Millimeter Wave Absorption Properties of Teflon at Frequency Range from 50 GHz to 67 GHz

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Abstract. In this paper, teflon material with dimensions 3.76 mm×1.88 mm×1.6 mm was prepared from the Indonesia materials market for the millimeter wave characteristics. The permeability, permittivity, and millimeter wave absorption properties were studied using a vector network analyzer in the frequency range of 50–67 GHz. The results indicated that teflon material have a good reflection loss and broadband absorption and a appropriate absorber in the millimeter wave frequency range.

1. Introduction
Millimeter radio waves, which are also called the millimeter band, are electromagnetic waves with wavelength between 1–10 millimeters and frequencies of 30–300 GHz [1,2]. The millimeter wave (milliwave) technology is applied mainly in Radio Detection And Ranging (Radar) systems to determine the range, location, or velocity of objects [3,4]. It can be used to detect aircraft, ships, cars and missiles. It is the well known that radar system consists of a transmitter and a receiver with the same antenna arranged in such a way as to quantify the electromagnetic resonance produced by a distant target [5]. Then, various signal processing techniques are employed to retrieve the desired information about the target. Fortunately, millimeter wave propagation has its own rarities including effects of the various physical factors on propagation and free space propagation [6,7]. One of the most significant issues in millimeter wave technology is that absorption by the solid materials throughout the band increases with frequency. Designing for millimeter wave spectrum use must take into the propagation characteristics of this frequency range. While lower frequency signals can penetrate more easily through buildings and propagate for many miles, millimeter wave signals do not penetrate solid materials very well and can travel only a few miles or less. [8–10].

Some research results on solid materials as millimeter wave absorbers have been published in many papers. Barium hexaferrite BaFe12xAl2O3y ceramics obtained the optimum reflection losses (RL) of −30 dB at frequencies above 39−42 GHz [11], polymers produced an optimal dielectric loss tangents at frequency of 30−50 GHz [2], and BaTiO3/Co3O4 composite powders reached the RL of −40 to −50 dB with sample thickness of 1.8 mm and the bandwidth of 5 GHz [1]. Therefore, this work is to characterize teflon material with using vector network analyzer (VNA) in the frequency of 50–67 GHz. The millimeter wave absorption properties of teflon material are studied in detail.

2. Method
The cutted teflon material with dimensions 3.76 mm×1.88 mm×1.6 mm was obtained from the Indonesia materials market. For the millimeter wave measurements, teflon material was measured with a Rohde Schwarz ZVA 67 vector network analyzer (VNA) with the WR15 sample holder in the frequency of 50–67 GHz. The scattering parameters (S11 and S21) data were recorded by VNA. The complex permeability (µ) and permittivity (ε) values were calculated by Nicolson-Ross-Weir (NRW) method using scattering parameters [12–14].
The reflection loss (RL) of the prepared absorbers versus the frequency is studied by calculating with various thicknesses of 1 to 5 mm, through transmission line theory using the equations

$$RL (\text{dB}) = 20 \log \left( \frac{Z_{in} - Z_o}{Z_{in} + Z_o} \right)$$

and

$$Z_{in} = Z_o \sqrt{\frac{\mu}{\varepsilon}} \tanh \left[ \left( -\frac{j2\pi f d}{c} \right) \sqrt{\mu \varepsilon} \right],$$

where $Z_{in}$, $Z_o$, $\mu$, $\varepsilon$, $f$, $c$, and $d$ are the input impedance, impedance of free space, complex permeability, complex permittivity, millimeter wave frequency, velocity of electromagnetic waves in free space, and thickness, respectively [15]. The VNA measurement mechanisms is illustrated in Fig. 1.

![VNA](image)

**Figure 1.** Measuring equipment, sample holder, and schematic illustration of the measurement of $S_{11}$ and $S_{21}$.

3. **Results and discussion**

The permeability ($\mu = \mu' - j\mu''$) and permittivity ($\varepsilon = \varepsilon' - j\varepsilon''$) in the range from 50 GHz to 67 GHz are shown in Fig. 1. The real part of permeability ($\mu'$) slightly increased over the whole frequency range (Fig. 1a). The real part of permittivity ($\varepsilon'$) remains decreased in the frequency range of 55 − 67 GHz (Fig. 2b). While for the imaginary part of permeability ($\mu''$) and permittivity ($\varepsilon''$) tend to fluctuations in the frequency range of 50 − 57.5 GHz. Furthermore the range values for the $\mu'$ and $\varepsilon'$ of the sample is observed between 1.0 and 2.5. The measured $\mu''$ and $\varepsilon''$ were small and approximately constant in the 50–67 GHz range.

![Graphs](image)

**Figure 2.** The complex permeability and permittivity as a function of frequency for the teflon material.

In order to find the millimeter wave absorption properties, based on a transmission line theory, the RL values of the teflon material backed by a conductor plate under the normal incidence electromagnetic field were calculated using some variables of the $Z_{in}$, $Z_o$, $\mu$, $\varepsilon$, $f$, $c$, and $d$ [16].

Fig. 3 shows the calculated RL results of the teflon material with various thicknesses. It can be observed in Fig. 3(a-d) that the resulted RL enhance with increasing the sample thickness up to 5 mm. The RL values were obtained less than −10 dB (90% absorption) in the frequency range of 52.19–52.55 GHz, 55.14–55.98 GHz, and 57.5–57.98 GHz.
GHz and 52.17–53.44 GHz, 54.55–54.71 GHz for 4 mm and 5 mm thickness, respectively. A minimum RL of −12.73 dB was observed at 52.43 GHz with an absorber thickness of 5 mm. The results also obtained a maximum broadband with RL values less than −5 dB (67% absorption) in the whole frequency range with a thickness of 5 mm (see Fig. 3d and 3f).

Figure 3. The reflection loss (RL) (a) 1 mm, (b) 2 mm, (c) 3 mm, (d) 4 mm, (e) 5 mm, and (f) a two-dimensional (2D) RL image map of the teflon material with different thicknesses in the frequency range of 50–67 GHz.

4. Conclusions
The teflon material was successfully prepared for measuring millimeter band in the frequency of 50–67 GHz. The millimeter wave absorption properties had higher magnetic energy storage (\(\mu'\)) than dielectric dissipation (\(\varepsilon'\)) in millimeter wave frequency range. The resulted RL values showed a good broadband absorption (>90% absorption, RL < −10dB) in the frequency range of 52.17–53.44 GHz and a minimum RL of −12.73 at 52.43 GHz with an absorber thickness of 5 mm. The results particularly indicated a optimum broadband with RL values less than −5 dB (67% absorption) in the whole frequency range with a thickness of 5 mm.
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