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Characteristics of HTS inverted circular patches on anisotropic substrates

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Abstract
In this study, an efficient full-wave method is developed for characterizing the resonant frequencies, bandwidths, and quality factors of an inverted circular superconducting patch antenna. Our technique is based on the Galerkin procedure in the Hankel transform domain (HTD) combined with the complex resistive boundary conditions. With the use of suitable Green's functions in the HTD, the analysis is performed for the case where the superconducting circular patches is printed on an anisotropic substrate. The numerical results obtained using this approach are compared with the experimental results. These comparisons were very good, which proves the correctness and the validity of the method. It is found that the optical properties combined with optimally-chosen structural parameters of anisotropic materials can maintain control of the resonant frequency and exhibit wider bandwidth characteristics.

Keywords Green function · HTS patch · Inverted antenna · Anisotropic materials

1 Introduction

The modern era microwave communication systems are developing rapidly due to the technical revolution in antennas and materials technology [1]. Microstrip patch antennas (MSAs) are widely used due to the variety of their advantages, such as low profile, simple and inexpensive to manufacture, lightweight, and compatible with monolithic microwave integrated circuits (MMIC) design [2–4], that brought the MSAs to the forefront. The circular microstrip patches (CMP) are among the most common geometric shapes; circular geometry has been studied, analyzed, and implemented widely over the past three decades at least [5–8]. In some applications, such as mobile and satellite applications, CMP has been preferred due to its ability to easily adapt to circular polarization and broadband operations with a smaller correction size [7]. Despite all of the above advantages, MSAs have great weaknesses in the narrow bandwidth and low gain.

Several intensive studies of the applications of high superconducting temperature thin film have been carried out [9–12] due to their low loss property at temperatures below the critical temperature (T_c). One of the first microwave components demonstrate as an application of high-temperature superconducting material is the superconducting antenna [13]. A high-temperature superconducting microstrip antenna (HTSMA) can obtain a rather high gain than their normal counterparts [14], due to the advantages of superconductors [12]. The main advantage is penetration depth regardless of frequency, which allows the implementation of compact designs with low dispersion [12–14]. HTS microwave devices can be miniaturized because of lower losses in HTS materials, which leads to greater combination density [12]. Besides, HTS is eligible to suppress the undesirable surface-wave of the antenna, which increases the radiation efficiency [13]. However, the bandwidth of HTSMA is still very narrow and is similar to its normal counterparts [12].

Letting aside the topic of high superconducting temperature and their applications, many researchers have given attention to studying how the performance of microstrip antennas is affected when using anisotropic materials that are used as substrates/superstrates of these antennas

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