Generalized Gauge A-Phi Formulation to Solve Electromagnetics Problems

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The enduring legacy of Maxwell's equations has been a boon to the modern world. Unbeknownst to Maxwell, these equations are seeing a broader range of impact, and myriads of applications since their conception in 1864-1865. In addition to being relativistically invariant, they are valid over a vast length scale as well as over a broad frequency range. More recent studies indicate that they are also valid in the quantum regime, even when loss is involved (Dung, et al, 1998, Scheel and Buhmann, 2008). Hence, Maxwell's equations (or electromagnetics) will continue to have tremendous impact on myriads of emerging technologies, such as nano-optics (Novotny & Hecht, 2012), quantum optics (Gerry and Knight, 2005), and quantum information (Nielsen and Chuang, 2010). Therefore, it is imperative that we investigate methods to solve these equations efficiently with new physical insight.

A recently developed generalized gauge method is useful to study large-scale, multi-scale and multi-physics simulation (Chew, 2014, Vico et al 2015). This method has the novelty that it has no low-frequency breakdown. This implies that it can be applied to problems with a large range of dimensions and frequencies. Second, it involves the use of vector potential $\mathbf{A}$ and scalar potential ϕ directly. As these potentials often appear directly in many quantum calculations (Scully and Zubairy, 1997), this method is also ideal for integrating with problems showing quantum effects.

Using the recently derived decoupled differential equations with A-phi formulation (Chew, 2014, Li et al, 2015), we will show that these equations have no low frequency breakdown. Moreover, the physics of the electromagnetic field is nicely captured by these decoupled equations.

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