# DOUBLE-LAYERED MICROWAVE ELEMENTS CONTROLLED BY MAGNETIC FIELD

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Dielectric materials are an essential choice for the microwave electronics due to low energy loss, high stabilities of physical and chemical properties under different environment conditions [1]. They are used in the development of wireless communication components and devices. Despite the named advantages new ideas of their use and new requirements for microwave elements reveal fundamental problems about dielectric materials: relatively low sensibility to all of external influences makes it less flexible and universal, reduces opportunities of the devices miniaturization. One of approaches to solve this challenge is a development of composite materials and elements, including an additional control component [2]. Additional constituents gave the opportunity to change resonance frequencies, frequency range and absorption of elements based on composites. Field control seems most relevant due to low delays and simplicity of implementation. And one of the options of a field-controlled composite is a composite resonator including ferromagnetic constituent.

Ferrites are non-reciprocal microwave magnetic materials, that are able to change their own resonance frequency and absorption in a magnetic field due to the ferromagnetic resonance phenomenon. They are the microwave magnetic dielectrics, have lowest energy losses among magnetic materials, but losses are still high compare to non-magnetic dielectrics.

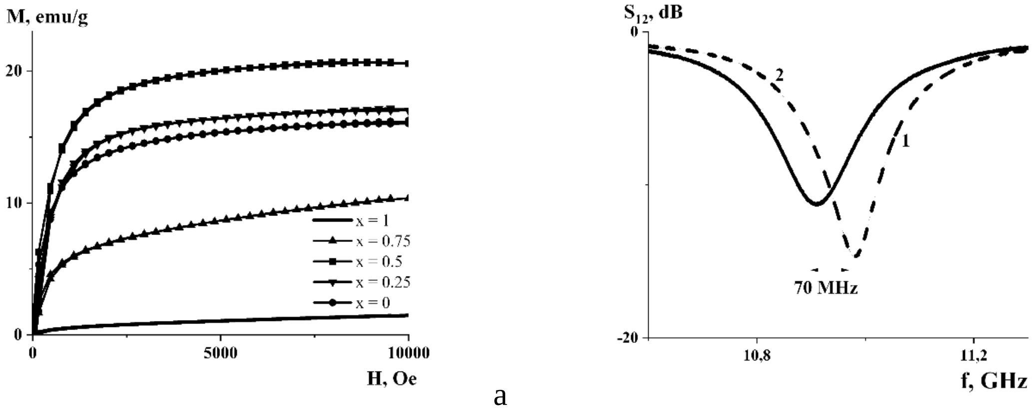
In this work, microwave dielectric resonators were developed, which include non-magnetic dielectric, ferrimagnetic film and are able to change resonance frequency and absorption in a magnetic field.

As a non-magnetic constituent was used barium tetratitanate $BaTi_4O_9$, obtained by a solid-state synthesis. Initial reagents were $BaCO_3$, $TiO_2$ and ZnO. $BaTi_4O_9$ powder with a little amount of ZnO were calcinated at the temperature of 900 °C for 3 hours. Ceramics was sintered at the temperatures of 1320–1340 °C for 2 hours. Addition of ZnO leads to formation of $BaTi_4O_9$ and $BaZn_2Ti_4O_{11}$ phases in $BaTi_4O_9$–ZnO system. The $BaZn_2Ti_4O_{11}$ phase is characterized by the higher value of *Q*-factor compared with the main phase ($BaTi_4O_9$) [1]. Moreover, the $BaZn_2Ti_4O_{11}$ phase has a positive value of the temperature coefficient of dielectric constant, as opposed to $BaTi_4O_9$. These differences cause a rise of a Q-factor in materials, thermal compensation and temperature stability of electrophysical properties. The samples of $BaTi_4O_9$–ZnO ceramics showed the value of the dielectric constant of $\varepsilon = 36$, $Qf = 35000–40000$, the temperature coefficient $\tau_\varepsilon = -3\cdot10^{-5}\ K^{-1}$.

Literature showed, that ferrites with high magnetization are required for a better opportunity of tuning. As ferromagnetic materials were used solid solutions of nickel-zinc ferrites $Ni_{1-x}Zn_xFe_2O_4$ ($x = 0, 0.25, 0.5, 0.75, 0.8, 0.85, 0.9, 0.95, 1$). Magnetization in this system rises after the addition of a limited amount of paramagnetic Zn atoms. It can be explained by the formation of partially inverted spinel structure and change in superexchange interaction [3, 4]. Powders were synthesized by the coprecipitation from aqueous solutions [5]. As initial reagents were used aqueous solutions of $Fe(NO_3)_3$, $Ni(NO_3)_2$ and $Zn(NO_3)_3$, an aqueous solution of NaOH was used as the precipitator. XRD patterns of powders showed, that particles are single-phased after the sintering in a muffle furnace at the temperatures above 500 °C, phase formation proceeds in one stage. The degree of crystallinity of the synthesized ferrite particles was determined according to the method presented in [6] and was 32.7 % after heat treatment at a temperature of 500 °C, 34.2% at 600 °C, 41.7 % at 650 °C, 51.7 % for 700 °C, 89.1 % for 800 °C. So, we used particles, sintered at 800 °C. The median size of particles was 50 nm. The study of magnetic properties showed, that the largest magnetization value of the particles take place at x = 0.5 (fig. 1a).

Ferrites films were formed in the magnetic field on the end faces of the $BaTi_4O_9$ resonators using suspension, consisted of ferrite particles and photopolymer Permabond UV630. Obtained element were investigated using Agilent N5230A PNA vector analyzer in the X-band, a measuring cell was a X-band waveguide. Parameters of the scattering matrix were measured.

On the figure 1b reversal the $S_{21}$ scattering parameter spectra, which represents the transmission coefficient, are shown. Best of obtained resonators (with the films including $Ni_{0.5}Zn_{0.5}Fe_2O_4$) demonstrate non-reciprocity of $S_{21}$ coefficient from 40 dB, inducted by external magnetic field of 0–3500 Oe. At the same time the observed resonance frequency shift reached the value of 71 MHz. Q-factor of the best resonator was higher than 1700 in the all of magnetic field range. Such composite resonators can become the alternative to common microwave elements in GSM communications.



a

b

Fig. 1. Saturation magnetization of $Ni_{1-x}Zn_xFe_2O_4$ powders (a) and $S_{21}$-parameter spectrum (b) of composite element, including $Ni_{0.5}Zn_{0.5}Fe_2O_4$ ferrite particles, at H = 1 (curve 1) and 3500 (curve 2).

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