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Reconfigurable Antennas – Antennas that can think for themselves

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ABSTRACT: - This paper describes a new approach of a simple design, fabrication, and measurement of a reconfigurable antenna measurement system for Software Defined Radio application. Concept of frequency selectivity and polarization selectivity is demonstrated using Two-crossed dipole antennas connected RF Sources and Aurdino Microcontroller with Real time plotting in MATLAB serve as a low cost measurement system. The crossed-dipole antennas with different resonating frequencies were simulated in FEKO simulation tool and then fabricated. The radiation patterns of the antennas were then measured using the low cost measurement system and compared to the simulated *FEKO* results.

KEYWORDS: Automated measurements, Reconfigurable Antennas, Frequency Selective

I. INTRODUCTION

Reconfigurable antennas can illustrate basic antenna engineering principles, such as the relationship between the physical shape of an antenna and its radiation pattern or physical shape of antenna and its resonating frequency. The technical goal of this project is to use reconfigurable antennas, build an easy-to-use antenna measurement system and also achieve frequency selectivity especially for Software Defined Radio applications. Such a system can help students in introductory physics and engineering courses to better understand antenna design principles. The primary goal is thus to introduce the concept specifically those with little or no background in electromagnetics or communication systems to the basic principles of antenna theory especially to students at Universities / Colleges, while still providing more experienced users with a scalable tool for more advanced exploration. Also provide opportunities for scalability in terms of desired frequency range and polarization. This paper demonstrates for design for 2.4 to 2.5GHz.

II. RELATED WORK

Authors in [2] have developed the concept of multi array patch antennas and have achieved beam steering based on demand. This adaptability is controlled by activating desired array of the patch antenna to achieve radiation beam in the desired direction. The design consists of using parasitic pixel surface with air as di-electric medium between the driven patch and parasitic pixel surface. In [3] A novel dual antenna is proposed for null compensation.The primary antenna is a rectangular antenna thatgenerates an electric-loop mode. A zeroth-order resonant (ZOR)antenna is used as the auxiliary antenna, which produces a magnetic-loop mode and reduces the overall antenna size. Since theauxiliary antenna can be placed inside the primary antenna, theoverall occupied space is the same as the size of the single primaryloop antenna. The electric- and magnetic-loop current distributionsare orthogonal to each other, so their nulls are effectivelycompensated. Important concept in this approach is the use of Dual antenna and switching techniques. In [4] the authors have effectively demonstrated the use of RF PIN diodes for switching purpose of a single fed Slot antennas with reconfigurable capability.

III. SYSTEM DESCRIPTION

This system emulates the measurement system found as shown in Fig. 1, the Antenna Under Test (AUT) sits on a mount attached to a 360° stepper motor; the Reference Antenna is fixed on a separate mount located in the far-field of the AUT.Both modules are fixed to independentPlexiglass platforms (8mm). The stepper motor rotates AUT, the output of Reference Antenna is connected to a microwave detector, output of this detector is digitized and measured using

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Arduino Microcontroller (MCU or μC). The measured value is normalized and sent to a software measuring program using MATLAB. This communication to laptop is done using serial communication on USB. There exists multiple measurement techniqueswhich can be used, (eg; RSSI) values are plotted in decibelsas the approach is to confirm achieving frequency selectivity.

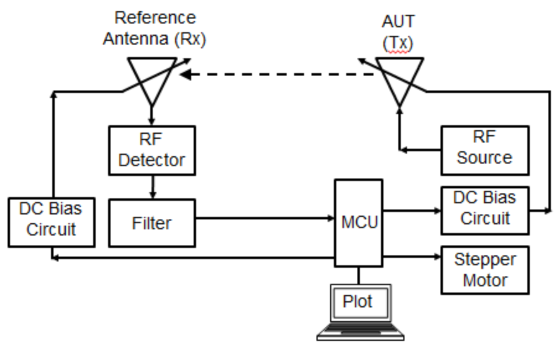

Fig. 1 – System Description

The system as shown in Fig1 consists of Antenna Transmission and Receiving part both integrated with MicroController Module which also controls the Biasing circuits as shown. Fig 2 shows the actual set up of the full system explained in the block diagram. The antennas are mounted on Plexiglas plates to secure in position at the time of performing test and measurements.The DC Bias Circuit, Stepper Motor and the Plotting will receive communication from the Microcontroller (MCU). Module.MCU handles the entire co-ordination till the test is completed.The electronics is powered by either 2 x 6AA batteries or 12V adapter. The frequency of operations is in the range of 2.4GHz to 2.5GHz

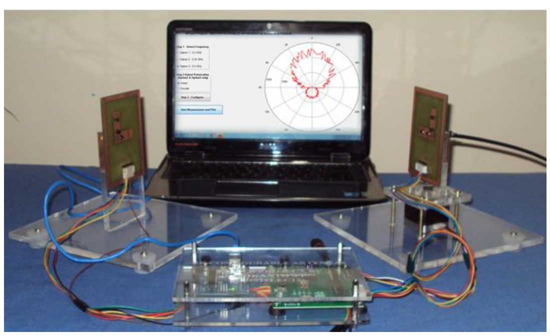

Fig-4 Full System

IV. Design of Antennas

A. *AUT (Antenna Under Test)*

The AUT shown is a Polarization reconfigurable based on two crossed microstrip patch antennas and is fabricated on a substrate with high ϵ_r (4.4). RF Pin diodes are used to select the patch element electronically. This is achieved by appropriately biasing the RF Pin diodes which is controlled by MCU. By enabling RF Pin diodes relevant patch is made active there by varying effective physical shape of the microstrip antenna as shown in Fig 2. This variation causes different resonant frequency thus demonstrating frequency selectivity concept. Fig 3 shows photograph of fabricated

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AUT. Antenna modelling and Design parameters are calculated based on standard formulas for patch antenna[1] by selecting frequency of 2.4GHz, 2.45GHz and 2.5GHz.

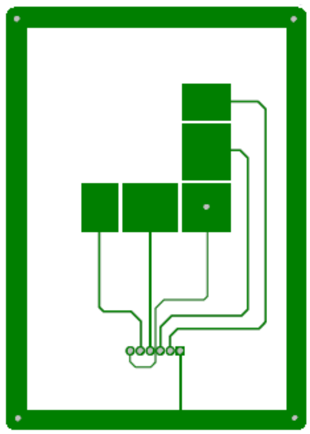

Fig-2 Layout design of AUT

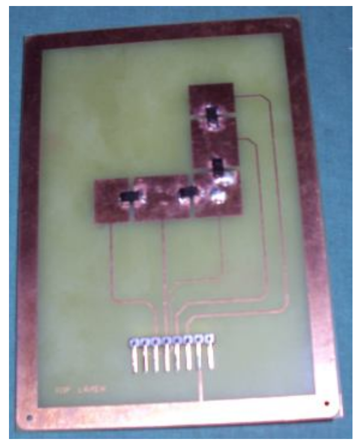

Fig-3 Fabricated AUT with RF PIN diodes

B. *Reference Antenna*

Like the AUT, the reference antenna is a polarization-reconfigurable antenna based on two crossed microstrip patch and is fabricated on similar substrate that of AUT. RF PIN diodes between to microstrip patches allow for electronic reconfiguration of the antenna's polarization. A DC bias circuit using comparator is controlled by the µC, in the RF feed line switches the PIN diodes. The µC determines the biasing of the antenna arms based on commands sent from the measurement software. Frequency reconfigurability of the reference antenna allows it to perform for the entire range of designed frequencies without physically being rotated. Both the AUT and Reference antennas are designed considering RF Source of 1V and 50Ω impedance.

V. Measurement System – Antenna Test Bed

The horizontal and vertical patch contains a second set of arms that can be activated with additional PIN diodes to increases the total arm to over half a wavelength, reconfiguring the radiation pattern from broadside to end-fire. A Comparator circuit controlled by the AurdinoµC in the RF feed line switches the PIN diodes. The µC determines the biasing of the antenna arms based on commands sent from the measurement software.During measurement, the AUT transmits constant signal from the source. This is kept constant throughout the measurement process till the test is complete (i.e. 0 to 360 degrees in steps of 1.8). Received power is calculated from the output of detector. This value along with angle is sent to measurement software in laptop using serial communication. After this is sent AUT is incremented by 1.8° by MCU and measurement is sent to software. This is repeated till it reaches its upper limit of 360°; at its upper limit the MCU that instructs to end the measurement, final plot is captured and stepper motor is given a 360 degrees full rotation in opposite direction and its original position is restored (this is done in order to avoid strangulation of cables on the system).The MCU is connected to a computer running measurement software on MATLAB. The code is written using the Graphical User Interface (GUI) feature in MATLAB which plots the received value on a Polar plot. With each step of 1.8° for a total 360° rotation, there will be 200 values measured and plotted in the polar plot.The configuration buttons allow the user to select between Vertical and Circular polarizations in both AUT and Reference Antenna. The 'Start Measurement' button begins the measurement and plots the received data on to Polar Plot. The data is normalized before plotting (value at 0 degrees is taken as maximum).

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VI. SIMULATION AND MEASURED RESULTS

The reference antenna and the AUT were first designed in 3D EM simulation software FEKO. These results are shown in Fig 4-6. These patterns were taken in an electromagnetically cluttered and noisy environment with full multipath effects. As such, the measurements illustrate the impact of realistic operational environments. The system can also be used in a more open environment (or anechoic chamber) to produce patterns behavior which more closely matches the predicted / simulated patterns in Figs. 4-6. This system not only demonstrates basic antenna principles, but allows students to explore other antenna designs and perform more exciting measurements with instant plot. Fig 4 and 5 shows the radiation pattern of E_θ obtained at 2.4GHz and 2.45GHz respectively.

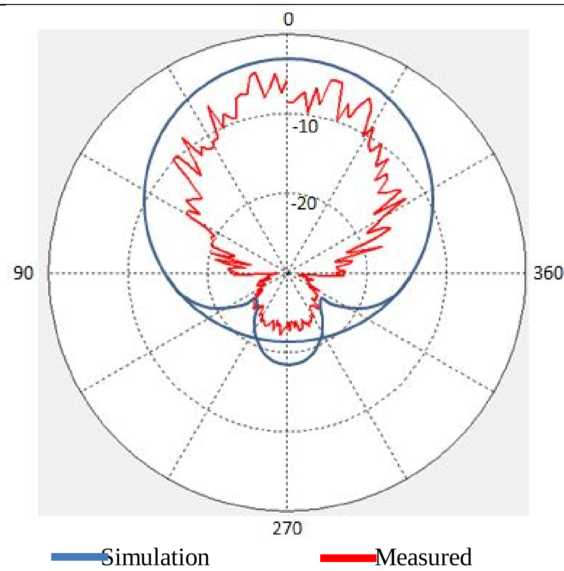

Fig-4Radiation pattern of E_θ, configuredat 2.4GHz, having both Simulated and Measured plots

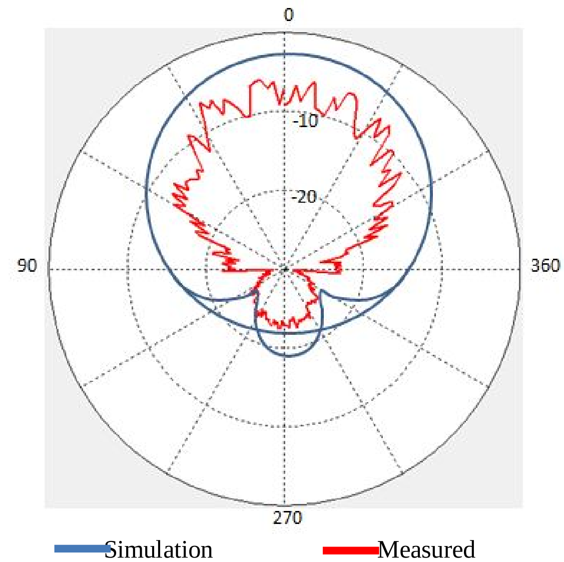

Fig-5Radiation pattern of E_θ, configured at 2.45GHz, having both Simulated and Measured plots

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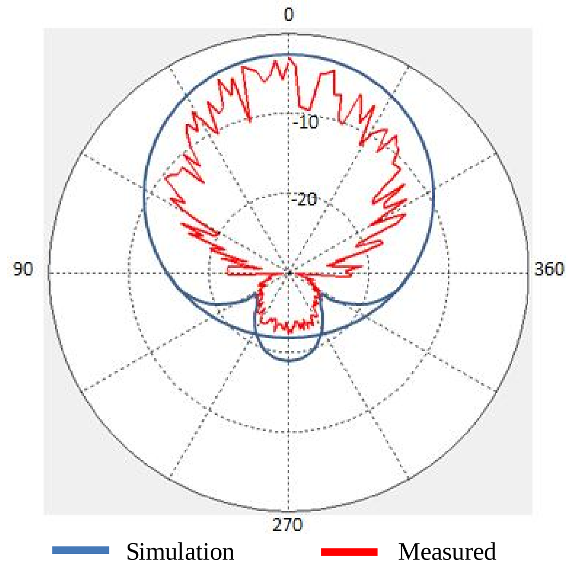

Fig-6 Radiation pattern of E_θ, configured at 2.5GHz, having both Simulated and Measured plots

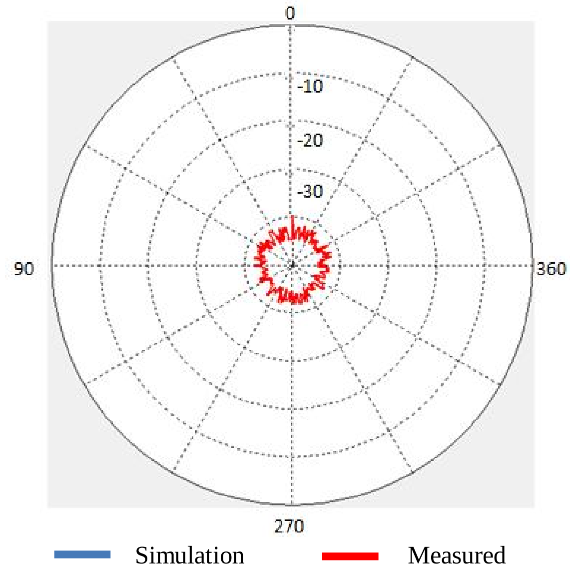

Fig-7 Radiation pattern of E_θ, configured at 3.3GHz, having both Simulated and Measured plots

As observed from the results obtained the designed and fabricated antenna resonates at specified frequencies of 2.4, 2.45 and 2.5GHz. It can be seen that maximum acutally measured is at 80% of the simulated value.

VII. CONCLUSION

The following conclusions are drawn from the obtained results.

- The obtained results are more realistic, since the system was placed in a electromagnetically cluttered environment. If system was tested using anechoic chamber the obtained results would be more closer to simulated results
- The patterns are more consistent for 2.4, 2.45 and 2.5GHz and not consistent at 3.3GHz. Which implies that the antenna patches have the resonating frequency as per the design. Fig-7 shows the response at 3.3GHz is poor.

In conclusion, the system achieves its goals of obtaining frequency selectivity by electronically varying the effective physical dimension of the microstrip antenna, thereby resonating at different frequency. Additional active elements can be added or different shapes can be tried to make the system compatible for wide range of frequencies and applications. Since selection is electronically performed it can be used for wide range of applications.

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BIOGRAPHY

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