On the Assessment of Dielectric Loss in Microstrip Reflectarray for Low/High Loss Substrates

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The microstrip patch forms the basis of many interesting electromagnetic applications. The patch can be used in radiation mode as a microstrip patch antenna. It can also be used in scattering mode as a microstrip patch reflectarray. The radiation efficiency of patch antennas is limited by conductor, dielectric and surface-wave losses. These loss mechanisms have already been investigated for patch antennas. This study will investigate these loss mechanisms from the patch reflectarray point of view.

For initial study, a dielectric slab backed by a perfect electric conductor (PEC) is considered. Using plane wave illumination at normal incidence, the reflection and transmission coefficients are analytically derived. The loss in the substrate region is then calculated by integrating the electric field in the substrate over the entire volume. A simulation model for the parallel plate waveguide is designed in High Frequency Structure simulator (HFSS) to obtain normal incidence. The analytical and numerical results show excellent agreement in this respect. Once the dielectric loss mechanism is fully understood for dielectric slab backed by ground plane, the next step is to study the dielectric loss for microstrip reflectarray.

The unit cell of the reflectarray consists of a microstrip patch on a grounded substrate. In this exercise, the patch and ground plane are assumed to be PEC so that conductor losses can be ignored and the focus is on dielectric loss. The dimensions of the patch are chosen such that it is at resonance in the frequency range of operation. For a low loss substrate, when the patch is at resonance, dielectric loss is present. Also, this loss is only present around the patch resonance and negligible at off-resonant frequencies. In the past, it has been suggested that the effect of a lossy material ($\sigma/\omega\varepsilon < 0.01$) can be largely offset by using a thicker substrate. This occurs due to the decrease in the strength of the electric field in the substrate region below the patch. The results of this study show that this trend is not followed for high loss ($0.01 < \sigma/\omega\varepsilon < 1$) substrates. This is attributed to the fact that the substrate has its own signature on the dielectric loss. Thus, in this case, the dielectric loss becomes a complex mechanism involving the dielectric loss tangent and substrate thickness.