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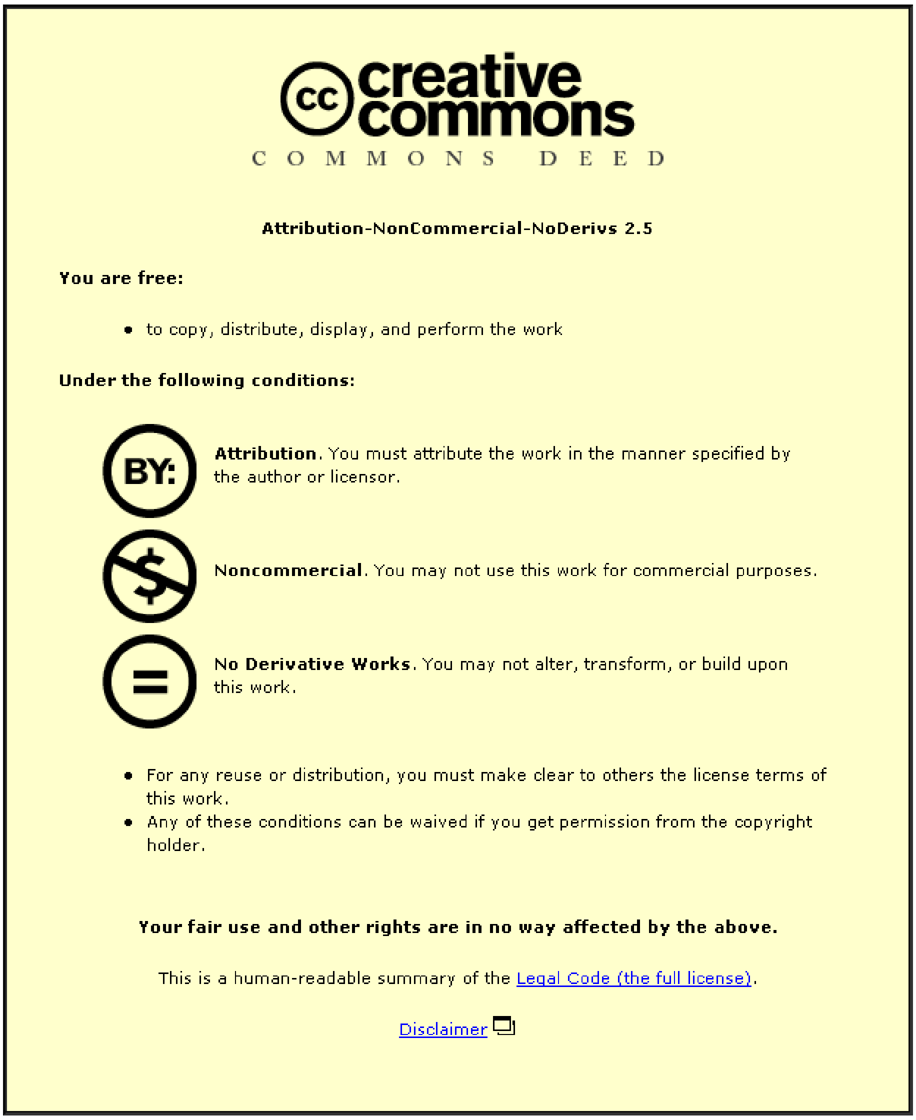

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Antenna Frequency and Beam Reconfiguring using Photoconducting Switches

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Antenna Frequency and Beam Reconfiguring using Photoconducting Switches

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Abstract This paper presents the use of photoconducting switches in antennas for reconfiguring operating frequencies and radiation patterns. It has also been demonstrated that these switches can be used in optically controlled phase shifters. A frequency shift of 40% is achieved with a dipole antenna and an array of patch antennas show beam scanning covering 30°.

Introduction

An antenna that is able to switch to different operating frequency bands is an attractive option in a market where multiband functionality is becoming a necessity. Similarly, beam scanning antennas have become popular in recent years. The use of optical control has many advantages. Fibre optic cables provide minimal interference at microwave frequencies compared to copper biasing lines used in other methods [1]. It also provides electrical isolation in high current systems.

Silicon Switches

Optically activated silicon switches have been developed for use on reconfigurable antennas and microwave devices [2]. The switch is a high resistivity passivated silicon die, 300μm thick and cut down to size from a wafer. The size of the die varies depending on the application. Near infra-red light is supplied through a glass fibre optic cable and illuminates the entire die top surface. LEDs have also been used as an alternative light source. This generates electron-hole pairs, significantly increasing the conductivity of the die. Controlling the light intensity controls the conductivity of the silicon dice and thus controls the microwave transmission.

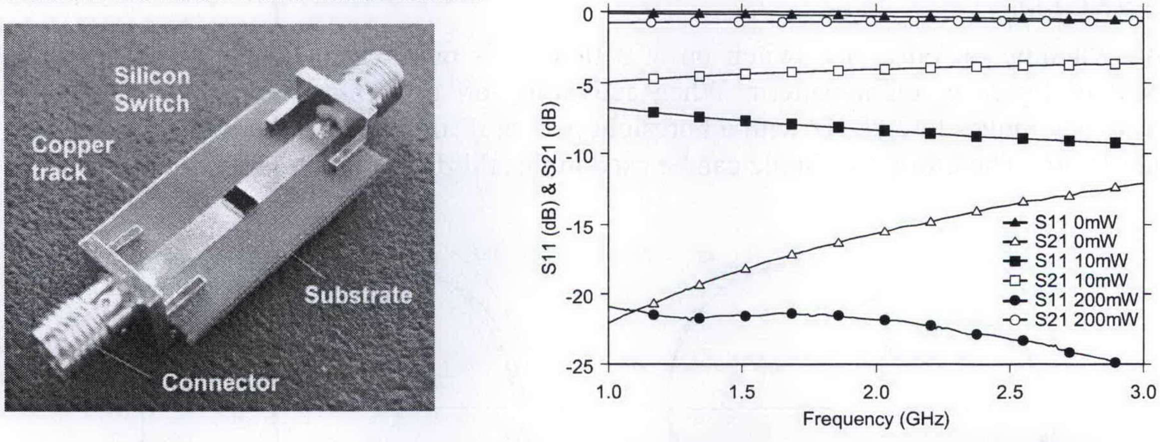

Figure 1 - Photograph of a photoconducting switch in a microstrip transmission line and its corresponding S-Parameters when activated by an 980nm light source

Figure 1 shows a silicon switch in use in a microstrip transmission line and its S-Parameters for a number of different incident optical powers. At 2GHz, when switched on, it has an insertion loss of just 0.68dB and when switched off, an isolation of 15dB.

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Reconfigurable dipole

A balanced planar reconfigurable dipole with a coplanar waveguide feed has been constructed and tested. The dipole is 62.3mm long with two silicon switches placed over gaps in both arms. Near infra-red light guided through optical fibres is used to independently activate the two switches when necessary.

Frequency shifting

The resonance frequency is changed by activating the Si switches. When the switches are fully on, the dipole resonates at its full length of 62.3mm. When both switches are off, the dipole resonates at a shorter length of 33.5mm due to the open gaps in the dipole arms. The glass fibres ensues that there is minimum interference to the dipole's near-field.

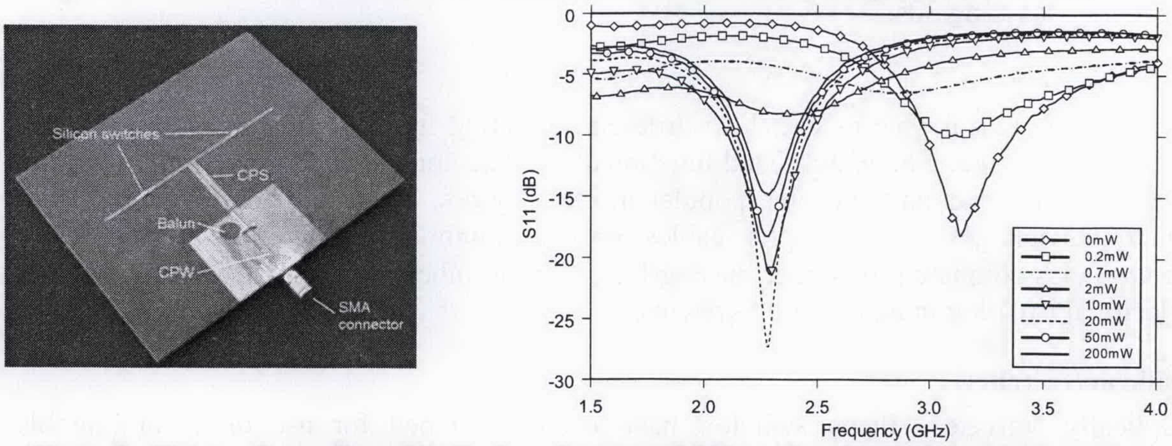
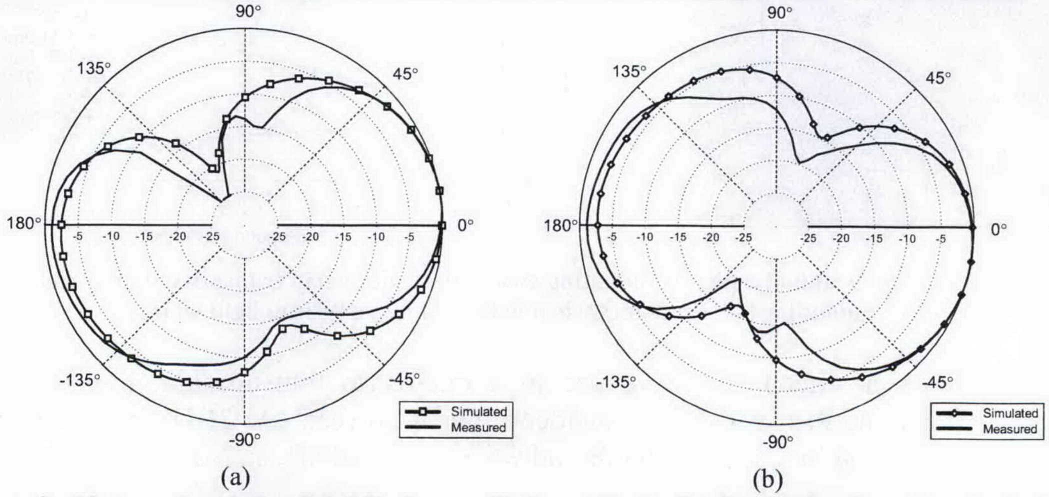


Figure 2 - Picture of reconfigurable dipole and measured S11 results when activated with varying optical powers

With 200mW of optical power, the frequency shifts from 3.15 to 2.26GHz. Measured radiation patterns show that the dipole retains a balanced figure of eight shape through the frequency shift. The boresight gains at 3.15 and 2.26GHz are 4 and 2.9dBi respectively.

Null Shifting

By switching on only one switch on at a time, it is possible to tilt the beam from its standard figure of eight pattern. When activating left or right switches, the resonance frequency moves to 2.7GHz with a boresight gain at 0° of 3.1dBi and a return loss better than 15dB. Therefore, the dipole can be used in this third state as a tri-band antenna.



(a) (b)

Figure 3 - Measured and simulated E-plane radiation patterns for the dipole when (a) only the left switch is on and (b) when only the right switch is on

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By changing the active switch from the left side to the right, the pattern null can be redirected by up to 50°. This can be utilised in avoiding interference sources or ensuring a broad beam in the E-plane of the dipole.

Beam Scanning

Optically controlled Phase Shifter

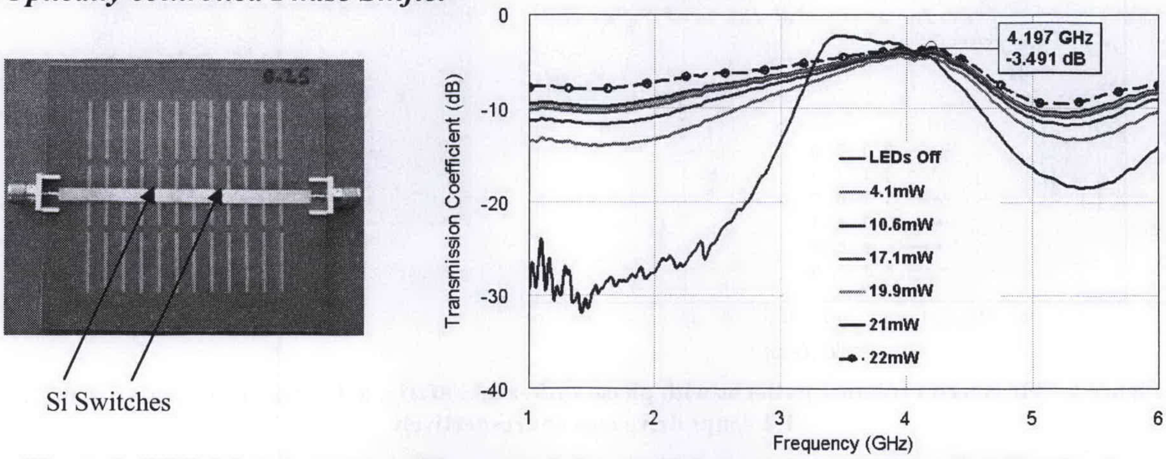

Figure 4 - EBG delay structure and its transmission coefficients under varying optical illumination powers

Figure 4 shows a prototype of a microstrip resonator integrated with Electromagnetic Band Gap (EBG) structure, and this device behaves as a delay line [3]. The EBG layer is made up of three rows of periodic dipole arrays etched onto a substrate and the resonator, fabricated on 0.07mm thick dielectric is placed perpendicular to the middle row. A pair of optically triggered switches that are placed at both ends of the resonator, act as the control mechanism of the delay line (see Fig 2). Silicon switches are used to alter and control the propagation constant (β) of the microwave signal, along the transmission line. Figure 5 shows that the Si switches act as the two phase shifting elements controlled by optical illumination.

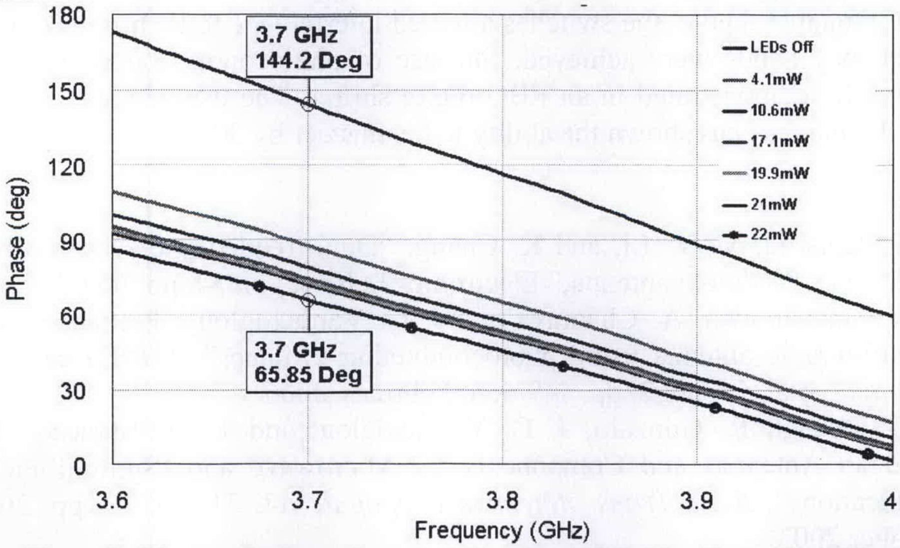

Figure 5 - Measured phase characteristics of an EBG delay line using LEDs

The ability to use conventional low cost LEDs makes the technology attractive in most applications. Using 22mW of optical power, the insertion loss can be close to 3dB, and the phase variation at 3.7 GHz is about 78° when compared to the off state.

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Beam Steering Antenna Array

Optically activated phase shifters have been integrated into each feeder of radiating elements in order to realise a beam steerable antenna.

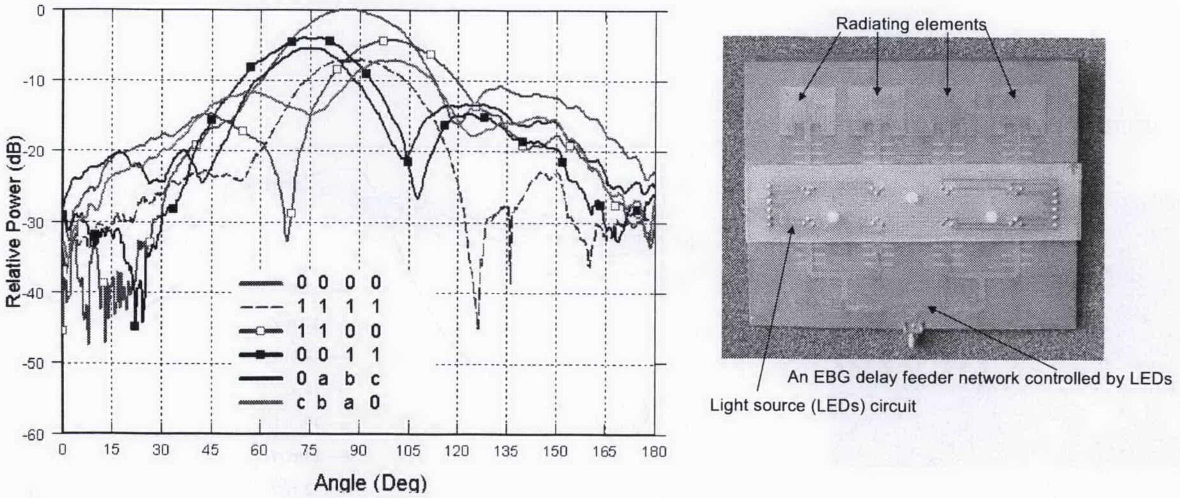

Figure 6 - Measured radiation patterns with phase shifter at 3.8GHz. a, b, and c represents 0.5, 0.75, 1.0 Amps drive current respectively

In order to demonstrate the ability to shift a beam of an antenna using the the EBG phase shifter, four microstrip patch elements were incorporated into the feeder network. The picture in Figure 6 shows a fabricated test device consisting of a compact integration of the a four element array with low-cost LEDs. The topology of the radiating elements consists of a rectangle patch measuring 29mm by 26mm. The spacing between these elements is 6.6mm, and it was demonstrated, (see Figure 6) that the beam of the antenna can be shifted with change in phase along the feeder network The maximum beam steering range is near ± 15°.

Conclusion

The use of photoconducting switches in two antenna applications have been presented. In the frequency tunable dipole, the switches allowed interference to be minimized and three distinct frequency bands were achieved. The use of photoconducting switches has also been successfully demonstrated in an EBG phase shifter. The use of phase shifters in an array of patch antennas has shown the ability to beam steer by 30°.

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