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RADIAL WAVEGUIDE SLOT ARRAY ANTENNA DESIGN AND IMPLEMENTATION FOR WLAN APPLICATIONS

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8.1 INTRODUCTION

The recent growth in the information technology and wireless communications has created many opportunities for enhancing the performance of existing signal transmission. However, Antenna designers are always searching for ways to improve existing designs or introduce novel designs in order to achieve desirable radiation characteristics, reduce the size and weight, which are mandatory requirement for antennas used in WLAN and thus make antennas more cost efficient. Transmission of data at higher rates requires adequate bandwidth for the elements characterize the communication link accordant to IEEE802.11b/g standard which well-handled in this project. For WLAN applications, where problems such as multi-path fading due to reflections from various scatterers occur, a linearly polarized RWSA antenna is a referable option. The reason is that this polarization enhances overall system diversity and permits freedom of orientation for the user-end antenna. Radial waveguide slot array Antennas (RWSA) is very attractive for applications in communication devices for wireless local area network (WLAN) systems in the 2.4 GHz (2400–2484MHz), the free Industry-Scientific-Medicine (ISM) frequency band. Work investigated on development of the low profile unidirectional Radial Waveguide Slot Array Antenna as a potential alternative to the WLAN AP antenna.

8.2 ANTENNA DESCRIPTION

The antenna is drafted of two radial waveguide made of copper plate of 0.15mm thickness with a dielectric material adhere between the two radial waveguide, with Four slots on the upper plate. The four slots are concentrically arrayed along as annular path with radius ρ_a to form a single ring RWSA antenna. Four slots are used as it produces vertical linear polarization due to the insignificant E_ϕ component. Every slot is positioned at the quadrant and tangent of the annulus as demonstrated in Figure 8.1.

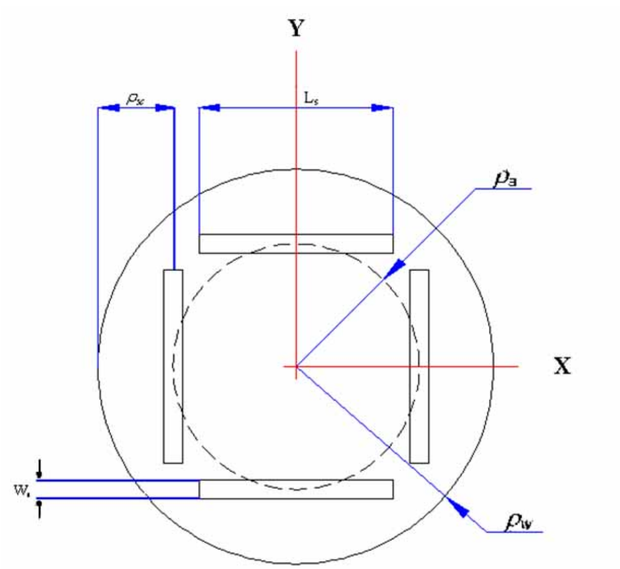

Figure 8.1 The radiating surface of the RWSA antenna

The four slots are arc-spaced by $0.47\lambda_g$ that produce the slot radius of $0.3\rho_a$, where: $\lambda_g < (\lambda_o / \sqrt{\varepsilon_r})$. The overall of the antenna radius is ρ_w, sum of ρ_a and ρ_{sc}. The length of the slots Ls is near to the half wavelength in the radial waveguide at the desired frequency. The radial waveguide slot array antenna is formed by an upper circular conductive surface carries a defined distribution of radiating slots, while the rear conductive surface is devoid of any slots. This rear surface incorporates a coaxial feeding element at its centre. Losses attainable in such structures, therefore slots were arrayed so that their radiations were added in phase in the beam direction. Power fed at the centre by coaxial cable and transfer into a radially outward traveling wave with a rotational symmetry to excite the slots. An area of certain radius on the upper conducting plate was left without any slot to let the axially symmetric traveling wave to stabilize when entering the feeding structure. The SMA connector with a coaxial fed monopole is used in the design for coaxial-to-radial line adapter, which excites the radial waveguide at the centre. Using the SMA connector, the adapter is free to change its probe length, Lp which provides a lot of flexibility to the design procedures. This project use coaxial-to-radial line adapter to be shorted (Lp=d) Probe as shown in Figure 8.2.

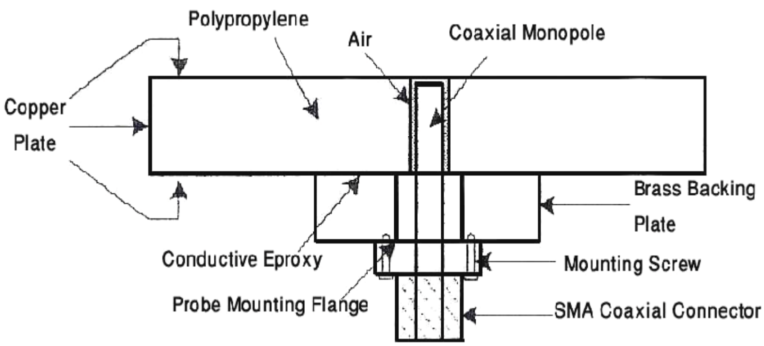

Figure 8.2 Insertion of coaxial monopole SMA connector into the slotted radial waveguide through the backing plate

An equivalent electrical lumped-circuit model of single slot is starting point for the RWSA analysis. This equivalent circuit with evident resonance features characterized by resonance frequency f_0 and setting quality factor is shown in Figure 8.3.

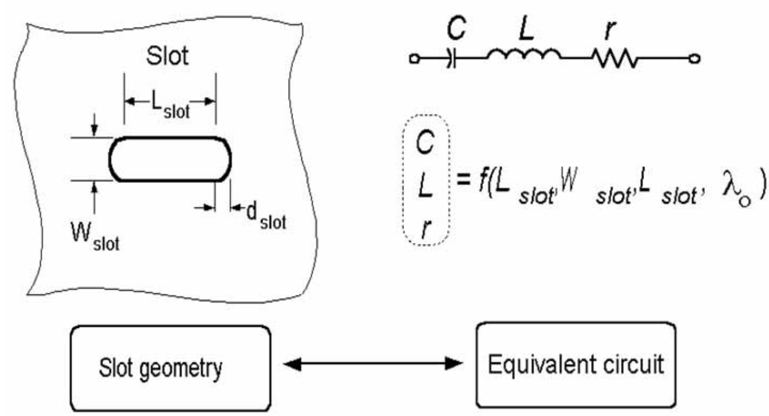

Figure 8.3 equivalent electrical lumped-circuit model of slot in thin metallic plate

8.3 ANTENNA SIMULATION MODELLING

The finite difference time domain (FDTD) method, Zeland FIDELITY version 4.0 used in the antenna structure modeling. Simulation is carried out in three organized stages. First of all, the material selections need to be determining before proceeding to the feeding technique determination. Finally, once the material and the type of feeding technique are selected; input impedance optimization is carried out to obtain the desired results. The initial parameters for the designed antenna used for initial simulation. Once the initial simulation result is obtained, next will proceed to the optimization of the parameters, and finally redesign of the RWSA antenna will be carry out if necessary. The sequence of the defined objects is important to form the antenna structure correctly in order to proportionment the antenna elements. A wire is used to define the dielectric cylinder. The SMA connector which made of gold is defined as an enclosed coaxial port to reduce the simulation domain and therefore the simulation speed. The antenna is excited with sine modulated Gaussian pulse. PML absorbing boundary condition (ABC) is applied in' the simulation to truncate the analysis region. Figure 8.4 shows the RWSA structure in 3D view.

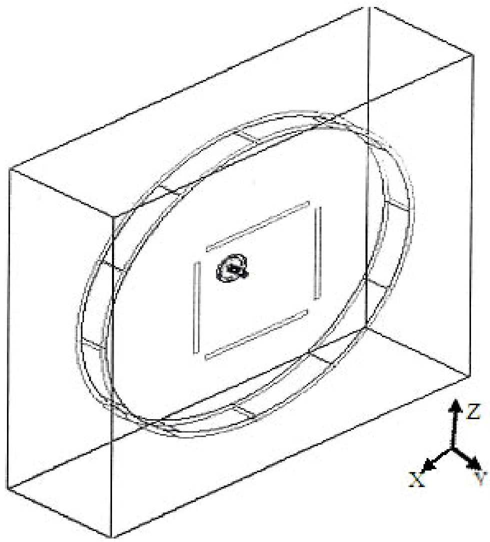

Figure 8.4 The 3D view of the antenna structure, built in FIDELITY

8.4 ANTENNA SIMULATION RESULTS

The radiation pattern is symmetric at the broadside axis and with a deep null at the broadside and small back lobe. Simulation showed that the design produces semi-omnidirectional flower like radiation pattern (Figure 8.5) with the beamwidth of more than 100 degree and directivity of 8.03214dBi from 30^0 up to 150^0. This harmonized with indoor WLAN applications which require a wide beamwidth. The measurement has very good agreement with the simulation result in terms of resonant frequency. Wide variation may occur due to the inaccuracy in the simulation meshing when it comes to very small structure like the SMA probe. This simulation radiation pattern is suitable for the indoor WLAN environment and the directivity value is within the FCC regulation.

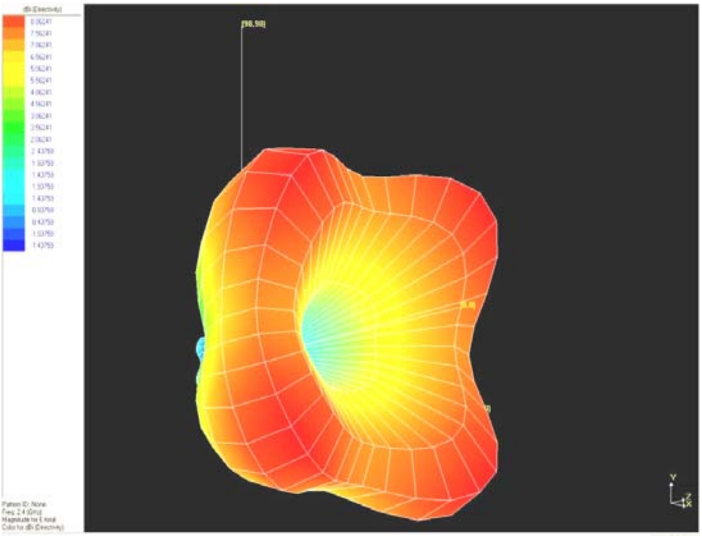

Figure 8.5 Radiation pattern of the 2.4GHz RWSA antenna design

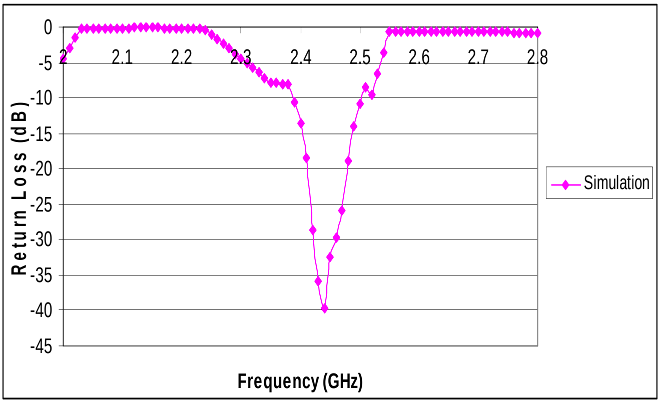

Figure 8.6 Return loss in case of polypropylene as radial waveguide cavity

Return loss simulation for RWSA antenna (shown in Figure 8.6) shows that the band width is 83.5 MHz = 3.68%, Return Loss = -30 dB, and the Return Frequency is 2.44 GHz. Next steps are to fabricate the antenna based on optimum simulation results considering frequency shift formulas and SMA tune-up.

8.5 ANTENNA MEASUREMENTS

The measurement of return loss versus frequency for RWSA antenna prototype was performed using S11 parameter. The setup of the measurement is demonstrated by utilizing an Agilent 8722ES vector network analyzer, the antenna radiating surface is aimed at free space or microwave absorbing material during measurement. Figure 8.7 illustrates the comparison between the simulation return loss and the fabricated antenna return loss measurement. And Table 8.1 clarifies the exact values of the comparison.

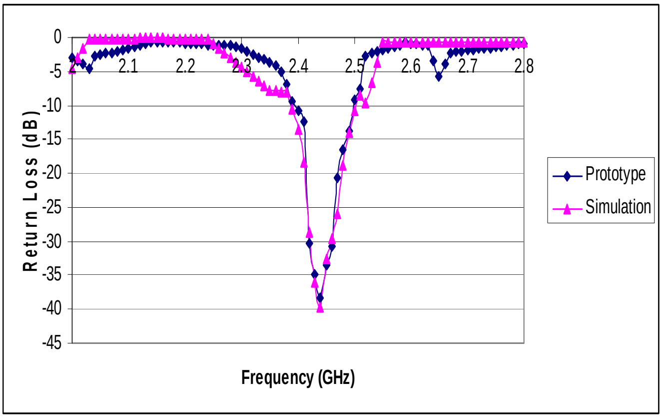

Figure 8.7 Return loss result Comparison between the Prototype and the simulation results

Table 8.1 RWSA 2.4 GHz simulation and prototype measurement comparison

Parameters	Zeland simulation	Prototype measurement
Resonant frequency	2.438GHz	2.44GHz
Return loss	-30dB	-30.3dB
Bandwidth	45MHz	45Mhz

Radiation Pattern measurements have been done in echoic electrical chamber and the results were perfectly compatible with our aim to cover vertical side opposite the antenna. However, this permits to cover many users with one access point. Figure 8.8 shows the radiation pattern measurements for Electrical field cross and co-polarization; in addition Figure 8.9 shows the radiation pattern measurements for Magnetic field cross and co-polarization.

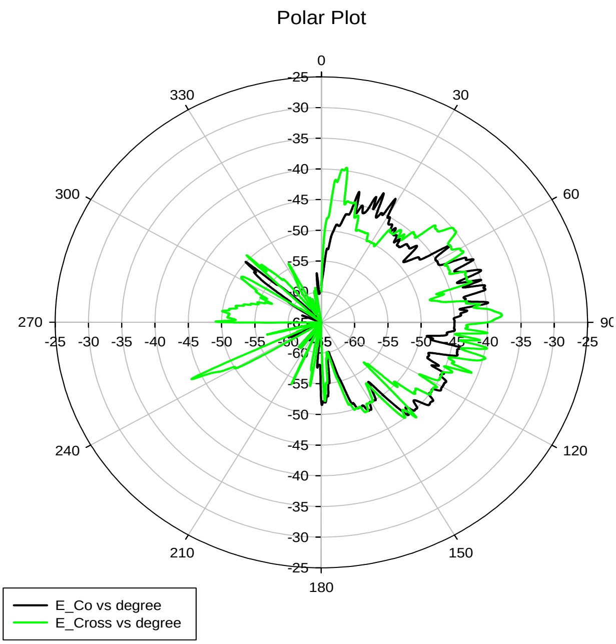

Figure 8.8 Radiation pattern measurements for Electrical field cross and co-polarization

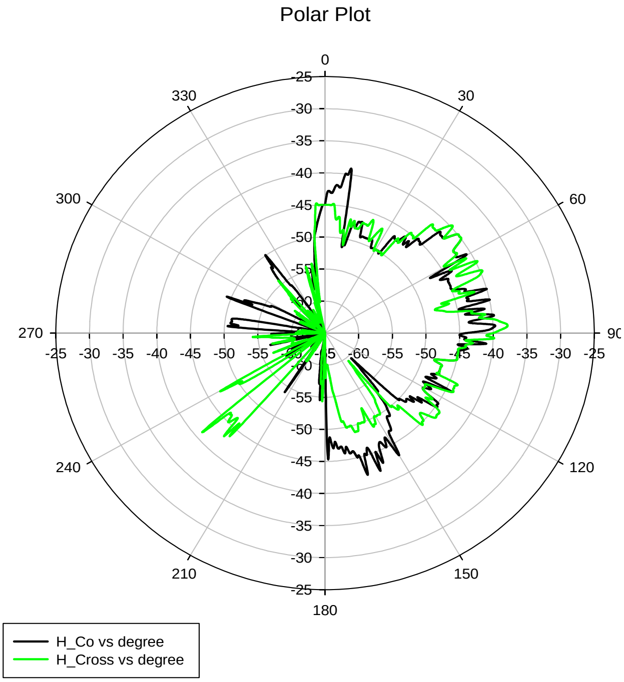

Figure 8.9 Radiation pattern measurements for Magnetic field cross and co-polarization

Received signal strength index measured to the fabricated prototype done by using AirMagnet software, which Delivers Remote WLAN Analysis to collect wireless data for real-time analysis when we apply the RWSA antenna on Access point (AP). Figure 8.10 and Figure 8.11 shows that RWSA gives a higher RSSI performance compare to the monopole antenna at the same measurement distance (5 and 22 meters) with the same frequency range of 2.4-2.4835 GHz over eleven channels.

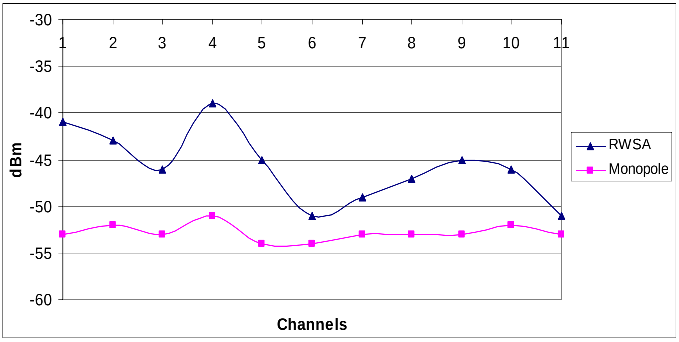

Figure 8.10 RSSI Comparison between RWSA & monopole antenna, using AirMag for a short distance

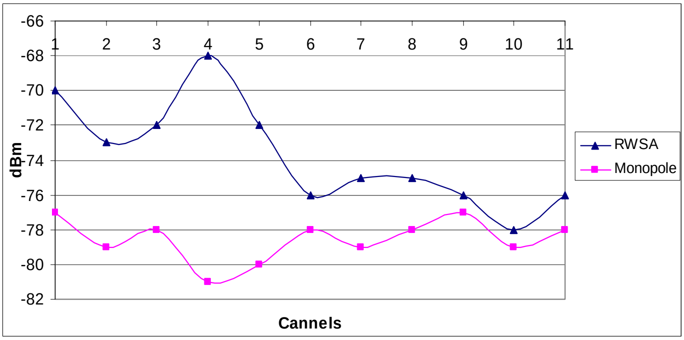

Figure 8.11 Comparison between the RSSI of the RWSA antenna monopole antenna using AirMagnet for a Long distance

8.6 RESULTS AND CONCLUSION

The design parameters, initial calculation results, simulation tools and antenna design modeling in the software environment have been presented, simulation analysis was performed and the optimum results were obtained for 2.4GHz RWSA antenna. Radial Waveguide Slot array antenna was successfully fabricated. Then, return loss Radiation pattern and received signal strength were measured and performed. There was a good agreement between simulation and prototype measurements. Receive signal strength results proved that the 2,4GHz RWSA antenna prototype has a better radiation quality than the monopole antenna in case that radiation should be in one direction. Therefore, RWSA antenna can operate in 2.4 GHz for WLAN indoor environment within higher gain.

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