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7 May 2024

Sensors and Communication Technologies in the 1 GHz to 10 THz Band (SD106)

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A community of technology experts working in the 1 GHz to 10 THz bands is brought together to present and discuss papers in those areas mentioned below, for novel system development. Device knowledge, system integration and target phenomenology are focused on market-driven problems in security, defence and many spin-out areas. Range profiling and imaging radars and radiometers are typical sensors in the band, operating on land, sea, air and satellite-based platforms.

Drivers in the lower frequency spectral regions are the low atmospheric absorption and high transmissivity of clothing and packaging materials, enabling remote sensing and security screening applications. Moving towards the higher frequency regions, the increasing interactions with media provide capabilities for material identifications via spectral information content.

The variability of atmospheric attenuation over the band means high-data rate directional communications can be offered for long-haul links through the atmospheric windows and short-range, secure, local area networks in the absorption bands. Furthermore, the variability of material reflection and transmission properties over the band highlights the wide scope for non-destructive testing. In addition, there are great opportunities for medical applications, as radiation penetration in the human body ranges from a few centimetres at the lower frequencies, to a fraction of a millimetre at the higher frequencies.

Papers are sought in the following areas:

- detectors, mixers, sources, modulators, I & Q receivers and ADCs
- materials (stealth, chiral, left-handed, plasmonics, metamaterials)
- MMICs and integrated systems, including PIC devices and subsystems
- sensors using machine learning and AI
- computational imaging (3D depth, time of flight and light-field sensing)
- simulation, modelling and target phenomenology
- quantum sensors exploiting superposition and entanglement, including quantum radar
- security screening systems for personnel (close range portal, and stand-off systems)
- systems for non-metallic & metallic knife/gun detection
- explosives & contraband detection
- vehicle screening systems for people trafficking
- shoe scanning for airport security
- handheld screening systems
- mail packages and hand baggage screening systems
- near-field scanning microscopes and imagers
- all-weather (rain, fog, cloud) imagers for (autonomous) air, sea and land vehicles
- drone detection and sensors using (swarms of) drones
- missile launch detection, tracking and seekers
- radars: late time response (LTR), ground probing, synthetic aperture, ultra-wide band, THz
- systems exploiting polarimetry and tomography
- aperture synthesis imagers and high-speed digital cross-correlators
- novel THz spectrometers
- non-contact, under-bandage (burn) wound inspection
- diagnosing local circulatory disorders and vascularisation
- biomedical imaging (micro-Doppler & spectral breath analysis)
- resolution enhancement/super-resolution
- nondestructive testing for industry
- novel communication systems.

RECENT DEVELOPMENTS BOOSTING CAPABILITIES IN THE BAND ARE:

Detectors in the band are mainly of the radio (or electromagnetic mode) type, very different from the photon detectors used in the infrared and visible bands. A constant evolution of these radio detectors, using new materials offers ever improved performances. The detectors are inherently polarimetrically sensitive, offering capabilities for target and material characterisation using well-established techniques from the field of passive and active polarimetry.

Mixers, which shift large bandwidths of energy from one spectral region to another, are also of interest, as they can enable higher signal-to-noise ratios for detection. As with detectors, their structures and semiconductor types are constantly evolving to offer better performance. A class of mixers which can shift large bandwidths into the optical band are of particular interest, as they enable imaging systems to be developed using well-established, lower-cost optical focussing technologies.

Sources, are based on positive feedback and negative resistance, and when combined with mixers generate radiation over a wide frequency range. Of heightened interest now are the photonic integrated circuit (PIC) devices. Fabricated on a monolithic substrate, these devices can be a quantum cascade laser, an Auston

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switch, or a two-frequency beat device. In the Auston switch and the two-frequency beat device, optical laser radiation incident on a semiconductor generates difference frequency radiation in the terahertz band through a nonlinear interaction. The two-frequency beat device generates particularly low phase noise coherent radiation, a great attribute for terahertz radars and communication systems. The PIC devices are enabling much smaller and lighter-weight systems for commercial exploitation.

Complementary technologies to the above are the plasmonic and metamaterial structures which confine electromagnetic modes to specific regions, to enable potentially compact and novel system architectures.

Recent innovations in structure simulator software have seen the appearance of open-source packages which compute full-wave Maxwell equation solutions. These enable efficient low-cost modelling of system components (antennas, lenses, transmission lines, couplers) and object responses for the investigation of novel applications and feasibility studies. Combined with phenomenology knowledge, a wide variety of materials, liquids, gases and plasma plumes can be modelled.

Microwave monolithic integrated circuit (MMIC) radar chips have become available over the past few years, motivated by the automotive radar industry, but now enabling a diversity of other applications. European companies are now integrating the MMICs on to a circuit board containing integral antenna(s), in-phase and quadrature (I & Q) processing and data acquisition electronics and open-source computer interface software. Having usually two or more antennas, they are available for only several hundred Euros each. With centre frequencies around 24 GHz, 60 GHz, 77 GHz and 120 GHz and several GHz of bandwidth, novel applications are enabled where ranging, polarisation and multi-in/out (MIMO) capabilities are required.

The rapid evolution of free and open-source machine learning modules over the past 10 years coupled with knowledge of target phenomenology means novel algorithms can now be written to provide unprecedented capabilities in target classification and recognition.

Contributing to the recent interest in sensors exploiting quantum superposition and entanglement, millimetre and terahertz continuous-variable systems can operate at ambient temperature, whilst discrete-variable systems can operate at cryogenic temperatures (where photon energy hf>kT electromagnetic mode energy).

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