Waveguide Loss Compensation in Resonant Slot Array Design

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Resonant waveguide slot arrays find wide application in systems that require narrow-beam or shaped-beam patterns, especially when high power, light weight and limited scan volume are priorities. Planar arrays of longitudinal slots are implemented using a number of rectangular waveguides (branch lines) arranged side-by-side, while waveguides located behind and at right angles to the branch lines (main lines) excite the radiating waveguides via centered-inclined coupling slots. The planar arrays radiate broadside beams, with all slots radiating in phase. The gain, beam pattern and sidelobe levels are controlled by adjusting the relative field amplitude in individual slots. The conventional design procedure (R. S. Elliott and W. R. O'Loughlin, *IEEE Trans. Antennas Propagat.*, 34, 1149-1154, 1986) accounts for internal and external mutual coupling between the radiating elements and can be used to accurately determine the position and length of each slot in order to achieve the desired excitation.

For satellite applications, there is tendency to implement these antennas using lightweight, non-metallic materials such as carbon fiber reinforced polymer (CFRP). Metal plating within the waveguides is sometimes used to achieve the desired levels of efficiency (M. Stangl, et al., in *Proc. IEEE Int. Symp. Phased Array Systems Technology*, 1, 70-75, 2003), but direct implementation in CFRP without metal plating has also been reported (A. Bojovschi, et al., in *Proc. Asia-Pacific Microwave Conf.*, Melbourne, 1206-1209, 2011). For high-frequency telecommunication applications, the small waveguide and slot dimensions dictate the use of substrate-integrated waveguide (SIW) with etched slots in lieu of conventional metallic waveguide with machined slots (L. Yan, et al., *IEEE Microw. Wireless Component Lett.*, 14, 446-448, 2004). The waveguides will exhibit inherent losses due to either the reduced conductivity of the waveguide walls (in non-metallic waveguides), or leakage and imperfect dielectrics (in SIW). Existing design procedures for slot arrays do not account for these losses. This will cause slots to be under-illuminated, especially those located further away from feed points, and may ultimately degrade the overall performance of the array.

The conventional design approach makes use of equivalent circuits comprising shunt active admittances for branch lines or series impedances for main lines, with elements separated by lossless half-wavelength transmission line sections. The equivalent circuits are utilized to construct sets of non-linear equations which are solved repeatedly to iteratively compute the lengths and offsets of radiating slots or inclination angles of coupling slots. The voltages across shunt admittances or currents through series impedances all have the same magnitude, which reduces the complexity of the non-linear equations used in the computation of slot dimensions.

In this paper, we present an amended design procedure which compensates for both main line and branch line losses in order to maintain phase coherence and the desired amplitude for each slot. In this case, the half-wavelength transmission line sections in the equivalent circuits are defined as having the same attenuation constant as the lossy waveguide. The voltages or currents in the equivalent circuits are explicitly calculated during each iteration, and modified non-linear equations are employed to compute the slot dimensions. The procedure accounts for arbitrary extent of waveguide loss, and the only additional input required is accurate data for the phase and attenuation constants of the lossy waveguide. Simulation results will be presented to demonstrate the effectiveness of the approach.