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Beam Scanning Antenna with Photonically Tuned EBG Phase Shifters

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Introduction

The rapidly growing communication market demands for powerful and low cost antenna systems operating at micro/mm-wave frequencies. Tunable phase shifters are the key components of steerable antennas. The system costs would be significantly lowered by using optical control techniques. Moreover, optical switches can offer the advantages of continuous, quick and low power consumption and are free from EMC issues. Here we describe and show measured data of a novel steerable antenna array incorporating optically controlled EBG phase shifters [1].

Phase Shifter

Figure 1 shows a picture of a resonator with Electromagnetic Band Gap (EBG) terminated at both ports with SMA connectors. The EBG layer is made up of a periodic array of dipoles etched onto a substrate. We have adopted three rows of the EBG in all our prototypes, and the resonator is placed perpendicular to the middle row. The functionality of the tunable phase shifter is based on the dielectric properties of silicon substrate incorporated in microstrip resonators. Silicon dice placed above resonator interdigital gaps (IDGs) act as the two phase shifting elements controlled by optical illumination. A layer of EBG underneath the resonator enables the phase shifter to be a better slow wave structure. The presence of the EBG suppresses harmonics of the fundamental frequency, and also improves the Q factor of the resonator[2].

Figure 1 Photograph of EBG phase shifter

This type of microstrip gap has been implemented in microswitches and it has been established that this type of gap has superior scattering characteristics over the commonly used simple straight gap or discontinuity. The width of the gap above the silicon dice was about 1.0mm wide.

Optical sources and results

The performances of the phase shifters were evaluated using illumination from laser Light Emitting Diodes (LEDs) running at various optical power levels. The illumination from the optical source was focused above the silicon dice by using a fiber optic cable. A calibrated optical power meter was used to measure the intensity of the illumination from the fibre. The amount of optical power was varied by changing the driving current to the LEDs. The transmission coefficient results from Figure 2 indicate that the application of this device is not only limited to a phase shifter, but it's uses can be extended to act as an optical microwave switch. The region it can be regarded as a switch is between 1 GHz and 3 GHz. The insertion loss at 2 GHz in the ON and OFF states are 1.5 dB and 42 dB. The insertion loss with the LEDs ON can almost be maintained near the resonance frequency, and can be as low as 0.7 dB at 4.2 GHz. The insertion loss values of various devices lie between 0.4 dB and 3.0 dB for the optical illumination of at least 50 mW. The corresponding differential phase of the magnitude is given in Figure 3. These results indicate that it is possible to control the phase linearly with an increase in the supply voltage.

Figure 2. Measured transmission responses at different optical LED power levels of phase shifter

Figure 3. Variations of the phase of IDG with changes in the LEDs supply voltage.

Beam-steering antenna

The antenna (shown in Fig 4) is designed in such way that the beam direction can be changed by illuminating the Si switches along each transmission line. The antenna structure is made up of four microstrip patch elements with their respective feeding lines pasted above a periodic dipole array (EBG array), a phase shifter and a simple optical LED system. Far-Fields radiation patterns and the return losses discussed here were measured from four conditions: when all four switch feeders are off, (0000), when all switches are turned on, (1111), when only transmission lines marked 1 and 2 are illuminating, (1100), and when only transmission lines marked 3 and 4 are switched on, (0011). The beam direction can also be tilted to the left when the LEDs are the 0011 state. The optical power measured at the end of each LED was about 22 mW when operating at 1.65 V. We have also observed a beam shift of about 15° with 10 mW of optical from each LED. The measured return loss of the test antenna is better than -19dB at 4.1GHz with a 10dB bandwidth of about 2 %. The patterns plotted in Figure 21 of antennas consisting of chamfered gaps show that the beam direction can be steered near a $+30^\circ$ to -30° .

Figure 4. 4 element array of patches with integrated phase shifters

Figure 5. Far-Field radiation patterns of the phased array antenna

Conclusion

In this paper we describe a phase array antenna architecture which has been experimentally tested in the laboratory. A photoconductive phase shifter using microswitches has been proposed, fabricated and used in the antenna. We have demonstrated the antenna's scanning capability near $\pm 30^\circ$. The ability to achieve such a wide beam scan when operated by low power LEDs makes them attractive over the existing mechanical or electrical phased array antennas. The Half-Power Beamwidth (HPBW) of the pattern is almost maintained in all steered states. However it is worth noting that the level of the side lobes needs to be reduced.

Acknowledgment

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References

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