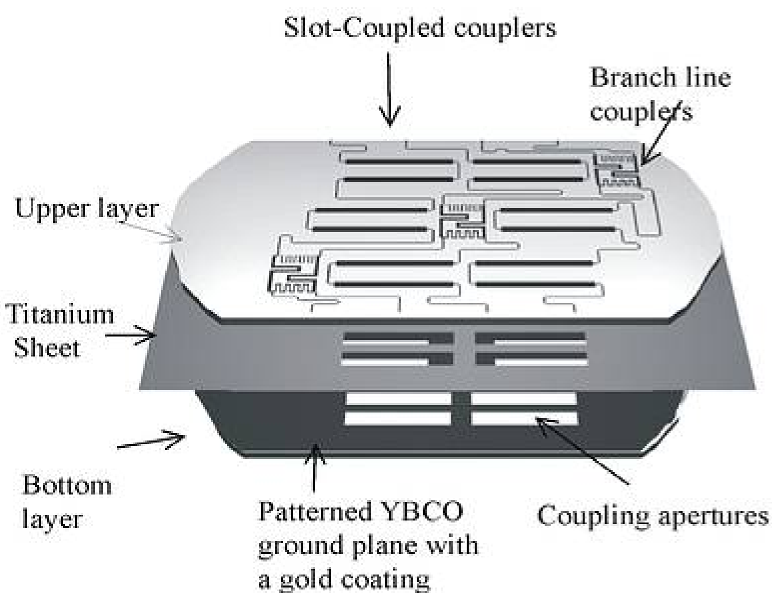
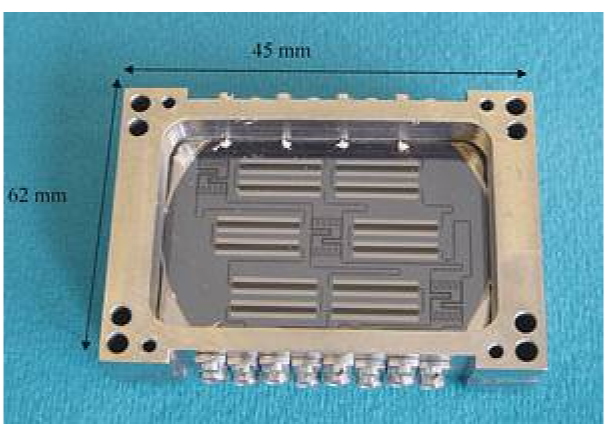
Emerging Device Technology > **Superconducting Antennas**

**Superconducting materials are useful in antenna technology. The very low surface resistance superconductor enables a number of improvements including miniature low loss beam forming networks, small highly efficient antennas, antenna arrays, and superdirectional antenna arrays. All there of these applications have been investigated in the EDT group at Birmingham.**

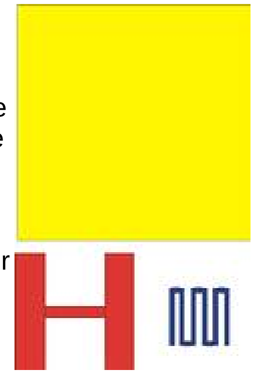
The two diagrams to the below show an 8-element Butler Matrix designed and made in the EDT group. There are 8 inputs and 8 outputs to the device. 8 antennas are connected to the 8 inputs and the function of the matrix is to provide outputs which receive signals from 8 different directions. In other words the matrix forms 8 separate beams in space. The advantage of using superconductors is to shrink the size of the device whilst still giving an improved performance over conventional methods.




The Butler Matrix is constructed of two $LaAlO_3$ single crystal substrates with superconductor on both sides. All four layers of superconductor are patterned and are bonded together with a 50 micron thick titanium sheet which acts as the ground connection. The construction allows microstrip circuitry on the upper and low sides of each substrate, with coupling of the microwave signal through the ground plane. This gives a much reduced size to the device.

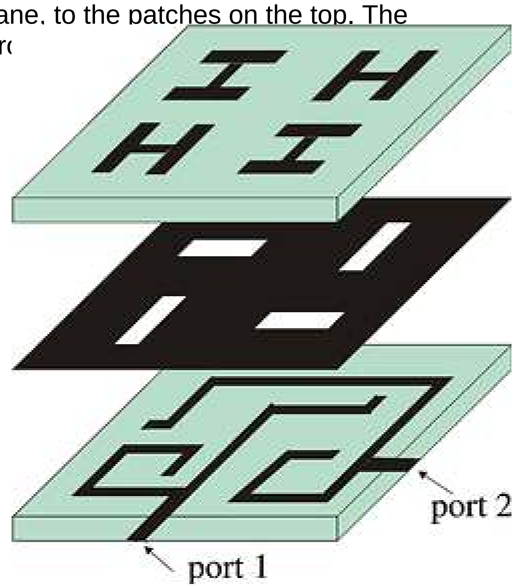


Antenna elements become inefficient as their size reduces below a wavelength, this is because the conductor losses begin to dominate the radiation properties. By reducing the conductor losses using superconductors the antennas can have a greatly improved efficiency. The diagram to the left shows three microstrip antennas elements. The top one is a conventional square patch, which is about a half wavelength square. This is a large antenna and its efficiency can not be improved much with superconductors, however the other two antennas radiate at the same frequency and become much smaller then the square patch. The meander antenna is the smallest shown, and can be arbitrarily shrunk to very small sizes.



A number of antenna arrays have been constructed using both the 'H' antenna and the meander antenna in the EDT group and a significant improvement in performance over conventional antennas has been demonstrated.

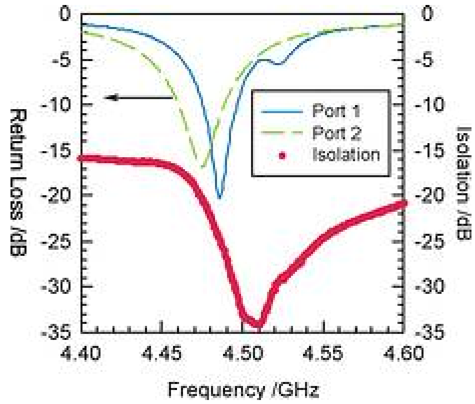
Because the superconducting antennas are small it is possible to fit many antennas in an area much less than a wavelength square. The diagram on the right shows four 'H' antennas organised in a square. There are two element pairs orthogonal to each other, allowing two separate transmission polarisations. The transmitted signal is coupled from the feed network at the bottom, through the rectangular holes in the ground plane, to the patches on the top. The matching of the feed lines to the antenna elements is contr ground plane, and the position of the 'H' elements.



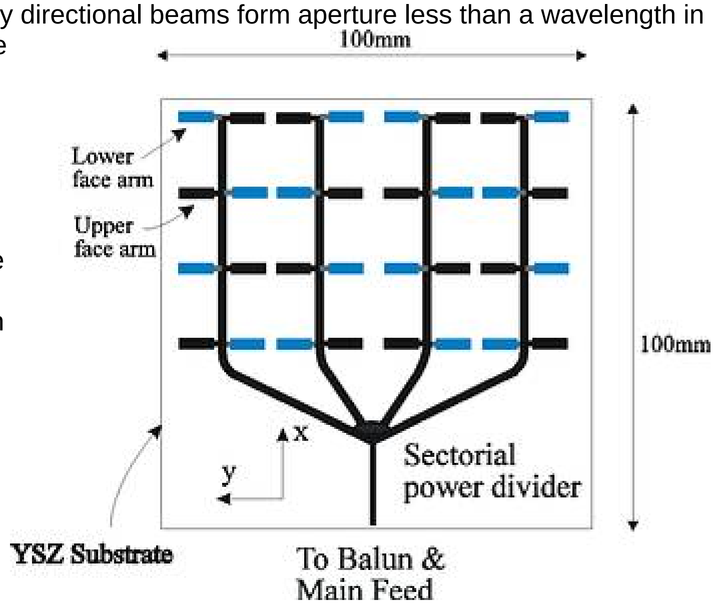

The feed network in the diagram is configured such that the antenna is self-diplexing. The patches are slightly different in size so that their resonant frequencies are slightly different. An input signal at port 1 transmits on one frequency, whilst at port 2 signals are simultaneously received on another frequency. The graph below shows the performance of this antenna.

It should be noted that although the antenna is configured as a diplexer, by altering the feed network such an antenna can be made to operate in a number of different ways, including circular or elliptical polarisation with up to four different frequencies.

The concept becomes more powerful if a number of such antenna groups are used in an array. In this case each group will be spaced about a half wavelength apart and various beam forming scenarios can be considered.

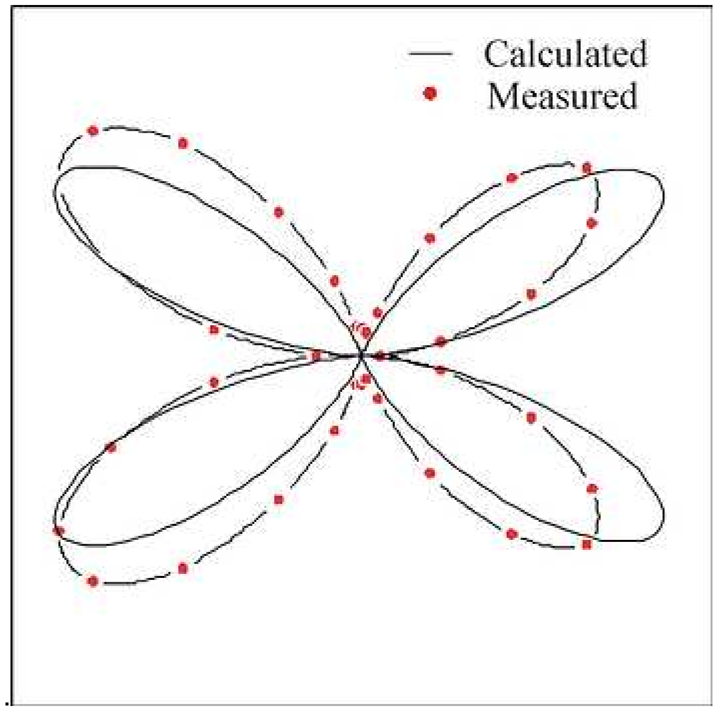



Superdirectional antennas allow highly directional beams form aperture less than a wavelength in size. In principle any directivity and be obtained from the smallest aperture. This is done by carefully controlling the phase of the current source across the aperture. The antennas are notoriously difficult to design and have inherent low efficiency. The latter can be improved at the expense of bandwidth by using superconductors. An example of such an antenna is shown in the diagrams above and to the right.




The sixteen element array is made in the Functional Ceramics group in the Department of Metallurgy and Materials Science out of thick film YBCO high temperature superconductor on a Zirconia substrate. The patterning is on both sides of the substrate. Short dipoles with parallel strip transmission line feed networks are used.

The diagram below shows the radiation pattern of the sixteen element antenna array. The array has an element spacing of approximately 0.07 wavelengths and the whole array is less than a quarter wavelength square. It has a directivity of 11.5dBi. This is an improvement of about 12.5db over a similar antenna made out of a normal metal.




A book has been written which relates to the work described here the reference is Lancaster M. J. 'Passive microwave device applications of high temperature superconductors' Cambridge University Press, Cambridge UK 1997. ISBN 0-521-48032-9