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DESIGN OF A POLARIZATION DIVERSITY BI-DIRECIONAL ANTENNA USING TWO-PROBE EXCITED CIRCULAR RING FOR 5 GHZ WLAN

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1. Introduction

In the indoor propagation channel which transmitter and receiver are surrounded by the various objects, the multipath signal can be received at the receiving antenna and the receiver. One possible way to mitigate multipath fading is to implement a diversity combining technique [1]. The horizontal space diversity is traditionally used to reduce the fading problems at the base station. In recent years, the polarization diversity is one of the most promising techniques to reduce multipath with compact antenna configuration requiring only one antenna location [2]. In cases where the radio unit will be applied in the long and narrow areas, such as in the corridor or long rows of objects, a uni- or bi-directional antenna may provide better coverage area than a conventional omni-directional antenna. There are a number of research works dealing with uni- and bi-directional antenna proposed for polarization diversity [3]. Nevertheless, the dual polarization can be achieved at the expense of complicated configuration with an expensive material. In this paper, to mitigate effectively the multipath influence to the indoor communications, we proposed the simple and cost-effective polarization diversity with bi-directional antenna using a circular ring with two probes. Since the antenna is used under the multipath environment, the radiation patterns have no direct meaning of the antenna performance [4]. Then, the diversity characteristics of the antenna are necessarily investigated. In this paper, the critical issues in the design for 5 GHz are determined, and both simulated and experimental results are presented.

2. Antenna Configuration and Design

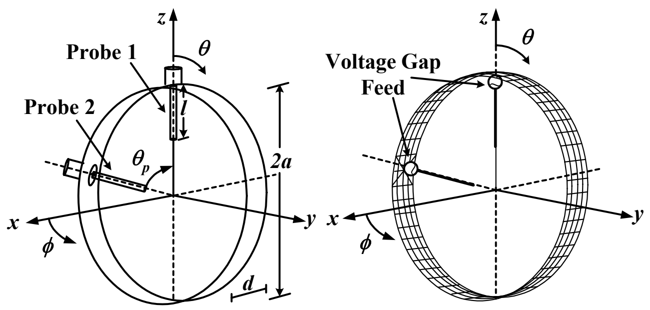

Fig.1 Configuration of the antenna (a) real model (b) wire-grid model

Figure 1(a) shows the structure of the presented polarization diversity bi-directional antenna [5]. The antenna consists of a circular ring of the radius a excited by two linear electric probes of the same length l which the angle between two-probe is θ_p. The ring width is equal to d with two circular apertures in $x = d/2$ and $x = -d/2$ planes. The probe 1 will be active while probe 2 is terminated with 50 Ω load resulting in vertical polarization, and vice versa resulting in horizontal polarization. The direction of beams of the antenna are along +x-axis and -x-axis for both polarizations. The optimization for design is carried out through the simulations using the Numerical Electromagnetics Code 2 [6] based on Method of Moment (MoM) by changing the dimension of radius a, width of ring d and length of probe l. The conductivity of the wire-grid antenna structure is 2.56×10^7 S/m as Brass. The selection of the wire radius is based on the equivalent surface area assumption [7]. The wires are divided into small segments about 0.01λ to 0.03λ in length that is efficiently small to achieve reliable impedance characteristics as well as radiation patterns [6]. The excitation at probes is modeled by delta-gap voltage source between the probe base and the ring strip. At each probe base, two diagonal wires are added to support the high current density from the excitation as shown in Fig. 1(b). The design resonant frequency is chosen as 5.25 GHz for wireless LAN. The variation in gain and return loss (S_{11}) with *a* and *d* are plotted in Fig. 2(a) and (b), respectively. In this case, the probe length is fixed and θ_p is 90°. The gain of branch 1 and 2 at $\phi = 0^\circ$ and 180° is considered. The antenna that has the highest gain with $S_{11} \leq -14$ dB (SWR $\leq$ 1.5:1) is selected. As a result, the optimum parameters were finally selected as $a = 0.32\lambda$ (1.83 cm), $d = 0.27\lambda$ (1.54 cm) and $l = 0.23\lambda$ (1.31 cm). The isolation (S_{21}) can be considered in term of θ_p. The maximum S_{21} (14.32 dB) is obtained when the angle between two probes is 120° with sacrificed gain and S_{11} as shown in Fig 3.

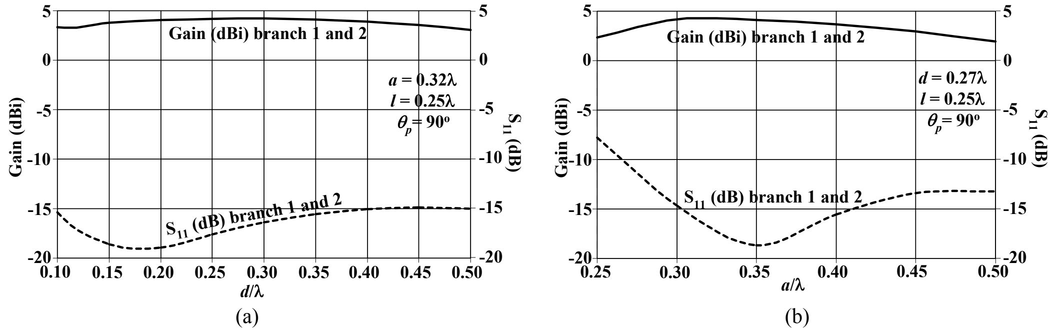

Fig. 2 Gain and S_{11} of the antenna (a) *d* is varied (b) *a* is varied

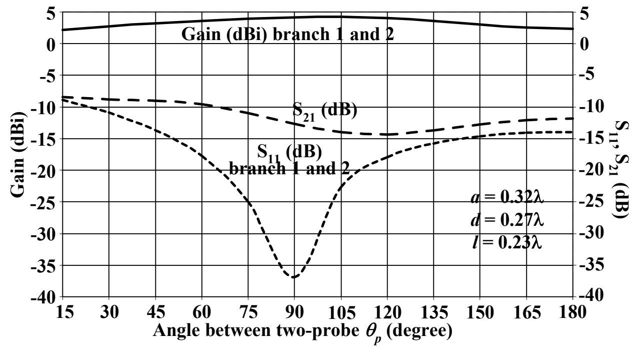

Fig.3 Gain, S_{11} and S_{21} of the antenna as function of angle between two probes

The variation of the angle between two-probe not only influences to the gain, S_{11} and S_{21} but also to the diversity performance of the antenna as shown in Fig. 4(a) – (d). In Fig. 4(a), The Mean Effective Gain (MEG) that can be expressed in [4] of the antenna in the indoor picocell angular power density function which the portion of line-of-sight is significant on the order of 40 % follow the measurement performed by Kalliola [8] is illustrated. The maximum MEG of branch 1 (G_{e1}) is 0.17 dBi when the angle between two probes is 105° while the minimum G_{e1} is -7.95 dBi when the angle between two probes is 180°. The maximum MEG of branch 2 (G_{e2}) is -5.45 dBi when the angle between two probes is 60° while the minimum G_{e2} is -7.95 dBi when the angle between two probes is 180°. The G_{e2} are changed over narrow interval of -5 to -7 dBi because the position of branch 2 is fixed while the position of branch 1 is altered in the simulation. This condition causes the various results of G_{e1} (removable probe) while the results of G_{e2} are almost uniform (fixed probe). The envelope correlation coefficient (ρ_e) [9] result is changed as shown in Fig. 4(b). The maximum result is 0.53 when the angle between two probes is 45°. The minimum result is 0.03 when the angle between two probes is 135°. The ρ_e are lower than 0.7 for any angles between two probes which the uncorrelated signal between two branches is obtained [10]. In Fig. 4(c) the diversity gain (G_{div}) [11] of the antenna for Binary Phase Shift Keying (BPSK) modulation on Maximum Ratio Combining (MRC) technique [12] is shown. The maximum result is 8.72 dB when the angle between two probes is 180° because the ratio of the MEG for each branch (*r*) is equal to 1. The minimum G_{div} of the antenna is 6.1 dB when the angle between two probes is 60° and 75°. The G_{div} result is not a sufficient parameter for determining the performance of the antenna. Then we use these G_{div} to calculate the effective parameter i.e., Diversity Antenna Gain (DAG) [11]. The maximum DAG is 6.61 dB when the angle between two probes is 120°. Furthermore from the above result, when the angle between two probes is 120°, the antenna yields the best isolation. The minimum DAG is 0.77 dB when the angle between two probes is 180°. Although the antenna that has the angle of 180° between two probes provides the maximum G_{div}, its DAG is the lowest result. When the angle between two probes is 90°, the DAG of the antenna is 6.15 dB which is 0.46 dB lower than the highest DAG.

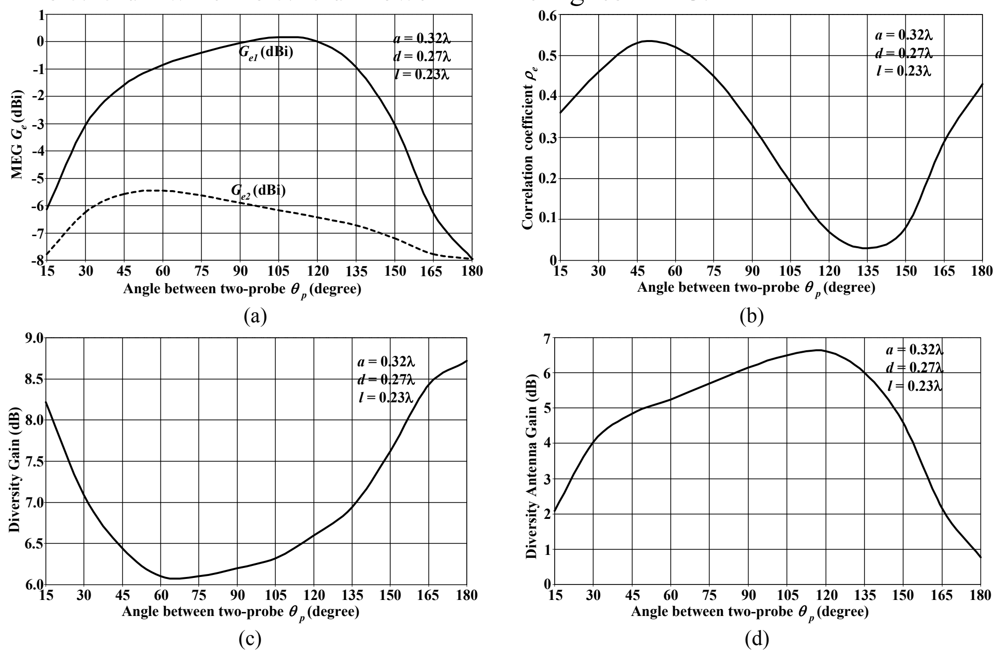

Fig. 4 Diversity performance of the antenna as function of angle between two probes (a) MEG (b) ρ_e (c) G_{div} (d) DAG

3. Simulation and Experimental Results

The prototype antenna is fabricated for validation. In Fig. 5, the simulation and experimental S_{11} and S_{21} of the antenna that has the angle of 120° between two probes are illustrated. The measured S_{11} of branch 1 and 2 at the design frequency is around -19 dB while S_{21} is approximately -13 dB. The -14 dB S_{11} bandwidth is 400 MHz (7.6%) at the center frequency of 5.25 GHz. The discrepancy which may be due to the error of fabrication can be found. The error of the fabrication can be avoided by using a superior process. The difference of the measured and the simulated S_{21} results is about 1 dB, however the graph is in the same trend. The S_{21} results are not high because the antenna has two probes in the same ring. Fig. 6 shows the *xy*-plane radiation pattern at 5.25 GHz when the angle between two probes is 120°. The result shows the bi-directional pattern of the experimental and simulation G_θ (vertical polarization), and G_ϕ (horizontal polarization) in *x*-direction for each branch of the antenna. When branch 1 is used, the major component is G_θ and vice versa when branch 2 is used. The radiation patterns are measured by using a linearly polarized monopole antenna in an anechoic chamber. The good agreement is found between simulated and measured results. The gain of branch 1 and 2 at $\phi = 0°$ and 180° are approximately 4 dBi for both the simulated and measured results.

4. Conclusion

This paper presents the design of a polarization diversity bi-directional antenna using two-probe excited circular ring. Both simulated and measured results are mentioned. The gain and return loss of the antenna are investigated when the radius (*a*) and the width (*d*) of the circular ring are varied. The dimension of $a = 0.32\lambda$ (1.83 cm), $d = 0.27\lambda$ (1.54 cm) and $l = 0.23\lambda$ (1.31 cm) gives the maximum gain with return loss ≤ -14 dB. The isolation of the antenna can be improved by changing the angle between two probes. The maximum isolation and DAG is obtained when the antenna has the angle of

120° between two probes. The antenna possesses a gain of 4 dBi with the 400 MHz bandwidth at the center frequency of 5.25 GHz. The simulated and measured radiation patterns of each branch are bi-directional pattern that are suitable for the long and narrow service area. The results of simulation and experiment almost agree with each other.

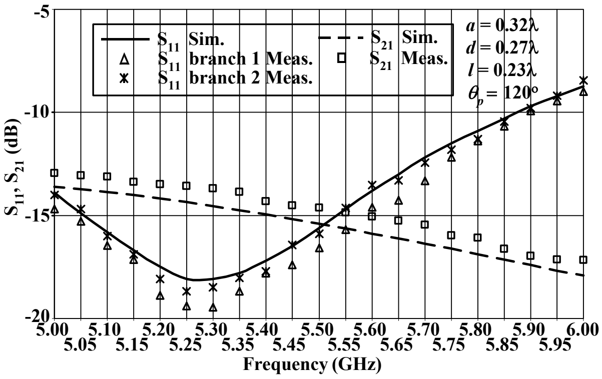

Fig. 5 S_{11} and S_{21} of the antenna that has the angle of 120° between two probes

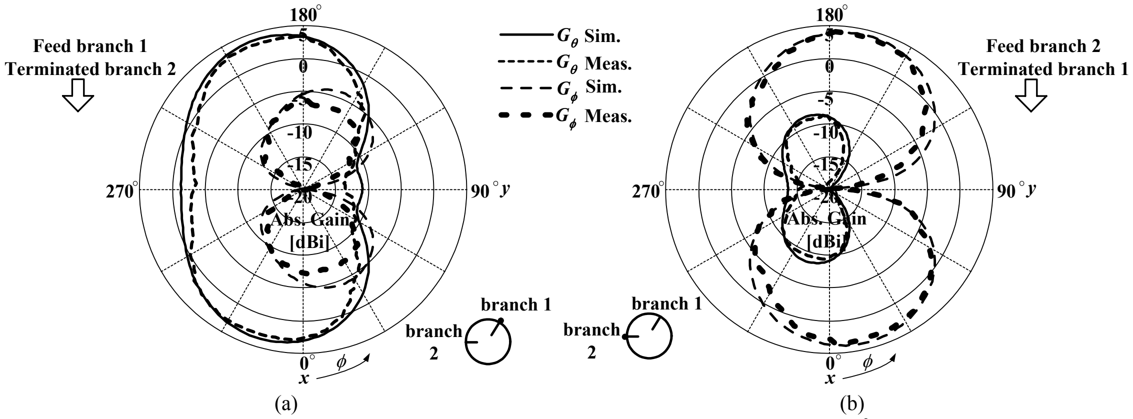

Fig. 6 The *xy*-plane radiation pattern of the antenna that has the angle of 120° (a) branch 1 is active and branch 2 is terminated (b) branch 2 is active and branch 1 is terminated

5. Acknowledgement

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References

[1] K. Fujimoto and J.R. James, Mobile Antenna Systems Handbook, ch.2, Artech House, Norwood, MA, 1994.

[2] R.G. Vaughan, "Polarization diversity in mobile communications," IEEE Trans. Veh. Technol., vol.39, no.3, pp.177–186, Aug. 1990.

[3] S.H. Hong, Y.S. Lee, M.S. Choi and Y.J. Yoon, "Polarization diversity with directional antennas for indoor environments," Proc. 1999 Asia Pacific Microwave Conf., vol.3, pp. 785–788, 1999.

[4] T. Taga, "Analysis for mean effective gain of mobile antennas in land mobile radio environments," IEEE Trans. Veh. Technol. vol. 39, no. 2, pp.117–131, May 1990.

[5] P. Keowsawat, A Bi-directional Antenna Using Two-perpendicular-probe Excited Ring for Polarization Diversity, Master Thesis (in Thai), Faculty of Engineering, King Mongkut's Institute of Technology Ladkrabang, Thailand, 2001.

[6] G.J. Burke and A.J. Poggio, Numerical Electromagnetics Code (NEC) –Method of Moments, Parts I–III, Lawrence Livermore Nat. Lab., Livermore, CA, 1981.

[7] E.K. Miller, "PCs for AP and other EM reflections: Wire-grid approximations to solid surfaces," IEEE Antennas and Propagat. Mag., vol.39, no.1, pp.94–97, Feb. 1997.

[8] K. Kalliola, K. Sulonen, H. Laitinen., O. Kivekas, J. Krogerus and P. Vainikainen, "Angular power distribution and mean effective gain of mobile antenna in different propagation environments," IEEE Trans. Veh. Technol., vol.51, no.5, pp.823–838, Sept. 2002.

[9] R.H. Clarke, "A statistical theory of mobile-radio reception," Bell System Technical J., vol.47, no.6, pp.957–1000, July–Aug. 1968.

[10] W. C. Y. Lee, Mobile Communications Engineering. 2nd ed., McGraw-Hill, Singapore, 1998.

[11] K. Ogawa and J. Takada, "An analysis of the effective performance of a handset diversity antenna influenced by head, hand and shoulder effects–A proposal for the diversity antenna gain based on a signal bit-error rate and the analytical results for the PDC system," IEICE Trans. Commun., vol.J83-B, no.6, pp.852–865, June 2000.

[12] K. Ogawa and J. Takada, "An analysis of the diversity antenna gain of a handset diversity antenna close to the human operator," Proc. 2000 Int. Symp. on Antennas and Propagat., pp. 1059–21062, Fukuoka, Japan, Aug. 2000.