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A Single-Feed Small Circularly Polarized Square MSA and Cavity Model for Square Patch Antenna

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Abstract**—*****Communication between humans was first by sound throughvoice. With the desire for slightly more distance communication came, devices such as drums, then, visual methods such as signal flags and smoke signals were used. These optical communication devices, of course, utilized the light portion of the electromagnetic spectrum. It has been only very recent in human history that the electromagnetic spectrum, outside the visible region, has been employed for communication, through the use of radio. One of humankind's greatest natural resources is the electromagnetic spectrum and the antenna has been instrumental in harnessing this resource.***

The design of a single-feed small micro strip antenna with circular polarization (CP) radiation is described. This design is achieved by cutting slits in the square patch and, by adjusting the lengths of the slits; the micro strip antenna can perform CP radiation with a reduced patch size at a fixed operating frequency. This design also provides a wide CP bandwidth and relaxed fabrication tolerances.

In cavity, it is shown that for a feed offset from one corner of the patch, the perturbation segment (ΔS) is increased, thereby reducing the effect of manufacturing errors.

Index Terms**—** ***Single feed, micro strip antenna ,single feed***

I. INTRODUCTION

A micro strip antenna consists of conducting patch on a ground plane separated by dielectric substrate. This concept was undeveloped until the revolution in electronic circuit miniaturization and large-scale integration in 1970. After that many authors have described the radiation from the ground plane by a dielectric substrate for different configurations. The early work of Munson on micro strip antennas for use as a low profile flush mounted antennas on rockets and missiles showed that this was a practical concept for use in many antenna system problems. Various mathematical models were developed for this antenna and its applications were extended to many other fields. The number of papers, articles published in the journals for the last ten years, on these antennas shows the importance gained by them. The micro strip antennas are the present day antenna designer's choice. Low dielectric constant substrates are generally preferred for maximum radiation. The conducting patch can take any shape but rectangular and circular configurations are the most commonly used configuration. Other configurations are complex to analyze and require heavy numerical computations [1, 2]. A micro strip antenna is characterized by its Length, Width, Input impedance, and Gain and radiation patterns. Various parameters of the micro strip antenna and its design considerations were discussed in the subsequent chapters.

The length of the antenna is nearly half wavelength in the dielectric; it is a very critical parameter, which governs the resonant frequency of the antenna. There are no hard and fast rules to find the width of the patch.

II. MICRO STRIP PATCH ANTENNA

Micro strip antennas are attractive due to their light weight, conformability and low cost. These antennas can be integrated with printed strip-line feed networks and active devices. This is a relatively new area of antenna engineering. The radiation properties of micro strip structures have been known since the mid 1950's.

The application of this type of antennas started in early 1970's when conformal antennas were required for missiles. Rectangular and circular micro strip resonant patches have been used extensively in a variety of array configurations. A major contributing factor for recent advances of micro strip antennas is the current revolution in electronic circuit miniaturization brought about by developments in large scale integration. As conventional antennas are often bulky and costly part of an electronic system, micro strip antennas based on photolithographic technology are seen as an engineering breakthrough [2, 4].

In its most fundamental form, a Micro strip Patch antenna consists of a radiating patch on one side of a dielectric substrate which has a ground plane on the other side as shown in Figure 2.1. The patch is generally made of conducting material such as copper or gold and can take any possible shape. The radiating patch and the feed lines are usually photo etched on the dielectric substrate.

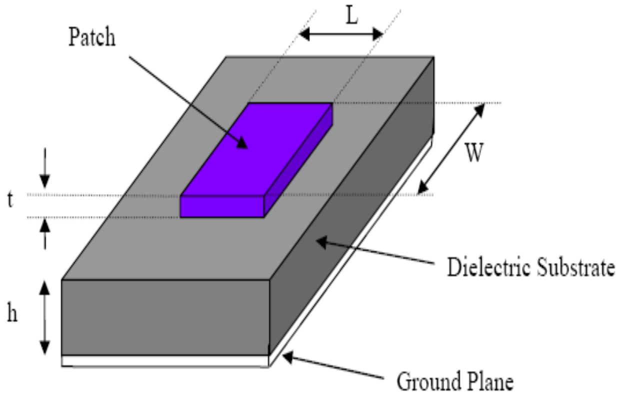

Fig.1: Structure of micro strip patch antenna.

In order to simplify analysis and performance prediction, the patch is generally square, rectangular, circular, triangular, and elliptical or some other common shape as shown in Figure 2.2. For a rectangular patch, the length L of the patch is usually $0.3333\lambda o < L < 0.5\ \lambda o$, where λo is the free-space wavelength. The patch is selected to be very thin such that $t \ll \lambda o$ (where t is the patch

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thickness). The height h of the dielectric substrate is usually $0.003\ \lambda o \leq h \leq 0.05\ \lambda o$. The dielectric constant of the substrate (εr) is typically in the range $2.2 \leq \varepsilon r \leq 12$.

A) Feed techniques

Micro strip patch antennas can be fed by a variety of methods. These methods can be classified into two categories- contacting and non-contacting. In the contacting method, the RF power is fed directly to the radiating patch using a connecting element such as a micro strip line [2, 3 4].

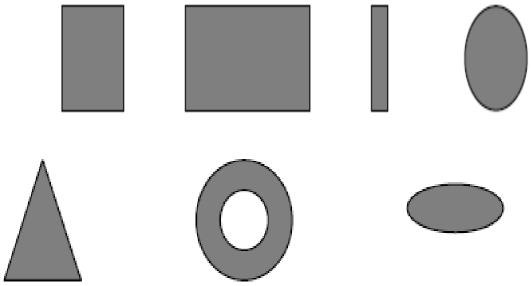


Fig. 2: Different shapes of MSA (a) Square (b) Rectangle (c) Dipole (d) Circular (e) Triangular (f) Annual ring (g) Elliptical.

In the non-contacting scheme, electromagnetic field coupling is done to transfer power between the micro strip line and the radiating patch. The four most popular feed techniques used are the micro strip line, coaxial probe (both contacting schemes), aperture coupling and proximity coupling (both non-contacting schemes).

i) Micro strip line feed
ii) Coaxial feed
iii) Aperture coupled feed
iv) Proximity coupled feed

III. ANTENNA CONSTRUCTION

A) Single feed small circularly polarized square MSA

The design of a single-feed small micro strip antenna with circular polarization (CP) radiation is described. This design is achieved by cutting slits in the square patch and, by adjusting the lengths of the slits, the micro strip antenna can perform CP radiation with a reduced patch size at a fixed operating frequency. This design also provides a wide CP bandwidth and relaxed fabrication tolerances.

Conventional designs of single-feed square micro strip antennas for CP are usually achieved by truncating patch corners, using a nearly square patch, or cutting a diagonal slot in the patch. These CP designs usually exhibit narrow axial-ratio bandwidth and have stringent manufacturing tolerances. In this Letter, we present a new design which involves cutting slits in the square patch (see Figure 3) to achieve CP operation.

These slits are cut in the patch in orthogonal directions, and due to the slits, the equivalent excited patch surface current path is lengthened, reducing the resonant frequency of the patch. By further adjusting the slits' lengths and feeding the patch using a single feed along the diagonal of the patch, two orthogonal modes with equal amplitudes and a 900 phase difference can be excited, which results in reduced-size CP operation at a feted frequency. Furthermore, due to the slits cut in the patch, the quality factor of the patch is expected to be lowered, which may increase the antenna bandwidth and ease the fabrication tolerances. Based on this design, several CP antennas have been implemented. Typical results are presented and discussed.

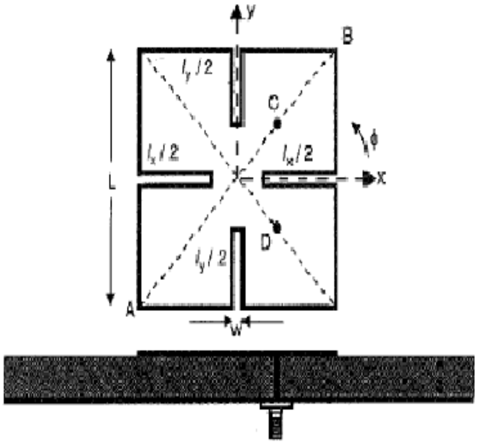


Fig. 3: Geometry of reduced-size square micro strip antenna with slits for CP radiation Feed at point C is for right-hand CP and point D is for left-hand CP.

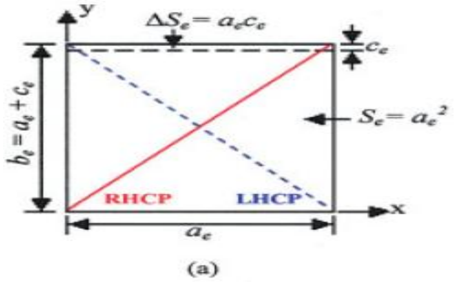
B) Analysis of circular-polarized nearly square-patch antenna using cavity model

For a given feed position, newly derived equations are used to determine the dimensions of a circular-polarized (CP) nearly square patch antenna. It is also shown that for a feed offset from one corner of the patch, the perturbation segment (ΔS) is increased, thereby reducing the effect of manufacturing errors.

In this project, it is shown that by using the cavity model and choosing a feed position, a unique solution for the dimensions of the patch is obtained without trial and error. By choosing an offset position, the area of perturbation is increased; hence, the effect of manufacturing error is reduced. Further, with an offset feed the input impedance of the patch is reduced, thus making it easier to design a simple matching network.

C) Analysis of patch antenna

A nearly-square-patch antenna having effective dimensions a_e and b_e, with $a_e < b_e$, is shown in Fig. 4(a). For a diagonal feed, the two orthogonal modes are generated for circular polarization, as shown in Fig.4 (b). If the patch is fed along one diagonal, a right-hand circular polarized (RHCP) antenna is obtained, but if fed along the other diagonal, then a left-hand circular polarized (LHCP) antenna is produced Circular polarization can also be achieved by a feed at any point on a locus (x_{0e}, y_{0e}), as shown in Fig.4(c). The design presented here is for an offset micro strip feed position (x0e, 0) as shown in Fig.5 (d).



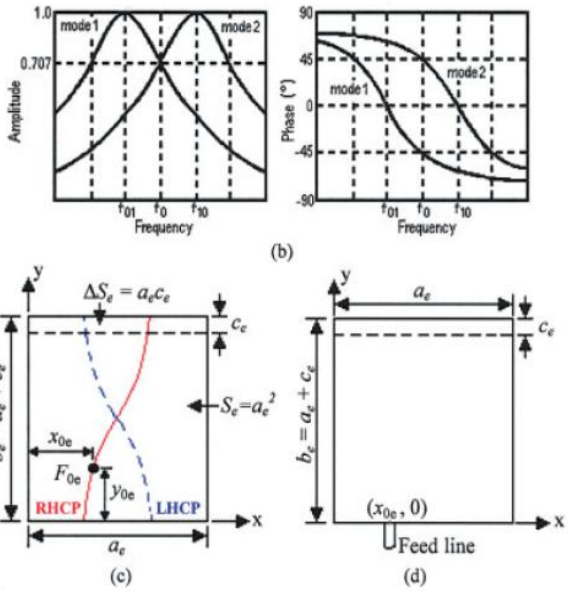


Fig.4: CP nearly-square-patch antenna with *be* > *ae*: (a) single diagonal feed; (b) amplitude and phase of the two modes of single diagonal feed; (c) offset probe feed; (d) offset micro strip feed.

$$E_x \propto \frac{\cos(\pi x_{0e}/a_e)}{k_e - k_{10}},$$

$$E_y \propto \frac{\cos(\pi y_{0e}/b_e)}{k_e - k_{01}},$$

Consequently,

$$\frac{E_y}{E_x} \cong A\,\frac{k_e - k_{10}}{k_e - k_{01}},$$

Where,

$$A = \frac{\cos(\pi y_{0e}/b_e)}{\cos(\pi x_{0e}/a_e)}.$$

Taking into account the losses on the patch, the effective wave number is given by

$$k_e \cong k_0\sqrt{\varepsilon_{reff}}\,(1 - j/2Q) = k_r - jk_i$$

where

$$k_0 = 2\pi f/c_0,\ k_r = k_0\sqrt{\varepsilon_{reff}},\ k_i = k_0\sqrt{\varepsilon_{reff}}/2Q = k_r/2Q,$$

ε_{reff} is the effective dielectric constant, $f = f0$ is the design frequency, c_0 is the free-space velocity of light, and Q is the unloaded (total) quality factor. The resonant wave numbers of the (1, 0) and (0, 1) modes are given by

$$k_{10} = f_{10}(2\pi\sqrt{\varepsilon_{reff}}/c_0) = \pi/a_e,$$

$$k_{01} = f_{01}(2\pi\sqrt{\varepsilon_{reff}}/c_0) = \pi/b_e,$$

where f_{10} and f_{01} are two mode frequencies.

To produce CP, the two field components (E_y, E_x) must have the same magnitude and be ±90° out of phase, that is, 1 ∟ ±90^0 = ±j. we obtain

$$\frac{E_y}{E_x} \cong A\,\frac{\left(k_r - \frac{\pi}{a_e} - \frac{jk_r}{2Q}\right)}{\left(k_r - \frac{\pi}{b_e} - \frac{jk_r}{2Q}\right)} = \pm j,$$

Where +*j* is for LHCP and -j is for RHCP. Equating the real and imaginary parts in for RHCP, we obtain

$$Ak_r + \frac{k_r}{2Q} - \frac{A\pi}{a_e} = 0$$

And,

$$\frac{Ak_r}{2Q} - k_r + \frac{\pi}{b_e} = 0,$$

Respectively. As can be seen, are linear and can be readily solved if the feed position *A* is selected and *Q* is known. The value of *Q* can be determined via the unperturbed square patch, or via simulation, or via practical measurement at the design frequency.

Eliminating k_r between, we obtain

$$A^2 - 2QA\left(\frac{b_e - a_e}{b_e}\right) + \frac{a_e}{b_e} = 0.$$

Let *A*1, *A*2 be the roots of the quadratic Eq., then

$$A_1A_2 = a_e/b_e.$$

From it can be seen that either A_1 or A_2 are both positive and both negative. The feed locations to produce RHCP and LHCP are shown in Fig.5(a), where f_1 and f_2 are the two possible CP design frequencies.

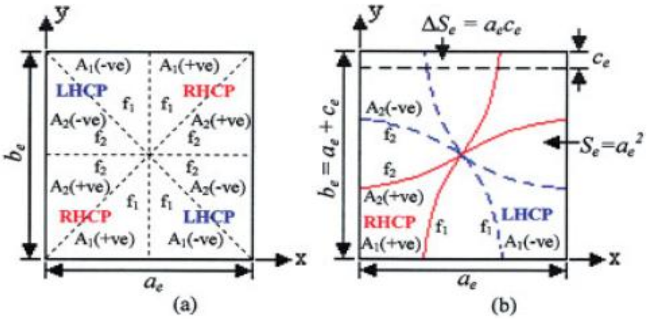


Fig.5: (a) Feed position for *A*1 and *A*2, for *be* > *ae*; (b) loci of the feed position for known dimensions of the patch (RHCP; LHCP).

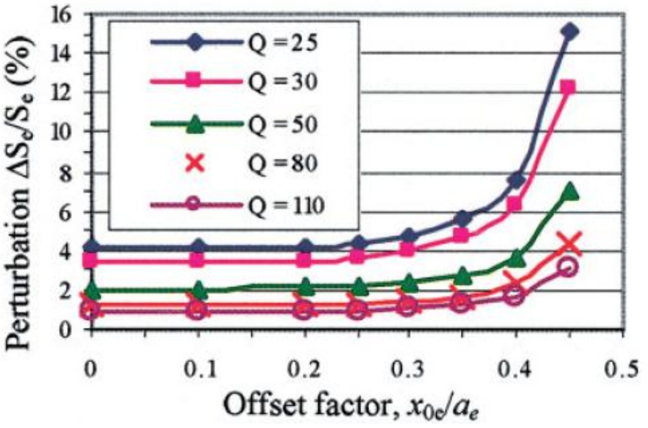


Fig.6: Relationship between the perturbation ΔSe/Se and offset feed positions and the Q-factor.

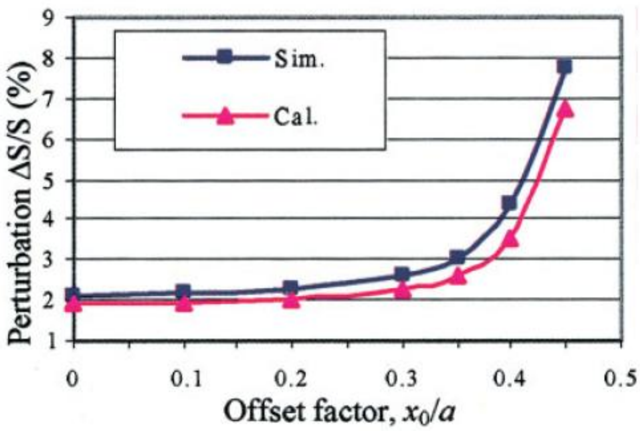


Fig.7: Relationship between the perturbation ΔS/S and the offset feed positions.

IV. RESULT

Compact antennas are required for applications where limited antenna real estate is available. A compact MSA is realized by increasing the dielectric constant of the substrate, by using shorting posts, or by cutting a slot. Compact MSAs are realized by shorting along the zero potential line of the RMSA, CMSA, ETMSA, and 30□-60□-90□□TMSA. The resonance frequency of the shorted RMSA decreases with a decrease in the shorting width and 248 Broadband Micro strip Antennas is minimum for a single shorting post. Similarly, C- and H-shaped MSAs and RRMSAs are realized by cutting a slot in the RMSA. When both of these techniques (i.e., shorting and cutting slot) are combined, a very compact MSA is realized. Shorted C- and H-shaped MSAs fall in this category. However, the BW and gain of these antennas are significantly lower.

The BW of the compact MSAs is increased by using multiple resonators in planar configurations. Various shorted RMSAs, 90□-shorted sectors, and shorted C and ring antennas are gap- or hybrid-coupled to achieve a broad BW. The multiresonator concept is also used in a stacked configuration to obtain a broad BW. By cutting a U-slot in the rectangular, circular, and triangular MSA on a thick, low dielectric substrate, a broad BW is obtained. This antenna is most attractive as it yields a large BW without increasing the surface area and with stable radiation characteristics over the entire BW.

A) Antenna geometry

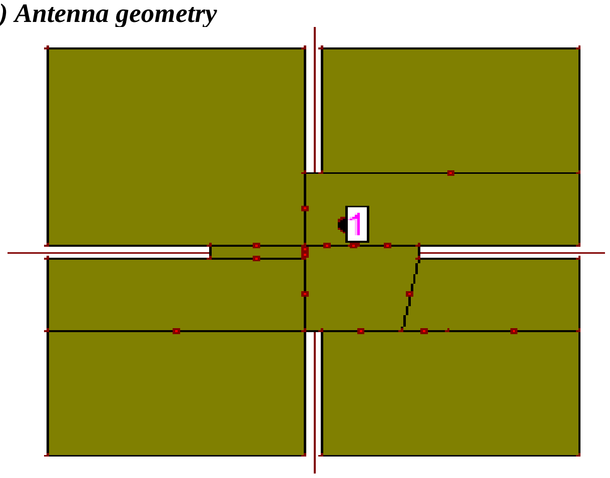


Fig.8: Current distribution.

B) S–Parameter

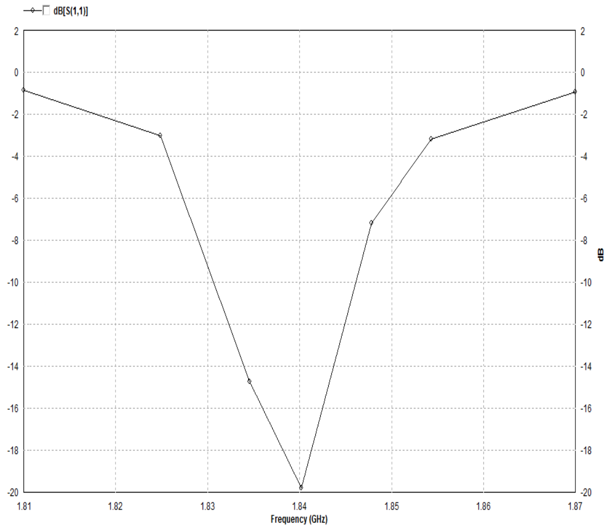


Fig.9: S-Parameter.

C) VSWR

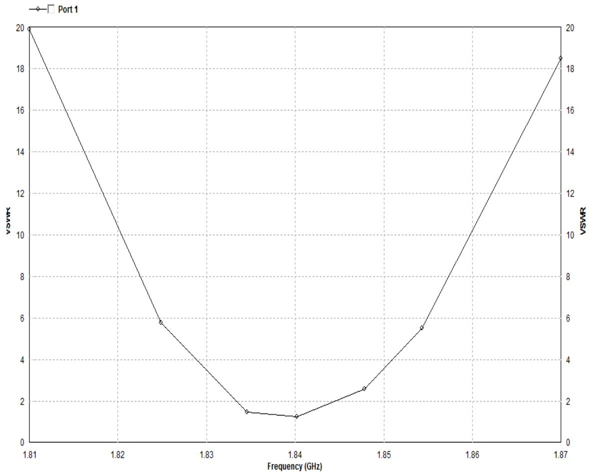


Fig.10: VSWR

D) Axial ration vs. frequency

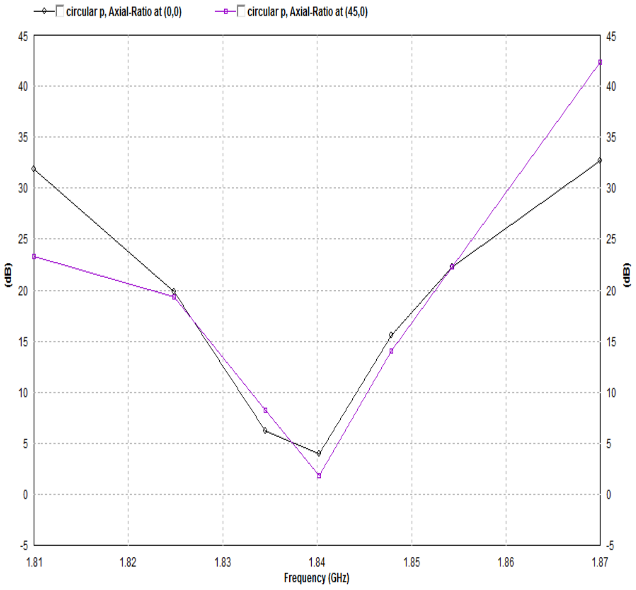


Fig.11: Axial ratio vs frequency

E) Smith chart (I/P impendence)

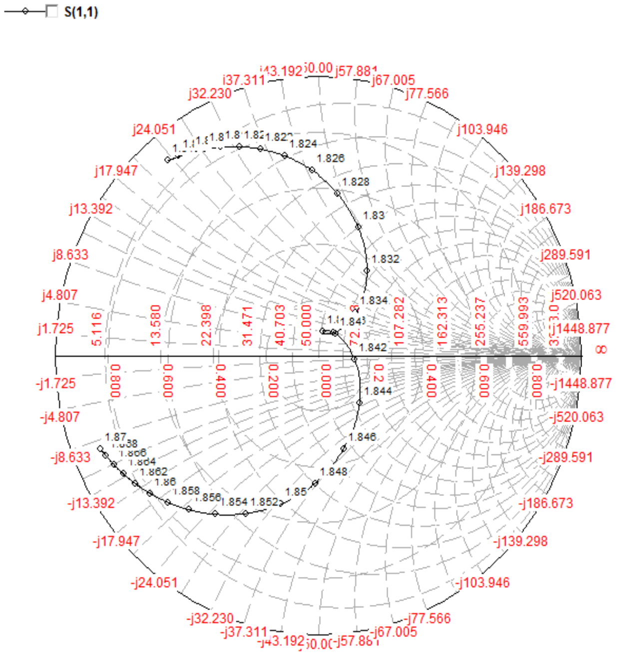


Fig.12: Smith chart.

F) Radiation pattern

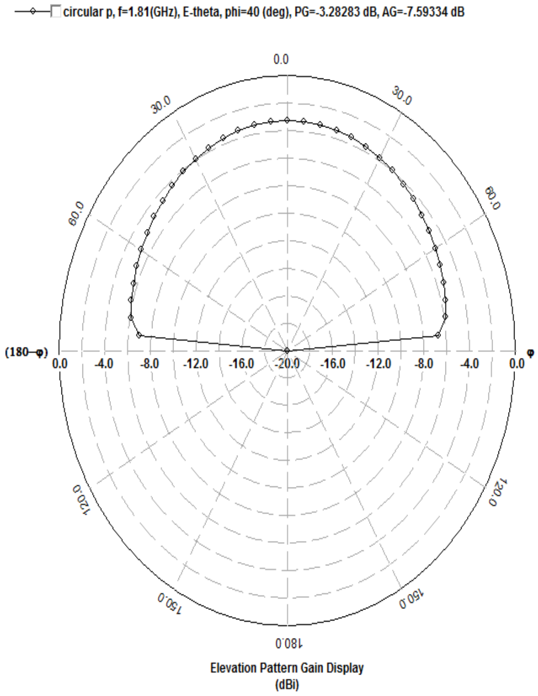


Fig.13: Radiation pattern.

V. CONCLUSION AND FUTURE SCOPE

Micro strip patch antenna used to send onboard parameters of article to the ground while under operating conditions. Micro strip antennas are attractive due to their light weight, conformability and low cost. These antennas can be integrated with printed strip-line feed networks and active devices. Conventional designs of single-feed square micro strip antennas for CP are usually achieved by truncating patch corners, using a nearly square patch, or cutting a diagonal slot in the patch. These CP designs usually exhibit narrow axial-ratio bandwidth and have stringent manufacturing tolerances

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