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Analysis of HTS circular patch antennas including radome effects

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Abstract

In this paper, the resonant frequencies, quality factors and bandwidths of high T_c superconducting circular microstrip patches in the presence of a dielectric superstrate loading have been studied using Galerkin testing procedure in the Hankel transform domain. The exact Green's function of the grounded dielectric slab is used to derive an electric field integral equation for the unknown current distribution on the circular disc. Thus, surface waves, as well as space wave radiation, are included in the formulation. London's equations and the two-fluid model of Gorter and Casimir are used in the calculation of the complex surface impedance of the superconducting circular disc. Galerkin testing is used in the resolution of the electric field integral equation. Two solutions using two different basis sets to expand the unknown disk currents are developed. The first set of basis functions used is the complete set of transverse magnetic and transverse electric modes of a cylindrical cavity with magnetic side walls. The second set of basis functions used employ Chebyshev polynomials and enforce the current edge condition. The computed values for a wide range of variations of superstrate thickness and dielectric constant are compared with different theoretical and experimental values available in the open literature, showing close agreement. Results are showing that the superstrate parameters should always be kept into account in the design stage of the superconducting microstrip resonators.

Introduction

In recent years, microstrip antennas are present in many communication systems such as mobile telephony, wireless multimedia systems, or again spatial communications due to their practical advantages such as low profile, light weight, planar configuration, relatively cheap, and ease in fabrication and integration with solid-state devices. [1–3]. However, these antennas suffer from some weak points such as low impedance bandwidth and gain level, which lead to their poor performance in some specific applications [4]. To overcome this problem, extensive research has been conducted so far and many techniques have been suggested to improve the antenna bandwidth such as increasing patch height, reducing substrate permittivity, using multiple resonators, etc. [1, 5–7]. The addition of a superstrate layer over microstrip patch antenna has been reported to allow for the enhancement of the antenna gain and radiation efficiency, effectiveness and polarization of the antenna [8]. Superstrate or dielectric cover protects the patch from environmental hazards. The patch antennas designed without consideration of this superstrate effect will not perform as expected once installed in a portable unit, aircraft radome, and sensor design [5, 7]. Apart from covered microstrip patches, high-temperature superconducting thin films (denotes as 'HTS' in the following sections) offer unique properties which can be utilized for a variety of high-frequency device applications in many areas related to the strongly progressing market of information technology [9].

An HTS antenna was one of the first microwave components to be demonstrated as an application of HTS material [10]. There are some distinct advantages of having HTS antennas. Primarily, present lower surface resistance in high T_c superconducting thin films compared with normal conductors, corresponding to a higher quality factor [11] and improved performance in passive microwave devices. Also, because of lower losses in superconductors, the reduction in size is another advantage using high T_c superconducting thin films. The second significant achievement advantage is the frequency independent penetration depth, unlike the regular conductor. This means that dispersion introduced in superconducting devices will be negligible up to frequencies as high as hundreds of gigahertz. The third advantage is that liquid nitrogen cheaper than liquid helium, as a refrigerant, can be used for cooling the superconducting devices because high T_c superconductors have T_c above the boiling point of liquid nitrogen, 77 K [12].

Besides giving some characteristics of microstrip antennas and an introduction into the microwave properties of HTS films, this paper provides an overview of the effects of both