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Dual-mode Stepped-impedance Resonator with High Signal Suppression

Phatsakul Thitimahatthanakusol
Department of Telecommunication Engineering, Faculty of Engineering and Technology
Rajamangala University of Technology Isan
744 Sura Narai Rd, Nai-muang, muang, Nakorn Ratchasima,Thailand
phatsagul@gmail.com

Nattapong Intarawiset
Department of Industrial Education and Technology, Faculty of Engineering
Rajamangala University of Technology Lanna
128 Huay Kaew Rd., Muang, Chiang Mai 50300,Thailand
nattapong.i@rmutl.ac.th

Jessada Konpang
Department of Electrical and Telecommunication Engineering, Faculty of Engineering,
Rajamangala University of Technology Krungthep
2 Nanglingee Rd., Thungmahamek, Sathorn, Bangkok 10120, Thailand
Jessada.k@mail.rmutk.ac.th

***Abstract*— A dual-mode stepped-impedance resonator with noise elimination is presented in this paper. The dual-mode resonator is designed as a meander input/output coupling port and still has a compact circuit structure. This circuit structure can also have a good passband in the operating frequency and eliminate interference from the required band. The operating response of the resonator circuit at a central frequency is 2.1 GHz. The passband of the proposed resonator has a loss of insertion at 0.52 dB and a loss of reflection at 30 dB. The frequency range of 2.5 to 5.5 GHz is suppressed by increasing the folded input/output feed, resulting in a 20 dB rejection.**

Keywords—stepped-impedance, upper stopband rejection, meander line, small circuit

I. Introduction

In communication systems, the filter planar circuits are trendy to design on the microstrip's structure. Generally, the filter circuits are designed using single-mode or dual-mode resonators, in which dual-mode forms are smaller than single-mode resonators because they can be half the size based on the doubly tuned resonant circuit principle [1]. There are a variety of different structures in the analysis, including the design of dual-mode using a circular ring structure [2], the design of microstrip square loop resonator [3], and the different dual-mode forms with circular disk and square patch [4], [5].

Popular methods include adding the bandstop or notched filter at the input/output port [6]. The defective ground makes circuit structures at the bottom designs and electromagnetic bandgap [7]; these design attempt to eliminate circuit interference. The dual-mode resonator as presented in [8]-[11]. The two frequencies are placed close together in the form of dual-mode resonance. However, the open loop resonator will have interference in which the upper side harmonics reduce the filter performance. So it is still interesting to design circuits with high suppression performance, small structure size, and low losses.

This paper introduces a dual-mode stepped-impedance resonator with a wide upper stopband using a meander input/output coupling port. The tuning stepped impedance resonator helps the structure with easy tuning frequency. It also has a small structure size and high efficiency.

II. Tuning Stepped-impedance on Open loop Resonator

This structure consists of two main parts: the open loop microstrip, which creates the first mode (odd mode). The tuning stepped impedance stub for changing the second frequency, which is called the even mode [10], which allows the two frequencies to be freely adjusted to each other.

The half-wavelength open-circuit resonator is presented in an even mode, as mentioned in Fig. 2(a). The quarter wavelength short-circuit resonator is presented in an odd mode, as presented in Fig. 2(b). A tuning stepped impedance resonator is placed to reduce the size of the open tuning stub at the resonator's center. The electrical lengths in each impedance, as mentioned in Figure 1, can be calculated as shown in the equation below.

$$\theta_1 \cong \frac{\pi}{2} \tag{1}$$

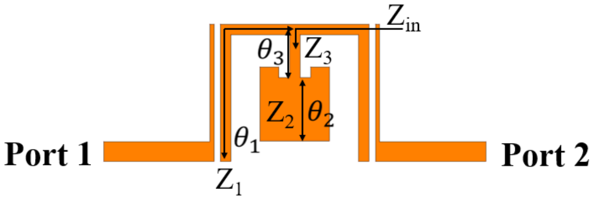

Fig. 1. The proposed structure using tuning stepped-impedance

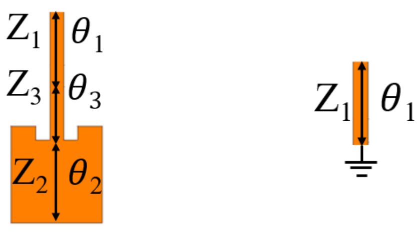

Fig. 2. The even-mode structure (a) and the odd-mode structure (b) of resonator circuit

The main resonator (Z_1) is connected by a tuning open stub (Z_2, Z_3) at the middle point. The tuning open stub with impedance Z_2 and Z_3 are represented by αZ_2 and βZ_3, which defines $R = \beta Z_3/\alpha Z_2$ and $R > 1$ and the $\beta Z_3 > \alpha Z_2$. The calculation of electrical length θ_2 is calculated by [11].

$$\theta_2 = cos^{-1}\left(\sqrt{\frac{R(R-1)}{(R^2-1)}}\right) \quad (2)$$

The open-circuited tuning stub has an electrical length (θ_3) that can be calculated from [11]

$$\theta_3 \cong (\pi + \text{atan}[-Rtan(\theta_2)]) - \left(\frac{c}{4f_{odd}\sqrt{\varepsilon_{eff}}}\right) \quad (3)$$

where θ_x (x = 1,2,3) is the electrical length and c is denoted as the speed of light in a vacuum.

The EM (Electromagnetic) program, specifically the IE3D Simulator, is utilized to design and simulate the structure of the dual-mode filter. The filter is developed on a dielectric substrate with a relative permittivity of 6.15 and a height of 1.27 mm, as depicted in Fig. 3. Input/output cables are used to transmit signals using a coupling line (cf) and gap (g). The stepped impedance open stub is used to tune dual-mode resonators' odd and even modes.

The fundamental frequency is determined by the resonator's size (a and c). The stub's length (d and e) can adjust the tuning second frequency. Fig.4 shows the frequency response of S_{21}, which does not affect S_{21} when varying the length of the open-stepped impedance stub. Moreover, The second resonance can be changed by using the length of (d) and has transmission zero (TZ) that produces a sharp response.

Table I provides the dimensions of the conventional dual-mode resonator, while Fig. 5 illustrates the current distribution on the resonator's surface at the operational frequency of 2.14 GHz. It is evident from the figure that the resonant frequency exhibits a highly distributed current. Fig. 6 showcases the simulated S-parameters of the fundamental dual-mode structure, demonstrating a resonant frequency of 2.14 GHz with an achievement of 0.53 dB insertion loss and 25 dB return loss. The fractional bandwidth (FBW) of the dual-mode filter is measured to be 2.8%. Nevertheless, the presence of spurious frequencies at 5 GHz attenuates the fundamental frequency, leading to interference issues.

TABLE I. THE BASIC DUAL-MODE STRUCTURE

Parameters of dual-mode sturcture	mm
w	1
wf	1.87
cf	0.4
g	0.6
a	14
b	0.9
c	11
f	10

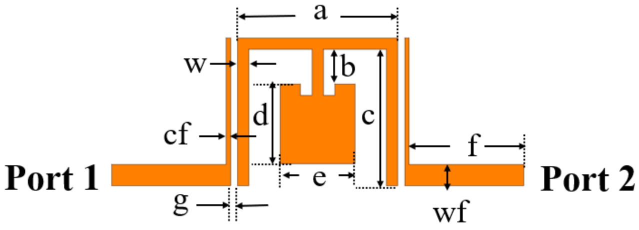

Fig. 3. The normal dual-mode configuration

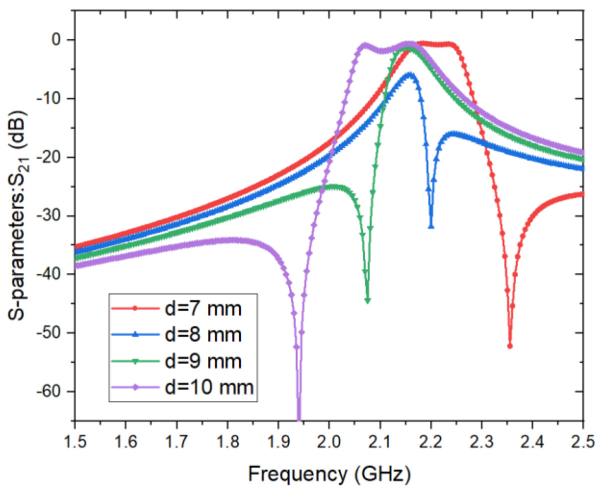

Fig. 4. Simulated response of tuning stub (d)

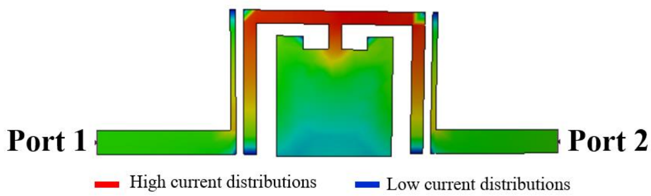

Fig. 5. The current surface on the resonator filter

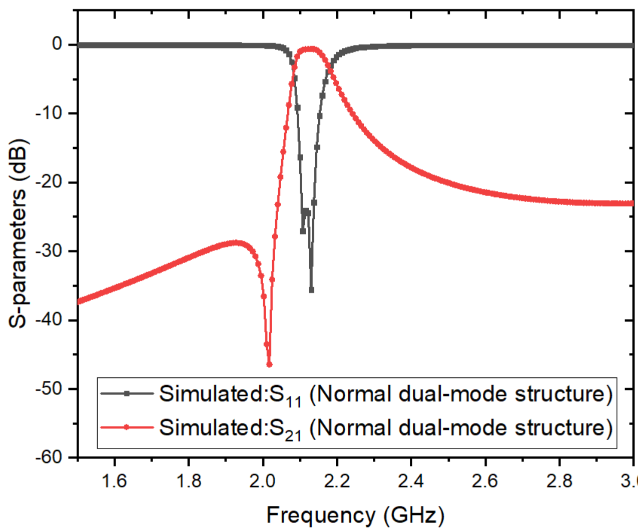

Fig. 6. The frequency respons of the conventrional circuit

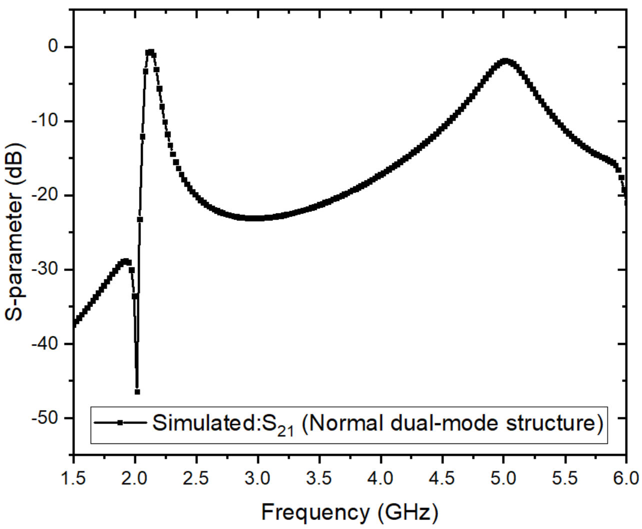

Fig. 7. The simulated wideband results of the insetion loss S_{21}

III. Proposed Resonator Filter with High Signal Suppression

The dual-mode resonator is designed as a meander input/output coupling port and still has a compact circuit structure for the upper stopband rejection. The meander feed lines are illustrated in Fig. 8, which are used to couple the signal between the feed lines and the dual-mode resonator. The dimensions of the proposed dual-mode filter structure are the same as those shown in Table I, except that the value of the meander feed lines L1 is 1.4 mm, and L2 is 8 mm for the proposed dual-mode filter with meander feed lines. The adding meander feed lines have a similar effect to the bandstop filter, which suppress higher frequency. Fig. 9 illustrates the wideband responses of S_{21}. By changing the length of L2 from 4 to 7 mm, it can be observed that the noise value is attenuated. The first frequency (2.14 GHz) remains unchanged, and the $/S_{21}/$ value is attenuated below 25 dB at 5 GHz.

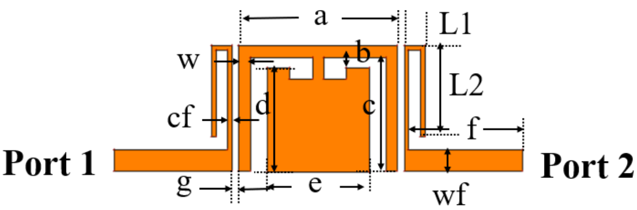

Fig. 8. Geometric structure of the proposed filter with meander feeds

Fig. 10 illustrates the flow of distributed current on the resonator and the meander-coupled feed lines. The center frequency of the proposed resonator circuit is 2.1 GHz. The passband of the proposed resonator has a loss of insertion at 0.52 dB and a loss of reflection at 30 dB, as shown in Fig. 11. The proposed dual-mode filter has fractional bandwidth (FBW) is 2.8%. The broad range of frequencies of S_{21} is shown in Fig. 12. The frequency range of 2.5 to 5.5 GHz is suppressed by increasing the folded input/output feed, resulting in a 20 dB rejection.

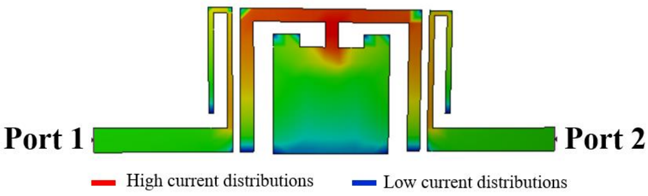

Fig. 10. The current surface on resonator filter with meander feeds

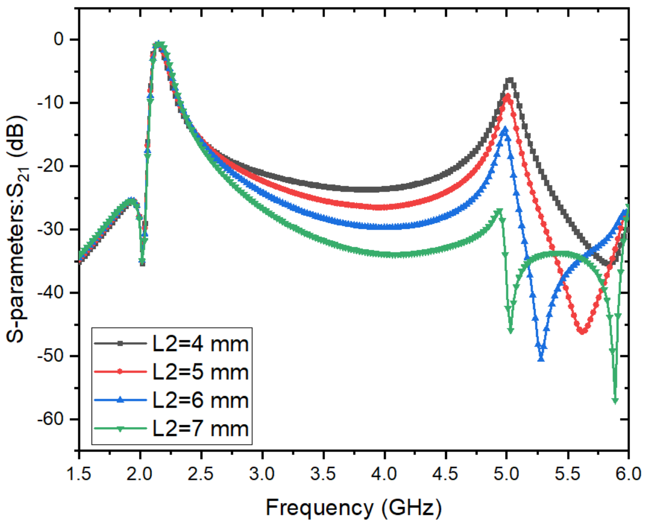

Fig. 9. The simulated results of S_{21} with different lengths of of tuning L2

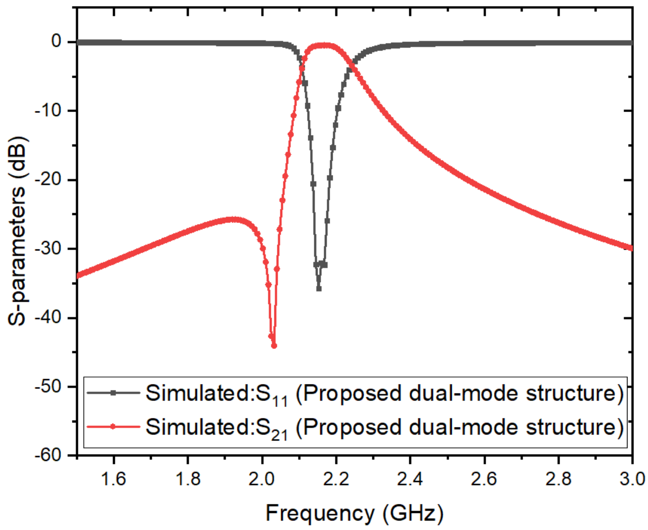

Fig. 11. The simulated S-parameters of narrowband responses

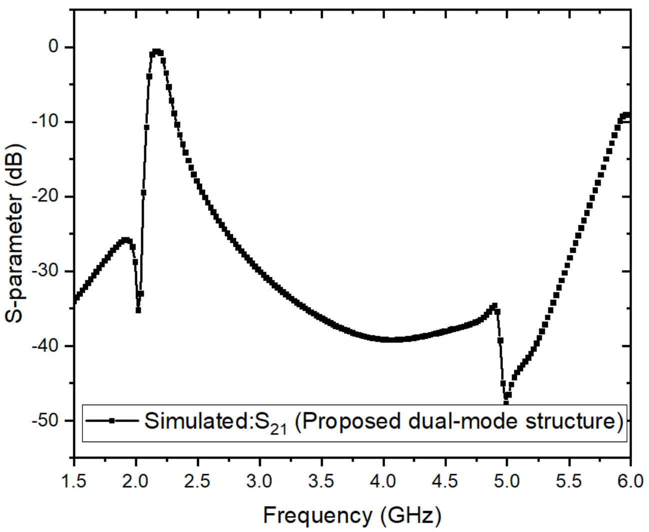

Fig. 12. The simulated s-parameters of wideband responses

IV. Conclusions

This paper presents the small dual-mode resonator, designed as a meander input/output coupling port. This circuit structure can also have a good passband in the operating frequency and out-of-band rejection. The operating response of the resonator circuit at a central frequency is 2.1 GHz. The passband of the proposed resonator has a loss of insertion at 0.52 dB and a loss of reflection at 30 dB. This proposed dual-mode offers a 20 dB upper stopband rejection in the 2.5 to 5.5 GHz frequency range.

Acknowledgment

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