A Dual-Band Frequency-Tunable Varactor-Loaded Single-Layer Multi-Ring Microstrip Antenna

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***Abstract* - This paper presents a dual-band frequency-tunable single-layer multi-ring microstrip antenna (MR-MSA) fed by an L-probe with varactor diodes. In order to develop a frequency-tunable multiband planar antenna, two split ring patches with two varactor diodes mounted on each ring patch are arranged concentrically on a dielectric substrate. An L-shaped feeding probe arranged in the same layer as the ring patches is used to excite them. The antenna structure is processed with a single-layer substrate, while bias circuits to apply a DC voltage to the varactor diodes are placed on the backside of the ground plane of the MR-MSA with another thin dielectric substrate. A prototype antenna is designed and tested. The measured results reveal that two resonant frequencies of the proposed antenna can be controlled by the DC bias voltage almost independently and that fractional bandwidth of the frequency-tunable range of the test antenna is around 10% for the both modes under the condition of more than 3 dBi gain. Basic operation of the proposed antenna is demonstrated by the measurement.**

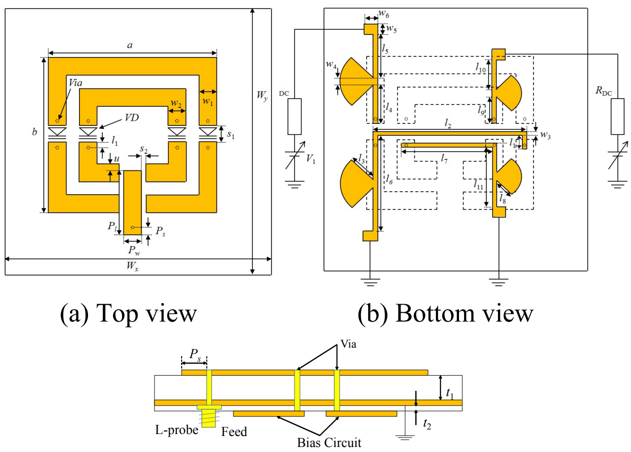
***Index Terms* — Planar antenna, Microstrip antenna, Multiband antenna, Frequency-tunable antenna, Reconfigurable antenna, Varactor diode.**

1. Introduction

Multiband or wideband antennas have been studied intensively for various wireless applications such as mobile communication systems and car electronics. In order to meet the trends, multi-ring microstrip antennas (MR-MSAs) have been proposed as a multiband planar antenna [1], [2]. The MR-MSA is composed of multiple ring patches placed concentrically on the upper dielectric substrate and an L-shaped feeding probe (L-probe) formed in the lower substrate [3], [4]. The MR-MSA provides excellent multiband performance as well as design flexibility because operating frequencies and its polarization including linear or circular polarization can be controlled very readily. One of disadvantages of the MR-MSA is narrow bandwidth of the operating frequencies. For the problem of narrow bandwidth of microstrip antennas, frequency-tunable MSAs with varactor diodes [5], [6] or with variable reactance circuits [7], [8] are reported. In order to realize a frequency-tunable multiband planar antenna, the MR-MSAs with variable reactance circuits [9] or with varactor diodes [10], [11] are proposed. In these antenna configurations, the variable reactance circuits or the varactor diodes are used to control the operation frequencies of the MR-MSA. A disadvantage of these antenna configurations is that a double-layer dielectric substrate is used for the MR-MSA.

On the other hand, a single-layer MR-MSA for linear polarization, in which the L-probe is arranged on the same dielectric substrate as the ring patches, is also developed by the authors [12]. In order to develop a frequency-tunable single-layer multiband planar antenna, frequency-tunable single-layer ring MSAs fed by an L-probe with varactor diodes are proposed [13]-[15].

In this paper, a dual-band frequency-tunable varactor-loaded single-layer MR-MSA fed by an L-probe is designed. Two ring patches are arranged concentrically and two varactor diodes are mounted on each ring patch for frequency-tunable dual-band operation. Two resonant frequencies of the proposed antenna are controlled by a DC bias voltage of the varactor diodes almost independently. The bias circuits that supply the DC voltage to the varactor diodes are placed on the backside of the ground plane of the MR-MSA. Firstly, basic configuration of the proposed antenna is described. Then, the measured performance of the prototype antenna including frequency-tunability is presented.



(a) Top view (b) Bottom view

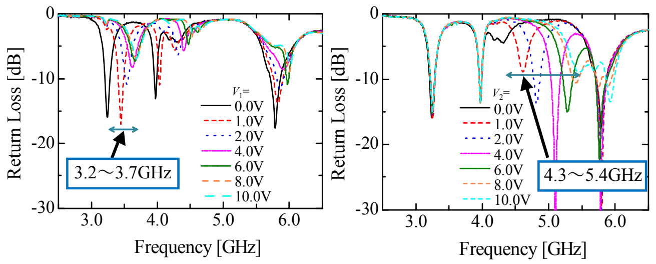
(c) Side view

W_x=80.0, W_y=80.0, a=b=22.1, c=d=16.1, w_1=w_2=2.5, w_3=0.4, w_4=0.8, w_5=w_6=3.4, s_1=1.5, s_2=0.3, P_l=7.0, P_w=1.0, P_s=0.75, u=0.5, l_1=1.7, l_2=20, l_3=12.7, l_4=12.9, l_5=15.3, l_6=31.3, l_7=13.8, l_8=8.7, l_9=8.9, l_{10}=8.5, l_{11}=18.0, t_1=2.4, t_2=0.6, unit:[mm], ε_r=2.6, θ=90deg., R_{DC}=10kΩ, V_1=0~10V, V_2=0~10V

Fig. 1. Configuration of a dual-band frequency-tunable varactor-loaded single-layer ring microstrip antenna.

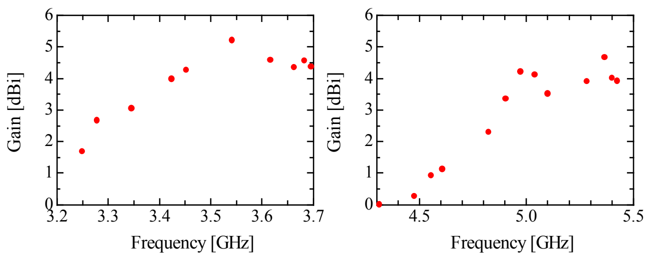
2. Configuration of the proposed antenna

Figure 1 presents configuration of the dual-band frequency-tunable varactor-loaded single-layer MR-MSA. Two square split ring patches and an L-shaped probe are placed on a dielectric substrate with a relative constant of 2.6 and a thickness of 2.4 mm. In order to control the resonant frequency as well as to preserve structural symmetry, two varactor diodes are mounted over the slits of the both sides of each ring patch, where the current on the ring patch is maximized. Bias circuits that supply DC voltages V_1 for the 1st mode and V_2 for the 2nd mode to the varactor diodes, RF choke circuits are designed for each patches and placed on the backside of the MR-MSA with another dielectric substrate of 0.6 mm thickness. The ring patch and the bias circuits are connected with via holes. Output lines of a DC power supply are connected at the ends of the bias circuits. Resonant frequencies of the ring patch can be controlled electronically since capacitance of the varactor diode is changed with the DC bias voltage.



(a) V_1 varied (V_2=0V) (b) V_2 varied (V_1=0V)

Fig. 2. Measured reflection characteristics of the test antenna.



(a) V_1 varied (V_2=0V) (b) V_2 varied (V_1=0V)

Fig. 3. Measured gain of the test antenna.

3. Measured results

Figure 2 presents measured reflection characteristics of the prototype antenna with varactor diodes as shown in Fig. 1, where the DC bias voltages V_1 and V_2 are varied from 0 to 10 V. The resonant frequency of the test antenna is varied from 3.2 to 3.7 GHz for the 1st mode and from 4.3 to 5.4 GHz for the 2nd mode. The both resonant frequencies are controlled almost independently Figure 3 presents frequency dependence of measured gain of the 1st and 2nd modes of the test antenna when the DC bias voltages V_1 and V_2 are changed from 0 to 10 V, respectively. The frequency-variable ranges of the test antenna under the condition of more than 3 dBi gain is from 3.35 to 3.7 GHz for the 1st mode and from 4.9 to 5.42 GHz for the 2nd mode. They are corresponding to around 10% fractional bandwidth. It is confirmed that measured radiation patterns of the test antenna are very stable and low cross polarization within the both tunable frequency ranges [16].

4. Conclusion

This paper presents the dual-band frequency-tunable varactor-loaded single-layer MR-MSA. Dual operating frequencies of the MR-MSA can be controlled with the DC bias voltages applied to the varactor diodes almost independently. The fractional bandwidth more than 3 dBi gain is around 10% for the both frequencies. Basic operation of the proposed dual-band frequency-tunable MSA is demonstrated by the measurement.

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