ABSTRACT

The dielectric constant is an essential property of dielectric materials hence its determination is very important in several engineering applications. The dielectric estimation can be basic outline parameter for some electronic designs. The cavity resonator and ring oscillator based systems functions well, however require high setup cost for dielectric constant measurement. These methods require long measurement cycle for characterizing the material over a wide range of frequencies. These methods also become specific to a range of frequency for precise measurement. Existing techniques for dielectric constant measurement fall into category of destructive measurement type where, the material will not be useful for further usage. The digital technique based dielectric constant measurement is proposed in this research work. Two techniques are produced considering the low frequency and high frequency applications. The time delay measurement based method with low cost setup is suitable up to 25 MHz frequency range. Whereas the phase measurement based method can be used up to 3 GHz. These methods rely on capacitor action resulting due to the dielectric material, which is under test. The proposed setup for wideband dielectric measurement estimation uses High speed ADC & DAC card interfaced to field programmable gate array (FPGA) board. The DSP architecture for digital filtering and phase estimation are implemented in VHDL. The Coordinate Rotational Digital Computer (CORDIC) algorithm is utilized for phase difference estimation.

The proposed research work is intended to evolve sophisticated setup for high frequency characterization of PCB materials. This type of high frequency characterization of PCB materials finds application in high frequency electronic circuits and also in micro strip antennas. With the ever growing demand for mobile and high frequency electronics, the usage of different PCB materials is becoming crucial. At high frequency as the dielectric characterization of PCB materials directly influences the signal integrity aspects, it is essential to precisely characterize the dielectric constant of materials.
The time delay based method uses principle of time interval measurement between two pulses and mapping it to phase for given frequency value. The high speed I/Os of LVCMOS FPGA are used to capture the rising edge and falling edge of pulses. The principle of phase shifted digital clock outputs are used to measure the time interval with resolution of 0.5 ns.

The setup is made with low cost hardware consisting RC integrator, high speed OPAMPs and low cost Spartan-6 FPGA board. This setup is useful for dielectric measurement for frequency values up to 25 MHz.

The high frequency suitable phase based method has capability to measure the dielectric constant over frequency range 400 MHz to 3 GHz. The two major advantages with proposed set up are non-destructive testing setup and fast dielectric measurement. For solid sheet type materials directly the connector’s attachment on both sides is only required. The dielectric measurement time is observed to be 24 seconds for a given frequency value. The developed embedded software can automatically measure the dielectric over given frequency range in programmable steps. The accuracy of established setup is compared with other theoretical and practical measurements of FR4 and paper materials. The results match with less than 10% error under all conditions. The accuracy of setup can be further improved by using phase calibrated cables and fine polished flat conductive plates.

The Xilinx Zynq-7020 FPGA, ADC (AD9643, 14-bit 250 Msps) and DAC (AD9122, 16-bit 1250 Msps) are the key components used in the setup. For Simulation and synthesis Xilinx ISE 14.6 software is used.

The research work presented here and the established digital based dielectric measurement setup can be useful in high frequency characterization of PCBs and micro strip antenna designs. The setup can be used for any solid sheet type of dielectric materials.