

A Compact Rx Antenna System for 3D Direction Finding Passive Radar

Hojoo Lee ¹, Dae Woong Woo ² and Jaehoon Choi ¹

Department of Electronics and Computer Engineering, Hanyang University ¹

Agency for Defense Development ²

Seoul ¹, Daejeon ², Republic of Korea

hojoo_1@naver.com, woodw@add.re.kr, choijh@hanyang.ac.kr (corresponding author)

Abstract— A compact receiving (Rx) antenna system for 3D direction finding passive radar is proposed. The proposed antenna system consists of two Yagi antennas and two waveguide slot antennas. The antennas are mounted on four sides of a parallelepiped plastic module while same type of antennas are facing each other on the opposite side of the module. The antenna is designed for direction finding radar Rx system as an Rx terminal on an aviating object with separate Tx base station on the ground. The proposed antenna system demonstrates the maximum return loss of 9.6dB (VSWR=2:1) ranging from 9.7 to 10.2 GHz in X band and has suitable radiation patterns for direction finding system. In addition, the proposed antenna system has a compact dimension and light gross weight of 37 mm × 46 mm × 50 mm and 97g which are satisfying features to be applied for avionic system.

Keywords— radar, direction-finding, waveguide slot antenna, Yagi antenna

I. INTRODUCTION

With the rapid development of various direction finding system applications such as vehicle automation and guidance, interest in the antenna design for guidance and control system has been increased explosively over the last few years. To meet the required performance of the antennas mounted on the moving object for direction finding, various studies have been conducted. In order to reduce the power consumption of the system, the antennas mounted on the moving objects usually operates as passive Rx only, with additional Tx base station on the ground for transmitting initial pulse [1]. After processing and computing the voltage values of the received multi-channel signals from the target, the direction of incoming signal can be found by analyzing the differential amplitude of voltage measured from each Rx channel. For such scheme, multi-channel Rx antenna system are generally used in the industrial field. In addition, the antenna system has to be compact and light-weighted in order to be applied for such applications.

II. ANTENNA DESIGN AND RESULTS

Since Tx antenna on the ground base station system usually has sharp beam with linear polarization [2] (e.g. dipole or patch array), linearly-polarized planes of antennas must coincide with each other in order to receive the reflected signal from the target transmitted by Tx antenna. One way to obtain such property is to use four identical antennas such as dipole antenna on each side of the platform as shown in Fig. 1. However, such configuration requires significantly large amount of space for antennas. Therefore, we propose the system consisting of two Yagi antennas and two waveguide slot antennas with much smaller space occupation. The proposed antenna system consists

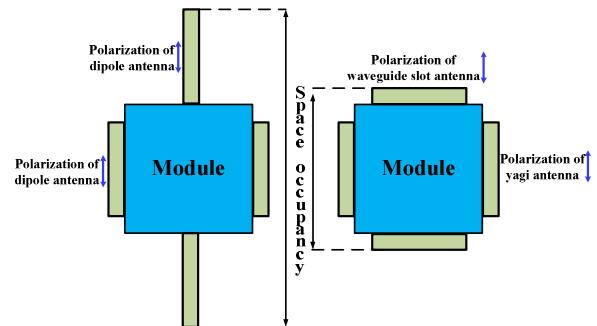


Fig. 1. Comparison of space occupancy between two types of antenna system.

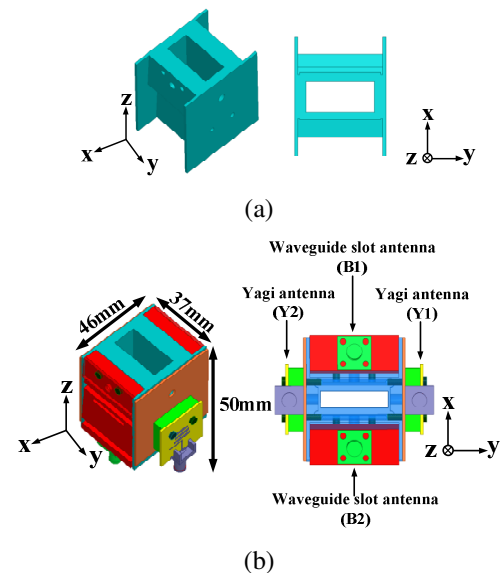


Fig. 2. Configuration of the proposed antenna system. (a) empty plastic module without mounted antennas (b) four antennas mounted

of two Yagi antennas (Y1 and Y2) and two waveguide slot antennas (B1 and B2) mounted on each side of the plastic module as can be seen from Fig. 2. By adapting such configuration, the linearly polarized planes of four antenna become identical (i.e. coincides within xz-plane) due to the polarization characteristics of two antenna types. Two Yagi antennas mounted on the right and left side of a module have directive radiation pattern in xz plane due to rear reflector and front driver [3]. On the other hand, they exhibit tilted beam from +z to +y direction due to the bottom reflector made of FR4 substrate with full-metal pattern on the upper side of it as shown in Fig. 3 (a). The waveguide slot antennas with three corrugation

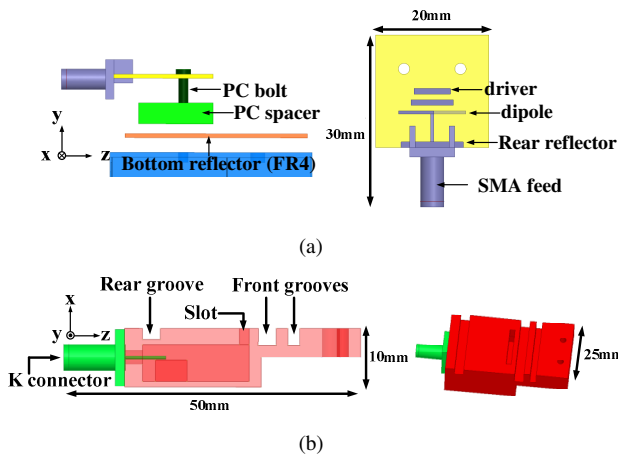


Fig. 3. Structure of the two types of antennas. (a) Yagi antenna (b) Waveguide slot antenna

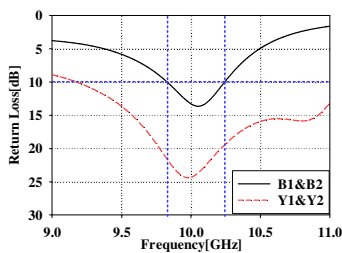


Fig. 4. Simulated return loss of the proposed antenna system.

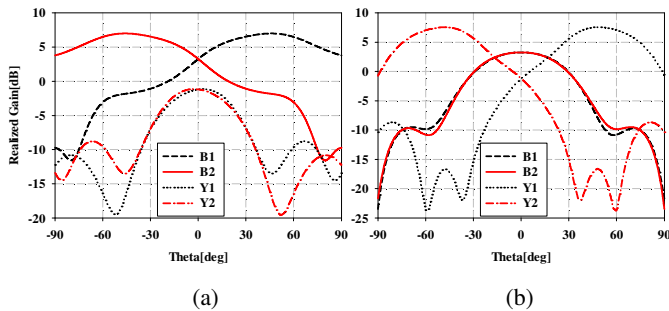


Fig. 5. Simulated radiation patterns of the proposed antenna system at 10GHz. (a) xz-plane (b) yz-plane.

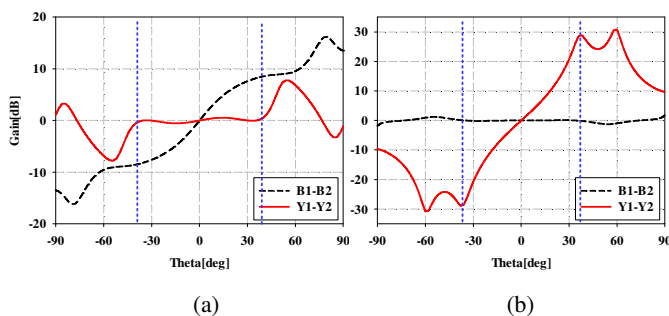


Fig. 6. Gain difference between B1-B2 and Y1-Y2 at 10GHz versus theta (a) xz-plane (b) yz-plane.

grooves are placed on the top and bottom sides of a module as shown in Fig. 3 (b). The corrugation in the rear is to suppress the surface wave towards $-z$ direction and the two corrugations in the front are to induce more surface wave towards $+z$ direction. The former is placed $\lambda/2$ away from the slot and the latter are located close to the slot [4-5]. As a result, the main beam of the

waveguide slot antenna in xz-plane is tilted from $+x$ direction to $+z$ direction while being symmetric in yz-plane. In order to supplement the shortage of beam tilting of the waveguide slot antennas in xz-plane, both are rotated about 3 degrees towards z-axis. In addition, the module for mounting the antennas is made of polycarbonate ($\epsilon_r = 2.8$) since it is economical, easily machinable and light-weighted. The simulated result for the return loss characteristics of the antenna mounted on the module is shown in Fig. 4. All four antennas satisfy maximum return loss level of 9.6dB (i.e. VSWR 2:1) from 9.70 GHz to 10.20 GHz. Fig. 5 illustrates the simulated radiation patterns of the proposed antenna system at 10 GHz in xz- and yz-plane. As can be seen from the figures, the radiation patterns of the B1 and B2 are identical in the yz-plane and symmetric in the xz-plane. On the other hand, the radiation patterns of the Y1 and Y2 are identical in the xz-plane and symmetric in the yz-plane. In addition, the maximum gains of waveguide slot antennas in xz-plane and Yagi antennas in yz-plane are 7.5dBi and 8.1dBi, respectively. The plots in Fig. 6 indicate the gain difference between the antennas with identical types in xz- and yz-plane at 10 GHz. Gradient of the gain difference plots between B1-B2 in xz-plane and Y1-Y2 in yz-plane are steep while those of B1-B2 in yz-plane and Y1-Y2 in xz-plane are relatively flat. Therefore, except for certain range within which such performance becomes deteriorated (e.g. $|\theta| > 40^\circ$ in both xz- and yz-plane), the proposed antenna system has suitable radiation patterns for direction finding.

III. CONCLUSION

A compact and light-weighted Rx antenna system suitable for 3D direction finding passive radar is proposed in this paper. The proposed antenna system exhibits return loss value under 9.6dB in the frequency band ranging from 9.85 to 10.15 GHz. The radiation patterns of the proposed antenna in both yz- and xz- plane is generally suitable for the direction finding system while being very compact and light. Therefore, it can be considered as a good candidate for antenna in a direction finding system of vehicle automation and guidance.

ACKNOWLEDGMENT

This research was supported by the Agency for the Defense Development, Korea.

REFERENCES

- [1] P. Knott, "Design of a Printed Dipole Antenna Array for a Passive Radar System," *International Journal of Antennas and Propagation*, vol. 2013, Article ID 179296, 6 pages, 2013.
- [2] H. Setiadji, F. Zulkifli and E. Rahardjo, "Radiation characteristics of Microstrip Array Antenna for X-Band Radar application," *Progress in Electromagnetic Research Symposium*, pp. 3992-3995, 2016.
- [3] V. Bankey and A. Kumar, "Design of Yagi-uda antenna with gain and bandwidth enhancement for Wifi and Wimax applications," *International Journal of Antennas*, vol.2, no. 1, 2016.
- [4] Y. Jin, H. Lee, D. Woo, J. Choi, "Low-profile Tilted-beam Waveguide Slot Antenna Using Corrugations for UAV Applications," *Microw. Opt. Technol. Lett.*, vol. 60, no.2, pp. 341-347, 2018.
- [5] M. Beruete, I. Campillo, J. Dolado, J. Rodríguez-Seco, E. Perea, F. Falcone and M. Sorolla, "Very Low Profile and Dielectric Loaded Feeder Antenna," *IEEE Antennas Wireless Propag. Lett.*, vol. 6, pp. 544-548, 2007.