Estimation of near field thermal emission from bodies with inhomogeneous temperature profile for radiometer calibration

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Plane wave normal reflectivity of radiometer calibration target was obtained by using full wave Finite Difference Time Domain (FDTD) method in a previous work (S. Sandeep, A. J. Gasiewski; "Electromagnetic analysis of radiometer calibration targets using dispersive 3D FDTD", IEEE Antenna and Propag., June 2012). The emissivity $e(\theta,\varphi)$ is related to plane wave reflectivity $r(\theta,\varphi)$ through $e(\theta,\varphi) = 1 - r(\theta,\varphi)$. The brightness temperature of the target $T_B(\theta,\varphi)$ is related to the physical temperature T_P of the target by

$$T_B(\theta,\varphi) = e(\theta,\varphi)T_P$$

The above procedure is based on two assumptions 1) The temperature of the body is uniform 2) Radiometer is in the far zone. Both of these assumptions fail in the real scenario. In order to calculate the thermal emission from a medium with nonuniform temperature, Fluctuation Dissipation Theorem (FDT) must be used. FDT (Rytov et. al. Statistical radio physics, Volume 3) gives an expression for the correlation between thermal current densities at a point as a function of temperature, frequency, and material properties at that point. However, to apply FDT for estimating the near field emission, the Dyadic Green Function (DGF) of the geometry need to be known. DGF (C. T. Tai, Dyadic Green Functions in Electromagnetic Theory, Second edition) can be derived only for simple geometries such as sphere, cylinder, layered media etc. In order to obtain near field thermal emission from objects of arbitrary shape and temperature profile, we need to use some stochastic numerical method such as Wiener Chaos Expansion (WCE) (M. Badieirostami et.al., "Efficient modeling of spatially incoherent sources based on Wiener chaos expansion method for the analysis of photonic crystal spectrometers") or estimate DGF numerically.

In this talk, we present the following work.

- Estimate the near field thermal emission from a cylinder made of dielectric, magnetic material
- Using WCE to estimate the thermal emission from arbitrary 2D objects and the comparison of the results with analytical results
- Comparison of results obtained with the WCE solution and analytical method to a novel heuristic method which uses the absorption coefficient weighting function
- Estimating the numerical DGF by using FDTD