Evaluation of Ferroelectric Resonators as RF Coils for Magnetic Resonance Spectroscopy

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The most important problems of any kind of magnetic resonance methods (NMR, EPR or MRI) are their sensitivity or imaging quality. Major new advances in sensitivity and quality of image can be provided by the development of new types of RF coils. Dielectric resonators (DRs) are proven to be very effective in solving those problems [1]. Over the past years the ferroelectric resonators (FRs) have attracted the attention of researchers because of its efficiency [2, 3]. An incipient ferroelectric, potassium tantalite ($KTaO_3$), is expected to be the best material for microwave/RF resonators applied for magnetic resonance (MR) spectroscopy. For applications in NMR and EPR studies, the advantage of the designed FRs made of single-crystal potassium tantalite is that it exhibits no background signals. Another advantage of this material is that it has very small frequency dependence of the dielectric constant in the RF range. We developed FRs to substitute: 1.conventional metal cavities in EPR and FRs, and 2. to substitute commonly used birdcage resonators in NMR and MRI with FRs without discrete network elements. This study demonstrated the advantages of RF resonators made of $KTaO_3$ in comparison with ceramic resonators made of titanium dioxide and aluminium oxide.

Ferroelectric Resonators for NMR and EPR

Our results show that application of FRs can significantly increase the sensitivity of NMR and EPR spectrometers – by the factors of 10 and 100, respectively. FRs make an observation of natural paramagnetic impurities in EPR and recording of impurities without special doping in NMR possible. Because the FR can be located outside standard cavity and generates a localised microwave magnetic field, it becomes possible to register an EPR Image. Recently, for the first time, a FR made of single-crystal potassium tantalite was applied in a new portable EPR spectrometer.

Ferroelectric Resonators for MRI

Until recently the most common model of a send-receive coil in MRI spectroscopy was a birdcage resonator. However, the dielectric structures can be very effective MR coils when made of materials of sufficiently high dielectric constant, ε, and low-loss factors, tanδ. Usually, DRs have high quality factors and well-defined field distributions. In order to provide a higher imaging quality for MRI, the strength of static magnetic field and proton resonance frequency need to be increased. However, it is difficult to find an optimal L/C, ratio between capacities and inductivities at frequencies above 300 MHz. To substitute conventional birdcage resonators, fully ceramic RF resonators without discrete network elements were recently developed [4, 5]. Those resonators, made of titanium dioxide (TiO_2) and aluminium oxide (AL_2O_3), are heavy, use a lot of material, and do not have enough space for the studying body. To cover a larger range of frequencies and avoid the shortcomings noted above we suggest applying a ferroelectric material, $KTaO_3$. For comparison, sizes of the resonators made of TiO_2, AL_2O_3 and $KTaO_3$ are presented in Table. Analysis of the calculated results indicate that at the same frequency, resonators made of $KTaO_3$ can be expected to have a larger space (by a factor of 1.54) for the body and use less material (by factors 1.9 and 1.5) with respect to the resonators made of TiO_2 and AL_2O_3. Computer simulations of RF field distributions in the proposed FRs will be discussed.

No	Material	Outer - inner diameters, mm	Height, mm	Frequency, MHz	Weight, kg
1.	TiO_2	71.2 - 45.5	240	472	2.26
2.	$KTaO_3$	71.2 - 64.6	240	472	1.18
3.	Al_2O_3	71.2 - 45.5	240	1334	2.26
4.	$KTaO_3$	71.2 - 70.4	240	1334	1.49

References

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