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Characterizing subsurface fractures based on forward molding of EM scattering from synthesized fractal fractures

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We developed a new full polarimetry subsurface borehole radar measuring system which can be applied for several applications one of them is subsurface fractures characterization. But, In order to understand the scattering behavior of electromagnetic waves from subsurface fractures, we utilize FDTD numerical simulation for synthesized fracture models. In this approach we use single fracture model as it represents the nucleus for whole fracture set and from it we realize the interaction of electromagnetic wave fractures. These synthetic fractures have isotropic surfaces and were created by a spectral method based on fractional Brownian motion. Thus the fractal surface is created by the inverse Fourier transform of the spectrum components with random phase that are given according to the scaling law of the surface height. On the other hand, the upper fracture surface is created by introducing spectrum components for the lower surface with the same amplitude as that of the upper surface but with a different relative phase from the lower surface. For simplification, we maintained a constant fracture aperture which can be considered as normal fracture case with full water saturated type for examination the fracture roughness parameter. In FDTD model, we use plane wave as electromagnetic source and frequency ranges between 1 MHz up to 200 MHz. Firstly, We observe the electromagnetic scattering for one fractal rough fracture aperture and examine the electromagnetic scattering properties from various fracture rough surfaces with 3 cm fracture aperture width and we concluded that the cross polarization (HV and VH) is a significant component for characterizing subsurface fractures where its mean power scatting matrix values are increasing with roughness of fracture models parameter for normal incidence plane wave case. Entropy and Alpha distribution are well known parameters for characterizing the scattering mechanism in SAR remote sensing; we proposed the same configuration in our forward modeling for EM scattering from fracture model by 2D observation plane which can be represented as SAR image. 2D observation plane is located regularly in X and Y directions close to the fracture model with a fixed separation in both directions to recover the scattering from certain illuminated zone from fracture surface. Analyzing the Entropy and Alpha distribution parameters at each single frequency from synthesized fractal fracture we notice variability of the results due to fracture roughness parameter as Entropy-Alpha distribution values increasing especially at 60 MHz and 80 MHz with RMS fracture roughness. Furthermore, we characterize the fracture aperture content when it has water, air and hydrocarbon filled materials and we figure out that Entropy parameters is the high for water filled fracture aperture as the scattering complexity is the largest in this case.

キーワード: subsurface fracture characterization, FDTD modeling, full polarimetry borehole radar, power scatting matrix, Entropy and Alpha distribution
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