

Modeling and optimization of signal to noise ratio in periodically time-varying electromagnetic systems

K. C. Kerby-Patel

University of Massachusetts Boston

Boston, MA, USA, 02125

<http://www.umb.edu>

Periodically time-varying electromagnetic structures have been of recent interest for their ability to realize exotic behaviors not found in linear time-invariant (LTI) systems, such as nonreciprocity, parametric amplification, and frequency conversion. A family of methods have been reported by several research groups for frequency-domain modeling and analysis of periodically time-varying electromagnetic problems. All these methods have their roots in well-known methods for time-varying circuit analysis, such as conversion matrices, which generalize standard network quantities such as impedance, admittance, scattering parameters, or transmission parameters to model conversion between harmonic frequencies (Maas, 2003). This frequency conversion is hybridized with full-wave electromagnetic analysis of the LTI parts of the problem and the entire system may be represented by a multifrequency matrix in which each physical port is represented by multiple virtual ports, one at each harmonic.

Representation of LTI radiating systems based on circuit parameters, such as impedance matrices in the method of moments, has convenient properties and clear physical significance. These properties allow optimization of several basic metrics of antenna performance via convex optimization (e.g. Gustafsson et al., 2007). While frequency-domain methods can represent periodically time varying systems using impedance conversion matrices superficially similar to those used in the method of moments, they lack many of the convenient properties exhibited by LTI systems. As a result, many quantities that may be optimized for LTI systems cannot be treated the same way for time varying linear systems, or are no longer useful to optimize.

In receiving systems with gain, the power delivered to a load can be arbitrarily large without necessarily producing a commensurate increase in information throughput. A more useful metric of system performance in such cases is the signal to noise ratio received by some LTI component of the system. This quantity is always associated with a specific noise environment, so maximizing it cannot produce a global optimal solution. However, it is informative to examine how the tradeoff between internal and external noise interacts with time-varying loading. This talk will discuss frequency-domain modeling for time-varying electromagnetics, outline a method for computation of received signal to noise ratio using the conversion matrix method of moments (Bass et al., 2022) and a covariance-based noise model (Russer and Russer, 2015), then present an example optimization of the signal to noise ratio of a radiating system with time-varying loads in a selected noise environment.