## Dielectric Measurement Using Fabry-Perot Resonator

EMlabs

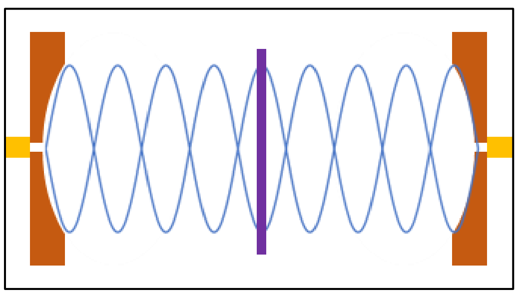
E-mail：info@emlabs.jp
Web：https://www.emlabs.jp

## Introduction

In recent years, with the expansion of 5G/6G communications, high-performance servers, and automotive radar, there has been a growing need for material evaluation in frequency bands exceeding 100 GHz. For accurate design and performance evaluation of substrates, antennas, radomes, and even liquid coolants in servers, the precise measurement of dielectric constant (ε′) and dielectric loss tangent (tanδ) has become essential. The Fabry-Perot resonator, covering a wide frequency range up to 330 GHz with high reproducibility, is now recognized as a key instrument for this purpose.

## 1. Measurement Principle

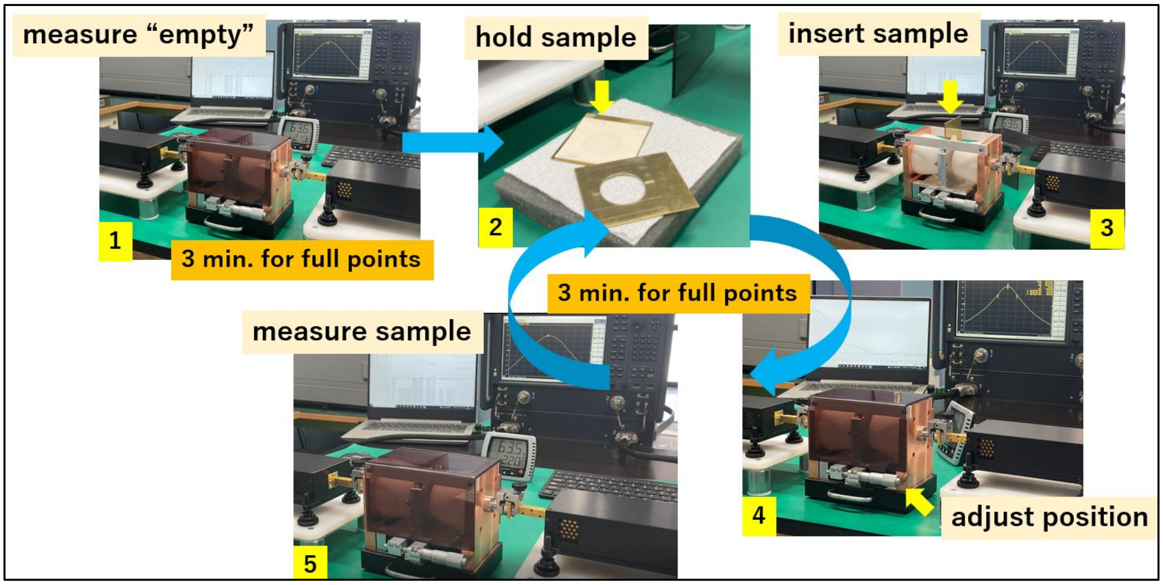
The Fabry-Perot resonator is constructed by placing two spherical mirrors in parallel.



【Fig. 1: Schematic diagram of Fabry-Perot resonator】

Standing waves are formed between the mirrors due to resonance. When no sample is present, the resonant frequency and Q-factor are measured. When a sample is inserted at the center, the resonance frequency shifts lower, and the Q-factor decreases due to losses in the material. From these changes, dielectric constant (ε′) and dielectric loss tangent (tanδ) are calculated. Because a wide frequency range can be measured with one fixture, this method is particularly effective for low-loss materials at high frequencies.

Figure 2 shows the external view and the measurement procedure of the Fabry-Perot resonator. For each sample, all frequency points can be measured in about three minutes.

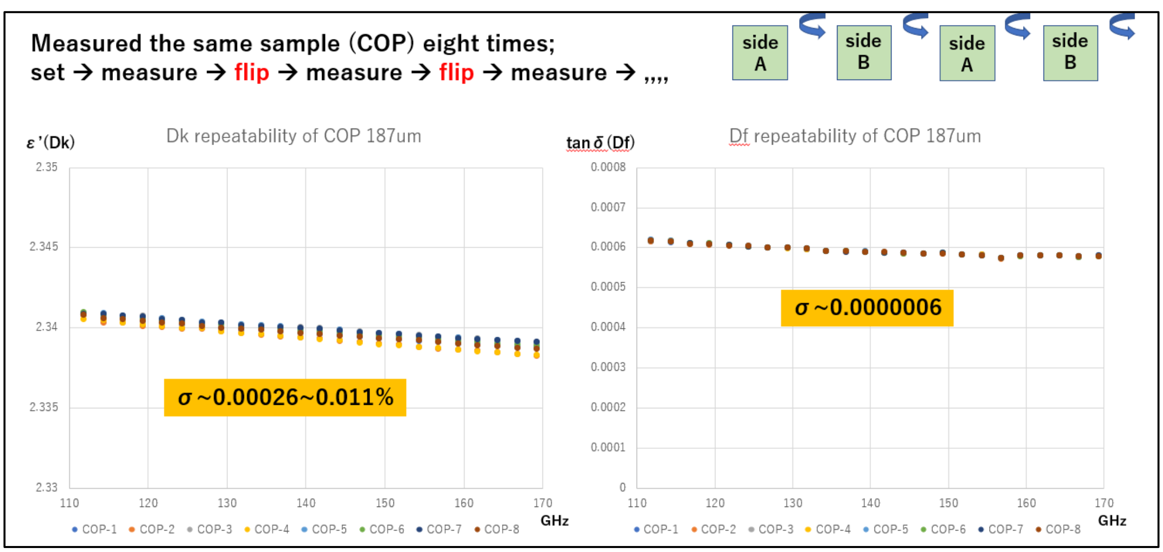



【Fig. 2: External view and measurement procedure of Fabry-Perot resonator】

## 2. Features of the Fabry-Perot Resonator

- Broadband coverage from 26 GHz to 330 GHz
- High reproducibility: for COP (180 µm), standard deviation of dielectric constant ≤ 0.00026, and dielectric loss tangent ≤ 0.000006
- Fast measurement: about 4 seconds per frequency point
- Capable of liquid measurement: stable results obtained with a dedicated liquid container

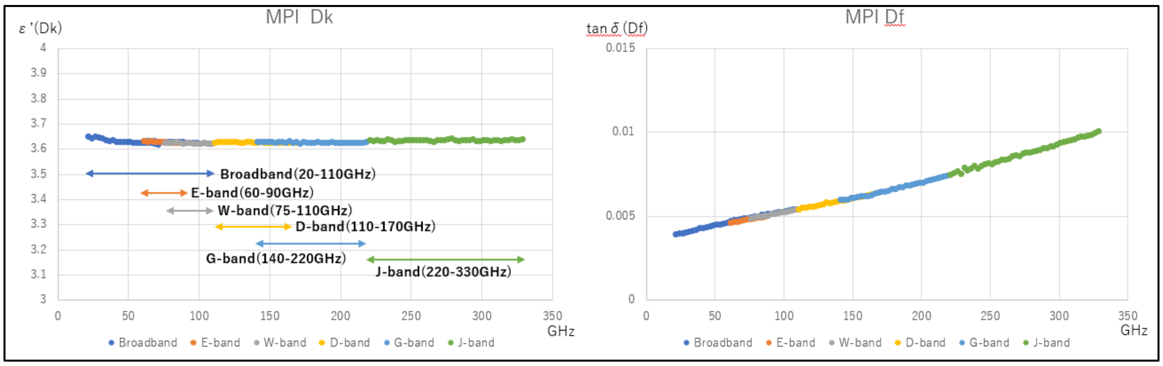
Figure 3 shows reproducibility data of dielectric measurement using the Fabry-Perot resonator.




【Fig. 3: Reproducibility of Fabry-Perot resonator measurement (average, standard deviation, coefficient of variation)】

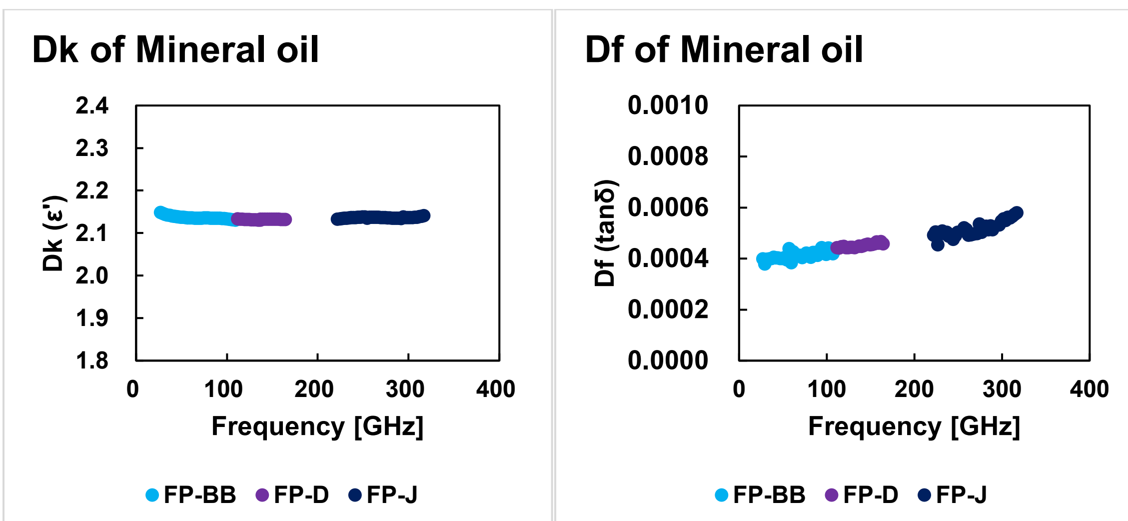
## 3. Application Examples

Figure 4 shows the dielectric characteristics of MPI film measured continuously from 26 to 330 GHz. Such broadband measurement allows the frequency dependence of material properties to be clearly identified.




【Fig. 4: 25~330GHz Dielectric measurement example of MPI film】

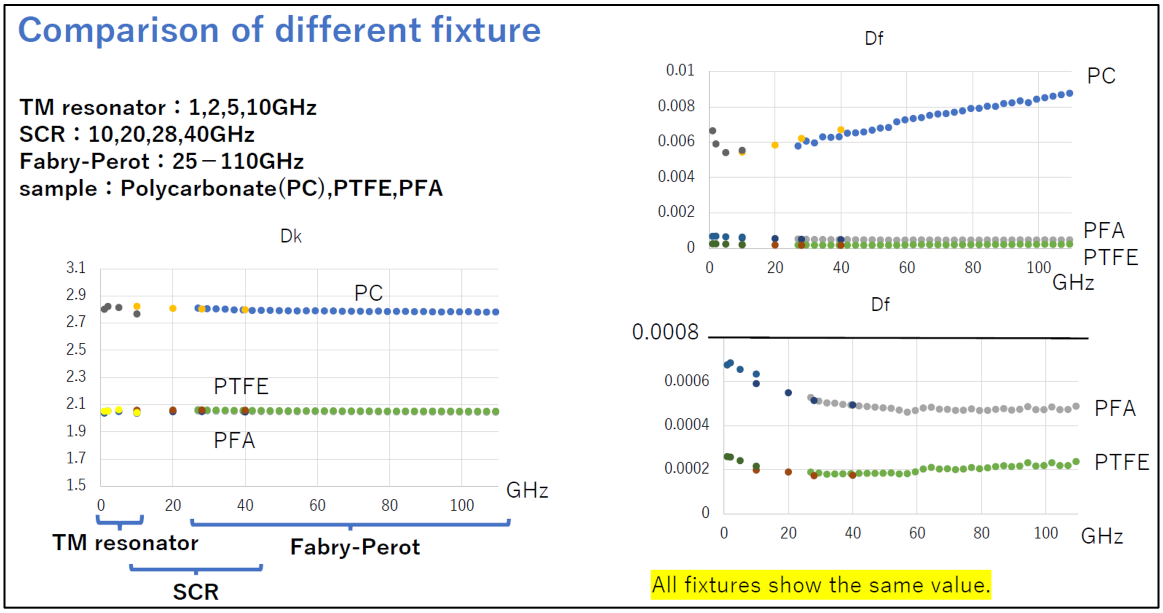
The Fabry-Perot resonator is also applicable to liquids. By using a dedicated liquid container, even mineral oil with an extremely low loss tangent of 0.0004 can be measured up to 330 GHz, as shown in Figure 5.




【Fig. 5: Dielectric measurement example of liquid (mineral oil)】

## 4. Comparison with Other Methods

The Fabry-Perot resonator is particularly strong for broadband and high-frequency measurements, while the split-cylinder resonator (10–80 GHz) provides extremely high precision at single frequency points. Cavity resonators are widely used in the 1–10 GHz band. By combining results from multiple resonators, highly reliable data can be obtained. For example, confirming that the same dielectric yields consistent values across different resonators provides strong evidence of reliability (see Fig. 6).




【Fig. 6: Results of measuring three types of resins with multiple resonators】

## 5. Key Points in Instrument Selection

When selecting a Fabry-Perot resonator, it is important to check the following:

- Whether continuous frequency characteristics can be measured without gaps
- Whether reproducibility data are available
- Whether there are measurement examples for low-loss materials
- Whether the measurement speed is practical
- Whether consistent results can be obtained across different resonators

## Conclusion

The Fabry-Perot resonator developed by EM Labs is being established as an international standard for dielectric measurement in the millimeter-wave to sub-terahertz range. Its broadband coverage, reproducibility, and speed provide a reliable foundation for material evaluation in next-generation communications and high-frequency devices, contributing significantly to future material development and applications.

Published: September 1, 2025