Recent Advances in 1-D Leaky-Wave Antenna Theory

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Most of the simple formulas used for the evaluation of the radiation properties of one-dimensional (1-D) leaky-wave antennas (LWAs) either assume an infinite aperture, or else assume a finite aperture but have a restricted domain of applicability, where the radiation efficiency is not too high. Leaky wave antennas may have arbitrary efficiencies, however, and more general closed-form expressions for the beam properties (e.g., beamwidth) of 1-D LWAs are thus desirable. For this reason, several efforts have recently been made to develop closed-form approximate CAD formulas that improve the estimation of the beam properties of 1-D LWAs as the effect of aperture truncation is accounted for. This work will review these developments that have been made in recent years.

The class of 1-D LWAs is commonly divided between unidirectional and bidirectional, depending on whether the radiating leaky mode travels along the $+z$-axis or the $\pm z$-axis, respectively. This distinction is necessary because the physics of 1-D unidirectional LWAs is different from that of 1-D bidirectional LWAs, and therefore the related radiating features are different. The case of 1-D unidirectional LWAs radiating at endfire also needs to be analyzed separately, as the beam behavior is different in this important special case.

In the unidirectional case, the aperture truncation mainly affects the beamwidth. The Authors have recently proposed a new beamwidth formula, which is able to provide an accurate estimation of the beamwidth for arbitrary combinations of the aperture length, the phase constant β, and the attenuation constant α, assuming a fast leaky wave, i.e., with $\beta < k_0$, k_0 being the free-space wavenumber. However, for endfire 1-D LWAs it is important to design the structure so as to support a slow leaky wave, i.e., with $\beta > k_0$, in order to optimize the gain. In a recent work, the Authors have shown that in the endfire case the aperture truncation may dramatically affect the sidelobe level. New formulas for the beamwidth and the sidelobe level in endfire 1-D LWAs have thus been proposed.

In the bidirectional case, the aperture truncation not only affects the beamwidth and the sidelobe level, but has also important consequences on the pattern shape. As is known, a bidirectional 1-D LWA may radiate a broadside beam (a beam with a maximum at broadside), a split beam (a beam with a maximum off-broadside but for which the radiated power at broadside is higher than -3 dB), or a dual-beam (a beam with two distinct maxima off broadside) depending on the values of β and α. Specifically, the boundary between the broadside and the split beam regimes, and that between the split and the dual beam regimes, are determined by specific ratios of β/α. These ratios are continuous functions of the aperture length that converge to well-known constants for the infinite case. The Authors have recently found simple analytic formulas to determine these boundaries. Furthermore, new formulas have been proposed for accurately evaluating the beamwidth of finite-size 1-D bidirectional LWAs in any radiating regime. The proposed formulas show a remarkable accuracy within a range of values that covers almost any practical LWA design.