Microwave Magnetoelectric Isolator-attenuator Based on Coplanar Line

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Abstract— An electrically controlled magnetoelectric (ME) microwave isolator-attenuator based on layered ferrite-piezoelectric structure formed on a coplanar waveguide is considered. The simulations of different structures of coplanar devices are made for selecting of optimal waveguide and resonator characteristics.

1. INTRODUCTION

Microwave devices, such as isolators, attenuators and circulators are the devices which enabling to protect the input of the transmitter from stray electromagnetic radiation acting in the operating frequency band. They are indispensable devices for television, radar system, broadcasting radio and communications.

The task of matching the microwave power source to the load is achieved by using nonreciprocal properties of ferrites. However, the non-reciprocal ferrite devices control the parameters realized by magnetic system, so these devices have low speed of operation, high power consumption and cannot be manufactured by integrated technology.

Magnetoelectric (ME) non-reciprocal devices can reduce the disadvantages of existing ferrite devices: reduce the cost of devices; improve the speed of switching; reduce the power consumption in the control circuit; use the integral technology manufacturing [1].

The difference between the ferrite devices and proposed ME nonreciprocal devices is to replace the ferrite resonator with magnetic control system by ME resonator and system of electrodes connected to the source of the control voltage.

2. DESIGN OF MICROWAVE ISOLATOR-ATTENUATOR

Here we discuss the microwave isolator-attenuator. The basic design of ME isolator-attenuator is coplanar waveguide and ME resonator which have rectangular (or disks) composite sample based on lead zirconate titanate (PZT) — ittrium iron garnet (YIG) layered structure. The permanent magnet creates a required magnetizing field in the area of ME resonator. The control voltage is applied to the electrodes.

Figure 1 shows the design of the microwave ME coplanar isolator-attenuator. To improve the ellipticity, and hence the isolation ratio, the ceramic plate with high permittivity ($\varepsilon = 60$) with beveled edges mounted on ME resonator, as proposed in [2].

Figure 2 shows the design of ME resonator.

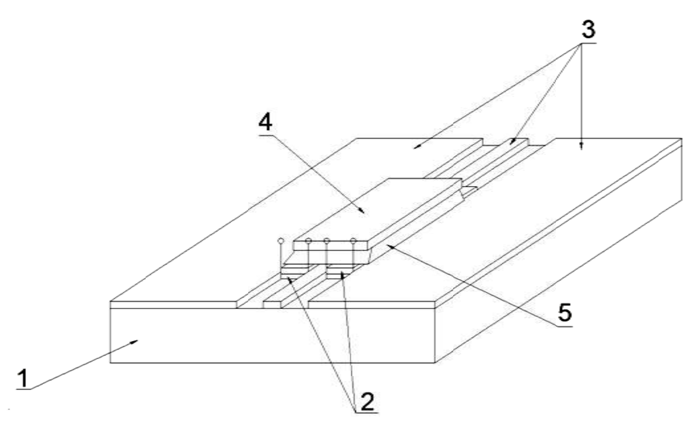

Figure 1: Microwave ME coplanar isolator-attenuator: 1 is dielectric substrate; 2 is ME resonator; 3 is metallic conductors forming the coplanar waveguide; 4 is magnet; 5 ceramic plate with high permittivity with beveled edges.

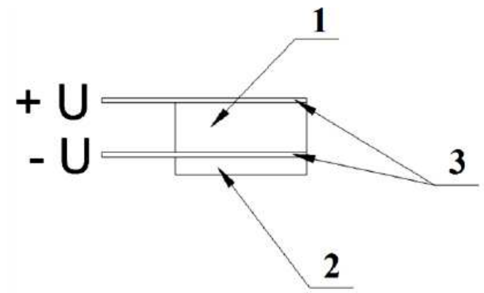

Figure 2: The structure of ME resonator: 1 is piezoelectric element; 2 is ferrite element; 3 is electrodes.

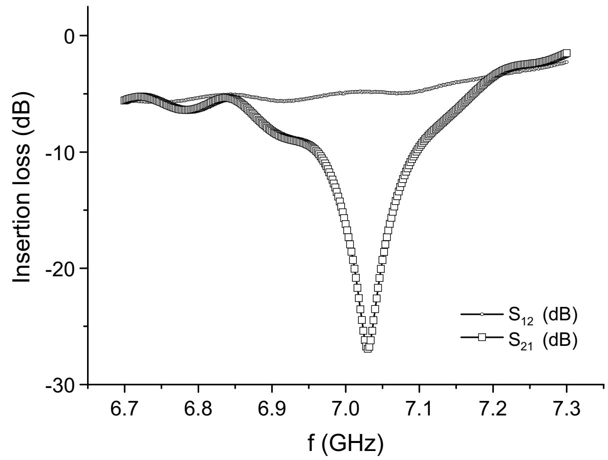

Figure 3: The experimental frequency dependence of attenuation. Constant magnetic field is $H_0 = 1780\,\mathrm{Oe}$.

The principle of operation of the isolator-attenuator based on microwave ME effect, is to shift the ferromagnetic resonance line under the influence of an electric field. ME layered structure in this case plays the role of a resonator. Shift of magnetic resonance line at applied an electric field is defined as $\delta H_E = AE\delta H_E = AE$, where A is magnetoelectric coefficient; E is applied DC electric field.

The simulation of coplanar isolator-attenuator was made. We conducted a simulation of various types of non-reciprocal magnetoelectric devices based on slot and coplanar lines by using HFSS. It allows to get the selection of waveguide substrate parameters and the shape of ferrite and piezoelectric.

3. RESULTS AND DISCUSSION

The ME resonator based on layered structure of YIG with dimensions $13 \times 4 \times 0.9\,\mathrm{mm}$ and PZT with dimensions $15 \times 4 \times 0.5\,\mathrm{mm}$. The coplanar waveguide has next parameters: the width of the gap $S = 3\,\mathrm{mm}$; distance between slits $W = 2\,\mathrm{mm}$; substrate thickness $h = 2\,\mathrm{mm}$; dielectric permittivity of substrate $\varepsilon = 10$. The measurement of the transmission characteristics of the prototype were carried out on the measuring stand, consisting of an Agilent vector network analyzer PNA-L N5230C, electromagnet GMW5403 and DC current source Sorensen DLM 20-30.

Figure 3 shows the experimental dependence of attenuation in the forward and reverse directions for the investigated structure.

Thus, we considered the microwave ME isolator-attenuator: ME resonator based on layered magnetostrictive-piezoelectric structure with metal electrodes placed in the gap of coplanar waveguide, a ceramic plate with beveled edges with high permittivity ($\varepsilon = 60$) and a permanent magnet mounted on ME resonator.

4. CONCLUSION

The simulation and experimental study of the various structures of the microwave ME coplanar isolator-attenuator. To decrease the control voltage and the increase the isolation ratio is necessary to reduce the thicknesses of the piezoelectric, and ferrite.

Isolation ratio was about 20 dB. The shift of the resonance line corresponded $\pm 30\,\mathrm{MHz}$ at applied an electric field $E = \pm 10\,\mathrm{kV/cm}$. Thus, the electric control allows to realize the tunable isolator or controllable isolator-attenuator. The magnitude of frequency tuning for the isolator was 60 MHz. The amount of attenuation change was about 20 dB.

The proposed model performs the functions of both the isolator and the attenuator; is controlled by an electric field; can be made by integral technology; has higher performance and lower power consumption on comparison with ferrite attenuators.

The use of ME structures in the resonant microwave devices allows electrical control of their parameters and opens promising opportunities of the designing the new devices for functional electronics.

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