# ISAP 2022

## 2022 International Symposium on Antennas and Propagation

31 Oct. – 3 Nov. 2022, Sydney, Australia

## Conference Topics

A. Antennas
A1. Small Antennas and RF Sensors
A2. Antennas for Mobile and V2X Applications
A3. Broadband and Multi-band Antennas
A4. Active, Adaptive, On-Chip and Smart Antennas
A5. Reconfigurable Antennas
A6. Planar/Printed Antennas and Arrays
A7. Conformal Antennas
A8. Antenna Theory and Measurements
A9. Millimetre-wave and Terahertz Antennas
A10. Metamaterials and Metasurfaces for Antennas
A11. Leaky Wave Antennas

C. Electromagnetic-wave Theory
C1. Computational Electromagnetics
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C4. Inverse and Imaging Techniques
C5. Optimization Methods in EM Problems
C6. Frequency Selective Surfaces and Filters
C7. EBG, Metamaterials and Periodic Structures
C8. Multiscale and Multiphysics

B. Propagation
B1. Indoor and Mobile Wireless Propagation
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B3. Propagation for V2X and IoT
B4. Channel Sounding and Channel Estimation
B5. Radar, DOA, localization and Sensing
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D. AP-related Topics:
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D2. MIMO and Array Signal Processing
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D4. Wireless Power Transfer
D5. Wearable Device and Medical Applications
D6. OAM and Near Field Communications
D7. Passive and Active RF Components
D8. RFID. RF Chip Design and Antennas in Package
D9. EMC/EMI Techniques
D10. Backscatter Communications
D11. Intelligent Reflecting Surface
D12. Industrial IoT and Environmental Monitoring
D13. Machine Learning for AP

## Technical and Social Activities

Kun Wu and Peiyuan Qin (University of Technology Sydney, Australia); Shu-Lin Chen (University of Technology, Sydney, Australia)

A highly efficient wideband transmitarray working at E band is developed in this paper. This transmitarray is composed by 1010 dielectric cells and fabricated through three-dimensional (3D) printing technology. To obtain the required phase distribution of the array, the height of dielectric cells is adjusted. To reduce the phase error under oblique incident angles, multiple-angle phase distribution is analyzed. This transmitarray can work within a wideband from 60 to 90GHz. The peak gain can reach 23.4 dBi at 74 GHz with the maximum aperture efficiency of 60.9%.

pp. 107-108
9:50 *Integrated mmWave 1x4 Half-Circle Monopole Antenna Array for Board-To-Board Communication*
Bernhard Klein and Ronny Hahnel (Technische Universität Dresden, Germany); Dirk Plettemeier (Dresden University of Technology, Germany)

An integrated 1x4 antenna array consisting of four planar half-circle monopole antennas for the frequency range from 165 GHz to 195 GHz has been designed. This antenna array is fabricated in the IHP SG13 semiconductor process. Besides the bandwidth of more than 30 GHz, a maximum realized gain of 5.2 dBi is achieved at 195 GHz. The overall chip size is 1.26 mm x 3.66 mm.

pp. 109-110

### RS5: Filters and Filtering Antennas

Room: C3.4
Chair: Girdhari Chaudhary (Jeonbuk National University, Korea (South))

8:30 *A Design of Optimum Distributed Highpass Filter Using Defected Ground Structure*
Minseong Kim (Soonchunhyang, Korea (South)); Sohui Kim (University of Soonchunhyang, Korea (South)); Juyoung Jung (Soonchunhyang University, Korea (South)); Hyeseong Cha (Soonchunhyang, Korea (South)); Yuseong Choi (University of Soonchunhyang, Korea (South)); Jaebok Lee (ERANGTEK Co., Ltd, Korea (South)); Youna Jang and Dal Ahn (Soonchunhyang University, Korea (South))

This paper proposes a third-order optimum distributed high-pass filter (HPF) using a dumbbell-shaped defected ground structure (DGS). The optimum distributed HPF with broadband bandwidth has a difficulty of fabrication due to its high impedance. The proposed circuit is to extend the line width when the cut-off frequency is 2GHz and passband is up to 8.5 GHz. The line width of the proposed circuit is increased about 3 times compared to the conventional circuit. As the measurement results of the proposed circuit, the insertion loss is -0.47dB, the reflection loss is -11.81dB. The measured results are well matched with the simulation results except the fabrication errors.

pp. 111-112
8:50 *A Design of 3-Pole Coupled Line Bandpass Filter Using Group Delay Analysis Approach*
Jaehun Lee, Girdhari Chaudhary and Phanam Pech (Jeonbuk National University, Korea (South)); Yongchae Jeong (Chonbuk National University, Korea (South))

In this paper, we present a design of 3-pole coupled line bandpass filter using group delay (GD) analysis approach. The proposed 3-pole BPF consists of two-coupled line with short-circuited stub instead of four coupled lines conventional BPF. The design equations are derived by equating GD of the proposed and conventional 3-pole BPF. The GD value of the proposed BPF is controlled by adjusting fractional bandwidth of filter. For proof of concept, the proposed BPF was designed and fabricated at center frequency of 3.50 GHz. The measured results are well agreed with simulations and theoretically predicted results. The measurement results revealed that the proposed BPF achieved the insertion loss of 0.8 dB with fractional bandwidth of 21.71% (760 MHz) and GD of 0.92 ns.

pp. 113-114
9:10 *Filtering Differential Phase Shifter With Arbitrary Prescribed Wideband Flat Phase Difference and Group Delay*
Girdhari Chaudhary and Samdy Saron (Jeonbuk National University, Korea (South)); Yongchae Jeong (Chonbuk National University, Korea (South))

Differential phase shifter is critical components for RF beamforming and feeding networks in phased array systems. In this paper, we present group delay (GD) analysis approach to design filtering differential phase shifter with arbitrary prescribed flat phase difference and GD. The proposed differential phase shifter consists of coupled lines with short-circuited stub in main and reference branch. The flat phase difference within passband frequency is achieved by maintaining same GD of main and reference branch. For validation, differential phase shifters with phase difference of 90o, 180o, 270o, and 360o are designed and simulated. The simulated results show that three-reflection poles and flat phase difference are achieved with passband fractional bandwidth of 20%.

pp. 115-116
9:30 *Design of Compact Bandpass Filter With Stub-Loaded to the Closed Loop Resonator*
Taehoon Kang (University of Soonchunhyang, Korea (South)); Seo Koo (Soonchunhyang, Korea (South)); Jiwon Kim (Soonchunhyang Univ, Korea (South)); Hyunduk Kang (Electronics and Telecommunications Research Institute (ETRI), Korea (South)); Heon-Jin Hong and Young Jun Chong (ETRI, Korea (South)); Youna Jang and Dal Ahn (Soonchunhyang University, Korea (South))

In this paper, a compact 3-order Band-pass filter (BPF) is proposed using a resonator that adds stub-loaded to the closed loop resonator. In consideration of coupled with 50Ω feeding line, the first and last resonator of λ0/4 is folded type. The proposed filter is designed and fabricated with a fractional bandwidth of 8% at 1GHz center frequency. As compared to the area of the conventional interdigital BPF, a decrease of 50.04% is verified. Experimental results have shown good agreement with simulated ones.

pp. 117-118
9:50 *Fast Optimization of Unbalanced Filtering Antenna and Phase Controlled Transmission Line With Arbitrary Reference Impedances*
Teng Chang and Hsi-Tseng Chou (National Taiwan University, Taiwan)

In this paper, an effective synthesis method is presented for fast design of filtennas. The bandpass Q-factor, bandwidth, and order are incoporated into the antenna design cascading phase controlled transmission lines to produce an unbalanced filtering feature. The presented synthesis reduces the design cycle time and also predict the filtering performance. This method is validated by designing a three-order bandpass filtenna at 2.4 GHz to achieve a broad bandwidth. The simulated results agree very well with commercial simulation tools. The technique provide great flexibility for a filtenna design.

978-1-6654-7962-2/22/$31.00 ©2022 IEEE

# A Design of 3-pole Coupled Line Bandpass Filter Using Group Delay Analysis Approach

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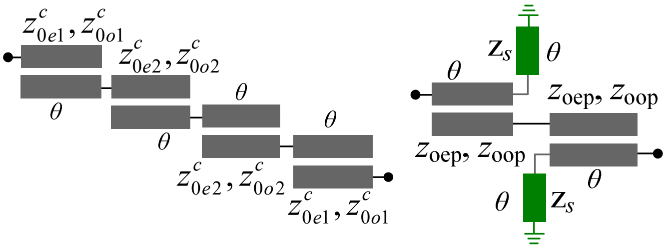
***Abstract*—In this paper, we present a design of 3-pole coupled line bandpass filter using group delay (GD) analysis approach. The proposed 3-pole BPF consists of two-coupled line with short-circuited stub instead of four coupled lines conventional BPF. The design equations are derived by equating GD of the proposed and conventional 3-pole BPF. The GD value of the proposed BPF is controlled by adjusting fractional bandwidth of filter. For proof of concept, the proposed BPF was designed and fabricated at center frequency of 3.50 GHz. The measured results are well agreed with simulations and theoretically predicted results. The measurement results revealed that the proposed BPF achieved the insertion loss of 0.8 dB with fractional bandwidth of 21.71% (760 MHz) and GD of 0.92 ns.**

***Keywords—Bandpass filter, coupled line, group delay analysis, shunt-stub, wide bandwidth.***

## I. INTRODUCTION

The parallel coupled transmission line resonators are widely used for designing microstrip line bandpass filter (BPF) [1]. Different configurations and analysis of coupled-line BPF have been reported in the literature [ 2]-[6]. In [2], three-pole coupled line BPF is designed using defected group structure. Likewise, parallel coupled line BPF with Chebyshev responses are presented based on insertion-loss functions by converting composite *ABCD* matrices of all coupled stages [3]. In [4], wideband parallel coupled BPFs are demonstrated using two sections of parallel coupled line and single multi-mode resonator. In [5], the 3-pole parallel coupled line BPF is designed using three-coupled line and shunt short-circuited coupled line. Likewise, impedance matching coupled line BPF is presented in [6] by using arbitrary image impedance.

In general, the conventional parallel coupled line BPF needs $N$+1 number of coupled lines ($N$ : number of filter stage), which increases the overall physical size. In this paper, we present a design of 3-pole parallel coupled line BPF using two coupled line and short-circuited stub instead of four ($N$+1) coupled lines, which can decrease overall physical circuit size. We used group delay (GD) analysis to obtain circuit parameters of the proposed BPF with given filter specifications. This approach can provide the BPF characteristics with arbitrary prescribed GD response.



(a) (b)

Fig. 1. Structure of 3-pole coupled line bandpass filter: (a) conventional and (b) proposed bandpass filters.

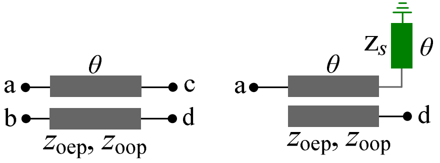


Fig. 2. Section of proposed BPF when ports b and c are terminated with open-circuited and short-circuited stubs.

## II. DESIGN THEORY

Fig. 2 shows the structure of conventional and proposed coupled line 3-pole BPFs. The proposed BPF consists of $\lambda/4$ coupled lines ($z_{0ep}$ and $z_{0op}$) with short-circuited shunt stub ($z_s$). For simplicity, even- and odd-mode impedances of coupled line and characteristic impedance of shunt sub are normalized with a port impedance of 50 Ω. Electrical lengths of coupled lines and shunt stubs are $\theta = \lambda/4$ at the designed center frequency ($f_0$). Assuming the coupling coefficient $k$ is a free design variable, $z_{0ep}$ is expressed in terms of $k$ and $z_{0oep}$ as (1).

$$z_{0ep} = \frac{1+k}{1-k} z_{0op} \tag{1}$$

To derive circuit parameters of the proposed BPF, Fig. 2 shows a section of proposed BPF, which is constructed by terminated ports b and c of four-port coupled with open-circuited and short-circuited stub. The $Z$-parameters of circuit shown in Fig. 2 are derived as (2).

$$z_{11} = -j\frac{z_{0op}}{1-k}\left(\cot\theta - \frac{k^2 \cot^3\theta}{A}\right) \tag{2a}$$

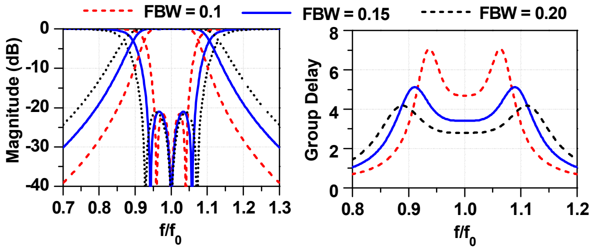


Fig. 3. Simulated magnitude and group delay responses of the proposed BPF with different fractional bandwidths.

Table I
Circuit parameters of proposed BPF with fractional bandwidths.

| Passband ripple : 0.01 dB, $g_1 = 0.8535$, $g_2 = 1.1039$, $z_{st} = 0.9$ Ω | | | |
|---|---|---|---|
| Δ (%) | $k$ | $z_{0ep}$ (Ω) | $z_{0ep}$ (Ω) |
| 10 | 0.218 | 3.342 | 2.146 |
| 15 | 0.281 | 2.929 | 1.644 |
| 20 | 0.328 | 2.695 | 1.364 |

$$z_{21} = z_{12} = -j\frac{kz_{0op}}{1-k}\left(\csc - \frac{\csc\theta\cot^2\theta}{A}\right) \tag{2b}$$

$$z_{22} = -j\frac{z_{0op}}{1-k}\left(\cot - \frac{\csc^2\theta\cot\theta}{A}\right), \tag{2c}$$

where

$$A = \cot^2\theta - z_{st}\frac{1-k}{z_{0op}} \tag{3}$$

By applying $Z$-to-$S$-parameter conversion relation [7] and phase of $S_{21}$, the GD of the proposed BPF at $f_0$ is derived as (4).

$$\tau = -\frac{1}{2\pi}\frac{d\angle S_{21}}{df} = \frac{z_{0op}^2 + 2z_{st}z_{0op}(1-k)}{4f_0 z_{st}\left[(1-k)^2 + k^2 z_{0op}^2\right]} \tag{4}$$

Equating (4) with the GD of conventional coupled BPF, the solution of $z_{0op}$ can be found as (5).

$$z_{0op} = \frac{(1-k)\sqrt{z_{st}^2 + z_{st}m\left(1 - z_{st}mk^2\right)} - z_{st}(1-k)}{1 - z_{st}mk^2}, \tag{5}$$

where

$$m = 1 + \frac{2g_1 + g_2}{\pi\Delta} + \frac{(g_1 + 2g_2)\pi\Delta}{4g_1g_2} \tag{6}$$

and $g_i$ is low-pass prototype element values and Δ is fractional bandwidth of 3-pole BPF. As observed from (5), the required $z_{0op}$ can be obtained by providing the value of $k$, $z_{st}$, and Δ. Once $z_{0op}$ is determined, the value of $z_{0ep}$ can be obtained using (1).

For illustration, Fig. 3 shows the simulated magnitude and GD responses of 3-pole BPF according to different Δ. The calculated circuit parameters are given in Table I. As seen from the results, the GD is decreased as the fractional bandwidth increases. The 3-pole BPF response is achieved by selecting appropriate value of $k_1$ if $z_{st}$ and Δ are specified by the designer.

## III. EXPERIMENTAL RESULTS

For proof of concept, a prototype of the proposed 3-pole coupled line BPF was designed and fabricated at $f_0$ = 3.50 GHz using Taconic substrate with a dielectric constant of 2.20 and thickness of 0.787 mm.

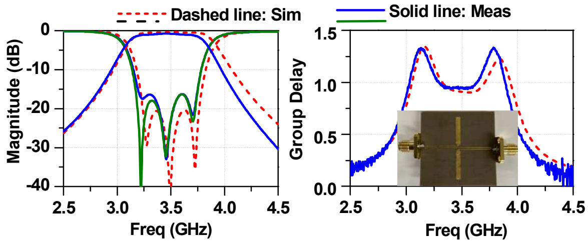


Fig. 4. Simulated and measured results of the proposed 3-pole BPF.

Fig. 4 shows the simulated results of the proposed BPF. The measurement results are well agreed with the simulations. As observed in Fig. 4, distinct 3-poles appear within passband frequency. The measured $|S_{21}|$ and $|S_{11}|$ at $f_0$ = 3.50 GHz are determined to be -0.8 dB and -23.06 dB with 0.92 ns of GD. The measured 3-dB bandwidth is 760 MHz (Δ = 21.71%).

## IV. CONCLUSION

In this paper, we demonstrated the design of a 3-pole coupled line BPF using group delay analysis approach. Analytical design equations are derived to obtain the circuit parameters. The proposed 3-pole BPF is designed using two coupled lines with short-circuited stubs instead of conventional four coupled lines, which can decrease the overall physical. For proof of concept, 3-pole BPF is designed and fabricated at a center frequency of 3.50 GHz.

## ACKNOWLEDGMENT

This research was supported by National Research Foundation of Korea (NRF) grant funded by Korea Government (MSIT) under grant no. 2020R1A2C2012057) and in part by Basic Science Research Program through the NRF of Korea, funded by the Ministry of Education under grant no. 2019R1A6A1A09031717.

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