PhD PROJECT PROPOSAL

PhD Project Title
Topological metasurface local area networks

PhD Supervisory Team
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Project Abstract
The proposed research programme aims to create a self-adhesive tape which is "sticky" for high frequency radio waves that can be guided along its surface robustly. The relatively new field of topological metamaterials has already demonstrated the possibility of such surface waveguides. However, the proposed solution needs to overcome considerable difficulties such as creating efficient "interconnects" signal sources, avoiding energy dissipation in the guides as much as possible, creating compatible components that join up to form a network and achieving seamless integration with room-based transmitters. We aim to achieve all these at the WiGig frequencies to avoid introducing further capacity bottlenecks.

How does the project utilise topology or topological design?
Topological metamaterials and metasurfaces have recently emerged as a new way to control the propagation of EM waves along surfaces and structures. Importantly, these metamaterials support topologically protected surface states, which produce strongly bound surface waves with no radiation even in the presence of sharp corners and discontinuities along the structure. This unique phenomenon makes tape-type topological metasurface waveguides promising for signal distribution system for indoor wireless environments.

In addition, the project will find the best possible metasurface local area network topology (e.g. star, bus, etc.) in terms of power link budgets and bandwidth/capacity.

Detailed Project Description
Research background, intended outcomes and methodology;
Societal reliance on a high-performance wireless broadband communications infrastructure has grown enormously over the last twenty years. Deployments can be either commercial or residential, and the performance of these systems (in particular their throughput, quality and capacity) is constrained by bottlenecks affecting one or more links in the communication path.

Before much longer connectivity to both commercial and residential spaces will be provided optically and so will have virtually unlimited bandwidth potential. In the UK this is being addressed in the fibre to the premises (FTTP) rollout. This will cause the performance bottleneck to unavoidably shift to the wireless 'local loop', which will be subject to either unacceptable levels of co-channel interference or insufficient capacity, should current wireless technologies continue to be used. Therefore, there is a need for a competing solution capable of mitigating against interference and providing very large bandwidth (~ 7 GHz), so as to remove any performance bottlenecks for the foreseeable future. Such a solution must be able to be retrofitted to existing buildings, and so a technology that can be applied non-invasively to the existing fabric of a building without having to drill holes, and otherwise bury or hide cables is highly desirable.

Millimetre-wave technology can provide a feasible solution. Significant unlicensed bandwidth resources are available, and the near line-of-sight propagation characteristics of millimetre-wave transmissions mean that co-channel interference can be effectively managed. This proposal seeks to develop a technology to leverage the advantages in using millimetre-wave technology to provide a low-cost, high-performance signal distribution system for indoor wireless environments. This embodies two key concepts: (a) the use a Millimetre-Wave Topological Metasurface Waveguide to distribute signals throughout a building from an optical entry point (or alternative distribution node); and (b) the use of a Passive Wireless Access Point (PWAP) node, which is attached to the topological metasurface waveguide to couple energy into a radiative mode to communicate with the wireless devices of interest. The topological metasurface waveguide is to be fabricated as a flexible, planar self-adhesive tape which can be attached to walls, skirting boards, coving, etc., as required. The proposed PWAPs will be low profile, lightweight and attached (possibly via a self-adhesive backing) to the topological metasurface waveguide at an appropriate location. These PWAPs will act in a manner similar to current WLAN access points, but will possess clear advantages in that they can be unpowered (i.e. passive) and can be straightforwardly repositioned to other locations along the topological metasurface waveguide.

The project will include (1) a system study which will investigate possible metasurface LAN topologies (e.g. star, bus, etc.) and their associated attenuation and dispersion characteristics leading to power link budgets and bandwidth/capacity; (2) metasurface waveguide and devices design and optimisation using full-wave electromagnetic software; (3) propagation studies and channel enhancement strategies based on VNA channel sounding and ray-tracing modelling; (4) manufacturability considerations.

Training and skills to be developed over the PhD;
This PhD project offers training in diverse areas of research in computational and applied electromagnetics. The student will develop critical thinking and analysis capability through strong linkage between the computational/theory and experimental outcomes. S/he will be supported in developing project management and leadership skills, and be active in the direction of the research. S/he will develop her/his communication skills through reporting, and disseminating the research outputs through publication and conferences.

Explanation of why the project is suitable for the CDT in Topological Design;
The project focuses on topological design at the device level (topological metasurface waveguides) and system level (network topology).

Links with research in the research groups of the supervising team;
This project will benefit from close synergy with other projects successfully completed or still active in the Department of Electronic Electrical Engineering as well as in the School of Physics and Astronomy. Namely, the following EPSRC projects “PATRICIAN: New Paradigms for Body Centric Wireless Communications at mm Wavelengths”, “Anisotropic Microwave/Terahertz Metamaterials for Satellite Applications (ANISAT)” and “Multi-functional metamaterials and antennas for RF/Microwave communication and sensing devices (MULTIMET)”; the following Royal Society-funded projects “Experimental demonstration of transmissive-type terahertz digital metamaterials based on microfluidic system”; and the EU-funded H2020 Rise "Non-Conventional Wave Propagation for Future Sensing & Actuating Technologies" project. The Metamaterials Research Group is also actively involved in the recently-launched EPSRC UK Metamaterials network led by the University of Exeter.

Links with research strategies, possibly including UoB, EPSRC, partner organisations;
The project falls within two of the UoB strategic priority areas within the overarching themes ‘Science Frontiers’ and ‘Advanced Manufacturing Research’; namely, metamaterials and radar, respectively.

The project will make full use of a recent investment in the School of Engineering in a new anechoic chamber and associated facilities for antenna characterisation (£2.5M) and the THz testing equipment (£1.2M EPSRC investment).

The proposed research is a foundational topic situated at the intersection of the ICT and Physical Sciences EPSRC thematic portfolio areas, specifically the RF & Microwave Communications area. This in turn, underpins much of the strategic priority themes of Digital Economy, Healthcare Technologies, Engineering (e.g. Sensors and Instrumentation) and Living with Environmental Change (e.g. Information Infrastructure).

An ideal/acceptable undergraduate background and interests;
First degree in Physics, Electronic Engineering or closely related subject, with background in basic electromagnetics, and advanced mathematics and preferably some experience or interest in microwave communications systems.