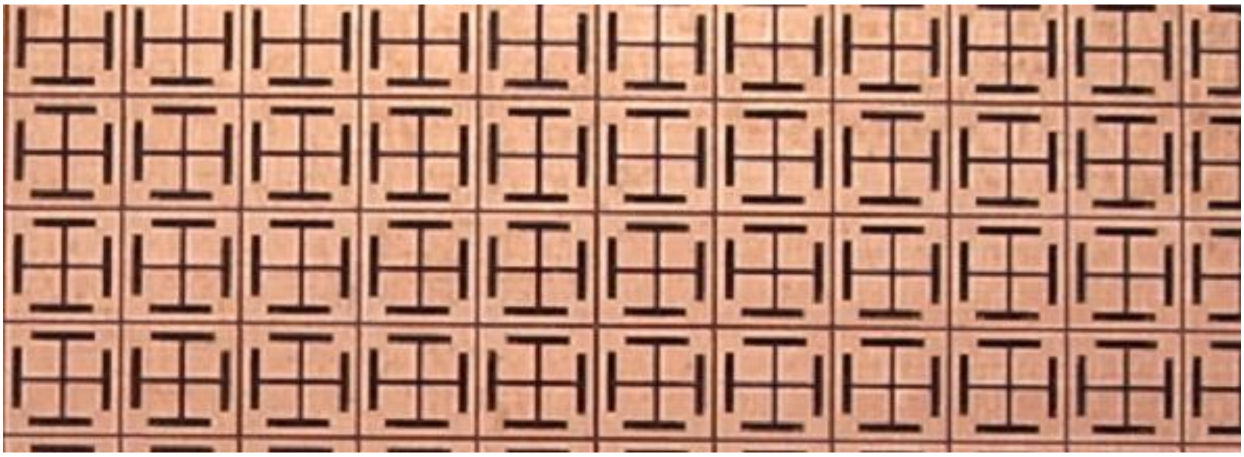
Liquid Crystals and New Manufacturing Processes Transform Frequency Selective Surface Performance



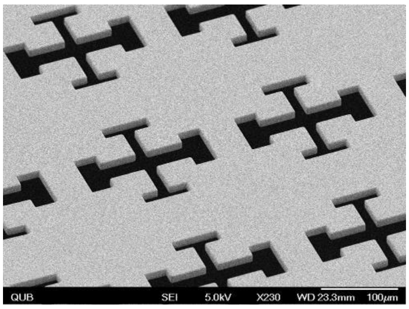
Frequency selective surfaces (FSS) are periodic structures in either one or two dimensions (i.e. singly or doubly periodic structures) which, as the name suggests, perform spatial filtering of microwave energy. They are normally composed of an array of metallic patches or a conducting sheet periodically perforated with apertures, which are designed to transmit and reflect signals from the surface at predetermined frequencies. The electromagnetic performance of FSS may also depend on the polarization and the angle of the electromagnetic waves striking the structure. Depending on their physical construction, material and geometry, FSS are often classified as either low-pass, high-pass, band-pass and band-stop filters.

Well known for their use in microwave ovens, other traditional uses of FSSs include reflectarray lenses, radomes, artificial magnetic conductors (AMC), EM Band Gap materials, and dichroic subreflectors. More recently, they have been used in applications such as RFID tags, collision avoidance radars, RCS augmentation, robotic guided paths, EMI protection, photonic bandgap structures, waveguide or cavity controlled coupling, and low-probability of intercept systems (e.g. “stealth”). Exciting new applications are also opening up for their use within metamaterials where the use of three dimensional structures, tight coupling between FSS layers and/or the flow of electric currents perpendicular to surfaces using conducting vias is key to controlling the effective permittivity and permeability tensors of the materials.

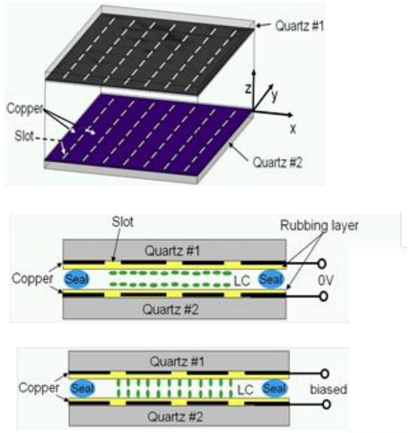
Supported by the Centre for Earth Observation Instrumentation and Space Technology (CEOI-ST), researchers at Queen’s University Belfast have been investigating how FSSs can improve the performance of microwave sounders used for measuring temperature, water vapour, and cloud ice from space. Innovations in tunable FSSs and in low cost solutions have resulted from this research and are separately opening up new application areas in:

- Electronically reconfigurable FSSs
- Tuneable antennas
- Thin, broadband microwave absorbers for reducing radar signature
- Enhanced transmission of signals through energy saver glass

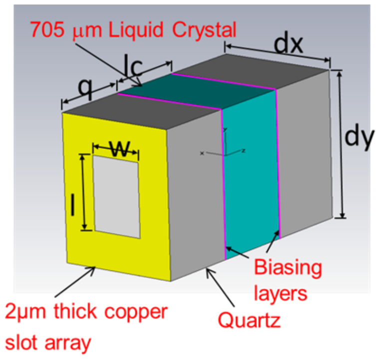
In one major research programme, the researchers have been creating an FSS which provides simultaneous filtering of vertically and horizontally polarised signals at sub mm wavelengths. The versatility of these structures is shown in designs where the FSS is completely opaque to certain frequency bands (stop-bands), yet simultaneously allows wave transmission at other frequencies.



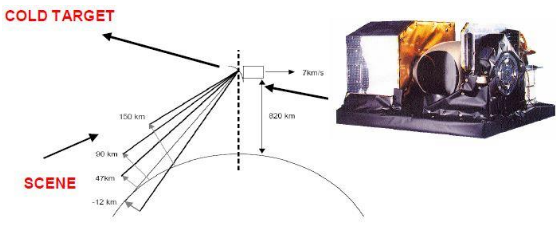
For electronically reconfigurable FSSs, the researchers have developed a novel technology which uses a combination of advanced micromachining and liquid crystal technology to create frequency selective surface devices that give system designers free space electronically configurable microwave filters for the first time. By applying a small voltage the filter can switch 'on' or 'off' an incident signal thus producing an electronically controllable shutter.



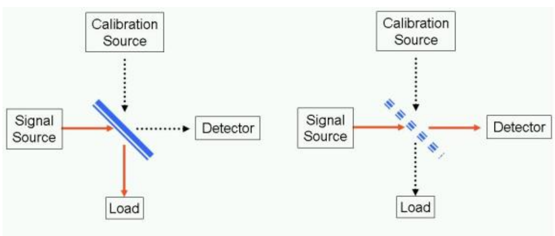
It is envisaged that this unique device will have use in a number of different applications including military stealth technology (reducing radar profile, cloaking vehicles, objects or revealing them electronically), microwave beam steering, target calibration, and control of signal transmissions through glass in secure environments. Applications for measuring trace gases large distances, such as the detection of explosives, are also envisaged.



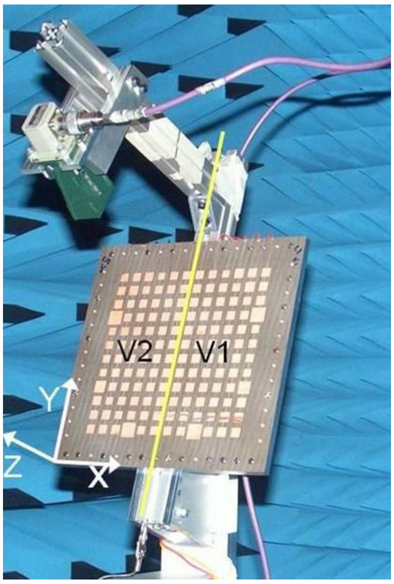
A major science application of switchable FSSs, is calibration of passive microwave radiometers in Earth Observation. These measure raw antenna counts from which the antenna temperature is determined and the brightness temperature of the Earth then calculated. Large antennas are used for the various channels of the radiometer, and during operation, each antenna feedhorn passes a hot and cold target in order to provide consistently calibrated raw counts. The microwave brightness temperatures (also referred to as TB) calculated from microwave radiometers are considered a fundamental climate data record and are the values from which we derive ocean measurements of wind speed, water vapor, cloud liquid water, rain rate, and sea surface temperature. Tuneable liquid crystal based FSSs have been developed to remove need for mechanically steerable systems, enabling integrated hot and cold target calibration to be undertaken.



Limbsounder Radiometer



(a) OFF State – for calibration (b) ON State – for signal detection



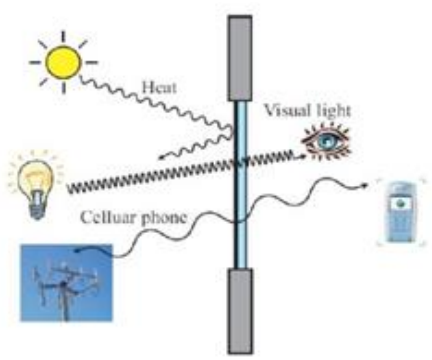
Electronically steered liquid crystal/FSS based antenna for communications systems, collision avoidance radar and tracking radar have also resulted from the research. This novel technology uses a combination of advanced micromachining and liquid crystal technology to create metal backed FSS devices that can be used as flat, solid-state electronically steered microwave antennae. It is envisaged that the planar device construction will have use in a number of applications including communication systems, collision avoidance, tracking and monopulse radar. Compared to conventional designs this approach allows the design of very compact portable lightweight systems with low power consumption.

In a parallel research programme, the researchers at Queen's University Belfast have created a carbon-based FSS EM Shielding technology that provides a low-cost and commercially viable solution for frequency selective electromagnetic shielding in a number of commercial applications, including the Building, Health, Defence and Government sectors. The premise of its value proposition is that EM shielding is becoming increasingly relevant amid concerns on potentially hazardous health effects, data security and spectrum reuse, and a low cost solution is needed. Current solutions in the marketplace provide a barrier for EM signals for the entire EM spectrum. This limits usage of these solutions as it may block out functionality of desirable wireless devices and services.

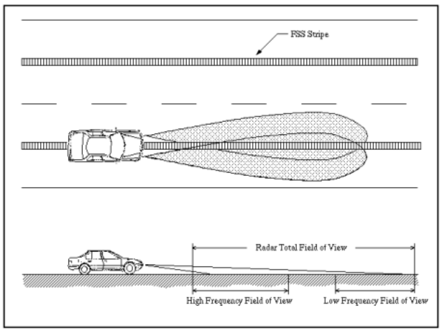
Thin, low cost broadband microwave absorbers can also be designed to reduce radar signatures. Military applications for stealth vehicles are well known, but requirements are also growing in civil applications. For example, when built in the line of sight of air traffic control radars, wind farms create interference that can adversely affect them, reducing the controller's ability to see what is happening in the sky. This is proving a huge issue for the wind tubine energy industry, with projects blocked by radar difficulties in the UK, Finland, Sweden, Germany, Czech Republic, France, Spain, and Ireland. According to Renewable UK, half of all wind farm developments in the UK will face objections from aviation stakeholders on the grounds of radar interference, obstruction or impact to low flying.

The thin FSSs developed at Queen's University Belfast act as low cost broadband microwave absorbers for reducing radar signature. They can easily be coated on to the blades of wind turbines dramatically reducing the interference with air traffic control radars.

In other commercial applications, these low cost Frequency Selective Surfaces can used to enhance transmission of signals through energy saving glass, and allow specific wavelength transmissions in and out of fully shielded rooms such as used for MRI scanners or high powered electron microscopes. For the Defence, Security and Government sectors, functionality of the surfaces can be tuned to allow specific signals into or out of different areas depending on the individual requirements.



In an interesting twist on this type of application, Ohio State University Center for Intelligent Transportation Research (CITR) recently used an FSS embedded in a road stripe as a lane locator for an autonomous vehicle demonstration system. The low cost and signal specificity of the Queen's University FSS material make it very suitable for this type of application



The Centre for Earth Observation Instrumentation (CEOI) is funding a wide range of innovative new instruments that measure our weather, our atmosphere, the icecaps, and many other aspects of the natural environment. The information from these instruments is constantly improving our understanding of our planet and how human activities are affecting it.

Addressing the larger challenges of increased performance and miniaturisation in Earth Observation instrumentation will require improvements in a wide range of enabling technologies. The CEOI-ST programme is always seeking high quality proposals for projects that are aligned with these objectives.

Further information about this project and others funded by the CEOI can be found at www.ceoi.ac.uk. You can also contact the CEOI Director, Professor Mick Johnson: Tel: +44 (0)1438 774421 or email: mick.johnson@astrium.eads.net.