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Analysis of Dielectric Loaded Hybrid Mode Coaxial Horns

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Abstract—This article presents a numerical solution for radiation from a novel coaxial horn with a partial dielectric loading. The horn is represented as a set of three-layer dielectric loaded coaxial waveguide sections. Characteristic equation has been obtained to calculate phase coefficients for hybrid modes in each section. Applying mode matching technique generalised scattering matrices for each junction between the sections have been obtained, besides that power coupling integrals for each of three different type of junctions have been found in closed-form solutions. Cascading these scattering matrices with transmission matrices of each section yields a generalised scattering matrix of the horn. For the given excitation at the throat of the horn, amplitude and phase of eigenmodes at the aperture of the horn have been determined. Finally, Fourier transform integral of the aperture electric field has been applied to solve radiation problem of the horn. Numerical results on propagation and radiation characteristics of the first four hybrid modes of the horn are presented and it is validated that this solution can be successfully used for full-wave electromagnetic analysis and optimisation of multiband dielectric loaded coaxial feeds.

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1. INTRODUCTION

Recent development in the area of satellite communication systems and radio-astronomy pushes higher operational frequency bands and imposes new requirements for high-quality feed system for large reflector antennas. It includes simultaneous operation at orthogonal polarisations in various frequency bands, keeping low-level cross-polarisation in each operational band. For many years, leading position among feed systems has been occupied by corrugated horns [1, 2]. Their operation is based on exciting a dominant hybrid mode, which provides highly symmetrical Gaussian-like radiation pattern with extremely low level of cross-polarisation over a wide frequency band. A cheaper alternative solution to achieve symmetrical and low cross-polar radiation can be found in partially dielectric loaded horns [3–5]. Their operational principle is also based on exciting hybrid modes [6]. However, despite excellent radiation characteristics, which are very close to those of corrugated horns, they suffer from the same drawback, namely, they are able as feeds to cover only limited frequency band. In fact, their operational frequency overlap is not more than 2:1.

In order to provide larger frequency band overlaps (e.g., 3:1 and more), a novel partially dielectric loaded coaxial-horn antenna with symmetrical co-polar and low level of cross-polar radiation in each frequency band has been proposed by authors of [7]. The antenna is able to generate hybrid modes due to the presence of air gaps between the metal walls of the coaxial conductors and a dielectric cone insertion, placed within the antenna. Due to this feature, the antenna performance is very close to that of corrugated horns. Furthermore, it provides almost identical half-power beam widths and stable coincident phase centre for every frequency band. Preliminary investigations of a novel dual-band antenna operating in C- and Ku-bands with 3:1 frequency overlap had confirmed the initial suggestions [8–10].

In this paper results of developing of a mathematical model of a three-layer dielectric loaded coaxial-horn antenna are presented. This model is a vital part for analysis and optimisation of characteristics of multiband coaxial-horn antennas partially loaded with dielectrics. An internal diffraction problem has been solved by applying the Mode Matching Technique (MMT) [11], which has been proved to be an excellent method for analysis of corrugated horns [12], disk-on-rod antennae within a hollow waveguides [13] and partially dielectric loaded conical horn antenna [6, 14]. An external diffraction problem of electrodynamics has been solved by Fourier's transform approximation of field distribution at the aperture of the three-layer dielectric-loaded coaxial horn antenna.