

Optimum Cavity Height in Two-Dimensional Fabry–Perot Cavity Leaky-Wave Antennas

Walter Fuscaldo(1), David R. Jackson(2), and Alessandro Galli(3)

(1) Consiglio Nazionale delle Ricerche, CNR-IMM, Rome, Italy

(2) Department of ECE, University of Houston, Houston, TX, USA

(3) DIET, Sapienza University of Rome, Rome, Italy;

Two-dimensional Fabry–Perot cavity leaky-wave antennas (2-D FPC-LWAs) are versatile and low-cost platforms for producing high-gain pencil beams at broadside with a simple planar structure that typically consists of a grounded dielectric slab with a partially reflecting surface (PRS) on top. Often, the PRS is in the form of a thin metalized layer (Frequency Selective Surface or FSS) that can be approximately modeled as a planar sheet susceptance. In this case the reflectivity of the PRS is often characterized through its sheet susceptance, whose value determines the broadside gain and the pattern bandwidth.

The first analysis of such kinds of antennas dates back to the ‘50s when G. von Trentini proposed a formula for optimizing the cavity height for maximum radiated power at broadside in terms of the PRS reflection coefficient. Later, a leaky-wave analysis of the same structure was proposed, providing an apparently different formula for the cavity height in terms of the PRS sheet susceptance. Recently, we have shown that a similar but different formula is found by exploiting the reciprocity theorem (W. Fuscaldo, D. R. Jackson, and A. Galli, “Optimization of Fabry–Perot Cavity Antennas having Horizontal or Vertical Dipole Sources,” National Radio Science Meeting. (NRSN), Boulder, CO, USA, Jan. 2024).

In this work, we thoroughly address the problem of optimizing the cavity height in 2-D FPC-LWAs by revisiting all the approaches described above and rigorously demonstrate that they all lead to the very same result, although being based on different assumptions. We first demonstrate this identity on a mathematical basis and then under a more intuitive physical viewpoint for the lossless case.

Ohmic and dielectric losses are then introduced to extend the validity of the formulation. An accurate formula that applies for the lossy case (lossy dielectric and/or lossy PRS) is introduced. It is shown that for practical cases in the microwave range—common metals for the PRS and Teflon-like materials for the dielectric filling—the introduction of losses barely affects the value of the cavity height. Appreciable differences only appear at very high frequency ranges (e.g., terahertz) when lossy metals (e.g., titanium) and lossy dielectrics (e.g., soda-lime glass) are considered. In these extreme cases, however, the power radiated becomes small with respect to the input power, resulting in 2-D FPC-LWAs designs featuring poor gain.

We also discuss the optimization of the cavity height to obtain maximum directivity at broadside; this condition being slightly different from that for maximum radiated power at broadside. Interestingly, this condition can accurately be found using the leaky-wave approach. While this result was already known in the literature for infinite apertures in the lossless case, we discuss here the effects of both the losses and the aperture truncation. For the latter, we also show how the type of edge termination (i.e., absorbing layer, perfect electric conductor, no termination) affects the radiation pattern.

All these findings are validated through accurate numerical simulations in the infinite case and compared against CST full-wave simulations in the finite case for a few relevant practical cases of interest.