DESIGN OF PLANAR OCTAGONAL-SHAPED ARRAY ANTENNA FOR RADAR APPLICATIONS

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Abstract

An array antenna is a set of multiple connected antennas which work together as a single Antenna,to transmit or receive radio waves. The larger the number of individual antenna elements used, the higher the gain and narrower the beam. The designed antenna is constructed on FR-4 substrate with a relative permittivity of 4.4, loss of tangent of 0.008, and a thickness of 0.762mm with the frequency of 3GHz under the s-band. The octagonal-shaped patch is fed by a tapered structured strip line. The overall dimension of the proposed antenna is 70 x60 mm. The simulations of the antenna were performed by using full-wave EM analysis tool, computer simulation technology. To provide high array gain by using simple antenna elements, enabling the array signal processing, and to maximize the signal to interference noise ratio this planar octagonal shaped array antenna plays an important role. It is mainly used in military, civilian, geology applications.

KEYWORDS: Microstrip antenna, monopole antenna, reduced radar cross section (RCS), ultra-wideband (UWB) antenna.

1. INTRODUCTION

The growing significance of UWB communication, encouraged researchers to investigate on small antennas, since in many applications the antenna has to be small enough to be integrated into portable devices [1]. There are two types of antenna which meet these demands. The first one is derived from biconical antennas, but in planar configuration which includes bow-tie, diamond, circular and elliptical disc dipoles. The second one is originated from the development of monopole elements [2, 3]. A number of UWB monopole based upon different planar elements like circular, elliptical, polygon (square, pentagon, octagon) etc, have been demonstrated to provide UWB characteristics. However, most of these antennas are not suitable for applications which demand reduced radar cross section (RCS).

It is well known fact that RCS determines how detectable an object is with the radar. There are various ways of reducing the RCS of target, like physical target shaping [4], applying Radar Absorbing Material (RAM) on surface of target, and using active elements on the surface [5]. The RAM material absorbs incident electromagnetic wave and reduces the RCS. For narrow bandwidth applications, a single coating of RAM is generally applied but for broad bandwidths different materials with multiple layers are coated [6]. Sometimes active elements are used which work on the principle of phase cancellation in the desired direction. In target shaping, the shape of the target is modified to change the direction of scattered energy from one angular region of interest to another unimportant region [7, 8].

Finally the proposed antenna characteristics were discussed both in frequency and time domain analysis. The radiation patterns, scattering characteristics and the RCS of both the modified and the reference octagonal- shaped UWB antennas were simulated and experimentally verified. About 10 dBsm RCS reduction was obtained in the whole bandwidth with these geometrical modifications. Unlike from reported studies, the designed antenna has very large RCS reduction up to 25 dBsm, in the low frequency range. Therefore the designed UWB antenna has the lower RCS in the whole operation bandwidth, especially in the low frequency range, compared to the previously reported RCS reduced UWB antennas. With these novel features, the proposed antenna can be conveniently used as an UWB antenna in the low RCS platforms.

2. RELATED WORK

Figure 1 shows the geometry of the reference and proposed antennas. The antenna is designed on two pieces of substrates, which is Rogers 5880 with relative dielectric constant of 2.2 and a thickness of 0.5 mm. A stripline with an impedance of 50 Ω is employed to excite the bilateral Vivaldi antenna. Two SIWs with the width of W1 are formed by the four rows of the metallic via-holes and two pieces of metallic patches on the two sides of the substrate. The first and last row of the metallic via-holes and the two pieces of metallic patches form two HMSIWs with the width of W2. In order to guide the scattering energy to the lateral side, four rows of oblique via-holes are introduced with an oblique angle of 45∘ , as shown in Fig. 1(b). The reference antenna has the same geometry with the proposed antenna except the via-holes structure.

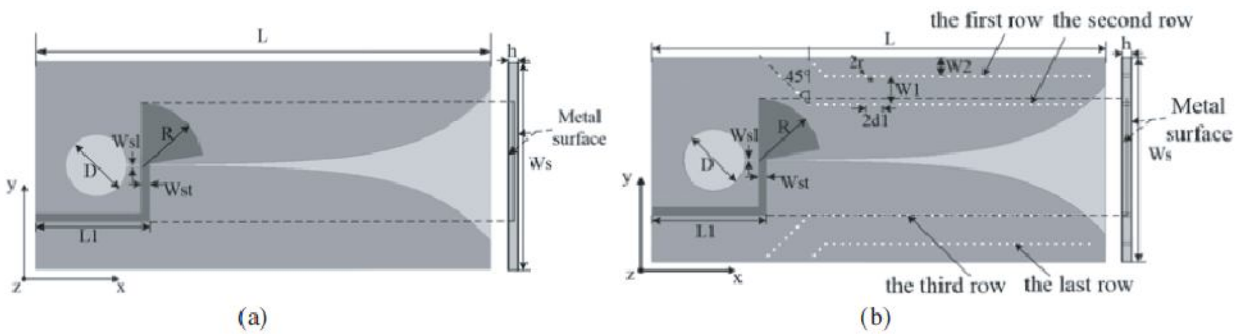


Figure 1.Geometry of (a) the reference antenna and (b) the proposed antenna.

In order to investigate the effect of some particular parameters on the antenna performance, the parametric study has been conducted. In this parametric study, each time, only one parameter was varied as the others were kept constant.

1) Effect of Radiator Patch Element: Different type of radiator elements can be used in order to obtain UWB performance. The design stages of the octagonal shaped antenna geometry. As seen from figure, maximum antenna performance was obtained with octagonal geometry. On the other hand, the octagonal-shaped patch was compared to the circular, elliptical and eye-shaped patch elements. The octagonal-shaped radiating patch element has better performance than other type of patch elements. As a result, the octagonal-shaped patch element was used for a radiator patch element.
2) Effect of Ground Plane: In the UWB antenna designs, the ground plane size is significantly controlling the antenna's bandwidth. In order to get the best UWB performance various simulations were carried out with different dimensions of H.
3) Effect of Feeding W_s : Beside them, one of the other important parameter is the feeding width W_s . The simulated results of the proposed antenna with the width W_s , from 0.86 to 1.44mm. It can be observed fromthe figure, the optimum antenna performance is obtained with W_s = 1.05.

3. LITERATURE REVIEW

E. Heidrich, W. Wiesbeck: Reduction and Minimization of Antenna Scattering**:** This paper analyses the radar cross section of antennas under various load conditions over a wide frequency range. Special emphasis is given to the polarization characteristics of radiated and scattered fields and their influence on the total scattered antenna field. Several techniques for reduction and minimization of antenna scattering are discussed.

H. Oraizi and A. Abdol: Ultra Wide Band RCS Optimization of Multilayered Cylindrical Structures for Arbitrarily Polarized Incident Plane Waves**:** Optimization of RCS by the method of least squares leads to the determination of layer thicknesses and the material complex permittivities and permeabilities. It is observed that broadband reduction of RCS is mostly achievable by a combination of conventional materials (ε_r, μ_r > 1), and unconventional materials (0 < ε_r, μ_r < 1) and lossy materials (σ > 0).

J. H. Zheng, Y. Liu, and S.-X. Gong: Perture Coupled Microstrip Antenna With Low RCS: A novel aperture coupled microstrip antenna is proposed, which utilizes the chip-resistor load, ground slot and miniaturization, to realize RCS reduction. The measured results show that the designed antenna realizes only 0.5 dB gain loss while RCS are reduced in almost all the frequency band.

X. F. Li, Y. J. Xie, and R. Yang : Bi-static RCS prediction for complex targets using modified current marching technique: The improved high-frequency method for solving the bi-static scattering from electrically large conductive targets is presented in this paper.

Y. Li, Y. Liu, and S. Gong: Microstrip antenna using ground-cut slots for low RCS with size miniaturization techniques: The techniques of ground-cut slots and miniaturization are applied in the design of microstrip antenna which reduces the resonance frequency and size of antenna and achieves the Radar Cross Section (RCS) reduction. Compared with the rectangular patch antenna working at the same frequency, the designed antenna realizes the RCS reduction

4. PROPOSED METHOD

RCS REDUCTION OF ANTENNA

A. Theoretical Antenna Scattering Analysis The feed terminations of the antennas control the scattering characteristics. When the antenna is fed by a match load, the scattering of antenna is structural mode. If antenna fed by other loads (except match load), the part of the energy would be reflected by the load and reradiate to the space. This type of scattering called as antenna mode scattering. Therefore, total $RCS(\sigma)$of antenna is consisting of RCS of structural mode (σ_S) and RCS of antenna mode(σ_a), [38]. It is expressed as

Figure 2. Pictures of octagonal-shaped UWB antennas. (a) Reference. (b) Modified.

$$\sigma = \left|\sqrt{\sigma_S} + \sqrt{\sigma_a} e^{J\varphi}\right|^2 \qquad (1)$$

where ∅ is the phase difference between these two modes. Beside this, total scattering field of an antenna ($\vec{E}^s(Z_l)$) can be divided into scattering fields of structural mode ($\vec{E}^s(Z_C)$) and antenna mode ($\vec{E}^a(Z_l)$). Their relationship can be expressed as (2)

$$.\vec{E}^s(Z_l) = \vec{E}^s(Z_C) + \vec{E}^a(Z_l) = \vec{E}^s(Z_C) + \frac{\Gamma_t}{1-\Gamma_t\Gamma_a} b_0^m \vec{E}_1^t \qquad (2)$$

$$\Gamma_l = \frac{Z_l - Z_C}{Z_l + Z_C} \qquad (3)$$

$$\Gamma_a = \frac{Z_{in} - Z_C}{Z_{in} + Z_C} \qquad (4)$$

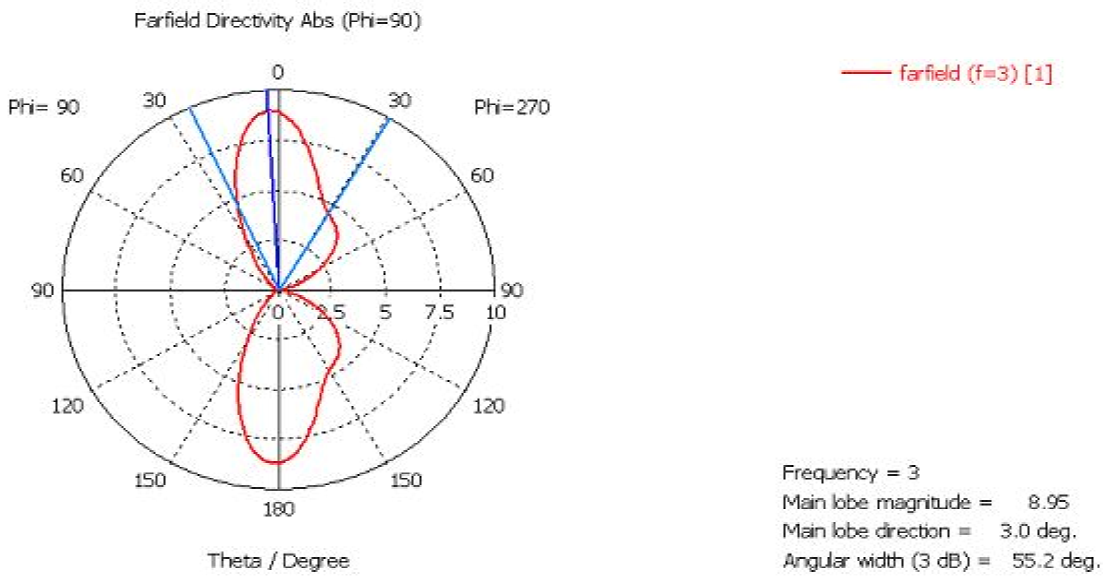


Figure 3.Simulation results of far field polar plot

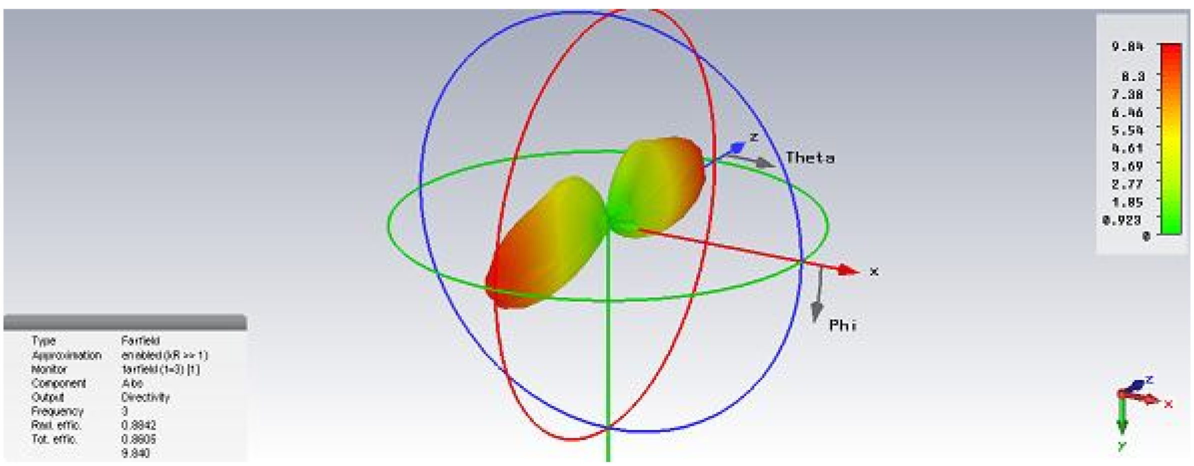


Figure 4.Three Dimensional Radiation pattern of directivity

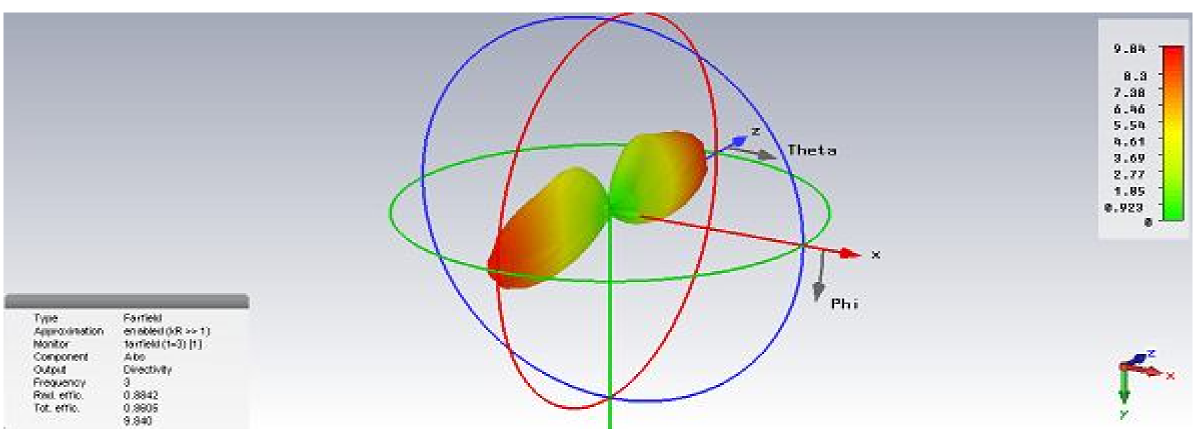


Figure 5.Three Dimensional Radiation pattern of far field 3D plot

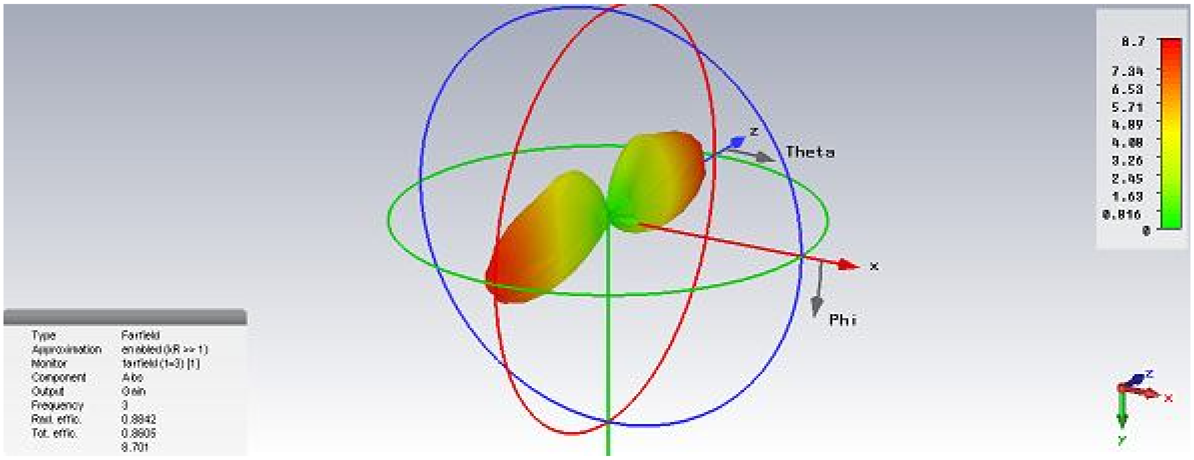
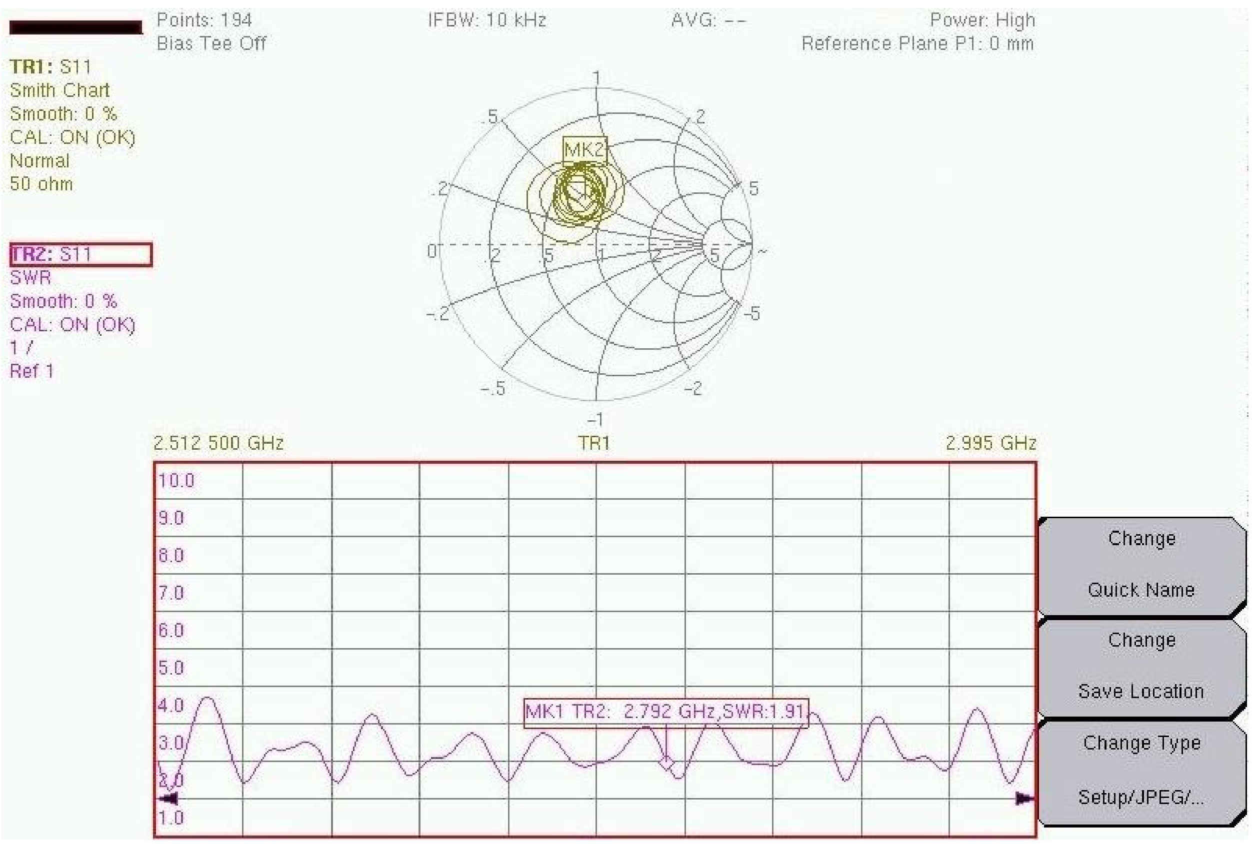
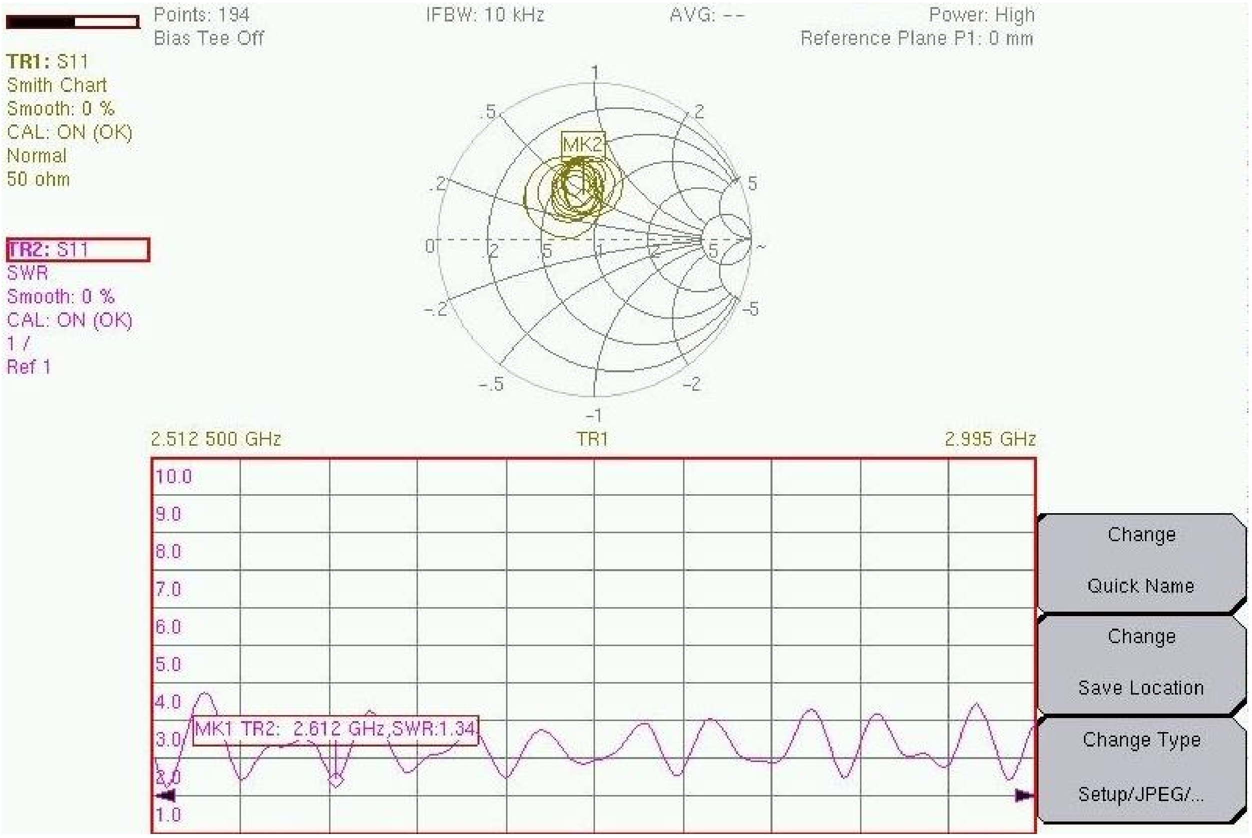


Figure 6.Three Dimensional Radiation pattern of gain

5. SIMULATION RESULTS

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IFBW: 10 kHz
AVG: --
Power: High
Reference Plane P1: 0 mm
TR1: S11
Smith Chart
Smooth: 0 %
CAL: ON (OK)
Normal
50 ohm
TR2: S11
SWR
Smooth: 0 %
CAL: ON (OK)
1 /
Ref 1
MK2
2.512 500 GHz
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MK1 TR2: 2.612 GHz,SWR:1.34
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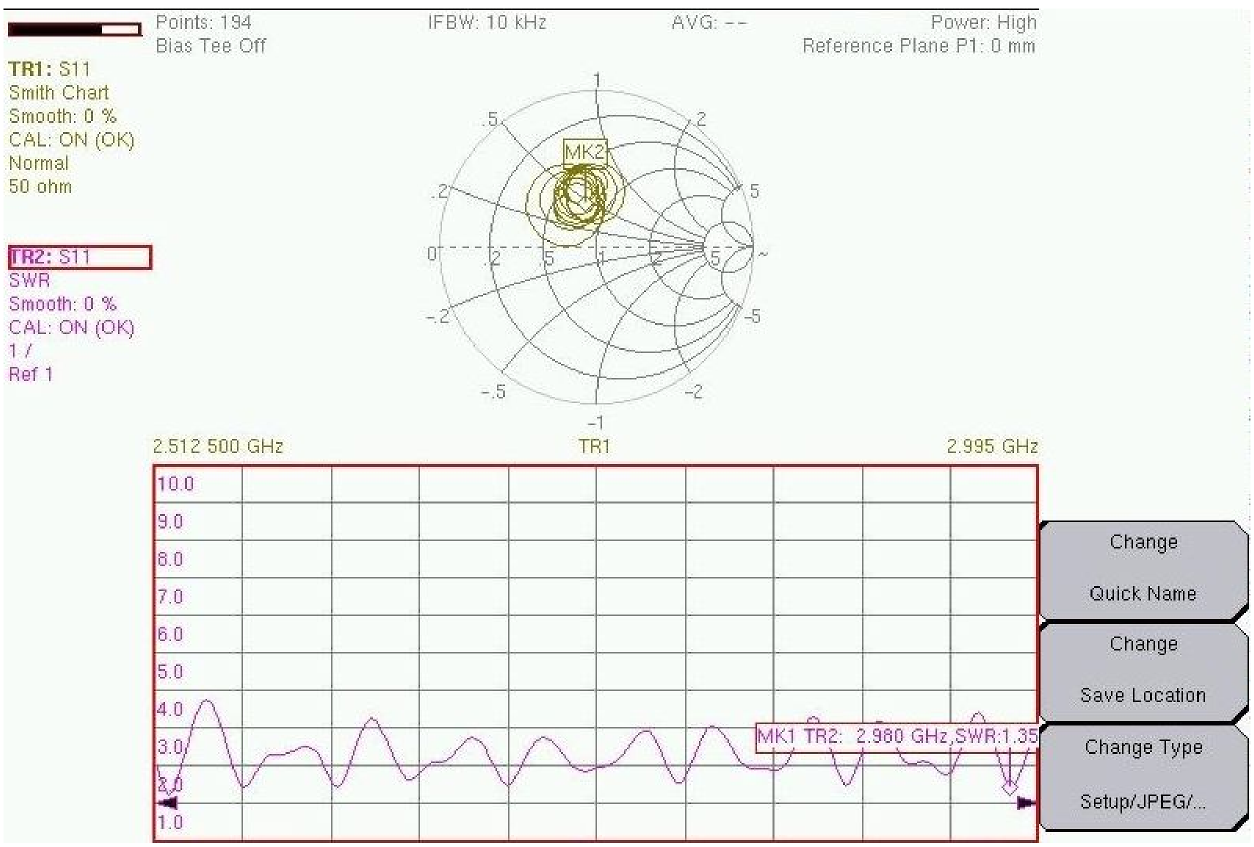
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TR1: S11
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Smooth: 0 %
CAL: ON (OK)
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TR2: S11
SWR
Smooth: 0 %
CAL: ON (OK)
1 /
Ref 1
MK2
2.512 500 GHz
TR1
2.995 GHz
MK1 TR2: 2.980 GHz,SWR:1.35
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6. CONCLUSION

The simulations of the antenna were performed by using full-wave EM analysis tool, computer simulation technology. To provide high array gain by using simple antenna elements, enabling the array signal processing, and to maximize the signal to interference noise ratio this planar octagonal shaped array antenna plays an important role. It is mainly used in military, civilian, geology applications.

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