ISSN 1561-8889. *Космічна наука і технологія. 2005. Т. 11. № 5/6. С. 30—34.*

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Possible seismogenic origin of changes in the ULF EM resonant structure observed at the Teoloyucan geomagnetic station, Mexico, 1999—2001

Received 26.09.04

The evolution of the ULF resonant structure observed at the Teoloyucan geomagnetic station is studied in a possible relation with seismic activity in Mexico in 1999—2001. Two resonant lines were observed in the H-component (linear polarization) in the frequency bands f_{R2} = 10.2...11.1 mHz and f_{R2} = 13.6...14.5 mHz, sometimes accompanied by satellite lines. The source of the observed resonances is possibly related with the geomagnetic location of the station (geomagnetic latitude λ = 29.1°) and its proximity to the equatorial electrojet ($\lambda \approx 30°$). An enhancement of the carrier frequency of both resonances in the period from one month to two weeks was found before the strongest EQs. Also, a depression of the resonant structure just a few days before and a few days after some EQs seems to be correlated with seismic activity.

INTRODUCTION

Geomagnetic monitoring of tectonically active areas has reported anomalous changes in the character of the geomagnetic field occurring before, during and after some earthquakes. In this respect, different theoretical models have been proposed about their origin, to be able to give a physical mechanism to explain the geomagnetic anomalies. Some of these studies emphasize the crustal origin of the source [8], and other argue on their ionospheric pertinence [6]. The analysis of the seismogenic geomagnetic emission depends strongly on the instrumental infrastructure available. In the case of a network of geomagnetic stations, the multi-station data set grants the possibility for analysis by means of different robust techniques, such as the location of the area of the geomagnetic disturbances [2], and for the separation of the geomagnetic field in its constituents by their statistical properties (for instance, Principal Component Analysis [1]). In the case of only one station, the data set possibilities for the analysis are lower but some techniques like fractal analysis are still available to evaluate and recognize the anomalous character of the magnetic field that are produced by forthcoming earthquakes.

The aim of this study is to test a new methodology for analysis of the geomagnetic data collected at the Teoloyucan station in the period from 1999 to 2001, and to find out a possible correlation with strong earthquakes occurring during that period.

EXPERIMENT AND METHODOLOGY

The analyzed geomagnetic data were recorded at the Teoloyucan station (Central Mexico, geographic coordinates: 99°11′35.735″ W, 19°44′45.100″ N, 2280 m height). This station was equipped with a 3-component fluxgate magnetometer designed at UCLA, Eight strongest earthquakes during 1999—2001 chosen for analysis

Date	UT	Longitude	Latitude	M_s	Depth	D, km	k_s
15 June 1999	20^h42^m	−97.51°	18.18°	7	69	262.74	54.736
21 June 1999	17 43	−101.72	17.99	5.8	54	343.11	2.5107
30 September 1999	16 31	−97.03	15.95	7.5	16	480.94	70.487
12 Mart 2000	03 44	−99.29	20.1	4.1	5	41.034	1.2642
9 August 2000	11 41	−102.66	17.99	6.5	16	427.86	9.8774
19 May 2001	23 21	−105.72	18.27	6.5	20	736.4	4.0513
20 May 2001	04 21	−105.12	18.64	6	12	663.35	1.2315
7 October 2001	21 39	−100.16	16.98	6.1	10	322.53	5.9505

operating at 1 Hz sampling rate frequency, with a GPS system for data synchronization.

We analyzed the events with $M_s > 4$, concentrating on the eight earthquakes with the highest seismic indexes $k_s = 10^{0.75}\ \Phi_a M_s/10D$ [4], where $\Phi_a \approx (1 + D/10^{M/2})^{-2.66}$ is an attenuation factor, M_s is the magnitude of the earthquake, D [km] is the distance from its epicenter to the station and occurred under quiet geomagnetic conditions (Table).

Recently, we performed an analysis of the continuous part of the geomagnetic spectra through two methods: a study of the spectral values $S_{H,D,Z}$ and their ratio S_Z/S_H as a part of the traditional analysis, and a study of the spectral ratio β for the fractal analysis [3]. In the line spectrum structure, we proved the existence of local geomagnetic pulsations possibly generated by a crustal source. In the present paper we extend our study of the line structure to the analysis of the resonance structure of the geomagnetic field and its possible connection with seismic activity.

The resonance structure of the geomagnetic field has been recently discovered for the data of the Teoloyucan magnetic station (paper in preparation). The ULF resonances have been observed in the H-component in the narrow frequency bands f_{R2} = 10.2...11.1 mHz and f_{R2} = 13.6...14.5 mHz (Fig. 1).

The resonance structure has a proper hourly character: it almost disappears during the period 10—18 UT (Fig. 2), and the central maximum is sometimes followed by higher and lower satellite lines (Fig. 1 and 2). The polarization of both resonances is practically linear, and no resonant line is observed either in Z- or D-components. In turn, no resonant lines were observed at the nearest to Teoloyucan (TEO) geomagnetic stations, such as Los Alamos (LAL), USA, and Jicamarca (JIC), Peru.

A very similar resonance structure was also observed at the Beijing (BJI) geomagnetic station, but it was not found at all even at the nearest to it Chinese station (situated at about 150 km from Beijing). The frequency of the first resonant line observed at BJI was the same as that of Teoloyucan, but with an elliptical polarization. A possible explanation to this phenomenon could be that these stations, TEO and BJI, are located at about the same geomagnetic latitude $\lambda \approx 30°$, which coincides with an equatorial electrojet displacement. In turn, the absence of a resonant structure at the station closest to the Beijing station suggests the presence of a channeling character of the observed phenomena. By that, it could be also a longitudinal Alfven resonance, as the frequency $f = V_A/2\pi R_Z$ for the values of Alfven velocity V_A = 400...600 km/s, f = 10...14 mHz fits well with the observed values. Those resonances are expected but almost never observed because of very specific circumstances for their generation, though the transversal Alfven resonances, or Ionospheric Alfven Resonances (IAR) are studied quite well [5].

RESULTS AND DISCUSSION

The qualitative analysis of the temporal evolution of the resonant structure shows rather interesting tendencies.

Both resonances express a visible growth until approximately two weeks before two strongest EQs that occurred in June, 1999 (Fig. 3a). The same tendency is observed for the EQ that occurred at the end of September, with a higher degree of growth for both resonances.

Unfortunately, due to lack of data for the year 2000 (Fig. 3b), we are not able to analyze the strongest EQ of the year that occurred in August. However, we did obtain a noticeable growth at the resonant frequencies a week before the series of moderate EQs that occurred in February. Also, we notice that after the last EQ occurring in March both frequencies stabilize.

For the year 2001 we observe a growth of the second resonant frequency until about one week before the two strongest EQs occurring in May

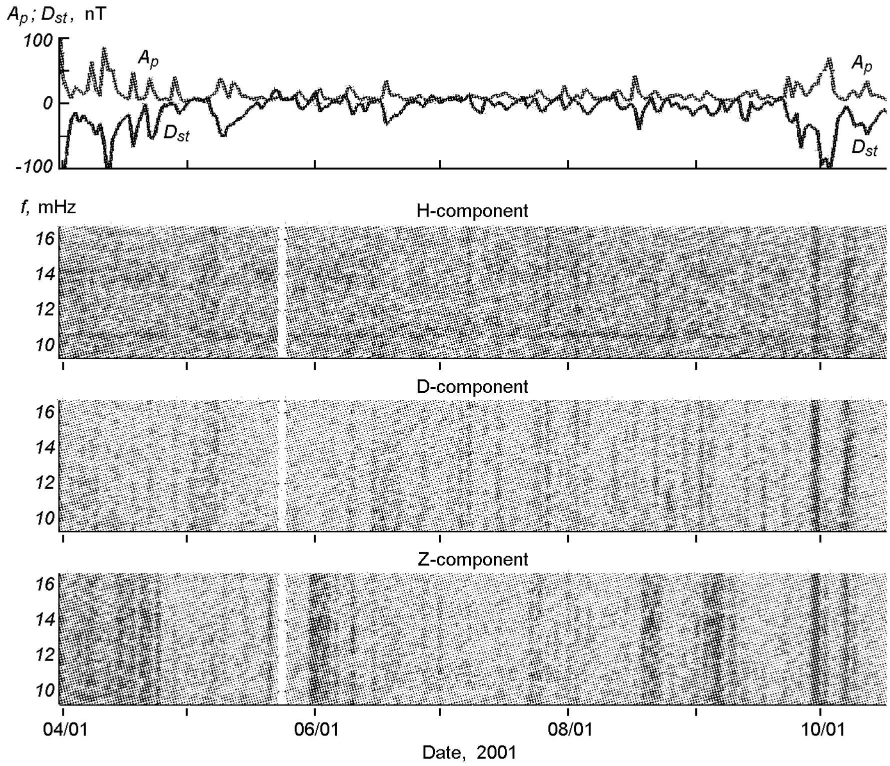

Figure 1. Observations of the ULF geomagnetic resonances structure in H-component, Teoloyucan station, 2001. Time interval 6:00—9:00 UT

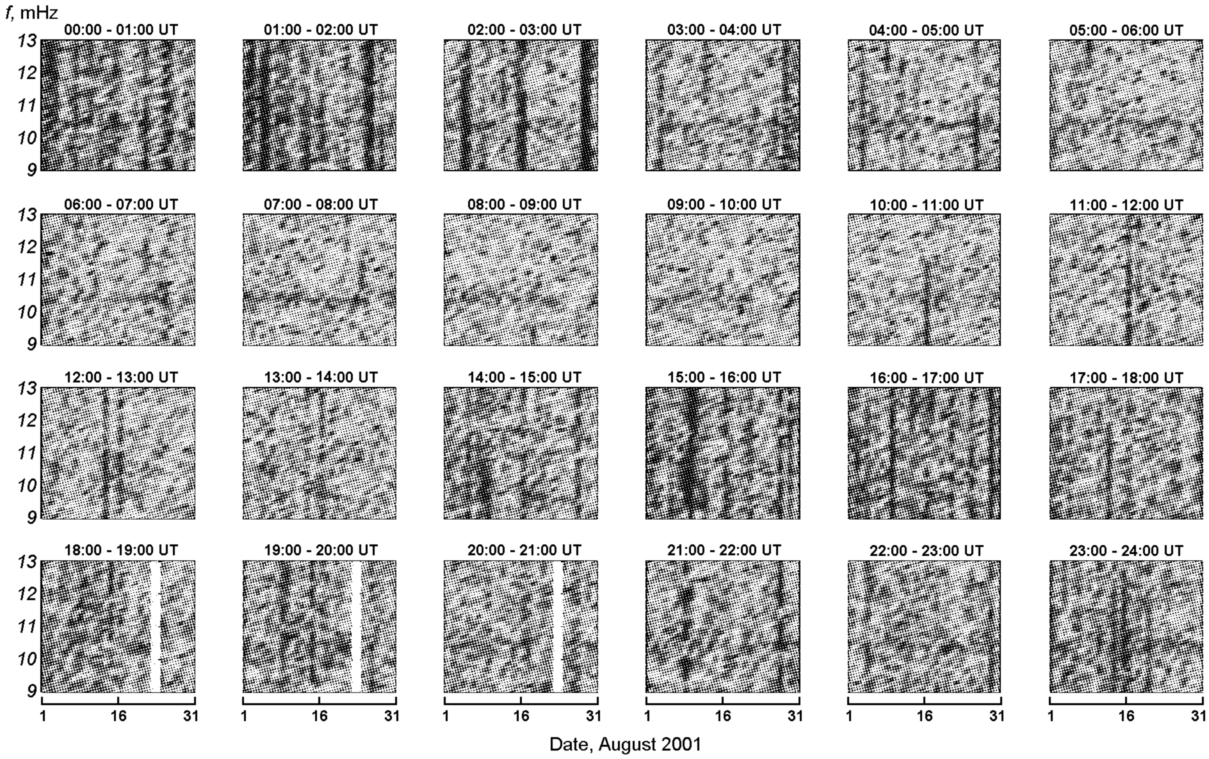

Figure 2. Appearance of the 1st resonant line in August, 2001, in the H geomagnetic component

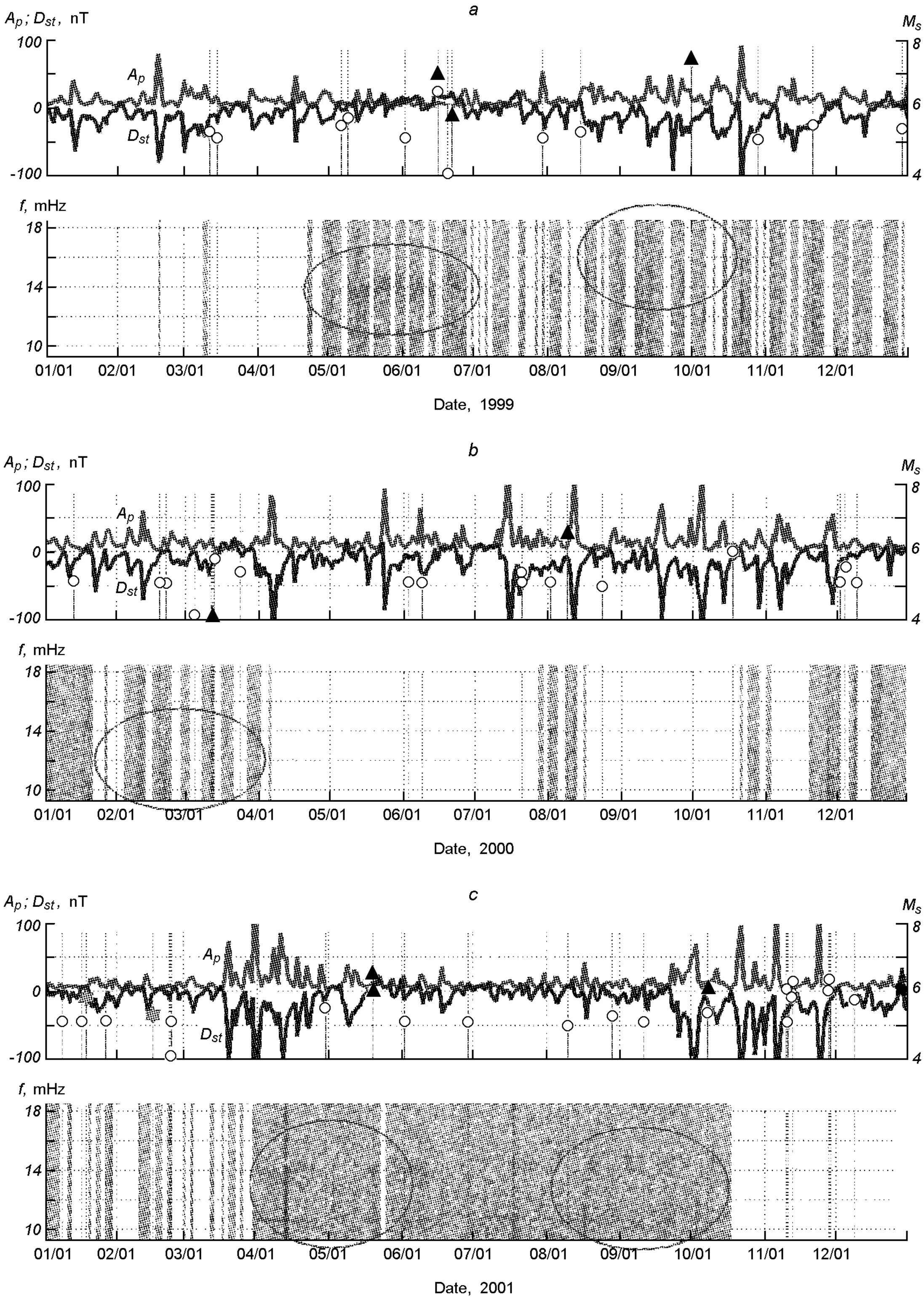

Figure 3. Values of A_p index, D_{st} index, and EQ magnitudes M_S (circles) in 1999 (a), 2000 (b), and 2001 (c). The EQs with the highest seismic indexes are marked by triangles. Lower panels: resonance structure observed in H-component

(Fig. 3c). Besides, there was a visible depression of the intensity of both resonant structures just a few days before the EQ occurring at the end of April, and some days after it. A similar depression mechanism but for geomagnetic pulsations was predicted by Sorokin et al. [7]. Another noticeable growth of the second resonant frequency was observed for the period starting about one month before the two strongest EQs occurring in October. The first resonance was not stable in this period, but its two lower satellite line frequencies increase just until the time that the first EQ occurs.

CONCLUSIONS

We studied the evolution of the ULF resonant structure observed at the Teoloyucan geomagnetic station in terms of a possible dependence with the strongest earthquakes occurring in Mexico from 1999 to 2001. The ULF resonance structure is observed in the H-component as two resonant packets (linear polarization) in the frequency bands f_{R2} = 10.2...11.1 mHz and f_{R2} = 13.6...14.5 mHz, with a certain hourly dependence. The probable reason of appearance of the resonant structure can be related to the proximity of the Teoloyucan station to the equatorial electrojet $\lambda \approx 30°$. The temporal evolution of this structure shows a noticeable correlation with EQ activity: a growth of the frequency of both resonances in the period of one month to two weeks before the strongest EQs, and a depression of the resonant structure just few days before and few days after some EQs. A more detailed analysis of the observed phenomena will be done in the near future.

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ІМОВІРНА СЕЙСМОГЕНІЧНА ПРИРОДА ЗМІН В УЛЬТРАНИЗЬКОЧАСТОТНІЙ ЕЛЕКТРОМАГНІТНІЙ РЕЗОНАНСНІЙ СТРУКТУРІ, СПОСТЕРЕЖЕНІЙ НА ТЕОЛОЮКАНСЬКІЙ ГЕОМАГНІТНІЙ СТАНЦІЇ В МЕКСИЦІ ПРОТЯГОМ 1999—2001 РР.

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Еволюцію ультранизькочастотної резонансної структури, яку спостерігали на Теолоюканській геомагнітній станції, досліджено в контексті її можливого звіязку із сейсмічною активністю в Мексиці протягом 1999—2001 рр. Зафіксовано дві резонансні лінії в Н-компоненті (лінійна поляризація) у частотних смугах f_{R2} = 10.2—11.1 мГц та f_{R2} = 13.6—14.5 мГц, біля яких інколи є лінії-супутники. імовірно, що джерело спостережених резонансів повіязане з геомагнітним розміщенням станції (геомагнітна широта λ = 29.1°) і з її близькістю до екваторіального електроджета ($\lambda \sim 30°$). Перед найсильнішими землетрусами виявлено збільшення несучої частоти обох резонансів за період один місяць — два тижні. До того ж, депресія резонансної структури за декілька днів перед і через кілька днів після деяких землетрусів, мабуть, корелю із сейсмічною активністю.