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Metamaterial Arrays and their Applications:
A journey from FSS to EBG & AMC structures.

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Since their discovery in the late 1980’s, interest in metamaterials has grown explosively. The potential take-up of these structures in applications like communication and sensing systems is primarily due to the control of the amplitudes, frequencies and wave-numbers of propagating and non-propagating electromagnetic modes enabled by metamaterials to an extent that was not previously possible. The control of electromagnetic modes in various application fields such as indoor and outdoor communication systems, communicating mobile objects, transport systems (high-speed trains), space/earth communication and microelectronics (at µ-wave and sum-mm wave frequencies), can include the following aspects:

i)Controlling wave propagation (Waveguides / planar circuit miniaturization / optical integration, Dispersive waveguides, Enhanced filters, Light emitting diodes / cavities for low-threshold lasers, Frequency selective reflection/transmission, Antennas / antenna arrays), ii)Enhancing fields / near field imaging / High-Q cavities, iii) Negative refraction, iv)Tuneable materials, v)High impedance layers/artificial materials.

The above description of advantageous properties of metamaterials gives a small insight into the large potential industrial application of these concepts. In the Wireless Communications Research (WiCR) Group at Loughborough University extensive research of antennas using FSSs, EBGs and AMCs has been conducted.

The flexible electromagnetic wave propagation control enabled by **Elecromagnetic Band Gap** (EBG), **Frequency Selective Surfaces** (FSS), and other metamaterials is an excellent opportunity to optimize the radiation characteristics of individual antennas, and to optimize and decouple more effectively antenna arrays for steerable antenna array or imaging applications. This has wide benefits for wireless communication technologies, microwave and millimetre wave imaging applications in medicine and security, and many other areas. The industry (especially for space applications) needs systems where several antennas covering several frequency ranges are packed in a very small volume. It would be possible to use one large antenna reflector to cover several frequency bands. The problem is to design “overlapping” antennas that would all fit into a small focal area of the reflector. This may be possible with the use of advanced metamaterials. There is a need to find materials useful in enhancing performance of small antennas for mobile terminals in communication systems. Especially artificial magnetism is promising. High-impedance surfaces can find one more application in reducing coupling in various antenna arrays, since they are more compact than conventional EBG structures. **Artificial Magnetic Conductors** (AMC) or high impedance surfaces, i.e. metamaterials that produce in-phase reflections are highly interesting for compact antenna solutions, in order to miniaturize and minimize the cost of communication components and systems. Such systems have already been transferred to the market and constitute and effective demonstration of the potential of metamaterials.

Metamaterials are, in essence, the materials of the future, since the main purpose for their study is to be able to go beyond where naturally occurring substances and current materials research have taken us. By combining different microscopic elements into large-scale designs, one will be able not only to create materials with fundamentally new properties but also to fabricate others that have properties on demand, as required by new technologies. In particular, new electromagnetic properties will allow us to control microwaves, millimetre waves, and optical light in revolutionary ways.