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A simple method of evaluating dielectric properties of dielectric layers at sub-terahertz frequencies using tapered dielectric waveguides

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The accurate knowledge of constitutive parameters of dielectric materials is demanded in numerous applications, from designing quasi-optical components, antennas and sensors to nondestructive testing. Terahertz time-domain spectroscopy (THz-TDS) is a recognized technique of the broadband material characterization, but it requires a well-adjusted measurement setup, special sample holders etc. Alternatively, the dielectric properties of materials can be evaluated using such widely used sub-THz apparatus as a vector network analyzer with frequency extenders. To this end, they must be additionally equipped with the dielectric measurement cells and corresponding software while the free-space measurements require a careful preparatory work similar to THz-TDS systems.

We propose a simple transmission-mode method of evaluating dielectric properties of thin-sheet materials utilizing a pair of metal-to dielectric waveguide transitions connected to the sub-THz frequency extenders. The dielectric sample under test is placed in the gap between two open-ended tapered dielectric waveguides (DW). The dimensions of DW, length and shape of the taper have been chosen to ensure the best operation in the near field. The main advantage of the tapered DW is an extremely low reflection from the taper both for outcoming and incident waves that makes the parasitic interference in the measurement area negligible. This allows to use simple formulas for extracting the constitutive parameters of dielectrics. Due to small dimensions of DW, the illuminated spot of the sample is even smaller than in a free-space setup with focusing lenses.

The method was tested using the frequency extenders V15VNA2-T/R (frequency range up to 75 GHz) and samples of Teflon, high-density polyethylene, high-frequency laminate RT/duroid 5870, alumina with the dielectric constant in the range 2.08 to 9.8 and thickness of 0.8 mm to 2.4 mm. The measurement error in all cases was about 1-3%.

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