A Smart Beam-Switching Multi-Antenna System for UAV

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***Abstract*— A 2.4 GHz five element circularly polarized patch antenna is designed and built for Unmanned Aerial Vehicle (UAV) application. The antenna switches its beam automatically to maximize the received signal power while suppressing the interferences. A received signal power with much less variation over single patch has been achieved using the switching algorithm.**

Keywords—UAV; Beam switching; Multi-antenna; Circular polarization

I. Introduction

Nowadays the use of UAVs has increased incredibly in civil and commercial applications including traffic control, HD camera FPV systems, data relay link [1,2]. Most of these applications require a robust and reliable communication link to transfer data and command between UAV and ground station.

In order to have a 360 degree field of view, omnidirectional antennas are used in current UAVs but it make the communication link vulnerable to interferers and jammers. Furthermore, its low gain makes the link coverage very limited.

To solve this problem, high gain antennas with beam steering techniques such as phased array antennas [3], beam switching [4] and mechanical antenna rotation [5] have been proposed. Beam switching seems to be a better choice for UAVs as it offers lower cost, weight and power consumption compare to other techniques.

In this paper, we used five elements of patch antennas placed on the sides of a pentagon to cover the whole azimuth plane. The antennas switch automatically to find the best receiving direction. With this method, we can preserve omni-directionality in the azimuth plane while having high gain for desired signal and suppression for any interference and jamming from other directions.

II. Multi Element Antenna With Beam Switching

A. Beam switching block diagram

Fig. 1 shows the block diagram of the implemented system. Two nVIP2400-OEM Wi-Fi modules from Microhard were used as transmitter and receiver and a single port five trough switch from Infineon (BGS15AN16) is used to do the switching between the antennas. The receiver Wi-Fi module measures the received signal power and feeds it back to an Arduino controller (Mega 328). The controller controls the RF switch with simple search algorithm to find the antenna element with maximum received signal power.

B. Antenna design and radiation properties

A circular polarized truncated corner patch antenna designed and built to operate from 2.4 to 2.48 GHz, for Wi-Fi 802.11n standard. The 2.4 GHz band of Wi-Fi 802.11 selected due to lower free space path loss and its longer range than 5 GHz but the size of the antenna doubles resulting to higher weight and size. The antenna body made from PC-ABS material and fabricated using 3D print technology. It has very little effect on the electrical performance of the antenna due to shielding effect of the antenna ground.

The dielectric substrate is RO3003 with 120 mils thickness. This thickness selected to increase the 3 dB axial ratio bandwidth of antenna to 70 MHz, which covers most of the 802.11n bandwidth at 2.4 GHz band. The ground size of the patch set to 6cm due to space limitations of UAV for the antenna and mechanical stability constraints.

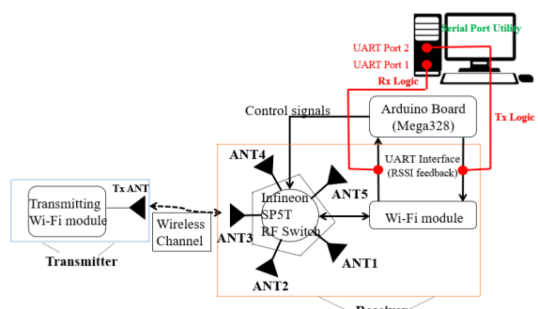
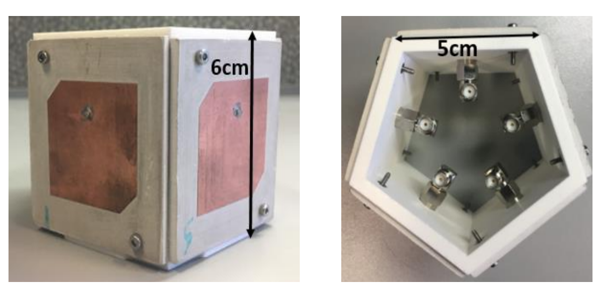


Fig. 1. Block diagram of the implemented smart beam switching antenna



(a) (b)

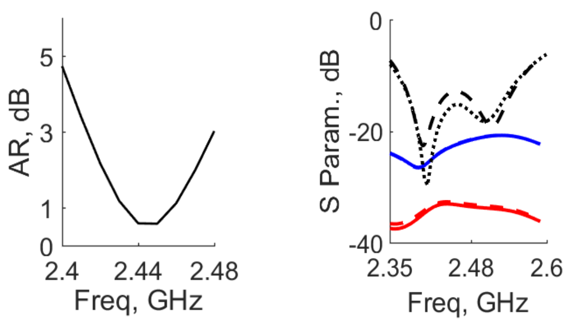
Fig. 2. Front (a) and top (b) view of the five-element antenna.

Fig. 3a and 3b show the simulated axial ratio and scattering parameters of the antenna respectively. The measured S_{11} of the antenna is also shown in Fig. 3b which has a reasonable agreement with simulation. Due to symmetry of the structure, only one of the antenna ports were excited in the measurement setup to find the antenna S_{11}. The adjacent and non-adjacent antenna elements have more than 20 and 35 dB isolation respectively.

Fig. 4 shows the simulated antenna pattern. The maximum and minimum gain are 6.7 and 4.2 dB after applying beam switching.

III. MEASUREMENT RESULTS

The receiver Wi-Fi module measures the received signal power as Received Signal Strength Indicator (RSSI) parameter. A circular polarized patch antenna with 6.7dB gain and a Wi-Fi module with 11dbm output power used as transmitter. The transmitter kept at a fixed distance of 1 meter with maximum direction of radiation kept toward the receiving multi-element antenna. Fig. 5 shows the measurement setup done in anechoic chamber and Fig. 6 shows the RSSI level versus the incidence angle of transmitter antenna. A received power with much less variation was achieved using the beam switching technique as shown in Fig. 6. The received signal expected to be -16.6dBm which is close to the measured -18dBm at the maximum gain direction. The small discrepancy is due to the cable and connector loss and errors in measuring RSSI level.



(a) (b)

Fig. 3. (a) Simulated axial ratio, (b) Measured S_{11}(black dotted line), and simulated scattering parameters of the 5 element antenna

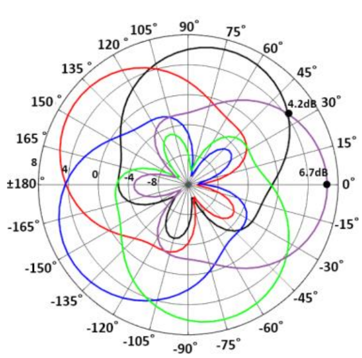


Fig. 4. Simulated antenna gain pattern for each beam direction

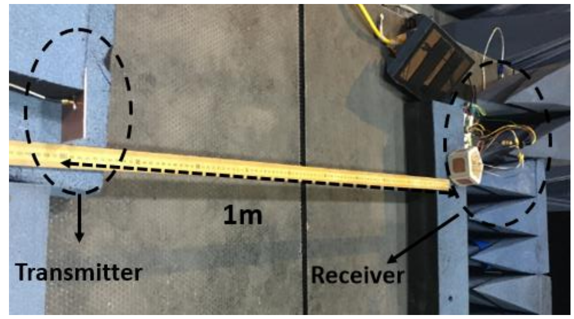


Fig. 5. Test setup for RSSI measurement of multi-element antenna

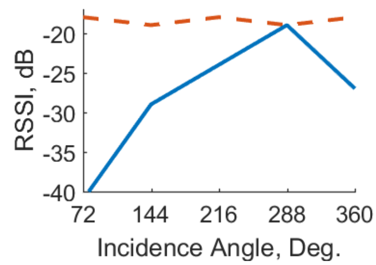


Fig. 6. Measured received signal power (RSSI) with(red dashed curve) and without(blue solid curve) beam switching.

IV. CONCLUSION

A high gain switched beam five-element antenna system presented for UAV application. The antenna switches the beam automatically to maximize the received signal power. A received power with much less variation achieved using this technique. The simulation and experimental results show the clear advantage of high gain antenna with beam switching over single omni-directional antennas.

ACKNOWLEDGMENT

The authors would like to thank SOC(System on Chip Technologies) and OCE(Ontario Centre of Excellence) for providing funding and support of this project.

REFERENCES

[1] US Department of Transportation, “Unmanned aircraft system (UAS) service demand 2015–2035: Literature review & projections of future usage,” Tech. Rep., v.0.1, DOT-VNTSC-DoD-13-01, Sep. 2013.

[2] Z. Xiao, P. Xia and X. g. Xia, "Enabling UAV cellular with millimeter-wave communication: potentials and approaches," in IEEE Communications Magazine, vol. 54, no. 5, pp. 66-73, May 2016.

[3] J. M. Inclan Alonso, M. Sierra Perez, “Phased Array for UAV Communications at 5.5 GHz”, IEEE Antennas and Wireless Propagation Letters, vol. 14, pp. 771 - 774, Dec. 2014.

[4] M. S. Sharawi, S. Deif and A. Shamim, "An Electronically Controlled 8-Element Switched Beam Planar Array," in IEEE Antennas and Wireless Propagation Letters, vol. 14, no. , pp. 1350-1353, 2015.

[5] A. A. Tolkachev, V. V. Denisenko, A. V. Shishlov and A. G. Shubov, "High gain antenna systems for millimeter wave radars with combined electronical and mechanical beam steering," Proceedings of International Symposium on Phased Array Systems and Technology, Boston, MA, 1996, pp. 266-271