RESEARCH ARTICLE

Differential-Fed Dual-Polarized Filtering Fabry-Perot Antenna With High Isolation

TRUONG LE-HUU¹, SON XUAT TA²¹, KHAC KIEM NGUYEN²¹, (Member, IEEE), CHIEN DAO-NGOC²¹, (Senior Member, IEEE), AND NGHIA NGUYEN-TRONG²², (Member, IEEE)

¹School of Electrical and Electronic Engineering, Hanoi University of Science and Technology, Hanoi 100000, Vietnam
²School of Electrical and Electronic Engineering, The University of Adelaide, Adelaide, SA 5005, Australia

Corresponding author: Son Xuat Ta (xuat.tason@hust.edu.vn)

This work was supported by the Vietnam National Foundation for Science and Technology Development (NAFOSTED) under Grant 102.04-2021.06.

ABSTRACT In this paper, a dual-polarized filtering Fabry-Perot antenna (FPA) with high-isolation is proposed. It consists of a feed element of differential-fed dual-polarized square patch and a partially reflecting surface (PRS). The patch is capacitively coupled with T-shaped resonators and shorting-vias to obtain broadband characteristic and radiation nulls. The PRS structure is composed of two complementary metasurface layers, which are selected for achieving a positive reflection phase gradient within the broad frequency range. More interestingly, thanks to the frequency selectivity feature, the PRS significantly enhances the filtering characteristic of the FPA. For verification, a prototype of the proposed antenna operating at the 5.5-GHz center frequency has been fabricated and measured. The prototype with an overall size of \(\sim 2.0 \lambda_{\min} \times 2.0 \lambda_{\min} \times 0.49 \lambda_{\min}\) (\(\lambda_{\min}\) is the free-space wavelength referring to the lowest operational frequency) result in an impedance bandwidth of 17.1\% (5.02 – 5.96 GHz) for 10-dB return loss and a high isolation of \(\geq 45\) dB. Moreover, the far-field measurements result in a good dual-polarized radiation with the peak gain of 13.0 dBi, cross-polarization level of \(\leq -25\) dB within the passband, and out-of-band suppression level of \(\geq 20\) dB.

INDEX TERMS Differential feed, dual polarization, Fabry-Perot antenna, partially reflecting surface, filtering, broadband, high gain, high isolation.

I. INTRODUCTION

In order to reduce losses, complexity, size, and cost in a radio system, filtering antennas or filtennas [1] have been considered as an effective solution as the filtering function can be realized within the antenna structure. There are numerous techniques to design filtering antennas, which have been continuously developed in the last decades. As surveyed in [1], those techniques, for instance, include the implementation of feeding structures incorporated with band-pass filters, the utilization of defected ground planes, coupling resonators, substrate integrated waveguides, and multi-layered structures.

In response to the recent rapid change of the wireless communications, especially with the 5G and beyond-5G cellular systems, highly-performing filtering antennas with additional incorporated functionalities, such as multiple polarizations and high isolation, become demanding. Dual-polarization is necessary for base station in cellular systems because it mitigates multipath fading effects and increases channel capacity. Accordingly, dual-polarized filtering antennas [2], [3], [4], [5], [6], [7], [8], [9], [10], [11], [12], [13], [14] have received much attention in recent years. Furthermore, in order to directly connect to differential RF/microwave circuits without additional balun, differential-feed scheme has applied to the dual-polarized filtering antennas [15], [16], [17], [18], [19], [20], [21]. Interestingly, with perfectly symmetrical structure, these antennas yield a theoretical infinite isolation and zero cross-polarization level.

To achieve higher gain, the traditional method of creating antenna arrays has been widely utilized in the existing...
filtering antennas, e.g., [22], [23], [24], [25], [26], [27]. However, these arrays require complicated feeding networks and antenna configurations. One effective method to overcome this is to use Fabry-Perot antenna (FPA) [28]. Its basic design is illustrated in Fig. 1(a), which includes a feed antenna in a parallel-plate cavity formed by a metallic ground plane (GND) on the bottom and a partially reflecting surface (PRS) on the top. Due to the presence of the PRS, the directivity of FPA ($D_{FPA}$) is theoretically related to the directivity of the feed ($D_{feed}$) as follows:

$$D_{FPA}(dB) = D_{feed}(dB) + D_{PRS}(dB)$$

(1)

where $D_{PRS}$ is the increase in directivity caused by the PRS and given by [29]:

$$D_{PRS} = 10 \log_{10} \left( \frac{1 + \gamma}{1 - \gamma} \right) (dB)$$

(2)

where $\gamma$ is the reflection magnitude of the PRS. Note that the equations (1) and (2) are accurate only when the resonant condition in (3) is satisfied and for a very large PRS. As analyzed in [28], the resonance frequency of an FPA is

$$f_0 = \frac{c}{4\pi H_c} (\phi_{PRS} + \phi_{GND} - 2N\pi), \quad N = 0, 1, 2, \ldots$$

(3)

where $c$ is the speed of light in free space, $H_c$ is the cavity height, $\phi_{PRS}$ is the reflection phase of the PRS, and $\phi_{GND}$ is the reflection phase of the GND given as

$$\phi_{GND} = \frac{4\pi H_c f}{c} + (2N - 1)\pi, \quad N = 0, 1, 2, \ldots$$

(4)

As the reflection phase of a typical PRS decreases with frequency, the resonance condition (3) is satisfied only for a narrow bandwidth, as illustrated in Fig. 1(b). For broadband operation, a positive reflection phase gradient is required as illustrated in Fig. 1(c). Different PRS structures have been designed to meet the above requirement. Examples of broadband PRSs include two complementary frequency selective surfaces [30], multilayer dielectric slabs [31], multilayer PRS [32], PRS with hexagonal unit [33]. It is noted that the PRS structures can contribute to the filtering performance due to its inherent frequency selective characteristics. Nevertheless, to the best of our knowledge, this feature has not been comprehensively investigated or exploited to achieve a highly-performing filtering FPA in the literature.

In this paper, we propose a dual-polarized filtering FPA with very high isolation, which can also be suitable for in-band full duplex (IBFD) applications [34]. The antenna employs a differential-fed dual-polarized patch, which is loaded with T-shaped resonators through a capacitively proximity coupling scheme to achieve the broadband-pass filtering feature. In order to further enhance the broadside gain and frequency selectivity, the patch antenna is incorporated with a PRS structure of two complementary metasurfaces.

**II. ANTENNA DESIGN**

**A. ANTENNA STRUCTURE**

Fig. 2 shows the structure of the proposed FPA, which is composed of a patch, PRS, and GND. To provide bandpass filtering feature, the patch is capacitively coupled with T-shaped resonator and shorting via [35]. Distinguished from the design in [35], which used a single-ended port with asymmetrical structure, the proposed antenna employs a symmetrical double differential-feed to achieve highly-isolated dual-polarized radiation. The patch and T-shaped resonators are printed on the top-side of Sub. 1 (Rogers RO4003, $\varepsilon_r = 3.38$ and $\tan\delta = 0.0027$) with dimensions of 50 mm × 50 mm, which is suspended on the GND via a foam (Rohacell, $\varepsilon_r = 1.07$, and $\tan\delta = 0.0006$). Four 50-Ω coaxial lines are used as inputs of the double differential feed. The PRS is placed at a distance of $H_c$ above the GND. To allow a broadband operation, the PRS is composed of two complimentary metasurfaces with $10 \times 10$ unit-cells, which are built on both sides of the Sub. 2 (Rogers Duroid RT5880, $\varepsilon_r = 2.2$, and $\tan\delta = 0.0027$).

![Figure 1](image1.png)

**FIGURE 1.** (a) Basic geometry of a Fabry-Perot antenna (FPA); (b) Phase response of a conventional PRS and the ground plane; (c) Phase response of broadband PRS ($\phi_{PRS}$) and the ground plane ($\phi_{GND}$).

![Figure 2](image2.png)

**FIGURE 2.** Structure of the proposed filtering FPA: (a) side-view, (b) top-view of the feed antenna, and (c) PRS unit-cell.
TABLE 1. Optimized design parameters of the proposed antenna.

| Par. | Value (mm) | Par. | Value (mm) | Par. | Value (mm) |
|------|------------|------|------------|------|------------|
| $H_c$ | 28         | $W_f$ | 7.5        | $h_{11}$ | 0.508      |
| $h_{x2}$ | 0.7874   | $L_f$ | 12         | $W_f$ | 7.5        |
| $W_2$ | 0.5        | $L_6$ | 18         | $S_2$ | 2.5        |
| $d_f$ | 3          | $R_v$ | 1.2        | $P$  | 12         |
| $\phi_1$ | 5         | $\phi_2$ | 4         | $\phi_3$ | 4         |
| $b_2$ | 10         | $b_2$ | 6.5        | $b_9$ | 5.2        |

FIGURE 3. (a) PRS unit-cell modeling in ANSYS HFSS and (b) its reflection characteristics.

The top-side and bottom-side of a PRS unit-cell are given in Fig. 2(c). The proposed FPA was optimized using ANSYS Electronics Desktop to achieve broadband, dual-polarization, high gain, and high isolation with filtering characteristics centered at 5.5 GHz. The optimized design parameters are listed in Table 1.

B. REFLECTION PROPERTIES OF THE PRS

As mentioned above, the PRS structure composed of two complimentary metasurfaces is chosen to provide a positive reflection phase gradient at a broad frequency range, and consequently, allow the broadband characteristic. First, the PRS unit-cell is simulated (see Fig. 3(a)) and optimized. For the simulation setup, periodic boundary conditions (PBC) are applied along the $x$- and $y$-directions, while a Floquet port excitation and perfect matching layer (PML) are applied along the $\pm z$ directions, respectively. The simulated reflection properties of the PRS are shown in Fig. 3(b). The reflection phase versus frequency yields a positive slope at around 5.2 to 5.8 GHz, while its reflection magnitude is $\geq 0.515$ with the minimum value at the resonance of 5.5 GHz. These reflection properties ensure that the PRS structure is proper to be employed in the broadband FPAs.

C. DESIGN EVOLUTION

To demonstrate the effectiveness of the technique, Fig. 4 shows design steps for the proposed FPA. First, the design procedure starts by considering a simple directly-fed patch as the feed element (Ant. 1). Since a conventional patch antenna suffers from a narrow bandwidth, it is capacitively coupled with T-shaped resonator and shorting via [35] to create Ant. 2 for the broadband and filtering characteristics. To generate a dual-polarized radiation, double T-shaped resonators are applied to the patch (creating Ant. 3). In the next step, to improve port-to-port isolation, double differential-feed is applied to Ant. 3 creating the feed element of the proposed FPA (Ant. 4). Finally, to enhance the gain and keep the high isolation, the PRS structure is added to Ant. 4 for establishing the proposed design. For demonstration, all antenna configurations have same design parameters as the final FPA.

All configurations in Fig. 4 are characterized and compared with the full design, as shown in Fig. 5. The initial design (Ant. 1) yields a 10-dB return loss bandwidth of 5.79 – 6.09 GHz ($\sim 5\%$) with one resonance at 5.95 GHz [Fig. 5(a)] and a gain of 8.72 dBi [Fig. 5(c)]. Due to the presence of the T-shaped resonator and shorting via, Ant. 2 yields a larger bandwidth and a similar gain relative to Ant. 1; i.e., its impedance bandwidth is 5.1 - 5.95 GHz ($\sim 15\%$) with two resonances at 5.1 GHz and 5.95 GHz. Moreover, Ant. 2 achieves a good out-of-band suppression with two radiation nulls at 4.3 GHz and 7.3 GHz. The T-shaped feed
can be applied for the dual-polarized antenna (Ant. 3) with unchanged bandwidth and gain. However, since the structure is asymmetric, Ant. 3 suffers a port-to-port isolation $\leq 25$ dB [Fig. 5(b)]. The isolation in the dual-polarized antenna can be significantly improved by using double differential-feed scheme (Ant. 4). For differential-feed, the antenna is excited by four ports (P1−P4), where the S-parameters of the differential ports are calculated as [36]

$$S_{dd11} = (S_{11} - S_{12} - S_{21} + S_{22})/2$$

$$S_{dd22} = (S_{33} - S_{34} - S_{43} + S_{44})/2$$

$$S_{dd21} = (S_{31} - S_{41} - S_{32} + S_{42})/2$$

$$S_{dd12} = (S_{13} - S_{14} - S_{23} + S_{24})/2$$

Due to the perfectly symmetrical structure, i.e., $S_{31} = S_{32}$ and $S_{41} = S_{42}$, the isolation of Ant. 4 ($S_{dd21}$ and $S_{dd12}$) is theoretically infinite. As shown in Fig. 5(b), Ant. 4 results in a simulated isolation of $\geq 55$ dB, which is only the error in meshing. By adding the PRS, the broad bandwidth and high isolation remain in the proposed FPA, whereas the broadside gain increases for more than 5 dB. The final design yields a 10-dB return loss bandwidth of 4.97 - 6.13 GHz ($\sim 21\%$), isolation of $\geq 50$ dB, and the peak realized gain of 15 dBi. More importantly, thanks to the frequency selectivity of the PRS, the FPA achieves an out-of-band suppression of about 20 dB.

III. MEASUREMENTS AND DISCUSSION

A. REALIZATION OF DIFFERENTIAL-FEED

For realizing the broadband differential-feeds (i.e., same magnitude and 180° phase difference with perfect isolation), the feeding network of the proposed FPA, as shown in 6(a), is adapted from a wideband planar balun in [37]. The two baluns are designed for the double differential-feeds and each balun is composed of a two-way equal Wilkinson power divider and a wideband 180° phase shifter. The simulated performances of the feeding network are illustrated in 6(b). The two baluns yield good performance across a broad frequency range; i.e., at 4.5 - 7.0 GHz, the reflection coefficients at the inputs ($|S_{11}|$ and $|S_{22}|$) are $\ll 15$ dB, nearly equal divided powers at the outputs, and phase differences of 180° $\pm 1.5°$. These results indicate that the feeding network just provides the differential signals and does not contribute the filtering characteristic at the desired frequency range.

B. MEASUREMENTS

For verification, the proposed dual-polarized FPA is fabricated and measured. Fig. 7 shows a fabricated prototype of the proposed FPA, which has an overall size of 120 $\times$ 120 $\times$ 29.3 mm$^3$ ($\sim 2.0\lambda_{\text{min}} \times 2.0\lambda_{\text{min}} \times 0.49\lambda_{\text{min}}$). The antenna is
realized by using the printed circuit board (PCB) technology and tin-soldering. Its components, including feeding network, GND, patch with T-shaped resonators, and PRS with two complimentary metasurfaces are printed on the substrates with conductor sheet of 50-µm. The PCB pieces are fastened with plastic posts and screws to form the antenna prototype. Two SubMiniature version A (SMA) connectors are used as the coaxial-to-microstrip transformers at the inputs of the feeding network.

The S-parameter measurements of the FPA prototype are carried out by using a vector network analyzer. The measured results are compared to the simulation predictions in Fig. 8. The measurements agree well with the simulations; i.e., the antenna achieves a measured overlapped bandwidth of 5.02 – 5.96 GHz (17.1%) for $|S_{11}|$ and $|S_{22}| < -10$ dB, whereas the simulated values are 4.99 – 6.06 GHz (19.4%). Within this bandwidth (pass-band), the measured isolation between the Port 1 and Port 2 is $\geq 45$ dB, while the simulated value is $\geq 43.5$ dB. There are radiations from the feeding network, which cause some undesired resonances in the $|S_{11}|$ and $|S_{22}|$ curves. Nevertheless, since the feeding network is isolated with the radiating elements by the GND, these undesired radiations do not affect the antenna performances.

The simulation and measurement broadside realized gains of the FPA prototype are illustrated in Fig. 9. The measurements resulted in a 3-dB gain bandwidth of 21.82% (4.9 - 6.1 GHz) with the peak gain of 13.0 dBi, while the simulations result in a 3-dB gain bandwidth of 21.98% (4.94 - 6.16 GHz) with the peak gain of 13.5 dBi. Due to the undesired losses caused by the feeding network, the realized prototype yields a slightly smaller gain as compared to the antenna excited by four ports. Also, both simulation and measurement yield an out-of-band suppression of about 20 dB.
The 5.2, 5.5, and 5.8 GHz radiation patterns of the antenna prototype for each port excitation are given in Figs. 10 and 11. Again, there is a good agreement between the simulation and measurement. The results indicate that the proposed FPA achieves a good broadside dual-polarized radiation. Within the pass-band, the measurements result in a cross-polarization level of $\leq -25$ dB, front-to-back ratio of $\geq 25$ dB, and half-power beamwidth of $34^\circ \pm 6^\circ$ in both principle plane cuts. The measured cross-polarization level is worse than the simulated value, which could be attributed to the fabrication tolerance and the effects of plastic post and screw, as well as the SMA connectors (not included in the simulations).

C. DISCUSSION
To clearly show the advantages and high performance of the proposed design, comparisons with other state-of-the-art designs are conducted. Firstly, compared to the previous dual-polarized filtering antennas [2], [3], [4], [5], [6], [7], [8], [9], [10], [11], [12], [13], [14], the proposed FPA achieves a much better gain and isolation while having comparable suppression level. The proposed design’s bandwidth of 17.1% is also considered as wide and sufficient for many applications.

Secondly, as compared to the differential-fed dual-polarized filtering antennas [15], [16], [17], [18], [19], [20], [21], the proposed antenna shows comparable operational-bandwidth and isolation, but achieves a higher gain and higher out-of-band suppression.

TABLE 2. Comparison of the proposed antenna and the related works.

| Ant. | Overall size ($\lambda_{min}$) | Filtering method | High-gain method | BW (%) | Iso. (dB) | Gain (dB) | Supp. (dB) |
|------|-------------------------------|------------------|------------------|--------|----------|-----------|------------|
| [22] | $2.13 \times 3.06 \times 0.38$ | Jerusalem cross radiator | 1x4 array | 10.5 | 22 | 14.0 | NA |
| [23] | $0.62 \times 2.48 \times 0.12$ | open/short circuit | 4x4 array | 22.2 | 35.2 | 13.4 | 17.1 |
| [24] | $3.40 \times 1.94 \times 0.15$ | SW cavity + stacked-patches | 4x4 array | 22.8 | 34 | 15.0 | 20 |
| [25] | $2.83 \times 2.83 \times 0.15$ | square + ring + open-strips | 4x4 array | 19.5 | 30 | 12.7 | 24 |
| [26] | $2.54 \times 2.54 \times 0.11$ | open and short stubs | 32-element array | 27.0 | 30 | NA | 16 |
| [27] | $9.10 \times 9.70 \times 0.23$ | filter + slotted dipoles | 4x4 array | 12.7 | 50 | 16.8 | 31 |
| [38] | $8.12 \times 8.12 \times 1.02$ | no | F-P cavity | 5.7 | 30 | 19.0 | NA |
| [39] | $3.03 \times 3.03 \times 0.67$ | no | F-P cavity | 7.1 | 30 | 16.1 | NA |
| [40] | $1.90 \times 1.90 \times 0.56$ | no | F-P cavity | 16.5 | 30 | 15.5 | NA |
| [41] | $4.20 \times 4.20 \times 0.60$ | no | F-P cavity | 1.78 | 18 | 18.6 | NA |
| [42] | $9.30 \times 9.30 \times 2.65$ | no | F-P cavity | 10.4 | 33 | 17.5 | NA |
| [43] | $1.90 \times 1.90 \times 0.48$ | no | F-P cavity | 19.1 | 43 | 14.2 | NA |
| Prop. | $2.00 \times 2.00 \times 0.49$ | T-shaped resonator + PRS | F-P cavity | 17.1 | 45 | 13.0 | 20.0 |

$\lambda_{min}$: free-space wavelength referring to the lowest operational frequency; NA: not available; F-P: Fabry Perot

Thirdly, table 2 shows a performance comparison between the proposed FPA and other related works. Relative to most of the high-gain dual-polarized filtering antennas [22], [23], [24], [25], [26], [27], the proposed design yields comparable overall-size, operational-bandwidth, gain, and out-of-band suppression level, but it yields simpler configuration and higher isolation. As compared to most of existing dual-polarized FPAs [38], [39], [40], [41], [42], [43], our design yields several advantages, such as wider bandwidth, higher isolation, and most importantly filtering characteristic.

IV. CONCLUSION
A design of broadband dual-polarized filtering FPA with high-gain, high-isolation, and high out-of-band suppression have been demonstrated. Its feed is a double differential-fed patch loaded with T-shaped resonators and shorting-vias for broadband and filtering characteristics. Its PRS is composed of two complementary metasurface layers for allowing a broad operational bandwidth. The presence of the PRS does not only enhance the broadside gain, but also improve the filtering feature of the proposed antenna. The antenna prototype with an overall size of $\sim 2.0\lambda_{min} \times 2.0\lambda_{min} \times 0.49\lambda_{min}$
achieves a 10-dB return loss bandwidth of 17.1% (5.02 – 5.96 GHz), an isolation of ≥ 45 dB, the peak gain of 13.0 dBi, cross-polarization level of ≤ –25 dB, and out-of-band suppression level of ≥ 20-dB. With the above advantages, the proposed FPA is a good candidate for many wireless communication systems, including for IBFD applications.

REFERENCES

[1] P. P. Shome, T. Khan, S. K. Koul, and Y. M. M. Antar, “Filtenna designs for radio-frequency front-end systems: A structural-oriented review,” IEEE Antennas Propag. Mag., vol. 63, no. 5, pp. 72–84, Oct. 2021.

[2] W. Duan, X. Y. Zhang, Y.-M. Pan, J.-X. Xu, and Q. Xue, “Dual-polarized filtering antenna with high selectivity and low cross polarization,” IEEE Trans. Antennas Propag., vol. 64, no. 10, pp. 4188–4196, Oct. 2016.

[3] C. F. Ding, X. Y. Zhang, Y. Zhang, Y. M. Pan, and Q. Xue, “Compact broadband dual-polarized filtering dipole antenna with high selectivity for base-station applications,” IEEE Trans. Antennas Propag., vol. 66, no. 11, pp. 5747–5756, Nov. 2018.

[4] Y. M. Pan, P. F. Hu, K. W. Leung, and X. Y. Zhang, “Compact single-/dual-polarized filtering dielectric resonator antennas,” IEEE Trans. Antennas Propag., vol. 66, no. 9, pp. 4747–4484, Sep. 2018.

[5] Z. Niu and Y. Fan, “Dual-polarized low-profile filtering patch antenna without extra circuit,” IEEE Access, vol. 7, pp. 106011–106018, 2019.

[6] S. J. Yang, Y. M. Pan, Y. Zhang, Y. Gao, and X. Y. Zhang, “Low-profile dual-polarized filtering magneto-electric dipole antenna for 5G applications,” IEEE Trans. Antennas Propag., vol. 67, no. 10, pp. 6235–6243, Oct. 2019.

[7] Y. Zhang, X. Y. Zhang, L. Gao, Y. Gao, and Q. H. Liu, “A two-port microwave component with dual-polarized filtering antenna and single-band bandpass filter operations,” IEEE Trans. Antennas Propag., vol. 67, no. 8, pp. 5590–5601, Aug. 2019.

[8] C. F. Ding, X. Y. Zhang, and M. Yu, “Simple dual-polarized filtering antenna with enhanced bandwidth for base station applications,” IEEE Trans. Antennas Propag., vol. 68, no. 6, pp. 4354–4361, Jun. 2020.

[9] S. J. Yang, Y. F. Cao, Y. M. Pan, Y. Wu, H. Hu, and X. Y. Zhang, “Balun-fed dual-polarized broadband filtering antenna without extra filtering structure,” IEEE Antennas Wireless Propag. Lett., vol. 19, no. 4, pp. 656–660, Apr. 2020.

[10] K.-R. Xiang, F.-C. Chen, Q. Tan, and Q.-X. Chu, “Design of novel printed filtering dipole antennas,” IEEE Trans. Antennas Propag., vol. 69, no. 5, pp. 2537–2545, May 2021.

[11] K. Xue, D. Yang, C. Z. Guo, H. Q. Zhai, H. K. Li, and Y. Zeng, “A dual-polarized filtering base-station antenna with compact size for 5G applications,” IEEE Antennas Wireless Propag. Lett., vol. 19, no. 8, pp. 1316–1320, Aug. 2020.

[12] Y. F. Cao, Y. F. Wu, Y.-M. Pan, and X. Y. Zhang, “A method of generating radiation nulls utilizing inherent resonance modes for dual-polarized filtering dipole antenna design,” IEEE Trans. Antennas Propag., vol. 68, no. 8, pp. 6413–6418, Aug. 2020.

[13] Y. Zhang, X.-Y. Zhang, and Q.-H. Liu, “Dual-polarized filtering magneto-electric dipole antenna utilizing intrinsic highpass filter network and integrated lowpass filter network,” IEEE Trans. Antennas Propag., vol. 69, no. 12, pp. 8090–8099, Dec. 2021.

[14] H. Yuan, F.-C. Chen, and Q.-X. Chu, “A wideband and high gain dual-polarized filtering antenna based on multiple patches,” IEEE Trans. Antennas Propag., early access, May 30, 2022, doi: 10.1109/TAP.2022.3177494.

[15] W. Yang, M. Xue, W. Chen, W. Feng, Y. Zhang, and Q. Xue, “No-overlap compact high-gain differential-fed dual-polarized filtering patch antenna,” IEEE Trans. Antennas Propag., vol. 67, no. 12, pp. 7261–7271, Dec. 2019.

[16] D. Yang, H. Zhai, C. Guo, and C. Ma, “A novel differentially fed dual-polarized filtering magneto-electric dipole antenna for 5G base station applications,” IEEE Trans. Antennas Propag., vol. 70, no. 7, pp. 5373–5382, Jul. 2022.

[17] X. Liu, S. Gao, W. Hu, L. Wen, Q. Luo, B. Sanz-Izquierdo, X. Chen, L. Qian, J. T. S. Sumantayo, and X.-X. Yang, “A compact dual-polarized filtering antenna with steep cut-off for base-station applications,” IEEE Trans. Antennas Propag., vol. 70, no. 7, pp. 5941–5946, Jul. 2022.

[18] Y. Luo, J. Lai, N. Yan, W. An, and K. Ma, “Wall of single-layer dual-polarized dual compressed high-order modes differentially fed patch antenna and solar cells for green communication,” IEEE Trans. Antennas Propag., vol. 70, no. 3, pp. 2289–2294, Mar. 2022.
TRUONG LE-HUU received the Engineer degree in electronics and telecommunications from the Hanoi University of Science and Technology, Vietnam, in July 2006, and the Master of Engineering degree in electronic engineering from Dongguk University, South Korea, in February 2009. He is currently pursuing the Ph.D. degree with the School of Electrical and Electronic Engineering, Hanoi University of Science and Technology. From March 2009 to November 2018, he worked with Viettel Group, where he was appointed to the Vice Director of the Engineering of Radar Institute, in 2012. From November 2018 to April 2021, he worked as a Lecturer at the School of Electronics and Telecommunication (SET), Hanoi University of Science and Technology (HUST). Since April 2021, he has been the Director of the Electronic Platform Center, Viettel Aerospace Institute, Viettel Group. His research interests include antennas, RF transceiver, RF power amplifier systems, radar, and electronic warfare.

SON XUAT TA received the B.Sc. (Eng.) degree in electronics and telecommunications from the University of Science and Technology, Vietnam, in August 2008, and the Ph.D. degree in electrical engineering from Ajou University, South Korea, in February 2016. From March 2016 to February 2017, he was a Postdoctoral Research Fellow with Department of Electrical and Computer Engineering, Ajou University. From March 2017 to August 2017, he was with the Division of Computational Physics, Institute for Computational Science, and the Faculty of Electrical and Electronics Engineering, Ton Duc Thang University, Ho Chi Minh City, Vietnam. Since September 2017, he has been working as a Lecturer at the School of Electronics and Telecommunication (now renamed as the School of Electrical and Electronic Engineering), Hanoi University of Science and Technology. He has authored or coauthored over 100 technical journals and conference papers. His research interests include antennas, metamaterials, metasurfaces, metamaterial-based antennas, metasurface-inspired antennas, circularly polarized antennas, and millimeter-wave antennas. He has served as a reviewer for over 15 scientific journals. He has been selected as a Top Reviewer of the IEEE Transactions on Antennas and Propagation, in 2020 and 2021.

KHAC KIEM NGUYEN (Member, IEEE) was born in Hanoi, Vietnam, in 1978. He received the B.Eng., M.Sc., and Ph.D. degrees from the School of Electronics and Telecommunication (SET) (now renamed as the School of Electrical and Electronic Engineering—SEEE), Hanoi University of Science and Technology (HUST), Vietnam, in 2001, 2003, and 2017, respectively. Since 2001, he has been working as a Lecturer at the SEEE, HUST, and a Researcher at the CRD Laboratory, HUST. His research interests include design microstrip antenna for next generation mobile communication systems as well as passive RF components.

CHIEN DAO-NGOC (Senior Member, IEEE) received the Dipl.Eng. degree from the School of Electronics and Telecommunication (SET), Hanoi University of Science and Technology (HUST), Vietnam, in 1997, and the M.Sc. and Ph.D. degrees from the Department of Electronics and Computer Engineering, Gifu University, Japan, in 2002 and 2005, respectively. From April 2005 to October 2011, he worked as a Senior Lecturer at the SET, HUST, and appointed as the Director of the Centre for Research and Development on Satellite Navigation Technology, South East Asia, in 2009. He has been appointed to an Associate Professor, since November 2010. Since November 2011, he has been with the Department of High Technology, Ministry of Science and Technology, Vietnam, and appointed as an Adjunct Professor at the SET, HUST. His research interests include computational electromagnetics based on MoM and FDTD method, analysis and design of modern antenna and of nanometric integrated optical circuits based on surface plasmon polaritons. Dr. Dao-Ngoc has been a reviewer of several journals/transactions of Optical Society of America (OSA), IEEE, Elsevier, and American Geophysical Union (AGU) as well as numerous of technical and science conferences.

NGHIA NGUYEN-TRONG (Member, IEEE) received the Ph.D. degree (Doctoral Research Medal) in electrical engineering from The University of Adelaide, Adelaide, SA, Australia, in 2017. He is currently a Lecturer with The University of Adelaide. His main research interests include microwave circuits, advanced materials, absorbers, and various types of antennas. Dr. Nguyen-Trong was one of the recipients of the Best Student Paper Award at the 2014 IWAT, the 2015 IEEE MTT-S NEMO, and the 2017 ASA Conferences, and the Best Paper Award at the 2018 and 2020 AMS Conference. He serves as a Technical Co-Chair for the 2020 Australian Microwave Symposium (AMS) and the 2022 IEEE International Symposium on Antennas and Propagation. He is listed among Australia’s Top 40 Early Career Researchers by The Australian, November 2021. He has been continuously selected as a Top Reviewer of the IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION, in 2018, 2019, 2020, and 2021, and the IEEE ANTENNA WIRELESS AND PROPAGATION LETTERS, in 2018 and 2021.

[41] M. W. Niaz, Y. Yin, S. Zheng, and Z. Zhao, “Dual-polarized low sidelobe Fabry–Pérot antenna using tapered partially reflective surface,” Int. J. RF Microw. Comput.-Aided Eng., vol. 30, no. 3, Mar. 2020, Art. no. e22070.
[42] Q.-Y. Guo and H. Wong, “155 GHz dual-polarized Fabry–Pérot cavity antenna using LTCC-based feeding source and phase-shifting surface,” IEEE Trans. Antennas Propag., vol. 69, no. 4, pp. 2347–2352, Apr. 2021.
[43] S. X. Ta and N. Nguyen-Trong, “Broadband dual-polarized Fabry–Pérot antenna with simple feed for full-duplex applications,” IEEE Antennas Wirel. Propag. Lett., early access, Jul. 18, 2022, doi: 10.1109/LAWP.2022.3191119.