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System calibration and energy transformation for radio wave detection due to rock fracture

T. Takano 1), J. Kato 1), M. Hirashima 1), K. Saegusa 1)

1) *Nihon University, Department of Electronics and Computer Science 7-24-1 Narashino-dai, Funabashi, 274-8501 JAPAN*

Radio wave emission has been measured during rock fracture at 18GHz, 2GHz, 300MHz and 1MHz. At the first stage, the experiment has been carried out to confirm the signal waveforms [1]. The emitted signal was revealed to be instantaneous so that the measurement should be well triggered. But the determination of the emitted energy is of prime importance for the quantitative study of the phenomena and applications [2].

This paper describes first the calibration method between the displayed voltage on an oscilloscope and the input power to receiving antennas in the experiment system. Next, the transformation from the received energy by the antenna to the emitted energy due to rock fracture is presented. The detailed methods and results will be represented.

For the calibration at higher frequencies than 300MHz, each antenna gain is known beforehand so that the calibration of only a receiving amplifier is needed for that purpose (Fig. 1). On the other hand, for the calibration at 1MHz, the antenna gain is not given so that we have to calibrate the antenna and receiver together. For the measurement, we have to satisfy the far field condition ($R > D2 / \lambda$) and the radiation field condition ($R \gg \lambda$). As the wavelength at 1MHz is 300m, we can not carry out the calibration in a laboratory. Instead, we used the radio signal from a radio broadcasting station which is located 37.2km apart from our university (Fig. 2).

For energy transformation at higher than 300MHz, we can estimate the maximum emitted power due to rock fracture using Friis equation, and convert the power to energy with the knowledge of a signal width (Fig. 3). On the other hand, for the transformation at 1MHz, the distance between a receiving antenna and a rock sample is much smaller than a wavelength. Namely, the radiation field condition is violated so that we have to use another tactics. In general, each electro-magnetic components of the emitted field by a current is expressed as follows:

$$H_\phi = I_z 2\ell G_0 (jk + \frac{1}{R}) \sin\theta \quad (1)$$

$$E_R = \frac{2I_z 2\ell}{j\omega\varepsilon} G_0 (\frac{jk}{R} + \frac{1}{R^2}) \cos\theta \quad (2)$$

$$E_\theta = \sqrt{\frac{\mu}{\varepsilon}} I_z 2\ell G_0 (jk + \frac{1}{R} + \frac{1}{jkR^2}) \sin\theta \quad (3)$$

$$H_r = H_\theta = E_\phi = 0 \quad (4)$$

where Iz and ℓ are the current and its length of the source, respectively, G0 is Green function of a point source which expresses a spherically propagating wave, k is equal to $2\pi/\lambda$, ω is angular frequency, ε is permittivity, μ is permeability, and $\theta = 0$ in the Iz direction.

In this situation, the emitted fields H ϕ and E θ is dominated by the second term in the bracket or an induction filed rather than the first term or a radiation field. Therefore, the radiation field has to be extracted from the measured field.

References

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[2.] Tadashi Takano, Ken-ichiro Maki, Eriko Soma, Katsumi Hattori, and Takashi Maeda, "Fundamentals of Microwave Detection in Association with Rock Fracture and Experimental Data for Various Rocks", Geophysical Research Abstracts, Vol. 13, EGU2011-9638, EGU General Assembly 2011, Vienna, April 2011.

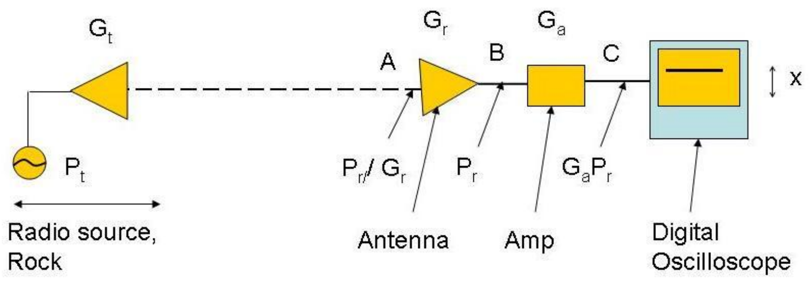

Fig.1 Configuration of a measuring system for the system calibration and the rock-emission measurement.

Fig.2 The locations of the transmission and reception for

the calibration of the 1 MHz receiving system.

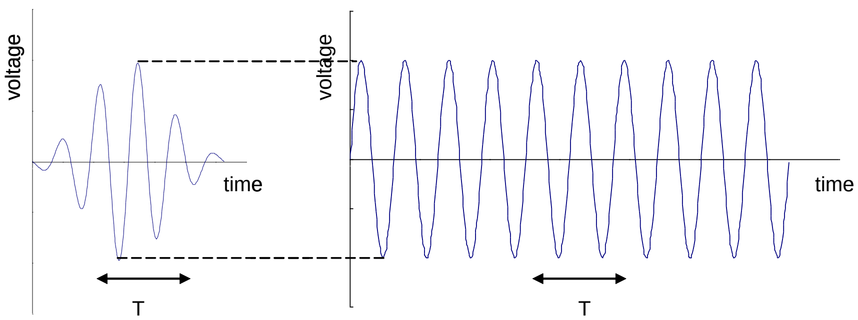

Fig.3 Equivalence of an instantaneous signal to a

continuous signal.