A Novel Evaluation Method of Degraded oil by using Scattering Microwave Spectrum

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The modulated scattering technique (MST) was proposed to measure the radiated electric field (J. H. Richmond, *IRE Trans. MTT-3*, 13-15, 1955). The improved MST estimates the objective electric field by the scattering intensity from a dielectric probe of which permittivity is well-known (T. Komakine, T. Kurosawa, and H. Inoue, *IEEJ Trans. FM*, Vol.130-A , No.5 462-466, 2010). The unique relationship between the scattering intensity and the permittivity could be utilized for estimating the permittivity conversely (T. Komakine, T. Kurosawa, K. Miyanaga and H. Inoue, *IEEJ Trans. FM*, Vol.131-A, No.4 277-282, 2011). Under the Rayleigh scattering condition ($2a<\lambda/10$) for the radius, a [m], of the spherical dielectric scatterer, and the wavelength, λ [m], of the incidental electromagnetic wave, the field strength of the scattered wave, E_{RCV} [V/m], is given by the following equation assuming the MST modulation ratio = 1:

$$\frac{E_{RCV}}{E_S}\frac{\lambda^2 r}{\pi V}=3\left(\frac{\varepsilon_r-1}{\varepsilon_r+2}\right)\equiv\alpha_S \ , \tag{1}$$

where, ε_r is the permittivity of the dielectric sphere, E_S [V / m] is the field strength of scatterer position, r [m] is the distance between the scatterer and the receiving position, and $V=4\pi a^3/3$ is the volume of sphere. The permittivity should be derived from Eq. (1) as follows:

$$\varepsilon_r=\frac{3+2\alpha_S}{3-\alpha_S}=\frac{9}{3-\alpha_S}-2 \ . \tag{2}$$

The permittivity generally varies with applied signal frequency, so that the scattered spectrum should represent the material property of the scatterer.

The authors have applied the method to evaluate degraded hydraulic oil. Forced deterioration oil from 24 to 192 hour were packed in the plastic bottles with the volume of 100 mm^3 each were used as the measured sample. The signal of a generator set to 0 dBm was radiated from standard horn antenna to the sample. The measured scattering signal spectra of the samples have relatively larger difference in the range from 2.0 to 2.5 GHz. Measured scattering wave spectra for the samples are shown in Fig. 1. Figure 2 demonstrates the relationship between the deterioration time of samples and the average spectrum power. The result shows three different stages; (i) Initial power reduction by evaporation of residual water, (ii) Proportional increase by deposition of oxide, and (iii) Power saturation by stopping precipitation. The result shows the strong coloration between the scattering spectrum and the degradation degree, and suggests its applicability to oil quality control.

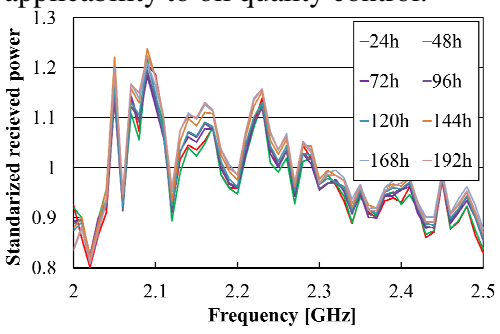

Figure 1. Observed scattered wave spectra.

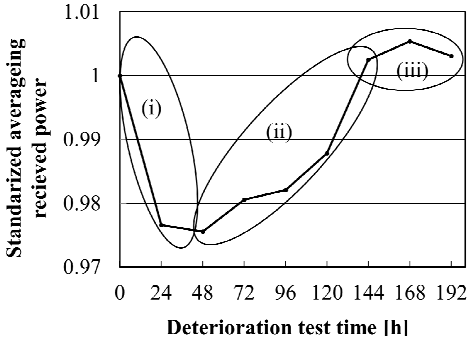

Figure 2. Relationship between the deterioration time and the average spectrum power.