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

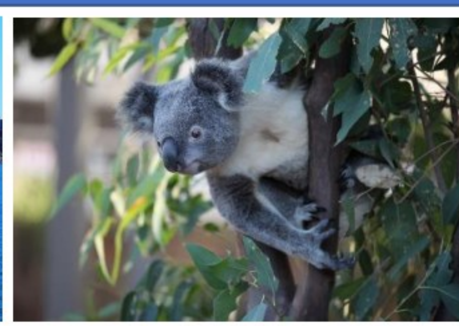
C. Electromagnetic-wave Theory
C1. Computational Electromagnetics
C2. Time-Domain Techniques
C3. Scattering, Diffraction and RCS
C4. Inverse and Imaging Techniques
C5. Optimization Methods in EM Problems
C6. Frequency Selective Surfaces and Filters
C7. EBG, Metamaterials and Periodic Structures
C8. Multiscale and Multiphysics

B. Propagation
B1. Indoor and Mobile Wireless Propagation
B2. Millimetre-wave, THz and Optical Propagation
B3. Propagation for V2X and IoT
B4. Channel Sounding and Channel Estimation
B5. Radar, DOA, localization and Sensing
B6. Propagation Measurement Techniques

D. AP-related Topics:
D1. Antenna Systems for 5G, B5G and 6G
D2. MIMO and Array Signal Processing
D3. DoA, Wireless Sensing and Radar
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.

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Filtering Differential Phase Shifter With Arbitrary Prescribed Wideband Flat Phase Difference and Group Delay

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***Abstract*—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 90°, 180°, 270°, and 360° are designed and simulated. The simulated results show that three-reflection poles and flat phase difference are achieved with passband fractional bandwidth of 20%.**

Keywords—Coupled line, filtering differential phase shifter, group delay analysis, shunt-stub, wideband flat phase difference.

I. Introduction

Differential phase shifter is one of critical component for phased array systems and beamforming networks [1]. Conventional Schiffman differential phase shifter consisting of an edge-coupled section in main branch and a uniform transmission line (TL) in reference was achieved a nearly constant phase of 90 ± 10° by properly selecting TL line lengths and degree of coupling of coupled line [2]. To realize ultra-wideband differential phase shifter, multilayer structures have been adopted, however, this technique increases cost and fabrication complexity [3]. To improve selectivity, filtering differential phase shifters have proposed by controlling fractional bandwidth of bandpass filter (BPF) between main and reference branches [4], [5]. Unfortunately, the conventional filtering differential phase shifter ignores the group delay (GD) analysis although GD characteristics is essential for designing phased array systems [6].

In this paper, we present a design of filtering differential phase shifter based on GD analysis. Analytical design method has been developed to achieve arbitrary prescribed flat phase difference and GD. Arbitrarily prescribed flat phase difference and GD can be achieved by controlling degree of coefficient of coupled lines and characteristics impedance of short-circuited sub in main and reference branches.

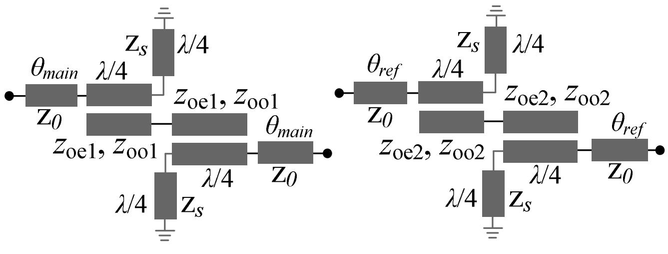

Fig. 1. Proposed structure of differential filtering phase shifter: (a) reference branch and (b) main branch.

II. Design Theory

Fig. 1 shows the proposed structure of filtering differential phase shifter, which consists of reference and main branches. Each branch comprises of series TL (z_0, θ_{main}, θ_{ref}), $\lambda/4$ coupled lines (z_{0ei}, z_{0oi}), and shunt stub (z_{st}). For simplicity, even- and odd-mode impedances of coupled line, and characteristic impedances of shunt sub and TL are normalized with a port impedance of 50 Ω. Assuming the coupling coefficient k_i is a free design variable, z_{0ei} is expressed in terms of k_i and z_{0oi} as (1).

$$z_{0ei} = \frac{1+k_i}{1-k_i} z_{0oi}, \quad i = 1,2 \tag{1}$$

Using even- and odd-mode analysis [6], [7], the *S*-parameters of each branch are expressed as (2).

$$S_{11}^{ref,main} = \frac{z_{even}^{ref,main} z_{odd}^{ref,main} - 1}{\left(1+z_{even}^{ref,main}\right)\left(1+z_{odd}^{ref,main}\right)} \tag{2a}$$

$$S_{21}^{ref,main} = \frac{z_{even}^{ref,main} - z_{odd}^{ref,main}}{\left(1+z_{even}^{ref,main}\right)\left(1+z_{odd}^{ref,main}\right)}, \tag{2b}$$

where

$$z_{even,odd}^{ref,main} = z_0 \frac{z_a^{even,odd} + jz_0 \tan\theta_{ref,main}}{z_0 + jz_a^{even,odd} \tan\theta_{ref,main}} \tag{3a}$$

$$z_a^{even} = -j\frac{z_{0oi}a}{1-k_i}, z_a^{odd} = -j\frac{z_{0oi}}{1-k_i}\left(a - \frac{k_i^2 b^2}{c}\right) \tag{3b}$$

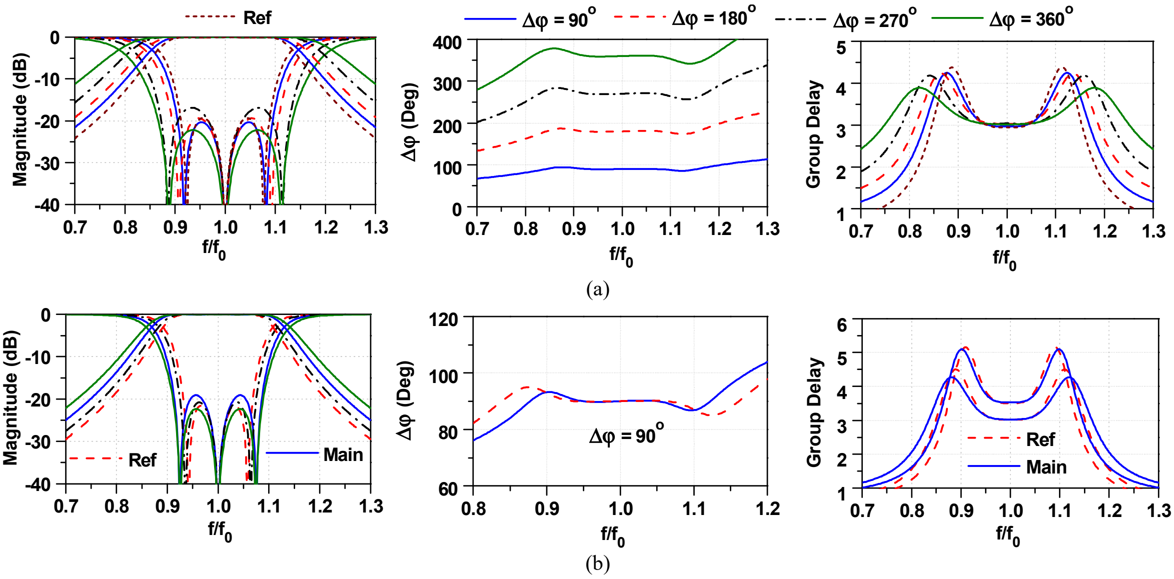

Fig. 2. Simulated magnitude, phase difference, and group delay responses of proposed differential phase shifter: (a) difference phase difference with fixed group delay at center frequency and (b) different group delay with fixed flat difference.

Table I
Circuit parameters of differential phase shift with flat phase difference.

Fig. 2(a) : arbitrary flat phase difference: θ_{ref}=30°, z_{st}= 0.9 Ω, z_0= 1 Ω					
$\Delta\varphi$	θ_{main}	z_{0e2} (Ω)	z_{0o2} (Ω)	z_{0e1} (Ω)	z_{0o1} (Ω)
90°	75°	2.7337	1.3679	2.6172	1.2485
180°	120°			2.5606	1.1558
270°	165°			2.4228	0.9990
360°	210°			2.3441	0.8714
Fig. 2(b) : arbitrary prescribed GD: θ_{ref}=30°, z_{st}= 0.9 Ω, z_0= 1 Ω					
90°	75°	2.7697	1.4047	2.5940	1.2632
		2.8881	1.7272	2.8262	1.5151

$$a=\cot\theta-\frac{\csc^2\theta\cot\theta}{m}, b=\csc\theta-\frac{\csc\theta\cot^2\theta}{m} \quad (3c)$$

$$c=\cot\theta-\frac{k_i^2\cot^3\theta}{m}, m=\cot^2\theta-z_{st}\frac{1-k_i}{z_{0oi}} \quad (3d)$$

and i =1, 2. The phase difference between the main and reference branches is derived as (4).

$$\Delta\varphi=\angle S_{21}^{main}-\angle S_{21}^{ref}=2\left(\theta_{main}-\theta_{ref}\right) \quad (4)$$

Using phase of S_{21} of main and reference branches, the GD at center frequency (f_0) can be found as (5).

$$\tau_{21}^{main}=\frac{1}{f_0}\left\{\frac{z_{0o1}^2+z_{st}z_{0o1}\left(1-k_1\right)}{4z_{st}\left(1-k_1\right)^2}+\frac{1-k_1}{4z_{0o1}k_1^2}+\frac{\theta_{main}}{\pi}\right\} \quad (5a)$$

$$\tau_{21}^{ref}=\frac{1}{f_0}\left\{\frac{z_{0o2}^2+z_{st}z_{0o2}\left(1-k_2\right)}{4z_{st}\left(1-k_2\right)^2}+\frac{1-k_2}{4z_{0o2}k_2^2}+\frac{\theta_{ref}}{\pi}\right\} \quad (5b)$$

To achieve flat phase difference, the GD of main and reference branches must be chosen same value.

III. Results

To validate the analytical analysis, Fig. 2(a) shows the simulated results of the proposed filtering differential phase shifter. Table I depicts circuit parameters of the designed phase shifter. The proposed differential phase shifter provides the flat difference of 90°, 180°, 270°, and 360° within passband fractional bandwidth of 20%. The GD remains constant at f_0 even though phase difference is varied from 90° to 360°. Likewise, the proposed differential phase shift can provide arbitrary prescribed GD as shown in Fig. 2(b).

IV. Conclusion

In this paper, we demonstrated filtering differential phase shifter with arbitrary prescribed flat difference and GD. The proposed differential phase shifter can be designed with differential phase of 0° ~ 360° without any fabrication difficulty. The flat phase difference within passband achieved by maintaining same GD of main and reference branches. An arbitrary GD value can be designed by controlling coupling coefficient of coupled line. The proposed filtering differential phase shifter is applicable for phased array systems in next generation communication system.

Acknowledgment

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References

[1] A. B. Guntupalli, T. Djerafi, and K. Wu, “Two-dimensional scanning antenna array driven by integrated waveguide phase shifter,” *IEEE Trans. Antennas Propag*., vol. 62, no. 3, pp. 1117–1124, Mar. 2014.

[2] B. M. Schiffman, “A new class of broad-band microwave 90-degree phase shifters,” *IRE Trans. Microw. Theory Techn*., vol. 6, no. 2, pp. 232–237, Apr. 1958.

[3] M. Sorn, R. Lech, and J. Mazur, “Simulation and experiment of a compact wideband 90° differential phase shifter,” *IEEE Trans. Microw. Theory Techn*., vol. 60, no. 3, pp. 494–501, Mar. 2012.

[4] Y. P. Lyu, L. Zhu, and C. H. Cheng, “Proposal and synthesis design of differential phase shifters with filtering function,” *IEEE Trans. Microwave Theory Techn*., vol. 65, no. 8, pp. 2906-2917, Aug. 2017.

[5] Y. P. Lyu, L. Zhu, Q. S. Wu, and C. H. Cheng, “Proposal and synthesis design of wideband phase shifters on multimode resonators,” *IEEE Trans. Microwave Theory Techn*., vol. 64, no. 12, pp. 4211-4220, Dec. 2016.

[6] G. Chaudhary and Y. Jeong, “Arbitrary prescribed wideband flat group delay circuits using coupled lines,” *IEEE Trans. Microwave Theory Techn*., vol. 66, no. 4, pp. 1885-1894, Apr. 2018.

[7] H.R. Ahn, *Asymmetric passive components in microwave integrated circuits*, Wiley & Sons Inc., Hoboken, NJ, USA, 2006.