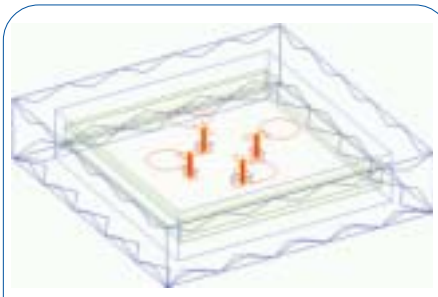
Using CONCERTO for a Cavity Backed, Circularly Polarised, Patch Antenna Array

The increase in demand for RF power sources at microwave frequencies, including low cost spatial power combining in personal communications and radar systems, has been considerable. Coupled active antenna oscillator arrays, which can be injection locked to form electronic beam scanning arrays without phase shifters, have recently been considered in power combining technology at microwave and millimetre-wave frequencies. It is known that coupled oscillator modal stability can be improved by coupling oscillators through lumped resistive or capacitive elements.

Based on this technology, a circularly polarised patch antenna can be produced to combine microwave power and actively steer the main beam. Moreover, the arrangement considerably reduces complex feed requirements when the 2x2 array discussed here is used as a building block in a larger array. Far-field radiation experiments for this antenna structure demonstrates the principle.

Model Specification

Each antenna (constructed on a substrate of FR4 with a thickness of 1.6mm and with relative permittivity 4.55) is designed to be a 4.4 GHz circular patch antenna of about one guided wavelength in circumference. It is matched using a CPW structure with an inset microstrip via-hole feed of 50 ohms.

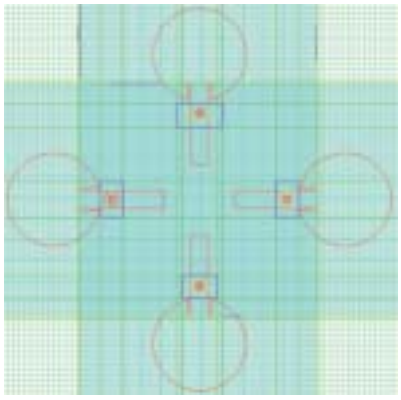


Patch antenna array modelled using CONCERTO

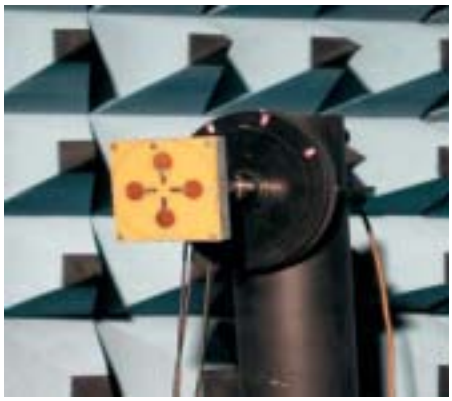
The dielectric board is on top of an earthed metal box to minimize the edge effect due to back radiation encountered in conventional patch antennas. The patch feed-through slot width and matching microstrip length are carefully chosen so that the mutual couplings through surface wave propagation on the substrate, and free space coupling between patches, are both reduced. As a result of this, each patch element can be independently driven at a different phase by an external excitation source. In experiments and simulations, each antenna had a progressive 90 degrees phase delay added to create the required circular polarisation and radiation pattern.

Modelling

The simulation package CONCERTO is based on a theory proposed by K.S.Yee, and uses the well established FDTD technique, including the use of conforming elements to allow accurate handling of inclined and curved boundaries. The mesh sizes in the x, y, z directions are specified, with local refinement in order to concentrate on particular regions of interest. The figure (below) shows the mesh used for this patch antenna array. Special care has been taken to refine the mesh near the matching slots in the patches and microstrip regions.



FDTD grid used to model the patch antenna



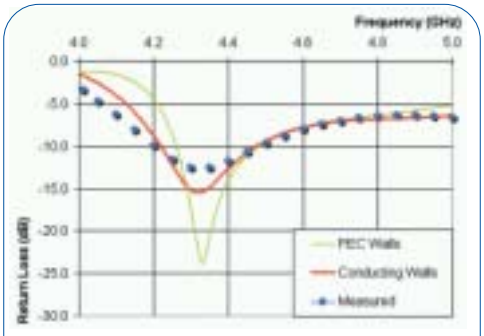
Antenna array under test in an anechoic chamber

Measurements

Experiments were carried out in the High Frequency Electronics Laboratory of the Queen's University of Belfast, UK. An HP 8510B network analyser (45MHz-40GHz) was used to measure the full port scattering parameters of the antenna array. The antenna far field radiation patterns were tested in an anechoic chamber using the measurement system shown in the figure (left).

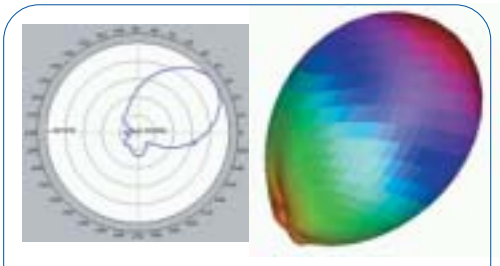
Results

The figure below shows the measured return loss compared with simulated results for the antenna array. The simulated results include the cases where the cavity walls and patch elements are treated as PEC, and when a conductivity of $5 \times 10^{7} Sm^{-1}$ was used. The agreement over the frequency range 4-5GHz is excellent.



Return loss compared with measurement

In the experiments, a VSWR of better than 1.6 at each antenna port was achieved at 4.4 GHz with a bandwidth of 250 MHz. In addition the simulated antenna gain is 5.6 dB, with an antenna directivity of 6.0.



Radiation pattern (2D and full 3D displays) showing active steering of the main lobe