Pattern reconfigurable techniques for LP and CP antennas with the broadside and conical beams

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***Abstract*—This paper presents two pattern reconfigurable techniques to realize the LP and CP broadside and conical-beam switchable radiation patterns. First, a wideband monopolar patch and a L-probe fed patch were organically integrated together to achieve the wideband reconfigurable broadside and conical-beam pattern with the linearly-polarized (LP) radiation. Radiation coverage and wireless channel capacity were largely improved which makes the reported antenna a good candidate as the ceiling mounted antenna for indoor wireless communications. Beside of the LP antenna, circularly-polarized (CP) broadside and conical-beam reconfigurable antenna is preferred for satellite communications. To realize this, we successfully excited both TM_{11} and TM_{21} modes on a circular patch with an annular slot. A reconfigurable feeding network was designed to provide the correct excitations for the two modes. The annular slot on the patch facilitates to shift the resonant frequency of the fundamental TM_{11} mode up close to the frequency of the TM_{21} mode. As the results, the CP switchable broadside and conical-beam radiations were realized within the same frequency overlap. Both LP and CP antennas with the switchable broadside and conical-beam patterns were fabricated and tested. Experimental results show good agreement with simulation. Decent radiation performance were observed.**

Keywords—Pattern reconfigurable antenna, TM_{11} and TM_{21} modes, circular patch antenna, L-probe, wideband monopolar patch, broadside pattern, conical-beam pattern.

I. INTRODUCTION

Reconfigurable antennas become more and more popular along with the rapid development of modern wireless communication systems due to their unique electrical characteristics. Frequency reconfigurable can tune their operating frequency electronically to cover the desired frequency band as in [1] – [2]. Polarization reconfigurable antennas can alter their polarizations but maintain all other radiation characteristics as shown in [3] – [7]. In addition, pattern reconfigurable antennas are able to change their radiation patterns among different modes as in [8] – [10]. In this paper, we will focus on the designs of the broadside and conical-beam pattern reconfigurable antennas. Antennas with such distinctive patterns can enhance the radiation coverage and the system capacity. In particular, the LP broadside and conical-beam reconfigurable antenna is suitable to be mounted on the ceiling of a large hall or stadium for indoor WLAN wireless communications. The CP version is preferred in geostationary satellite applications where the CP broadside or conical beams are individually desired for the specific regions on the earth. We will introduce two techniques to realize the above LP and CP antennas with broadside and conical-beam pattern reconfigurability in the following sections.

II. LINEARLY-POLARIZED BROADSIDE AND CONICAL BEAM RECONFIGURABLE ANTENNA DESIGN

Many antenna designs of the LP broadside and conical beam reconfigurable antennas have been reported in [11] – [13]. However, their bandwidth and radiation performances are not satisfactory (the maximum is 9%). To realize the wide bandwidth and decent switchable radiation patterns, we organically integrated a wideband monopolar patch and a L-probe fed circular patch radiators together into a compact entity as shown in Fig. 1 [14]. The monopolar patch with seventeen shorting vias is located on the bottom. The radiating monopolar patch acts as the ground for the upper L-probe fed circular patch. The coaxial cable to feed the upper patch goes through one shorting via instead of penetrating though the cavity of the monopolar patch. This is to avoid the interference to the radiating mode of the monopolar patch. The radiation pattern will become asymmetrical if the cavity mode is disturbed. To control the pattern modes, a simple

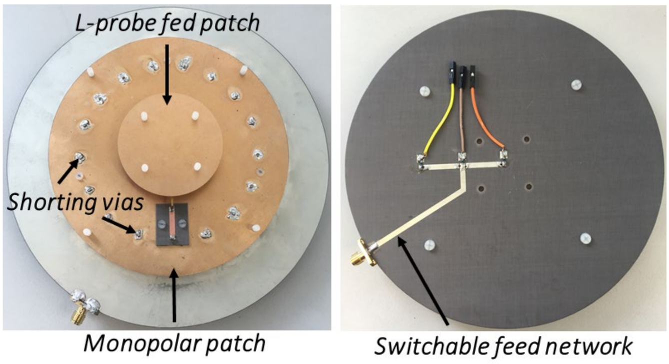

Fig. 1 Prototype of the LP wideband broadside and conical-beam reconfigurable antenna.

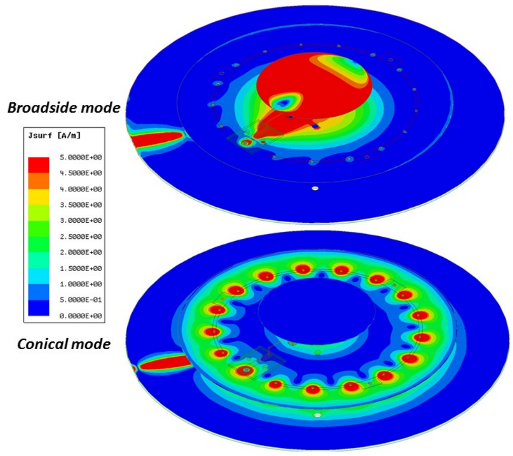

Fig. 2 Current distributions on the antenna in broadside and conical modes.

reconfigurable feeding network was designed by introducing PIN diodes on the transmission lines of the network. From the current distributions in both modes in Fig. 2, it is clearly observed that the L-probe patch (Broadside) mode and the monopolar patch (Conical) mode can be switched by the designed feed network.

The antenna prototype was fabricated and tested. The measured results in Figs. 3 and 4 exhibit good switchable broadside and conical-beam radiation patterns across a wide bandwidth of 23% from 2.25 to 2.85 GHz. The peak measured realized gain value is 8.2 dBi for the broadside mode and 6.9 dBi for the conical mode. The whole structure is compact with the profile of 0.13 λ_0. It is a good candidate as the ceiling mounted antenna for indoor WLAN wireless communications.

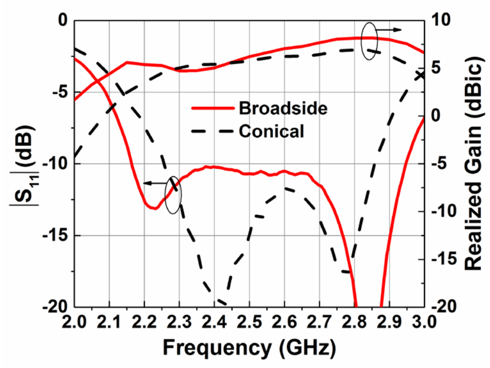

Fig. 3. Measured $|S_{11}|$ and realized gain values as functions of the source frequency for both modes.

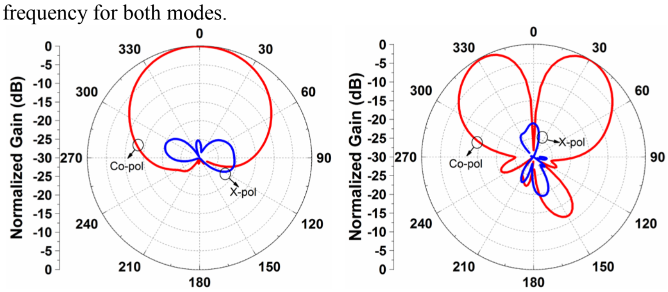

Fig. 4. Measured radiation patterns for both modes at 2.55 GHz.

III. Circularly-Polarized Broadside and Conical Beam Reconfigurable Antenna Design

Besides of the LP version discussed above, circularly-polarized broadside and conical-beam reconfigurable antenna is preferred for geostationary satellite communications [16] – [18]. Different places on earth would require distinctive CP radiation patterns from the communicating antennas. For example, the broadside CP antenna is required in the regions where the satellite is situated upright. On the other hand, the conical-beam CP antenna is needed for the places that has a certain elevation angle respect to the satellite. However, it is quite challenging to realize such reconfigurability. Before our reported antenna as shown in Fig. 5 [19], there is only one reported antenna design (to the best of our knowledge) can realize the switchable CP broadside and conical-beam radiation patterns as in [20]. However, it has a narrow bandwidth of 1.6%, low realized gain values (4.0 dBic for broadside mode and 2.0 dBic for conical mode) and complex feed network. In this work, we successfully excited both TM_{11} and TM_{21} modes on a circular patch radiator with an annular slot by a L-probes reconfigurable feed network. TM_{11} (TM_{21}) mode is corresponding to the CP broadside (conical-beam) radiation pattern. A L-probes based output reconfigurable feeding network was designed to provide the proper

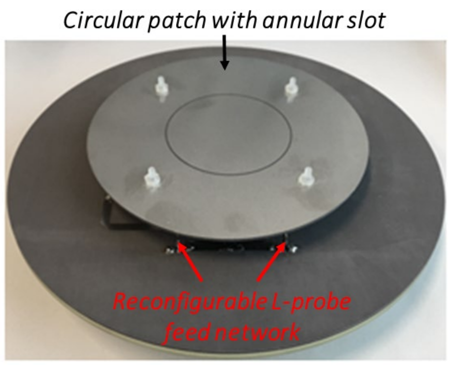

Fig 5. Prototype of the CP broadside and conical-beam reconfigurable antenna.

excitations (location and phase) for the two modes. In this feeding structure, six L-probes are active and the other two are suspended. The reason for keeping the two suspended L-probes is to achieve the symmetric radiation patterns. Fig. 6 illustrates the current distributions on the feed network in both modes, which provide proper excitations for TM_{11} or TM_{21} mode. Importantly, an annular slot was etched on the circular patch to move the operating frequency of the fundamental TM_{11} mode up closer to the frequency of the TM_{21} mode. As the results, the switchable CP broadside and conical-beam patterns will operate at the same frequency band.

The antenna components were fabricated, assembly and tested. Experimental results in Figs. 7 and 8 show good CP switchable broadside and conical-beam patterns at the same operating frequency band 2.45 to 2.65 GHz. The measured realized gain values are stable for both radiating states, the peak value being 8.5 dBic for the broadside mode and 5.8 dBic for the conical mode. The realized operating bandwidth is 4.8 times larger than the design in [20]. And the peak realized gain values are 4.5 dB (broadside) and 3.8 dB (conical) higher as well. With such unique CP pattern reconfigurability, the reported antenna is a good candidate for many wireless applications such as the worldwide geostationary satellite applications.

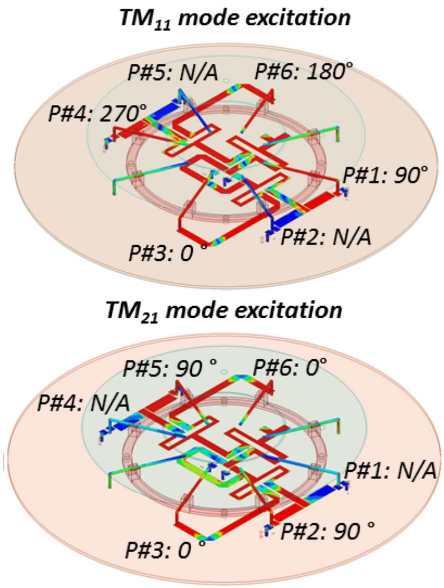

Fig. 6. Current distributions on the L-probes feed network in both modes.

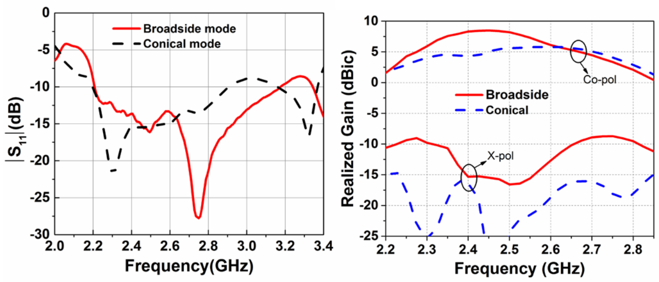

Fig. 7. Measured $|S_{11}|$ and realized gain values for both modes.

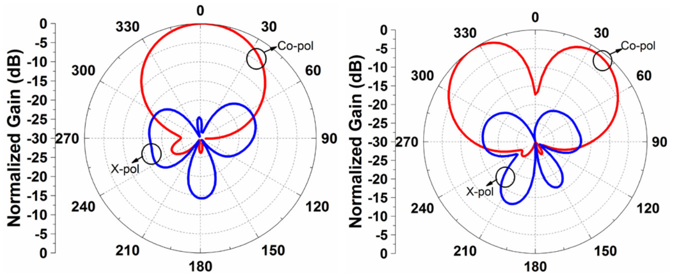

Fig. 8. Measured radiation patterns for both modes at 2.5 GHz.

IV. References

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