DUAL POLARISATION ANTENNA ARRAYS WITH SEQUENTIALLY ROTATED FEEDING

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ABSTRACT

The application of sequentially rotated feeding to antenna arrays with dual polarisation capabilities can lead, not only to the well known improvements in cross polarisation and input VSWR, but also to significantly better polarisation isolation. There are many such array configurations, for either dual linear or dual circular polarisation. This paper describes analysis of such configurations in order to clarify their design and performance. New results for dual circularly polarised arrays suggest improved design methods for reduced cross polarisation input, VSWR and isolation.

1 INTRODUCTION

Dual polarisation antenna arrays are now required in many communications and radar applications. Either dual linear or dual circular polarisation may be used. This paper discusses the application to dual polarised arrays of the concept of sequentially rotated feeding [1]. Illustrations from the field of microstrip patch arrays will be used although the ideas discussed have wider relevance. The current use in dual linear arrays will be reviewed. The concept will then be developed for dual circularly polarised arrays and recommendations given for array design.

2 DUAL POLARISED ELEMENTS

Dual polarised elements can take many forms. If a microstrip patch is used then dual linear polarisation is obtained, for example, by through the substrate pin feeding along orthogonal axes as in FIG 1. Dual circular polarisation can be achievd by the use of shape deformation as in FIG 2. Patch boresight radiation is characterised for an element rotated by an angle o_{pm} as

$$E_m = \Big[(a\cos\phi_{pm} - b_1\cos\phi'_{pm} - jb_2\sin\phi_{pm})\hat{\underline{\theta}} + (a\sin\phi_{pm} - b_1\sin\phi'_{pm} + jb_2\cos\phi_{pm})\hat{\underline{\phi}}\Big]e^{j\phi_{em}} \qquad (1)$$

where ϕ_{pm} is the rotation angle of the orthogonal feed point. a and b_2 are the amplitudes of the primary radiated components. For dual linear polarisation $b_2 = 0$; for dual circular $a = jb_2$. b_1 represent the field generated by the perturbing influence of the orthogonal feed and can lead to significant degradation in cross polarisation. For example the 1.2dB axial ratio of a single circularly polarised patch degraded to about 7dB upon insertion of a feed for dual circular polarisation. In addition to this extra component in the radiated field, the othogonal feeds will also couple. Coupling in linearly polarised patches is of the order of -20dB, but may rise to greater than -10dB in a dual curcularly polarised patch. This limits the polarisation isolation of arrays of such elements. The following sections describe how appropriate array configurations can be used to cancel these coupled signals.

3 DUAL LINEARLY POLARISED ARRAYS

Sequential rotation in dual linearly polarised arrays is effected by a 180 degree element rotation. If this is applied to both polarisations in the same manner then no cross polarisation cancellation, input VSWR nor polarisation improvement is obtained. However by suitably combining rotated and non rotated groups Huang [2] has shown that both improved cross polarisation and isolation result. The improved isolation is a novel and important consequence of the use of the rotation concept in dual polarised arrays. It will also be shown that all even mode radiation is cancelled leading to improved pattern symmetry in the face of higher order mode generation. Cross polarisation improvement factors will also be presented which indicate that narrower bandwidths than circularly polarised rotated arrays will be obtained.

4 DUAL CIRCULARLY POLARISED ARRAYS

In an M element sequentially rotated array the rotation angle and feeding phase are given by

$$\phi_{em} = (m-1)\frac{p\pi}{M} \qquad \phi_{pm} = (m-1)\frac{p\pi}{M} \qquad 1 \leqslant m \leqslant M \tag{2}$$

For circular polarisation $0 < p < M$. Examples for $M=4$, $p=2$ are shown in FIG 3. For the orthogonal polarisation either opposite polarity phasing, FIG 3a, or opposite sense rotation, FIG 3b, can be used. The broadside radiated field is given by

$$E_{t1} = \frac{M}{2}(a + b_2)\left[\underline{\hat{\theta}} + j\underline{\hat{\phi}}\right] - \frac{Mb_1}{2j}\left[\underline{\hat{\theta}} + j\underline{\hat{\phi}}\right] \tag{3}$$

It is clear that cross polarisation due to $a <> b_2$, that is due to elements that are operated off resonance for example, is cancelled. In addition radiation due to b_1, which is due to the presence of the orthogonal feed, is also cancelled. Input VSWR of both polarisations is improved as expected. However no impovement of the polarisation isolation is noted, as the opposite polarity sequential phasing of the orthogonal polarisation effectively equalises the path lenghts through the various elements and feeds. It can be shown that the same occurs with opposite sense rotation of the othogonal polarisation.

Polarisation isolation can however be improved by operating the array with a squinted beam. Assume that the feeding phase of polarisation 1 is now modified to be

$$\phi_{1em} = (m-1)\left[\frac{p\pi}{M} + k_0 d \sin\theta_s\right] \tag{4}$$

where

$$M\, k_0 d \sin\theta_s = n\pi$$

where θ_s is the squint angle, k_0 is the free space wavenumber and n is an integer. The signal coupled between the two input ports is

$$V_i = \frac{V_0 T}{M} \frac{\sin(Mk_0 d\sin\theta_s)}{\sin(k_0 d\sin\theta_s)} \exp(-j(M-1)k_0 d\sin\theta_s) \tag{5}$$

which goes to zero when the squint angle is given by eqn (4). Cancellation of the orthogonal polarisations is now achieved. It can be shown that the other improvements due to sequential rotation are maintained.

FIG 4 shows the measured isolation for a 4 element microstrip patch array of the form of FIG 3a with and without beam squint. Isolation is improved by more than 18dB across the 12% frequency range shown. FIG 5 shows measured radiation patterns with and without squint. A degradation of 1.4dB in the axial ratio is attributed to small constuctional errors in the array manufacture. The high measured sidelobe level is due to the poor axial ratio of the dual polarised elements which is worsened by the squint. Previous work has shown that poor element axial ratio can give rise to large cross polarised lobes in the diagonal planes whose magnitude is a function of element spacing and array size and which can be reduced to acceptable levels in large arrays by array spacing less the about 0.7 wavelengths. This will also apply the squinted dual polarised array. In addition the sidelobe level in the squint plane is a function of the element axial ratio, element spacing and squint angle. As eqn (4) indicates that the squint angle will reduce as the array size increases, the sidelobe increase will also be small in a large array. FIG 6 shows squint angle and cross polar sidelobe level. It can be seen that for spacing less than 0.75 wavelength, sidelobe level will decrease with array size and that appropriate choice of spacing will lead to cross polarised sidelobe levels below the co-polarised level.

5 CONCLUSIONS

Sequential rotation can be applied advantageously to both dual linear and dual circularly polarised arrays. Analysis is presented which quantifies these improvements. Dual linear arrays possess reduced cross polarisation and improved isolation whilst it has been shown that dual circular arrays have low cross polarisation and input VSWR and by the use of a squinted beam good polarisation isolation.

6 REFERENCES

1 Hall,P.S., Dahele,J.S. and James,J.R., "Design principles of sequentially fed wide bandwidth circularly polarised microstrip antennas", Proc IEE, pt H, 136, 5 Oct 1989, pp381-389

2 Huang,J., "Dual polarised microstrip array with high isolation and low cross polarisation", Microwave and Optical Technology Letters, 4, 3, Feb1991, pp99-103

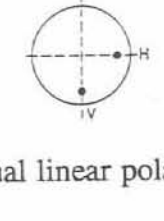

FIG 1 Dual linear polarisation patch

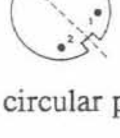

FIG 2 Dual circular polarisation patch

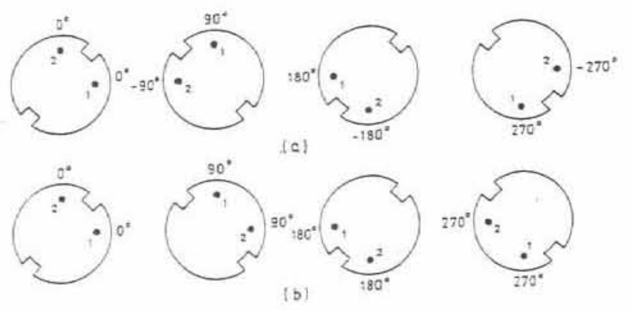

FIG 3 Patch arrays for dual circular polarisation

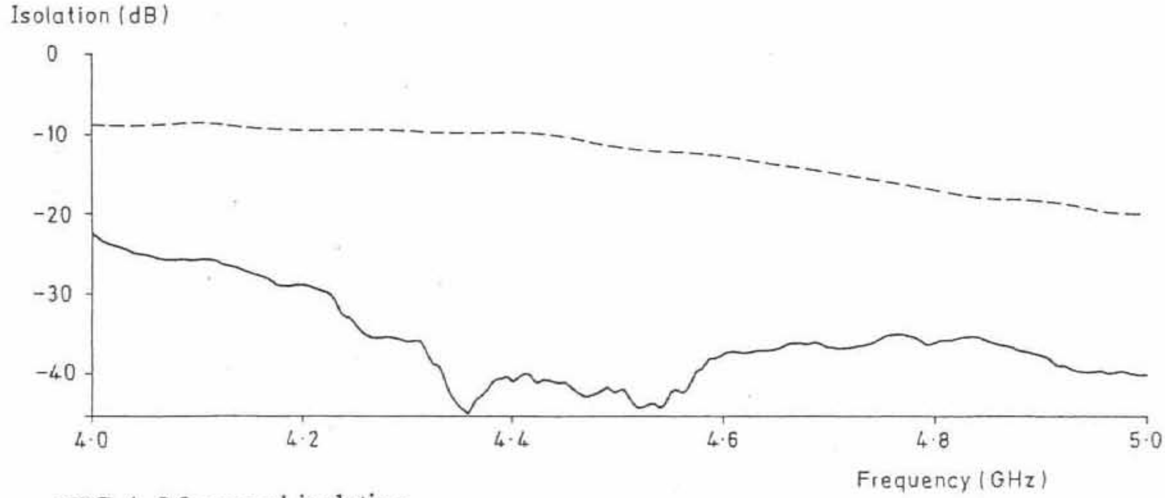

FIG 4 Measured isolation of array of FIG 3a

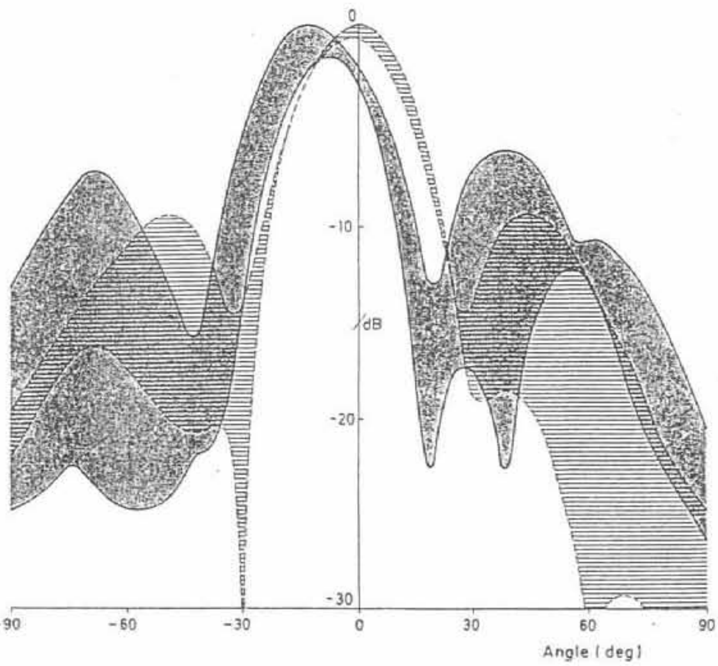

FIG 5 Measured radiation patterns of array of FIG 3a

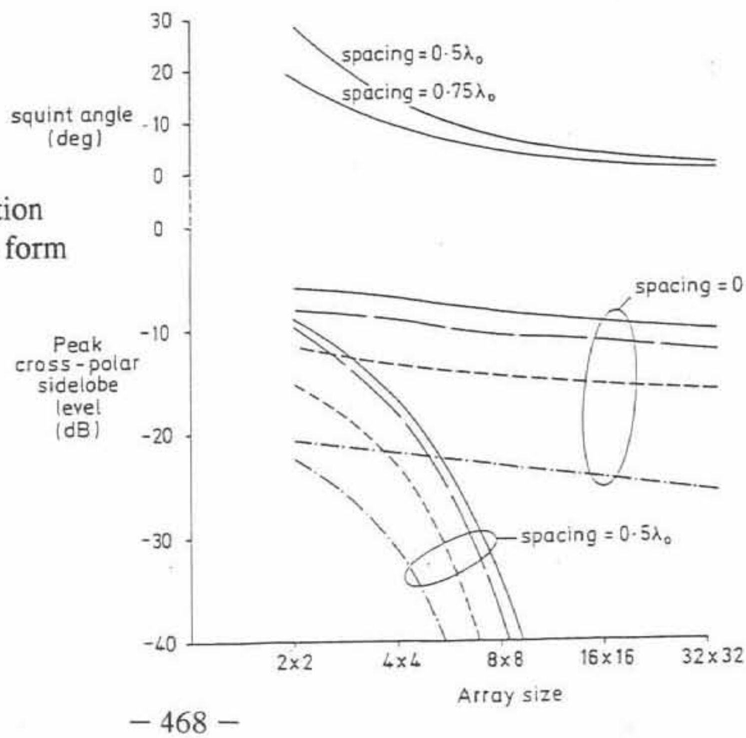

FIG 6 Squint and cross polarisation of two dimensional arrays of the form of FIG 3a.