Small Aperture Radial Waveguide Slot Array Antenna Design for Indoor Bluetooth Application

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Abstract – The Radial Waveguide Slot Array (RWSA) Antenna is known for its good characteristics such as low profile, low cost, aesthetically pleasing, ease of installation and simple structure. This research project involves the design and development of the novel linearly polarized small aperture Radial Waveguide Slot Array (RWSA) Antenna for Indoor Bluetooth applications operating based on ISM frequency band standard, with frequency range of 2.4 – 2.4835 GHz. Zeland Fidelity 4.0, an FDTD based antenna simulation is utilized to estimate the input impedance and radiation pattern of the antenna design. The second part of this project includes the antenna prototypes fabrication and experimental evaluation. Finally, the measurement analysis is compared with the theoretical result.

1. Introduction

The quarter-wave monopole antenna posed certain disadvantage due to its physical limitation. The physical structure of monopole makes it susceptible to physical damage as the antenna probe can be bent or broken easily. Beside that, the moving and tilting of the antenna probe will change the radiation pattern and hence recalibration is necessary. The omni directional radiation pattern of the monopole can penetrate the wall. This will reduce the propagation envelope and its efficiency for a specific room or area for the indoor WLAN application.

Radial Line Slot Array (RLSA) which is known for its flat, low profile and rugged structure is considered as one of the potential options for the indoor WLAN application. RLSA was introduced by Kelly K.C. in the 1960s [1]. Takada and several authors proposed the use of RLSA in the mobile satellite communication [2 – 4]. Tharek and Farah Ayu proposed the linear polarized RLSA for indoor WLAN application for 5.5GHz [5]. This design applied the similar concept to design the antenna in the more popular 2.4GHz range for indoor WLAN and Bluetooth applications.

This paper is organized as follows. In section 2, we explain the tools and procedures used in the antenna design. Section 3 presents the simulation and measurement results and analysis of the RWSA antenna. Lastly, in section 4, we conclude the paper.

2. The Antenna Design

The Linear Polarized (LP) RWSA 2.4GHz antenna for indoor WLAN and Bluetooth applications is designed based on the small aperture RLSA 5.2GHz antenna [5]. The RLSA antenna structure consists of two radial metal plates adhered to a radial dielectric material acting as a radial waveguide cavity. The radiating slots pattern is at the upper plate while the feed element is incorporated at the center its rear plate. Both plates are spaced d apart filled with a dielectric material with dielectric constant of more than 1 to provide a slow wave structure in the waveguide and thus avoiding grating lobes in the radiation pattern [5]. The orientation of the slots will determine the polarization whether it is linear or circular. The linear polarization pattern is chosen for this design. Few slots are needed to obtain a wide beam width of radiation pattern. The slots are arrayed so that the radiations are added in phase in the beam direction [6]. Power feed at the center by coaxial cable will transfer into a radially outward traveling wave with a rotational symmetry to excite the slots [7]. An area of certain radius is left without any slots on the upper plate to allow the axially symmetric traveling wave to stabilize when entering the feeding structure [5]. The LP RWSA 2.4 GHz antenna structure is shown in the Figure 1, while the proposed geometry of the LP RWSA 2.4 GHz antenna design is shown in Figure 2.

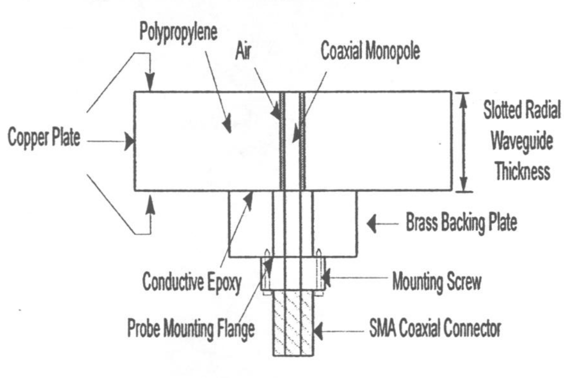

Figure 1: The LP RWSA 2.4 GHz antenna structure.

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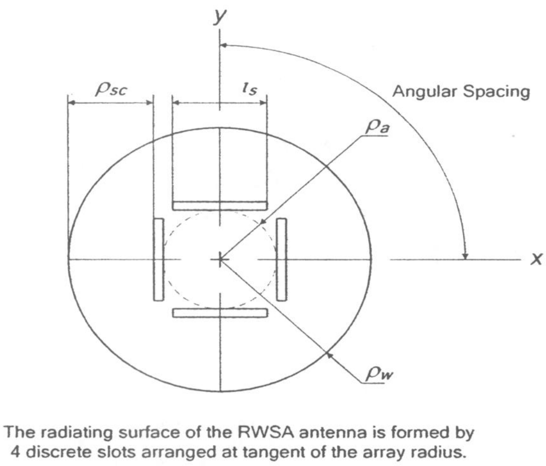

Figure 2: The proposed geometry of the LP RWSA 2.4 GHz antenna design.

3. Simulation and Measurement Analysis

The design is simulated using Zeland 3.0, a Finite Difference Time Domain (FDTD) based full-wave electromagnetic simulator. Simulation showed that the design produce a semi-omnidirectional flower like radiation pattern (Figure 3) with the beamwidth of more than 100 degree and directivity of 5.06241dBi. This fits indoor WLAN and Bluetooth applications which require a wide beamwidth. The measurement has very good agreement with the simulation result in terms of resonant frequency with the variation of 0.002%. The bandwidth variation of the simulation and the measurement is 52.6%, with the prototype having a wider bandwidth. This wide variation is due to the inaccuracy in the simulation meshing when it comes to very small structure like the SMA probe. The simulation and the measurement results are shown in Figure 3 and Figure 4.

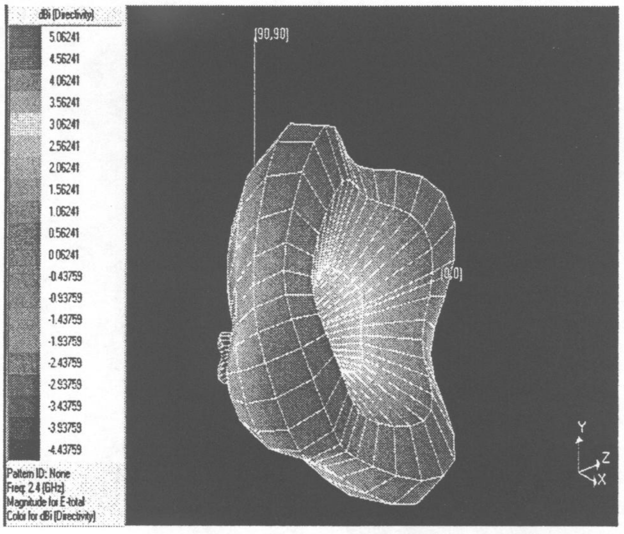

Figure 3: Radiation pattern.

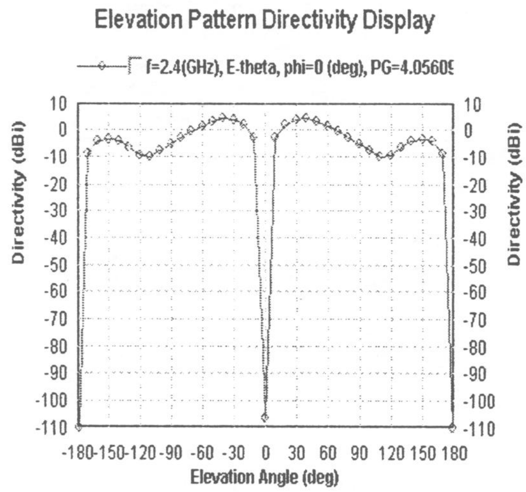

Figure 4: Beamwidth of more than 100 degree.

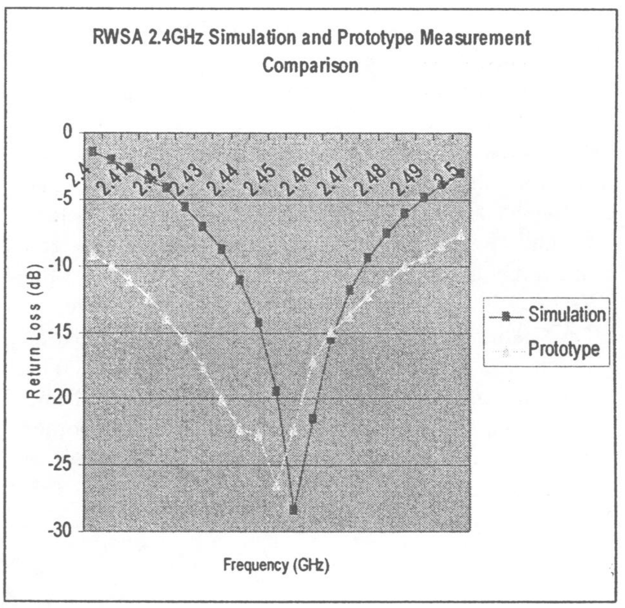

Figure 5: Return loss simulation and measurement comparison.

The Received Signal Strength Index (RSSI) measurement was carried out on the RWSA 2.4GHz antenna prototype to check for its performance in the indoor WLAN with -100dBm as the noise bed. The RSSI of the RWSA antenna covers the whole WLAN operating channel range from channel 1 to channel 11. This result revealed that the antenna can be applied for the IEEE 801.11b/g and Bluetooth applications. The result is compared to the monopole antenna operating at the same frequency measuring at the same distance shown in Figure 6. Overall, RWSA antenna shows a better RSSI compare to monopole antenna.

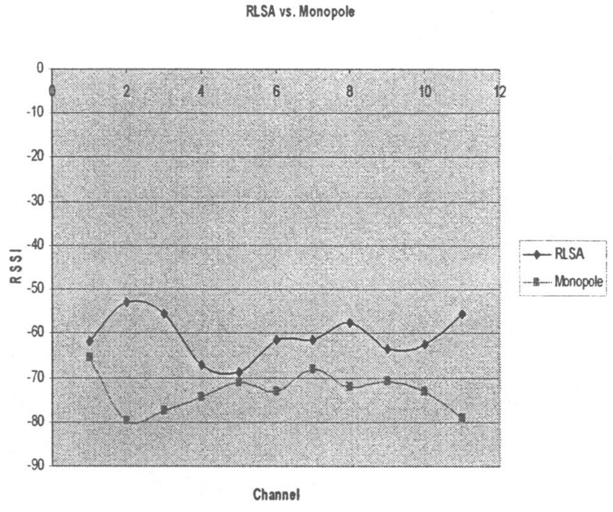

Figure 6: RSSI comparison for RLSA and monopole.

4. Conclusion

This paper has proposed the Linear Polarized RWSA antenna as access point antenna for 2.4GHz based on IEEE 802.11b/g and Bluetooth applications. FDTD electromagnetic full-wave simulator, Zeland 3.0 has been used to analysis the operations of the design based on theoretical parameter investigation. The antenna has been fabricated and tested for its return loss and RSSI performance. The simulation and measurements shows good result agreement. From the RSSI result, RWSA 2.4GHz covers the range of WLAN and Bluetooth and it shows a better RSSI performance than the monopole antenna. The advantages of the RWSA 2.4 GHz antenna itself and its performance enable it to be considered as another alternative for the monopole antenna.

References

[1] Kelly K. C., "Recent Annular Slot Array Experiments," in *IRE International Convention Record*, vol. 5, March 1957, pp. 144 – 152.

[2] Kechagias, K.; Vafiadis, E.; Sahalos, J.N., "On the RLSA Antenna Optimum Design for DBS Reception," in *IEEE Transactions on Broadcasting*, vol. 44, issue 4, Dec. 1998, pp. 460 – 469.

[3] Davis, P.W.; Bialkowski, M.E., "Experimental Investigations into a Linearly Polarized Radial Slot Antenna for DBS TV in Australia," in *IEEE Transactions on Antennas and Propagation*, vol. 45, issue 7 , July 1997, pp. 1123 – 1129.

[4] Ando, M.; Sakurai, K.; Goto, N., "Characteristics of a radial line slot antenna for 12 GHz band satellite TV reception," in *IEEE Transactions on Antennas and Propagation*, vol. 34, issue 10, Oct 1986, pp. 1269 – 1272.

[5] Farah Ayu I.K, Tharek, A.R, "Theoretical Investigations of Linearly Polarized Radial Line Slot Array (RLSA) Antenna for Wireless LAN Indoor Application at 5.5 GHz," *in 11th Mediterranean Electrotechnical Conference, MELECON 2002*, 7-9 May 2002, pp. 364 – 367.

[6] J.Hirokawa, M. Ando, N. Goto, "An Analysis of Slot Radiation on a Parallel Plate Waveguide for a Radial Line Slot Antenna," *in IEEE Trans. On Antenna and Propagation*, San Jose, CA., June 1989, pp. 1452-1455.

[7] M. Takahashi, J. Takada, M. Ando, N. Goto, "Characteristics of Small Aperture, Single-layered Radial Line Slot Antennas," *in IEEE Trans. On Antenna and Propagation*, vol. 139, no. 1, Feb 1992.