# BANDWIDTH OF A MICROSTRIP PATCH ANTENNA ON A MAGNETO-DIELECTRIC SUBSTRATE

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The bandwidth of a microstrip patch antenna is a commodity that is constantly in demand. There are many commercial applications that could use more if it were available. Many schemes have been devised to increase it. In a very interesting paper, R.C. Hansen and Mary Burke ("Antenna with Magneto-Dielectrics", *Microwave Opt. Tech. Lett.*, **26**, 2000, 75-78, 2000) predicted that the best substrate to use to increase the bandwidth of a basic microstrip patch antenna (MPA) was one in which $\varepsilon_r = 1.0$ and $\mu_r \gg 1.0$. The Hansen and Burke result is based on a first-order approximate model for the MPA. On the other hand, with the excitement associated with metamaterials, artificial materials that mimic known material responses or that qualitatively have new response functions that do not occur in nature, there have been alternate claims that a substrate with $\varepsilon_r \gg 1.0$ and $\mu_r \gg 1.0$ will actually produce a better bandwidth result (e.g., H. Mossallaei and K. Sarabandi "Periodic meta-material structures in electromagnetics: Concept, analysis, and applications," 2002 IEEE APS International Symposium Digest, vol. 2, San Antonio, TX, 380-383, 2002). The issue is clouded somewhat in the metamaterial case because the large positive permittivities and permeabilities are achieved with a complex mixture of electrically small inhomogeneities that are loaded into the substrate in a specific periodic arrangement and an electromagnetic bandgap response may be affecting the overall results.

Because these two results are contradictory, it was felt that a more in-depth analysis was required to settle the issue. In this paper we will review the derivation of the bandwidth of MPAs on a magneto-dielectric substrate. The substrate is assumed to have both the relative permittivity ($\varepsilon_r$) and permeability ($\mu_r$) greater than or equal to one. The radiation process of the antenna was carefully investigated with a complete cavity model and the bandwidth has been expressed as a function of both $\varepsilon_r$ and $\mu_r$. These results will be reviewed; they show that the optimal substrate to achieve the widest bandwidth with a single coaxial-fed patch antenna operating at its dominant mode is the one predicted by Hansen and Burke, i.e., one in which $\varepsilon_r = 1.0$ and $\mu_r \gg 1.0$. Using ANSOFT's High Frequency Structure Simulator (HFSS,), it will be shown that these more complete simulation results agree very well with the analytical results. Additional results for MPAs on DNG metamaterial substrates will be discussed if completed in time.