Development and Demonstration of Accurate Free Space Measurement System at Millimeter/Submillimeter-wave Band

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In developing millimeter/ submillimeter-wave band applications, it is essential to accurately characterize the high-frequency properties of material-intrinsic parameters, particularly complex permittivity. When designing optical elements, i.e., the shape of the lens surface, and the anti-reflection coating, it is necessary to accurately understand the permittivity of the materials in advance to obtain the performance as designed. We are developing a high-accurate permittivity measurement system for millimeter/submillimeter-wave bands to design high-performance optics for radio telescopes [1].

The free-space method, one of the transmission/reflection methods, does not require inserting a sample inside the transmission line. Therefore, it is a widely used measurement method because it can be easily performed with relatively few restrictions owing to the size and shape of the sample. As an analytical model for the free-space measurement, a plane-wave model that assumes that a plane wave is perpendicularly incident on a specimen is commonly used. However, the actual electric field distribution interacting with the sample is a higher-order Gaussian beam containing various modes. Therefore, the plane-wave model produces systematic errors due to the plane-wave approximation (PWA), which is the dominant error in measuring permittivity with high accuracy [2], [3].

We have developed an analysis method that does not introduce errors due to PWA or higher-order modes in any incident electric field distribution. The proposed method rigorously calculates the interaction between the electric field distribution and the dielectric slab in the actual optical system with the angular spectrum method. In this conference, we present the verification of high-accurate permittivity measurement of low-loss polymer with the 140-220 GHz band, and 325-500 GHz band measurement system.

References

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