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Engineering Circular Polarization in Chip-integrated High-T_c Superconducting THz Antennas

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Abstract— We report on the control of circularly polarized terahertz (THz) wave in BSCCO superconducting THz antennas with center and edge-bias injected standard pentagonal cavity. The corners of the standard pentagonal cavity were engineered, to form the two-corner-rounded and all-corner-rounded, to investigate how it would affect the circular polarization at the fundamental frequency, at which the fundamental mode emerges. The results indicate that corner-rounding has detrimental effects on the center-injected pentagonal cavity, but has positive effects on the edge-injected pentagonal cavity.

1. INTRODUCTION

Efficient and practical components are essential in the terahertz (THz) range (100 GHz–10 THz) including emitters, waveguides, detectors, and receivers [1–7]. Consequently, between the developed optical technologies and the mature microwave, a frequency gap exists [8–16]. Pentagonal cavity attracts great attention due to its high-power capability contributed to waveguides and transmission lines [2, 17–21]. In addition, pentagonal cavity offer circular polarization THz light with only one feed point for application in THz telecommunication and IoT [2].

To further enhance THz radiation in intrinsic Josephson junctions (IJJs) high-superconducting BSCCO based devices [1, 21–25], we study regular pentagonal THz patch antennas. The pentagonal cavity is considered to be BSCCO with a feed point either at the centre or at the edge of the cavity, as shown in Fig. 1. We use high-frequency finite element software to study characteristics of the fundamental mode. Furthermore, the circular polarization is a functionality of emission that could be exploited to gain a more comprehensive understanding of emission from the pentagonal cavity. Here, we discuss our approaches to calculating the fundamental frequency, to investigate the effects of corner-rounding of the pentagonal cavity on the quality of circular polarization at fundamental mode, and to compare the value of the axial ratio, which represents the circular polarization, to summarize its effects.

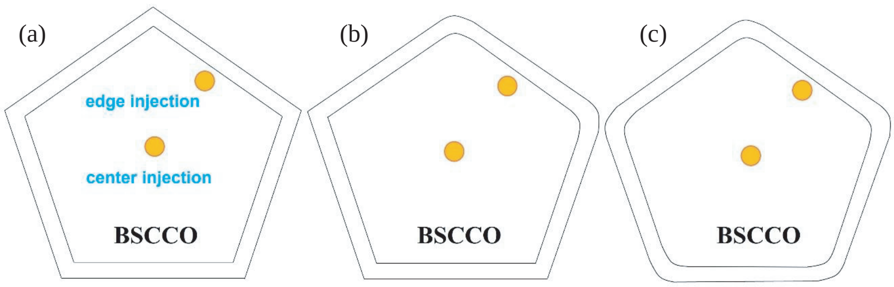

Figure 1: (a) Schematic view of standard, (b) two-corner-rounded, and (c) all-corner-rounded pentagonal cavity with center and edge bias-injected points.

To investigate whether the rounding of corners of the pentagonal cavity would improve or degrade the quality of circular polarization, three pentagonal cavities are proposed. They are standard pentagonal cavity, two-corner-rounded pentagonal cavity, and all-corner-rounded pentagonal cavity. Initially, the bias current is injected in the center of the standard pentagonal cavity. Then at the fundamental frequency, the fundamental mode is found and its circular polarization is investigated. The fundamental frequency calculation for the pentagonal cavity can be made by: $f_{11} = (cx_{11})/(2\pi a_{fit} n_r)$, where c is the speed of light in the vacuum, $n_r = 4.2$ is the refractive index of BSCCO, $x_{11} = 1.8412$ and the approximated radius of the pentagon is $a_{fit} = 45.3\,\mu m$ [2]. Based on the principles of circular polarization, the axial ratio (AR) less than or equal to 3 dB (AR $\leq$ 3 dB) could represent circular polarization, and the smaller value of the axial ratio, the better quality of circular polarization [20]. As mentioned earlier, the bias point is moved to the edge to investigate the circular polarization. This process is repeated for two-corner-rounded and all-corner-rounded pentagonal cavity respectively. Then all the results are compared to look for the effects of corner-rounding on the quality of circular polarization.

2. RESULTS

As shown in Fig. 2, at the fundamental frequency $f = 0.462$ THz, center-injected standard pentagonal cavity produces better circular polarization than two-corner-rounded pentagonal cavity because the axial ratio of the former is 1.4766 dB, which is smaller than the 2.0734 dB of the latter. However, the all-corner-rounded standard pentagonal cavity cannot produce circular polarization since its axial ratio is 4.0683 dB, which is over 3 dB. Similarly, applying the same analysis approach as above, at the fundamental frequency $f = 0.428$ THz, edge-injected standard pentagonal cavity cannot produce circular polarization, but edge-injected two-corner-rounded pentagonal cavity produces better circular polarization than the all-corner-rounded pentagonal cavity. These results are summarized in Table 1.

Table 1: Circular polarization for two feed point positions and three pentagonal cavities at the fundamental frequency of $f = 0.462$ THz (in the center) and $f = 0.428$ THz (in the edge).

	Standard pentagonal cavity	Two-corner-rounded pentagonal cavity	All-corner-rounded pentagonal cavity
Feed point in the centre	Better CP	CP exists	No CP
Feed point in the edge	No CP	Better CP	CP exists

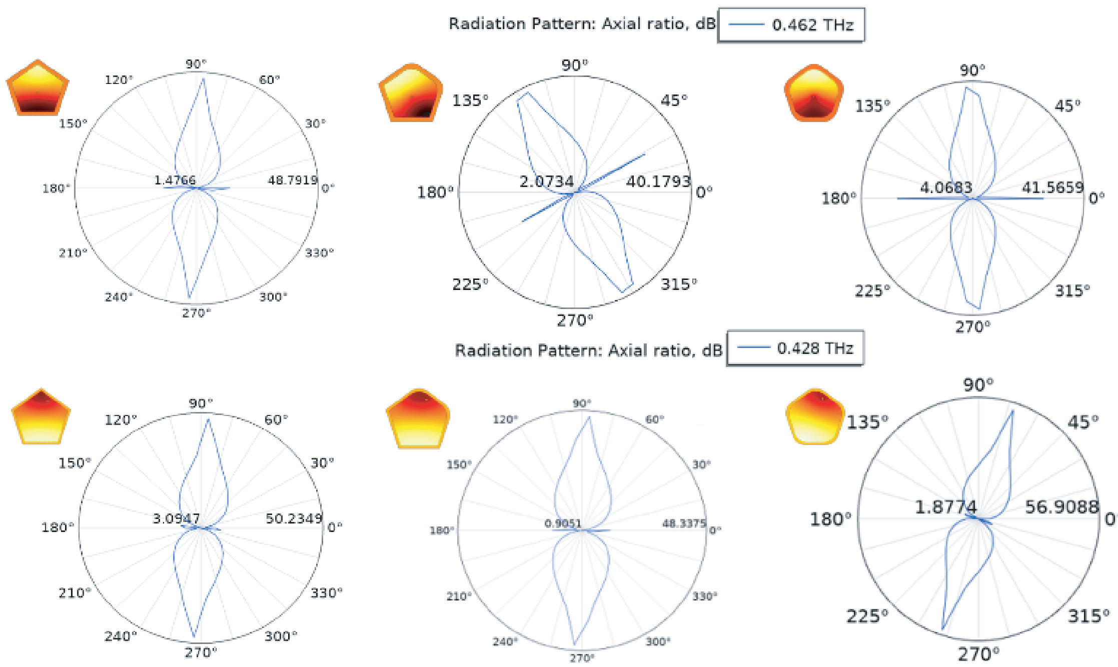

Figure 2: The radiation pattern (axial ratio) for fundamental frequency ($f = 0.462$ THz) of centre-injected standard, two-corner-rounded and all-corner-rounded pentagonal cavity, and for fundamental frequency ($f = 0.428$ THz) for edge-injected standard, two-corner-rounded and all-corner-rounded pentagonal cavity. The value in the center of each figure indicates the smallest value of the axial ratio while the value in the right indicates its largest value. The mode patterns are located in the upper left of each subfigure.

3. SUMMARY

The effects of corner-rounding on circular polarization of fundamental mode for center-injected and edge-injected standard, two-corner-rounded and all-corner-rounded pentagonal cavities are investigated. The results show that for the center-injected pentagonal cavity, the more corners are rounded, the worsen the quality and even the disappearance of circular polarization; But for the edge-injected cavity, rounding corners can produce circular polarization with better quality.

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