A PHYSICS-BASED IMPEDANCE MODEL FOR A MINIATURIZED BROADBAND SPIRAL ANTENNA

Lee M., Kramer B.A., Chen C.C.   , Volakis, J.L.
ElectroScience Laboratory, Dep. Electrical and Computer Engineering,
The Ohio State University

There is a strong interest in the commercial and military sectors for small and broadband antennas. Existing commercial applications have a need for a single antenna operating in the frequency range of 825-2500 MHz (AMPS, DAB, GPS, PCS, SDARS), for example. For military applications, there is also a need to have a single aperture which permits operation in different communication bands and can also be used for imaging and guidance applications. These needs require wide band antennas, such as the miniaturized spiral antenna. Due to its broadband nature, broadband antenna miniaturization usually can not be achieved by conventional ways of port impedance tuning. Instead, more homogenous treatment across the whole antenna aperture has to be applied. Various such techniques had been developed, including dielectric material loading, distributed lumped element loading, etc. Almost all of these strategies intend to reduce the effective wavelength inside antenna geometry, thus making the antenna electrically larger. However, it has also been observed that this approach results in diminishing gain-shift return when more aggressive miniaturization is applied to a broadband antenna. To understand such behavior one has to explain the impact of miniaturization strategies on antenna impedance. This paper presents a simple physics-based working model describing broadband spiral antenna impedance as a function of frequency. Comparison between the model and the full wave simulation shows very good agreement. Further more, this model is able to include the impact of miniaturization strategies on spiral antennas. Based on this model, we are able to explain the two major issues associated with broadband spiral miniaturization, namely, the diminishing gain-shift return and the broadside gain drop at high frequency. Specifically, we model the spiral antenna as a wrapped transmission line structure in terms of wave propagation, and a continuous set of radiating loops in terms of radiation. The model shows that the slow wave situation results in unavoidable spiral antenna radiation pattern broadening. At the same time, radiation resistance shows mixed response, namely, shifting toward lower frequency but was also lowered in magnitude. The physical insight into these issues can not be provided by full wave simulation, which is also computationally heavy for a broadband spiral structure. We also show that this working model is in line with the well known small antenna limit theory. While the small antenna limit theory grandly provides a universal limitation on all radiation elements, the working model proposed in this paper provides more functional details when spiral antenna is of concern. This allows more focused solutions to the miniaturization issues to be developed.

Abstract Submission Form

2006 National Radio Science Meeting

Abstract: lee6861

Date Received: September 17, 2005

1. (a) Ming Lee
   1320 Kinnear Rd.
   Columbus, OH
   43212 USA
   `lee.2070@osu.edu`
   (b) 614-596-7880
   (c) 614-292-7297
2. B - Fields and Waves
3. (a)
4. C - Contributed Paper
5. No special instructions