Hybrid FDTD/PSTD Simulation for Ultrawideband Microstrip Antenna

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***Abstract* — Full design, modeling and measurement of an ultra-wideband microstrip antenna are described for millimeter wave applications. To solve 3-D mixed-scale problems, a hybrid modeling technique combining the finite-difference time-domain (FDTD) method with pseudospectral time-domain (PSTD) method is proposed. Measurement of input impedance, radiation pattern and conversion loss of the antenna is performed and compared with the hybrid FDTD/PSTD simulations at 20-70GHz.**

I. Introduction And Background

RECENTLY, broadband antennas have received much attention in millimetre-wave and submillimetre-wave receivers. With this antenna, radio signals can be transmitted at different operation frequencies dependent on signal source availability. Compared with the common shapes of microstrip antennas such as rectangular, circular, and the triangular, the ring resonator studied in [1], is a good candidate for the planar circuit applications in millimeter-wave frequencies. The ultrawideband (UWB) circular ring antennas fed by the coplanar waveguide and the microstrip line have been presented in [2]. As the dual of the microstrip ring resonators, double-ring slot resonators with a new feed-line structure represent an enhanced wideband characteristic. Specifically, the multiple elliptical rings demonstrate the antennas of multiband and UWB [3]. In order to analyze the characteristics of the multiband and UWB, more efficient numerical technique has to be developed.

In a typical computational electromagnetics problem, there are three different length scales present: (a) Problems with the fine details and wavelength are comparable in size, thus allowing the efficient application of many electromagnetic solvers such as the widespread finite-difference time-domain (FDTD) method and its improved versions. Such an FDTD method is usually applied to problems with several wavelengths in size in each direction. However, it is limited by their large numerical dispersion errors when solving electrically large- scale problems. (b) Problems with the physical fine details are much smaller than the wavelength, for example, in the signal integrity problem in integrated circuit design. In this situation, we need to use a high sampling density to capture the geometry detail. It is advantageous to use the alternate-direction-implicit (ADI) FDTD method [4] for such small-scale problems. (c) Problems with the extreme structure details are much larger than typical wavelengths. In this case, higher-order methods such as the pseudospectral time-domain (PSTD) methods [5] are more efficient than the conventional FDTD methods. For the PSTD method, the sampling rate is not just determined by the minimum wavelength, but also by the length of time integration. Under the UWB circumstance, there are large-scale and small-scale objects coexist. Using any single solver from the above list is not efficient.

In this study, the drawback of traditional ring antenna with a quite narrow bandwidth has been overcome. The newly designed antenna adopts a proximity-coupled configuration with a multilayer structure. The parameters affecting the antenna wideband characteristic are discussed. Measurement of return loss, gain, and radiation patterns is performed at 20-70GHz. Meanwhile, a hybrid method combining the discontinuous Galerkin's PSTD method with an ADI-FDTD method has been developed for the mixed-scale UWB antenna. The PSTD method is applied in regions with low-density variation of structures and a large computation volume, whereas the ADI-FDTD method is applied to regions with fine structures and relatively small computation volumes. Numerical results demonstrate the effectiveness of this hybrid method.

II. Results

A new designing is processed. The measured results follow the simulated results very well. According to the simulation results, the return loss from 20 to 70 GHz is less than 3 dB. This performance avoids the re-radiation of the second harmonics generated by the circuit components fed to the antenna element. Operation bands and bandwidths of the broadband antennas mentioned are summarized in Table I.

TABLE I
SUMMARY OF THE MEASURED AND SIMULATED ANTENNA PERFORMANCE

f_0 (GHz)	20.5	35.0	42.5	50.0	60.5
Operation (GHz)	17.6 -23.4	29.4 -40.6	35.5 -49.5	40.9 -59.1	48.4 -72.6
Bandwidth (%)	28.1	32.0	33.0	36.4	40.0

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