Progress In Electromagnetics Research, PIER 77, 281–284, 2007

STUDY ON THE IMPEDANCE-MATCHING TECHNIQUE FOR HIGH-TEMPERATURE SUPERCONDUCTING MICROSTRIP ANTENNAS

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Abstract—Impedance-Matching technique is in common use for antennas to broaden their bandwidth. Its application in high-temperature superconducting microstrip antennas is studied theoretically in this paper. It is found that employing an impedance-matching network directly to HTS microstrip antennas to broaden their bandwidth is of little significance.

1. INTRODUCTION

Due to the much lower surface resistance compared with normal metals and high transition temperature over the boiling point of liquid nitrogen, the high-temperature superconductor (HTS) has found wide applications in microwave circuits and antennas [1]. A high-temperature superconducting microstrip antenna (HTSMA) can obtain a rather high gain, but suffers from a very narrow bandwidth, which severely limits its application. Generally, the bandwidth of HTSMAs is only 0.85%–1.1% [2], which is even narrower than that of its normal counterparts.

There are many techniques [3–7] to enhance the bandwidth of conventional microstrip antennas, among which the impedance-matching technique [3] is also commonly used. It has been shown that some of these methods are also efficient for HTSMAs [8].

In this paper, the theory associated with impedance-matching techniques is proposed and the feasibility of employing the technique in HTSMAs is investigated theoretically.

2. THEORY ASSOCIATED WITH THE IMPEDANCE-MATCHING TECHNIQUE

In the vicinity of its fundamental resonant frequency, the input impedance of a microstrip antenna can be modeled by a parallel-resonant RLC and expressed by [3]

$$Z_{in} = \frac{R_0}{1 + jQv} \tag{1}$$

where R_0 is the resonant resistance, Q is the quality factor and

$$v = \frac{f}{f_r} - \frac{f_r}{f} \tag{2}$$

Here f is the frequency variable and f_r is the resonant frequency. If the feed line has a characteristic impedance Z_0 , the input VSWR ρ is given by

$$\left| \frac{Z_{in}(f) - Z_0}{Z_{in}(f) + Z_0} \right| = \frac{\rho(f) - 1}{\rho(f) + 1} \tag{3}$$

If the bandwidth criterion is taken to be $\rho \leq S$, and f_1 and f_2 are the lower and upper band edge frequencies respectively, so that $\rho(f_1) = \rho(f_2) = S$, the relative bandwidth is given by

$$B = \frac{f_2 - f_1}{f_r} \tag{4}$$

It can be derived that

$$B = \frac{1}{Q} \sqrt{\frac{(TS - 1)(S - T)}{S}} \tag{5}$$

where $T = R_0/Z_0$. It follows from (5) that to maximize B, T must be equal to its optimal value, which is given by

$$T_{opt} = \frac{1}{2} \left(S + \frac{1}{S} \right) \tag{6}$$

It is evident that the bandwidth given by (5) can be increased, at least in principle, by using an impedance matching network. The best situation of utilizing an impedance-matching network is to realize a constant (but not perfect) match within the band of operation and a total mismatch outside the band. The maximum $\rho \leq S$ bandwidth obtainable for a parallel-resonant circuit is given by [3]

$$B_m = \frac{1}{Q} \frac{\pi}{\ln[(S+1)/(S-1)]} \tag{7}$$

For a microstrip antenna, the quality factor Q can be expressed by

$$Q = \frac{\pi}{2} \frac{R_0}{Z_{c1}} \tag{8}$$

where $Z_{c1} = 1/Y_{c1}$ is the equivalent characteristic impedance of the microstrip antenna in the transmission line model (shown in Figure 1).

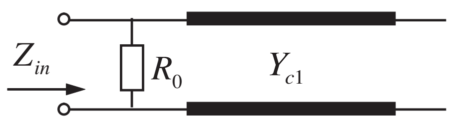

Figure 1. The transmission line model for microstrip antennas.

3. FEASIBILITY INVESTIGATION OF THE IMPEDANCE-MATCHING TECHNIQUE FOR HTSMAS

Usually a HTS substrate has a rather high permittivity which will lead to a considerably large resonant resistance for HTS microstrip antennas. According to the theory proposed above, the maximum bandwidth will be affected.

A rectangular patch antenna with a typical HTS material is analyzed. The length and width of the antenna is 935 μm and 1630 μm respectively. The typical HTS film has a critical temperature of 89 K and magnetic penetration depth of 140 nm at 0 K.

The resonant resistance of the antenna, which is estimated from a measured result at 77 K, is 1690 Ω [2]. Using a transmission line model [9] the equivalent characteristic impedance of the HTS microstrip antenna is calculated and shows a value of 9.4 Ω. Taking these values into Equation (8) and Equation (7), we find that the maximum bandwidth of $\rho \leq 2$ is only 0.01.

Since the structure and the HTS material of the antenna here are very typical, it indicates that employing impedance-matching networks directly to a HTS microstrip antenna to broaden its bandwidth is not so efficient.

4. CONCLUSION

To investigate the feasibility of employing impedance-matching techniques to broaden the bandwidth of a HTS microstrip antenna, a typical HTS microstrip antenna is taken as an example. The numerical result shows that utilizing an impedance-matching network directly to HTS microstrip antennas is not an efficient method to improve the frequency bandwidth.

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