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# Design and Implementation of a "MIMO Smart Antenna": A Candidate for "Green Technology"

By Neeraj Kumar, A. K. Thakur & Arvind Kumar
*Amity University, India*

*Abstract-* In this paper, Dielectric-Loaded Microstrip Patch Antenna (DL-MPA), has been synthesized and analyzed, which is also referred as "MIMO Smart Antenna" In the designing procedure, three different antennas are designed and simulated. Firstly, "Antenna 1" is a RDRA (Rectangular Dielectric Resonator Antenna) which has been simulated using only one probe coaxial feed technique. Secondly, "Antenna 2" RDRA has been simulated using multiple ports, in addition to the previous excitation it has been excited using other two, strip feed coaxial probe ports. At last, bandwidth improvement method has been implemented to a MPA, and multi frequency operability has been obtained, referred as "Antenna 3". Experimental approach has been implemented to support antenna analysis and obtained simulated results. Antenna parameters such as return loss, VSWR plot and EH field has been plotted and studied to obtain characteristics performance of the radiating structure. Antenna offers operability at frequency range of 1.5GHz, 3.32GHz and 4.14GHz and having return loss of -21.82dB, -17.48 dB and - 36.32dB respectively, and radiation efficiency of the system ranges from 99-135%. These results verify the use of proposed antenna in different frequency of operation; The obtained performance of proposed design, confirms the practicability of antenna in different indoor/outdoor wireless applications. Suitability and applicability of antenna has been found in GSM and other wireless systems frequency range.

*Keywords: dielectric resonator, microstrip patch antenna, MIMO, smart antenna, co-axial probe, return loss, VSWR, resonating frequency, multiple ports, gsm application.*

*GJRE-F Classification : FOR Code: 100501*

DESIGNANDIMPLEMENTATIONOFAMIMOSMARTANTENNAACANDIDATEFORGREENTECHNOLOGY

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# Design and Implementation of a "MIMO Smart Antenna": A Candidate for "Green Technology"

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## I. Introduction

Antenna, important from point of view of research and because of growing demand of bandwidth, frequency of operability and capable to support high data rate and throughput.

### a) MIMO Antenna

Multiple Input Multiple Output is MIMO technology which is gaining popularity in field of antennas because of its improved performance. Antenna is being widely accepted for emerging technologies, LTE and for applications which requires multiple frequency applicability. Both at the transmitter and the receiver end multiple radiating structures are used and performance of system is increased by minimizing the error and optimizing the system. It gives significant increase in link range and in data throughout. MIMO system is also useful in cell phone networks to meet the growing demands of the subscribers. It is useful for providing high end services such as video conferencing and for high speed mobile internet. MIMO is one of the several forms of smart Technology. It does not require additional band width or additional transmit power. It offers higher spectral efficiency.

### b) Smart Antenna

Receiving and transmission characteristics of antenna are adapted and modified accordingly, to minimize the error and thus enhance the performance of antenna. Smart antennas are important for reducing the deleterious effects of intentional jamming signals, unintentional co-channel interference, and multipath. These antennas were first known as "Side Lobe Cancellers", and then renamed as "Adaptive Antenna" and more recently, "Smart Antenna". Functioning of smart antenna rely on signal processing. Multiple antennas which are installed at transmitter and receiver end, transmit and receive signals. Amplitude and phase of signals are modified, in order to improve the reception of desired signal. To implement, smart antenna in communication system, must also rely on fact that the system should also be capable of holding it, so a smart system can have a smart antenna. On the other hand it should also be implemented such that cost of establishing the wireless network should be minimum, quality of service should also be better, realization of reconfigurable, robust, and transparent operation across multi-technology wireless networks.

### c) Microstrip Patch Antenna

Micro-strip patch antenna is a simple and low profile antenna. It is conformable to planar and non-planar surfaces. The manufacturing of such antennas can be done at a very low cost using modern printed circuit technology, hence making it inexpensive. Micro-strip antennas are very versatile in terms of resonant frequency, polarization pattern and impedance. All this depends on the selection of patch shape and mode. These are mechanically robust when are placed on rigid surface. In order to create variations in the above mentioned resonant frequency, impedance and polarization pattern loads are added in between the patch and the ground plane.

### d) Dielectric Resonator Antenna

These antennas are fulfilling the demand of higher bandwidth for video conferring, video call, IP TV

*Authors α σ: Amity Institute of Telecom Engineering and Management, Amity University, Noida, India. e-mail: neeraj767@gmail.com*
*Author ρ: Department of Physics, C. M. Sc. College, Darbhanga, Bihar, India.*



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and many other application which demands for higher bandwidth to support and efficiently manage the demands and growing need of customers. Hence, the antennas for modern wireless communication system should be low in profile and efficient in high frequencies. DRA are being considered because this material has many advantages in comparison to other. DRA offers many features such as small size, low cost, good bandwidth, high gain, Low ohmic loss and light weight. The DRA can be used at millimetre frequency bands and they are available in basic shapes such as rectangular, cylindrical, spherical and hemispherical geometries.

## II. Theory

### *a) Calculation for MIcrostrip Patch*

Dimension of the patch antenna for desired frequency, relative permitivity and substrate has been obtained using different conventional equations of the microstrip patch antenna systems. These equations are as follows:

$$W = \frac{c}{2f_0}\sqrt{\frac{2}{\epsilon_r + 1}} \qquad (1)$$

$$L = \frac{c}{2f_0\sqrt{\epsilon_{eff}}} - 2\Delta L \qquad (2)$$

$$L_{eff} = L + 2\Delta L \qquad (3)$$

$$\Delta L = 0.412\,h\left[\frac{(\epsilon_{eff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\epsilon_{eff} - 0.258)\left(\frac{W}{h} + 0.813\right)}\right] \qquad (4)$$

$$\epsilon_{eff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2}\left(1 + 12\frac{h}{W}\right)^{-\frac{1}{2}} \qquad (5)$$

In these equations, $f_0$, c and h, are central resonant frequency, c is speed of light and h is the substrate thickness.

### *b) Calculation for RDRA*

The RDRA is characterized by a height *h*, a width *w*, a depth *d*, and a dielectric constant $\varepsilon_r$, as shown in Fig. 1. The rectangular shape offers two degree of freedoms, making it the most versatile of the basic shapes. The ratios *w/h* and *w/d* can be chosen independently.

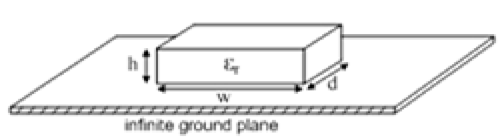


*Figure 1 :* A Rectangular Dielectric Resonator Antenna (RDRA)

The modes in an isolated rectangular dielectric guide can be divided into TE and TM, but with the DRA mounted on the ground plane, it is the TE modes which are typically excited.

For the $TE^x_{\delta 11}$ mode, the resonant frequency, $f_0$, is found by solving the following transcendental equation:

$$k_x \tan(k_x d/2) = \sqrt{(\varepsilon_r - 1)k_0^2 - k_x^2} \qquad (1.1)$$

where,

$$k_x = \frac{2\pi}{\lambda_0} = \frac{2\pi f_0}{c}, k_y = \frac{\pi}{w}, k_z = \frac{\pi}{b}$$

and,

$$k_x^2 + k_y^2 + k_z^2 = {}_r k_0^2 \qquad (1.2)$$

The following approximate equation has been derived for the normalized frequency F:

$$F = a_0 + a_1(w/b) + a_2(w/b)^2 \qquad (1.3)$$

where

$$a_0 = 2.57 - 0.8(d/b) + 0.42(d/b)^2 - 0.05(d/b)^3 \qquad (1.4)$$

$$a_1 = 2.71(d/b)^{-0.282} \qquad (1.5)$$

$$a_2 = 0.16 \qquad (1.6)$$

Different excitation techniques have been employed in antenna which helps in making the system to radiate well. Most popular techniques are coaxial probe feed, micro-strip line, aperture coupling and proximity coupling.. Proposed Antenna is excited using coaxial probe fed technique. Coaxial probe feeding is feeding method in which the inner conductor of the coaxial is attached to the radiating element of the antenna while the outer conductor is connected to the ground plane.

## III. Antenna Design

The proposed design uses a substrate of material Rogers RT/Duroid 5880 (tm) having relative permittivity of 2.2 and dimension 10 cm X 9 cm X 0.32 cm. In order to minimize the back-lobe radiation phenomenon, upper surface of antenna has a finite conductivity layer. The rectangular dielectric resonator of relative permittivity 15 is used, having dimension of 5.352 cm X 1.784 cm X 1.784 cm. The co-axial probe feed mechanism is used for the excitation of antenna. Antenna microstrip patch has been calculated by using eqn. 1-5, mentioned in section II. Width of the Patch is 65.84mm and length of the patch is 53.59 mm. Figure 1, shows the modeled 3D view of antenna system.



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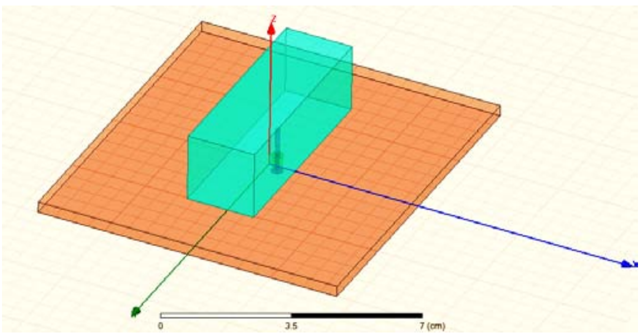
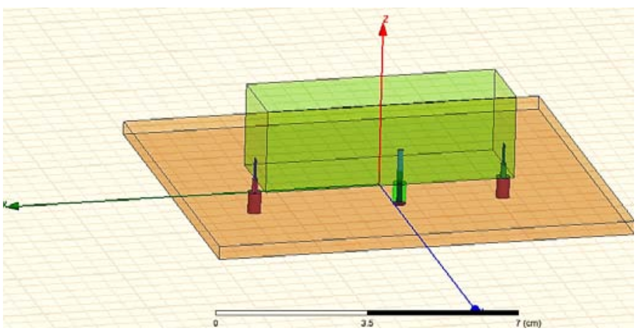
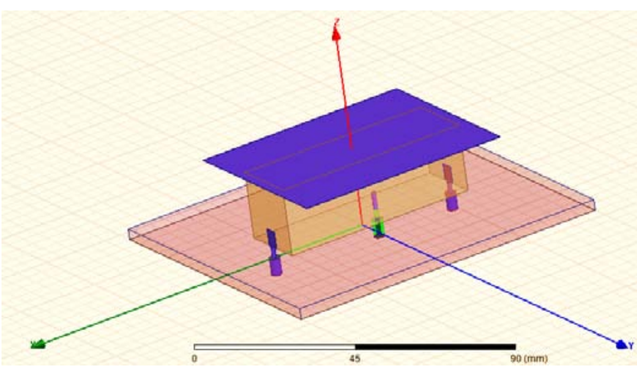


(a)



(b)



(c)

*Figure 1 :* 3D view of the modeled antenna (a) RDRA ("Antenna 1") (b) Multi-feed RDRA ("Antenna 2") (c) Patched Multi-feed RDRA ("Antenna 3")

## IV. Simulation

Designed antenna is simulated on Ansoft HFSSv13 simulation software. The parametric variation of the project was done by choosing different radiating antenna. Result obtained was studied in detail to know the relation between dielectric and patching. Simulation was performed in three steps.

Firstly, Antenna 1 was designed and analyzed to obtain its characteristics. Figure 2 (a), (b) and (c) present return loss, VSWR and impedance of RDRA. It is found that antenna has resonant frequency of 1.5GHz having return loss of -21.82dB. VSWR of the system is 5dB and impedance is well matched at the resonating frequency. It has only real part, which confirms antenna radiating efficiently at 1.5GHz.

In second simulation process, Antenna 2 has been simulated. Figure 3 (a), (b) and (c), show return loss, VSWR and impedance of multi-feed RDRA (Antenna 2). It is well matched at 3.32GHz and 4.14GHz. Return loss at these frequencies is found to be -17.48dB and -27.86dB respectively. VSWR value decreased to approximate value of 2. Impedance of system has real value at operating frequency of 3.32GHz. Antenna 2 has better characteristics, than that of Antenna 1. Return loss of system has further improved, whereas multi-feed RDRA has multi-frequency of operation, only the fact is that antenna needs impedance matching more in comparison to Antenna 1.

In third simulation process, Antenna 3 has been simulated and results have been shown in figure 4. Figure 4 (a), (b), (c), (d) and (e), presents antenna's return loss, VSWR, Impedance vs. frequency, EH-field in terms of radiation pattern and directivity of the antenna system respectively. Frequency of operation is found to be at 4.14GHz at return loss of -36.32dB. VSWR value is 1.2. Impedance value is lowered than that of Antenna 2 and 1, thus patch has additional advantage over RDRA and multi-feed RDRA. Radiation pattern in terms of field parameters is shown in Figure 4 (d). It shows that H-plane has maximum value in $\theta = 90^0$ while E-plane has the minimum value in this direction and maximum value in $\varphi = 0^0$. Figure 4 (e), shows directivity of the system. It is observed that antenna has directional pattern and concentration of energy in direction of angle $40^0$.

Antenna has radiation efficiency of 135%, 101% and 99% respectively. It is found that as antenna is being multi-feed, its frequency range of applicability increases whiles its radiation efficiency decrease but because of advantage, antenna can be multi-feed, through different ports.



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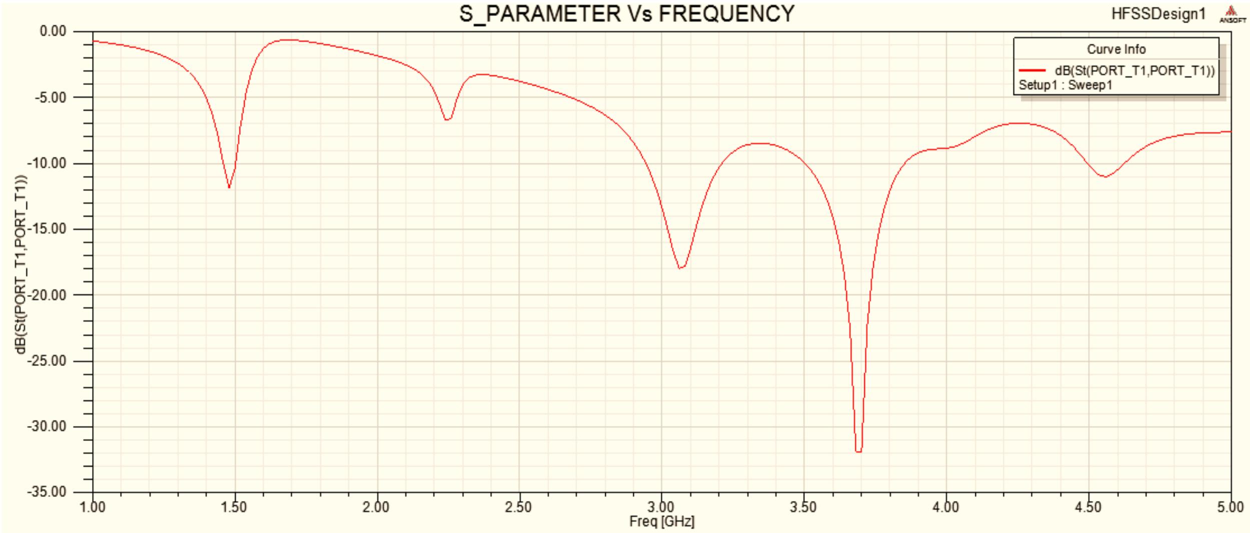


*Figure 2 (a) :* Return Loss Curve of "Antenna 1"

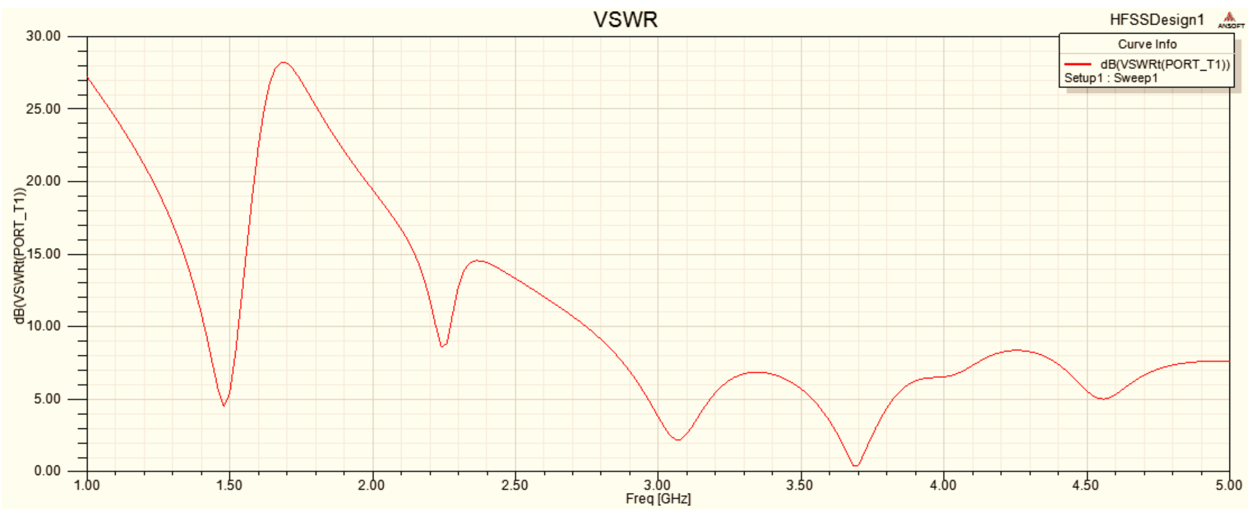


*Figure 2 (b) :* VSWR vs. Frequency Plot of "Antenna 1"

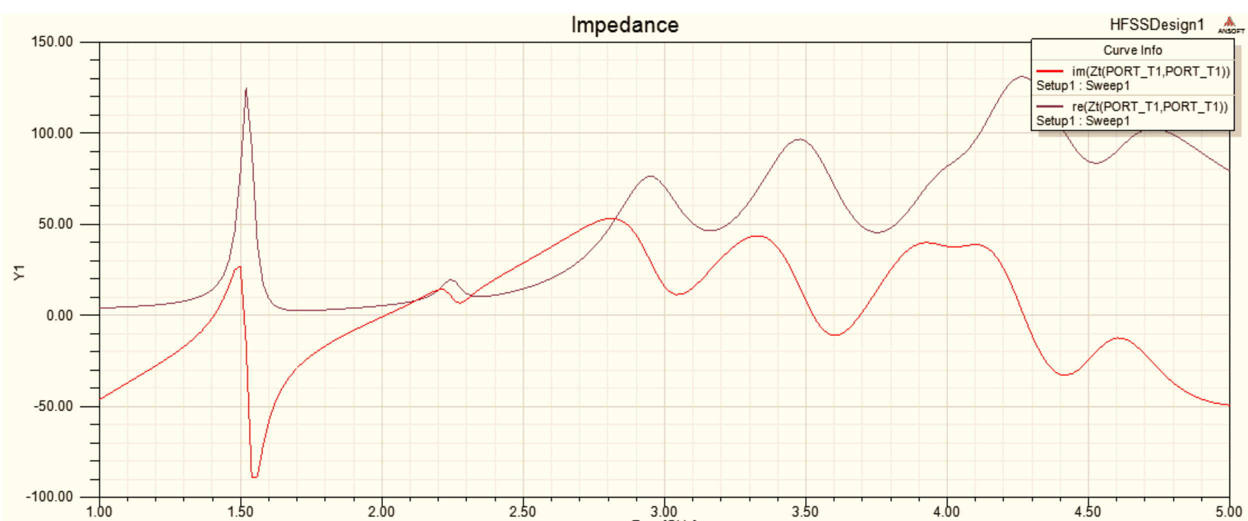


*Figure 2 (c) :* Impedance vs. Frequency curve of "Antenna 1"



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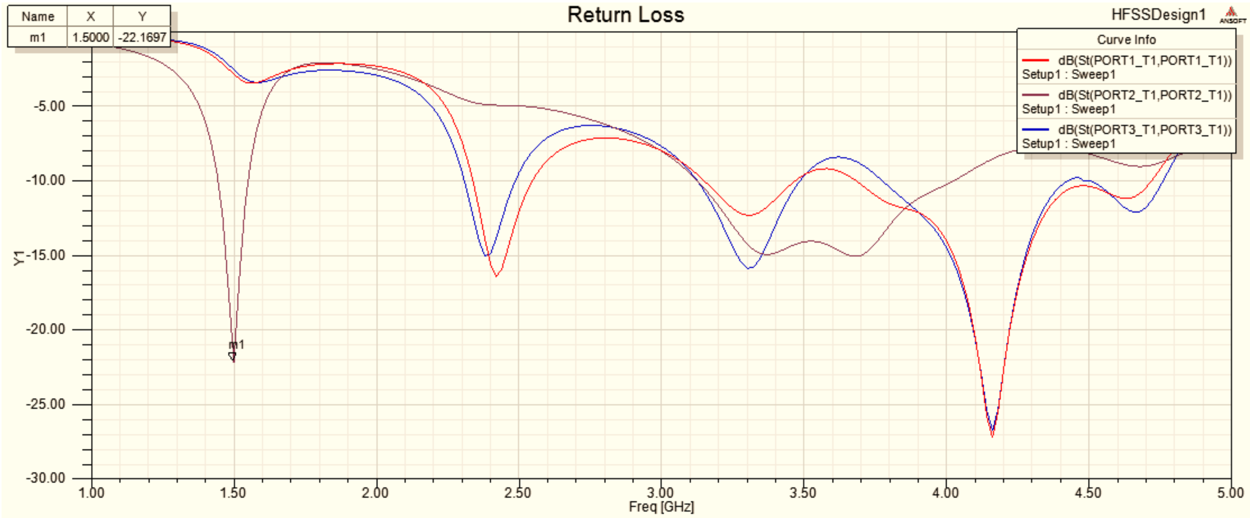


*Figure 3 (a) :* Return Loss Curve of "Antenna 2"

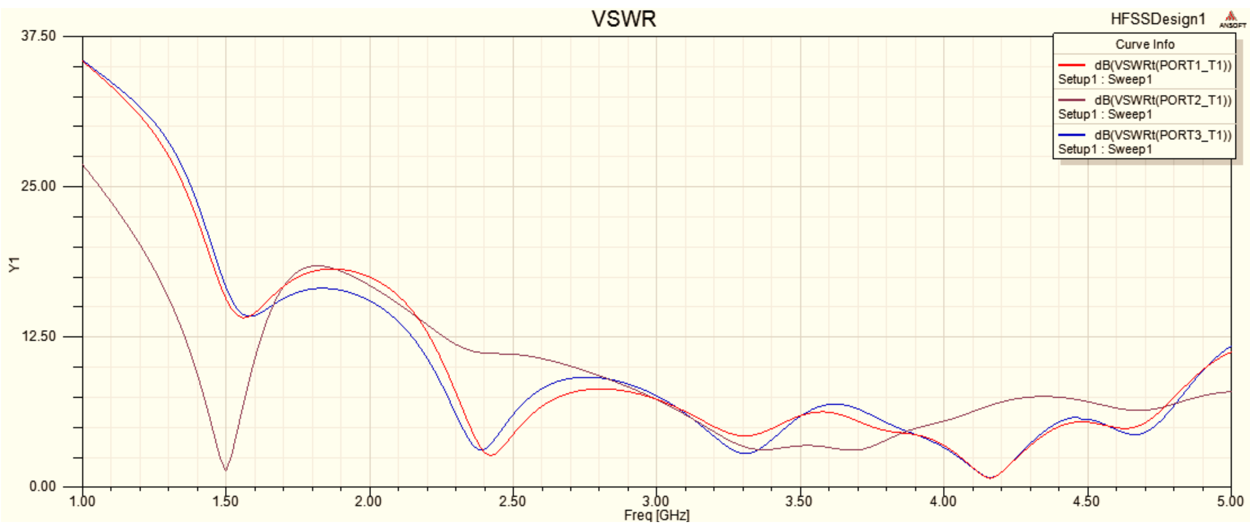


*Figure 3 (b) :* VSWR vs. Frequency Plot of "Antenna 2"

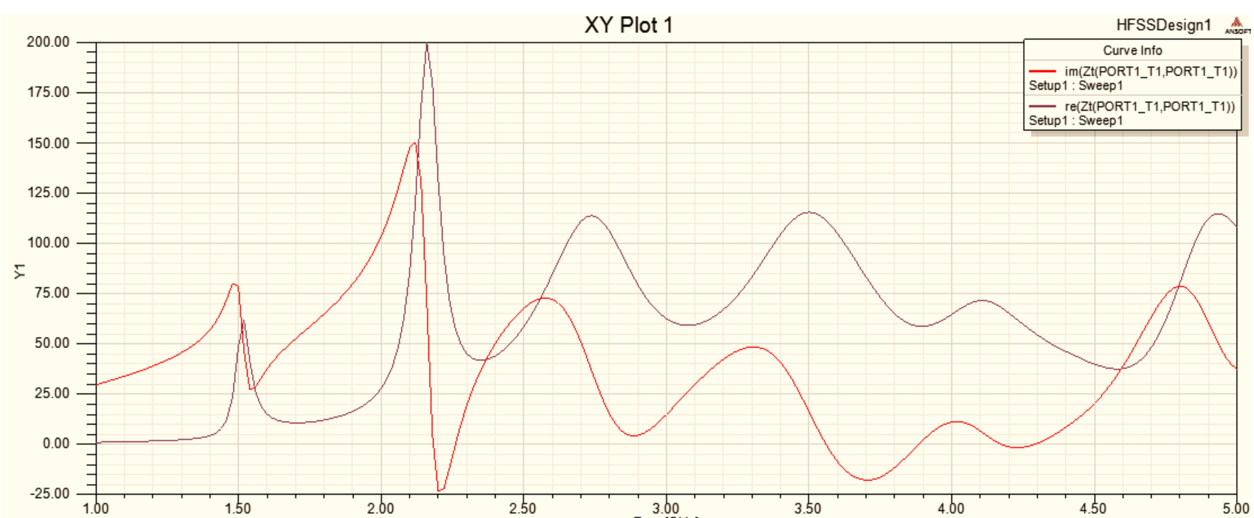


*Figure 3 (c) :* Impedance vs. Frequency curve of "Antenna 2"



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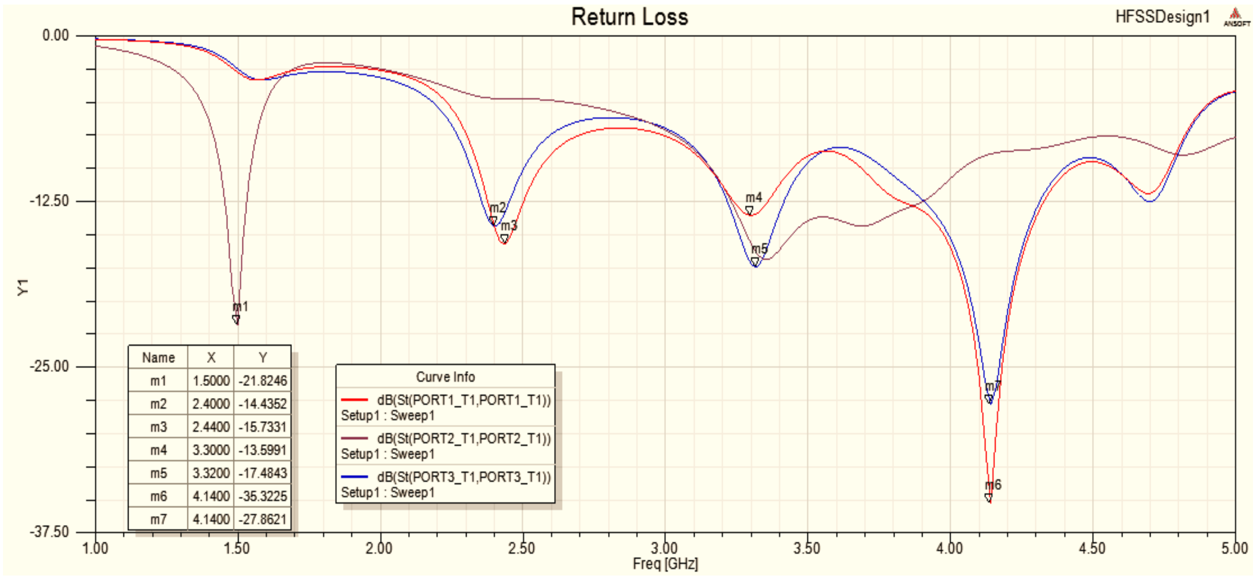


*Figure 4 (a) :* Return Loss Curve of "Antenna 3"

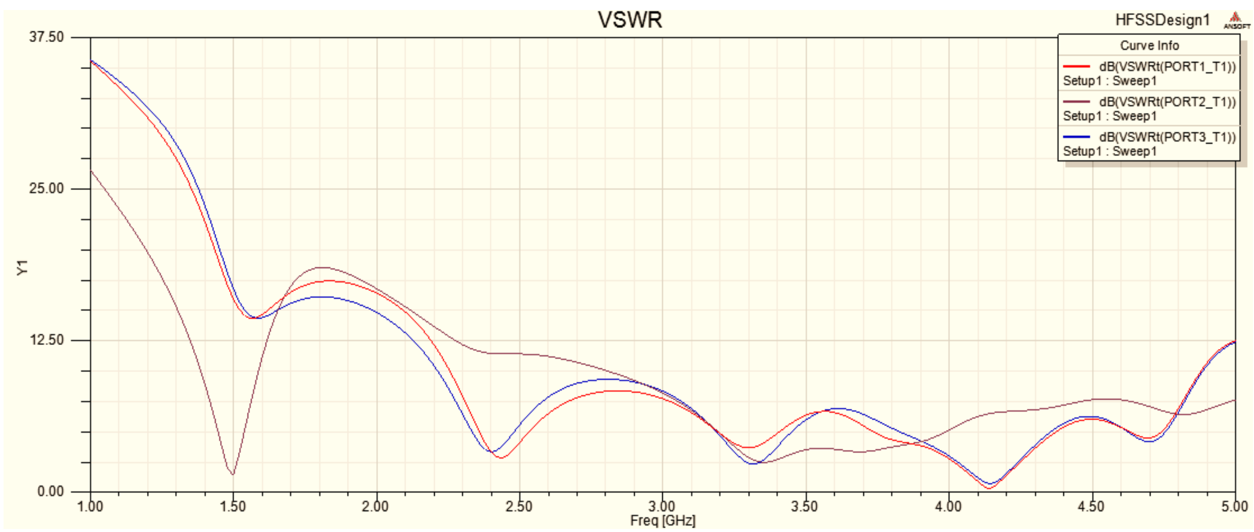


*Figure 4 (b) :* VSWR vs. Frequency Plot of "Antenna 3"

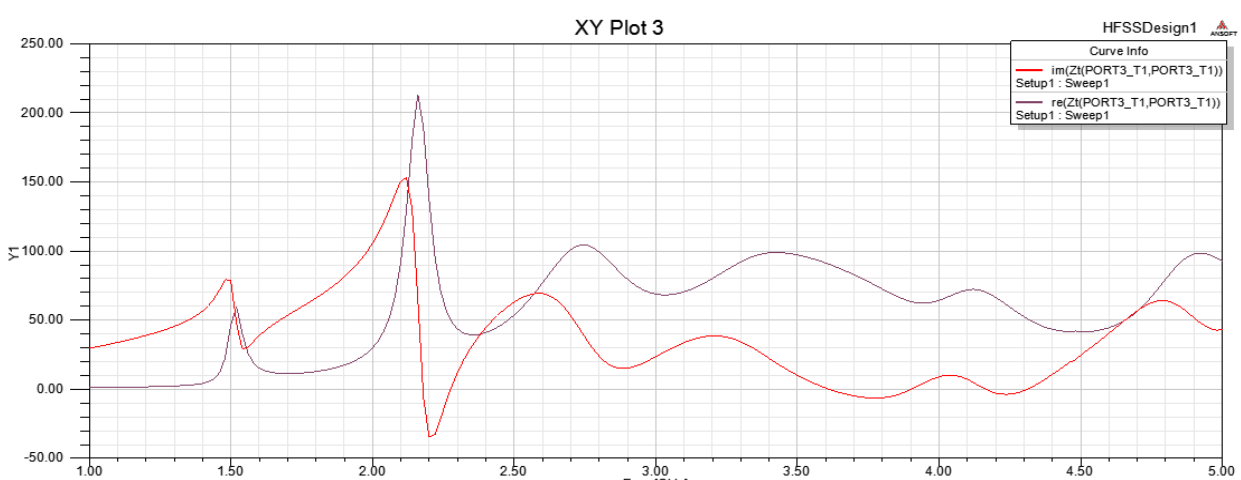


*Figure 4 (c) :* Impedance vs. Frequency curve of "Antenna 3"



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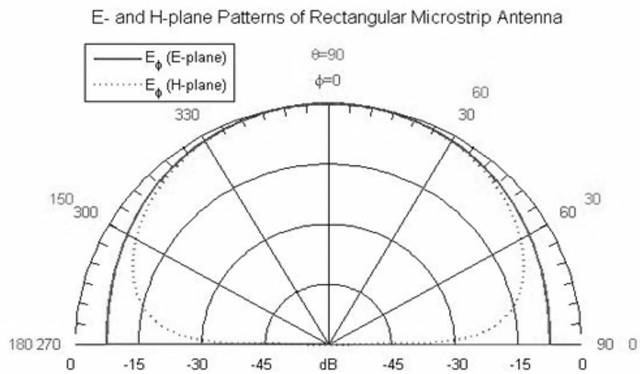


*Figure 4 (d) :* EH-field of "Antenna 3" in terms of Radiation Pattern

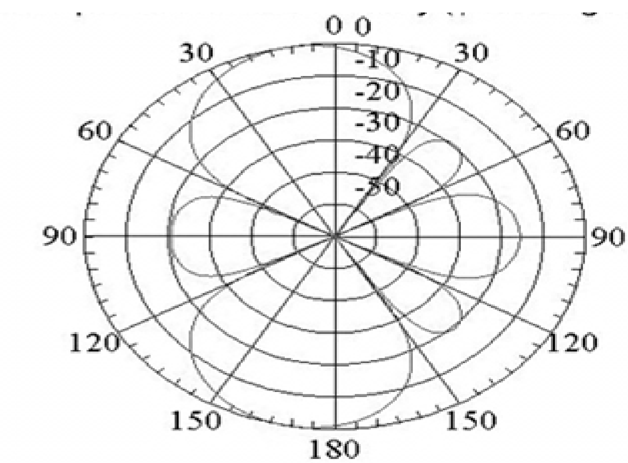


*Figure 4 (d) :* Directivity of "Antenna 3" in terms of Radiation Pattern

## V. Green Technology

This radiating system satisfies growing demand of technology in a green way. Following are the points which support the statement:

1. Antenna serves the purpose of three different antennas, which are operating at three different frequencies 1.5 GHz, 3.32 GHz and 4.14GHz. Therefore, implementation of the antenna can be done for three different antennas, and power requirement will be less for excitation of single antenna than a group of antenna.
2. Radiation efficiency of antenna is more than 99%, if excited from any of the excitation port.
3. Antenna, acts and directed more efficiently at an angle $40^0$, i.e., directivity of antenna is maintained at this angle. Further, single processing can be applied to the output of antenna at the transmitter end, which can make this antenna acts "*Smartly*".

## VI. Conclusion

Antenna has been successfully designed and experimentally verified. Its multi frequency operability has been most advantageous property within most commonly used frequency range, 1.5GHz, 3.32GHz and 4.14GHz and having return loss in optimum value. Antenna is also suitable candidate for Green Technology and has been supported with positive points. Its operating frequency has been verified for GSM and wireless communication system applications. Also, the VSWR value is restricted to 1.2 and directional directivity pattern has been obtained. Further, it requires a impedance matching circuits, which must be incorporated to increase the energy radiation effectively.

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