Modeling of Microwave Magnetoelectric Devices

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Abstract— Design of integrated devices, and combine properties of several microwave nonreciprocal devices, are analyzed. The possibility for the development of a complex approach to designing and manufacturing of nonreciprocal microwave devices with improved technical characteristics is shown. Electromagnetic simulation of devices in the HFSS program is made.

1. INTRODUCTION

Computation, design and manufacturing technology of nonreciprocal microwave devices intended for application in receiving-transmitting modules of antenna array have a great interest in current time. Currently, a large development has program High Frequency System Simulator (HFSS) of company AnSoft, which is intended for the analysis of three-dimensional microwave structures, including antennas and non-reciprocal devices containing ferrites and ferroelectrics. Electromagnetic simulation in HFSS is based on the use of the finite element method (Finite Element Method, FEM).

Microstrip line, coplanar line and slot line are used in the microwave range. The microstrip lines are used most widely [1]. However, at designing the non-reciprocal devices using ferrites it requires the microwave field of circular polarization. In microstrip line this region is absent and the additional elements are needed, for example in the form of stubs to create an area of circular polarization. From this point of view, the slot and coplanar line are of interest. The structure of the microwave field in the slot line and coplanar waveguide is significantly different from the structure of the wave field in microstrip line. Coplanar waveguide (CPW) is a transmission line which consists of a center strip, two slots and a semi-infinite ground plane on either side of it [2]. This type of waveguide offers several advantages over conventional microstrip line, namely, it facilitates easy shunt as well as series mounting of active and passive devices; it eliminates the need for wraparound and the holes, and it has a low radiation loss. Another important advantage of CPW which has recently emerged is that CPW circuits render themselves to fast and inexpensive on-wafer characterization at frequencies as high as 50 GHz. Lastly, since the RF magnetic fields in the CPW are elliptically polarized, nonreciprocal components such as ferrite circulators and isolators can be efficiently integrated with the feed network.

These as well as other advantages make CPW useful for a monolithic microwave integrated circuit based microwave distribution network. Grounded CPW (GCPW) is a variant of CPW which incorporates an additional ground plane on the back side of the substrate. This additional ground plane can serve as a heat sink and provide mechanical strength. In addition, the ground plane serves as a shield between stacked antenna boards to improve isolation.

The use of modern simulation software allows the fast design of various types of non-reciprocal microwave devices. We conducted a simulation of various types of non-reciprocal magnetoelectric devices based on slot and coplanar lines by using the HFSS. A comparison with similar devices based on the microstrip line was made.

2. MODELING OF NON-RECIPROCAL MICROWAVE DEVICES

The simulation of ME coplanar isolator-attenuator was made. That simulation allows to get the selection of waveguide substrate parameters and the shape of ferrite and piezoelectric. The ME resonator based on layered structure of YIG and PZTwith electrodes was used.

The principle of operation of the proposed isolator-attenuator is based on microwave ME effect, which consists in a shift of the FMR line under the influence of an electric field. The design of coplanar ME isolator-attenuator is coplanar waveguide on a dielectric substrate and ME resonator, which have a rectangular shape (or in the form of disk) of layered composite of lead zirconate titanate (PZT) — yttrium iron garnet (YIG). Control voltage is applied to the ME resonator electrodes. The permanent magnet provides required magnetizing field.

Figure 1 shows the construction of the coplanar ME isolator-attenuator model with a resonator in the slot of waveguide.

Variants with two resonators in each slot of waveguide or with one resonator overlapping the both slots are also possible. All options were modeled. The layered structures of different thicknesses and configurations were investigated as resonators. Magnetizing field was directed tangentially to the plane of structures.

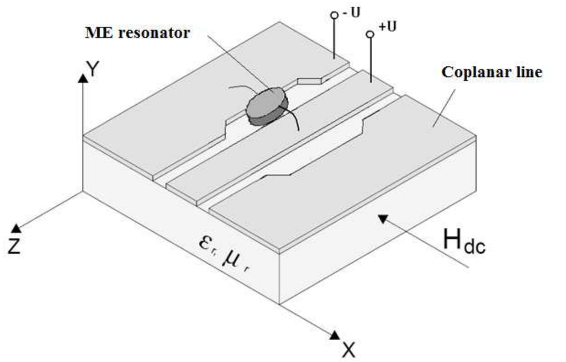

Figure 1: Model of ME coplanar isolator-attenuator.

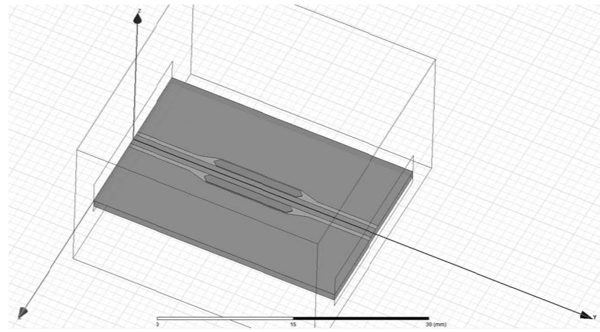

Figure 2: The model of the coplanar ME isolator-attenuator.

3. RESULTS AND DISCUSSION

Simulation of the device is made in the software environment of the HFSS program. S-parameters in the frequency range are optimized for investigated device. The phase and amplitude characteristics of inverse and direct losses were investigated.

The following simulation results are presented for the variant of the isolator-attenuator with two resonators. The magnetizing field applied to one resonator. The second resonator needs for matching of microwave signal. It allows to get symmetrical characteristics of isolator-attenuator.

Figure 2 shows the model of the coplanar ME isolator-attenuator created in the HFSS program.

Figure 3 shows the frequency dependence of inverse and direct losses.

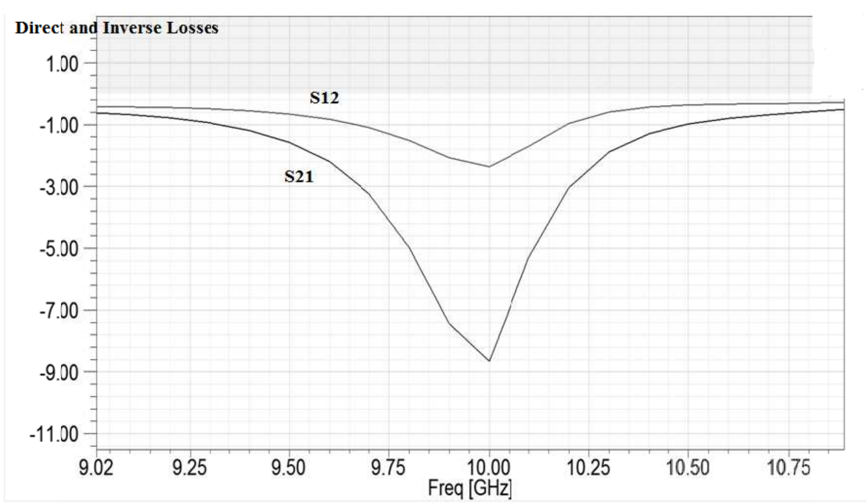

Figure 3: The frequency dependence of inverse and direct losses.

The resulting level parameters for direct loss S_{12} is less than 1 dB, and the level of return loss S_{12} is the order of -10 dB in the frequency range of 200 MHz. The level of return loss may be varied by the component thickness ratio of the layered ME structure and may reach 25–30 dB. To decrease the control voltage and increase the isolation ratio one needs to reduce the thicknesses of the piezoelectric and the ferrite.

4. CONCLUSION

The paper presents the design and performance of CPW microwave nonreciprocal devices which have potential applications in phased arrays and in other systems.

The use of computer simulation by the HFSS program for ME structures in the non-reciprocal microwave devices opens promising opportunities for the design of new devices.

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