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A Frequency Tunable Double Band-Stop Resonator with Voltage Control by Varactor Diodes

Yang Wang[1] · Ki-Cheol Yoon[1,2,3] · Jong-Chul Lee[1,*]

Abstract

In this paper, a frequency tunable double band-stop resonator (BSR) with voltage control by varactor diodes is suggested. It makes use of a half-wavelength shunt stub as its conventional basic structure, which is replaced by the distributed LC block. Taking advantage of the nonlinear relationship between the frequency and electrical length of the distributed LC block, a dual-band device can be designed easily. With two varactor diodes, the stop-band of the resonator can be easily tuned by controlling the electrical length of the resonator structure. The measurement results show the tuning ranges of the two operating frequencies to be 1.82 GHz to 2.03 GHz and 2.81 GHz to 3.03 GHz, respectively. The entire size of the resonator is 10 mm × 11 mm, which is very compact.

Key Words: Band-Stop Resonator, Dual-Band, Half-Wavelength, Transmission Line, Varactor Diode.

I. INTRODUCTION

Many high-performance radio frequency (RF) and microwave circuits are required these days for electronic systems. Attention has been given to low cost, miniaturized, multiband, and frequency tunable propriety. A microstrip structure is cheap, easy to fabricate, and easy to be integrated into an electronic system. For size reduction, some novel topologies are applied [1, 2], and some metamaterial related composite right/left-handed (CRLH) transmission lines are used [3–5]. Multi-band devices are playing an increasingly important role in integrated circuits, as it can be realized for multi-functions without increasing the physical size significantly [6, 7]. For tunability, varactor diodes are used in many designs [8, 9].

In this paper, a compact frequency tunable dual-band bandstop resonator (BSR) is presented. The proposed resonator takes use of a distributed LC block structure as a shunt part of the circuit. The proposed resonator is compact and tunable, and its entire size is 10 mm × 11 mm with tunable double-resonant frequencies of 1.82 GHz to 2.03 GHz and 2.81 GHz to 3.03 GHz.

This paper is divided into the following parts. In Section II, the resonator design and the instruction are proposed; in Section III, the simulation and measurement results are discussed; and the conclusion will follow in the last section.

II. RESONATOR DESIGN

The resonator designed in this paper is based on a kind of shunted half-wavelength transmission line with a short stub, as shown in Fig. 1. The resonance condition is reached when its electrical length βl reaches $n\lambda_g/2$, where n is an arbitrary

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[1] Department of Radio Science and Engineering, Kwangwoon University, Seoul, Korea.
[2] RFIC Center, Kwangwoon University, Seoul, Korea.
[3] The Cho Chun Shik Graduate School for Green Transportation, KAIST, Daejeon, Korea.
[*] Corresponding Author: Jong-Chul Lee (e-mail: jclee@kw.ac.kr)

integer. The resonator will show a stop-band characteristic at these frequencies. In this paper, the distributed LC block structure is inserted into a half-wavelength transmission line and it provides a tunable phase response with a compact size.

Fig. 2 shows the geometry of the proposed resonator, and Fig. 3 shows the related equivalent circuit. The distributed elements are added in Fig. 3 (L_R and C_R), because they will produce an unavoidable affect in the phase characteristic. The structure is designed on a Teflon substrate with a thickness of 0.54 mm and a dielectric constant of 2.54.

In this shunt structure, as shown in Figs. 2 and 3, two interdigital capacitors and varactor diodes with bias voltages act as tunable capacitive components (C_{L1} and C_{L2} in Fig. 3) in the shunt part. The inductors are realized using distributed components, and the RF choke inductor and bypass capacitor are used to isolate the DC source from the RF signal. Lumped elements are applied in the RF choke and bypass circuit for good performance.

The capacitance of the capacitors C_{L1} and C_{L2} can be set freely in this shunt circumstance to control the relationship between the electrical length and the frequency. The component value of the transmission line will affect this relationship greatly; then, the electrical length in a specified frequency will be changed rapidly while changing the component values. The circuit shows frequency rejection when the electrical length of the short-ended shunt stub reaches $n\lambda_g/2$. The simulation of the phase response for the distributed LC block part with a different DC voltage supplied is carried out through the combined simulation from AWR and ADS, and one of the results is as shown in Fig. 4 for evaluation. The electrical lengths in the frequency of 1.9 GHz and 2.9 GHz correspond to 0 and $\lambda_g/2$, respectively. Furthermore, the tunable electrical length of the shunt part can be realized by tuning the DC voltages.

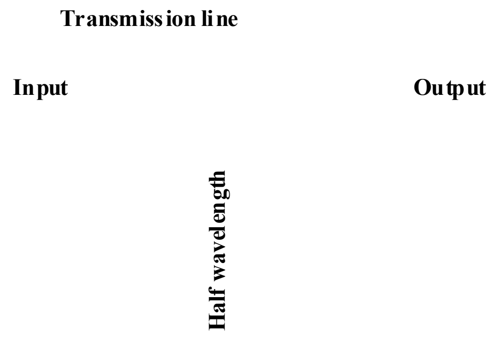


Fig. 1. Structure of the half-wavelength band-stop resonator.

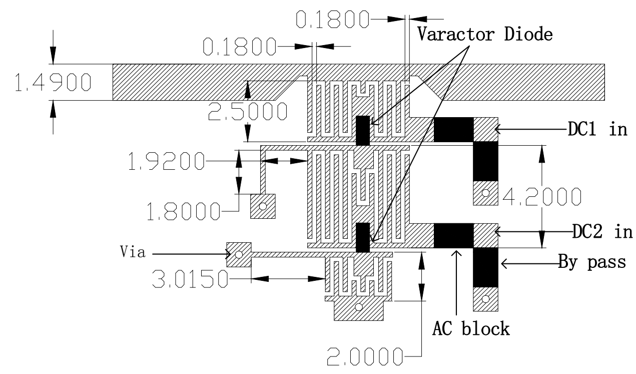


Fig. 2. Layout of the proposed resonator (units in mm).

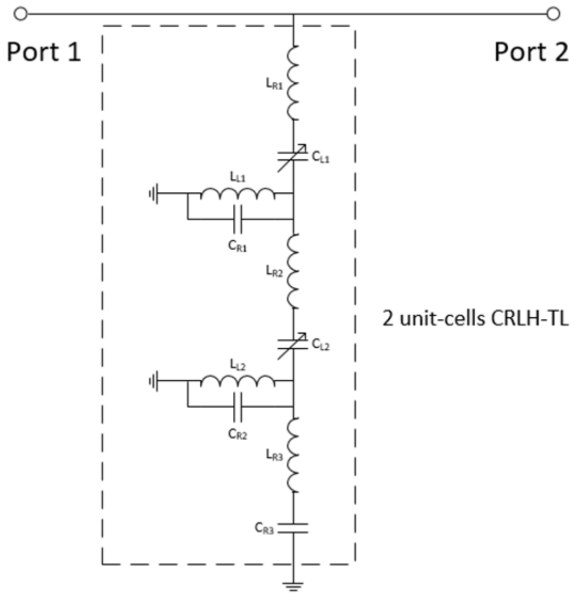


Fig. 3. Equivalent circuit of the proposed resonator.

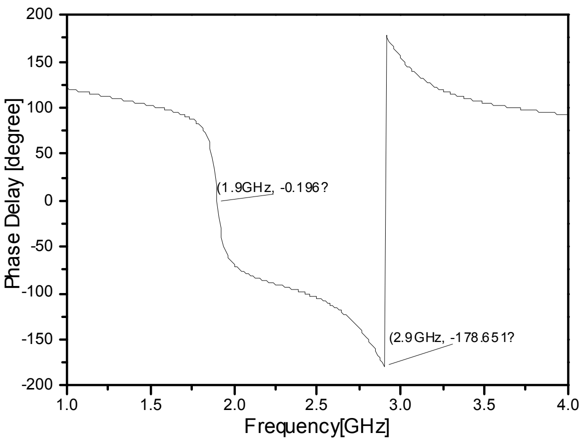
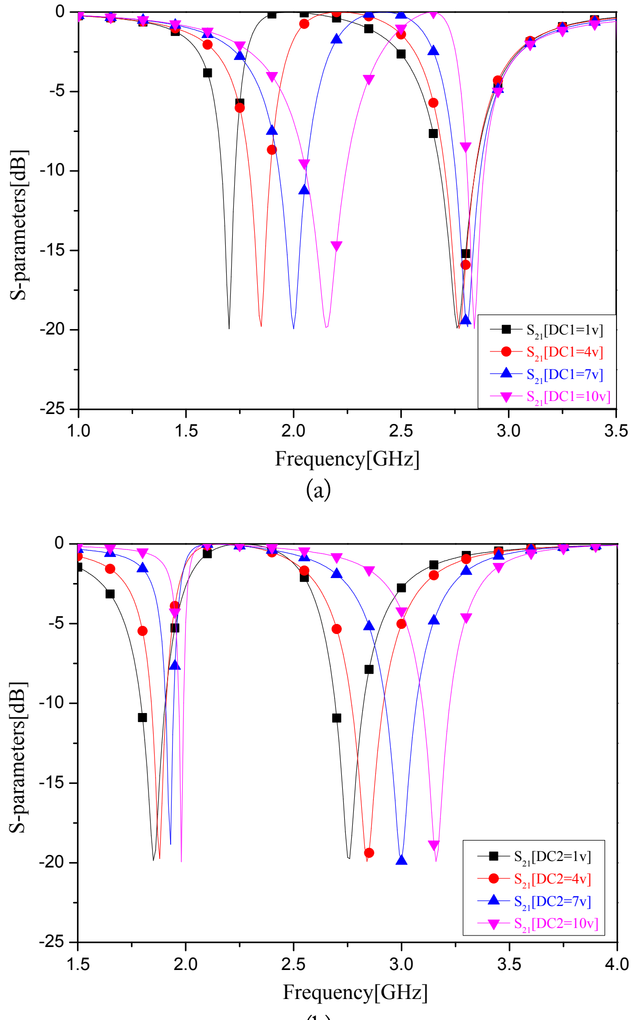


Fig. 4. Phase response of the shunt part circuit in the proposed resonator.

III. SIMULATION AND EXPERIMENT RESULTS

The simulations are carried out using ADS 2012 and AWR simulation software. The simulation results are shown in Fig. 5. Fig. 5 shows the S_{21} parameters as a function of the voltage



(a)

(b)

Fig. 5. Simulation results of the proposed resonator. (a) S_{21} parameter as a function of DC1 with DC2 fixed to 4 V. (b) S_{21} parameter as a function of DC2 with DC1 fixed to 1 V.

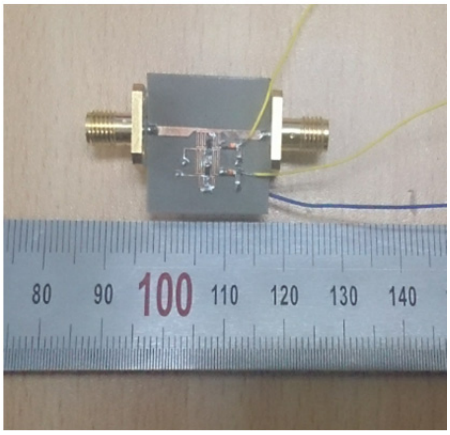


Fig. 6. Photograph of the proposed resonator.

of DC1 and DC2 with the other DC supply fixed. The applied voltage range is from 1 V to 10 V, referring to the applied diode. The result calls for the operating frequency of the resonator to be tunable at two frequency bands: 1.72 GHz to 2.15 GHz and 2.76 GHz to 3.15 GHz, respectively, with an insertion loss of around −20 dB. The limitation of the frequency range depends on the capacitance tuning range of the varactor diodes.

A photograph of the proposed resonator is shown in Fig. 6. The two lighter wires connect to two DC supplies and the darker wire is to be connected to the ground. An Agilent vector network analyzer (VNA) is used to measure the resonator. All measurement results are listed in Table 1. For comparison, some of the DC supply conditions are picked and their *S*-parameters are drawn into two figures, which are shown in Fig. 7. They indicate that the first tuning range (operating frequency as a function of DC1 with DC2 = 1 V) is 1.82 GHz to 2.03 GHz, and the second tuning range (operating frequency as a function of DC2 with DC1 = 10 V) is 2.81 GHz to 3.03 GHz, where the tuning bandwidths are 10.91% and 7.53%, respectively. The DC supply condition we chose here differs from that of the simulation condition, however. The entire size of the proposed resonator is 10 mm

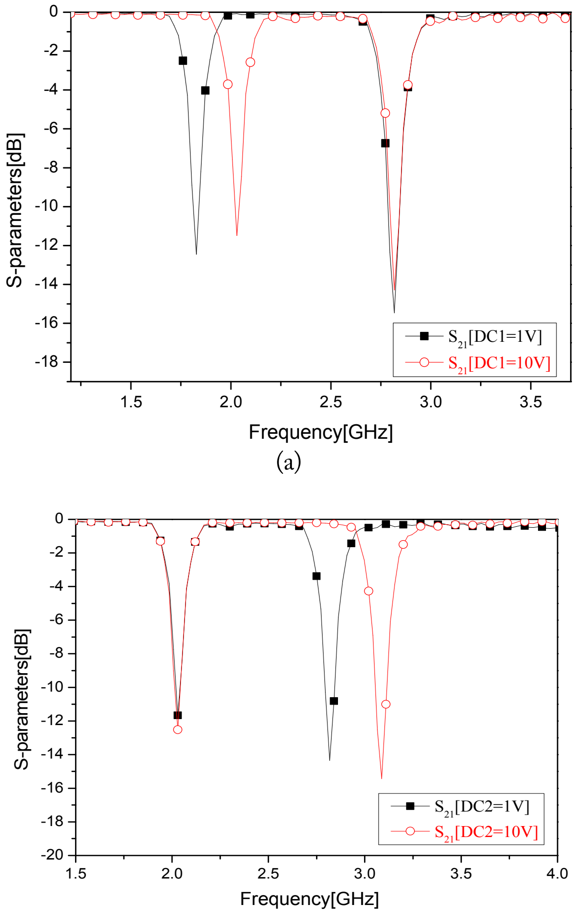
Table 1. Measured operating frequencies with the tuning of DC supplies

DC1	DC2					
	1 V	3 V	5 V	7 V	9 V	10 V
1 V	1.82, 2.81	1.82, 2.90	1.82, 2.98	1.82, 3.05	1.82, 3.06	1.82, 3.07
2 V	1.87, 2.81	1.87, 2.90	1.87, 2.98	1.88, 3.05	1.88, 3.06	1.88, 3.07
3 V	1.92, 2.81	1.92, 2.91	1.92, 2.98	1.92, 3.06	1.92, 3.07	1.92, 3.07
4 V	1.96, 2.82	1.96, 2.91	1.96, 2.99	1.92, 3.06	1.92, 3.07	1.96, 3.07
5 V	1.98, 2.82	1.99, 2.92	1.99, 2.99	1.98, 3.04	1.99, 3.07	1.99, 3.07
6 V	2.00, 2.82	2.00, 2.92	2.00, 2.99	2.00, 3.06	2.00, 3.07	2.00, 3.07
7 V	2.01, 2.82	2.01, 2.92	2.01, 3.00	2.01, 3.06	2.01, 3.08	2.01, 3.07
8 V	2.02, 2.82	2.01, 2.91	2.02, 3.00	2.02, 3.06	2.02, 3.08	2.02, 3.08
9 V	2.03, 2.82	2.03, 2.92	2.03, 3.00	2.03, 3.06	2.03, 3.08	2.03, 3.08
10 V	2.03, 2.82	2.03, 2.92	2.03, 3.00	2.03, 3.06	2.03, 3.08	2.03, 3.08

Values are presented as freq/GHz (f_1, f_2).

Table 2. Size comparison between the proposed resonator and other works

Ref.	Operating frequency/frequencies	ε_r	Size (mm)
This work	1.82–2.03 GHz and 2.81–3.03 GHz	2.54	10 × 11
[10]	850 MHz and 2.5 GHz	4.3	26.3 × 43
[11]	1.494 GHz	10.2	15.3 × 10.8
[12]	3.5 GHz	6.15	6.5 × 14



(a)

(b)

Fig. 7. Measurement results of the proposed resonator. (a) S_{21} parameter as a function of DC1 with DC2 fixed to 1 V. (b) S_{21} parameter as a function of DC2 with DC1 fixed to 10 V.

× 11 mm, which is compact both physically and electrically compared to some other recent resonator designs, and it has an extra function of frequency tunability. The comparisons are shown in Table 2 [10–12]. The measurement results and size of the proposed resonator are in good agreement overall with the simulation ones.

IV. CONCLUSION

In this paper, a compact tunable dual-band BSR has been proposed. The shunt stub with a distributed LC block can be achieved for a tunable property in the frequency response. By setting the input voltages (from 1 V to 10 V) of the two ports, the operating frequency band can be easily tuned with a good frequency rejection. The simulation and the experiment results are in good agreement. This proposed resonator is compact and may achieve a self-tuning function with proper feedback when used in microwave circuit systems.

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Yang Wang

received his B.S. degree in Electric and Information Engineering from Harbin Institute of Technology (HIT), China, in 2013. Since then, he has joined WICS Lab., Dept. of Radio Science and Engineering in Kwangwoon University, Korea, working toward his Ph.D. degree under the supervision of Prof. Jong-Chul Lee. His research interests are RF devices and electromagnetic metamaterials.

Ki-Cheol Yoon

received his M.S. and Ph. D. degrees in Radio Science and Engineering from Kwangwoon University in 2007 and 2011, respectively. He is a chief research scientist at Korea Advanced Institute of Science and Technology (KAIST) in Daejeon, Korea. His research interests are wireless power transfer and bio-medical science.

Jong-Chul Lee

received the B.S. and M.S. degrees in electronic engineering from Hanyang University, Seoul, Korea in 1983 and 1985, respectively. He received the M.S. degree from Arizona State University, Tempe, Arizona in December 1989 and the Ph.D. degree from Texas A&M University, College Station, Texas in May 1994, all in electrical engineering. From June 1994 to February 1996, he was a senior researcher in Photonic Devices Lab., System IC R&D Lab., Hyundai Electronics Ind. Co., Ltd., Korea where he was involved in the development of several high speed laser diodes and photo diodes, and transmitter/receiver modules. Then, he joined the Department of Radio Science and Engineering at Kwangwoon University, Seoul, where he is currently a Professor. He also served as Project Director at ITRC RFIC Center, Kwangwoon University, which was funded by the Ministry of Information and Communication from Aug. 2000 to Aug. 2007. He is a Guest Professor in the Dept. of Electronics and Communication at Harbin Institute of Technology since December 2001. He was a Visiting Scholar at the Dept. of Electrical and Computer Eng., Univ. of California, San Diego from Dec. 2002 to Feb. 2004. He has authored and co-authored over 200 papers in international conferences and journals. His research interests include microwave and millimeter-wave passive and active devices, electromagnetic metamaterials, it convergence with bio-medical devices, and energy harvesting devices. He is a senior member of IEEE and a life-time member of KIEES, KICS, and KITS.