

Antenna Array Design for Directional Networking

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Abstract—In this paper, a dual-polarized long slot array antenna is developed for directional networking. The dual-polarization is achieved with 2-D slot array. Additional layer of resistively terminated elements are added to the edge of the antenna to minimize the edge effect. The antenna operating frequency is 2-6 GHz with 70° beamwidth and 6-10 dB gain.

I. INTRODUCTION

Nowadays, omni-directional antennas are used in vast majority of the mobile networks, especially ad-hoc networks, due to their simplicity. While the omni-directional antenna simplifies the infrastructure of the network, it also limits the capability of the network. In contrast to omni-directional antenna, directional antennas would provide advantages such as range, capacity, security and power efficiency [1]. Previously, a cylindrical long slot array (CLSA) with dual polarization property had been developed by our group [2, 3]. It also had been shown that the CLSA has the capability of beam forming [4]. Thus an antenna array based on the long slot array concept is proposed to cover the frequency range of 2-6 GHz for directional networking.

II. ANTENNA DESIGN AND SIMULATION SETUP

Fig. 1 shows the geometry of the proposed dual-pol long slot array antenna. The antenna consists of a spherical 2D slot array, spherical PEC ground plane on top of a circular PEC ground plane. The distance between the slot array and the spherical PEC ground is a quarter wavelengths at the center frequency of the 2-6 GHz band. The radius of the slot array and the spherical ground are 50 mm and 38 mm respectively, which was suggested as an initial size for a prototype. The high of the antenna is 34 mm. The dimension of patch size, w_1 , w_2 and slot width, w_3 determine the impedance of the slot. The slot width is determined to be 3.5 mm, while the patch size is slightly different in each patch varying from 10 mm to 12 mm, due to the spherical shape. The slot dimension resulted in a slot impedance of 180 ohm and hence an impedance transformer design will be needed to feed the 180 ohm slot using conventional 50 ohm coaxial line. For simulation study, however, lumped ports with impedance of 180 ohm are used to feed the slot. For limited number of feeding, the number of slots is chosen to be four by three, which result in a total of thirty one feeding ports. To minimize the edge effect, additional layer of elements terminated with 180 ohm resistors are placed around the active region [5]. Since the long slot array is a type of connected array, mutual coupling can be high in between the adjacent ports. It is therefore important to study the overall return loss (ORL) parameter that represents the overall impedance matching of the antenna, in addition to achieving reasonable S11 value in each port. The ORL parameter is defined as:

$$ORL = 10 \log_{10} \left(\frac{\text{Incident power} - \text{Accepted power}}{\text{Incident power}} \right) \quad (1)$$

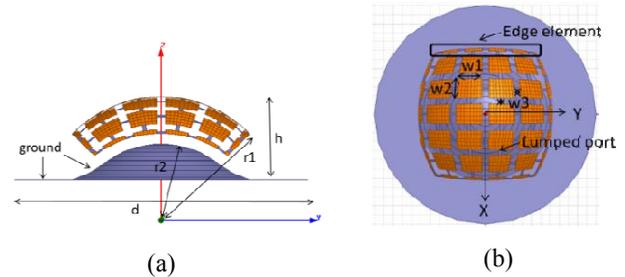


Fig. 1. (a) Antenna side view, $r_1 = 50$ mm, $r_2 = 38$ mm, $h = 34$ mm, $d = 120$ mm. (b) Antenna top view, $w_1 = 12$ mm, $w_2 = 10$ mm, $w_3 = 3.5$ mm.

III. SIMULATION RESULT

Since the number of slots are different in the x and y direction, the performance of the antenna in the x and y polarizations are investigated separately. Fig. 2 illustrates the S11 of each feeding port in smith chart. As shown in Fig. 2a, due to edge effect, the S11 of each port are not quite the same in the case of no resistively terminated elements on the antenna. The S11 curves on the 0.5 ohm circle of the smith chart represent the feeding ports on the edge of the active region. In contrast, the S11 of the feeding ports are similar and tend to focus on the center of the smith chart while resistively terminated elements added to the antenna as shown in Fig. 2b. Thus resistively terminated elements improve the impedance matching of the feeding ports on the edge of the active region and through simulation it is shown that the resistively terminated elements do not have much effect on the ORL of the antenna. Slight improvement of the ORL at lower frequency due to the additional terminated elements is indicated in Fig. 3a. Fig. 3 also shows the ORL and the peak realized gain of the antenna in different polarization modes. The ORL is below -7 dB from 2 to 6 GHz in all of the polarization modes. The peak realized gain is vary from 6 to 8 dB in the frequency range of 2 to 5 GHz, while in 6 GHz the peak realized gain reach 10 dB. Due to limited space, Fig. 4 only shows the radiation pattern of the antenna in x polarization modes. The 3-dB beamwidth of the antenna is about 70° throughout the operating frequencies. In Fig. 4, the cross polarization gain is shown to be below -30 dB. However, the peak cross polarization gain of the x and y polarization modes are not in the angle of $\phi = 0^\circ$ and $\phi = 90^\circ$. The peak cross polarization gain is about -9 dB. Thus there is 17 dB isolation between the x and y polarization modes. In the circular polarization mode the peak cross polarization gain

is at $\phi = 0^\circ$ and $\phi = 90^\circ$, the cross polarization isolation is about -13 dB at the direction of the broadside.

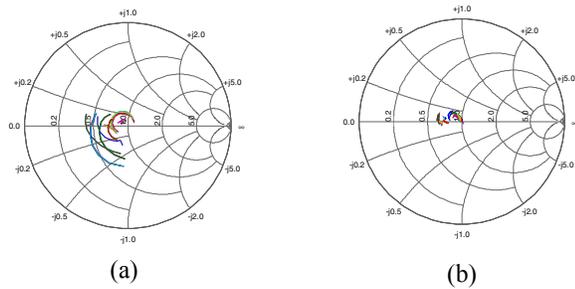


Fig. 2. (a) S11 of each feeding port in smith chart: (a) antenna without resistively terminated edge elements, (b) antenna with resistively terminated edge element.

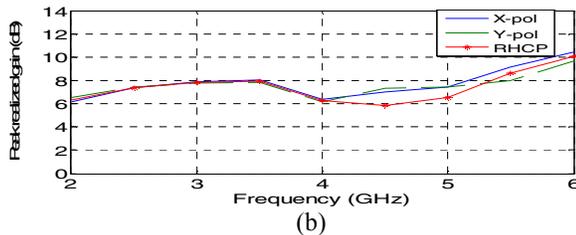
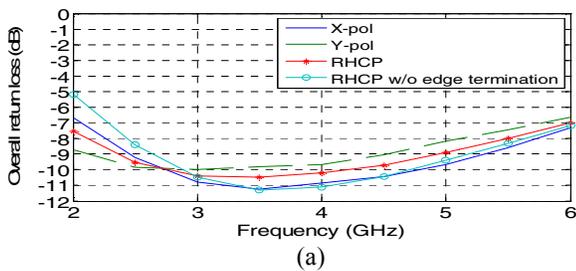


Fig. 3. Simulation result in different excitation mode: (a) Overall return loss, (b) Peak realized gain

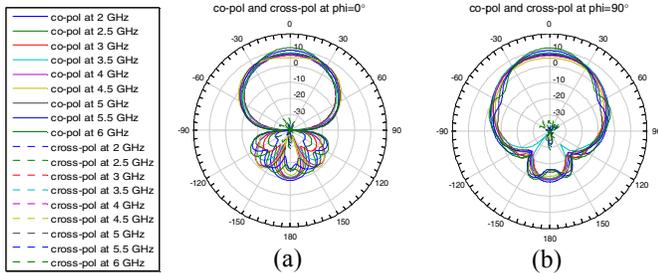


Fig. 4. Co-pol and Cross-pol radiation pattern of the antenna in x-pol: (a) at $\phi = 0^\circ$, (b) at $\phi = 90^\circ$.

IV. FABRICATION AND MEASUREMENT

The designed antenna is fabricated as shown in Fig 5a. The spherical shape of the antenna is fabricated using 3D printer, which is hollow with the thickness of 1mm. The 50-ohm to 180-ohm impedance transformer [6] is designed and placed on top of the antenna. The 180-ohm ports of the transformers are used to feed the antenna while the 50-ohm ports are connected to the coaxial cable. A brief measurement of the antenna gain is done with a horn

antenna. As the TX antenna is 2 m away from the fabricated antenna, the fabricated antenna receives signal power at about -42 dBm in both x-pol and y-pol modes at 5.1 GHz as shown in Fig. 5a, 5b. In compare to a 12 dB horn antenna which the received signal power is -33 dBm, the measured antenna gain conform with the simulation result after accounting 4 dB loss on the power splitter and cable.

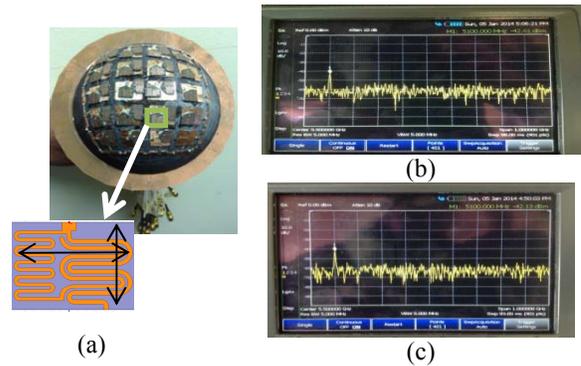


Fig. 5. (a) Fabricated antenna. (b) Field measurement in x-pol. (c) Field measurement in y-pol.

V. CONCLUSION

A new 2-6 GHz dual polarization antenna array is developed, simulated, prototyped and measured. The design is based on the broadband long slot antenna technology, and the prototyping was developed using 3D printing facilities. S11, radiation pattern and gain were measured and in all cases measured data confirmed simulation results. Specifically, measurements confirmed adequate impedance matching performance while the gain measurements agreed with the simulation data after accounting for the cable losses. New antenna array implementations to address the beamwidth and beam steering requirements in advanced directional Networking applications are underway.

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