permeability on the parameters of the structure is rather small at the working frequency, in comparison with the sensitivity near the negative maximum. Fig. 6 shows that the lens can be designed using resonant elements with the resonance frequency distribution defined by resonance frequency 0.0554 GHz and by standard deviation raised up to 1.5 MHz. The real part of the effective permeability still reaches a value of -1 around frequency 0.0635 GHz, but the imaginary part value starts to grow.

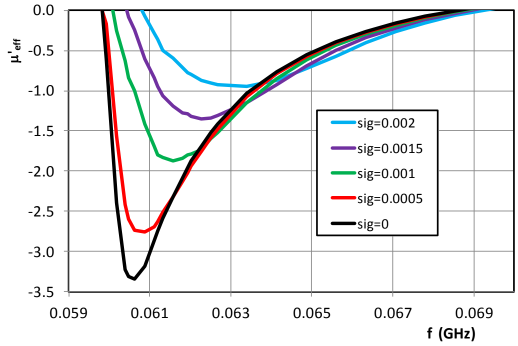

Figure 6. Calculated real part of the effective permeability of the metamaterial for an MRI lens with period a = 15 mm.

V. Conclusions

Metamaterials are composed as periodic systems of resonant elements. The fabrication process of the elements always has some dispersion of the dimensions and the material parameters that is represented by the corresponding dispersion of the resonance frequencies. The randomness is incorporated into the metamaterial homogenization process. In this process, ring resonators are represented by point magnetic dipoles. The complex effective permeability of the metamaterial is calculated.

The random distribution of the resonance frequencies of particular current loops - BC-SRRs - significantly widens the resonance frequency band of the effective permeability of the metamaterial. The magnitude of the real and imaginary parts of the effective permeability decrease, the frequency band of negative real part is narrowed, and at higher standard deviation values for the resonance frequencies this band disappears. The procedure was verified experimentally by measuring the scattering parameters of the metamaterial block in the rectangular waveguide. This data can be well compared with the parameters calculated by the CST Microwave Studio, which uses complex permeability determined by the homogenization procedure.

Finally, the presented homogenization procedure was used to determine the limit in which the dispersion of the resonance frequencies of particular resonators can be varied to obtain a working lens designed for improving the quality of the images of the 1.5 T MRI system working at 63.87 MHz. The homogenization procedure was modified here for an analysis of a structure with cubic cells, where the resonant elements are located on particular faces of the cubes. At the same time, the procedure was verified by proving that the analyzed structure shows an isotropic response.

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