

Microstrip Filter Design With Defected Ground Structure By Arjun Kumar

The book features research papers presented at the International Conference on Computer Networks and Inventive Communication Technologies (ICCNCT 2018), offering significant contributions from researchers and practitioners in academia and industry. The topics covered include computer networks, network protocols and wireless networks, data communication technologies, and network security. Covering the main core and specialized issues in the areas of next-generation wireless network design, control, and management, as well as in the areas of protection, assurance, and trust in information security practices, these proceedings are a valuable resource, for researchers, instructors, students, scientists, engineers, managers, and industry practitioners.

This book addresses the true innovation in engineering design that may be promoted by blending together models and methodologies from different disciplines, and, in this book, the target was exactly to follow this approach to deliver a new disruptive architecture to deliver these next-generation mobile small cell technologies. According to this design philosophy, the work within this book resides in the intersection of engineering paradigms that includes “cooperation”, “network coding”, and “smart energy-aware frontends”. These technologies will not only be considered as individual building blocks, but re-engineered according to an inter-design approach resulting in the enabler for energy efficient femtocell-like services on the move. The book aims to narrow the gap between the current networking technologies and the foreseen requirements that are targeted at the future development of the 5G mobile and wireless communications networks in terms of the higher networking capacity, the ability to support more users, the lower cost per bit, the enhanced energy efficiency, and adaptability to new services and devices (for example, smart cities, and the Internet of things (IoT)).

Computational Science and Engineering contains peer-reviewed research presented at the International Conference on Computational Science and Engineering (RCC Institute of Information Technology, Kolkata, India, 4-6 October 2016). The contributions cover a wide range of topics: - electronic devices - photonics - electromagnetics - soft computing - artificial intelligence - modern communication systems Focussing on strong theoretical and methodological approaches and applications, Computational Science and Engineering will be of interest to academia and professionals involved or interested in the above mentioned domains.

This book gathers the proceedings of the 8th International Conference on Frontiers of Intelligent Computing: Theory and Applications (FICTA 2020), held at NIT Surathkal, Karnataka, India, on 4–5 January 2020. In these proceedings, researchers, scientists, engineers and practitioners share new ideas and lessons learned in the field of intelligent

computing theories with prospective applications in various engineering disciplines. The respective papers cover broad areas of the information and decision sciences, and explore both the theoretical and practical aspects of data-intensive computing, data mining, evolutionary computation, knowledge management and networks, sensor networks, signal processing, wireless networks, protocols and architectures. Given its scope, the book offers a valuable resource for graduate students in various engineering disciplines.

This book comprises the proceedings of 1st International Conference on Computational Advancement in Communication Circuits and Systems (ICCACCS 2014) organized by Narula Institute of Technology under the patronage of JIS group, affiliated to West Bengal University of Technology. The conference was supported by Technical Education Quality Improvement Program (TEQIP), New Delhi, India and had technical collaboration with IEEE Kolkata Section, along with publication partner by Springer. The book contains 62 refereed papers that aim to highlight new theoretical and experimental findings in the field of Electronics and communication engineering including interdisciplinary fields like Advanced Computing, Pattern Recognition and Analysis, Signal and Image Processing. The proceedings cover the principles, techniques and applications in microwave & devices, communication & networking, signal & image processing, and computations & mathematics & control. The proceedings reflect the conference's emphasis on strong methodological approaches and focus on applications within the domain of Computational Advancement in Communication Circuits and Systems. The content also emphasizes the emerging technologies in the Electronics and Communication field together in close examinations of practices, problems and trends.

This highly practical resource offers you an in-depth understanding of microwave front end integration and how it is applied in the avionics field. You find detailed guidance on circuit integration, including coverage of component miniaturization, hybrid and monolithic integrated circuits, and 3D design. The book addresses system integration with discussions on the combination of different avionic systems, single antenna design, top/bottom front end combination, and integration of passive and active antenna modules. This first-of-its-kind volume features unique material on novel structures of avionics front end, novel transmission lines, elements, and devices, as well as new strategies for microwave front-end design. Supported with nearly 200 illustrations and more than 160 equations, this book is a valuable professional reference and also serves well as a postgraduate textbook.

The first edition of "Microstrip Filters for RF/Microwave Applications" was published in 2001. Over the years the book has been well received and is used extensively in both academia and industry by microwave researchers and engineers. From its inception as a manuscript the book is almost 8 years old. While the fundamentals of filter circuits have not changed, further innovations in filter realizations and other applications have occurred with changes in the technology

and use of new fabrication processes, such as the recent advances in RF MEMS and ferroelectric films for tunable filters; the use of liquid crystal polymer (LCP) substrates for multilayer circuits, as well as the new filters for dual-band, multi-band and ultra wideband (UWB) applications. Although the microstrip filter remains as the main transmission line medium for these new developments, there has been a new trend of using combined planar transmission line structures such as co-planar waveguide (CPW) and slotted ground structures for novel physical implementations beyond the single layer in order to achieve filter miniaturization and better performance. Also, over the years, practitioners have suggested topics that should be added for completeness, or deleted in some cases, as they were not very useful in practice. In view of the above, the authors are proposing a revised version of the “Microstrip Filters for RF/Microwave Applications” text and a slightly changed book title of “Planar Filters for RF/Microwave Applications” to reflect the aforementioned trends in the revised book.

This book focuses on new techniques, analysis, applications and future trends of microstrip and printed antenna technologies, with particular emphasis to recent advances from the last decade. Attention is given to fundamental concepts and techniques, their practical applications and the future scope of developments. Several topics, essayed as individual chapters include reconfigurable antenna, ultra-wideband (UWB) antenna, reflectarrays, antennas for RFID systems and also those for body area networks. Also included are antennas using metamaterials and defected ground structures (DGSs). Essential aspects including advanced design, analysis and optimization techniques based on the recent developments have also been addressed. Key Features: Addresses emerging hot topics of research and applications in microstrip and printed antennas Considers the fundamental concepts, techniques, applications and future scope of such technologies Discusses modern applications such as wireless base station to mobile handset, satellite earth station to airborne communication systems, radio frequency identification (RFID) to body area networks, etc. Contributions from highly regarded experts and pioneers from the US, Europe and Asia This book provides a reference for R&D researchers, professors, practicing engineers, and scientists working in these fields. Graduate students studying/working on related subjects will find this book as a comprehensive literature for understanding the present and future trends in microstrip and printed antennas.

CSIT (APTİKOM Journal on Computer Science and Information Technologies) Published by APTİKOM & Organized by Aptikom Publisher and Pandawan. CSIT is published three a year, every March, July, and November.

The volume comprises best selected papers presented at International Conference on Wireless Communication (ICWiCOM) which is organized by Department of Electronics and Telecommunication Engineering of D J Sanghvi College of Engineering. The volume focusses on narrowed topics of wireless communication like signal and image processing applicable to wireless domain,

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networking, microwave and antenna designs, tele-medicine systems, etc. The papers are divided into three main domains like, networking, antenna designs and embedded systems applicable to the communication domain. The content will be helpful for Post-Graduate and Doctoral students in their research.

The aim of this book is to show some applications of fractal analysis in the fields of sciences. The first chapter introduces the readers to the book, while the second chapter shows the methods and challenges of fractal analysis of time-series data sets. The third chapter demonstrates fractal geometry as an attractive choice for miniaturized planar microwave filter design. The fourth chapter presents fractal antennas for wearable applications. The objective of the fifth chapter is to show some Parrondian games in discrete dynamic systems, while the last chapter reveals fractal structures of carbon nanotube system arrays.

Microelectromechanical Systems (MEMS) stand poised for the next major breakthrough in the silicon revolution that began with the transistor in the 1960s and has revolutionized microelectronics. MEMS allow one to not only observe and process information of all types from small scale systems, but also to affect changes in systems and the environment at that scale. "RF MEMS Switches and Integrated Switching Circuits" builds on the extensive body of literature that exists in research papers on analytical and numerical modeling and design based on RF MEMS switches and micromachined switching circuits, and presents a unified framework of coverage. This volume includes, but is not limited to, RF MEMS approaches, developments from RF MEMS switches to RF switching circuits, and MEMS switch components in circuit systems. This book also: -Presents RF Switches and switching circuit MEMS devices in a unified framework covering all aspects of engineering innovation, design, modeling, fabrication, control and experimental implementation -Discusses RF switch devices in detail, with both system and component-level circuit integration using micro- and nano-fabrication techniques -Includes an emphasis on design innovation and experimental relevance rather than basic electromagnetic theory and device physics "RF MEMS Switches and Integrated Switching Circuits" is perfect for engineers, researchers and students working in the fields of MEMS, circuits and systems and RFs.

The book comprises select proceedings of the first International Conference on Advances in Electrical and Computer Technologies 2019 (ICAECT 2019). The papers presented in this book are peer reviewed and cover wide range of topics in Electrical and Computer Engineering fields. This book contains the papers presenting the latest developments in the areas of Electrical, Electronics, Communication systems and Computer Science such as smart grids, soft computing techniques in power systems, smart energy management systems, power electronics, feedback control systems, biomedical engineering, geo informative systems, grid computing, data mining, image and signal processing, video processing, computer vision, pattern recognition, cloud computing, pervasive computing, intelligent systems, artificial intelligence, neural network and fuzzy logic, broad band communication, mobile and optical communication, network security, VLSI, embedded systems, optical networks and wireless communication. This book will be of great use to the researchers and students in the areas of Electrical and Electronics Engineering, Communication systems and Computer Science.

Advanced, specialized coverage of microstrip filter design Microstrip Filters for RF/Microwave Applications is the only professional

reference focusing solely on microstrip filters. It offers a unique and comprehensive treatment of filters based on the microstrip structure and includes full design methodologies that are also applicable to waveguide and other transmission line filters. The authors include coverage of new configurations with advanced filtering characteristics, new design techniques, and methods for filter miniaturization. The book utilizes numerous design examples to illustrate and emphasize computer analysis and synthesis while also discussing the applications of commercially available software. Other highlights include: Lowpass and bandpass filters Highpass and bandstop filters Full-wave electromagnetic simulation Advanced materials and technologies Coupled resonator circuits Computer-aided design for low-cost/high-volume production Compact filters and filter miniaturization Microstrip Filters for RF/Microwave Applications is not only a valuable design resource for practitioners, but also a handy reference for students and researchers in microwave engineering.

This Special Issue focuses on the state-of-the-art results from the definition and design of filters for low- and high-frequency applications and systems. Different technologies and solutions are commonly adopted for filter definition, from electrical to electromechanical and mechanical solutions, from passive to active devices, and from hybrid to integrated designs. Aspects related to both theoretical and experimental research in filter design, CAD modeling and novel technologies and applications, as well as filter fabrication, characterization and testing, are covered. The proposed research articles deal with different topics as follows: Modeling, design and simulation of filters; Processes and fabrication technologies for filters; Automated characterization and test of filters; Voltage and current mode filters; Integrated and discrete filters; Passive and active filters; Variable filters, characterization and tunability.

This book includes papers presented at the Second International Conference on Electronic Engineering and Renewable Energy (ICEERE 2020), which focus on the application of artificial intelligence techniques, emerging technology and the Internet of things in electrical and renewable energy systems, including hybrid systems, micro-grids, networking, smart health applications, smart grid, mechatronics and electric vehicles. It particularly focuses on new renewable energy technologies for agricultural and rural areas to promote the development of the Euro-Mediterranean region. Given its scope, the book is of interest to graduate students, researchers and practicing engineers working in the fields of electronic engineering and renewable energy.

The first of its kind, this comprehensive work details the theory and practical design of new multi-band filters.

In the front-end trans-receiver of a communication system, a microwave filter is required to suppress some unwanted frequencies while pass some of the desired frequencies. One of the filter types is a bandpass filter. There are numerous types of bandpass filter design methods. One of the bandpass filters is a microstrip based parallel coupled line bandpass filter, which offers reasonable matching bandwidth. This thesis presents the investigations results of the wideband microstrip bandpass filters using defected ground structures (DGS). The advantage of DGS is that it improves the matching bandwidth performance of the filter without adding any extended length to the filter design. The proposed

bandpass filter using DGS on low loss Roger's substrate ($\epsilon_r = 2.2$, $\tan \delta = 0.0004$) is excited using two edge launchers 50 Ω coaxial probes. The reference parallel coupled bandpass filter shows a fractional bandwidth of 62% ($S_{11} < -10$ dB) with the passband frequency range of 2.9 GHz to 5.6 GHz and insertion loss better than -0.5 dB. Various shapes of defected ground plane structures were investigated and their effect on the filter performance was recorded. In comparison to the reference filter, implementation of DGS with the filter offers an improved passband frequency range of 2.65 GHz to 5.75 GHz and insertion loss and reflection coefficient magnitude better than -0.3 dB and -15dB, which accounts to a fractional bandwidth of 74%. The effect of employing electromagnetic bandgap (EBG) structures with the defected ground plane based filter was also studied, which shows a fractional bandwidth of 80%, the insertion loss and reflection coefficient magnitude are better than -0.3 dB and -15 dB, respectively. So, clearly the performance of the filter is significantly improved by employing the DGS and EBG structures. This filter was fabricated on a low cost FR-4 substrate ($\epsilon_r = 4.5$, $\tan \delta = 0.04$) while physical dimensions of the filter remained unchanged. The prototype filter's experimental verification was performed using a vector network analyzer. This DGS filter on FR-4 substrate exhibits an insertion loss, S_{21} more than -3 dB, and reflection coefficient magnitude, S_{11} less than -10 dB with the center frequency of the proposed filter 2.4 GHz and thereby an operating bandwidth of 64%. For comparison, the operational bandwidth of the bandpass filter without DGS is only 44%.

Provides a comprehensive discussion of planar transmission lines and their applications, focusing on physical understanding, analytical approach, and circuit models Planar transmission lines form the core of the modern high-frequency communication, computer, and other related technology. This advanced text gives a complete overview of the technology and acts as a comprehensive tool for radio frequency (RF) engineers that reflects a linear discussion of the subject from fundamentals to more complex arguments. Introduction to Modern Planar Transmission Lines: Physical, Analytical, and Circuit Models Approach begins with a discussion of waves on transmission lines and waves in material medium, including a large number of illustrative examples from published results. After explaining the electrical properties of dielectric media, the book moves on to the details of various transmission lines including waveguide, microstrip line, coplanar waveguide, strip line, slot line, and coupled transmission lines. A number of special and advanced topics are discussed in later chapters, such as fabrication of planar transmission lines, static variational methods for planar transmission lines, multilayer planar transmission lines, spectral domain analysis, resonators, periodic lines and surfaces, and metamaterial realization and circuit models. Emphasizes modeling using physical concepts, circuit-models, closed-form expressions, and full derivation of a large number of expressions Explains advanced mathematical treatment, such

as the variation method, conformal mapping method, and SDA Connects each section of the text with forward and backward cross-referencing to aid in personalized self-study Introduction to Modern Planar Transmission Lines is an ideal book for senior undergraduate and graduate students of the subject. It will also appeal to new researchers with the inter-disciplinary background, as well as to engineers and professionals in industries utilizing RF/microwave technologies. This new volume provides an abundance of information on new biomedical applications being used today. The book covers a wide range of concepts and technologies, discussing such modern technological methods as the Internet of Things, e-pills, biomedical sensors, support vector machines, wireless devices, image and signal processing in e-health, and machine learning. It also includes a discussion on software implementation for the devices used in biomedical applications. The different types of antennas, including antennas using RF energy harvesting for biomedical applications, are covered as well.

The book includes research papers on current developments in the field of soft computing and signal processing, selected from papers presented at the International Conference on Soft Computing and Signal Processing (ICSCSP 2018). It features papers on current topics, such as soft sets, rough sets, fuzzy logic, neural networks, genetic algorithms and machine learning. It also discusses various aspects of these topics, like technologies, product implementation, and application issues.

Wireless communications have become invaluable in the modern world. The market is going through a revolutionary transformation as new technologies and standards endeavor to keep up with demand for integrated and low-cost mobile and wireless devices. Due to their ubiquity, there is also a need for a simplification of the design of wireless systems and networks. The Handbook of Research on Advanced Trends in Microwave and Communication Engineering showcases the current trends and approaches in the design and analysis of reconfigurable microwave devices, antennas for wireless applications, and wireless communication technologies. Outlining both theoretical and experimental approaches, this publication brings to light the unique design issues of this emerging research, making it an ideal reference source for engineers, researchers, graduate students, and IT professionals.

This book represents a collection of papers presented at the 2015 International Conference on Advanced Material Engineering (AME 2015), held in Guangzhou, China. With the rapid development of industry and information technology, researchers across all fields began to discuss new ideas related to materials science and manufacturing technology. This proceedings provide a valuable insight from researchers and scientists who exchanged their ideas in the conference.

Contents:Material Physics and Chemistry:Composites MaterialsNanomaterials and NanocompositesIron and SteelCeramic, Films and GlassesSemiconductors MaterialChemical MaterialBiomaterialsOptical, Electronic, Magnetic

MaterialsNew Energy Materials and Environmental Friendly MaterialsNew Functional MaterialsMaterials Process Engineering:Thermal Engineering Theory and ApplicationsPolymer Materials ProcessingMetallurgy Technology and ApplicationSurface Engineering/CoatingsMaterials FormingWelding & JoiningLaser ProcessingSevere Plastic DeformationTribology in Manufacturing ProcessesCasting and solidificationEmerging Areas of Materials Science:Atomic Molecular and Laser PhysicsSpintronicsSolid State Ionics (Materials and Devices)Plasma PhysicsNanobiomaterials / Drug Delivery Readership: Graduate students and research professionals in materials engineering keeping up with the latest advancements in the field. Keywords:Composites;Nanomaterials;Biomaterials;Energy Materials;Functional Materials;Semiconductors;Metallurgy;Semiconductors;Solid State Ionics;Optical Materials;Magnetic Materials;Electronic MaterialsKey Features:Latest Research results on Material EngineeringCross-disciplinary ResearchResearch results come from all over the worldSome famous professors give the keynote speech on the conference

Advanced Design Techniques for RF Power Amplifiers provides a deep analysis of theoretical aspects, modelling, and design strategies of RF high-efficiency power amplifiers. The book can be used as a guide by scientists and engineers dealing with the subject and as a text book for graduate and postgraduate students. Although primarily intended for skilled readers, it provides an excellent quick start for beginners.

This book presents peer-reviewed articles from the 6th International Conference on Wireless Technologies, Embedded and Intelligent Systems (WITS 2020), held at Fez, Morocco. It presents original research results, new ideas and practical lessons learnt that touch on all aspects of wireless technologies, embedded and intelligent systems. WITS is an international conference that serves researchers, scholars, professionals, students and academicians looking to foster both working relationships and gain access to the latest research results. Topics covered include Telecoms & Wireless Networking Electronics & Multimedia Embedded & Intelligent Systems Renewable Energies.

One of the most critical resources required for wireless communication is the radio spectrum. Traditionally, the administration of the spectrum rights tends to grant exclusive rights to some services in the major geographic regions. On the other hand, several studies have shown that the spectrum is actually underutilized and that new devices should use the underutilized spectrum in an opportunistic manner. Cognitive radio is a way to do that. The cognitive radio needs to collect cognition about the radio environment to operate efficiently. Such a radio needs to understand if the spectrum it intends to use is free or utilized by some primary user. By primary user we mean the licensed user of the band, and correspondingly the cognitive radios are often termed as secondary users. The goal of this book is to collect recent research about cognitive radio and provide an up-to-date review of the challenging topic.

Continuing advancements in electronics creates the possibility of communicating with more people at greater distances.

Such an evolution calls for more efficient techniques and designs in radio communications. Emerging Innovations in Microwave and Antenna Engineering provides innovative insights into theoretical studies on propagation and microwave design of passive and active devices. The content within this publication is separated into three sections: the design of antennas, the design of the antennas for the RFID system, and the design of a new structure of microwave amplifier. Highlighting topics including additive manufacturing technology, design application, and performance characteristics, it is designed for engineers, electricians, researchers, students, and professionals, and covers topics centered on modern antenna and microwave circuits design and theory.

This book addresses the design challenges in near-field wireless power transfer (WPT) systems, such as high efficiency, compact size, and long transmission range. It presents new low-profile designs for the TX/RX structures using different shapes of defected ground structures (DGS) like (H, semi-H, and spiral-strips DGS). Most near-field WPT systems depend on magnetic resonant coupling (MRC) using 3-D wire loops or helical antennas, which are often bulky. This, in turn, poses technical difficulties in their application in small electronic devices and biomedical implants. To obtain compact structures, printed spiral coils (PSCs) have recently emerged as a candidate for low-profile WPT systems. However, most of the MRC WPT systems that use PSCs have limitations in the maximum achievable efficiency due to the feeding method. Inductive feeding constrains the geometric dimensions of the main transmitting (TX)/receiving (RX) resonators, which do not achieve the maximum achievable unloaded quality factor. This book will be of interest to researchers and professionals working on WPT-related problems.

This book (CCIS 839) constitutes the refereed proceedings of the First International Conference on Communication, Networks and Computings, CNC 2018, held in Gwalior, India, in March 2018. The 70 full papers were carefully reviewed and selected from 182 submissions. The papers are organized in topical sections on wired and wireless communication systems, high dimensional data representation and processing, networks and information security, computing techniques for efficient networks design, electronic circuits for communication system.

The book presents papers delivered by researchers, industrial experts and academicians at the Conference on Emerging Trends in Computing and Communication (ETCC 2014). As such, the book is a collection of recent and innovative works in the field Network Security and Cryptography, Cloud Computing and Big Data Analytics, Data Mining and Data Warehouse, Communication and Nanotechnology and VLSI and Image Processing.

This book reports on innovative concepts and practical solutions at the intersection between engineering design, engineering production and industrial management. It covers cutting-edge design, modeling and control of dynamic and multiphysics systems, knowledge management systems in industry 4.0, cyber-physical production systems, additive and

sustainable manufacturing and many other related topics. The original, carefully selected, peer-reviewed chapters highlight collaborative works between different countries and between industry and universities, thus offering a timely snapshot for the research and industrial communities alike, as well as a bridge to facilitate communication and collaboration.

The increasing demand for electronic devices for private and industrial purposes lead designers and researchers to explore new electronic devices and circuits that can perform several tasks efficiently with low IC area and low power consumption. In addition, the increasing demand for portable devices intensifies the call from industry to design sensor elements, an efficient storage cell, and large capacity memory elements. Several industry-related issues have also forced a redesign of basic electronic components for certain specific applications. The researchers, designers, and students working in the area of electronic devices, circuits, and materials sometimes need standard examples with certain specifications. This breakthrough work presents this knowledge of standard electronic device and circuit design analysis, including advanced technologies and materials. This outstanding new volume presents the basic concepts and fundamentals behind devices, circuits, and systems. It is a valuable reference for the veteran engineer and a learning tool for the student, the practicing engineer, or an engineer from another field crossing over into electrical engineering. It is a must-have for any library.

With the development of mobile 4G communication system, people's requirements for the speed of wireless communication are rapidly increasing. In order to meet this need, the research and development of the fifth generation (5G) wireless systems has been carried out. Compared with previous generation (1G~4G), 5G will have significant improvements in transmission rate, latency, mobility and so on. The book "Microwave/RF Components for 5G Front-End Systems" is outlines the simulation, design, and fabrication of microwave components including Antennas, Filters, and Power Amplifiers for 5G wireless communications. In addition, exhaustive reviews have been presented, classifying the various types and applications of reconfigurable antennas, Filters and amplifiers for current and future wireless networks. This book presents the design, development and field trials of radio frequency based wireless monitoring system for sleep apnoea patients. It contains 4 major areas including general background of wireless monitoring technology and MIMO in wireless body area network (WBAN), microwave hardware designs, virtual MIMO in WBAN and hardware system level implementation and field trials. At components level, this book presents the design theory, process and examples of bandpass filters, lowpass filters, low profile patch antennas, power amplifiers and oscillators which are the key elements in transducer designs in the body area network and cooperative communication wireless sensor network system. At system level, this book features the hardware integration, field trial and network coding techniques. This book

also gives a presentation of virtual MIMO applications, e.g. MIMO implementation using FPGA, correlation coefficient measurement. The book will create impact in the fields of wireless monitoring technology in biomedical engineering, which have been growing exponentially.

Arjun Kumar received the B.Tech. and M.Tech. in electronics and communication engineering from U.P. Technical University of India and Graphic Era University of India, in 2004 and 2010, respectively. He received PhD degree at Microwave and Millimeter wave Laboratory, from Indian Institute of Technology Roorkee of India, in 2014, is currently working as Post Doctoral Fellow at Korea University, Korea. His research interest include microwave and millimeter-wave integrated circuits at Terahertz frequency

This proceedings volume contains selected papers presented at the 2014 AASRI International Conference on Applied Engineering Sciences, held in Hollywood, LA, USA. Contributions cover the latest developments and advances in the field of Applied Engineering Sciences.

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