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NOVEL DESIGN OF MULTI LAYER RADIAL LINE SLOT ARRAY ANTENNA USING FR-4 SUBSTRATE

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7.1 INTRODUCTION

The antenna designers always look for low profile, durable, attractive and high gain antennas for point to point and point to multipoint as well as satellite broadcasting applications. From this point of views, Radial Line Slot Array (RLSA) antenna is very attractive for this types of communications because of geometrical simplicity, low profile feature and cost effectiveness. Nowadays Radial Line Slot Antenna (RLSA) became a unique choice for wireless bridge point to point application. A RLSA antenna has been proposed nearly 40 years ago and became the subject of study as perspective antenna for direct TV satellite broadcasting and any other wireless communications since 1980.The RLSA antenna belongs to the slotted waveguide arrays family, which is the only and the most promising candidates for high gain planar antennas, having the smallest conductor losses among all the planar feeding structures such as the microstrip lines. It is composed of three circular parallel plate waveguide, which can supports two types of wave traveling or standing wave. Therefore, this antenna is more versatile in comparison of other antennas. Outstandingly, the RLSA can achieve more than 30dBi of gain in the 11 GHz band. The low cost feature of RLSA has motivated some researchers to expand its design for lower frequency applications, such as WLAN and Solar Power Satellite antenna. Advantages of this antenna include its high radiation efficiency, low profile due to it can be mounted at roof and wall, ease of installation, feed rear-mounted, not subject to leaf and water build-up due to its flat surface.

7.2 THE RLSA ANTENNA STRUCTURE

A radial line slot array antenna is a high gain antenna. It is a kind of slotted waveguide array that is filled with dielectric material that suppresses the grating lobes. The slots are arrayed so that their radiation is added in phase in the beam direction. The structure of the investigated multi-layer linearly polarized RLSA antenna is shown in Figure 7.1. In this configuration, the antenna consists of three layers FR-4 spaced a distance d apart, the upper plate bearing a radiating slot pattern and the rear plate has additional non radiative slots. The radial cavity formed between these plates is filled with a dielectric material of relative permittivity $\varepsilon r>1$. The purpose of this dielectric is to create a slow wave structure with the guided wavelength λg being smaller than the free space wavelength $\lambda 0$ to avoid grating lobes in the radiation pattern. The orientation of slots is such that to receive waves of proper polarization, linear in this case, are coupled inside the cavity. The operation of the antenna can be considered in either receive or transmit modes of operation. Both are equally valid due to the reciprocity theorem. In the transmit mode, energy fed to the antenna via the coaxial cable is launched by the feeding mechanism into an outward traveling axially symmetric wave inside the radial cavity. An area on the upper guide surface of radius ρ around the feeding mechanism is left devoid of slots to allow the radial cavity mode to stabilize and form an axially symmetric traveling wave. In turn, this cavity mode is coupled into a radiated free space wave via the pattern on the upper cavity surface. The structure of RLSA shown in Figure 7.1 and final prototype is shown in Figure 7.2.

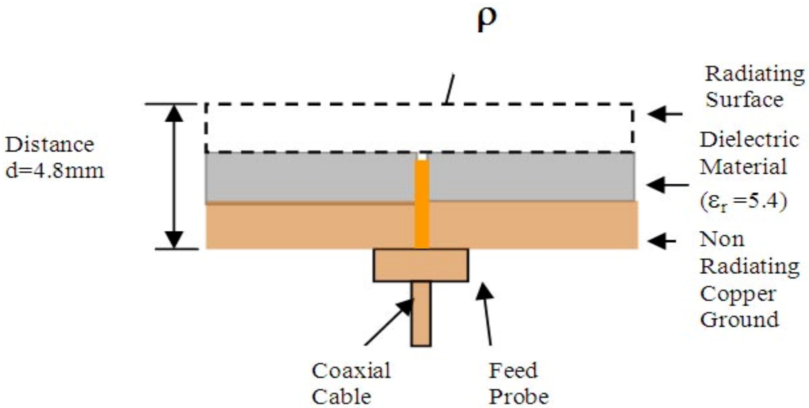

Figure 7.1 RLSA antenna structure

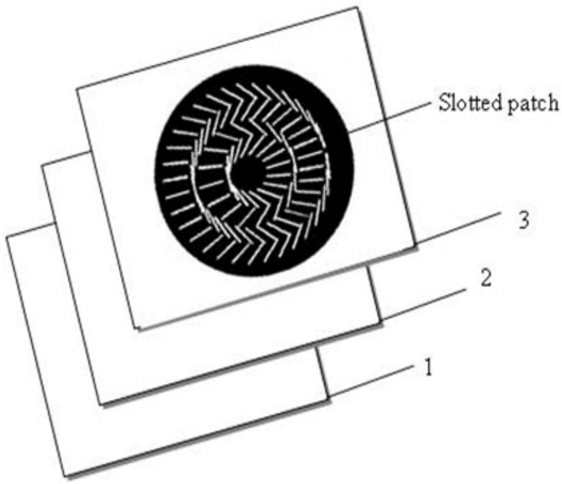

Figure 7.2 Final prototype of RLSA using 3 layers FR-4

7.3 SIMULATION AND ANTENNA PROTOTYPE MANUFACTURING

For the radiation pattern simulation, a software was developed using Borland C++ 5.00. To achieve the desired radiation pattern in the slots surface design, some parameters in the input data file have to be changed according to the desired frequency, relative permittivity of dielectric material and dimension of RLSA antenna. The resulting slot surface parameters such as slot position and orientation are fed into the theoretical radiation pattern modeling software developed using Matlab to evaluate the expected radiation pattern. After the obtained theoretical radiation pattern result is satisfied, the design software will output desired Computer Aided Manufacturing (CAM) file format in order to develop the antenna prototypes.

Table 7.1 RLSA antenna design parameters

Design Frequency	5.8 GHz
Dielectric constant (FR-4)	5.4
Height of radial cavity	4.86mm
Number of slot pairs in the inner ring	16
Radiating slot length	15mm
Radiating slot width	1mm
Radiating slot counts	94
Each layer thickness	1.6 mm

7.4 ANTENNA SIMULATION RESULTS

The RLSA antenna is an array type antenna. Therefore this antenna needs to accumulate the radiation field from every single element to form the entire radiation pattern. The simulated radiation pattern is shown in Figure 7.3. From Figure 7.4 it could be observed that the beamwidth of radiation pattern is narrow and directional. This is because the radiation pattern from every slot pairs is added in phase. The narrower the beamwidth of an antenna, the higher antenna gain would be obtained. In order to achieve higher antenna gain, it is necessary to obtain 3 degree beamwidth by arraying the rings of slots to achieve a more directive pattern. This was achieved by choosing a radial spacing between every ring in the radial direction of one guide wavelength λg.

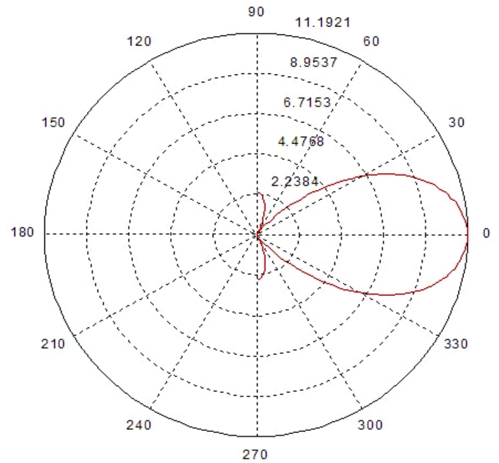

Figure 7.3 Radiation pattern from Simulation

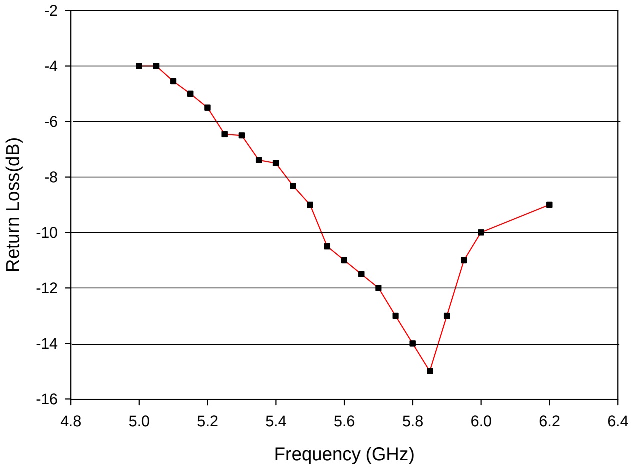

Figure 7.4 Return loss from simulation

From the Figure 7.4, it could be observed that the return loss for this antenna is roughly between -14 to -16dB at the 5.8 GHz (Which means that 98% signal transmitted and 2% signal reflected back). It can be said that the antenna posts average good return-loss in 5.8 GHz, so it is expected to be receive and transmit point to point signal.

7.5 ANTENNA PARAMETERS MEASUREMENTS

7.5.1 Return Loss

An experiment had been setup to measure the return-loss of RLSA antenna using Marconi 6204 Microwave test set. In order to validate the measured result, the result is compared with simulated result and has been depicted in Figure 7.5.

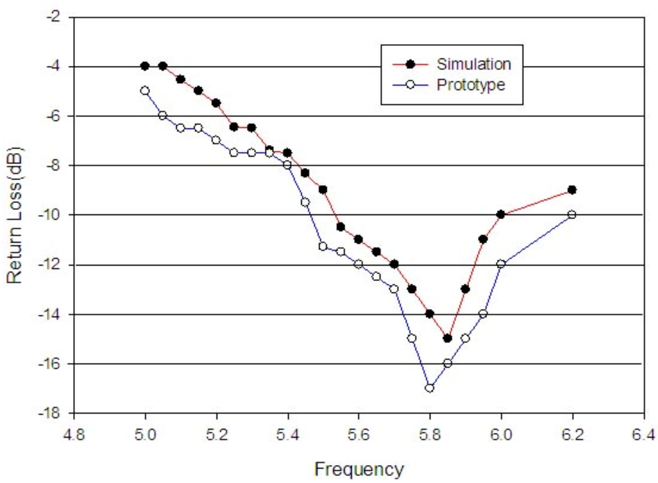

Figure 7.5 Return loss comparison between simulation and measurement

7.5.2 Radiation Pattern

In order to obtain the radiation pattern measurement results, the vital feature is to maintain the constant large distance between the antennas and to vary the observation angle. This is accomplished by rotating the test antenna (antenna under test, AUT). The fields from the motionless source antenna provide a constant illumination of the test antenna whose output varies with its angular position. This leads to the rule that the pattern of the rotated antenna that is being measured.

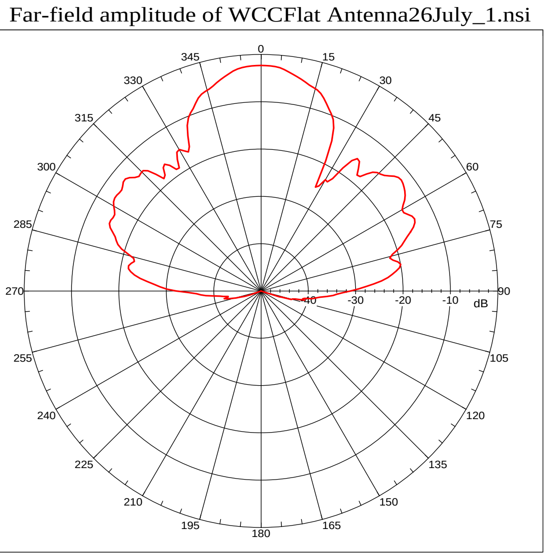

Figure 7.6 Measured radiation pattern result at anechoic chamber

The results showed in the Figure 7.6. As shown in the figure, the main beam exists between +30deg to -30deg and this exhibits a close agreement between the measured radiation pattern of the flat antenna and the prediction. However, a small discrepancy can be noticed in the lower power regions (-75° to 35°, +35° to +75°).

7.5.3 RSSI

To measure the Received Signal Strength Index (RSSI) a test bed was setup at different distances. The figure shows the comparison of RSSI between RLSA and commercial 5.1-5.8Ghz Integrated Router Antenna. The result is shown in Figure 7.7.

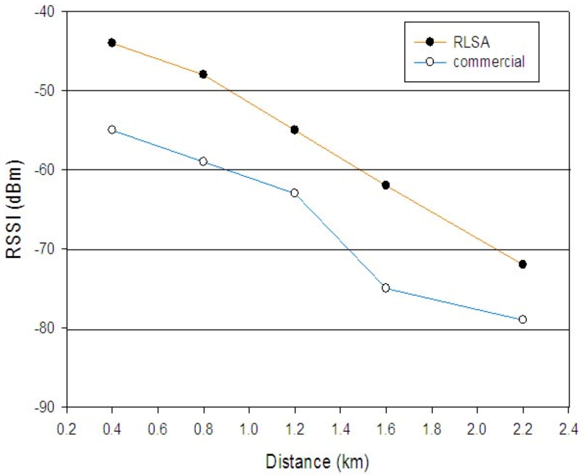

Figure 7.7 RSSI comparison between RLSA and commercial antenna

7.6 CONCLUSION

Simulation and measurement results have been presented. A test-bed had been setup using developed RLSA antenna and commercially wireless router on board antenna to evaluate the performance of RLSA in receiving point to point signal as wireless backbone. These results have proved the prototype has a better transmission quality and validate the potential for developed RLSA to be used in point to point communication.

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