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Beam scanning using microstrip line on biased ferrite

J.C. Batchelor and R.J. Langley

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Beam scanning using microstrip line on biased ferrite

J.C. Batchelor and R.J. Langley

Indexing terms: Antenna arrays, Ferrites, Microstrip lines

Abstract: The beam scanning properties of a 2-element patch array fed by a microstrip feed situated on a ferrite substrate are presented. Biasing the femte changes the phase length of the microstrip line, scanning the beam by up to 40°. The resulting scan loss is -2dB, mainly due to the ferrite becoming lossy as it approaches absorption resonance.

Introduction: Ferrite substrates have been the subject of much interest for microstrip antennas recently. The high dielectric constant of the ferrite reduces the antenna dimensions and, when biased with a DC magnetic field, the antennas exhibit a number of novel properties [1 – 4]. These include frequency tuning agility, the generation of circular polarisation and radar cross-section reduction. A microstrip line printed on a ferrite changes its phase significantly when a normal directed bias is applied. This concept can be used to steer the beam of a travelling wave fed array. In this Letter, a simple but effective means of controlling the beam angle from 2- and 4-element microstrip arrays is described, where the patch array elements are fed by a microstrip line on a ferrite substrate. Biasing the ferrite causes a shift in the phase length of the line, hence varying the beam angle. The YIG ferrite used in the experiments had a saturation magnetisation of $4\pi Ms$ = 348 Gauss, a relative permeability of $\varepsilon_r = 13.8$ and a loss tangent of 0.0002.

Experimentation: To demonstrate the principle, a 3cm long microstrip line was printed on ferrite substrate. The line fed a 2-element microstrip array as shown in Fig. 1. A composite substrate was manufactured. The microstrip line was situated on the ferrite and the patches were printed on the high permittivity substrate with ε_r = 10.2 which adjoined it to minimise the impedance mismatch between the two substrates. **A** magnetic bias was applied using a permanent magnet underneath the substrate and normal to the line. The DC bias field affected -1.5cm of the microstrip feed line, with the resonant frequency of the circular patches on the dielectric remaining unchanged as the bias field was applied. The array was designed to fire a broadside beam and operated at 8GHz. The overall performance of this array is summarised in Fig. 2. The solid line in Fig. 2 shows the measured beam angle from the broadside of the array against magnetic bias. The beam angle changes little for magnetic bias fields of up to -2.l kOe. The beam direction shifts ~25° when the bias is increased a further 200 Oe, moving it out to ~45° from the broadside. At this bias point, the ferrite is operating close to the absorption resonance region and consequently the ferrite becomes lossy. This is illustrated by the dashed curve in Fig. 2. Above a bias of ~2.3kOe, the loss increases dramatically. At 2.3kOe, the loss is ~2dB.

The resulting normalised radiation patterns for this simple array are shown in Fig. 3 for three magnetic bias fields. There was little change at first in the beam direction as the bias was applied, the beam direction squinting just 5° at 2000 Oe. Increasing the bias by 100 Oe moves the beam angle to 20°, while a further small increase of just 30 Oe moves it to over 30°. Sidelobes appeared as the scan angle increased as expected in a simple array, and at a

40° scan angle, a loss of -2dB was measured. Calculated patterns for the array, simulated using Hewlett Packard MDS software, are also shown in Fig. 3. These show good agreement, although the predicted sidelobe levels were lower. A 4-element array has also been designed and simulated. Increasing the number of elements to four obviously narrows the beam width of the pattern in one plane but an additional benefit is that less magnetic bias is needed to produce an equivalent shift in beam direction. For example, 150° of line phase shift is needed to move the 2-element array beam by a 30°, whereas only 100° is needed for the 4-element linear array. Beam steering of up to 35° is easily achieved, with less magnetic bias field required than for the 2-element array, and better sidelobe levels predicted. This array is currently under construction for testing.

Conclusion; The principle of beam steering a simple 2-element array using a biased microstrip line printed on a ferrite substrate has been demonstrated. The biased microstrip line feed produces a phase shift of 30° per cm with low loss. Significant changes in phase were noted for small bias field changes. Beam scan angles of up to 40° were measured. This technique has potential for use in phased arrays, particularly if pre-biased hexaferrite substrates were to be used, since only small bias field changes would be needed to bring about useful shifts in beam direction.

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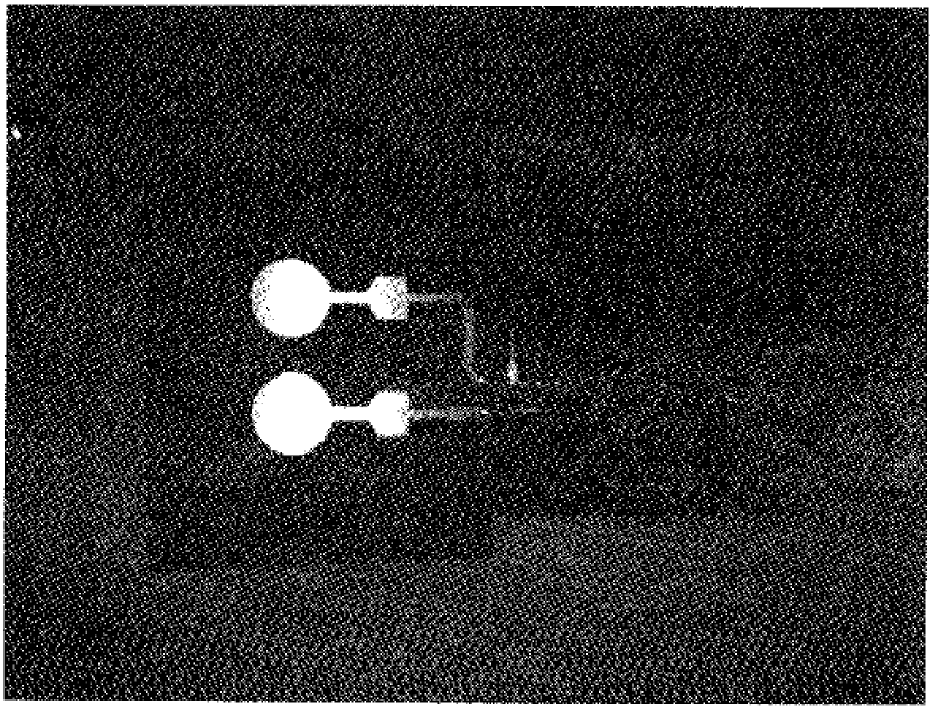

Fig. 1 *Two element array fed by microstrip line on ferrite*

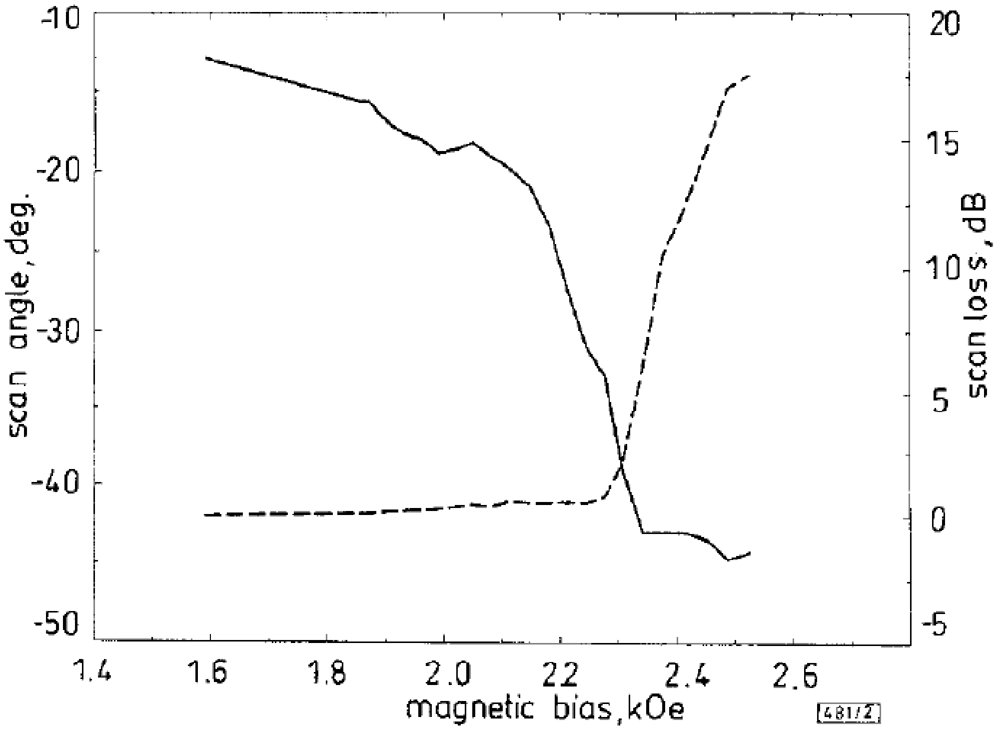

Fig. 2 *Beam angle and scan loss against DC magnetic bias at 8 GHz*

——— beam scan angle
– – – – scan loss

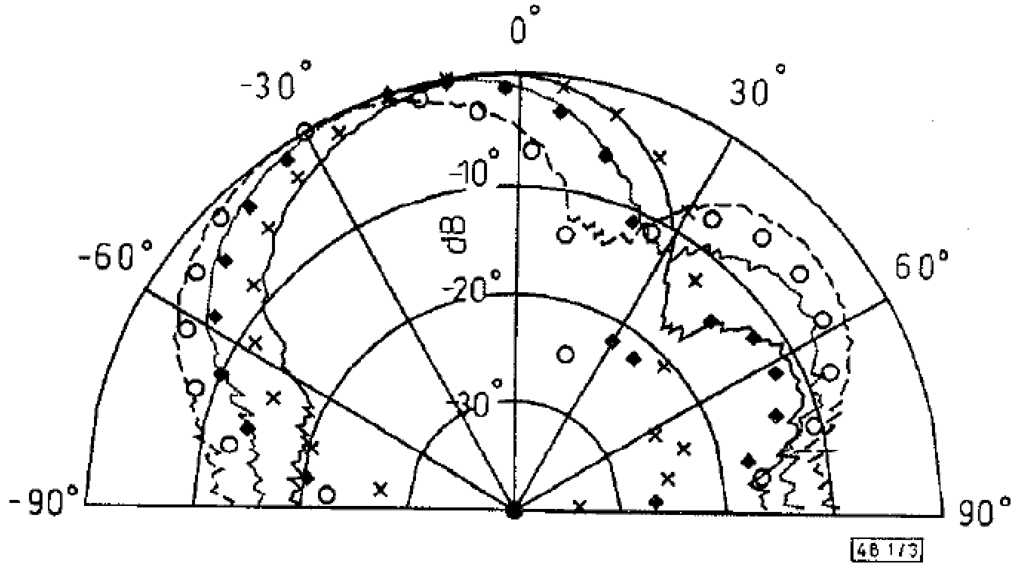

Fig. 3 *Measured and calculated radiation patterns for array*

Bias 2.00kOe: ——— measured, × calculated
2.10kOe: ········· measured, ▲ calculated
2.13kOe: ——— measured, ○ calculated