FDTD and PSTD Simulations for W-Band Linear Tapered Slot Antenna

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Abstract — **Three-dimensional finite-difference time-domain (FDTD) and pseudospectral time-domain (PSTD) algorithms, with perfectly matched layer absorbing boundary condition, are presented for analysis of the newly designed W-band linear tapered slot antenna on rectangular-grooved silicon substrate. Compared to its ungrooved version, the W-band coplanar-waveguide-fed antenna shows significantly improved endfire radiation patterns in the whole band. Also, the symmetric patterns together with moderately high gain, high front-to-back ratio, and low sidelobe level are achieved.**

I. Introduction And Background

ENDFIRE tapered slot antennas (TSAs), viz. the Vivaldi antenna [1], was proposed and developed by Gibson et al. in 1979. Since then, the variations related to the profile of the TSA have been proposed in the literature [2]. The low sensitiveness to manufacturing error at millimeter wave frequency, and easy connection with integrated circuits make the TSAs particularly well suited for millimeter wave applications. However, the substrate thickness constraint of the TSAs renders their design in a somewhat limited way. Specifically, the radiation characteristics are deteriorated owing to the unwanted substrate modes that are excited by increasing the thickness. Indeed, the upper bound of the constraint renders the substrate thickness of the TSA impractical for millimeter wave applications since the TSA, on such a thin substrate, is fragile. Several avenues have been proposed in the past to alleviate this constraint. To design this extremely complex structure, the efficient numerical method has to be investigated.

Recently, finite-difference time-domain (FDTD) method, one of the most powerful full-wave computational methods, has been applied to antennas analysis. When simulating an open-region problem, all previous work on FDTD for the antenna application employed absorbing boundary conditions, such as perfectly matched layer (PML), which gives zero reflection at the absorbing boundary for all frequency, and all angles of incidence [3]. The PML has been demonstrated to be the most efficient algorithm, and found intensive applications for various nondispersive media when combined with the FDTD method. Although the FDTD method has found widespread successful applications, to ensure the accuracy of the computed spatial derivatives of electromagnetic fields, it requires a fine spatial discretization of more than 10 cells per minimum wavelength, which limits the scale of problem solvable by FDTD method with the existing computation resources. As one of the improvements, the pseudospectral time-domain (PSTD) algorithm has been recently developed for nondispersive media, and proves to provide high accuracy and efficiency for large-scale problems [4]. The efficiency of the PSTD method is due to the accurate approximation of spatial derivatives using the fast Fourier transform. Hence, the spatial sampling rate in the PSTD method approaches the Nyquist sampling rate, i.e., two points per minimum wavelength.

Here, a W-band (75–110 GHz) coplanar-waveguide-fed linear TSA on a rectangular-grooved silicon substrate is proposed. Predominately tackled via the grooved substrate design, the proposed coplanar-waveguide-fed TSA shows well-behaved and symmetric radiation patterns along with a moderately high gain, high front-to-back ratio, and low sidelobe level in the whole band. In addition, three-dimensional FDTD and PSTD algorithms incorporated with the PML are presented for the TSA as a special example of general inhomogeneous, dispersive media. We develop the formulation of algorithms, and several examples for validation and applications are given. In what follows, the antenna design, fabrication, and measurement are described, respectively.

II. Results

The simulated parameters of the coplanar-waveguide-fed TSA are listed in Table I. As a result, this relatively wide-band small TSA design shows well-behaved and symmetric patterns along with a moderately high gain (8–10dBi), high front-to-back ratio (16–28 dB), and low sidelobe level (-15 to -17 dB for the *E*-plane and -11 to -18 dB for the *H*-plane) in the whole band.

TABLE I
PARAMETERS OF THE COPLANAR-WAVEGUIDE-FED TSA AT DIFFERENT FREQUENCIES

f(GHz)		75.5	85.0	92.5	100.0	107.5
GAIN		10.0	10.0	9.1	9.2	8,0
F/B		28.1	22.2	23.0	23.0	16.1
SLL	E-	-15.0	-16.1	-17.3	-16.0	-15.0
	H-	-17.0	-14.2	-11.3	-18.1	-15.0

References

[1] K. S. Yngvesson, D. H. Schaubert, T. L. Korzeniowski, E. L. Kolberg, T. Thungren, and J. F. Johansson, ‘‘Endfire tapered slot antennas on dielectric substrate,’’ *IEEE Trans. Antennas Propag.*, vol. AP-33, no. 12, pp. 1392–1400, Dec. 1985.

[2] T. G. Lim, H. N. Ang, I. D. Robertson, and B. L. Weiss, ‘‘Tapered slot antenna using photonic bandgap structure to reduce substrate effects,’’ *Electron. Lett.*, vol. 41, pp. 393–394, Mar. 2005.

[3] Hong-Xing Zheng and Dao-Yin Yu, “Modal analysis of nonuniformly dielectric waveguide using semivectorially compact finite-difference time-domain method,” *International Journal of Infrared and Millimeter Waves*, vol. 26, no. 5, pp. 725-738, May 2005.

[4] H.-X. Zheng, L.-Y. Feng, L.-Q. Wang, and F.-Y Gao, “Full-wave analysis of dielectric resonator antenna with unconditionally stable pseudospectral time-domain method,” in *Proceedings of Asia-Pacific Microwave Conference*, Bangkok, Thailand, Dec. 2007, pp. 2765–2768.

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