The ferroelectric materials developed at Birmingham have application in microwave devices. Tunable filter, phase shifter and even switches can be made with these materials. Some devices, developed in the EDT centre are described below.

Microwave filters based on ferroelectric thin films have been designed and tested. An example is shown in Figure 1. The filter consists of three resonators each with a separate bias applied through the bias network shown. The filter is realised on a ferroelectric thin film on top of which a high temperature superconductor thin film has been deposited and patterned to form the circuit.

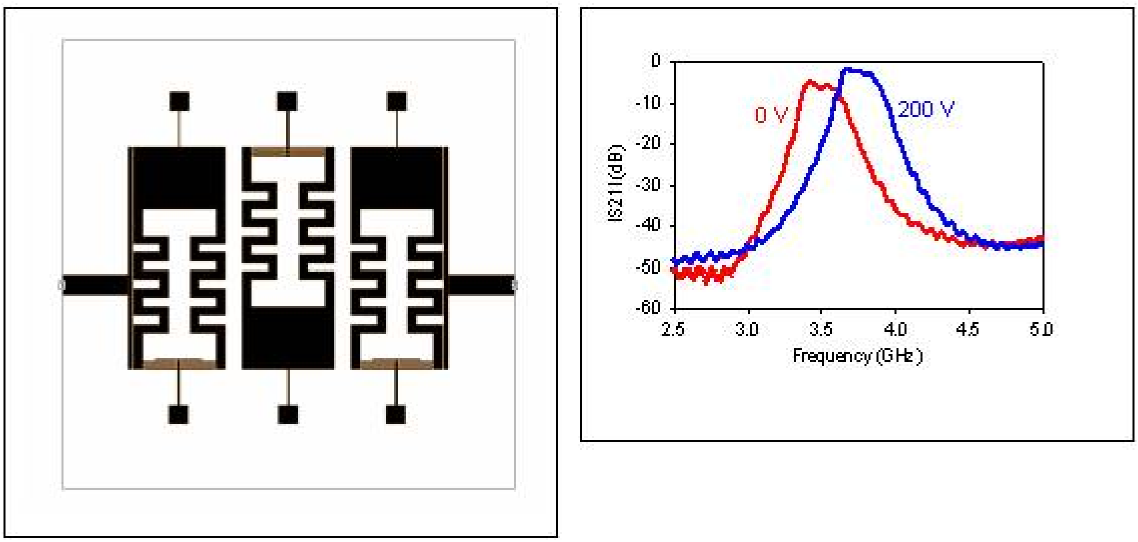

Figure 1: Layout and transmission characteristics of the three pole microstrip tunable filter.

In the layout shown in Figure 1, each resonator comprises of an interdigital capacitor connected to a half-wavelength meander line. The bias is applied between the fingers of the interdigital capacitors and the ground pads. The layout of the bias network, consistent with the small size of the devices (less than 100mm2) and providing minimal disturbance to the response of the filter, is one of the main challenges faced by the device designer.

The electromagnetic design, simulation, film growth, patterning and testing were all carried out in our laboratories.

This filter illustrates two valuable properties of such devices. The first is that the centre frequency of the filter can be shifted by application of a bias voltage, in this case 200V. The second is that each resonator can be tuned individually, which allows fine-scale optimisation of the response of the filter. It is particularly important that the reflection losses are minimised and this can be achieved through tuning the individual resonators.

An example of another filer is shown in figure 2. This is a low pass filter and the response is varied by making the capacitors C1, C2 and C3 out of ferroelectric material. The layout of the device in figure 2 shows the meandered inductors and a coplanar line for the input and output signals. The ferroelectric capacitors are extremely small and formed by the junction of the blue lines and the yellow lines. Both yellow and blue represent metal, but one is below the ferroelectric layer (blue) and the other above (yellow). The performance of this circuit is shown in figure 3.

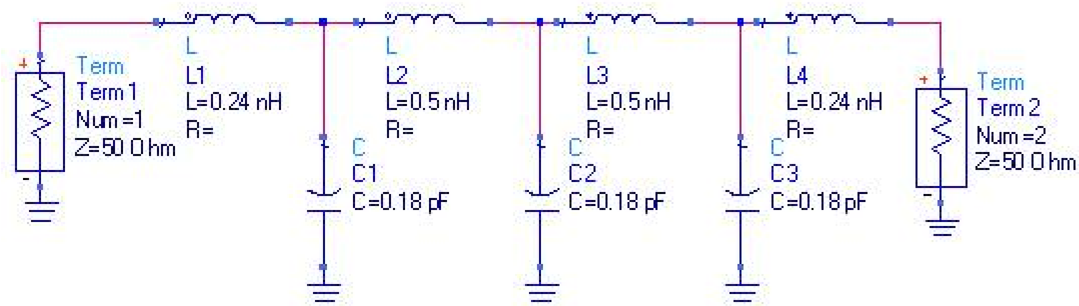

figure 2 a

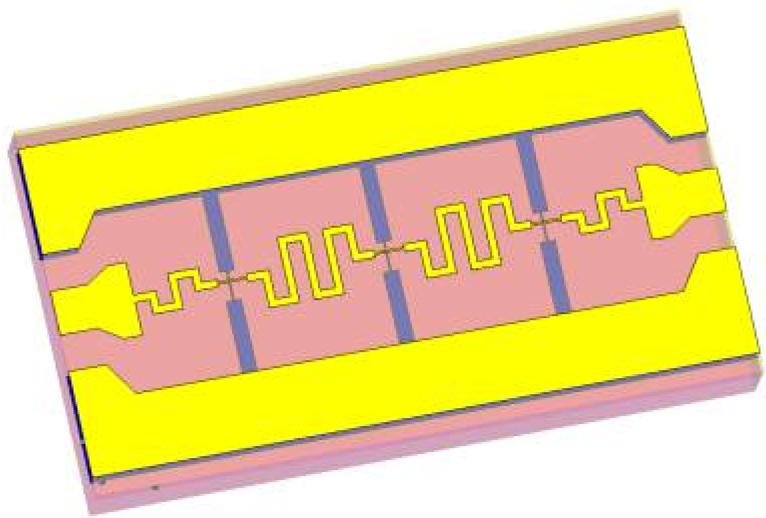

figure 2 b

Figure 2. A low pass filter with ferroelectric capacitors.
(a) equivalent circuit for the filter (b) The layout of the filter.

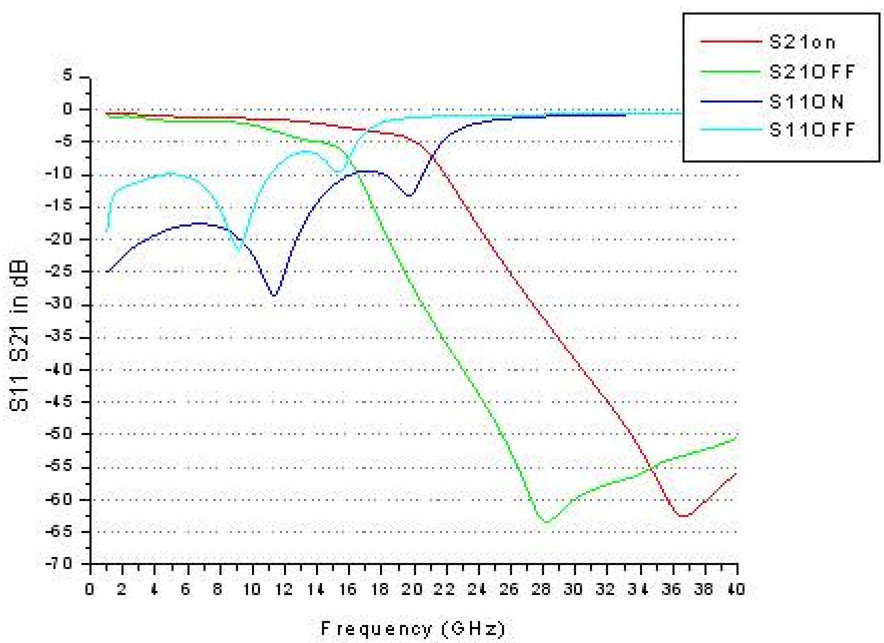

Figure 3 Simulated response of the filter in figure 2 showing
how the frequency response changes with the bias on and off.

In addition to the work on filters described above it is also possible to make phase shifting components. Here a microwave signal is input to the device and the output is a phase shifter version of the input. The amount of phase shift can be controlled by the application of a voltage. Figure 4 shows a coplanar circuit which produces a phase shift, there the black areas are metal and the ferroelectric lies between the long gaps. The microwave signal travels from the input on the left to the output on the right. The measured performance of the phase shifter is shown in figure 5. Here both the phase shift and figure of merit are shown as a function of frequency.

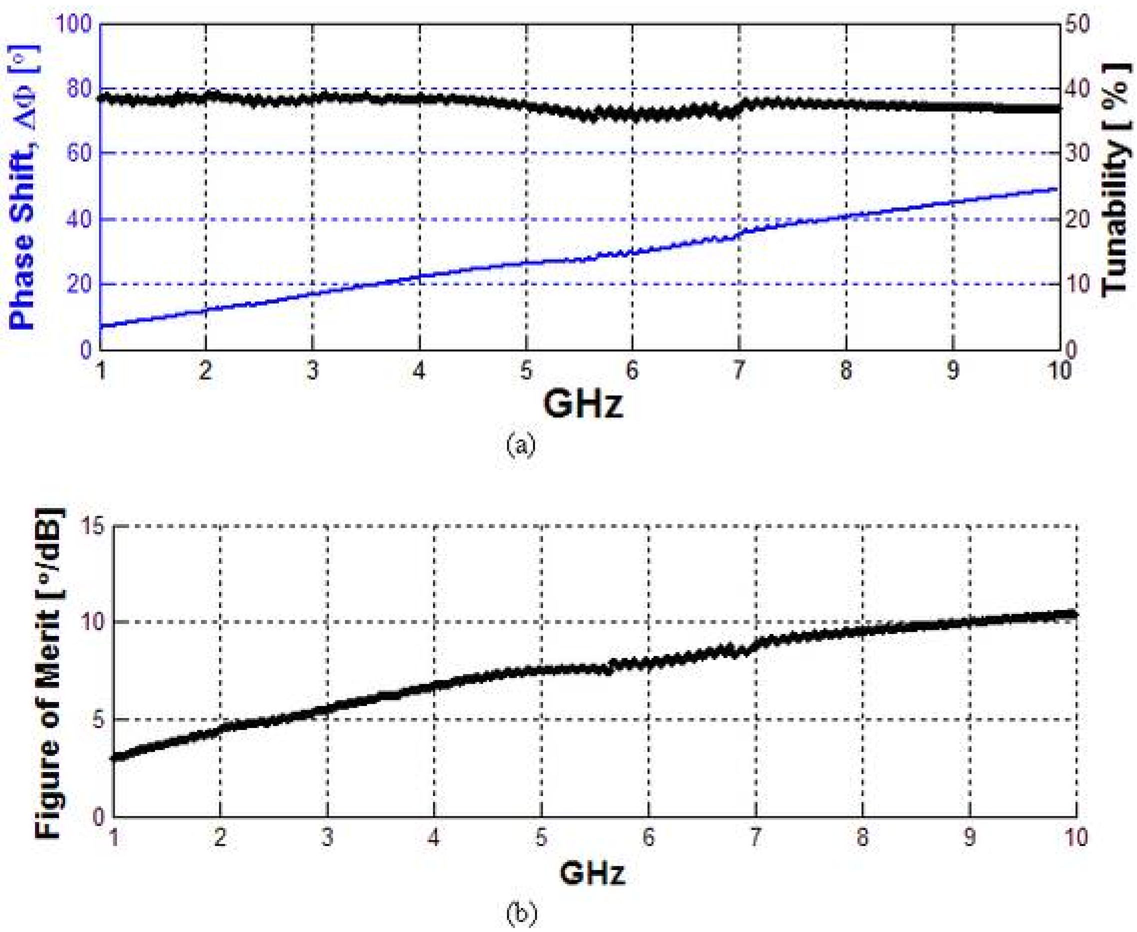

Figure 5 (a) Phase shift with application of 80V to the phase shifter in figure 4
(b) Figure of merit of the phase shifter in degrees per decibel.

As well as filters and phase shifters it is also possible to make attenuators. Figure 6 shows one such device. Here an input signal is split into two and then each of the two signals is passed through a phase shifter, the signals are then recombined. If both phase shifters have exactly the same phase shift then the combined signal is the same as the input signal. However if the two signals are phase shifted so they are 180 degrees out of phase then the output signal will be zero. By combining the signals with difference phase any amount of attenuation is possible. The simulated performance of the attenuator is shown in figure 7.

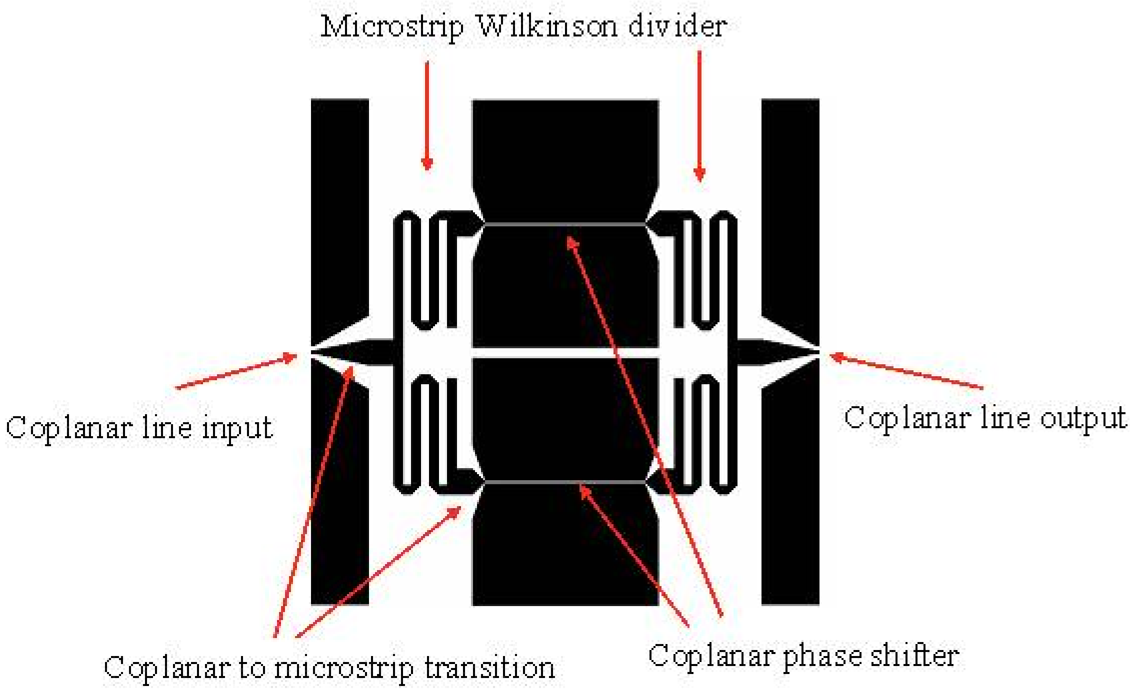

Figure 6 Microwave attenuator using ferroelectric materials

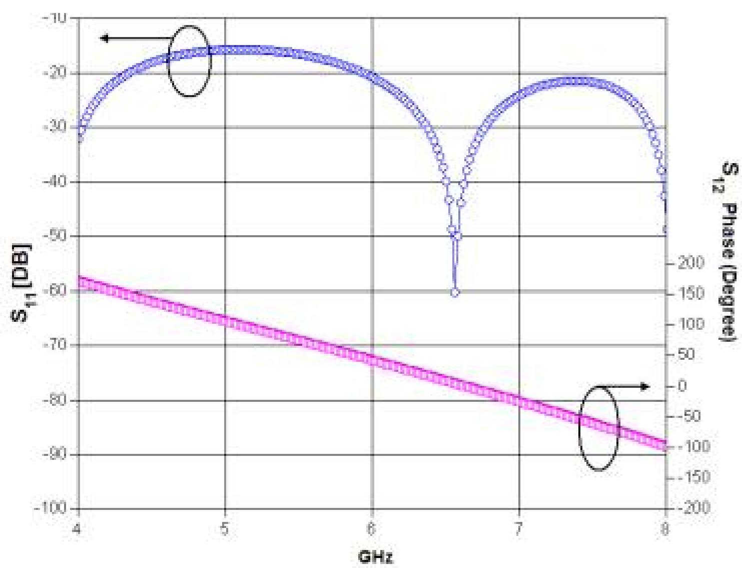

Figure 7. Simulated performance of the ferroelectric attenuator shown

In figure 7. The blue line indicates the return loss (S11) of the attenuator whilst pink line shows the phase in degree of the insertion loss (S12).