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Dual Polarized Phased Array Antenna Simulation Using Optimized FDTD Method with PBC

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Objectives

The motivations to develop own fast and accurate phased array antenna simulator are: (1) since the source code is available, it is easy to introducing new features to do pattern predictions (2) high performance and expensive computer clusters are needed for massive multifunctional phased array antenna simulation using commercial software. In this work, initial results of development of a finite-difference time-domain (FDTD) simulator (called PASim) for dual polarization phased array antenna is presented. The numerical model is based on periodic boundary condition (PBC), which handles finite phased array antenna and reduces vast amount of computational time compared to some other finite array simulation tools.

Theory

The updating equations, updating coefficients, absorbing boundaries, radiating boundaries, voltage, and current probes/sources can be evaluated using standard FDTD updating equations except at the locations of periodic boundaries. For example, the updating equation for E_y and E_z at the $x = 0$ and $x = x_p$ periodic boundaries can be evaluated in the time marching loop as

$$E_y^{n+1}(x_p,y,z) = C_{eye}(x_p,y,z)E_y^{n}(x_p,y,z) + C_{eyhx}(x_p,y,z)\left[H_x^{n+\frac{1}{2}}(x_p,y,z+1) - H_x^{n+\frac{1}{2}}(x_p,y,z)\right] - C_{eyhz}(x_p,y,z)\left[H_z^{n+\frac{1}{2}}(\Delta x,y,z) - H_z^{n+\frac{1}{2}}(x_p,y,z)\right]$$

$$E_z^{n+1}(x_p,y,z) = C_{eze}(x_p,y,z)E_z^{n}(x_p,y,z) + C_{ezhy}(x_p,y,z)\left[H_y^{n+\frac{1}{2}}(\Delta x,y,z) - H_y^{n+\frac{1}{2}}(x_p,y,z)\right] - C_{ezhx}(x_p,y,z)\left[H_x^{n+\frac{1}{2}}(x_p,y+1,z) - H_x^{n+\frac{1}{2}}(x_p,y,z)\right]$$

$$E_z^{n+1}(0,y,z) = E_z^{n+1}(x_p,y,z) \quad \text{and} \quad E_y^{n+1}(0,y,z) = E_y^{n+1}(x_p,y,z)$$

At $x = x_p$ and $y = y_p$ the E_z can be evaluated using the equation below:

$$E_z^{n+1}(x_p,y_p,z) = C_{eze}(x_p,y_p,z)E_z^{n}(x_p,y_p,z) + C_{ezhy}(x_p,y_p,z)\left[H_y^{n+\frac{1}{2}}(\Delta x,y_p,z) - H_y^{n+\frac{1}{2}}(x_p,y_p,z)\right] - C_{ezhx}(x_p,y_p,z)\left[H_x^{n+\frac{1}{2}}(x_p,\Delta y,z) - H_x^{n+\frac{1}{2}}(x_p,y_p,z)\right]$$

The updating equation for E_x and E_z at the $y = 0$ and $y = y_p$ periodic boundaries can be adapted in the same way from the standard FDTD updating equations (such as in reference 2).

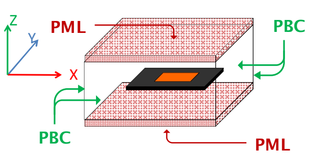

Figure 1: The model of one unit cell in the phased Array

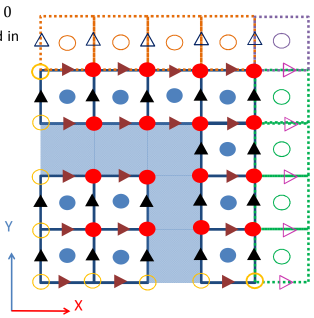

Figure 2: The model of one unit cell in the phased Array

Results

A computer with Intel® Core™ i7-4770K CPU @ 3.50 GHz and 32GB memory (RAM) is used to perform the simulation with HFSS and PASim. The near field range measurements and HFSS simulations are also obtained to to verify the results from PASim.

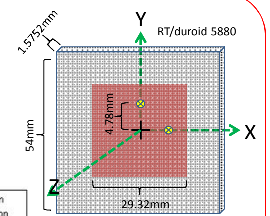

Figure 3: Structure of The Patch Antenna Element

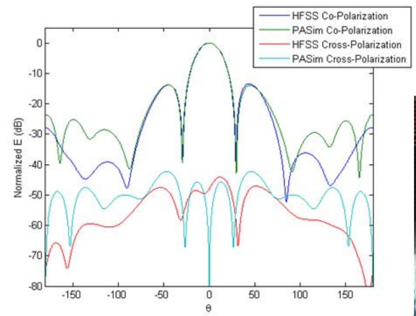

Figure 4: principal plane cut of 4x4 array simulation by HFSS and PASim

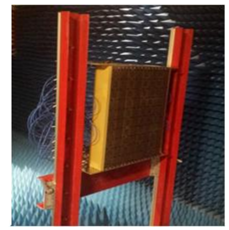

Figure 5: 64 elements array in NF chamber

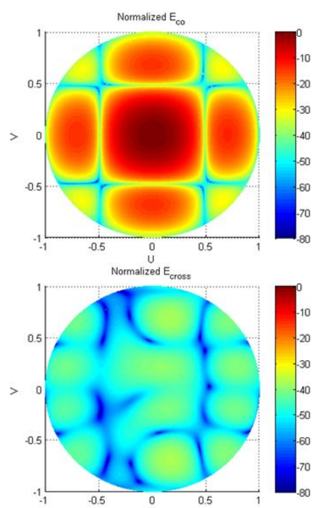

Figure 6: 4x4 Array simulation by HFSS

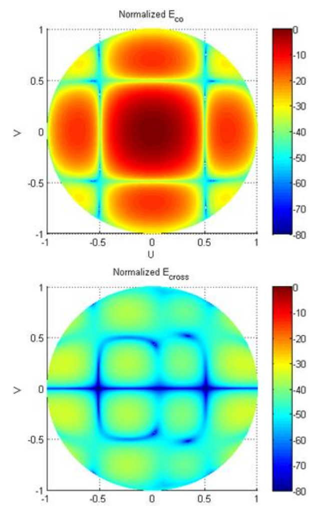

Figure 7: 4x4 Array simulation by PASim

	A Patch Antenna	4X4 Array of Patches	8X8 Array of Patches
HFSS	277 Seconds	4016 Seconds	Not Possible
PASim - MATLAB	22468 Seconds	32684 Seconds	42431 Seconds
PASim - C	187 Seconds	272 Seconds	353 Seconds
PASim - Java	248 Seconds	361 Seconds	468 Seconds

Table 1: Elapsed time (black) and anticipated elapsed time (gray) for each simulation

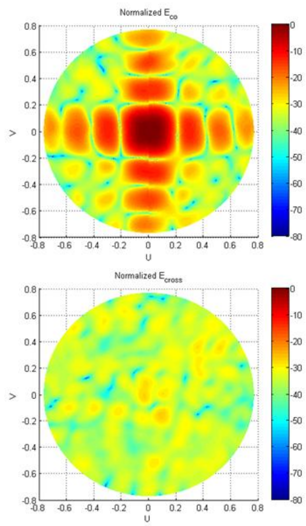

Figure 8: 8x8 Array measurements

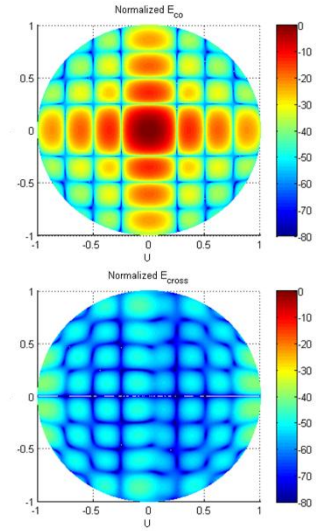

Figure 9: 8x8 Array simulation by PASim

For a specific example result, an S-band 4x4 array was simulated using HFSS and a MATLAB/C/JAVA versions of PASim program and an S-band 8x8 array was simulated using PASim and measured in a Near-Field Chamber at OU-RIL. For the 8x8 array results, The measurements was taken in the range of $V \in -0.8, 0.8]$ and $U \in [-0.8, 0.8]$.

Conclusion

The performance of the PASim is very promising according to the benchmark result in Table 1. For 4x4 array results, there is a good agreement between PASim and HFSS. Co Polarization from PASim is slightly higher than HFSS results. Since we have full control of the source code, there are multiple ways to further improve the full-wave simulation accuracy.

C implementation of PASim with PBC for simulating wide band array with steering beam will be the next step with high priority. Since none-periodic excitation in beam forming is a necessary in phased array antenna, introducing Array Scanning Method (ASM) is another milestone to be achieve. Modifying PASim for cylindrical coordinates is highly desired. Using GPU to aculeate the computation is also part of future plan.

References

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