Observed HF radiation from an earthquake fault: properties; relation to fault structure; possible generation mechanisms

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A. Observed HF radiation from earthquake faults has significant peculiarities, namely (1) Random appearance of time functions suggests that ruptures are organized stochastically in a loose sense. Factorization of HF source into well-defined local history of rise function and propagating continuous rupture front line may be inadequate. (2) Deteriorated or absent directivity of HF energy suggests irregular geometry of rupture front at high wavenumbers. Locally, rupture velocity may have random magnitude and random orientation. Rupture front may be idealized as a propagating fractal line, tortuous and, generally, disconnected. (3) Fault-controlled Fmax is revealed unequivocally only in rare cases. I believe that this feature, mostly in the range 10-50 Hz, is actually a common one; scarcity of its observations seem be related to technical difficulties. When real, Fmax provides estimates of the upper fractal limit of the above-mentioned rupture front geometry. (4) HF signals are non-Gaussian, with (moderately) heavy distribution tails, manifested systematically as prominent acceleration spikes. Two causes may be operative in creation such spikes, both quite probable: failure of high-strength fault patches and random rare formation of arc-like coherent features of the rupture front. (5) Recently, data have been collected that permit to compare the distribution of HF radiation capability in space-time over the area of a propagation fault, with similar distribution of local slip rate. No good correlation has been revealed. (6) Similar descripancy can be seen in spectral domain. Recently, stohastic structure of envelopes of band-filtered HF teleseismic P waves of large earthquakes has been systematically analysed. Clear features of self-similar (fractal) behavior have been revealed, both for teleseismically recorded and for source-radiated signals. This is established for the frequency range from f-corner to 1Hz for teleseismic data, and less reliably from f-corner to 20 Hz for accelerogram data. These facts do not match the behavior of broad-band source spectra where no accurate fractal scaling is observed. (The multiplicity of temporal scales in source formation is a well-established general fact; what is lacking for broad-band signals is self-similarity in a more formal sense. Note that for large earthquakes, the common assumption of the omega-square model typically represents rather crude simplification.) The listed properties bear important information regarding fault structure in space-time, and, ideally, are to be emulated by advanced fault models.

B. One of the main causes of multiple-scaled complexity of ruptures and their radiation may be related to non-flat, random fault geometry, also with multiplicity of scales. It can be shown that relative sliding of monolithic and rough fault walls with realistic multiple-scaled random relief leads to unlimited gaping formation and thus cannot be supported in geological time. To explain why this unlimited gaping is never ovserved, one has to drop that assumption of monolithic behavior of fault walls. They must be assumed discontinuous, consisting of multiple blocks permitting relative motion. This motion may be localized near to the fault, or may extend to the day surface or ductile deep layers. Block shapes may be stable only as a rough approximation; gradual crushing of material must arise around corners of individual blocks. Along the main fault, random normal stress concentrations will be formed. These concentrations lead to intermittent shear strength distribution (barriers and asperities) that eventually explain many properties of HF radiation.