2022 Asia-Pacific Microwave Conference

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Program at a Glance

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Greetings from the Steering Committee Chair

Message From the Technical Program Committee Chair

2022 Asia-Pacific Microwave Conference Committee Officers

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Program at a Glance

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Technical Program

Program at a Glance | 11/30 (Wed) | 12/01 (Thu) | 12/02 (Fri) | Interactive Forum

12/02 (Fri) 09:15- | 12/02 (Fri) 12:45- | 12/02 (Fri) 15:15-

FR1-F1

Frequency/Signal Control Circuits

Room

F201

Date and Time

12/02 (Fri) 09:15-10:55

Category

Active Components

Chairs

Takayuki Tanaka (Saga Univ., Japan), Adel Barakat (Kyushu Univ., Japan)

Papers

01	09:15	PVT-Insensitive Ka-Band Class-D VCO with Average Current Control in 65 nm CMOS
		Chuan Ding, Yang He and Tiedi Zhang (UESTC, China); Chao Fan (Chengdu Corpro Technology Co., Ltd., China)
02	09:35	Fully Integrated Bandpass Filter with High Isolation Attenuator Function Using Semi-Conductor Distributed Doped Areas
		Corentin Le Lez, Rozenn Allanic, Denis Le Berre and Cédric Quendo (Univ. Brest, France); Rose-Marie Sauvage (DGA/AID, France); Aude Leuliet and Thomas Merlet (Thales-LAS, France); Douglas Silva De Vasconcellos, Virginie Grimal, Damien Valente and Jérôme Billoué (Université de Tours, France)
03	09:55	DC-Feedback-Mode Transistor Rectifier/Voltage-Doubler Diode Rectifier for Negative Gate Biasing to Microwave Power Amplifiers
		Taki Nagata, Kazuhiko Honjo and Ryo Ishikawa (The Univ. of Electro-Communications, Japan)
04	10:15	30GHz Band Double Voltage Rectifier MMIC with the 0.1 μm E-pHEMT Gated Anode Diode
		Naoya Kakutani, Fumiya Komatsu, Naoki Sakai and Kenji Itoh (Kanazawa Inst. of Tech., Japan)
05	10:35	Additional Loss Component in the Si-SBD Model for Low Power Rectennas in the High-Impedance Operation
		Takumi Itoh, Tsubasa Yonemura, Naoki Sakai and Kenji Itoh (Kanazawa Inst. of Tech., Japan)

FR1-F2

Advances in Synthesis and Design Techniques for Wideband Filters

Room

F202

Date and Time

12/02 (Fri) 09:15-10:55

Category

Passive Components

Chairs

Chun-Ping Chen (Kanagawa Univ., Japan), Xiaolong Wang (Jilin Univ., China)

Papers

01	09:15	High-Order Input-Reflectionless Quasi-Elliptic-Type Wideband Bandpass Filter Using Dual-Mode Slotline Resonator
		Li Yang (Univ. of Alcalá, Spain); Dimitra Psychogiou (Univ. College Cork, Ireland); Roberto Gómez-García (Univ. of Alcalá, Spain)
02	09:35	Arbitrary Prescribed Wideband Flat Group Delay Higher-Order Quasi-Reflectionless Bandpass Filter
		Girdhari Chaudhary, Phanam Pech, Jaehoon Lee and Yongchae Jeong (Jeonbuk National Univ., Korea)
03	09:55	GA-Optimized UWB Filters Using Slot-Loaded Two-Layered Microstrip Resonators
		Yuichi Tsujino, Yuichi Nishioka, Hiroyuki Deguchi and Mikio Tsuji (Doshisha Univ., Japan)
04	10:15	Synthesis Design of Wideband Differential Bandpass Filter with Intrinsic CM Noise Rejection Using Branch-Line Configuration
		Pin Wen and Zhewang Ma (Saitama Univ., Japan); Shuangshuang Zhu (Zhengzhou Univ., China); Fan Liu and Masataka Ohira (Saitama Univ., Japan)
05	10:35	Design of CRLH-TL UWB Filter Using Interdigital Capacitor and Short Stub by Genetic Algorithm
		Hinata Ishikawa, Atsuya Hirayama, Seiya Fujino, Takanobu Ohno, Kosei Tanii and Satoko Iida (National Inst. of Tech., Kisarazu College, Japan)

FR1-F3

EM Propagation and Antennas for Propagation Measurement

Room

F203

Date and Time

12/02 (Fri) 09:15-10:55

Category

Antennas & Propagation

Chairs

Sergio Colangeli (Univ. of Rome Tor Vergata, Italy), Takuichi Hirano (Tokyo City Univ., Japan)

Papers

01	09:15	A Compact Overmoded Waveguide Test Environment: Investigation of Propagation Behaviour
		Manuel Funk, Christoph Dahl, Jan Barowski, Ilona Rolfes and Christian Schulz (Ruhr-Universität Bochum, Germany)
02	09:35	A Transmitter Protection Scheme Through Reciprocal Elements
		Sergio Colangeli, Walter Ciccognani, Patrick E. Longhi, Antonio Serino and Ernesto Limiti (Università of Rome Tor Vergata, Italy)
03	09:55	Analysis and Design of Conformal Antenna Cavity for RCS Reduction
		Minhuan Chen (UESTC, China); Tao Dong (Beijing Institute of Satellite Information Engineering, China); Peng Yang (UESTC, China)
04	10:15	On Surface Wave Propagation Characteristics of Porosity-Based Reconfigurable Surfaces
		Zhiyuan Chu, Kai-Kit Wong and Kin-Fai Tong (Univ. College London, U.K.)
05	10:35	A Triple Band Notched UWB MIMO Antenna with Improved Performance
		Anees Abbas, Md. Abu Sufian, Jinkyu Jung, Azimov Uktam, Jaemin Lee and Nam Kim (Chungbuk National Univ., Korea)

FR1-F4

Brand-New Communication Systems Opening Up New Fields

Room

F204

Date and Time

12/02 (Fri) 09:15-10:55

Category

Systems & Applications

Chairs

Hideaki Kimura (Chubu Univ., Japan), Masashi Nakatsugawa (National Inst. of Tech., Hakodate College, Japan)

Arbitrary Prescribed Wideband Flat Group Delay Higher-Order Quasi-Reflectionless Bandpass Filter

Girdhari Chaudhary[1], Phanam Pech, Jaehoon Lee, and Yongchae Jeong[2]

Divison of Electronics Engineering, JIANT-IT Human Resource Development Center, Jeonbuk National University
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***Abstract* — This paper presents a design of quasi-reflectionless bandpass filter (BPF) with arbitrary prescribed wideband flat group delay (GD). The proposed circuit consists of λ/4 series short-circuited coupled lines and shunt coupled line terminated with transmission line and resistor. Analytical design equations are derived based on GD analysis. The proposed quasi-reflectionless BPF can be further extended to higher-order by cascading first-order quasi-reflectionless BPFs. For proof of concept, first and second-order quasi-reflectionless BPFs with GD of 1 ns and 2 ns are designed and fabricated at a center frequency of 3.5 GHz. The measurement results are well agreed with the simulations.**

Index Terms — Arbitary prescribed group delay, coupled line, reflection-less bandpass filter, wideband flat group delay.

I. INTRODUCTION

Reflectionless bandpass filters (BPF), which dissipate non-transmitted stopband input-signal energy in the inside themselves instead of reflecting back to the source, have become attractive to prevent interblock signal interference from unwanted RF-signal power reflections [1], [2]. In recent years, different topologies of reflectionless BPPs have been investigated in the literatures. In [3], first-order input-reflectionless BPF is designed using input-matching resistive components. Reflectionless BPFs consisting of a complementary duplexer in a main and auxiliary channel with opposite filtering functions are presented in [4]-[6]. Similarly, symmetrical quasi-reflectionless BPF is realized using complementary branch-line BPF and bandstop filter [7]. Similarly, higher-order quasi-reflectionless BPF is realized using a bandpass section and matching section in [8].

Despite significant research, the conventional reflectionless BPFs mainly focus on a frequency-dependent magnitude transfer function rather than a group delay (GD) response and suffer from arbitrary prescribed flat GD characteristics. In fact, BPF with arbitrary prescribed GD response with respect to frequency have various applications including real-time analog signal processing (R-ASP), RF self-interference cancellation in-band full duplex [9], [10]. The reflectionless BPFs with arbitrary prescribed flat GD response can play important role in designing magnet-less non-reciprocal components.

In this paper, we present a design of quasi-reflectionless BPF based on GD analysis. The proposed quasi-reflection BPF can provide the arbitrary prescribe flat GD response and can be easily extended to higher order quasi-reflectionless BPF.

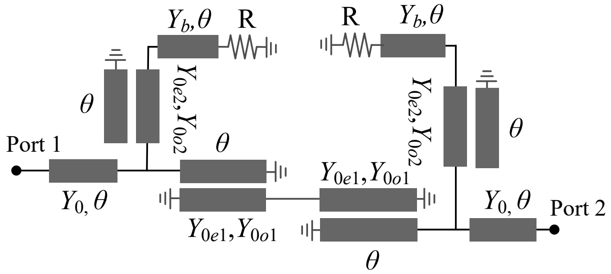
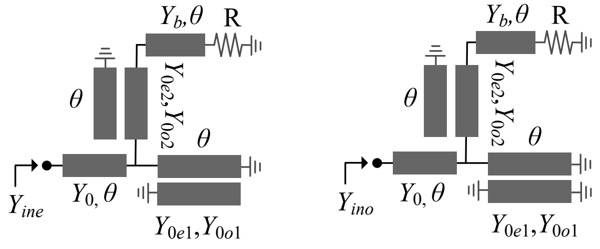


Fig. 1. Proposed structure of first-order (n = 1) quasi-reflectionless BPF with arbitrary prescribed flat group delay.



(a) (b)

Fig. 2. Equivalent circuits of proposed first-order quasi-reflectionless BPF: (a) even-mode excitation and (b) odd-mode excitation

II. OVERVIEW OF THE DIGEST FORMAT

Fig. 1 shows the proposed structure of quasi-reflectionless BPF with arbitrary prescribed GD, which consists of a series short-circuited coupled lines (Y0e1, Y0o1) and shunt coupled line (Y0e2, Y0o2) terminated transmission line (Yb) and resistor (R). The electrical lengths of coupled lines and transmission lines are λ/4 at the designed center frequency (f0). Since the structure is symmetrical, even- and odd-mode analysis is used to find the S-parameters, Using Fig. 2(a) and 2(b), the S-parameters of the proposed circuit are expressed as (1).

$$S_{11}=\frac{Y_0^2-Y_{ine}Y_{ino}}{\left(Y_0+Y_{ine}\right)\left(Y_0+Y_{ino}\right)},S_{21}=\frac{Y_0\left(Y_{ino}+Y_{ine}\right)}{\left(Y_0+Y_{ine}\right)\left(Y_0+Y_{ino}\right)} \quad (1)$$

where

$$Y_{in}^{e,o}=Y_0\frac{Y_a^{e,o}+Y_0\tan\theta}{Y_0+jY_a^{e,o}\tan\theta},Y_a^o=\frac{1}{Z_{inb}}-j\frac{Y_{0o1}\cot\theta}{1+k_1} \quad (2a)$$

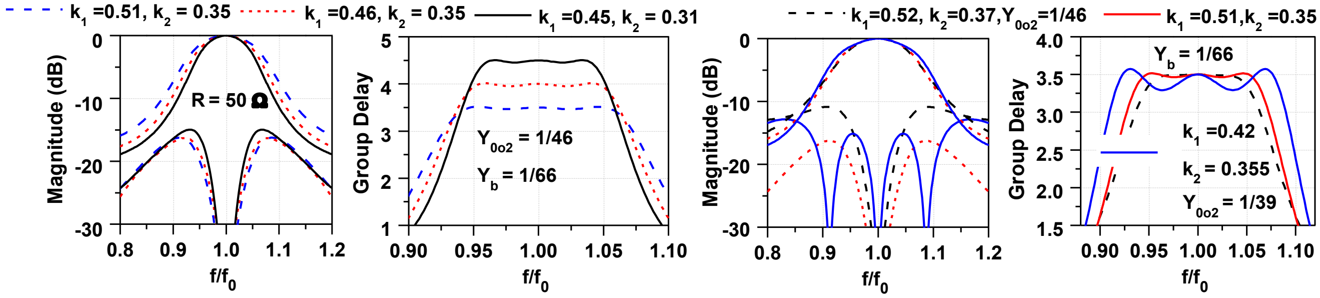


Fig. 3. Group delay and magnitude responses according to different k_1, k_2, Y_b, and Y_{0o2}: (a) different group delay value and (b) different group delay ripple.

$$Y_a^e = \frac{1}{Z_{inb}} - j\frac{Y_{0o1}\left(\cot\theta - 2k_1^2\csc 2\theta\right)}{1+k_1} \tag{2b}$$

$$Z_{inb} = \frac{Ak_2^2}{Y_{0o2}\left(1-k_2\right)^2} - j\frac{\cot\theta + 2k_2^2\csc 2\theta}{Y_{0o2}\left(1-k_2\right)} \tag{2c}$$

$$A = \frac{\left(\cot\theta - 2\csc 2\theta\right)^2}{B - j\dfrac{\cot\theta + 2\csc 2\theta}{Y_{0o2}\left(1-k_2\right)}}, B = \frac{Y_bR + j\tan\theta}{Y_b + jRY_b^2\tan\theta} \tag{2d}$$

$$Y_{0e1} = \frac{1-k_1}{1+k_1}Y_{0o1}, \quad Y_{0e2} = \frac{1-k_2}{1+k_2}Y_{0o2} \tag{2e}$$

and k_1 and k_2 are coupling coefficients of series and shunt coupled lines, respectively.

Using the phase of S_{21}, the GD according to operating frequency (f) can be calculated as (3).

$$\tau = -\frac{1}{2\pi}\frac{d\angle S_{21}}{df} \tag{3}$$

To calculate circuit parameters with arbitrary prescribed GD, equation (3) can be further simplified at f_0.

$$\tau\big|_{f=f_0} = \frac{1}{4f_0}\left(2 + \frac{m^2Y_{0o1}^2 + Y_0^2}{nY_{0o1}} + c\right), \tag{4}$$

where

$$m = \frac{k_1}{1+k_1}, n = \frac{k_1^2Y_0}{1+k_1}, c = Y_{0o2}\frac{1-k_2}{k_2^2Y_0} \tag{5}$$

Based on the above analysis, arbitrary prescribed GD and magnitude responses can be obtained by selecting appropriate Y_{0o1} and k_1 if Y_{0o2} and k_2 are specified by the designer. Therefore, the solution of Y_{0o1} in terms of specified GD at f_0 can be found as (6).

$$Y_{0o1} = \frac{x \pm \sqrt{x^2 - 4m^2Y_0^2}}{m^2}, \quad x = n\left(4f_0\,\tau\big|_{f=f_0} - c - 2\right) \tag{6}$$

The required circuit parameters can be obtained by solving (6), while providing the values of specified GD, f_0, k_1, k_2, and Y_{0o2}.

For illustration, Fig. 3 shows the S-parameter and GD responses of arbitrary prescribed GD quasi-reflectionless BPF. As seen from these results, higher GD can be obtained by decreasing k_1 and k_2. The flat GD bandwidth and 3-dB passband magnitude bandwidth are decreased as GD increases. Similarly, GD ripple at passband can be controlled by changing k_1 and k_2 while fixing GD at f_0. The input and output return losses (RLs) are higher than 15 for all frequencies.

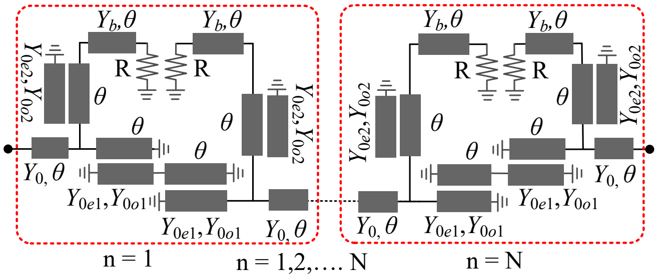


Fig. 4. Higher-order quasi-reflectionless BPF with arbitrary prescribed flat group delay.

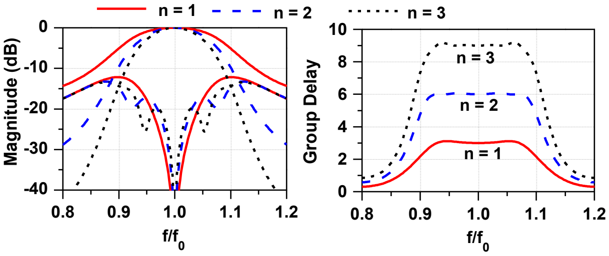
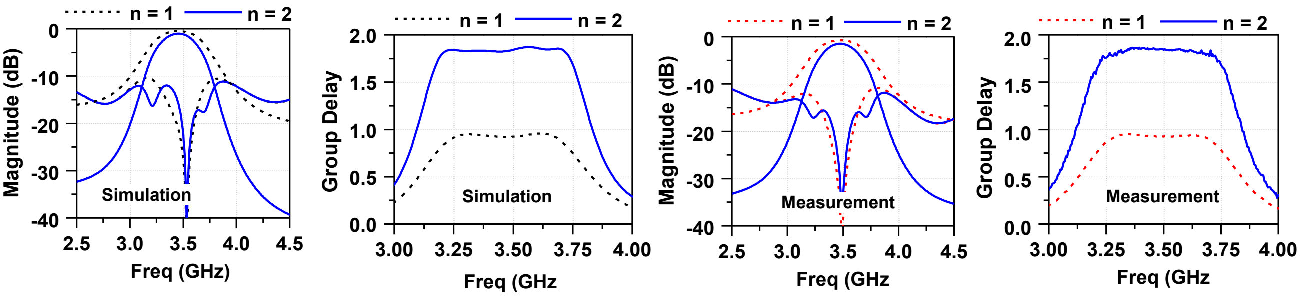


Fig. 5. Magnitude and group delay responses with different number of filter order. Circuit parameters: k_1 =0.5, k_2 = 0.35, Z_{0o2} =1/Y_{0o2} = 46 Ω, Z_0 = 1/Y_0 = 50 Ω, Z_b = 1/Y_b = 66 Ω, R = 50 Ω.

The proposed quasi-reflection BPF with arbitrary prescribed GD response can be further extended to higher-order cascading one-stage BPF as shown in Fig. 4. Fig. 5 shows magnitude and GD responses of first-order and (n =1) and second-order (n = 2) quasi-reflectionless BPF. As seen from these results, GD is increased as the number of stages increases, while maintaining the same in-band GD bandwidth. Similarly, both stopband attenuation and the passband roll-off are improved, however, the 3-dB passband bandwidth is decreased as a number of stages increases. The input and output RLs are higher than 12 dB for all frequencies.

III. SIMULATION AND MEASUREMENT RESULTS

For experimental demonstration, a prototype of first-order (n = 1) and second-order (n =2) quasi-reflectionless BPFs are designed and fabricated on a Taconic substrate with a dielectric constant of 2.2 and thickness of 0.787 mm. The design goals of first and second-order BPFs are set to achieve GDs of 1 ns and 2 ns at f_0 = 3.50 GHz.



(a) (b)

Fig. 6. Simulated and measured results: (a) simulation and (b) measurement group delay and magnitude responses.

Fig. 7. Photographs of fabricated quasi-reflectionless BPF.

The circuit parameters of designed BPFs are summarized as $k_1 = 0.51$, $k_2 = 0.392$, $Z_{0e1} = 1/Y_{0e1} = 149.64\ \Omega$, $Z_{0o1} = 1/Y_{0o1} = 48.56\ \Omega$, $Z_{0e2} = 1/Y_{0e2} = 96\ \Omega$, $Z_{0o2} = 1/Y_{0o2} = 46\ \Omega$, $Z_b = 1/Y_b = 66\ \Omega$, $Z_0 = 1/Y_0 = 50\ \Omega$, and $R = 50\ \Omega$.

Fig. 6 shows the simulated and measured results of first and second-order quasi-reflectionless BPFs. The measurement results are well agreed with the simulation. The GD is flat within a bandwidth of 500 MHz. The measured GD and insertion loss at $f_0 = 3.5$ GHz are 0.925 ns and 0.776 dB for first-order, and 1.91 ns and 1.60 dB for second-order. The measured 3-dB passband bandwidth of first and second-order quasi-reflectionless BPFs are 500 MHz and 377.86 MHz, respectively. The input and output RLs at f_0 are 26.96 dB and higher than 10 dB for all frequencies. Fig. 7 shows photograph of fabricated filter.

IV. CONCLUSION

This paper demonstrated a design of quasi-reflectionless BPF with arbitrary prescribed flat GD response. The proposed BPF is designed by using group delay analysis. To achieve the quasi-reflectionless characteristics, shunt coupled line terminated transmission line and resistor are used. Higher-order quasi-reflectionless BPFs can be easily designed by cascading first-order symmetrical quasi-reflectionless BPF. For proof of concept, first and second-order quasi-reflectionless BPFs with arbitrary prescribed GD are designed and fabricated at center frequency of 3.50 GHz. The measured results are well agreed with simulations.

ACKNOWLEDGEMENT

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REFERENCES

[1] R. Gomez-Garcia et.al. "Avoiding RF isolators: reflectionless microwave bandpass filtering components for advances RF front ends," *IEEE Microwave Magazine*, vol. 21, no. 12, pp. 68-86, Dec. 2020.

[2] B. Mini-Circuits, "Reflectionless filters improve linearity and dynamic range," *Microwave Journal*, vol. 58, no. 8, pp. 42–50, Aug. 2015.

[3] T. H. Lee, B. Lee, and J. Lee, "First-order reflectionless lumped-element lowpass filter (LPF) and bandpass filter (BPF) design," *IEEE Int. Microw. Symp. Dig.*, pp. 1–4, May 2016.

[4] D. Psychogiou and R. Gomez-Garcia, "Reflectionless adaptive RF filters: Bandpass, bandstop, and cascade designs," *IEEE Trans. Microw. Theory Techn.,* vol. 65, no. 11, pp. 4593–4605, Nov. 2017.

[5] D. J. Simpson, R. Gomez-Garcia, and D. Psychogiou, "Mixed-technology quasi-reflectionless planar bandpass filters," *in Proc. 48th Eur. Microw. Conf. (EuMC),* Sep. 2018, pp. 551–554.

[6] R. Gomez-Garcia, J.-M. Munoz-Ferreras, and D. Psychogiou, "Split-type input-reflectionless multiband filters," *IEEE Microw. Wireless Compon. Lett*., vol. 28, no. 11, pp. 981–983, Nov. 2018.

[7] R. Gomez-Garcia, J.-M. Munoz-Ferreras, and D. Psychogiou, "Symmetrical quasi-absorptive RF bandpass filters," *IEEE Trans. Microw. Theory Techn*., vol. 67, no. 4, pp. 1472–1482, Apr. 2019.

[8] X. Wu, Y. Li, and X. Liu, "High-order dual-port quasi-absorptive microstrip coupled-line bandpass filters," *IEEE Trans. Microw. Theory Techn.*, vol. 68, no. 4, pp. 1462–1475, Apr. 2020.

[9] C. Caloz, S. Gupta, Q. Zhang, and B. Nikfal, "Analog signal processing: A possible alternative or complement to dominantly digital radio schemes," *IEEE Microw. Mag*., vol. 14, no. 6, pp. 87–103, Sep. 2013.

[10] S. Hong *et al*., ''Applications of self-interference cancellation in 5G and beyond,'' *IEEE Commun. Mag*., vol. 52, no. 2, pp. 114–121, Feb. 2014.