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APPLICATION OF HIGH TC SUPERCONDUCTING MATERIAL FOR MICROSTRIP ANTENNAS AND ARRAYS

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ABSTRACT

Recent advances in high TC superconducting materials created great interest and opened up many potential application avenues in microwaves. Since superconductors offer the possibility that the conductor losses can be eliminated or at least reduced significantly, it is worthwhile to design and develop HTSC microstrip antennas and arrays. By using HTSC transmission lines in feeding network, a substantial reduction in loss is expected to be achieved, which ultimately improve the gain and efficiency of microstrip antenna arrays. Because of the limitation in substrate size, it may be difficult to design arrays on the same substrate. Aperture coupled microstrip arrays may be the best choice for high TC superconducting microstrip antenna arrays.

Introduction

The normal mirostrip small antennas have a primary draw back that they are inefficient. This inefficiency results from the fact that radiation resistance is much smaller than the antenna losses in metallic as well as dielectric ports. Efforts were made to improve the efficiency of small antennas by cooling them to cryogenic temperature (Moore 1955). An antenna operating in the superconducting state, may have loss resistance several orders of magnitude less than its radiation resistance. The principal advantages of microstrip antennas are light weight, low volume, low fabrication cost, easy mounting and compatibility with integrated circuits. The features make the superconducting microstrip components very attractive for use in high speed vehicles, rockets, satellite etc. For planar antenna array feed or corporate feed, the feeder losses limit the achievable gain. By using HTSC transmission lines in feeding network, a substantial reduction in loss could be achieved, which ultimately improve the gain and efficiency of microstrip antenna arrays. Aperture coupled high TC microstrip antenna array structure with high gain and efficiency may have a great impact on various ground and space applications. This novel configuration has been proposed. is based on the review study recently conducted by the author on the subject.

Review - State of Art

Antennas: Experiments on superconducting loop antennas has been carried out by Walker (1969) and Adachi (1978) at low temperature (4.2 K). A super directive supergain antenna have been achieved by Adachi, by using two elements superconducting dipole array. The improvement of the field intensity due to the superconduction is reported to be about 17.6 dB. Khamas (1988, 1990) conducted measurements on liquid nitrogen cooled superconducting dipole aerial at 550 MHz. A gain enhancement of 12 dB has been achieved above that of room temperature copper antenna. Lyon (1990) proposed that matching networks can be implemented with planar superconducting circuits to eliminate restrictions imposed by lossy transmission lines. No work has been reported so far on HTSC microstrip antennas and arrays. Bhatnagar (1991) has reported some feasibility experiments on superconducting patch antennas.

<u>HTSC Material</u>: Since the observations by Muller and Berdnorz of an oxide of Baruim, lanthanium and copper that was superconducting at temperature upto 35°K, most of the research centered on increasing the transition temperature and the Barium copper oxide composition is probably the most widely used material at present. Samples can be prepared by thoroughly mixing of Y_2O_3, $BaCO_3$ and CUO in appropriate amounts. As reported, typical TC value of 90 K and current density around 10^6 - 10^7 A cm^2 has been obtained with this material. Other materials are BiSrCaCUO and TiCA BaCUO. The superconducting materials for thin films for microwave circuits need to fulfil the requirements of high critical current density (JC), high critical temperature (TC) and low surface resistance (RS). The expected value of surface resistance with good HTSC film is reported about 0.1 mΩ at 10 GHz. YBaCUO material is appropriate for this fabrication of HTSC microstrip patches and for feeding network.

<u>Substrate Selection</u>

Substrate materials play an essential role in microstrip antenna design and performances. Substrate characteristics must be compatible with design objectives. Complex permittivity is one of the important factor either for conventional structures of high TC superconducting structures. It has two components; relative permitivity (dielectric constant) and dissipation factor (loss tangent). To develop high TC superconducting film, acceptable substrate material must fulfill two major requirements. They must promote crystalline growth of the high TC films and they must have low loss tangents. The most common single crystal substrate currently in use are magnesium oxide (Mgo) and lantanum aluminate ($LaAlO_3$). At 10 GHz and 77°K, the dielectric constant for MgO is 9.6 and loss tangent is less than 6 x 10^{-5}. The dielectric constant and loss tangent for $LaAlO_3$ at 6.2 GHz and 77°K are 23.8 and 6 x 10^{-5} respectively. But MgO is hydrophylic and will become more lossy when exposed to moisture. $LaAlO_3$ exhibits in homogeneties in dielectric constant by several percentages. In addition these substrates are limited to 1.5 x 1.5 cm size. Alumina (Al_2O_3) is another substrate with dielectric constant of 9.8 and loss tangent is 10^{-4} cm size. Alumina (Al_2O_3) is another substrate with dielectric constant of 9.8 and loss tangent is 10^{-4} at 10 GHz.

However, it is slightly anisotropic. Sapphire is the mono crystalline form of alumina and may be used with a buffer layer to prevent film degradation. Alumina is the cheapest substrate, available in bigger size.

Processing Technique

Various deposition techniques, such as off axis sputtering/multitarget sputtering, E-beam evaporation and laser ablation are capable of producing high quality films of the new copper oxide superconductors. Laser ablation has been one of the most successful thin film deposition method for high TC superconductors, and for other materials two. In this process a pulsed beam from a excimer laser is focussed on to a pressed pellet of SC oxide that is mounted in a vacumme cell and the ablated material is collected on a substrate. Good HTSC film can also be prepared by multitarget supttering. The large SC pellet are bombared by electrons and are evaporated. The evaporated material collects on the substrates placed at a suitable position. A notable other technique is plasma etched metal organic chemical vapour deposition.

Potential Application

High TC superconducting aperture coupled microstrip antenna have potential applications in satellite communication applications. Proposed configuration (Fig. 1) may be used for satellite transponder or DBS/satellite reception system, since they reduce loss and size, increase bandwidth and provide low noise.

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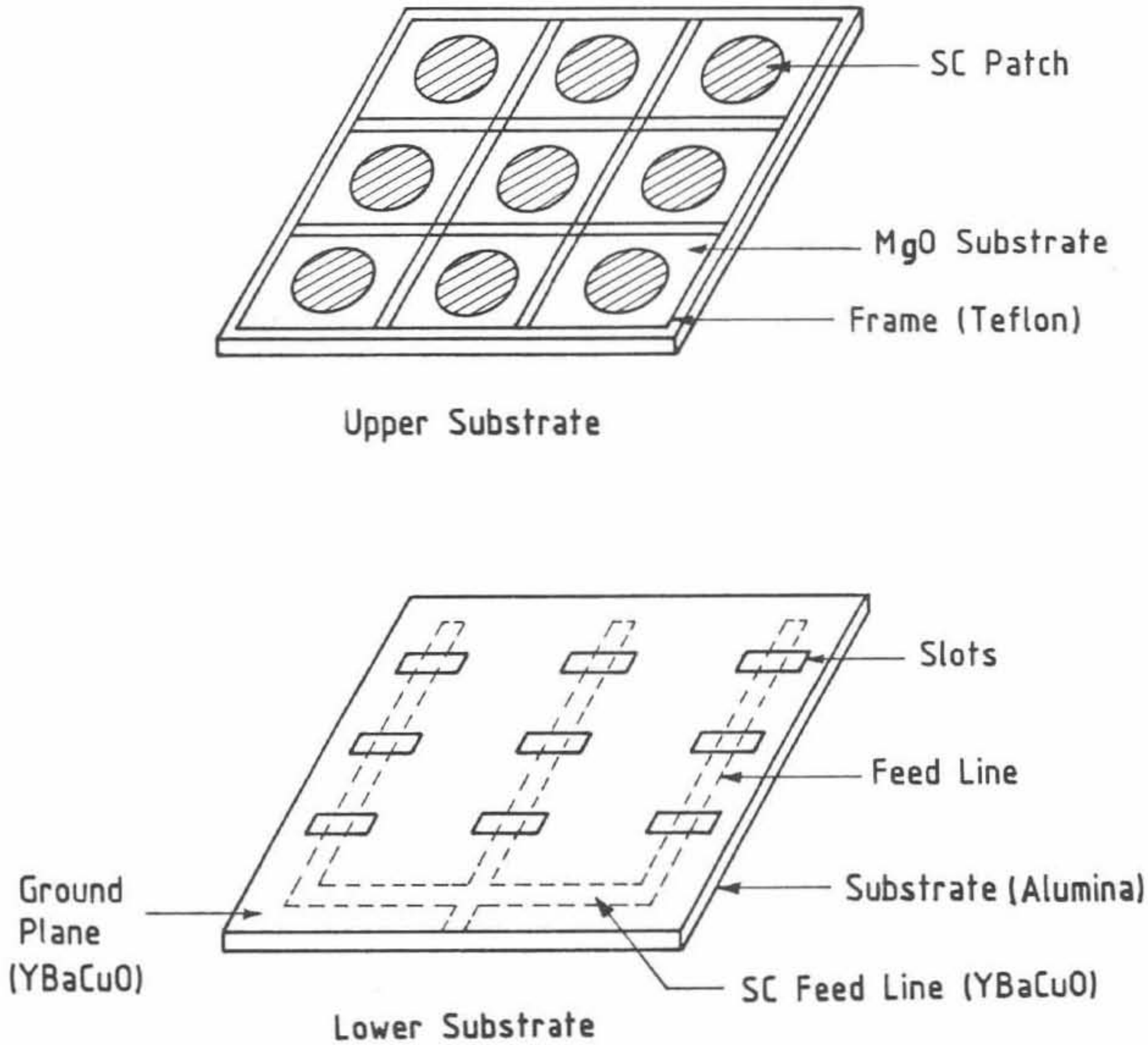
SC Patch
MgO Substrate
Frame (Teflon)
Upper Substrate
Slots
Feed Line
Ground
Plane
(YBaCuO)
Substrate (Alumina)
SC Feed Line (YBaCuO)
Lower Substrate

FIG. 1