Miniaturized Delay-enhanced Substrate-Guided Wave Based Holograms for Continuous Tuning of Delay Times

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As one of the key technologies in modern radar and communication systems, phased array antennas have the advantages of low visibility, high directivity, quick and accurate beam steering, as well as reduced weight and power consumption. True time delay techniques are free from the beam-squint effect in phase array antenna systems compared with conventional phase shifter technologies [1, 2]. Optical true time delay techniques also have features of wide bandwidth, compact size, reduced weights and low electromagnetic interference.

We designed and reported several continuously tunable true-time-delay modules for continuous microwave beam steering, which were realized by tuning different wavelengths within the different modules [3]. However, for the wavelength-controlled true-time-delay modules that have been reported, the position of output beam moves along the length of the substrate during incident wavelength tuning. Therefore, a set of collimators with large diameter is needed to receive the moving output beam, which causes the true time delay system bulky and heavy [3]. In this paper, we implement a novel symmetric structure for optical true time delay modules that provides miniaturized package size and enhanced delay time. This is also the first time to realize fixed both input and output positions for continuously tunable substrate-guided wave based true time delay modules.

This true-time-delay module is designed for 4X4 2-D phased array antennas. It is composed of twenty subunits, four for one direction and sixteen (4x4) for the other. Each subunit includes one prism, which is used to implement symmetric structures. The general configuration of the proposed wavelength-tuning scheme is shown in Fig. 1. Deviation of the optical path inside the substrate corresponds to variation of the incident wavelength, such that controlled time delay comes into being, while the final output position is fixed due to the symmetric compensation. With this benefit, we can use small collimators with single-mode fiber pigtail, which miniaturize the package size and avoid insertion loss from multimode-to-single-mode connections. Fig. 2 shows measured output power at a wavelength tuning range of 10nm after four times of diffraction within the waveguide hologram. Another advantage of this module is that the incident beam experiences two similar zigzag beam paths as shown in Fig. 3, such that the new structure can provide larger time delay than the original one. Fig. 4 shows simulated time delay corresponding to different input wavelength. Approximately, the delay time is doubled with the same incident wavelengths. This feature determines that the maximum scanning range of the module with new symmetrical structures is enhanced in comparison with the original one.

Further experimental results and system demonstration will be shown in the conference.

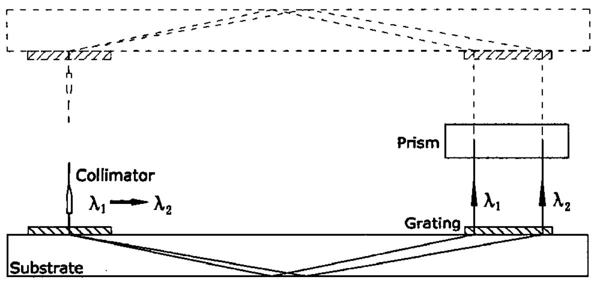

Fig.1 Introductory configuration of the wavelength tuning hologram symmetric-structure-based true time delay modules. Continuous time delays are achieved by tuning wavelengths in the different time-delay modules.

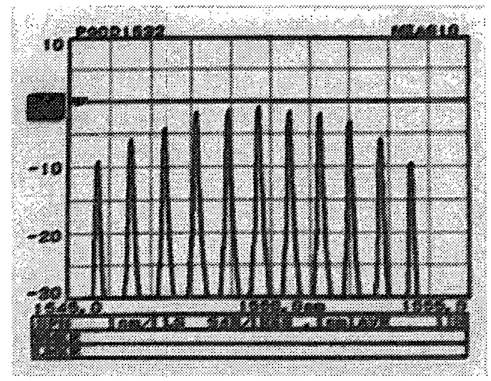

Fig.2 Output power at different wavelengths

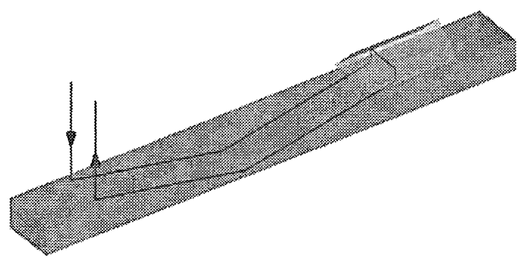

Fig.3 Preview of actual configuration with optical path inside the substrate and prism.

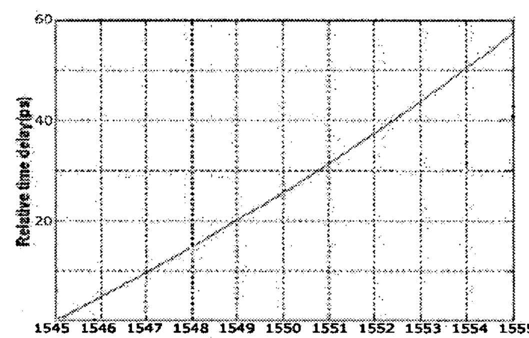

Fig.4 Simulated time delay at a given wavelength tuning range

In conclusion, a miniaturized continuously tunable optical true-time-delay module has been designed, fabricated and evaluated for integrating into a X-band 4X4 2-D phased array antenna system. A novel symmetric structure is introduced to keep the output beam position fixed and avoid using a set of large collimators. This new structure is compact and easy to package while providing doubled delay time. Therefore, this module can easily scale up for large arrays due to its compressive structure.

References

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