International Conference on Microwave Acoustics & Mechanics

18 –20 July 2022

Program

PRELIMINARY

EuMA European Microwave Association

MTT-S® IEEE

Sessions

Session M1: Opening Session

Welcome Address

Amelie Hagelauer, Conference Chair

Keynote Talk
The Path Towards 6G: From Millimeter Waves to THz

Taro Eichler
Technology Manager for Wireless Communications and Photonics
Rohde & Schwarz

Research activities in academia and industry worldwide towards the 6th generation (6G) mobile communication system have recently considerably gained momentum. In this introduction we will provide an overview of the anticipated 6G timeline and technology concepts which have to fulfil even more stringent requirements in comparison to 5G, such as ultra-high data rates, energy efficiency, global coverage and connectivity as well as extremely high reliability and low latency. One of the 6G technologies are sub-Terahertz and terahertz (THz) waves which have frequencies extending from 0.1 THz up to 3 THz and fall in the spectral region between microwave and optical waves. The prospect of offering large contiguous frequency bands to meet the demand for highest data transfer rates up to the terabit/sec range make it a key research area of 6G mobile communication. In light of the approaching ITU WRC23, academic and industrial research is striving to demonstrate the feasibility of this frequency region for communication. This workshop highlights the required interdisciplinary approach, with close interaction of high-frequency semiconductor technology for RF electronics but also including alternative approaches using photonic technologies. The THz region also shows great promise for many applications areas ranging from imaging to spectroscopy and sensing. To fully exploit the potential of the new frequency ranges it is also crucial to understand

the propagation characteristics for the development of the future communication standards by performing channel measurements. We will highlight the characteristics of channel propagation in this frequency region and present new results from channel measurements at 158 GHz and 300 GHz.

Keynote Talk
Perspectives on Acoustic Filters Found in Today's Smartphones

Rich Ruby
Director of FBAR and SiSAW Technology
Broadcom

Smartphones contains 50 to 70 radios — each radio is assigned a radio band and a filter. Duplication of radio bands matching the number of antennas further increases filter count. Two technologies: SAW and BAW technologies dominate the filtering in phones. Today, filters are 'bundled' into Front End Modules that include 10 to 40 filters per module. The demand for these modules generate filter volumes in excess of tens of billions per year. Stakes are incredibly high in this "winner take all" environment. And the 'battle' for ascendency in filter technology can decide who wins the module business (and all the filters inside the module). BAW has dominated the high end Smartphone slots where performance is paramount. SAWs dominate low frequency modules where cost/commoditization occurs. However, SAW technology has evolved from low performing leaky-mode SAWs to Temperature Compensated SAWs and most recently SAWs manufactured on ultra-thin piezo layer bonded to a silicon carrier wafer. These latest SAW devices, first championed by Murata (Guided Wave or GWSAW) achieve an impressive performance in the mid/high frequency bands. GWSAWs, is a disruptive breakthrough and has received tremendous press. In recent years, BAWs have quietly adapted dopants (like Scandium) into the AlN unit cell. Adding impurities can greatly increase the coupling coefficient. This is also very much a disruptive technology. As wide band filtering becomes more common, filters require increasing coupling coefficients to meet wider bandwidths. This talk will cover both SAW and BAW technologies, their performance improvements over time and touch on alternative technologies.

Session M2: Systems & Applications

Chairs: Holger Maune Otto von Guericke University Magdeburg, Germany
tbd

14:00 **M2.1 RF Phase Shifters Design Based on Barium Strontium Titanate Thick and Thin Films**
Patricia Bouça, Rui Pinho, Anna Wlodarkiewicz, Alexander Tkach, João Matos, Paula Vilarinho and Nuno Borges Carvalho
University of Aveiro, Portugal

14:20 **M2.2 Analytical Synthesis of Acoustic Wave Duplexers and Multiplexers**
Eloi Guerrero, Lluis Acosta, Jordi Verdu and Pedro de Paco
Universitat Autonoma de Barcelona, Spain

14:40 **M2.3 Acoustic Wave Focusing Lens at Radio Frequencies in Thin-Film Lithium Niobate**
Jack P Kramer, Daehun Lee, Sinwoo Cho, Shahin Jahanbani, Keji Lai and Ruochen Lu
University of Texas at Austin, USA

15:00 **M2.4 Shear-Horizontal SAW Driven Asymmetric Structure of Array Gold Nanoparticles for Reconfigurable Localized Surface Plasmon Resonance Spectrum**
Teguh Firmansyah[1], Gunawan Wibisono[2], Eko Tjipto Rahardjo[2] and Jun Kondoh[3]
[1] University of Sultan Ageng Tirtayasa, Indonesia,
[2] University of Indonesia, Indonesia,
[3] Shizuoka University, Japan

15:20 **M2.5 Fingerprint Imaging With Arrayed GHz PbTiO3 Transducers**
Yuna Koike, Yusuke Sato and Takahiko Yanagitani
Waseda University, Japan

Session M3: Non-Linearities

Chairs: Vikrant Chauhan Qualcomm, Germany
Markus Mayer Qualcomm, Germany

16:20 **M3.1 Recent Studies on Nonlinearity in SAW Devices**
Ryo Nakagawa[1], Haruki Kyoya[1], Hiroshi Shimizu[1], Masahiro Gawasawa[1], Takanao Suzuki[1], Tatsuya Omori[2] and Ken-ya Hashimoto[2]
[1] Murata Manufacturing Co. Ltd., Japan,
[2] Chiba University, Japan

16:40 **M3.2 Application of the Input-Output Equivalent Sources Method for the Simulation of Nonlinearities in TC-SAW Resonators and Filters**
Marta González-Rodríguez[1], Carlos Collado[1], Jordi Mateu[1], Jose-María González-Arbesú[1], Sebastian Huebner[2] and Robert Aigner[3]
[1] Universitat Politècnica de Catalunya, Spain,
[2] Qorvo, Munich, Germany,
[3] Qorvo, USA

17:00 **M3.3 Interferometric Investigations of BAW Filter Harmonic Performance**
Susanne Kreuzer
Qorvo, USA

17:20 **M3.4 Dependency of Nonlinearity on Design Parameters in SAW Devices**
Thomas Forster[1], Vikrant Chauhan[2], Markus Mayer[2], Elena Mayer[3], Andreas Mayer[3], Thomas Ebner[2], Karl Wagner[2] and Amelie Hagelauer[1]
[1] Technical University of Munich, Germany,
[2] Qualcomm, Germany,
[3] Hochschule Offenburg, Germany

17:40 **M3.5 Perturbation Analysis of Nonlinearity in Radio Frequency Bulk Acoustic Wave Resonators**
Ken-Ya Hashimoto
University of Electronic Science and Technology of China, China

Session T1: Simulation & Modelling (I)

Chairs: Jordi Verdu Universitat Autonoma de Barcelona, Spain
tbd

09:00 **T1.1 Enabling Microwave-Acoustic Ladder Filters Feasibility by Bounded Filter Reflection Responses**
Carlos Caballero, Lluis Acosta, Eloi Guerrero, Jordi Verdu and Pedro de Paco
Universitat Autonoma de Barcelona, Spain

09:20 **T1.2 A 3D Finite Element Model of H2 Emissions in Apodized BAW Devices**
Christopher Kirkendall, Pen-Li Yu, Dong Shim, Siamak Fouladi and Chenchen Liu
Broadcom Limited, USA

09:40 **T1.3 A Modified H2 Emissions Circuit Model for BAW Devices**
Pen-Li Yu, Dong Shim, Christopher Kirkendall and Siamak Fouladi
Broadcom Limited, USA

10:00 **T1.4 Thickness Shear Mode Epitaxial (10-12) LiNbO3 (11-20) AZO/(10-12) Al2O3 BAW Resonator**
Shinya Kudo and Takahiko Yanagitani
Waseda University, Japan

10:20 **T1.5 Synthesis of Acoustic Wave Multiport Functions by Using Coupling Matrix Methodologies**
Lluis Acosta, Eloi Guerrero, Carlos Caballero, Jordi Verdu and Pedro de Paco
Universitat Autonoma de Barcelona, Spain

Session T2: Plenary Session

Keynote Talk
Radio Frequency Surface and Bulk Acoustic Wave Devices for Mobile Communications, What are Next?

Ken-ya Hashimoto
Professor
University of Electronic Science and Technology of China, Chengdu, China

Radio frequency (RF) surface and bulk acoustic wave (SAW/BAW) devices are indispensable in mobile communications. Although many decades have been passed from their first proposal, their recent evolution is remarkable. Authorities often taught us that theoretical limits were approaching, but many of them have already been overcome by innovative ideas. Technologies are really market-driven.

This talk starts from overview of current RF SAW/BAW devices. Their market was expanded dramatically by their massive use in 4G smart phones, and now the hottest research topic is ultra wideband and high frequency filters for the 5G new radio. Currently use of an extremely thin LiNbO3 or LiTaO3 plate is studied aggressively for developing incredibly high performance SAW/BAW devices. This technology has already been applied to mass production, and demonstrated drastic loss reduction in addition to temperature compensation. Proper choice of the device structure may offer giant electromechanical coupling, super high wave velocity and/or excellent power handing.

What are next? We may not know how, but demands are clear. In addition to items given above, size and price reduction, spurious removal, and design automation are also highly demanded. Anyway, loss reduction is crucial in any time, but it is unclear where remaining losses occur. Detailed discussions will be given on this at the presentation. Nonlinearity suppression is also an issue with high priority, but its discussion will be left for the focused session held in this Symposium.

Keynote Talk
Trends in Acoustic Filtering, New Frontiers, and Orthogonal Markets

Gernot Fattinger
Senior Director EDA and BAW R&D
Qorvo

Acoustic filters are ubiquitous in today's mobile phone front ends and have found their way into many other areas previously dominated by other filter technologies. The steady performance improvements of acoustic technologies were an important enabling factor to that trend. However, the continued shrink in application sizes, and the associated real estate restrictions for filters are – and have been before - opening the door for new, smaller technologies with enough performance to replace the incumbents. In the first part of this talk, this will be reviewed in a historic context, and predictions on where this might happen going forward will be attempted.

The second portion of this talk will address the next frontier for acoustic filtering. 5G has been hailed by many in the industry as the advent of mm-wave technology going mainstream, and mm-wave front ends have found their way into many top-tier mobile phones. However, the focus of what is indeed being implemented by network providers has shifted away from that domain. The reasons for this have been discussed elsewhere and will only be recouped briefly. Instead, in this talk we will focus on the extension of mobile communication frequencies to the 8 GHz–16 GHz range as the new frontier for acoustic filtering and shine a light on the implications for these technologies. The factors that have been traditionally limiting acoustics in frequency will be evaluated, and some potential methods to overcome them will be considered.

Lastly, this talk will touch on an opportunity for the use of acoustic technology in an application other than RF filtering. Specifically, the use of acoustic resonators as the core function of a biosensor will be debated. The fundamental structure will be discussed, the advantages of an acoustic based sensor over traditional technologies will be highlighted, and real-life sensitivity data will be showcased.

Session T3: Advanced SAW Technology

Chairs: Shogo Inoue Qorvo, U.S.A.
Stefan J. Rupitsch University of Freiburg, Germany

14:00 **T3.1 Revisiting Piston Mode Design for Radio Frequency Surface Acoustic Wave Resonators**
Ken-Ya Hashimoto[1], Zhaohui Wu[1], Ting Wu[1], Yiwen He[1], Yawei Li[1], Keyuan Gong[1], Yu-Po Wong[2] and Bao Jingfu[1]
[1] University of Electronic Science and Technology of China, China,
[2] Chiba University, Japan

14:20 **T3.2 8 GHz Third Harmonic SAW Resonator With Grooved Electrodes in LiNbO3**
Michio Kadota, Toshiya Kojima and Shuji Tanaka
Tohoku University, Japan

14:40 **T3.3 Towards the Design of Layered SH-SAW Resonators With Inherent Transverse Mode Suppression**
Ventsislav Yantchev, Kiryl Kustanovich and Yuancheng Ji
Huawei Technologies Oy, Finland

15:00 **T3.4 XBARs & YBARs - Acoustic Resonators Based on LN Membranes**
Victor Plessky
Ecole Polytechnique Federale de Lausanne, Switzerland

15:20 **T3.5 Laterally Excited Bulk Acoustic Resonators (XBARs): Optimization Method and Application to Resonators on LiTaO3**
Natalya Naumenko
National University of Science and Technology MISIS, Russia

Session T4: Panel – 5G and Acoustics: Quo vadis?

Tuesday 19th July
16:20–18:00

In this session, a panel will discuss the requirements future generations of wireless communications pose to RF hardware and system concepts.

The panel will be composed of top-class experts from industry and academia. The list of names will be disclosed soon via our LinkedIn Account and in the final program.

If you want to submit questions for discussion in the panel, please write an email to chairs.icmam@mtt.org.

Session W1: Simulation & Modelling (II)

Chairs: tbd
tbd

09:00 **W1.1 Impact of Backward Waves to FEM Simulations of SAW Resonators**
Yiwen He[1], Ting Wu[1], Yu-Po Wong[2], Temesgen Workie[1], Bao Jingfu[1] and Ken-Ya Hashimoto[1]
[1] University of Electronic Science and Technology of China, China,
[2] Chiba University, Japan

09:20 **W1.2 Generation of Subharmonic Responses by Small Particles on RF SAW Resonators**
Tatsuya Omori, Kazuki Yamamori and Ken-ya Hashimoto
Chiba University, Japan

09:40 **W1.3 Mechanical Transmission Loss of the Sole Bragg Reflector by GHz Pulse Echo Technique With Thick SiO2 Delay Line**
Naoki Ishii, Takahiko Yanagitani, Keita Kondo and Motoshi Suzuki
Waseda University, Japan

10:00 **W1.4 Epitaxial Piezoelectric Layer SMR Fabricated Using Epitaxial Sacrificial Layer Proccess**
Shinya Kudo, Satoshi Tokai and Takahiko Yanagitani
Waseda University, Japan

10:20 **W1.5 Experimental Observation of Electron-Phonon Interaction in Semiconductor on Solidly Mounted Thin-Film Lithium Niobate**
Siddhartha Ghosh[1], Sinwoo Cho[2] and Ruochen Lu[2]
[1] Northeastern University, USA,
[2] University of Texas at Austin, USA

10:40 **W1.6 Synthesis Perspective to Technology Accommodation Approaches in Shunt Resonators for Wide-Band Acoustic Wave Filters**
Lluis Acosta, Eloi Guerrero, Carlos Caballero, Jordi Verdu and Pedro de Paco
Universitat Autonoma de Barcelona, Spain

Session W2: Filters & Resonators

Chairs: Fabian Lurz Hamburg University of Technology
Andreas Link Qorvo, Germany

11:40 **W2.1 6.2 GHz Lithium Niobate MEMS Filter With FBW of 11.8 % and IL of 1.7 dB**
Ziying Wu, Kai Yang, Fuhong Lin and Chengjie Zuo
University of Science and Technology of China, China

12:00 **W2.2 A Winding Frame Structure Thin-Film MEMS Resonator for Quality Factor Improvement**
Shuxian Wu[1], Zonglin Wu[1], Feihong Bao[1], Gongbin Tang[2], Feng Xu[1] and Jie Zou[1]
[1] Fudan University, China,
[2] Shandong University, China

12:20 **W2.3 High Electromechanical Coupling SAW Resonators Based on a-Plane AlScN-AlN-Sapphire Substrate**
Kai Yang[1], Fuhong Lin[1], Ziying Wu[1], Danyang Fu[2], Liang Wu[2] and Chengjie Zuo[1]
[1] University of Science and Technology of China, China,
[2] Ultratrend Technologies Inc., China

12:40 **W2.4 An Electrothermally Actuated Bulk Mode UHF Silicon Resonator**
Sepehr Sheikhlari[1], Hamed Nikfarjam[1], Amin Abbasalipour[1], Abouzar Abouzar Gharajeh[1], Qing Gu[2] and Siavash Pourkamali[1]
[1] University of Texas at Dallas, USA,
[2] North Carolina State University, USA

13:00 **W2.5 Coupling Analysis of a Tunable Microwave and Laterally Vibrating MEMS Resonator**
Siddhartha Ghosh[1], Danna Rosenberg[2], Dave Kharas[2] and Cyrus Hirjibehedin[2]
[1] Northeastern University, USA,
[2] MIT Lincoln Laboratory, USA

Session W3: Closing Session

Keynote Talk
Microacoustics: What's Next?

Gianluca Piazza
Professor
Carnegie Mellon University, Pittsburgh, PA, USA

The burgeoning field of wireless communication is rapidly transforming to respond to an ever-growing demand for spectrum and interconnected devices. Simple need for bandwidth combined with extremely low power consumption and component size requirements are challenging existing communication technologies and favoring the development of innovative microsystems. Microscale acoustic systems are poised to have an impact in enabling disruptive approaches that address the challenges faced by the development of modern communication systems.

This talk will present recent advancements in piezoelectric microacoustic devices spanning from material and processing, to devices and microsystems. I will touch upon thin film technologies such as doped AlN and lithium niobate, which resulted in micromechanical resonators with record-high figure of merit. I will also show how the exceptional characteristics of these devices can be exploited to demonstrate unique microsystems for ultra-low-power wake-up receivers, ultrasonic tags, and 5G mm-wave filtering. Given the wide energy bandgap and unique low losses of these piezoelectric thin film technologies, the same materials can also be micromachined to support not only acoustic, but also photonic structures. I will present how piezoelectric transducers can be co-fabricated with photonic waveguides and resonators to develop innovative low-power microsystems for RF and microwave communications. I will conclude by highlighting how these microacoustic technologies can be readily integrated with electronics to build very compact communication platforms as well as more broadly impact the general field of sensors and actuators.

	Monday 18.07.2022			Tuesday 19.07.2022			Wednesday 20.07.2022		
09:00			09:00	Session T1 Simulation & Modelling	Registration opens at 8:30	09:00	Session W1 Simulation & Modelling	Registration opens at 8:30	09:00
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10:00		Registration opens at 10:00	10:00			10:00			10:00
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10:40			10:40	Coffee Break		10:40			10:40
11:00	Session M1 Opening Session		11:00			11:00	Coffee Break		11:00
11:20			11:20	Session T2 Plenary Session		11:20			11:20
11:40			11:40			11:40	Session W2 Filters & Resonators		11:40
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13:20			13:20			13:20	Lunch Break		13:20
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14:00	Session M2 Systems & Applications		14:00	Session T3 Advanced SAW Technology		14:00	Session W3 Closing Session		14:00
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16:20	Session M3 Non-Linearities		16:20	Session T4 Panel Discussion		16:20			16:20
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18:00	Welcome Reception		18:00			18:00			18:00
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19:00			19:00	Conference Dinner		19:00			19:00
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