Fourier Optics Analysis for Quasi-Optical Imagers with Large Focal Plane Arrays

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Sub-millimeter imagers for stand-off security applications are widely used to detect hazardous objects concealed under clothing. Future security imagers will require Field of Views comparable to the size of a human body (i.e., images with over 100.000 pixels). The use of many detectors in the focal plane of an optical system, in a CCD like configuration, allows designing systems with such requirements. For example, in the last years, there has been a significant effort in developing large format focal plane arrays (FPAs) of bare absorbers which could be used in commercial imaging systems. A full-wave electromagnetic analysis of such structures is not applicable since it is numerically cumbersome and time-consuming. For this reason, high-frequency techniques, such as Fourier Optics (FO), have been employed (N. Llombart, B. Blazquez, A. Freni, and A. Neto, IEEE TTST, 5, 4, 573-583, 2015).

By using a FO analysis combined with Floquet Modes Theory for periodic array antennas or absorbers in the focal plane, one can analyze the performance of the imaging system in terms of various parameters, such as the point source angular response, the optical efficiency, Half Power Beam-width (HPBW), sensitivity of the imager to incoherent distributed sources, etc.. To this aim, recently, an analytical FO formulation approach (S. O. Dabironezare, A. Neto, N. Llombart, APS, 2017) was introduced. In detail, it was used to analyze the performance of the central pixel of a FPA of absorbers. This analysis was performed for broadside and slightly off-broadside scanning scenarios. In this approach, the field reflected by a parabolic reflector is propagated toward the focal plane till to the FO equivalent sphere centered at the center of the FPA. The reflected field is expressed in an analytic closed form. The FO approach links the field on the equivalent sphere to the field in the focal plane by a Fourier transform. And, therefore, the field in the focal plane is expressed in the form of a plane wave spectrum (PWS), which can be linked to a Floquet field representation. Such analysis is reasonable for broadside and slightly off-broadside illuminations. However, for a more general off-axis illumination, a closed form solution for the field on the equivalent sphere is not available. Moreover, the FO current analysis cannot accurately represent the focal field for large off-focus feeds. Therefore, in order to cover large FPAs with thousands of elements, the discussed methodology needs to be improved.

For scenarios with large scanning angles, and also for reflectors whose surfaces does not allow a closed form solution for the reflected field, a more general Geometrical Optics (GO) ray method (P. Pathak, IEEE Proceedings, 80, 1, 44-65, 1992) is proposed in the present work. Moreover, to extend the region where FO can be used, we sub-divide the large FPA into sub-regions where a local FO approximation is applicable. An equivalent sphere is defined at the center of each sub-region. As a result, the field in the focal plane can be depicted locally as a PWS in each sub-region and assume a slightly different incident angle. The proposed approach allows to effectively evaluate the same figures of merit for each pixel in a large FPA. Moreover, the proposed methodology is also applicable to lens-based imaging systems. The details of the proposed approach, along with some numerical examples, will be discussed during the conference.