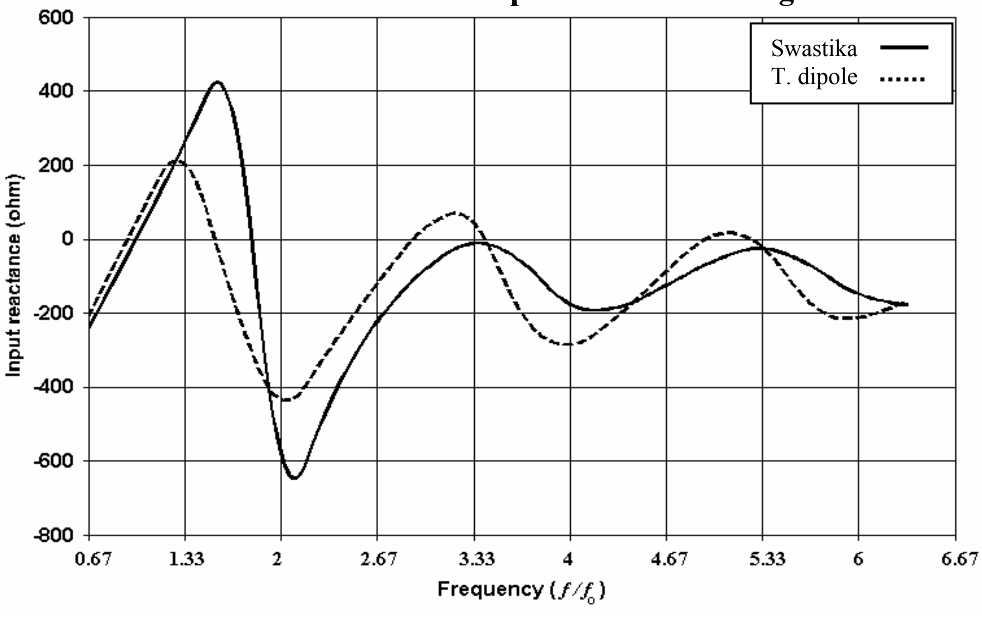

Fig.31: The input reactance as a function of frequency for the swastika antenna and a turnstile dipole of the same length

The VSWR at Z_o=300 Ω for the same previous antennas is shown in figure 32. From the figure it’s clear that Swastika antenna has superiority performance compared with the turnstile dipole.

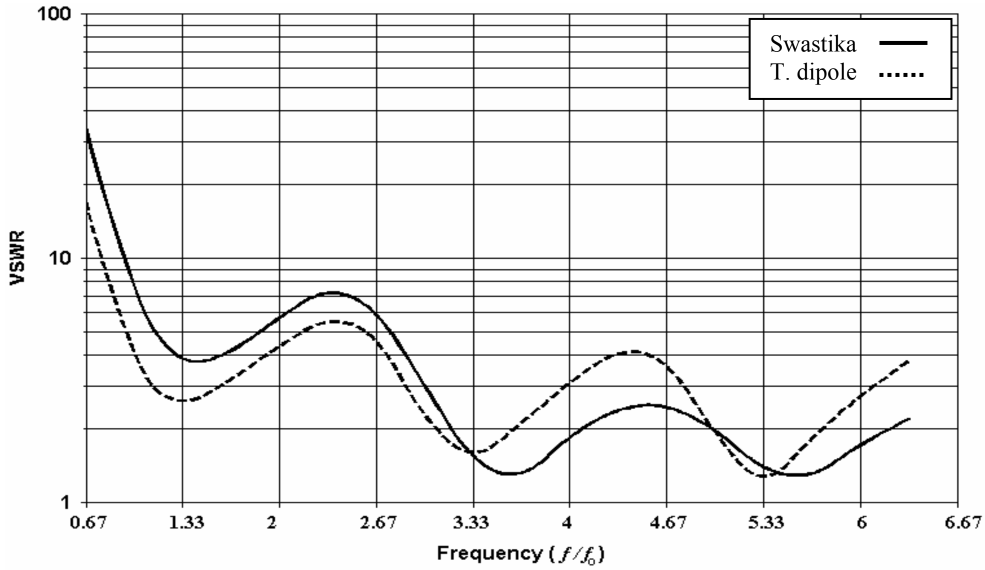

Fig.32: The VSWR as function of frequency for the Swastika antenna and a turnstile dipole of the same length

The current distribution over one side of the Swastika antenna and the current distribution over the same length dipole at the frequencies f_o, $2f_o$ and $3f_o$ are shown in figures 33 to 35.

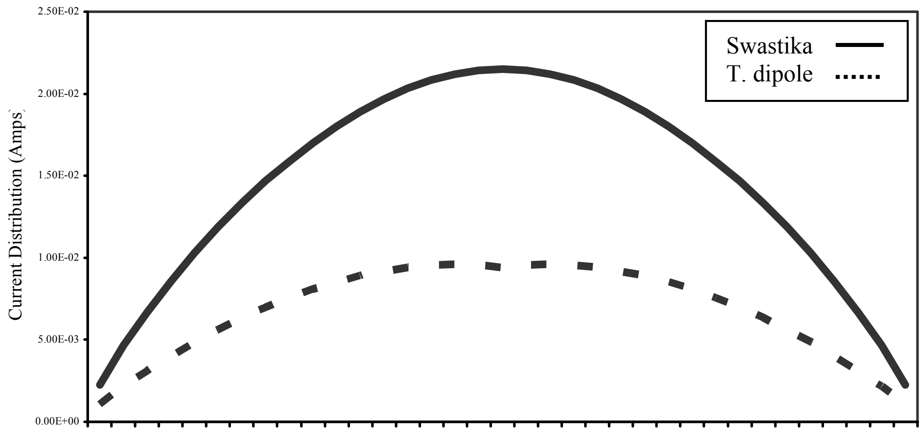

Fig.33: Current distribution at f_o on the Swastika antenna and a turnstile dipole of the same length

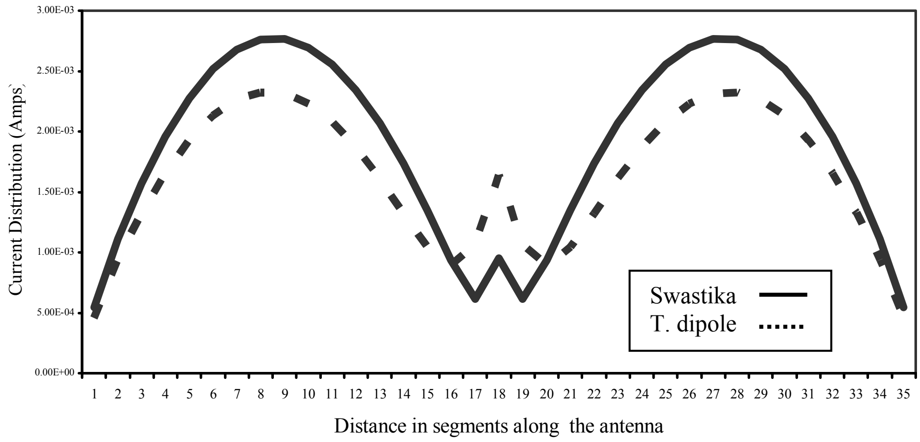

Fig.34: Current distribution at $2f_o$ on the Swastika antenna and a turnstile dipole of the same length

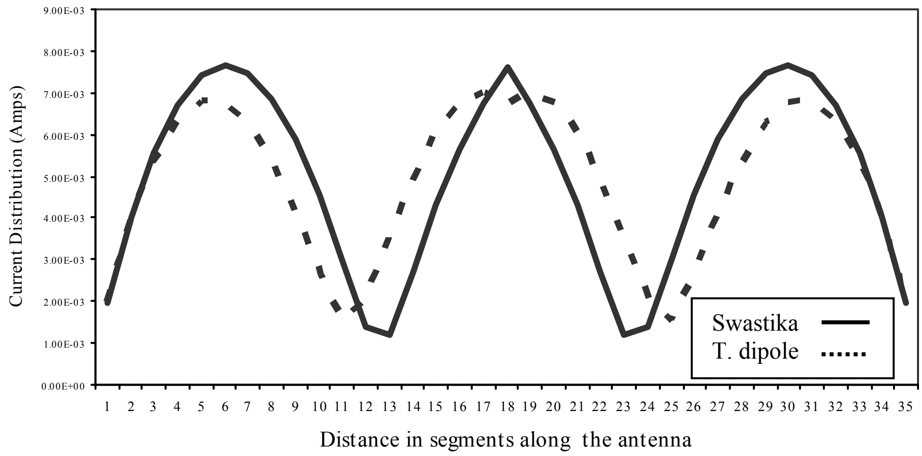

Fig.35: Current distribution at $3f_o$ on the Swastika antenna and a turnstile dipole of the same length

The antenna gain in dB relative to an isotropic source as a function of frequency for Swastika antenna when it is located in free space and over a PCGP, is shown in figure36. It is clear that the antenna over a perfectly conducting ground plane has superior performance.

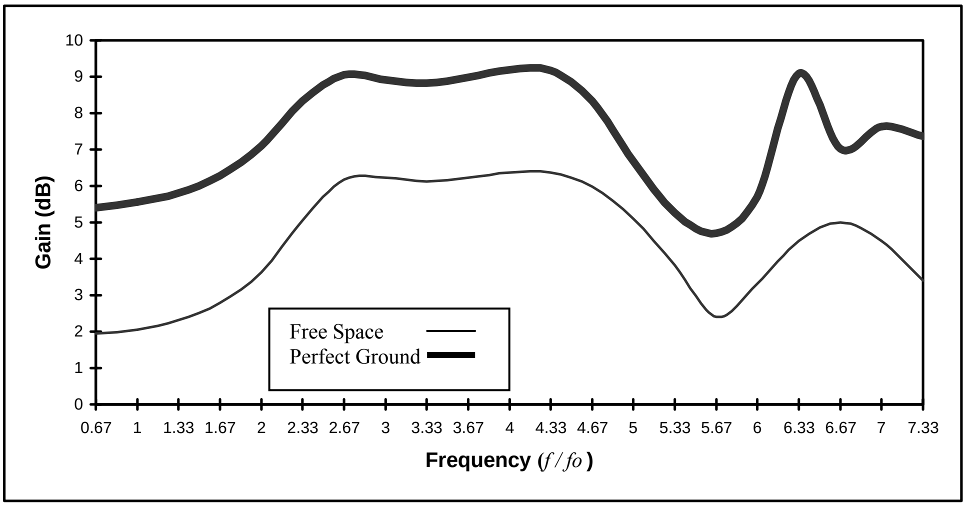

Fig. 36: Gain relative to an isotropic source for the Swastika antenna in free space and PCGP

Typical power radiation patterns at f_o and $3f_o$ for normal and inverted Swastika antenna in the free space and over perfectly conducting ground plane are given in Figs. 37 and 38.

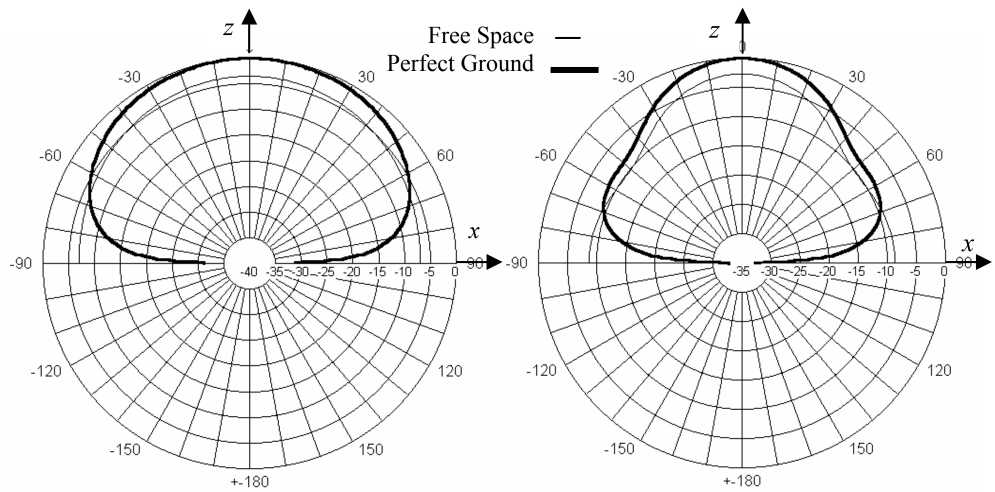

Fig.37: Total power radiation pattern in *zx*-plane at f_o

Fig.38: Total power radiation Pattern in *zx*-plane at 3 f_o

VI. 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 and its turnstile arrangements shown in figures 1 and 18 respectively.

By choosing the turnstile S-Shaped dipole with (L_S = 50 cm and α = 180°) and Swastika antenna with side length 50 cm, the input impedance and the VSWR are shown in figures 39, 40 and 41.The radiation characteristics are nearly the same for both antennas.

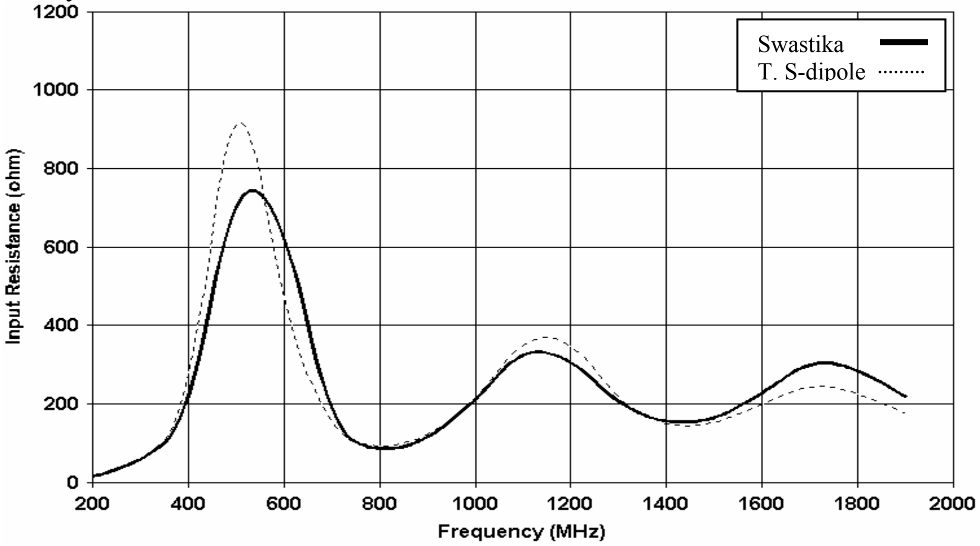

Fig. 39: The input resistances for turnstile S-Shaped with L_S =50 cm and α=180° Swastika antenna of L_S = 50 cm.

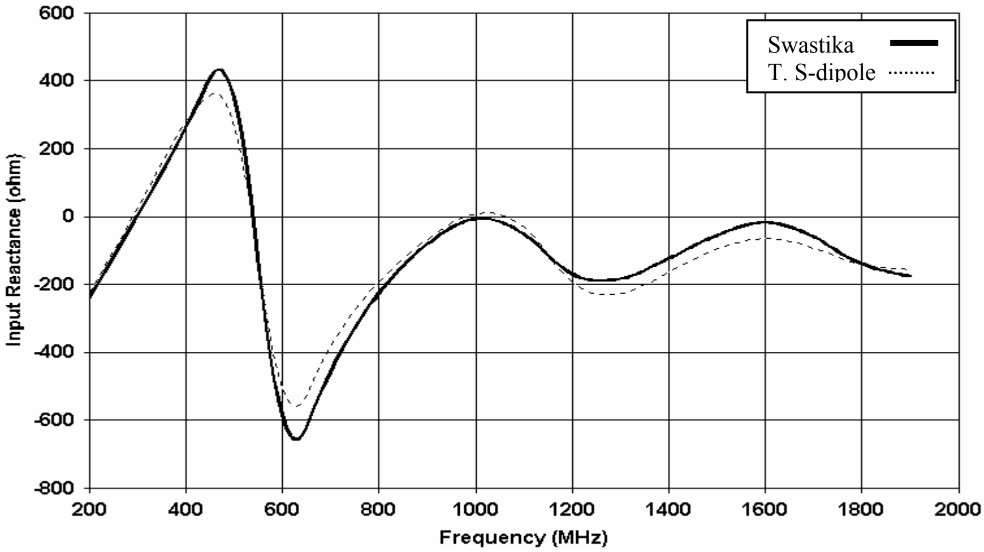

Fig. 40: The input reactance for turnstile S-Shaped with L_S = 50 cm and α=180° Swastika antenna of L_S = 50 cm.

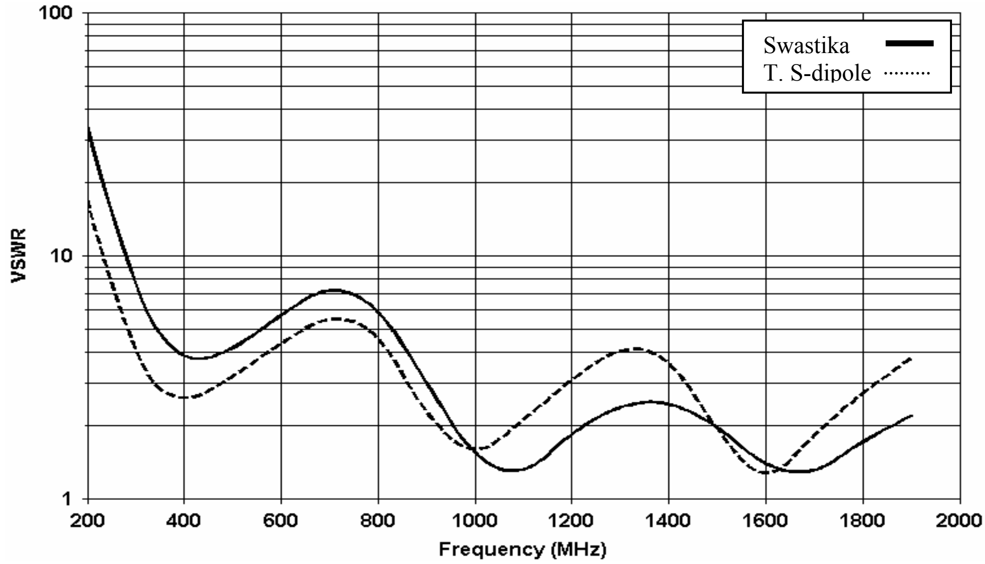

Fig. 41: The VSWR for turnstile S-Shaped with L_S = 50 cm and α = 180° Swastika antenna of L_S = 50cm.

The radiation patterns at 300 MHz and 900 MHz are shown respectively in figures 42 and 43. The gain behavior as a function of frequency for both antennas is shown in Fig.44

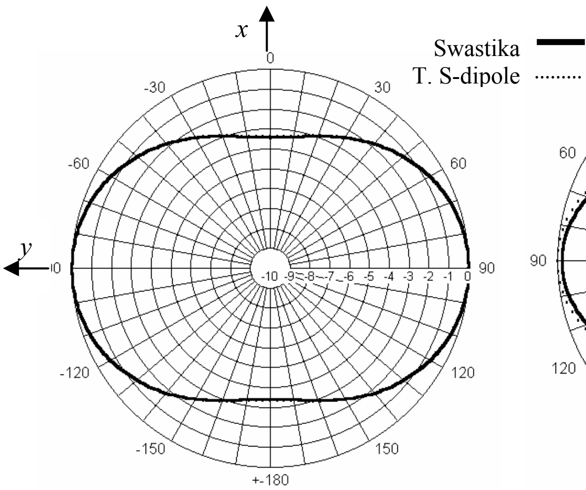

Fig.42: Total power radiation pattern z in *xy*-plane at 300 MHz

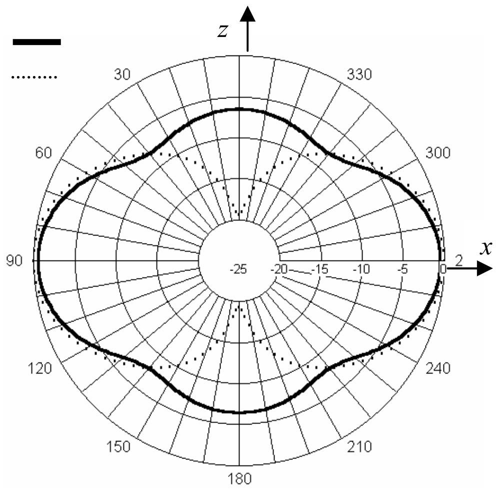

Fig.43: Total power radiation pattern in *zx*-plane at 900 MHz

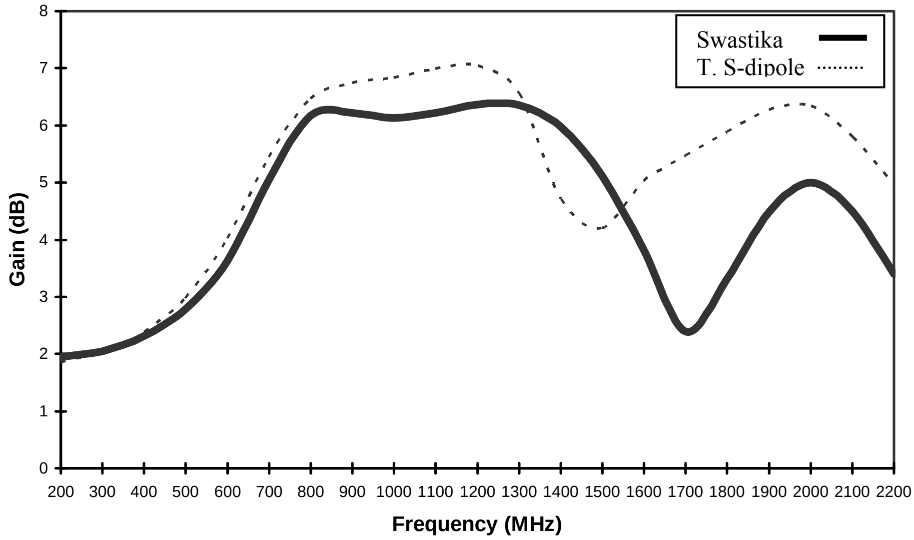

Fig. 44: Gain response, as a function of frequency, relative to isotropic source for the turnstile S-Shaped with L_S = 50 cm and α = 180° and Swastika antenna of L_S = 50 cm.

It is obvious that the power patterns are the same for both antennas at 300 MHz, but some differences occur at 900 MHz. The difference in the gain between the two models is quite clear after frequency of 600 MHz.

VII. The measured radiation patterns of the S-Shaped dipole antenna (L_S = 50 cm and α = 180°):

The practical work is performed using the Antenna Training and Measurement System at the microwave lab, Electrical Engineering Department, Faculty of Engineering, Alexandria University, which is computer based for the study of antenna at 1 GHz. It consists of Windows-based software, four hardware modules and wide selection of antennas included in the microwave lab kit. The system operates by transmitting a constant-level signal from a fixed antenna towards the antenna under test, which rotates when it receives the signal. The Lab Volt Data Acquisition and Management for Antenna (LVDAM-ANT) software control the rotation and record the received signal level. When the antenna is rotated through 360°, the software display a polar plot of the intensity of the signal received versus the antenna position. This plot is the radiation pattern of the antenna.
The real photos for the designed antennas are attached in addition to the measured and simulated radiation patterns.
Figure 45 shows The S-Shaped dipole antenna with L_S = 50 cm and α = 180° and wire radius = 0.1 cm. The power radiation patterns are shown in the figures 46 to 53.

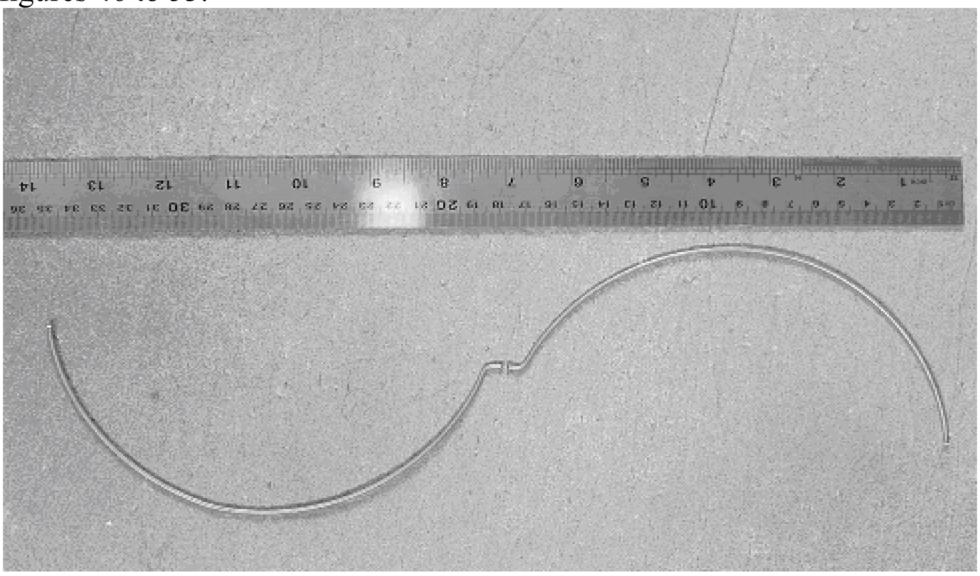

Fig. 45: The S-Shaped dipole antenna (L_S = 50 cm and α = 180°)

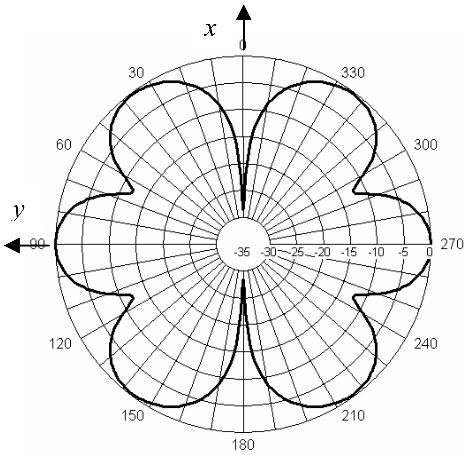

Fig.46: The calculated horizontal power radiation pattern in *xy*-plane

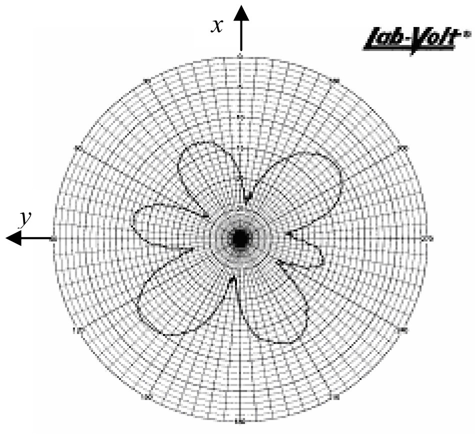

Fig.47: The measured horizontal power radiation pattern in *xy*-plane

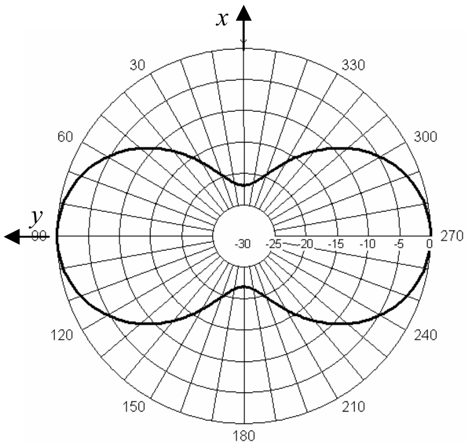

Fig.48: The calculated vertical power radiation pattern in *xy*-plane

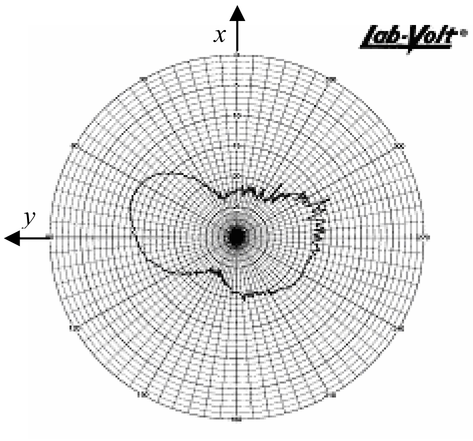

Fig.49: The measured vertical power radiation pattern in *xy*-plane

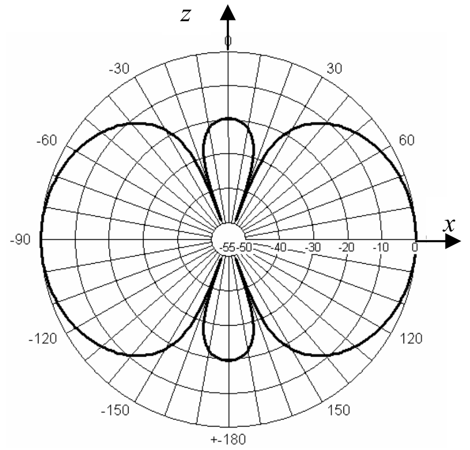

Fig.50: The calculated horizontal power radiation pattern in *zx*-plane

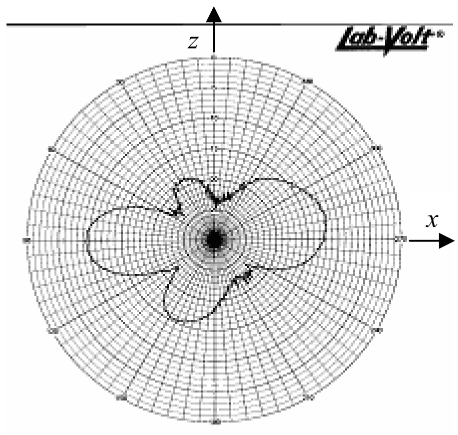

Fig.51: The measured horizontal power radiation pattern in *zx*-plane

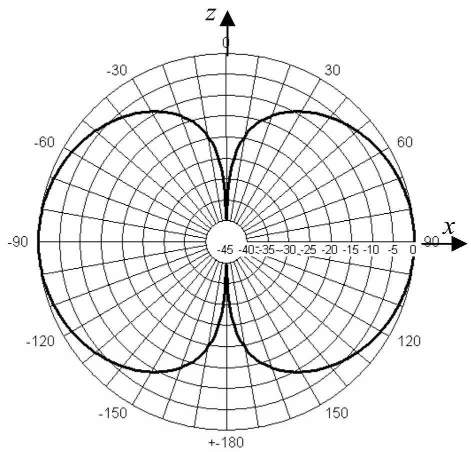

Fig.52: The calculated vertical power radiation pattern in *zx*-plane

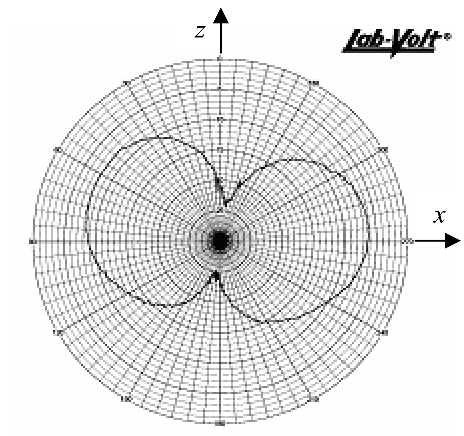

Fig.53: The measured vertical power radiation pattern in *zx*-plane

VIII. CONCLUSIONS:

New simple wire antennas are proposed and analyzed, namely the S-Shaped and the inverted S-Shaped dipoles, 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 a function of frequency, for different proposed antennas, are reported.

The measurements of the power radiation patterns in the principal planes for a S-Shaped antenna are performed and show good agreements with the calculated results. 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.

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