Statistical characteristics of VHF Scattering Waves (Over-horizon Propagated FM Broadcasting Waves) as a Precursor of the Earthquake Occurrence

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Kushida and Kushida (2002) introduced an empirical forecast method for earthquake occurrence by monitoring of scattering waves of FM broadcast electro-magnetic wave (EQ echo), which is emitting from very far broadcast station beyond the horizon. By this method, high probability of success for the forecast was showed but there are many curious manners for observing system. However, it was notable that duration times of the scattering waves seems to relate to magnitude of earthquake, suggesting a possibility of quantitative analysis. To improve these objections we have modified VHF digital tuning receiver with quadrature detection circuit, which have high resolvable power and stability. To confirm Kushida's empirical method, five observing stations had been set up in Hokkaido, Japan. To select observing station, noise level had severely investigated. The minimum condition was to be able to observe meteor and airplane echoes, which have peculiar and easily distinguishable forms. Each station has three to eight radios to monitor the strength of erector-magnetic field of FM broadcast frequencies. Target broadcasting stations were selected to have effective paths over seismically active regions and not to have duplicate frequencies to other broadcasting stations in Japan. All records were sent to our laboratory in Hokkaido University campus by telemetry system.

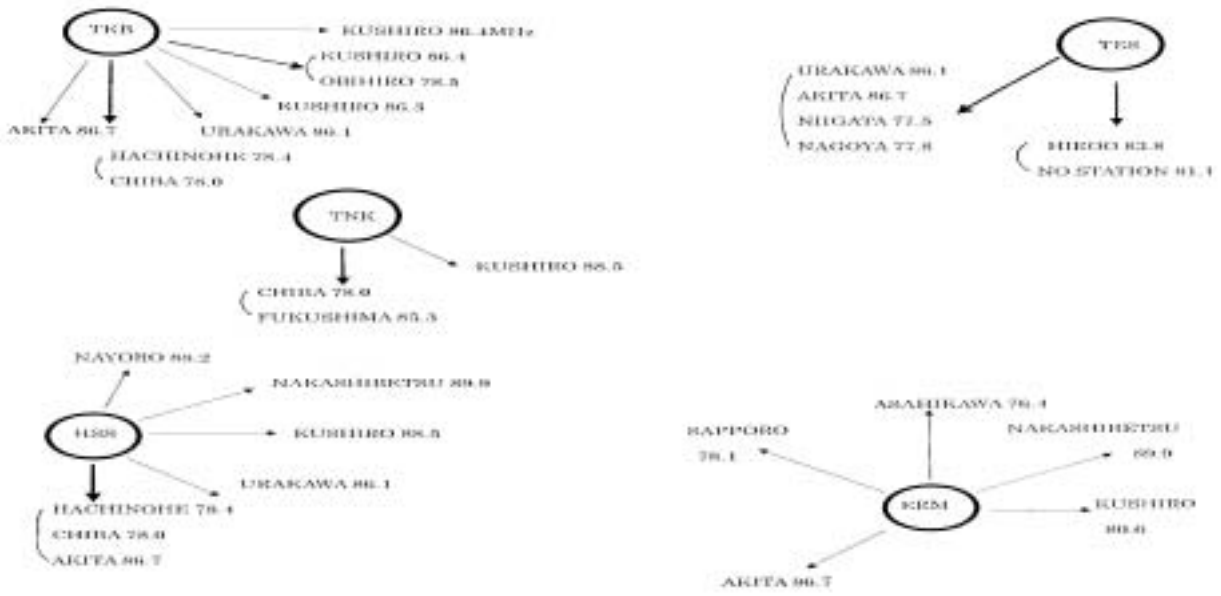

Fig. 1. Antenna directions, FM broadcasting stations and tuning frequencies.

Monitoring records have shown clear airplane and meteor echoes and sometimes EQ echoes, which have a sharp onset and multi-pulse form, continuing one to ten minutes. EQ echo used to appear one to several times in a day and before ten to three weeks of earthquake occurrence. After two to nine days from the last appearance of EQ echo earthquake, of which magnitude (M) relates to total duration time, have occurred. Relation between EQ echoes and earthquake is shown by time chart in Fig.1.

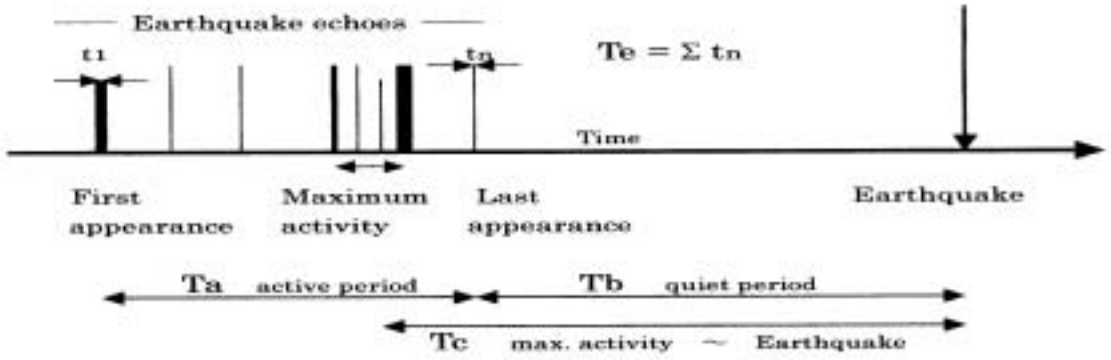

Fig.2. Time relation of EQ echoes and earthquake.

Sometimes, disturbance by the sporadic E layer activity caused similar echoes. EQ echo have appeared restricted paths above epicenter of related earthquake, on the contrarily, disturbance by the sporadic E layer activity, all paths have affected. Therefore, scatterer, which cause EQ echo is inferred to exist in the middle atmospheres, not in the ionosphere, as suggested by Fukumoto et al, (2002). In the period of Dec. of 2002 to Sep of 2004, we could distinguish that EQ echoes observed before major 61 earthquakes, which occurred in the northern Japan. Total duration time of EQ echoes (Te, measured in minute) seems to relate to depth and M of earthquake. Moreover, for earthquake beneath land area, EQ echoes were sensitive, and detective lower limit of M was 4, but those beneath sea area, lower limit of M was 6.0. In generally, precursor of earthquake must have characteristics that, the intensity of precursor may be stronger in the nearer epicentral region, and for greater M, however, weaker for deeper hypocenter, suggesting existence of trade off relation between depth of hypocenter and magnitude. These characteristics are based on homogeneous

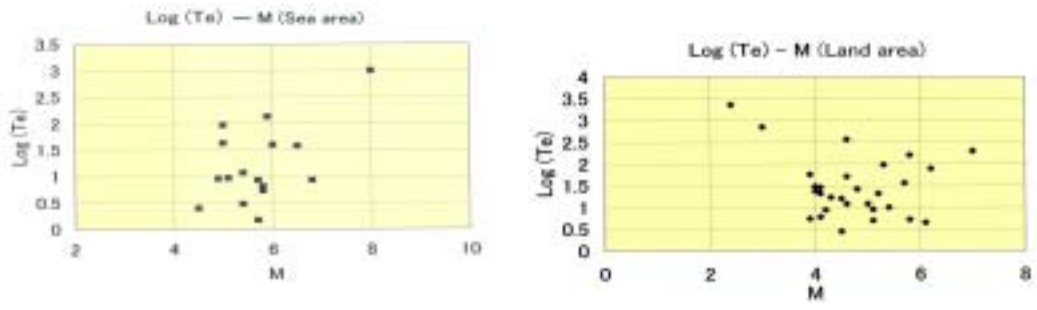

Fig. 3. Relation between Te and M for earthquakes beneath the sea (left) and land (right).

structure, however, actually earthquake are occurring beneath sea, conductive material, and in the upper crust, almost semiconductor. Therefore we treat data distinguishing sea and land areas. Observed relation between Te and M is show in Fig.3. Observed earthquakes have various depths, and relation between Te and depth of hypocenter is shown in Fig. 4.

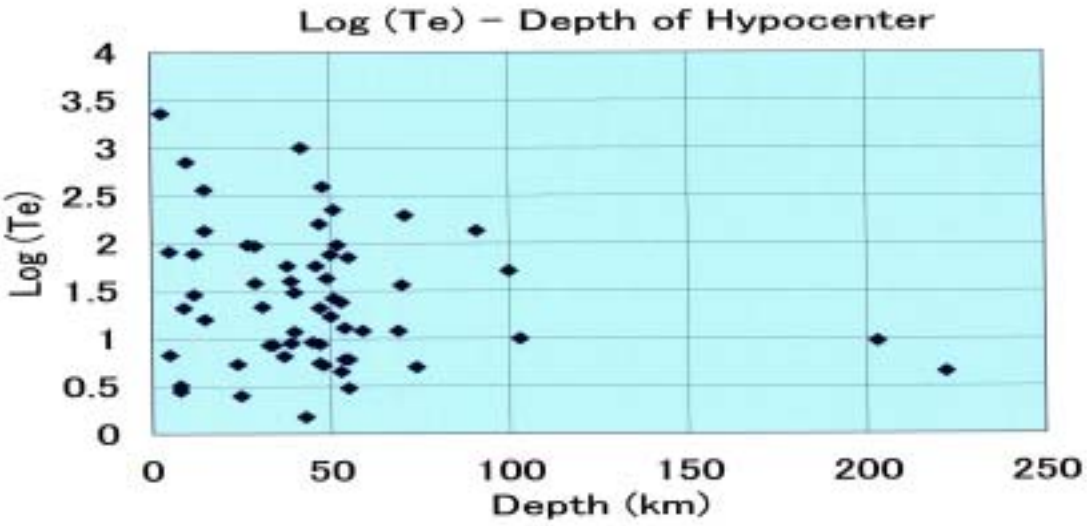

Fig. 4. Relation between Te and depth of hypocenters.

These statistics suggests that Te depends on region (sea or land), M, and depth of hypocenter. Moreover, Te seems to depend on power of broadcasting station and path. Beneath southern Hidaka mountains, Hokkaido, one of our test areas, hypocenters are concentrated in a narrow depth range, from 50 to 60km. Before these earthquakes activity, ERM have observed scattering wave from HOO FM station. For Hidaka mountains earthquakes, having almost constant depth, we obtained a relation between Te and M showing good linearity (Fig. 4).

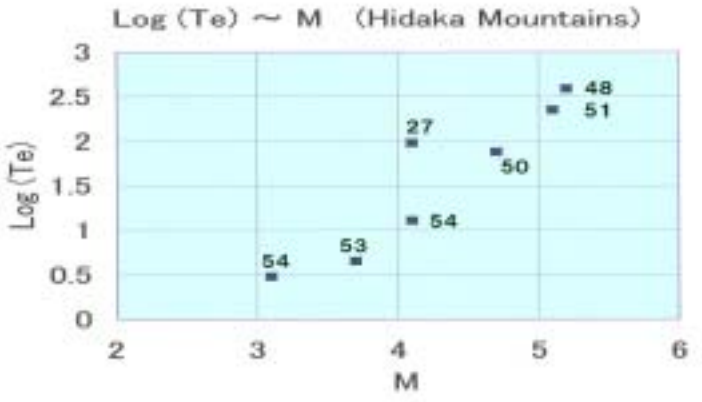

Fig. 5. Relation between Te and M for Hidaka mountains earthquakes. Numerals denote depth in km. Each Te was observed by the path from HOO, broadcasting station, to ERM, observing station.

There is quiet period (Tb measured in day) between the last appearance of EQ echo and earthquake occurrence. Histogram of Tb is shown in Fig.3. Almost Tb is distributed in the period from 2 to 9 days. Though geophysical reason why the EQ echo precedes earthquake, is not yet clarified, we could confirm that appearance of the EQ echo contains important scientific truth. Systematic EQ echo observation becomes strong tool to forecast earthquake activity and to reduce human damage.

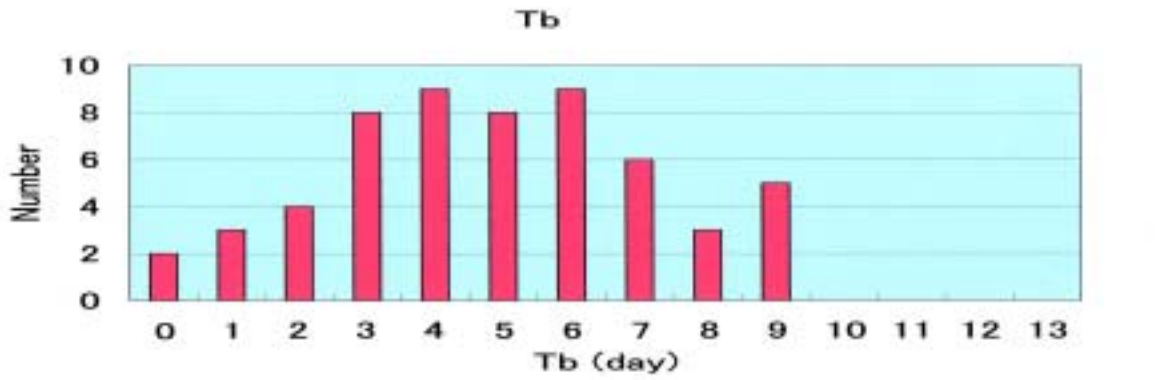

Fig. 6. Histogram of quiet period, Tb (day), between last appearance and earthquake. Two earthquake, which occurred beneath Hidaka mountains, have “0” day, but actually, quiet period were 20 hours.

[REFERENCE]

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