MICROSTRIP ACTIVE PATCH PHASED ARRAY

P.S Hall

Royal Military College of Science, Shrivenham, Swindon, UK

ABSTRACT

An four element active patch array consisting of locked patch oscillators with varactor diode phase control is described. A wide range of radiated phase from each element can be achieved by DC bias control only. Preliminary results indicate that beam scanning in excess of 40 degrees can be achieved.

1 INTRODUCTION

Active patch antennas consisting of a patch radiator and integral oscillator can be used singly or in arrays operating as transmitting sources or as Doppler transmit-receive modules. The examples of array operation to date have demonstrated self locking amongst array elements which produce a broadside beam [1] or limited scanning using the inter-injection locking method [2]. Beam scanning using diode grids is also possible [3]. A new configuration is presented here that combines active patch power combination with varactor diode phase control to produce an active patch phased array.

2 ARRAY ELEMENT

The array element [4] consists of a microstrip patch radiator with integral transistor oscillator as shown in FIG 1. A bipolar transistor operating in common base mode is used with the patch forming the frequency controlling element. The phase control element consists of a varactor diode. The diode is connected between the parasitic patch and the ground plane, thus isolating the transistor and diode bias circuits. A tuning range of 100MHz at 2.25GHz is achieved with a output power variation of less than 4dB. Although phase control can be achievd by using the transistor bias the extra degree of freedom introduced by the diode is necessary both in achieving both phase and some degree of amplitude control and in offsetting the patch to patch variations introduced by transistor variations and constructional tolerances. Measured harmonic power is less than 25 dB below the fundamental. The isolated element pattern is well controlled [4] with a cross polarisation level of less than -25dB at band centre.

Phase control is effected by locking the patch oscillator to an external source and pulling the patch resonant frequency by means of the diode. Kurokawa [5] has shown that the oscillator phase will vary by 180 degrees over the locking bandwith. This has been experimentally verified for the diode tuned patch and results are given in FIG 2. The locking signal is injected into the patch through a small probe located close to but physically isolated from the patch edge. FIG 2 shows the radiated signal phase against diode bias at a frequency of 2.28GHz. Close to 180 degree phase change is achieved for various transistor bias voltages. Beyond the edge of each phase range shown in FIG 2 the oscillator looses lock. It may well be undesirable to operated the active patch close to the edge of the locking frequency band and this is likely to reduce the available phase shift that can be obtained from each element. The full consequences of this has not yet been fully assessed although it is likely that this will be less significant in a large array.

For full phased array operation, 360 degrees phase shift is required from each element. Various methods have been considered to achieve this. FIG 3 illustrates some likely options. In FIG 3a the locking signal is injected at either of two locations close to the patch edge, with 0 - 180 or 180 - 360 degree operation being selected by a switch in the locking feed network. This method gives a compact element design but was discounted here due to the need for RF switching. The other two methods shown in FIG 3 need only DC bias control to achieve 360 degree phase control. FIG 3b shows two closely spaced patch elements, one of which is inverted. Both patches are locked by the same signal injected as shown. The sense of the radiated phase is controlled by switching on or off each patch oscillator as appropriate. This configuration is adopted in the demonstration array described below. An alternative configuration, shown in FIG 3c, involves the use of two transistors on one patch which is locked at a single injection point. Again phase sense is selected by switching the transistors.

3 ARRAY DESCRIPTION AND PERFORMANCE

FIG 4 shows the array configuration which consists of four elements of the form of FIG 3a. Bias details are not shown. The locking signals are injected as shown and are derived from a corporate feed located behind the array substrate. The locking signal level was approximately -25dB down on the power radiated by each patch oscillator. The array is scanned by excitation of appropriate choice of transistor and diode bias. FIGs 5 and 6 show measured radiation patterns for array excitations appropriate to 0 and 40 degree scan angles. These are compared to computed patterns based on a cavity model patch analysis and measured phase and amplitude values of the patch excitation. The diode bias for each measured pattern was adjusted by hand to maximise the main beam peak level. This method of setting up the array was used as the mutual coupling significantly perturbed the phase of the elements when set up in isolation. Well formed beams scanned out to angles in excess of 40 degrees have so far been achieved with power combining efficiencies of greater than 70%. The high sidelobe in the 40 degree scan case is attributed to the non linear spacing appropriate to this case and the difficulties encountered in setting the desired phase distribution on the array.

4 CONCLUSIONS

A novel form of active patch phased array has been described. By pulling the resonant frequency of a diode tuned patch oscillator locked to an external signal phased control of 180 degrees is achieved. This is extended to 360 degrees by use of a dual oscillator element. Beam scanning to angles in excess of 40 degrees has been demonstrated. The technique significantly extends the capability of active patch arrays.

5 REFERENCES

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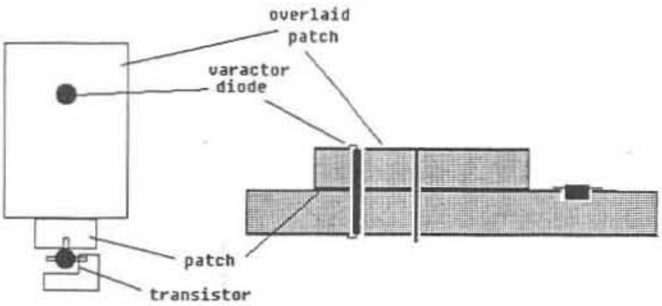

FIG 1 Microstrip patch active antenna

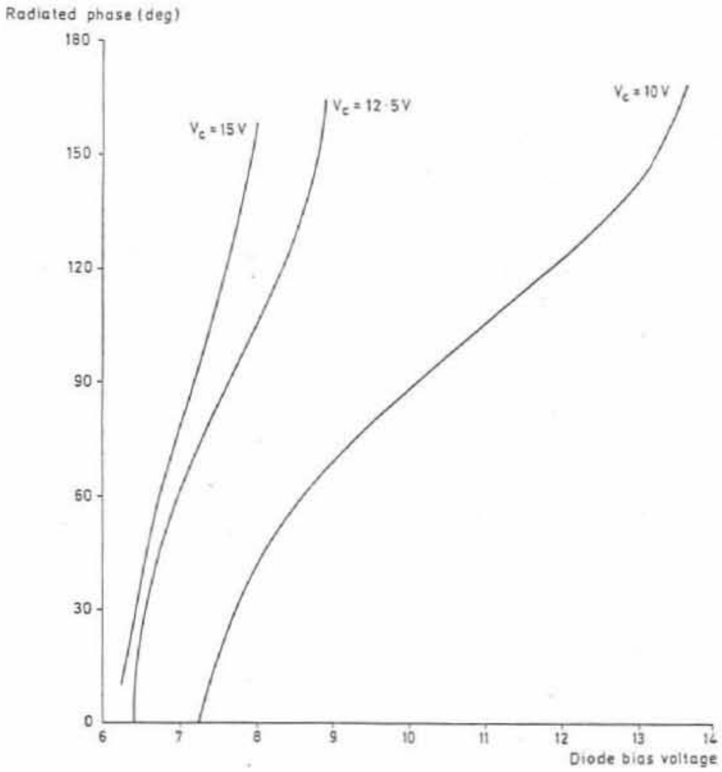

FIG 2 Active patch radiated phase control

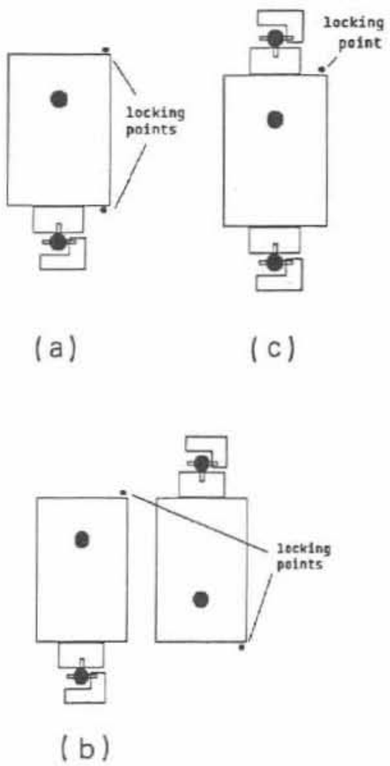

FIG 3 Arrangements for 0 - 360 phase

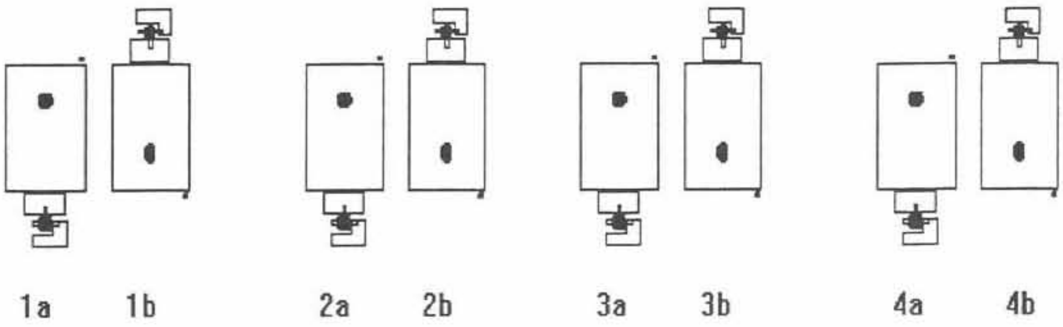

FIG 4 Four element active patch phased array
(Patch size = 20*27mm, substrate height = 1.5mm, e_r = 4.0, freq = 2.28GHz)

FIG 5 Radiation pattern of array of FIG 4 phased for 0 deg beam angle
(Elements 1b, 2b, 3b, 4b used)

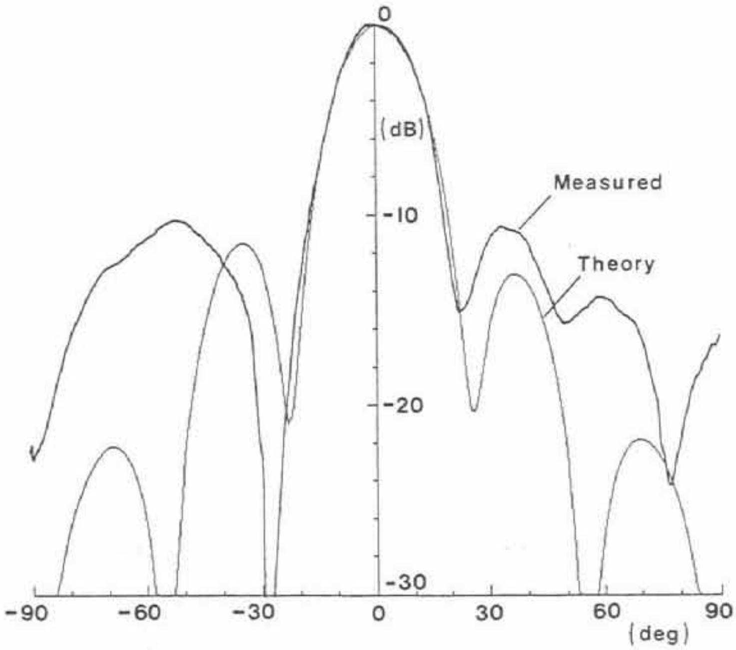

FIG 6 Radiation pattern of array of FIG 4 phased for 40 deg beam angle
(Elements 1a, 2b, 3a, 4b used)