

Editorial

Microwave Liquid Crystal Technology

Holger Maune 

Institute of Microwave Engineering and Photonics, Technische Universität Darmstadt, 64283 Darmstadt, Germany; maune@imp.tu-darmstadt.de; Tel.: +49-6151-16-28450

Received: 17 August 2020; Accepted: 18 August 2020; Published: 18 August 2020



Keywords: liquid crystal; 5G communications; millimeter wave devices; steerable antennas; tunable filters

Information and communication technologies (ICT) are the foundation of growth and development in the modern global economy. They are striving to bring robust connectivity to all corners of the globe, driving both innovation and ways in which technologies can be used to improve economic and social development towards a *smart society*. New means of connectivity plus enhanced architectures promise improved coverage, greater capacity, higher data rates, more efficient use of spectrum resources, lower latency, higher system reliability, and more flexibility for effective provision of information and communication services. These activities can be summarized under the development of the 5th generation of mobile communication systems (5G). Innovative wireless technologies will be a key component in this development, which allow new applications summarized under the term of Internet of Everything including the Internet of Things (IoT), Machine-to-Machine (M2M) communications, smart cities, smart manufacturing, intelligent transportation systems, and inter-connected cars. Key differentiators of 5G to provide future wireless connectivity are: (1) 10-fold decrease in latency down to 1 ms, (2) 10-fold data throughput with multi-Gbps peak rates, and (3) 100-fold traffic capacity, e.g. by network densification with local femto cells. Efficiency is one major aspect within the development of 5G systems with massively deployed new communication nodes. To advance beyond conventional terrestrial 4G communication systems such as Long Term Evolution (LTE) and LTE-Advanced, groundbreaking disruptive systems and hardware concepts are required to comply with all promises by 5G. In this frame, the following key areas will play a significant role:

- Millimeter-wave (mm-wave) communication systems with very high absolute bandwidth to cope for highest data rates
- Small femto cells to serve a small area with highest data rates
- Enhanced and new platforms such as high-throughput satellites (HTS) in geostationary (GEO) or medium earth orbits (MEO). Constellations of low earth orbit (LEO) satellites or high-altitude platforms (HAPS) spanning a network in the sky with connectivity everywhere.
- Network architectures, software advances, and other complementary technologies that increase the flexibility and efficiency of services, such as cloud-radio access network (cloudRAN), heterogeneous networks, network function virtualization (NFV), and network slicing.

Enhanced and new hardware concepts and innovative technologies for smart user devices and terminals as well as for base stations and satellites are crucial for the deployment of new platforms and services to fulfill these requirements.

The Microwave Liquid Crystal Technology addressed in this Special Issue is a promising candidate to cope with the demands of reconfigurable systems in the millimeter-wave frequency range from 30 GHz to 300 GHz. In [1] fundamentals and the progress of microwave LCs concerning its performance metric is reviewed. Different phase shifter implementations for antenna arrays are compared. Wideband, high-performance metallic waveguide phase shifters and low-profile planar

delay-line phase shifter stacks are investigated not only in terms of phase shifting performance but also regarding system parameters such as response times. Here, the very thin planar devices show advantages over bulky waveguide phase shifters at the cost of higher insertion loss. While there are many works addressing the improvement of response times while keeping a high level of phase shifter performance, the authors of [2] discuss tunable bandpass filters employing liquid crystal for space applications. Design aspects dealing with the harsh space environment and the operating principles for commanding tunable components in reconfigurable systems on board of satellites. The described qualification campaign is not only important for tunable filters but can also be adapted to antenna systems based on array antennas with LC-based phase shifters.

In [3] recent development of dielectric waveguides are presented as a promising alternative to conventional waveguides, since electrodes can be easily integrated in the open structure. The numerous subcategories of dielectric waveguides offer a high degree of freedom in designing smart millimeter wave components such as tunable phase shifters, filters and steerable antennas. A similar approach with a clear focus on response time is included in [4] for non-radiative dielectric waveguides. By the alignment of a nanofiber/liquid crystal complex, the switching time could be reduced while keeping the phase change above 360° . In [5] the phase shifter is realized as enclosed coplanar waveguide with LC as tunable dielectrics encapsulated by a unified ground plate. This approach significantly reduced the instability due to floating effects and losses due to stray modes.

Beside the advancement of microwave components and systems, the development of novel and improved LC mixtures is key component for the success of the whole Microwave Liquid Crystal Technology. In [6] two new nematic liquid crystal mixtures are proposed by adding LC monomers to commercial LC. This and also the addition of nanofibers as in [4] are two examples for recent material development.

In summary, the articles presented in this Special Issue are representative of latest research in Microwave Liquid Crystal Technology. They cover aspects ranging from material characterization over component concepts and integration to system considerations and system implementation.

Funding: This research received no external funding.

Acknowledgments: The Guest Editor thank all the authors contributing in this Special Issue, all of reviewers who provided constructive and helpful feedback on all submissions, and the Editorial staff of Crystals for their priceless support.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Jakoby, R.; Gaebler, A.; Weickhmann, C. Microwave liquid crystal enabling technology for electronically steerable antennas in SATCOM and 5G Millimeter-Wave Systems. *Crystals* **2020**, *10*, 514. [[CrossRef](#)]
2. Kaesser, T.; Fritzsche, C.; Franz, M. Tunable RF filters based on liquid crystal for space applications. *Crystals* **2020**, *10*, 455. [[CrossRef](#)]
3. Polat, E.; Tesmer, H.; Reese, R.; Nickel, M.; Wang, D.; Schumacher, P.; Jakoby, R.; Maune, H. Reconfigurable millimeter-wave components based on liquid crystal technology for smart applications. *Crystals* **2020**, *10*, 346. [[CrossRef](#)]
4. Lang, T.N.; Bui, V.B.; Inoue, Y.; Moritake, H. Response improvement of liquid crystal-loaded NRD waveguide type terahertz variable phase shifter. *Crystals* **2020**, *10*, 307. [[CrossRef](#)]
5. Li, J.; Chu, D. Liquid crystal-based enclosed coplanar waveguide phase shifter for 54–66 GHz applications. *Crystals* **2019**, *9*, 650. [[CrossRef](#)]
6. Zheng, A.; Chu, X.; Wang, P.; Wang, P.; Gao, S.; Yang, J.; Lu, H.; Deng, G.; Yin, Z. The characterization and application of two liquid crystal mixtures in the Low THz Region. *Crystals* **2020**, *10*, 99. [[CrossRef](#)]



© 2020 by the author. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<http://creativecommons.org/licenses/by/4.0/>).