Effect of amplitude tapering and frequency-dependent phase errors on radiation characteristics of radial waveguide fed non-resonant array antenna

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Abstract: A high-gain low sidelobe level array antenna that is fed by a radial waveguide and designed to operate over a frequency range is considered. Assuming azimuthally symmetric excitation, the radiation pattern of the circular array is approximated by the space factor for the equivalent circular aperture and a simple and efficient tool is introduced for analysis of the array radiation pattern. The effect of the tapering, for both paraboloidal and bell-shaped aperture amplitude distributions, and the consequences of the phase errors, caused by the variation with frequency of the electrical lengths in the radial waveguide feed structure, on the gain and sidelobe level are studied in detail. Results obtained based on the proposed analysis are validated with respect to experimental data available in the literature. They are applicable to designs of arrays as well as aperture antennas.

1 Introduction

The idea of a radial waveguide (radial line) fed array antenna (RWAA) was introduced at the end of the 1950s. Since then, various designs of RWAA with different radiating elements have been proposed [1]. Characterised by low profile and high efficiency, such antennas can offer an alternative to conventional reflector antennas in many communication systems.

RWAA have already been considered for use in some satellite systems as high gain pencil beam antennas. High gain has been attained by designing the coupling between the radial waveguide feed network and the array element for a uniform aperture field distribution. The resultant sidelobe levels were regarded as less important.

Recently, however, such antennas have been required to have not only high gains but also low sidelobe levels [2]. Moreover, some of these antennas are also expected to operate over a given frequency range. The objective of this paper is to study the interplay between gain and sidelobe level requirements which is encountered in RWAA designs. Special attention is given in this paper to the effect of excitation phase errors, caused by the variation with frequency of the electrical lengths in the radial waveguide feed structure (the long line effect). These phase errors, occurring when the operating frequency deviates from the centre design frequency of the RWAA, not only manifest themselves in gain reduction, as was noted in [2–5], but also in higher sidelobe levels, which may be prohibitive for some purposes. Without sacrificing accuracy, these studies, for simplicity, are carried out based on an analysis of the equivalent aperture antenna. The results are applicable to the design of arrays as well as aperture antennas.

2 High-gain low sidelobe RWAA model

The RWAA antenna model under consideration is shown schematically in Fig. 1. The array consists of \( N \) identical radiating elements arranged in \( M \) concentric rings and pin-fed from a radial waveguide supporting an outward travelling wave. We denote the number of array elements on the \( i \)th ring by \( N_i \), \( (i=1, 2, \ldots, M) \). Hence the total number of array elements is \( N=N_1+N_2+\ldots+N_M \). It is

![Fig. 1 Model of RWAA with loaded radial waveguide](image)