Quality Factor of Tunable Shielded Cylindrical Metal-Dielectric Resonator Caused by Dielectric Loss

The paper discusses quality factor of tunable shielded cylindrical metal-dielectric resonator taking into account dielectric losses. It was shown that dielectric loss decrease in case of the resonant frequency tuning with inclusion of the air gap between dielectric cylinder and metal plate. Calculations were performed using mode matching technique and finite integration technique. The results obtained with both methods are in good agreement. References 3, figures 2.

Keywords: metal-dielectric resonator, quality factor, dielectric loss, air gap, tuning.

Introduction

In microwave systems dielectric resonators became widely used in filters, oscillators etc. Dielectric materials make it possible to reduce dimensions of resonant elements. Shielded dielectric resonators are distinguished by their high quality factor, competitive to that of microwave cavities.

Radios of modern communication systems with dynamic channel allocation require variable filters with high quality factor maintained during tuning process.

Regular cylindrical shielded dielectric resonator usually touches the shield with its bases. It was shown, that small variable air gap between resonator's base and shield plane can serve as efficient tuning method 1. Presence of the air gap between resonator base and the shield not only allows frequency tuning, but makes influence on electromagnetic energy loss in the system.

The value of Q factor of the resonator is very important for practical application. Microwave resonators which use varactors as a tunable element 2 have very good tuning range. But the Q factor of such resonators decreases with a resonant frequency tuned. MEMS-based designs presented in 2 also have the similar problem: its Q factor declines in case of tuning the resonant frequency.

This paper presents study of dielectric loss phenomena in tunable cylindrical shielded metal-dielectric resonator. It is shown that its Q factor caused by dielectric loss does not decline with an electromechanical tuning of resonant frequency.

Resonator Study

Topology of the tunable shielded cylindrical metal-dielectric resonator is presented in Fig. 1. It consists of the cylindrical-shaped dielectric of radius \( R \) and height \( h \) between two parallel metal plates and the shielding metal wall of radius \( R_s \). The dielectric cylinder and the plates are coaxial. The bottom side of the cylinder is fixed to the lower plate and the upper plate is movable. There is a tunable air gap of width \( d \) between the cylinder and the upper plate.

Fig. 1. Tunable shielded cylindrical metal dielectric resonator topology

Analysis

The unloaded Q factor of this resonator is determined by losses of two possible mechanisms: dielectric loss and metal loss. Because of that we can describe the unloaded Q factor as

\[
\frac{1}{Q_0} = \frac{1}{Q_d} + \frac{1}{Q_m},
\]

where \( Q_0 \) is the unloaded Q factor, \( Q_d \) is the Q factor of the resonator caused by dielectric loss only (i.e. metal loss equals to zero), \( Q_m \) is similarly the Q factor caused by metal loss only.

\( Q_d \) is defined as

\[
Q_d = \frac{\omega_0 U_d + U_{cav}}{P_d},
\]
where $U_d$ is the energy stored in the dielectric cylinder, $U_{cav}$ is the energy stored in the volume of metal cavity except the dielectric cylinder, $P_d$ is the dissipated power in the dielectric cylinder.

$U_d$, $U_{cav}$ and $P_d$ can be achieved as

\[
U_d = \frac{\varepsilon \varepsilon_0}{2} \iiint_{\text{diel}} \left| E_2(r) \right|^2 dV,
\]

\[
U_{cav} = \frac{\varepsilon_0}{2} \iiint_{cav} \left| E_1(r) \right|^2 dV + \iiint_{\text{gap}} \left| E_2(r) \right|^2 dV,
\]

\[
P_d = \frac{\varepsilon \varepsilon_0 \tan \delta}{2} \iiint_{\text{diel}} \left| E_2(r) \right|^2 dV.
\]

where $\varepsilon$ is the relative permittivity of the dielectric, $\varepsilon_0$ is the permittivity of free space, $E_1(r)$ is the electric field in region 1, $E_2(r)$ is the electric field in region 2.

**Results and Discussion**

The finite integration technique (FIT) and mode matching technique (MMT) were used to calculate the Q factor caused by dielectric losses for different values of the air gap thickness in case of different $R/h$ ratios.

The dependences of the normalized quality factor $Q_d\tan \delta$ caused by dielectric losses of the TM$_{010}$ mode in case $R_S=1.5R$; $\tan \delta=10^{-3}$; $\varepsilon=30$ versus normalized air gap thickness $d/h$ for various values of the $R/h$ ratio are presented in Fig. 2.

**References**


Добротність перелаштовуваного екраниованого циліндричного метало-діелектричного резонатора, обумовлена діелектричними втратами

Стаття присвячена дослідженню добротності перелаштовуваного екраниованого циліндричного метало-діелектричного резонатора, що обумовлена діелектричними втратами. Було показано, що діелектричні втрати спадають при перелаштуванні резонансної частоти шляхом утворення повітряної щілини. Розрахунки були проведені методом часткових областей та методом скінчених інтегралів. Результати розрахунків обома методами добре узгоджені. Бібл. 3, рис. 2.

Ключові слова: метало-діелектричний резонатор, добротність, діелектричні втрати, повітряна щілина, перелаштування.

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