Theory and Design of a New Class of Vivaldi Arrays with Low Cross-Polarization

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Vivaldi antenna elements have played a critical role in the development ultra-wideband (UWB) electronically scanned array (ESA) systems and continue to be the most widely-used radiator in UWB-ESAs. The popularity of Vivaldi arrays stems from decades of research analyzing their inherent wideband characteristics, resulting in well-known design guidelines that have been applied and realized in a plethora of embodiments (Tan-Huat Chio and D.H. Schaubert, IEEE Trans. Antennas Propag., vol.48, pp.879-886, June2000). One such guideline is the approximate relationship in achieving the bandwidth ratio governed by (M.N. Vouvakis and D.H. Schaubert, Chapter 3 in Frontiers in Antennas: Next Generation Design & Engineering edited by F.B. Gross, McGraw Hill, 2011):

$$\frac{f_{high}}{f_{low}} = \frac{2H}{D} \tag{1}$$

where H is the total height of the element and D is the unit-cell dimension (typically half-wavelength at the grating lobe frequency). As a result, high bandwidth Vivaldis inherently have high-profiles that lead to significant cross-polarization deterioration when scanning in planes other than the principal ones (most notably the diagonal planes) to yield detrimental polarization loss factors when left untreated (M.N. Vouvakis and D.H. Schaubert, Chapter 3 in Frontiers in Antennas: Next Generation Design & Engineering edited by F.B. Gross, McGraw Hill, 2011). External correctional procedures (adjusting excitation weights) have been successfully applied to fix the issue at exclusive frequency/scan angles (R. Kindt and D. Taylor, Proc. IEEE Antennas Propag. Soc. Int. Symp., pp. 1961-1964, Jul. 2011), but this solution leads to narrowband and narrow angle correction only.

This work will propose the Sliced Notch Antenna (SNA) array as an intrinsic design solution that alleviates the Vivaldi non-principal plane scanning polarization purity drawbacks. The chief technical innovation are the introduction of frequency-selective discontinuities (slices) along the radiating fins that control cross-polarization and, to a lesser degree, impedance. The proposed SNA arrays maintain the core of Vivaldi array electrical design and tuning features to achieve the same UWB impedance performance and remain structurally backwards-compliant with legacy Vivaldi UWB-ESA systems. This paper will identify the root cause of poor polarization issues in Vivaldi arrays and give intuitive explanations and design equations/guidelines for the tuning of SNA arrays. The theory will be validated with full wave infinite and finite results.