SEM37-P03 Room:Convention Hall Time:May 22 18:15-19:30

Electromagnetic Wave Propagation through Layered Gouges of Nojima Fault, Japan

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The attenuation and scattering of electromagnetic (EM) wave propagating through geological media are represented by skin depth which is the penetration length decaying to 1/e from the initial intensity of EM wave. The transmission and reflection of EM waves depend on continuous internal structures beneath the ground, such as changes in density (Robin et al. 1969, Ono et al. 2009), conductivity (Paren and Robin 1975) and changes in crystal orientation fabric (Harrison 1973, Muto and Nagahama, 2005). Given the appropriate frequencies of EM waves, the magnetotelluric exploration and the ground-probing radar detect the underground structures in the Earth's crust. Some researchers have reported, prior to earthquake, the detection of ultralow frequency (ULF) band electromagnetic waves (Loma-Prieta earthquake: Fraser-Smith et al. 1990) as well as direct currents (DC) (Hyogo-ken Nanbu earthquake: Enomoto and Zhang 1998). It appears that the EM waves should be transmitted from an in-depth focal region or nearby stressed region through highly damaged fault zones. Takahara et al. (2010) revealed from fractal skin depth theory that the skin depth decreases as the crustal media is fractured in a homogeneous crust, suggesting that highly damaged fault zones heavily attenuate the EM waves from hypocenter or nearby deep stressed region. Here we show this contradiction is solved by considering the internal layered structure of fault zones. The skin depth of bianisotropic layered Nojima fault gouges is measured in different lithology at different orientations. The Nojima fault is an active fault and is separating the Osaka formation of silt and protolith granite. The fault gouge samples consist of bianisotropic layered structures of comminuted siltstone, granitic gouge and pseudotachylyte. Previous paleomagnetic studies of layered fault gouges showed that stable remanence oriented parallel to the fault foliation, suggesting that coseismic direct currents magnetized the pseudotachylyte. This anomalous remanence can be interpreted as a remanence acquisition by direct currents perpendicular to the fault foliation. Our laboratory measurements of dielectric constant and loss tangent of siltstone, granite and pseudotachylyte revealed that pseudotachylyte have the longest skin depth in the ULF-DC band. Moreover, the results suggest that ULF band wave penetrates pseudotachylyte perpendicular to the fault foliation more deeply than paralle. These results agree well with the paleomagnetic implication. This bianisotropic transmission of EM waves explains why some earthquakes have accompanied EM wave radiations at the surface and others don't have done.

Keywords: Nojima Fault, skin depth, electromagnetic wave, bianisotropy