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Electromagnetic Scanning 3 Element Array with Integral Phase Shifters

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Electromagnetic Scanning 3 Element Array with Integral Phase Shifters

B.M. Cahill and J.C. Batchelor

Indexing terms: Antenna Arrays, Ferrites, Microstrip

Abstract: A structure is presented for a three element beam scanning array where integrated phase shifters are fabricated on ferrite plugs inserted into a microstrip feed network. A combination of permanent magnets and electromagnets are used to achieve beam steering of 30° with coil drive currents of 2A.

Introduction: The integration of ferrite substrates with microstrip technology offers potential for achieving electromagnetic switching of component properties by the application of an external low frequency biasing magnetic field, [1-3]. It is possible to produce low complexity phase shifting structures for vehicle cruise control radar and interference rejection in future mobile systems. However, a recurrent problem associated with ferrite components is the large current magnitudes necessary to achieve the conditions where the material permeability is described by a tensor. This letter presents a development of work [2,3] where the principle of using small bias variations near the magnetic resonant regions was demonstrated. Two complimentary phase shifters have been implemented and the small bias field shifts are provided by an electromagnet.

Experimentation: When a microstrip line is printed on a ferrite substrate, the variation in phase length with normally applied static magnetic bias is described in [3]. As the bias field is increased, a change of more than 50° is observed in the phase of S_{12} before the line insertion loss increases by

3dB. Significant phase changes can be accomplished for bias changes of several hundred Oersted. When the ferrite is biased just below one of its magnetic resonance regions, very high rates of change in phase length are observed for alterations in applied bias of several tens of Oersted. This extreme sensitivity of phase shift to applied magnetic field has the advantage that significant beam steering can be achieved for small field changes, but suffers the disadvantage of reproducibility when more than one shifter is required in a design. To achieve a uniform phase gradient on a series fed array, each shifter structure must be as similar as possible, and the applied bias field must be identical on each shifter. However, profiling the excitation across the radiating elements is problematic due to progressive attenuation in the feed. Conversely, magnitude profiling is more straightforward for corporate feed arrays, but different phase shifts can be required at different points in the feed to obtain a uniform phase slope. The design presented in this letter comprises a 3 element antenna array with a corporate feed that utilises identical phase shifters offering positive and negative shifts around the central reference element, Fig.1. The phase shifters were printed on 1mm thick G350 YIG ferrite tiles with a saturation strength of 348Oe. The rest of the array structure was fabricated on dielectric with ε_r = 2.33 and a thickness of 0.79mm. The identical phase shifters on the outer elements are biased at the same point below magnetic resonance using permanent magnets. This bias point is then varied using two coils wound with opposing senses around the biasing permanent magnets. The biasing structure is shown in Fig.2.

Results: Phase shifters were designed and fabricated. The measured return loss was better than 15dB and the insertion-loss was 2.5 dB. In this design, the insertion-loss of the outer elements helps to taper the magnitude profile and reduce sidelobe levels. The phase shifters were biased at a reference level of 2.67KOe using permanent magnets. This static field placed the ferrite on the knee of the phase slope for the resonant absorption region, [2]. Ferrite permeability is not sensitive to bias field polarity, when the field is applied normally to the direction of propagating modes. Therefore the magnets were aligned with opposite polarity to improve the magnetic circuit as indicated in Fig.2. The radiation pattern for the reference static bias is shown by the solid line in Fig.3. When a 2.0A current was applied to the coils, the radiation pattern was observed to steer out to 15° from boresight, the dot-dash line in Fig.3. Reversing the sense of the current changed the squint direction, as shown by the broken line in Fig.3. Further increase in the current magnitude resulted in only a very small change in squint angle. A steering range of ±15° would give sufficient sweep for a vehicle cruise control radar. The measured magnetic field change, ΔH, and the coil drive currents required to steer the beam to ±15° are indicated in table 1, where ΔH is defined as the difference between the static bias field and the resultant total field. The differences noted in ΔH for each coil are caused by the difficulties in fabricating identical windings and the sensitivity of the phase shifter to the applied field strength. The sidelobes always remain more than 12dB down on the main beam.

Conclusion: The successful steering of a 3 element array beam has been demonstrated. The beam was squinted over a total sweep of 30° without significant degradation being observed in the radiation pattern. Applied field changes of only 40 Oe were required to sweep the beam, which dissipated about 4W in the coils. The necessary power could be easily provided by a vehicle battery.

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Table 1: Coil currents and fields, ΔH, for beam steering

Coil1 Current (A)	Coil2 Current (A)	Coil1: ΔH_1 (Oe)	Coil2: ΔH_2 (Oe)	Beam Angle
+2	+2	-41	+34	+15°
-2	-2	+30	-43	-15°

Figure Captions:

Figure 1.

Microstrip layout of corporate feed 3 element array

Figure 2.

Phase shifter biasing structure.

Figure 3.

Array radiation patterns.

——— Static reference bias, 2.67KOe

— · — · · Positive squint, ΔH_1=-41Oe, ΔH_2=34Oe

– – – – – Negative squint, ΔH_1=30Oe, ΔH_2=-43Oe

Figure 1

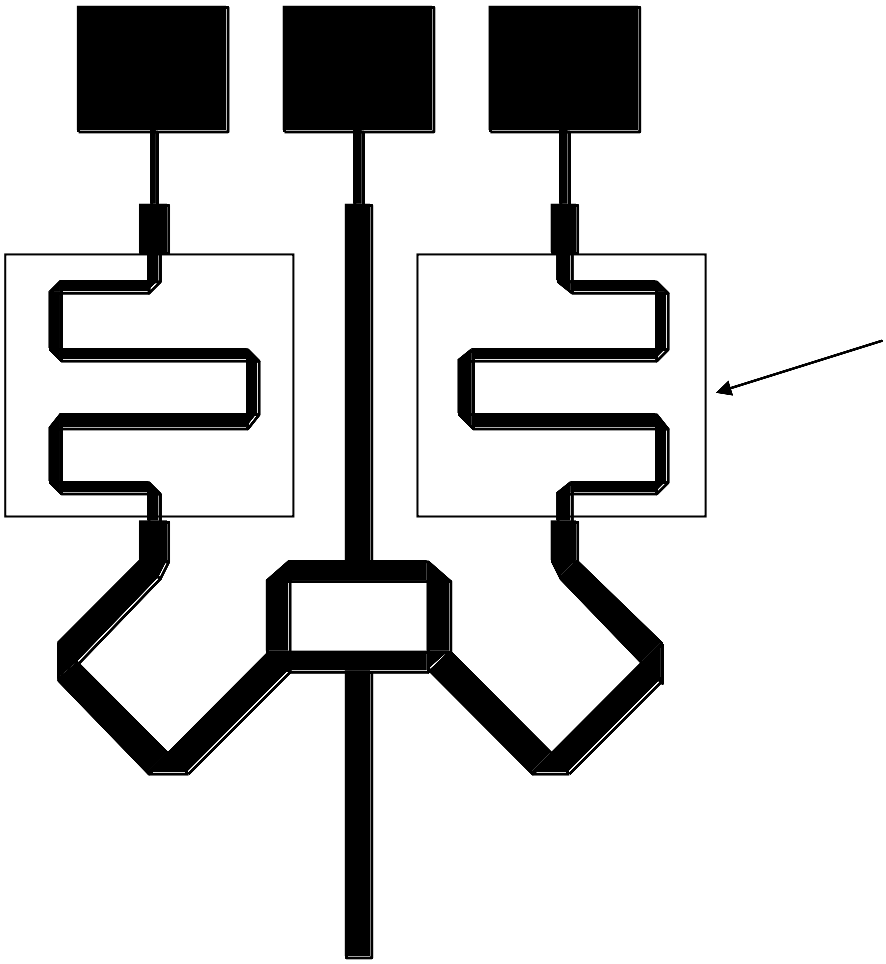

Figure 2

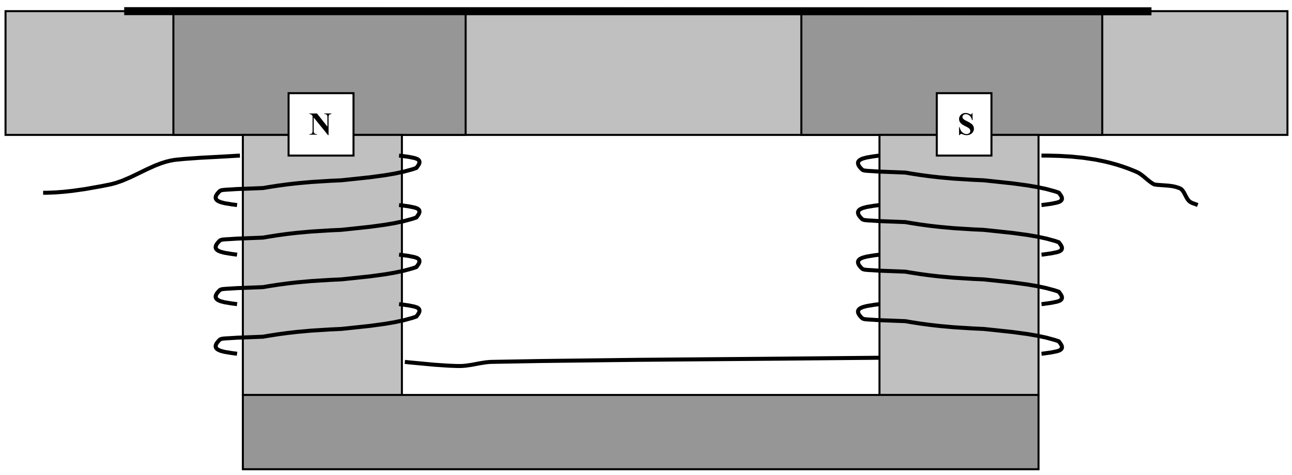

Figure 3

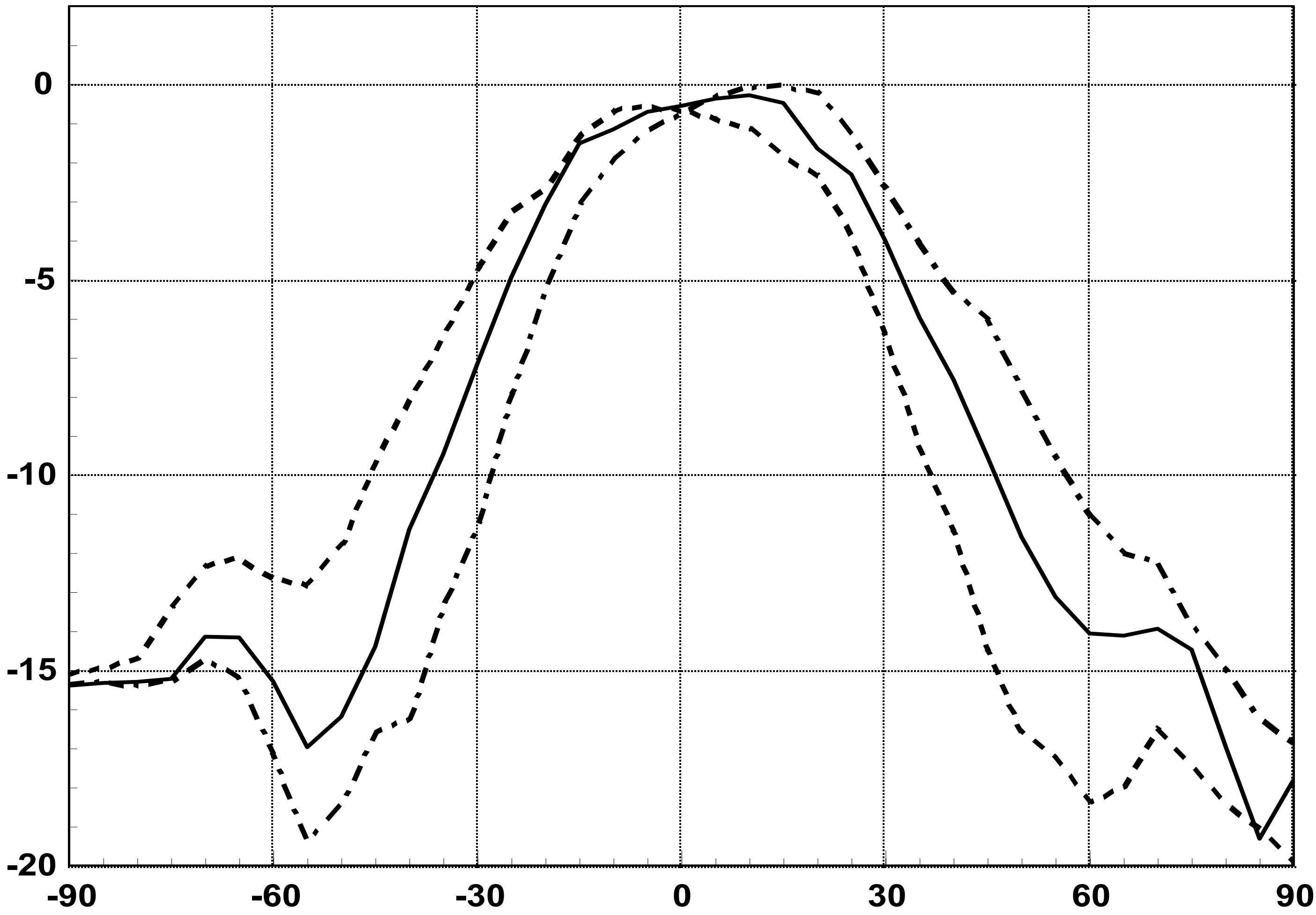

Figure 2 with labels: