(10) Analysis of Coplanar Waveguide Resonators

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Introduction

In this report, the field decay method based on the FDTD algorithm, which is proposed by I. Awai, is used to analyze CPW resonators. Every kind of Q factor of a CPW resonator, including radiation Q, conductor Q, dielectric Q and unloaded Q, is studied. External Q of a CPW resonator indicating the coupling with an external circuit is also calculated. Some CPW resonators are fabricated and measured in order to check the numerical results. A good agreement between the experimental and theoretical result is obtained. Lastly, a further plan will be discussed in the conclusion.

Principle of calculation

It is efficient and useful to apply a Gaussian modulated CW as an excitation, where the center frequency of the excitation pulse is always taken near the resonant frequency of the CPW resonator. A typical response of any field component is usually a decaying wave with the time. If two amplitudes of a field at any two times are determined and the number of cycles between these two times are known, the resonant frequency and the Q factor can be calculated easily by the field decay method.

If a resonator is shielded by a perfectly conductor in the numerical implementation, we can calculate dielectric Q or conductor Q according to the introduced loss mechanism. If radiation loss is to be calculated, the perfectly matched layer (PML) is used as an absorbing boundary condition. When all the loss factors are included, unloaded Q can be calculated. When we want to calculate conductor Q of a CPW resonator, the surface impedance boundary condition should be used if the metal layer is thicker than ten skin depths but smaller than the FDTD cell size D. If the thickness of the conducting layer is too small, an accurate modeling of thin conducting layer in the FDTD method should be applied. Then, a little manipulation has to be performed for the FDTD iterative formula. Because a CPW resonator operates at its resonant frequency and the Gaussian modulated CW is used as an excitation, only the non-dispersive surface impedance boundary condition or the relationship of the tangential electric field with the tangential magnetic field at the surface of an imperfect conductor is adopted here.

Numerical results

From numerical results, we find that the radiation Q of the quarter-wavelength resonator is far greater than that of the open-ended CPW resonators and the radiation loss of the basic type of CPW resonator will decrease when the width of the strip is reduced. Reduction of radiation loss in a CPW resonator can be attained if we adopt a CPW-SIR. A CPW-SIR consists of two different characteristic impedance lines, Z_{01} and Z_{02}. The ratio k $(=Z_{01}/Z_{02})$ is an important parameter in designing a CPW-SIR because it determines the length of the resonator and the spurious resonant frequency. Radiation loss of a CPW-SIR is far less than that of the relevant basic CPW resonator and decreases with the reduction of k. The external Q of an open-ended CPW resonator, which is connected with an external circuit at the end of the resonator, decreases greatly when the width of the coupling gap is reduced.

Discussion and conclusion

In this report, an analysis of CPW resonators by use of the FDTD algorithm combing with the field decay method is described. This method can be readily used to analyze another types of planar resonator. Analysis of the superconducting film resonators will be presented in our further work.

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