



Aims and Scope

Electronics Letters is an internationally renowned peer-reviewed rapid-communication journal, which publishes short original research papers every two weeks. Its broad and interdisciplinary scope covers the latest developments in all electronic and electrical engineering related fields. Each issue also provides further insight into recent research with special features and interviews with its authors, editorial board and guest writers.

The major themes of the journal are listed below with some key topics in each field indicated:

Antennas and Propagation:

- Metamaterials and Metasurface Antennas
- Antenna Design and Testing
- Wearable/Implantable Antennas
- Wave Propagation and Detection
- Radiofrequency Identification

Biomedical and Bioinspired Technologies, Signal Processing and Applications:

- Healthcare Technologies
- Biomedical Signal and Image Processing
- Medical Instrumentation
- Robotics for Healthcare Applications
- Synthetic Biology
- Biometrics

Control Engineering:

- Control Theory, Engineering and Practice
- Robotic Control and Navigation
- Control Networks and Algorithms
- Support Vector Machines and Learning Systems
- Motor and Robust Control

Electromagnetism – Theory, Materials and Devices:

- Magnetic Materials and Devices
- Dielectric Materials and Devices
- Superconducting Circuits and Systems
- Electromagnetic Compatibility and Interference
- Electromagnetic Theory and Wave Propagation
- Electromagnetic Device Simulation and Measurement

Electronic Circuits and Systems:

- Organic and Inorganic Circuits and Devices
- Analog and Digital Circuits
- Cryptographic Circuits
- Embedded and CMOS Integrated Circuit Systems
- Circuit Theory and Modelling

Image, Video and Vision Processing and Applications:

- Display Technologies
- Computer, Machine and Robot Vision
- Human Visual System

- Image Sensors
- Colour Coding and Analysis
- Neural and Deep Learning Networks for Image and Video Processing

Information, Computing and Communications:

- Artificial Intelligence and Machine Learning
- Information and Graph Theory
- Computing, Programming and Coding
- Cyber Security and Cryptography
- Communication Theory and Network Management
- QPSK and Queueing Theory

Instrumentation and Measurement:

- Acoustical Engineering
- Sensors
- Automated Equipment and Measurement Processes
- Industrial Device Applications

Microwave Technology:

- Microwave, Radio and Terahertz Circuits, Systems and Devices
- Substrate Integrated Waveguides
- Waveguide and Microwave Circuit Components

Micro and Nanotechnology:

- 'Lab-on-a-chip' Systems
- Micro and Nanoscale Devices and Structures
- Microelectronics and MEMS
- Fabrication and Modelling of Micro and Nano-systems

Optical Communications:

- Optical Computing, Logic and Signal Processing
- Optical Sensors
- Fibre Optic Communication, Theory and Devices
- Free-Space Optical Communications

Photonics and Opto-Electronics:

- Laser Design, Testing, Measurement and Applications
- Optical Integrated Circuits and Components
- Wave Control: Filters and Gratings
- Photodetectors

Power Electronics, Energy and Sustainability:

- Smart Grid and Power Distribution
- Energy Harvesting and Storage
- Power Circuits and Devices
- Photovoltaic and Renewable Power Systems

Radar, Sonar and Navigation:

- Transport and Traffic Management
- Remote Sensing
- Autonomous Vehicles
- Target Tracking and Navigation
- Radar and Sonar Image and Signal Processing

Semiconductor Technology:

- Lithography and Device Fabrication Techniques

- Semiconductor Device Testing and Characterisation
- Semiconductor Circuit Components
- Semiconductor Materials Production and Testing

Signal Processing:

- Speech and Audio Processing and Translation
- Analogue and Digital Signal Processing
- Processing Theory
- Time-frequency Analysis and Signal Transforms

Wireless Communications:

- MIMO
- Wireless Networks
- Channel Fading and Optimisation
- Cognitive Radio
- User Access, Management and Security

Indexing Information:

- CAS: Chemical Abstracts Service (ACS)
- COMPENDEX (Elsevier)
- Directory of Open Access Journals (DOAJ)
- INSPEC (IET)
- Science Citation Index Expanded (Clarivate Analytics)
- SCOPUS (Elsevier)

**Sign up for email alerts**

Enter your email to receive alerts when new articles and issues are published.

Email address*

Continue



Average time to first decision:
4 weeks

Topics



Help & Support

Contact Us

Training and Support

DMCA & Reporting Piracy

Opportunities

Subscription Agents

Advertisers & Corporate Partners

Connect with Wiley

The Wiley Network

Wiley Press Room

Copyright © 1999-2023 John Wiley & Sons, Inc. All rights reserved

WILEY



Editorial Board

Editors-in-Chief



Chris Toumazou, Imperial College London, UK

Professor Chris Toumazou is Regius Professor of Engineering, Chair in Biomedical Circuit Design, Director of the Centre for Bio-Inspired Technology and Founder and Chief Scientist for the Institute of Biomedical Engineering at Imperial College London. He is distinguished for his innovative silicon technology and integrated circuit design for electronic devices in the field of medical diagnosis and therapy, and his research highlights include cochlear implants, an artificial pancreas for type 1 diabetics and semiconductor-based DNA sequencing.



Ian White, University of Bath, UK

Professor Ian White is currently Master of Jesus College, Cambridge, Deputy Vice Chancellor, van Eck Professor of Engineering, and Head of the Photonic Research Group at the University of Cambridge. He has built substantial research activities in the field of optoelectronics and optical communications and several of his advances have made commercial impact: the off set launch technique for enhancing the bandwidth of optical fibre links has been adopted within Gigabit Ethernet standard.

Subject Editors-in-Chief

Antennas and Propagation: Ahmed A. Kishk, Concordia University, Canada

Biomedical Technology: Varun Bajaj, Indian Institute of Information Technology, Design & Manufacturing, India

Circuits and Systems: Paolo S. Croveti, Politecnico di Torino, Italy

Control Engineering: Peng Shi, University of Adelaide, Australia

Electromagnetism: Vicente E. Boria-Esbert, Universidad Politécnic de Valencia, Spain

Image Processing: Antonios Gasteratos, Democritus University of Thrace, Greece

Information and Communication: Turgay Celik, University of the Witwatersrand, South Africa

Microwave Technology: Herve Aubert, CNRS-LAAS/University of Toulouse, France

Optical Communication: Chester Shu, Chinese University of Hong Kong, Hong Kong, China

Photonics: Patrick Fay, University of Notre Dame, USA

Power Electronics, Energy Conversion and Sustainability: Yuh-Shyan Hwang, National Taipei University of Technology, Taiwan

Radar, Sonar and Navigation: Matthew Ritchie, University College London, UK

Semiconductor Technology: Enrico Zanoni, University of Padova, Italy

Signal Processing: Yujie Gu, Aptiv, USA

Wireless Communications: Kai-Kit Wong, University College London, UK

Subject Editors

Antennas and Propagation

Hiroyuki Arai, Yokohama National University, Japan

Zhengwei Du, Tsinghua University, China

Ying Liu, Xidian University, China

Biomedical Technology

Albert H. Titus, University of Buffalo, USA

Circuits and Systems

Christophe Boulanger, OneAccess, France

Yong Chen, University of Macau, Macau

Blaise Ravelo, Nanjing University of Information Science & Technology, China

Control Engineering

Xiaojie Su, Chongqing University, China

Electromagnetism

Antonio Orlandi, University of L'Aquila, France

Image Processing

Ioannis Andreadis, Democritus University of Thrace, Greece

Sam Kwong, City University of Hong Kong, Hong Kong, China

Xuelong Li, Northwestern Polytechnical University, China

Tim Morris, University of Manchester, UK

Information and Communication

Renato J. Cintra, Federal University of Pernambuco, Brazil

David Greaves, University of Cambridge, UK

Shi Jin, Southeast University, China

Yuhui Shi, Southern University of Science and Technology, China

Chi-Man Vong, University of Macau, Macau

Instrumentation and Measurement

Hamid Reza Karimi, Polytechnic University of Milan, Italy

Magnetic Devices and Materials

David Lowther, McGill University, Canada

Microwave Technology

Jiasheng Hong, Heriot Watt University, UK

Optical Communication

Lawrence R. Chen, McGill University, Canada

Giampiero Contestabile, Scuola Superiore Sant'Anna, Italy

Photonics

Catrina Coleman, University of Texas at Dallas, USA

Edmund Linfield, University of Leeds, UK

Power Electronics, Energy Conversion and Sustainability

Angel Cid-Pastor, University Rovira i Virgili, Spain

Radar, Sonar and Navigation

David Blacknell, DSTL, UK
Alexander Charlish, Fraunhofer FKIE, Germany
Yide Wang, University of Nantes, France

Wireless Communications

Sungrae Cho, Chung-Ang University, Republic of Korea
Lie-Liang Yang, University of Southampton, UK

Associate Editors

Seungyoung Ahn, KAIST, Republic of Korea
Orazio Aiello, University of Genoa, Italy
Aparna Akula, Central Scientific Instruments Organisation, India
Mehdi Alimadadi, University of Tehran, Iran
Guilhem Almuneau, LLAS-CNRS, France
Jaume Anguera, Universitat Ramon Llull, Spain
Robin Augustine, Uppsala University, Sweden
Loukas Bampis, Democritus University of Thrace, Greece
Daniel Basso Ferreira, Aeronautics Institute of Technology, Brazil
Adrian Bekasiewicz, Gdansk University of Technology, Poland
Matthew Burfeindt, US Naval Research Laboratory Radar Division, Washington, DC, USA
Paolo Burghignoli, Sapienza University of Roma, Italy
João M. P. Cardoso, University of Porto, Portugal
Ivan R. S. Casella, Universidade Federal do ABC, Brazil
Stefania Cecchi, Università Politecnica delle Marche
Dajana Cassioli, University of L'Aquila, Italy
Luigi Celona, University of Milano-Bicocca, Italy
Korhan Cengiz, Trakya University, Turkey
Laurent Cerutti, Université de Montpellier, France
Rifai Chai, Swinburne University of Technology, Australia
Gaojie Chen, University of Leicester, UK
Yikai Chen, University of Electronic Science and Technology of China, China
Guoyang Cheng, Fuzhou University, China
Jonathan Chisum, University of Notre Dame, USA
Kin Kee Chow, Manchester Metropolitan University, UK
Qing-Xin Chu, South China University of Technology, China
Gianluigi Ciocca, Università degli Studi di Milano-Bicocca, Italy
Michel Clénet, Ottawa Research Centre/Defence Research and Development Canada, Canada
April Rui Dai, University of Cincinnati, USA
Pooya Davari, Aalborg University, Denmark
Wei Deng, Tsinghua University, China
Mircea Dragoman, National Research Institute in Microtechnology, Romania
Guillaume Ducournau, Université de Lille, France
Rostyslav Dubrovka, Queen Mary University of London, UK
Wenjie Feng, Nanjing University of Science & Technology, China
Philippe Ferrari, University of Grenoble, France
Francesco Fioranelli, University of Glasgow, UK
Denis Flandre, Université Catholique de Louvain, Belgium
Martin Fleury, University of Essex, UK
Walter Fuscaldo, La Sapienza University, Italy
Steven Gao, University of Kent, UK
Wei Gao, Peking University, China
Ivana Gasulla, Universitat Politècnica de València, Spain
Ming-Feng Ge, China University of Geosciences, China
Salvador Pinillos Gimenez, Centro Universitário da FEI, Brazil
Alfio Dario Grasso, University of Catania, Italy
Lu Guo, Nanjing University of Science and Technology, China
Xiaojie Guo, Jinan University, China
Zhang-Cheng Hao, Southeast University, China

Stephen Harman, QinetiQ, UK
Tsung-Chu Huang, National Changhua University of Education, Taiwan
Xiaojing Huang, University of Technology, Sydney, Australia
Laure Huitema, University of Limoges, France
Lianping Hou, University of Glasgow, UK
Sanggeun Jeon, Korea University, Korea
Jiajia Jiang, Tianjin University, China
Hailong Jiao, Peking University, China
Young-Seok Jung, Pukyong National University, Republic of Korea
Muhammad Ramlee Kamarudin, Universiti Tun Hussein Onn, Malaysia
Ebrahim Karami, Memorial University, Canada
Taimoor Khan, National Institute Of Technology Silchar, India
Moonil Kim, Korea University, Republic of Korea
André Kokkeler, University of Twente, The Netherlands
Slawomir Koziel, Reykjavik University, Iceland
Abhinav Kranti, Indian Institute of Technology Indore, India
Rakesh Singh Kshetrimayum, Indian Institute of Technology Guwahati, India
Somnath Kundu, Intel Labs, USA
Oh-Kyong Kwon, Hanyang University, Korea
Fabrice Labeau, McGill University, Canada
Xianfu Lei, Southwest Jiaotong University, China
Guang Li, Queen Mary University of London, UK
Liya Li, Tiangong University, China
Shaolan Li, Georgia Institute of Technology, USA
Xiao Li, Southeast University, China
Bor-Ren Lin, National Yunlin University of Science and Technology, Taiwan
Feng Lin, Beijing Institute of Technology, China
Steve Ling, University of Technology, Sydney, Australia
Lei Liu, Liaoning University of Technology, China
Neng-Wu Liu, Xidian University, China
Yina Liu, Xi'an Jiaotong, China
Guido Lombardi, Polytechnic of Turin, Italy
Wen-Jun Lu, Nanjing University of Posts & Telecommunications, China
Maurizio Magarini, Politecnico di Milano, Italy
R. Maheswar, Centre for Research and Development, KPR Institute of Engineering and Technology, India
Rongwei Mao, University of California, Irvine, USA
Paolo Marconcini, University of Pisa, Italy
Stephan Marini, Universidad de Alicante, Spain
Diego Masotti, University of Bologna, Italy
X. Mei, University of Salford, UK
Matteo Meneghini, University of Padova, Italy
Kambiz Moez, University of Alberta, Canada
Giorgio Montisci, Università degli Studi di Cagliari, Italy
Rajani K. Mudi, Jadavpur University, India
Ravibabu Mulaveesala, Indian Institute of Technology, India
Liam Murphy, University College Dublin, Ireland
Fabio Narducci, Parthenope University of Naples, Italy
Raouf Senhadji Navarro, Universidad de Sevilla, Spain
Hiraku Okada, Nagoya University, Japan
Ram Bilas Pachori, Indian Institute of Technology, India
Shantanu Padhi, Amphenol MCP, USA
Sanjeevikumar Padmanaban, University of South-Eastern Norway, Norway
Christos Papavassiliou, Imperial College London, UK
Ikmo Park, Ajou University, Republic of Korea
Shivnarayan Patidar, National Institute of Technology Goa, India
Santi Concetto Pavone, University of Catania, Italy
Jun Peng, University of Lincoln, UK
Adriano Peres, Universidade Federal de Santa Catarina, Brazil
Jan C. Petersen, Danish National Metrology Institute, Denmark
Ajay Poddar, Synergy Microwave Corporation, USA

Symon K. Podilchak, Heriot-Watt University, UK
Guodong Qin, Xidian University, China
Harikrishnan Ramiah, University of Malaya, Malaysia
Paul Record, Heriot-Watt University, UK
Pedro Reviriego, Universidad Carlos III de Madrid, Spain
Hendrik Rogier, Ghent University, Belgium
Ankur Guha Roy, Broadcom Inc., USA
Syed Sabir Hussain Bukhari, Chung-Ang University, Republic of Korea
Kunio Sakakibara, Nagoya Institute of Technology, Japan
Arindam Sanyal, Arizona State University, USA
Michael A. Saville, Wright State University, USA
Andrey V. Savkin, University of New South Wales, Australia
Michele Scarpiniti, Università di Roma "La Sapienza", Italy
Jacob Scharcanski, Federal University of Rio Grande do Sul, Brazil
Dominique Schreurs, University of Leuven, Belgium
Winston Seah, Victoria University of Wellington, New Zealand
Yuliya Semenova, Dublin Institute of Technology, Ireland
Abhishek Sharma, Stevens Institute of Technology, USA
Manish Sharma, Institute of Infrastructure Technology Research and Management, India
Andy Shaw, Liverpool John Moores University, UK
Arman Shojaeifard, BT Labs, UK
Zhan Shu, University of Alberta, Canada
Simranjit Singh, Punjabi University, India
G. R. Sinha, International Institute of Information Technology, Bangalore (IIIT-B), India
Ali Hassan Sodhro, Mid Sweden University, Sweden
Nutapong Somjit, University of Leeds, UK
Young Ik Son, Myongji University, Republic of Korea
Sameer Sonkusale, Tufts University, USA
Leonel Sousa, Universidade de Lisboa, Portugal
Patrick Steglich, Leibniz-Institut für innovative Mikroelektronik, Germany
Bidyadhar Subudhi, Indian Institute of Technology Goa, India
Hongbo Sun, Nanyang Technological University, Singapore
Jiayue Sun, Northeastern University, China
Sheng Sun, University of Electronic Science and Technology of China, China
Chi Wan Sung, City University of Hong Kong, Hong Kong, China
Safumi Suzuki, Tokyo Institute of Technology, Japan
Kenichi Takahota, University of British Columbia, Canada
Kimberly Tam, University of Plymouth, UK
Hark Hoe Tan, The Australian National University, Australia
Ming-Chun Tang, Chongqing University, China
Yang Tang, East China University of Science and Technology, China
Luciano Tarricone, University of Salento, Italy
Chih-Cheng Tseng, National Ilan University, Taiwan
Ayşegül Uçar, Firat University, Turkey
Kazuhiro Umetani, Okayama University, Japan
Sundarapandian Vaidyanathan, Vel Tech University, India
Shelly Vishwakarma, University College London, UK
Antonio Vilches, London South Bank University, UK
Anna Vizziello, University of Pavia, Italy
Chao Wang, Xidian University, China
Chao-Fu Wang, National University of Singapore, Singapore
Hanli Wang, Tongji University, China
Ning Wang, Harbin Engineering University, China
Shiqi Wang, City University of Hong Kong, Hong Kong, China
Xiangchuan Wang, Nanjing University of Aeronautics and Astronautics, China
Yan Wang, Fudan University, China
Yueying Wang, Shanghai University, China
Zhaohao Wang, Beihang University, China
Kunpeng Wei, Honor Device Co. Ltd., China
Graham Weinberg, Defence Science and Technology Group, Australia

Fangqing Wen, Nanjing University of Aeronautics and Astronautics, China
Zhen Wen, Soochow University, China
Alexander Wong, University of Waterloo, Canada
Hang Wong, City University of Hong Kong, Hong Kong, China
Yue Ivan Wu, Sichuan University, China
Wenchao Xia, Nanjing University of Posts and Telecommunications, China
Mingyang Xie, Nanjing University of Aeronautics and Astronautics, China
Wen Xing, Harbin Engineering University, China
Kai-Da Xu, Xi'an Jiaotong University, China
Kaikai Xu, University of Electronic Science and Technology of China, China
Kuiwen Xu, Hangzhou Dianzi University, China
Scott Yam, Queen's University at Kingston, Canada
Makoto Yamada, Osaka Prefecture University, Japan
Dongsheng Yang, Northeastern University, China
Rongni Yang, Western Sydney University, Australia
Min-Hsin Yeh, National Taiwan University of Science and Technology, Taiwan
Jinpeng Yu, Qingdao University, China
Ye Yuan, Jiangsu University, China
Sherali Zeadally, University of Kentucky, USA
Huanqiang Zeng, Huaquai University, China
Dan Zhang, Zhejiang University of Technology, China
Gang Zhang, Nanjing Normal University, China
Hongming Zhang, Beijing University of Posts and Telecommunications, China
Huiyan Zhang, Chongqing Technology and Business University, China
Kaihua Zhang, Nanjing University of Information Science & Technology, China
Xuefeng Zhang, Northwestern University, China
Yun Zhang, Chinese Academy of Science, China
Zhao Zhang, State Key Laboratory for Superlattices and Microstructures, Institute of Semiconductors, Chinese Academy of Sciences, China
Guodong (Philip) Zhao, University of Glasgow, United Kingdom
Tiesong Zhao, Fuzhou University, China
Jun Zheng, New Mexico Institute of Mining and Technology, USA
Shiqi Zheng, China University of Geosciences (Wuhan), China
Tong-Xing Zheng, Xi'an Jiaotong University, China
Caijun Zhong, Zhejiang University, China
Xinyu Zhou, Stanford University, USA
Guopu Zhu, Chinese Academy of Sciences, China
Yanzheng Zhu, Huaqiao University, China
Haoyu Zhuang, University of Electronic Science and Technology of China, China
Qunbi Zhuge, Shanghai Jiao Tong University, China
Yunlong Zi, Chinese University of Hong Kong, Hong Kong, China
Guangdeng Zong, Qufu Normal University, China
Thomas Zwick, Karlsruhe Institute of Technology, Germany



Sign up for email alerts

Enter your email to receive alerts when new articles and issues are published.

Email address*

Continue



Average time to first decision:
4 weeks

Topics



Stay Connected



Twitter



LinkedIn



Facebook




Instagram



YouTube

Tweets from @IET_Research


IET Research Solut... 
@IET_Resea... · Apr 28

Stay updated with cutting-edge research from IET Journals.

Our [#OpenAccess](#) journals span all areas of engineering and technology, which you can freely browse on the IET Research Hub.

To access the IET Research Hub:
ow.ly/SsvV50NQ8pk

ALT

  1 

 **IET Research Solutions**
Retweeted

Wiley Engineering 
@WileyEngi... · Apr 10

IET Computer Vision call for papers!



[ABOUT THE IET](#)

[IET PRIVACY STATEMENT](#)

[CONTACT IET](#)

Copyright (2023) The Institution of Engineering and Technology. The Institution of Engineering and Technology is registered as a Charity in England & Wales (no 211014) and Scotland (no SC038698)

About Wiley Online Library

- [Privacy Policy](#)
- [Terms of Use](#)
- [About Cookies](#)
- [Manage Cookies](#)
- [Accessibility](#)

[Wiley Research DE&I Statement and Publishing Policies](#)

Pages: 1112-1113 | First Published: August 2017

[Abstract](#) | [Full text](#) | [PDF](#) | [References](#) | [Request permissions](#)

Information and communications

[Free Access](#)

Optimum and quasi-optimum relaxation parameters for low-complexity massive MIMO detector based on Richardson method

J. Minango, C. de Almeida

Pages: 1114-1115 | First Published: August 2017

[Abstract](#) | [Full text](#) | [PDF](#) | [References](#) | [Request permissions](#)

[Free Access](#)

Parsimonious adaptive rejection sampling

L. Martino

Pages: 1115-1117 | First Published: August 2017

[Abstract](#) | [Full text](#) | [PDF](#) | [References](#) | [Request permissions](#)

Microwave technology

[Free Access](#)

Miniaturised unequal Wilkinson power divider using lumped component elements

M. Heydari, S. Roshani

Pages: 1117-1119 | First Published: August 2017

[Abstract](#) | [Full text](#) | [PDF](#) | [References](#) | [Request permissions](#)

[Free Access](#)

Hepta-band bandpass filter based on folded cross-loaded stepped impedance resonator

T. Firmansyah, S. Praptodiyono, A.S. Pramudyo, C. Chairunissa, M. Alaydrus

Pages: 1119-1121 | First Published: August 2017

[Abstract](#) | [Full text](#) | [PDF](#) | [References](#) | [Request permissions](#)

[Free Access](#)

Copyright (2023) The Institution of Engineering and Technology. The Institution of Engineering and Technology is registered as a Charity in England & Wales (no 211014) and Scotland (no SC038698)

About Wiley Online Library

[Privacy Policy](#)

[Terms of Use](#)

[About Cookies](#)

[Manage Cookies](#)

[Accessibility](#)

[Wiley Research DE&I Statement and Publishing Policies](#)

[Help & Support](#)

[Contact Us](#)

[Training and Support](#)

[DMCA & Reporting Piracy](#)

[Opportunities](#)

[Subscription Agents](#)

[Advertisers & Corporate Partners](#)

[Connect with Wiley](#)

[The Wiley Network](#)

[Wiley Press Room](#)

Copyright © 1999-2023 John Wiley & Sons, Inc. All rights reserved

WILEY

Hepta-band bandpass filter based on folded cross-loaded stepped impedance resonator

T. Firmansyah[✉], S. Praptodiyono, A.S. Pramudyo, C. Chairunissa and M. Alaydrus

A hepta-band bandpass filter (HB-BPF) based on folded cross-loaded stepped impedance resonator (SIR) was investigated. A cross-loaded SIR microstrip structure was arranged to produce several transmission zeros. In order to reduce the filter size, a folded cross-loaded SIR was proposed. The HB-BPF was designed on FR4 microstrip substrate with $\epsilon_r = 4.4$, thickness $h = 0.8$ mm, and $\tan \delta = 0.0265$. This HB-BPF achieves transmission coefficients of 0.15, 0.61, 0.45, 1.14, 1.57, 1.77, and 2.08 dB at 0.74, 1.49, 2.25, 3.19, 3.93, 4.68, and 5.50 GHz, respectively. The HB-BPF only occupies $0.1 \times 0.22 \lambda_g$, where λ_g is the guided wavelength at a first passband centre frequency. A good agreement between simulated and measured results validates the design method.

Introduction: In modern wireless communication systems, a multiband band-pass filter (MBPF) is an important and essential component. MBPF is a sub-system of a multiband radio frequency transceiver. An MBPF shall simultaneously operate at several frequencies with high performance [1]. There are some well-known methods frequently used for MBPFs design such as microstrip double-layered structure [2], stub-loaded resonators [3], penta mode resonator (PMR) [4], mixed electric and magnetic coupling [5], semi-lumped resonators [6], stepped impedance resonator (SIR) [7–9], and multiple coupling paths [10]. The authors in [2, 3] present effective methods to design MBPF with good performances by using microstrip double-layered structure [2] and stub-loaded resonators structure [3], however the fractional bandwidth (FBW) of this MBPF is not good. A PMR was proposed by [4], the result shows that the filter has a good performance MBPFs with a little poor result at the last frequency band. The MBPFs proposed by the authors in [5, 6] are still a fairly complex filter geometry with complicated designs and an MBPF with SIR [7] still achieves narrow bandwidth. Furthermore, the authors in [10] present efficient methods to design MBPF by using multiple coupling paths, however the FBW of this MBPF is low.

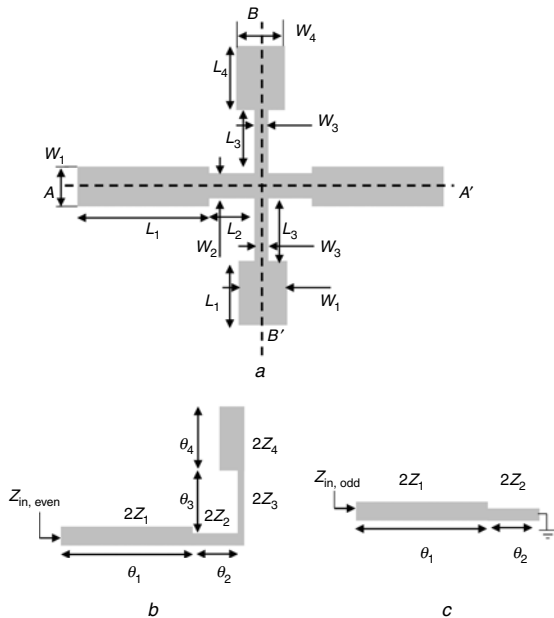


Fig. 1 Structure of cross-loaded SIR: even-mode and odd-mode equivalent circuit
 a Structure of CL-SIR
 b Even-mode equivalent circuit
 c Odd-mode equivalent circuit

In this Letter, a cross-loaded SIR (CL-SIR) microstrip structure was proposed to produce hepta-band bandpass filter (HB-BPF). The CL-SIR is clearly distinct from the microstrip structure as used in [1–10]. The CL-SIR microstrip structure can significantly improve transmission coefficients, wider bandwidth, compact size, and ease of

fabrication. A good agreement could be observed between the simulated and measured results, which demonstrated the validity of the design.

Proposed cross-loaded SIR: The proposed resonator constructed by several SIR is shown in Fig. 1a, where (W_1, L_1) and (W_2, L_2) represent the widths and lengths of the SIR. The cross-loaded is connected to the centre of SIR, where (W_3, L_3) , and (W_4, L_4) show the widths and length of the CL-SIR. Since the resonator is symmetrical to the $A-A'$ plane and $B-B'$ plane, the resonant frequencies for the even and odd excitation can be extracted from admittance condition $Y_{in} = 0$ or impedance condition $Z_{in} = \infty$ [11].

For the even excitation as shown in Fig. 1b, the resonance condition of the structure is found as follows:

$$\frac{Z_2}{4Z_3} \left(1 + \frac{Z_2}{Z_1} \tan \theta_1 \tan \theta_3 \right) \left(\frac{Z_2}{2Z_3} \tan \theta_3 + \frac{Z_2}{2Z_4} \tan \theta_4 \right) + \left(\tan \theta_2 + \frac{Z_2}{Z_1} \tan \theta_1 \right) \left(\frac{Z_2}{2Z_3} + \frac{Z_2}{2Z_4} \tan \theta_4 \right) = 0 \quad (1)$$

Simultaneously, for the odd excitation, we obtained the following resonance condition:

$$\tan \theta_1 \tan \theta_2 = \frac{Z_1}{Z_2} \quad (2)$$

with the Z_n ($n = 1, 2, 3, 4$) and θ_n ($n = 1, 2, 3, 4$) denote the characteristic impedance and electrical length, respectively.

The dependency of the frequency ratios on the impedance ratio is given in Fig. 2a. The chart shows that by increasing the impedance ratio (Z_1/Z_2), the resonant frequencies will vary from fundamental frequency. Meanwhile, the f_2 and f_3 are more stable than f_4, f_5, f_6 and f_7 . Fig. 2b shows the transmission coefficients with varied width W_3 . It shows that the transmission coefficients in f_5, f_6 and f_7 fall dramatically, but still higher than -3 dB. Fig. 2c illustrated the extraction of reflection coefficients with varied L_4 . It shows that the variation of L_4 affected to reflection coefficients values and it also have effect on the frequency shift.

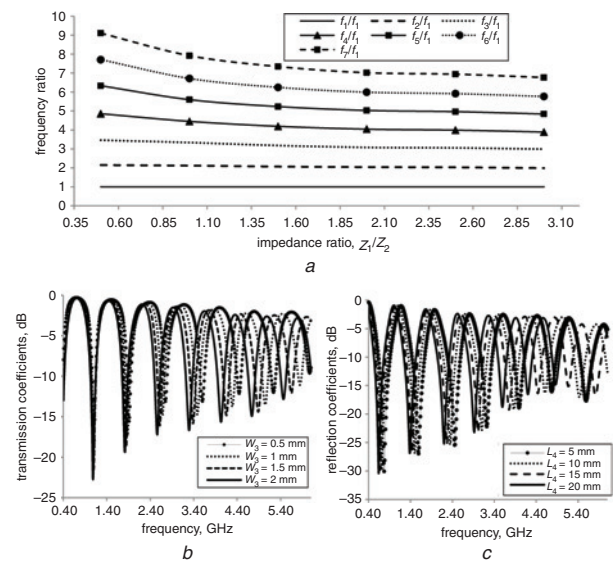


Fig. 2 Frequency ratio, transmission coefficient, and reflection coefficient
 a Relationship between impedance ratio and normalised resonance
 b Transmission coefficients characteristics with varied stub width W_3
 c Reflection coefficient characteristics with varied stub length L_4

Experiment and results discussion: The HB-BPF was designed on FR4 microstrip substrate with the relative permittivity $\epsilon_r = 4.4$, a thickness $h = 0.8$ mm, and a loss tangent $\tan \delta = 0.0265$. The HB-BPF was simulated by using momentum simulation advanced system design, whereby a RS-ZVA vector network analyser was used to test the fabricated prototype of HB-BPF. The layout and the prototype photograph are shown in Figs. 3a and b, respectively. The dimensions are given as follows (all in millimetres): $L_1 = 10, L_2 = 10, L_{3a} = 5.0, L_{3b} = 15, L_{3c} = 30, L_{3d} = 5.0, L_{3e} = 5.0, L_4 = 10, W_1 = 3.5, W_2 = 3.0, W_3 = 1.0$, and $W_4 = 3.0$. The HB-BPF only occupies $0.1 \times 0.22 \lambda_g$, where λ_g is the guided wavelength at a first passband centre frequency.

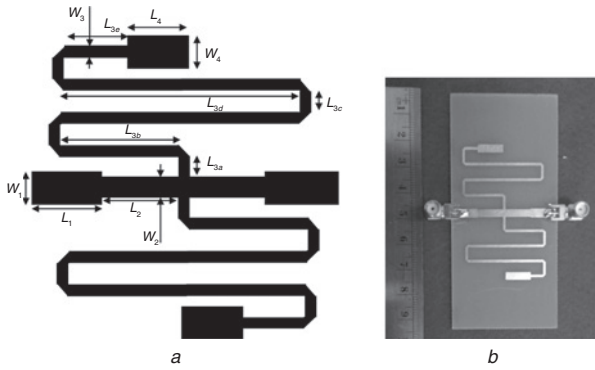


Fig. 3 Layout and photograph HB-BPF

a Layout
b Photograph

Fig. 4 shows the simulated and measured transmission and reflection coefficients of the HB-BPF in a wideband response view. The measured group delays of all pass bands <math>< 5\text{ ns}</math> are also depicted in Fig. 4. Table 1 gives the performance comparison of the multiband BPF with some previous works, from which it can be deduced that the presented study has great merits of transmission coefficient, wide bandwidth, compact size, and ease of fabrication.

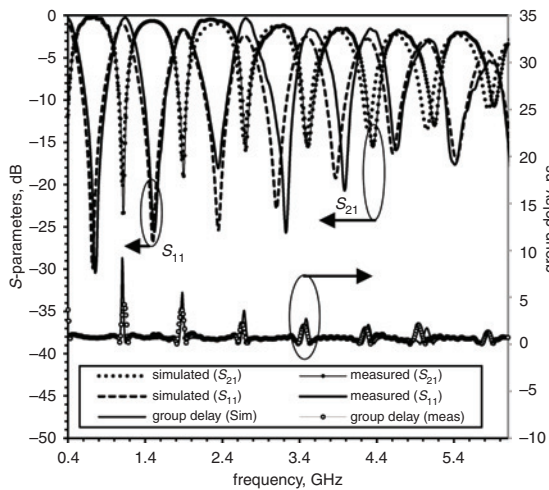


Fig. 4 Simulated and measured results

Table 1: Comparison with some previous multi-band BPFs

Refs.	Pass bands	Frequency, GHz	Transmission coefficients, dB	Size λ_0^2	-3 dB FBW (%)
[4]	5	0.63/1.2/1.8/2.49/3.46	0.43/0.86/1.10/1.98/2.55	0.02	28.5/10/13.6/4.8/4.2
[5]	5	2.1/3.0/4.0/4.7/7.2	0.98/1.76/1.22/1.77/2.39	0.01	13.7/5.6/10.5/5.1/2.9
[6]	6	0.8/1.2/1.4/1.8/2.2/2.5	2.9/2.34/2.59/2.24/2.67/2.64	0.01	2.3/2.9/3.3/3.2/2.0/2.0
[7]	6	0.9/1.2/1.4/1.7/2.0/2.4	2.3/2.0/2.3/2.7/2.2/2.0	0.01	1.5/1.3/1.4/1.3/1.5/1.4
[10]	7	1.05/1.3/1.5/1.8/2.05/2.35/2.85	1.05/1.3/1.5/1.8/2.05/2.35/2.85	0.027	8/4/5/7.5/4.5/5.5/6.5
This work	7	0.74/1.49/2.25/3.19/3.93/4.68/5.50	0.15/0.61/0.45/1.14/1.57/1.77/2.08	0.022	67.5/32.2/25.3/12.8/9.16/6.19/6.00

Conclusion: A HB-BPF based on folded cross-loaded SIR was investigated, which has a good transmission coefficient, wide bandwidth, compact size, and ease of fabrication. The HB-BPF only occupies $0.1 \lambda_g \times 0.22 \lambda_g$, where λ_g is the guided wavelength at a lower passband centre frequency. A good agreement between simulated and measured results validates the design method.

Acknowledgments: The work was supported by the Ministry of Research, Technology and Higher Education, Indonesian Government

in terms of Penelitian Kerjasama Perguruan Tinggi (grant no. 267/UN43.9/PL/K/2016).

© The Institution of Engineering and Technology 2017
Submitted: 27 March 2017 E-first: 12 July 2017
doi: 10.1049/el.2017.1121

T. Firmansyah, S. Praptodiyono and A.S. Pramudyo (*Department of Electrical Engineering, University of Sultan Ageng Tirtayasa, Cilegon, Banten, 42435, Indonesia*)

✉ E-mail: teguhfirmansyah@untirta.ac.id

C. Chairunissa (*School of Engineering–Electronics, University of Edinburgh, Edinburgh EH9 3JN, UK*)

M. Alaydrus (*Department of Electrical Engineering, Universitas Mercu Buana, Meruya, Jakarta, 11650, Indonesia*)

References

- Jing, A., Yonghong, Z., Kai, X., Yingjiang, G., William, J., and Huo, L.: 'Compact sext-band bandpass filter based on single multimode resonator with high band-to-band isolations', *Electron. Lett.*, 2016, **52**, (9), pp. 729–731, doi: 10.1049/el.2016.0227
- Hsu, K., Hung, W., and Tu, W.: 'Compact quint-band microstrip bandpass filter using double-layered substrate'. IEEE MTT-S Int. Digest, Seattle, 2013, pp. 1–4, doi: 10.1109/MWSYM.2013.6697353
- Chen, C.: 'Design of a compact microstrip quint-band filter based on the tri-mode stub-loaded stepped-impedance resonators', *IEEE Microw. Wirel. Compon. Lett.*, 2012, **22**, (7), pp. 357–359, doi: 10.1109/LMWC.2012.2202894
- Chuanming, Xu J., Jin, Z., and Kang, W.: 'Compact QB-BPF based on single PMR', *Electron. Lett.*, 2016, **52**, (17), pp. 1463–1465, doi: 10.1049/el.2016.2202
- Jing, A.: 'Miniaturized quint-band bandpass filter based on multi-mode resonator and $\lambda/4$ resonators with mixed electric and magnetic coupling', *IEEE Microw. Wirel. Compon. Lett.*, 2016, **26**, (5), pp. 343–345, doi: 10.1109/LMWC.2016.2549643
- Tu, W.H., and Hsu, K.W.: 'Design of sext-band bandpass filter and sextaplexer using semi-lumped resonators for system in a package', *IEEE Trans. Compon. Packag. Manuf. Technol.*, 2015, **5**, (2), pp. 265–273, doi: 10.1109/TCPMT.2014.2387198
- Hsu, K.W., Lin, J.-H., and Tu, W.H.: 'Compact sext-band bandpass filter with sharp rejection response', *IEEE Microw. Wirel. Compon. Lett.*, 2014, **24**, (9), pp. 593–595, doi: 10.1109/LMWC.2014.2328895
- Gunawan, W., Teguh, F., and Tierta, S.: 'Design of triple-band bandpass filter using cascade tri-section stepped impedance resonators', *J. ICT Res. Appl.*, 2016, **10**, (1), pp. 43–56, doi: 10.5614%2Fitbj.ict.res.appl.2016.10.1.4
- Gunawan, W., Teguh, F., Priambodo, P.S., et al.: 'Multiband bandpass filter (BPF) based on folded dual-crossed open stubs', *Int. J. Tech.*, 2014, **5**, (1), pp. 32–39, doi: 10.14716/ijtech.v5i1.151
- Chen, C.F., Chang, S.F., and Tseng, B.H.: 'Design of compact microstrip sept-band bandpass filter with flexible passband allocation', *IEEE Microw. Wirel. Compon. Lett.*, 2016, **26**, (5), pp. 346–348, doi: 10.1109/LMWC.2016.2549023
- Velazquez-Ahumada, M.D.C., et al.: 'Application of stub loaded folded stepped impedance resonators to dual-band filters', *Prog. Electromagn. Res.*, 2015, **102**, pp. 107–124, doi: 10.2528/PIER10011406