Radiation properties of a linearly dual-polarized dual-band and wideband multi-ring microstrip antenna fed by two L-probes

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Abstract: This paper presents a linearly dual-polarized dual-band and wideband multi-ring microstrip antenna fed by two L-probes. The proposed antenna consists of two circular ring patches and two L-probes arranged in a multi-layered dielectric substrate. By using a thick substrate for the L-probe and arranging two ring patches as radiation elements, the proposed antenna exhibits wideband and dual-band characteristics. Furthermore, by arranging two L-probes at the orthogonal positions, the proposed antenna can operate as a linearly dual-polarized planar antenna. The measured fractional bandwidths corresponding to a reflection coefficient below −10 dB were 21.7% and 10.6% for the first and second modes, respectively. The measured isolation between two ports of the test antenna in the above bandwidths were larger than 13 dB.

Keywords: planar antenna, multi-ring microstrip antenna, wideband, multi-band, dual-polarized

Classification: Antennas and Propagation

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1 Introduction

Microstrip antennas are characterized by their small size, thinness, lightness, and low cost, and they have been extensively researched for various purposes [1, 2]. Multi-ring MSAs fed by an L-probe shows good characteristics as a multi-band planar antenna [3, 4]. The one-ring MSA fed by an L-probe for single-band operation that uses a dielectric substrate having a thickness of about 0.14 wavelengths at the center frequency can provide a relative bandwidth (~10 dB or less of reflection) of about 46% [5, 6] and the two-ring MSA for dual-band operation can provide relative bandwidths of about 20.3% and 15.7% for the first and second modes [7, 8, 9]. These antennas are designed for single linear polarization.

Dual-polarized MSAs for dual-band and wideband operation have been reported [10, 11, 12, 13]. The stacked dual-patch antenna with four parasitic patches arranged around the upper layer patch presents fractional bandwidths of 12.4% and 14.9% for the dual bands by the simulation [10]. A thin substrate with a thickness of 0.90 wavelengths at the lower frequency band is used and results in slightly narrow bandwidths. Furthermore, the four parasitic patches to improve the isolation between the two ports increase the area occupied by the patches. The stacked triple-patch antennas fed by eight L-probes for dual-band and dual circularly-polarized operation [11], the 2 × 1 stacked patch antenna array the stacked patch antenna arrays fed by four L-probes for single-band and dual linearly-polarized operation [12] and for

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dual-band and dual linearly-polarized operation [13] are presented. These dual-band antennas in [11] and [13] provide wide fractional bandwidths of 22.4% to 55.2% below −10 dB reflection, however, the antenna height becomes large more than 0.150 wavelengths at the lower band because the patches for upper band are stacked on the patches for lower band. Furthermore, at least four L-probes for dual-polarized operation, the feeding circuits for the L-probes, and additional sidewalls and vias around the patches are used to improve the isolation between the ports, which makes the antenna structure complex [11, 12].

In this paper, we examine the dual-band and wideband MSA for dual linear polarizations. Two L-probes are arranged at the orthogonal positions of the dual-band and wideband two ring MSA [9]. The advantage of the proposed antenna is simple and compact structure. Because the patch for the upper band is placed beneath the patch for the lower band, the antenna height is not increased by adding the patch for the upper band for dual-band operation. Furthermore, the two ring patches for the first and second modes are excited by one L-probe in the proposed antenna. Therefore, dual-band and linearly dual-polarized operation is realized by the two L-probes. The wideband performance of 21.7% and 10.6% fractional bandwidths below −10 dB reflection for the two modes are obtained by the prototype antenna. The measured isolation between the two ports is more than 13 dB in the two bands. Although the proposed antenna is simple without additional structures, reasonable isolation characteristics are observed.

2 Configuration of the proposed antenna

Figure 1 presents a configuration and parameters of the proposed antenna. The target fractional bandwidths and the design frequencies are 20% at 4.75 GHz for the first mode and 10% at 6.5 GHz for the second mode, respectively. The proposed antenna has three layers of dielectric substrates. The circular ring patch on the upper layer is a radiation element for the first mode and the one on the middle layer is a radiation element for the second mode. The two L-probes to excite the patches on the upper and middle layers are deposited on the lower layer. For wideband characteristics, the L-probes were implemented with a thick dielectric substrate. At 4.75 GHz for the first mode, the height of the overall antenna \( t_1 + t_2 + t_3 \) is corresponding to approximately 0.114 wavelengths. Two L-probes are placed at orthogonal positions to achieve dual linear polarizations. 50-Ω coaxial connectors were attached to the backside of the ground plane of the L-probes for feeding. Port 1 and port 2 are assumed to feed the two L-probes that excite orthogonal linear polarizations for the simulation. The relative dielectric constant of the dielectric substrates was \( \varepsilon_r = 2.6 \), and the loss tangent was \( \tan \delta = 1.8 \times 10^{-3} \). The proposed antenna presented in Fig. 1 was simulated and measured. The simulations were performed with Zeland IE3D and ANSYS HFSS.

3 Simulated and measured results of the proposed antenna

Figure 2 (a) presents the measured and simulated reflection characteristics (S11 and S22) of the proposed antenna, where only the simulated results of the port 1 are presented because of the structural symmetry. The antenna was confirmed to
achieve good wideband characteristics for the both port 1 and port 2 and for the both target bands. Two frequency ranges of S11 with a reflection of less than $-10\,\text{dB}$ were 4.1–5.1 GHz for the first mode and 6.2–6.9 GHz for the second mode. The fractional bandwidths are 21.7% for the first mode and 10.6% for the second mode, respectively. The simulated and measured results were in good agreement.

Figure 2 (b) presents the measured and simulated isolation characteristics (S12) between the two ports of the proposed antenna, where only the results of S12 are presented due to the reciprocity. Good isolation characteristics between the two ports over the target bands were confirmed. The measured isolation characteristics in the above bandwidths were from 13 to 22 dB for the first mode and 13 to 24 dB for the second mode. The simulated and measured results were in good agreement.

Figure 2 (c) presents the measured gain of the proposed antenna excited by the port 1 and port 2, and the simulated gain excited by the port 1 of the antenna, where only the simulated gain of the port 1 is presented because of the structural symmetry. The measured gain of the port 1 was 4.7–7.1 dBi in the first mode and 3.6–5.1 dBi in the second mode. The gain of the port 2 was measured similarly. The simulated and measured results were in good agreement. Figure 2 (d) shows the measured and simulated radiation patterns of the proposed antenna excited by the port 1 at 4.1 and 5.1 GHz of the first mode and at 6.2 and 6.9 GHz of the second one, where only the radiation patterns excited by the port 1 are presented because of the structural symmetry. The radiation patterns of co-polarization in both the E- and H-planes were good and stable. The cross-polarization in H-plane is increasing as the frequency is increased because of unwanted radiation from the L-probe, however, the measured cross-polarization at the broadside direction was preserved below $-12\,\text{dB}$ at the frequencies. The simulated and measured patterns of co-polarization were in good
agreement. These results confirmed that the proposed antenna shown in Fig. 1 has good wideband, dual-band, and isolation characteristics for dual linear polarizations.

4 Performance of the proposed antenna

The performance of the proposed antenna in comparison with the antennas of Ref. [10] to [13] is summarized in Table I. The proposed antenna exhibits 1.7 times wider bandwidth for the lower band in comparison with Ref. [10] while the antenna height of the proposed antenna is larger. On the other hand, the proposed

Fig. 2. Characteristics of the proposed antenna
The performance of the proposed antenna in comparison with the antennas of Ref. [10]–[13] is simple and compact in comparison with Ref. [11] to [13] because the patch for the upper band is arranged beneath the patch for the upper band. Additionally, only two L-probes are used and additional feeding circuits and structures for isolation improvement are not necessary for the proposed antenna, although the isolation characteristics are degraded in comparison with Ref. [11] to [13].

### 5 Conclusions

This paper presented the linearly dual-polarized wideband and dual-band MSAs fed by two L-probes. In order to realize a linearly dual-polarized antenna, two L-probes are placed at the orthogonal positions of the proposed antenna. Good wideband characteristics were confirmed for the both bands and for the both ports. The fractional bandwidths of $-10$ dB reflection were 21.7% for the first mode and 10.6% for the second mode, respectively. Furthermore, good isolation characteristics between the two ports were confirmed. The isolation in the two bands was larger than 13 dB. The validity of the proposed antenna as a linearly dual-polarized wideband and dual-band planar antenna was demonstrated by measurement and simulation.

### Table I. The performance of the proposed antenna in comparison with the antennas of Ref. [10]–[13]

| Antenna Design          | Proposed | Ref. [10] | Ref. [11] | Ref. [12] | Ref. [13] |
|-------------------------|----------|-----------|-----------|-----------|-----------|
| Fractional bandwidth of lower and upper bands | 21.7% 10.7% (below $-10$ dB reflection) | 12.4% 14.9% (below $-10$ dB reflection) | 43.9% 55.2% (below $-10$ dB reflection) | 19.8% (below $-14$ dB reflection) | 15.7% 23.7% (below $-14$ dB reflection) |
| Minimum isolation in the above bands (dB) | 13 | 17 | 30 | 36 | 30 |
| Polarization            | Dual linear | Dual linear | Dual circular | Dual linear | Dual linear |
| Number of L-probes      | 2 | 2 | 8 (Need for feeding circuits) | 4 (Need for feeding circuits) | 4 |
| Height (wavelength of lower band) | 0.114 | 0.090 | 0.150 | 0.132 | 0.195 |