APPROXIMATE RECIPROCAL PHYSICAL EQUIVALENT: WHY NOT USING IT?

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The Physical Optics (PO) approximation is still one of the most widely used high-frequency technique. Although PO is based on one of the crudest approximations of the equivalent current density on the surface of a scatterer, it has been providing effective results in a wide variety of practical engineering applications. However, it is well known that the estimate of the scattered field provided by the PO approximation does not satisfy the reciprocity theorem. Although in several practical instances this problem may not cause severe impairments, reciprocity is still a desirable property for any field approximation since it is a fundamental property imbedded in Maxwell's equations. Introducing a similar crude (image) approximation into the induction equivalent for scattering by a perfectly conducting object, provides an estimate that is in general different from that by PO, but does not yet satisfy reciprocity. An interesting and profound discussion about the accuracy and applicability of these above approximate physical and induction equivalents may be found in [R.F. Harrington, *IRE Trans. Antennas Propagat*., AP-7, 2, 150-153, 1959]. There, the reciprocity issue was also addressed. This discussion has neatly been resumed in [C.A. Balanis, *Advanced Engineering Electromagnetics*, Ch.7, 1989]. Also, an interesting discussion on the possible approximate formulations for physical equivalents was presented in [S.W. Lee et al., *IEEE AP-S Int. Symp.*, 24-1, 408-411, 1988].

In focusing on the reciprocity issue, it should be noted that when considering a scattering problem and its reciprocal configuration, the relevant distributions of the exact equivalent surface currents are in general very different and there is no simple relationship between them. Therefore, when introducing any approximation in calculating them, the subsequent field estimates are expected to violate reciprocity. Indeed, reciprocity is a peculiar property of the field that does not explicitly provide any guidance on how to enforce approximate equivalent currents to satisfy this property. As a consequence, it is believed that it may be extremely difficult to achieve reciprocity by resorting to strictly source based approximations. At a variance, this property may more easily be preserved by resorting to a more field based approximation. Enforcing reciprocity by averaging the two PO solutions obtained by interchanging the transmitter and the receiver is a quite often used practice. However, most of the engineers are reluctant to admit that they have used it; sometimes, this practice is looked upon as a *dirty trick*.

In order to emphasize that this is not the case, a specific rigorous formulation of the reciprocity theorem is presented, and the relevant PO-based approximation is introduced therein to provide an approximate, reciprocal physical equivalent field representation. Explicit formulations for both perfectly and non perfectly conducting scatterers are discussed. Relationships with conventional, approximate physical and induction equivalents are also discussed. The reciprocal field representation referred to here is based on the same crude approximation as PO; thus, its formulation and related implementation are more or less as simple as those of commonly used in standard PO. Its accuracy and applicability, as well, are expected to be comparable. However, this field representation may be more appealing when considering its additional property of explicitly satisfying reciprocity. This property may also be relevant when considering those techniques that have been proposed for improving the accuracy of the PO approximation, such as PTD and its more recent developments or ITD in its fringe formulation; indeed, this augmentations do not guarantee a rigorous remedy for the non reciprocity introduced by PO.