DESCRIPTION FOR GENERAL PUBLIC

It is known from the school physics course that properties of dielectric materials play significant role in analysis and understanding of various electromagnetic phenomena. Classical example to be given, known since early Faraday's works, is that dielectrics act to increase the capacitors charge capacity. This elementary phenomenon has a plethora of practical applications – it is enough to recall that because of it common electrical devices and electronics are working. Obviously one can mention hundreds of other applications – the general property which links all them is that dielectric materials may store energy provided them by the electric field and may release it; moreover the cycle may be repeated and repeated. The last phenomenon, because of its existing and future applications, interests scientists and engineers very much and remains the subject of extensive research. It is not easy to get complete information about physical properties of dielectric materials – the crucial quantity which has to be measured is the so-called dielectric permittivity which informs us about the difference between the electric field E which enters the dielectric medium and induction field D which describe (in some sense) the reaction of dielectric materials to the presence of E. Polarization is not a stable effect: it may change, in particular disappear, as a result of external electric fields be present or as a consequence of processes which take place in the dielectric itself. Moreover, it appears that dielectric permittivity depends on the frequency of the electric field affecting the dielectric material. This is caused by irregularities and heterogeneities occuring in the dielectric, e.g. related to its complex molecular structure. The aim of our investigations is to build a consistent mathematical model which will enable us to understand the dependence of dielectric permittivity on frequency for the high frequency range, i.e. for frequencies 10^5-10^{10}Hz. Next, we are going to apply our model in order to explain and to understand some properties of materials under investigation. Motivation to do such research is two-fold. The first argument comes from a simple assumption that if elementary centers in the sample are relaxing according to the Debye exponential laws (analogous to the radioactivity decay law) with different characteristic times then the observed signal will be their resultant, in mathematical language the weighted sum where the weight means the probability of finding in the sample elements with given characteristic time. The shape of the Debye exponential law implies that, using the mathematical notions, we deal in such a case with the Laplace transform. Now, if we know the time behavior of the signal and know how to invert the Laplace transform then we get the probability distribution from which the information about the structure and properties of the sample may be extracted, i.e. we are reaching our goal. The second observation is rooted in the analogy between the rules which govern the changes of the electric permittivity and the law which describes the so-called anomalous diffusion, i.e. the time spreading of the system during which diffusing particles move faster or slower than in the case of classical Brownian motion. The problem arising from this observation is that suitable evolution equations are not usual differential equations - they contain some complicated mathematical objects called fractional derivatives which action on functions joins ordinary differentiation and integration. But fractional derivatives have their advantages – using them one can describe the memory existing in the system and/or mutual connections between parts of the system, i.e. correlations. Our aim is to apply this observation and fractional derivatives to the description and analysis of such complex system like the dielectric is. To realize this plan, and to get physically valuable results, we will need to use extensively new, some still not very popular, mathematical methods of fractional analysis, theories of integral transforms and special functions, operational calculus and so on. But description how to use them for our purposes is a completely different story…