Power Bandwidth Analysis of Planar Fabry-Pérot Cavity Antennas

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Planer Fabry-Pérot cavity (FPC) antennas have been investigated for decades due to their highly efficient directive radiation, as well as for their attractive features of being low-profile, light-weight, and having low-cost fabrication. The pattern exhibits a very sharp pencil beam near the antenna resonance frequency. Unlike an antenna array, a FPC antenna is constructed by using a simple feeding mechanism, which is used to excite a half-wavelength resonant cavity formed by a planar partially reflective surface (PRS) over a ground plane, possibly with a substrate in between. The PRS is often realized by a thin periodically-patterned metallic layer that acts as a capacitive or inductive FSS. This thin periodic lossless surface (the PRS) is the key element in any FPC antenna, and it is engineered to control the far-field radiation pattern from the antenna. The general properties and radiation behavior for different type of PRS structures have 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).

An analysis of the far-field pattern of the FPC antenna can be obtained using a transmission-line equivalent circuit called the transverse equivalent network (TEN), where a thin lossless PRS is represented as a shunt susceptance. Under the assumption of a passive and lossless PRS, where the PRS obeys Foster theorem, the value of the PRS susceptance is a monotonically increasing function of frequency. Using the TEN and reciprocity, the radiated power density at broadside is calculated in terms of the PRS susceptance as a function of frequency. From this the power-density bandwidth can be calculated. Simple formulas for the power-density bandwidth of the FPC antenna exist for cases where the PRS susceptance is a constant, and is not varying with frequency. These formulas show that the higher the directivity is, the smaller the bandwidth is.

An analysis of the power-density bandwidth for an FPC antenna having a thin lossless PRS reveals that the maximum possible power-density bandwidth is obtained when we assume that the value of the PRS susceptance is taken to be frequency independent. That is, for any thin lossless PRS that obeys Foster's theorem, the maximum bandwidth for the FPC antenna is obtained when the value of the shunt susceptance is constant with respect to frequency, and is not changing away from the cavity resonance frequency. A full-wave simulation of actual PRS structures shows agreement with this theorem, namely that the power density bandwidth is always smaller than that obtained for a structure having a constant value of the PRS susceptance, assuming that the two structures have the same PRS shunt susceptance at the cavity resonance frequency.

This theorem implies that in order to increase the bandwidth of an FPC antenna, it is necessary to use a thick PRS. Using a thin lossless PRS will never allow for a greater bandwidth than what is obtained from a PRS with a constant susceptance. A thick PRS allows for larger bandwidths, however, which can be much larger than what is obtained from a thin planar PRS.