Leaky-mode Analysis of Wideband Fabry-Pérot Cavity Antennas

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Fabry-Pérot cavity (FPC) antennas have stimulated significant research interest in recent years. They can produce highly-directive broadside radiation with a high radiation efficiency using a low-profile design, and feature simplicity of design and low-cost fabrication. The FPC antenna is constructed by a periodically-patterned layer forming a partially reflected surfaces (PRS) that acts as the antenna aperture, placed above a grounded layer. The operational frequency is mainly dictated by the cavity height and the phase of the reflection at the PRS. Unfortunately, this high-gain class of antennas exhibits a narrow gain-bandwidth product due to the resonant nature of the dielectric-filled cavity formed by the ground plane and the PRS. The fundamental limit of this gain-bandwidth product has been shown in [D. R. Jackson et al., The fundamental physics of directive beaming at microwave and optical frequencies and the role of leaky waves," *Proc. IEEE*, pp. 1–26, Oct. 2011]. More investigations recently have managed to alleviate the narrowband constraints and engineer the phase dispersion of the PRS to produce a wide-band response. We propose to explain the behavior of such wide band FPC antennas thorough the excitation of leaky-waves. We analyze broadband FPC antennas with complex PRS layers and show that the gain-bandwidth is obtained analytically using leaky-mode theory.

We derive a broadside 3dB gain-bandwidth formula when the antenna is formed by an electrically thick PRS, based on leaky-mode theory. The antenna structure is modeled using an equivalent transmission line with the cavity being approximated as a parallel-plate waveguide. We analytically approximate the broadside radiated power density in the limit where only the dominant leaky-mode propagating transversely in the cavity is responsible for the radiation. We validate our formula with different examples of wideband FPC antennas constructed using single-layer and multiple-layer layer PRS structures. Full-wave simulations of the designed FPC antennas with thick PRS structures are shown and their performance in terms of the broadside 3dB gain-bandwidth is demonstrated along with our approximate result.