Pulsed LF-HF-VHF Radio Emission Possibly Associated with the Burakin Seismic Activity in Western Australia

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Abstract

The new kind of radio emission possibly related with seismic activity is reported. This emission is observed in a wide frequency band from 132 kHz up to 149 MHz. It has pulsed character of short 20 microseconds -ve. The "mother" wavelet shape was developed for the observed emissions which is Daubechies Filter D12. Observed pulsed emission appears 10-24 hours before the seismic shock (even of very small magnitude up to 2), and can be registered up to distances 1500 km from the future epicenter. The intensity and repetition frequency of observed emission increases with earthquake magnitude and with distance diminution between the source and the receiver. The local time dependence of the observed radio emission was detected with the maximum of intensity near 1300 LT. Almost continuous observation of the described emission on different frequencies was conducted during several months and some statistical parameters of the emission were obtained. The possible physical mechanism of the observed emission is discussed as well.

Introduction

As it often happens with the new findings the reported emission was disclosed by case by Australian author of the present paper listening in his car the commercial radio in the amateur band frequency 144-148 FM band. He was considerate enough to mark that 24 hours later the strong (M=5.9) earthquake hit the Newcastle in New South Wales, Australia. The recollection of the first event came when in October 2001 the similar anomaly was registered by him in Esperance, Western Australia, (even on the FM music band at 104.75FM) and 14 hours later the earth trembled under Esperance (the epicenter was 200 km; west at Ravensthorpe). Having had 35 years experience as a radio amateur, TV electronics engineer, ex RAAF avionics technician and part time post trade industrial electronics teacher he started to record the suspicious signals using the transceivers tuned on different frequencies.

But going back to the history of HF emission registered before the strong earthquakes we should mention as a first case the registration of anomalous signals on frequency 18 MHz before the Catastrophic Chilean earthquake (May 22, 1960), by the network of radio receivers to register cosmic radio noise (Warwick et al., 1982). The receivers input circuits were designed by such a way that they eliminated the pulsed emission, so, in case the described here emission was present, it could be registered only as increase of overall level of emission on the receivers' frequency 18 MHz. Later on the attention of researchers was attracted mainly to the LF, VLF and ELF frequency bands (Hayakawa et al., 1994). Nevertheless, in VLF frequency band pulsed character emission was observed also associated with seismic activity (Sobolev and Husamiddinov, 1985). Recently the new communications on the HF radio emissions associated with anticipated earthquakes appeared (Vallianatos and Nomikos, 1998; Maeda, 1999) what is the evidence of existing interest to HF EM phenomena, associated with seismic activity. Maeda (1999) also reports the pulsed emission on the frequency 22.2 MHz but only positive polarity and only around the time of the Kobe earthquake (40 min. before the shock and 1.5 hours after it).

Starting from the first publication of Warwick et al. (1982) the rock fracture and associated piezoelectric effect were proposed as a main explanation of the observed emission. This hypothesis finds support in the direct measurements of EM emission in mines at Australia (O'Keefe and Thiel, 1999) but again the pulsed emission was recorded only up to frequency 20 kHz, and not in the HF frequency band. The comprehensive review of Parrot et al. (1993) on the HF seismo-electromagnetic phenomena brings a lot of possible physical explanations, but the use of the term "high frequency" is very limited: it is used not in the sense of accepted in the plasma physics and radio wave propagation but in relation to the frequency of seismic oscillation, i.e. again we deal with the VLF signals.

The results reported in present paper has specificity discriminating them from other kinds of HF emissions observed before: they have fixed shape (wavelet), they are registered not on one frequency but in the wide frequency band (132 kHz - 149 MHz), and they are registered enough before the seismic shock (12-24 hours).

Experimental setup

The measurements of the HF pulsed emission (to distinguish it from other kinds of emissions reported before we will call it P-H emission, i.e. Pulsed High frequency) were carried out in the Western Australia not far from the Burakin seismically active area. One can see in the Figure 1 the corresponding map showing the seismic area as a star and arrows showing the receiver sites. The seismicity spatial distribution from 1966 up to now for magnitudes higher than 2 is shown in Figure 2. The dark cluster in the center of picture is a Burakin area. The measurements were conducted not only at the sites indicated in the Figure 1 but directly within the Burakin area during the special expedition in Burakin area in December 2002. During expedition to the Burakin area the signal was recorded along the way and directly in the region.

The measurements were carried out on the following frequencies (129-132 kHz, 2.3xx MHz, 4.2xx MHz, 148.060 MHz) during October 2001 – December 2002. The measurement installation diagram is shown in Figure 2. For the different frequencies the different professional standard amateur receivers (transceivers) were used: Yaesu VX1R (Transceiver rx 500 kHz to 999 MHz AM, FM (wide, narrow), Icom 726, all mode 100 Wssb, AM, FM CW), Tandy 1000 channel scanner (25 MHz-1300 MHz. Standard antenna (for the wide band portable) was a multiband transceiver 'rubber duck' (Yaesu VX-1R as well as FT23R) also a 10 element Yagi were used, the signal was from primarily from the NW direction (at Esperance) vertical polarization was ~3 dB greater than horizontal polarization; the best signal strength was at 45 degrees azimuth (using the 10 element Yagi) for the 148.060MHz FM narrow (455 kHz), (there was no man made interference nor when the web site NOOA for the solar activity was scanned regularly it did not coincide with the P-H pulse activity). Although when the signal pulses/min was being processed the rates were seemingly altered by the sun and the moon's position in the sky above the Burakin seismic centre, i.e.: from 1200 P-H pulses /min with sun and or moon to 200 P-H pulses/min no sun and or moon. The sensitivity of these standard receiver/transceivers is ~ 0.5 μV 12 dB SINAD. The LF signal was acquired from the ICOM 726 transceiver in the FM mode at 129-132 kHz as was the signals at 2.3xx MHz and 4.2xx MHz (this was dependant upon various man made). There were several types of data processing applied. To obtain the quantitative characteristics of the signal (pulses rate, amplitude, etc.) the special counter was designed which permitted to detect the P-H pulses and calculate them (observing the ratio of P-H pulses/ background noise). The amplitude of the pulses was estimated with the digital oscilloscope and a frequency counter. For the posterior analysis output signal was digitized with sampling frequency 44 kHz and recorded on the hard disk. There were periods when the records were made on one selected frequency. Multifrequency recording is being implemented. Schematic diagram of the experimental installation is shown in Figure 3.

Results of measurements

Example of P-H pulses shape is shown in Figure 4a, and screenshots of low and high P-H activity in Figures 4b and 4c respectively. The pulses rate varies from 300 per minute for quiet period up to 2000 12-24 hours before the earthquake. This rate depends also on the distance to epicenter area. During the expedition it was detected that the rate and signal strength of the P-H pulses increased from LF-HF-VHF proportionally to being in the seismic area. The same tests were at 0 km with respect to Burakin, 200 km Burakin, 400 km Burakin, and 600 km Burakin the rates of P-H pulses diminished away from the seismic area. Also whilst in a commercial aircraft flying over the area it was also observed that a larger number of P-H pulses were detected (no recordings were allowed to be made). The signal strength and the P-H rate was higher.

One of the prominent features of the registered pulses is their stable shape regardless changing pulse rate and intensity. As one can see from Figure 4a it the P-H pulse consist of two negative peaks, and one positive between them with total pulse duration 2 – 2.5 ms. This feature permits to create the pulse wavelet for their automatic recognition and registration. Using the commercial Mathematica4.1, with wavelet and signal analysis modules from Wolfram, the "mother" wavelet was sorted out which was determined to be a Daubechies Filter D12 (Daubechies 1988). Applying the wavelet analysis to the signal records with the determined filter will permit automatically identify the precursory signal what is very important in the real time analysis of the data in probable practical application in the short-term prediction.

This is being undertaken by the author in C language integrating with the Mathematica4.1 and its modules as well as a standard astronomy package under supervision of the computer science research laboratories at Edith Cowan University, Perth Western Australia.

The correspondence of pulse rate daily changes and consequent earthquake is shown in the Figure 5. As one can see, the technique is very sensitive even to the very small shocks like in the given example.

The distance to the epicenter of the earthquake probably associated with the registered emission was up to 1500 km (sometimes the registrations imply the possibility to register even more distant earthquake in Australia).

Data interpretation

Putting forward some hypothesis one should bear in mind the following experimental facts: the registered emission has not continuous but pulsed character. The emission has very wide frequency spectrum from kHz up to more than hundred of MHz. These tow facts imply that emission should be the electric discharge-like emission similar to thunderstorm flushes emission. The emission is connected in some way with the seismic activity because of increase the emission intensity and pulse rate with quake approach 12-24 hour before the seismic shock. Another intriguing factor is that emission is registered at large distances up to 1500 km. Taking into account that emission is registered at VHF band also, the source of emission cannot be situated on the ground. The estimations show that the source altitude should be at heights from 40 to 80 km. One cannot expect the thunderstorm clouds on such heights. Does something exist at all on these heights? The answer is YES. The rocket experiments demonstrate existence on these altitudes of aerosol layers (Zadorozhny, 2001), see Figure 6. And here arise two questions:

1 – could the aerosol layers be formed in some way due to seismic activity?

2 – could some electromagnetic emissions be generated inside the formed layers?

Aerosols or ion clusters are always present in the lower troposphere. The ions clusters formation was demonstrated by Pulinets et al. (2002) as a result of ion-molecular reactions in the boundary layer. Naturally, they will move in the atmospheric electric field or electric field of other origin in vertical direction. Depending on the electric field sense (natural field is directed down, but during thunderstorms or before earthquake the opposite direction of electric field may exist. The calculation of the charged particles movement in the strong vertical electric field is demonstrated lower

The diffusion cannot provide the vertical transport to the level of order (60 – 90 km) for time intervals of order of days. Moreover, the inverse temperature height intervals where the temperature lowers with the height make such transport even more problematic. But quasistatic electric fields of the seismogenic origin can make such transport of the ions essentially more effective. We will use the calculations made for the thunderstorm cloud which easily could be applied to the acceleration process from the ground surface.

It was shown by Park and Dejnakarintra, (1973) that the vertical electric field of the thunderstorm cloud which at the heights of 15 km is of order 100 kV/m could provide the electric field on the height of 90 km of order of 1 mV/m. To simplify calculations we will mean that the troposphere height h=15 km corresponds to $z = z_{tr} = 0$ km. In such conditions the ionosphere height h==90 km will correspond to $z=z_i = 75$ km. Taking at z=0 the electric field value $E_0 = 10^5$ V/m we will describe its exponential drop with height as:

$$E_z(z) = E_0 \cdot \exp\{-z/H_E\} \ , \qquad (1)$$

where H_E=3 km – characteristic scale of electric field change in the giant thunderstorm cloud providing electric field of 1 μV/m at z_i according to Park and Dejnakarintra, (1973).

The ions velocity **V** under action of electric field **E** could be expressed as

$$\mathbf{V} = \mu \mathbf{E} \ , \qquad (2)$$

where $\mu = q/(m_i \nu_i)$ – correspondent ion mobility, q – ion charge, m_i – ion mass, and ν_i – ion-neutral collision frequency which could be well approximated by exponential dependence:

$$\nu_i = \nu_0 \cdot \exp\{ -z/H_\nu\} \qquad .(3)$$

In the given case the rising time T from $z_{tr} = 0$ to z_i could be expressed by the integral:

$$T = \int_0^{z_i} \frac{dz}{V_z} = \frac{m_i \nu_0}{qE_0} \int_0^{z_i} \exp\{z/H_E - z/H_\nu\} dz, \tag{4}$$

or after integration

$$T = \frac{m_i \nu_0}{qE_0} \cdot \frac{H_\nu H_E}{H_\nu - H_E} \cdot \{\exp\left(\frac{H_\nu - H_E}{H_\nu H_E} \cdot z_i\right) - 1\} \tag{5}$$

When $H_E = H_\nu$, we obtain:

$$T = \frac{m_i \nu_0}{qE_0} \cdot z_i \quad .(6)$$

It is obvious that the transport time is proportional to the ion mass and collisional frequency and reversaly proportional to the ion charge and electric field intensity. Let us calculate the T for Fe^+ and Mg^+ ions. Our calculations show that the collision frequencies for Fe^+ and Mg^+ could be expressed in the heights interval 15 - 90 km as:

$$\nu(Fe^+) = \nu_0(Fe^+) \cdot \exp(-z/H_\nu), \tag{7}$$

$$\nu(Mg^+) = \nu_0(Mg^+) \cdot \exp(-z/H_\nu),$$

where $\nu_0(Fe^+) \cdot = 7{,}91 \cdot 10^8$ s^{-1}, $\nu_0(Mg^+) \cdot = 1{,}53 \cdot 10^9$ s^{-1}, and $H_\nu = 7$ km. Substituting the correspondent values in (9), we will obtain for the rising time:

$$T(Fe^+)_{[hours]} = 6{,}69 \cdot 10^{-6} \cdot (\exp\{4z/21\} - 1),$$

$$T(Mg^+)_{[hours]} = 5{,}54 \cdot 10^{-6} \cdot (\exp\{4z/21\} - 1),$$

if z is expressed in km. These dependencies are shown in Fig. 7. One can see that for the duration of anomalous electric field which is of order of several hours, the effective rising height for both kinds of ions is more than 75 km. We can claim therefore that the anomalous electric field can transport the ions into the ionosphere. We can mark also that if we will diminish the value of the electric field by order of magnitude what corresponds to the electric field of seismic origin on the ground surface, the rising time up to level of 65 km will be near 1 hour, what does not exceed the experimentally determined time of duration of the anomalous electric field of seismic origin. So we can conclude in general that the vertical electric effective in the troposphere can be an effective source of the charged particles in the ionosphere.

The process of the electrization in the dusty plasma was described by Kikuchi (2001). The formation of crystal-like quadrupole structure and subsequent acceleration of the particles in the created electric field up to initiation of critical ionization phenomena can lead to spontaneous discharges within the aerosol cloud.

So our vision of the observed phenomena is following: due to stress increase on the final stage of earthquake preparation in solid granite block of Burakin area the additional electric field appears as result of piezo-electric effect reaching the value of order 1 kV/m (in comparison with ordinary value near 100 V/m). The alternative mechanism of the electric field generation due to ion molecular reactions in boundary layer was presented in (Pulinets et al. 2002). Depending on the electric field direction the positive or negative ions/ion clusters/charged aerosols will drift upwards up to heights 40-80 km (where the anisotropy of the air conductivity can be neglected). At the heights where the anisotropy of the air conductivity appears the vertical component of the electric field decays and the ions vertical drift stops. They form the aerosol dusty clouds. These clouds subject to electrification according to Kikuchi (2001). Due to the process of electric field reconnection the micro electric discharges start to be generated. These discharges emit short pulses of wideband electromagnetic emission from hundreds of kilohertz up to hundreds of megahertz. Due to high altitude of the aerosol clouds the emission can be registered at large distances up to 500-1500 km. The schematic presentation of the proposed hypothesis is shown in the Figure 8.

Conclusion

The experimental results on the registration of P-H pulses in Western Australia before the seismic shocks imply their possible relation to the earthquake preparation process. The proposed conception of the aerosol cloud formation is still only some speculation based on the existing experimental data but still needing the solid confirmation as from the side of theory, so the further experimental investigation. The different ways can be proposed including the optical observations (lidar). At least at the present moment the authors see only one possibility to explain the observed emission. Its regular character, close correlation with earthquake occurrence in the Western Australia may make it is promising instrument of the short-term earthquake prediction. These results could be checked at the other seismic areas where the electromagnetic emissions associated with seismic activity are registered, especially at Japan. The change of the experimental setup for registration may be recommended to be able to register short-time pulses, not only the level of emission.

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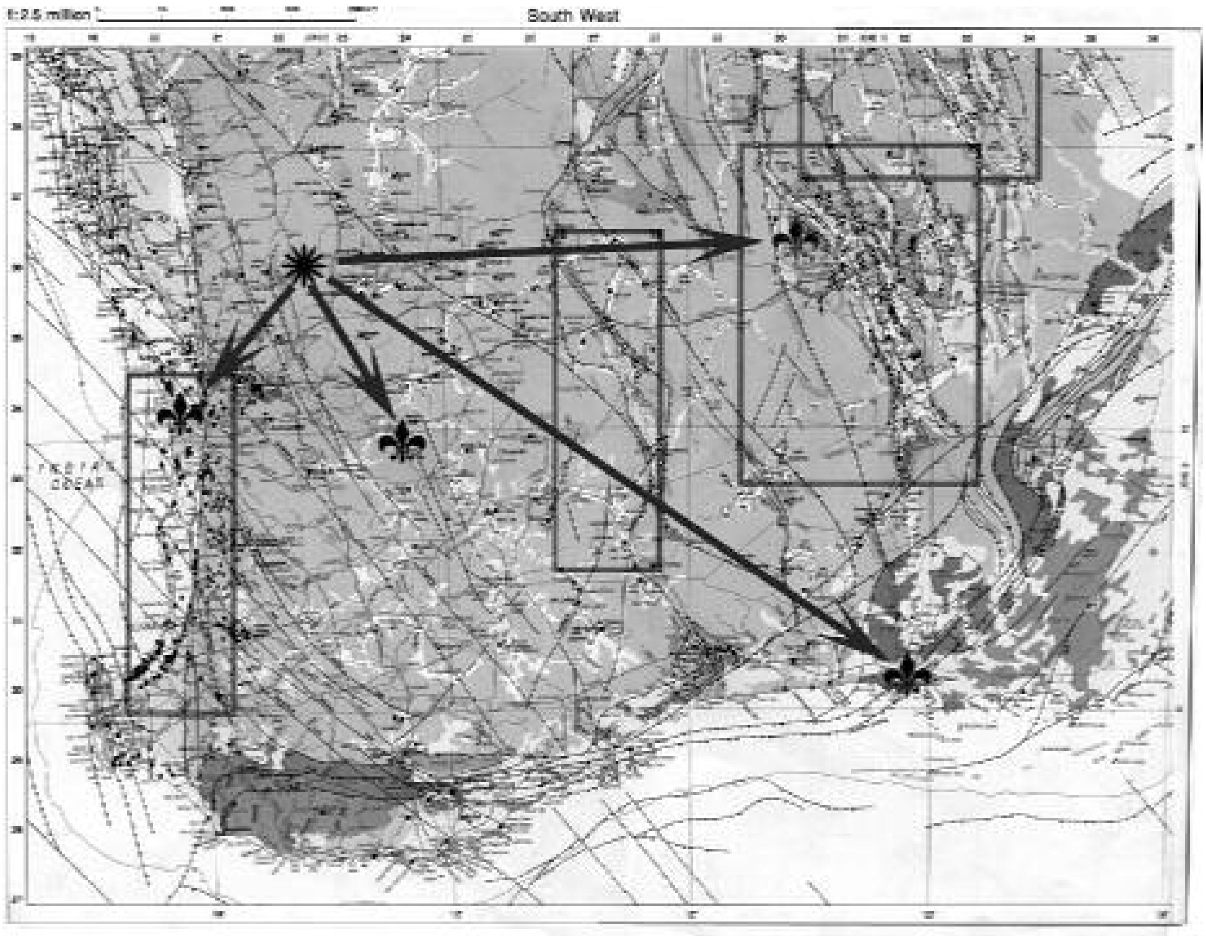
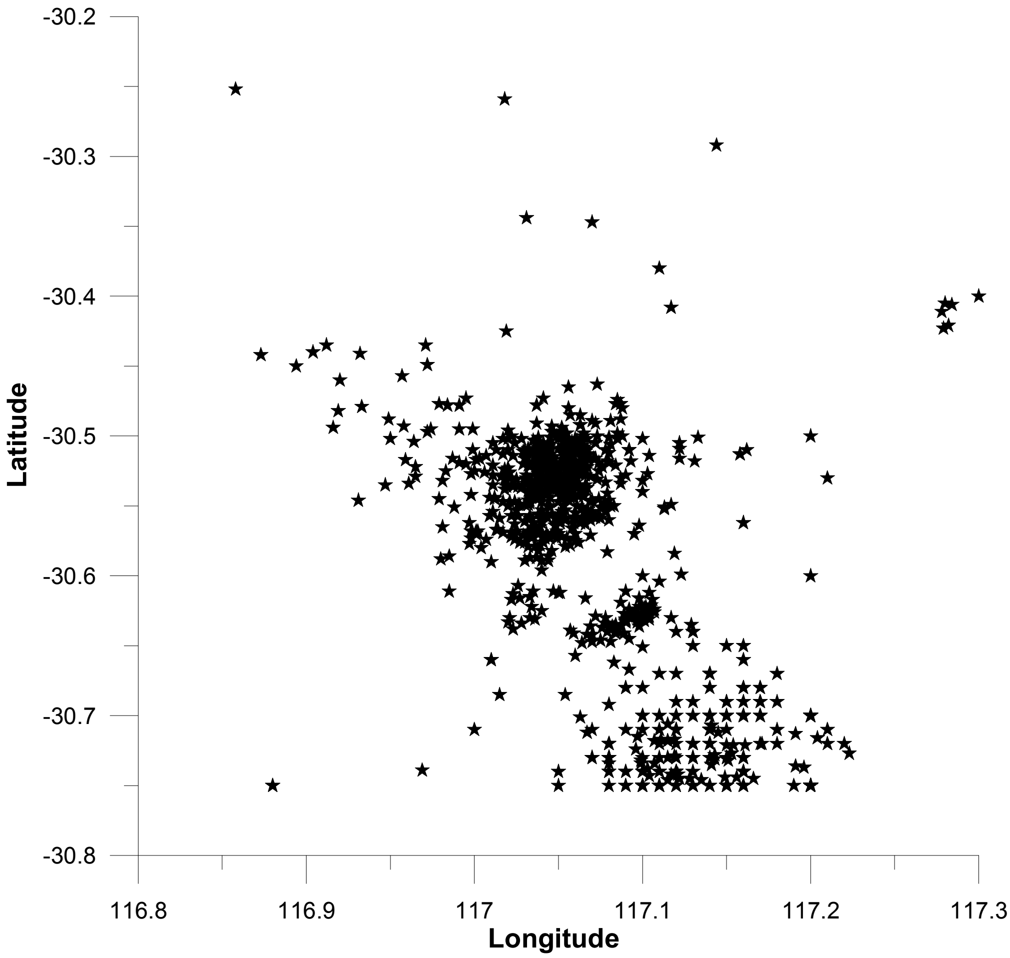


Fig. 1


-30.2
-30.3
-30.4
-30.5
-30.6
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Latitude
116.8
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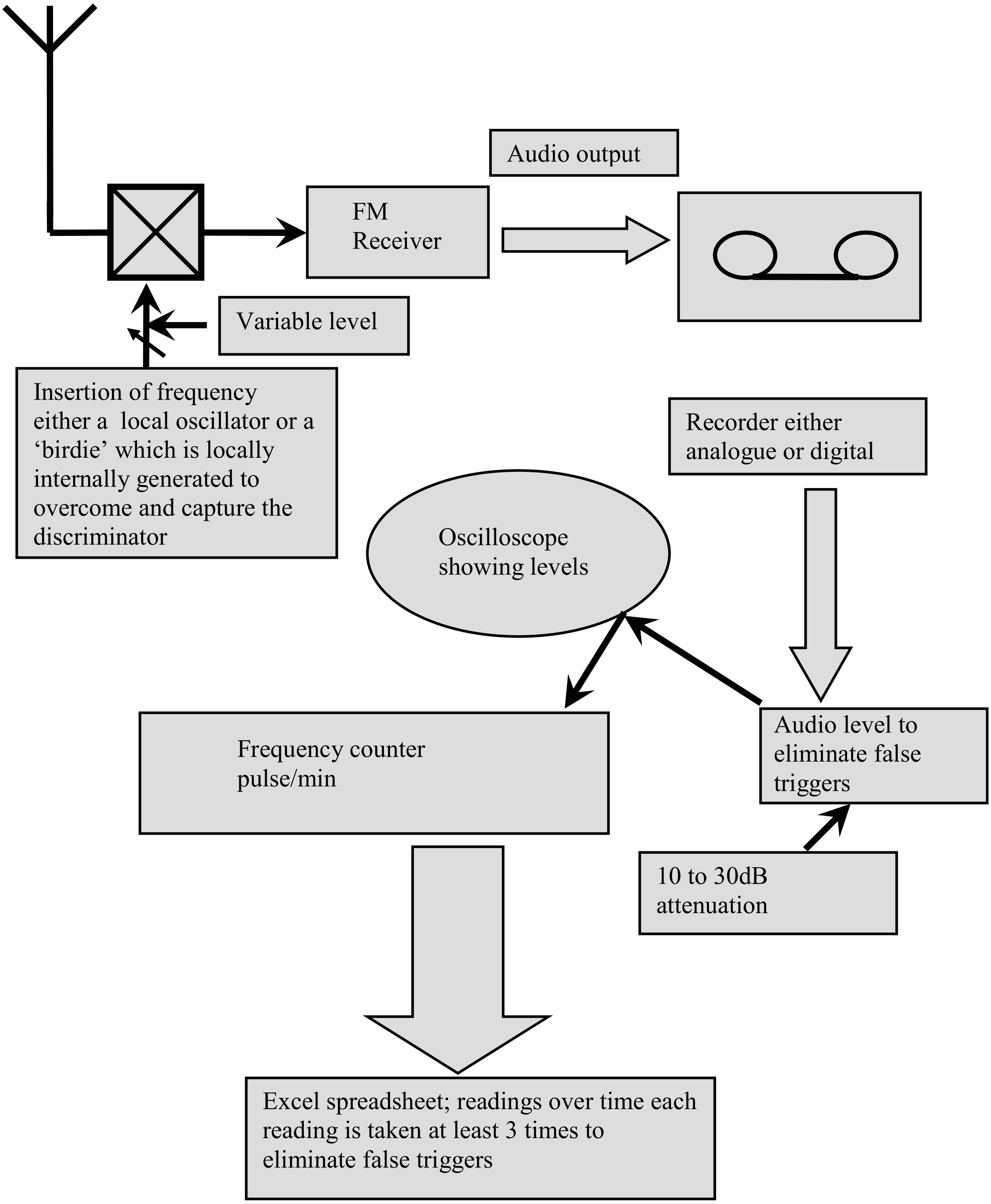
117
117.1
117.2
117.3
Longitude

Fig. 2

Fig. 3


Audio output
FM Receiver
Variable level
Insertion of frequency either a local oscillator or a 'birdie' which is locally internally generated to overcome and capture the discriminator
Recorder either analogue or digital
Oscilloscope showing levels
Frequency counter pulse/min
Audio level to eliminate false triggers
10 to 30dB attenuation
Excel spreadsheet; readings over time each reading is taken at least 3 times to eliminate false triggers

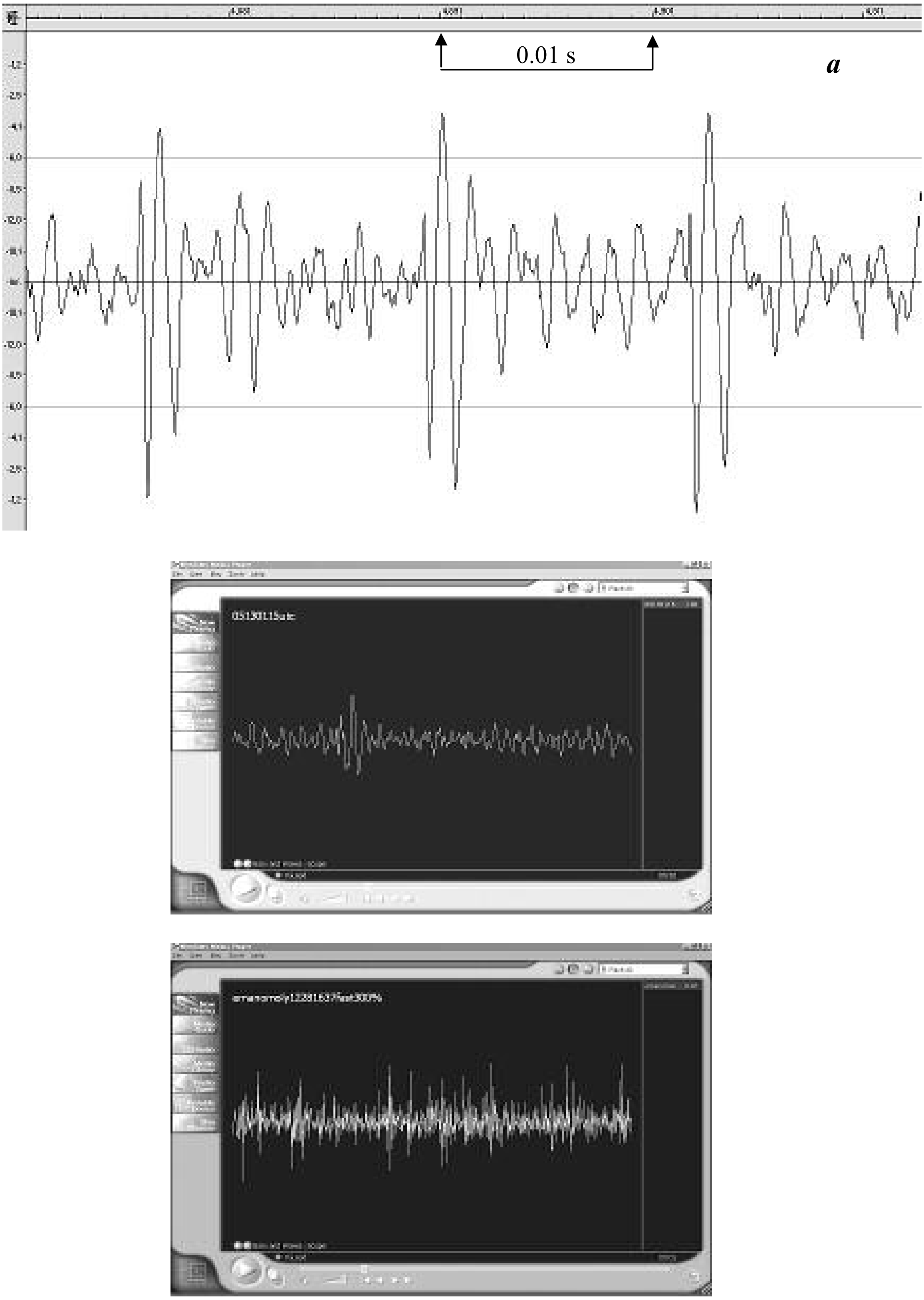
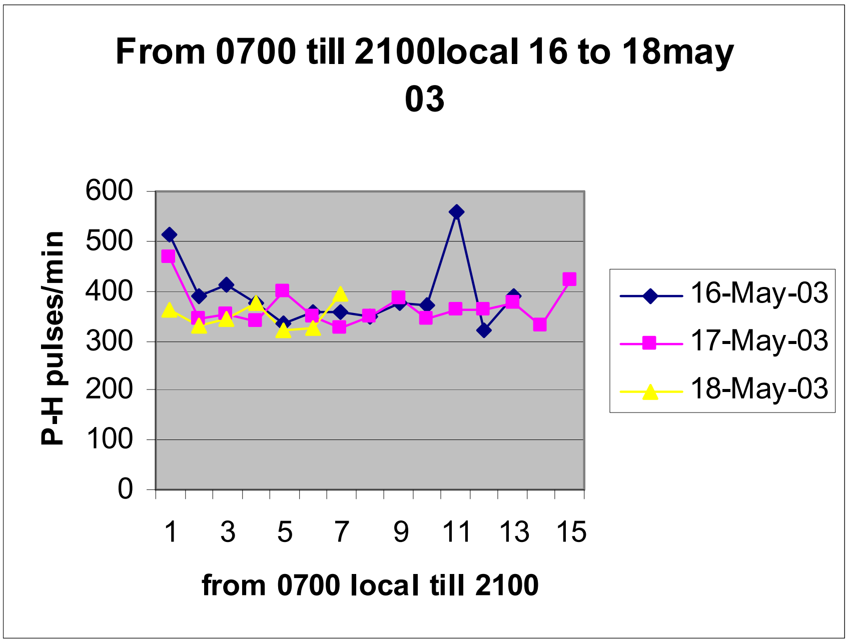
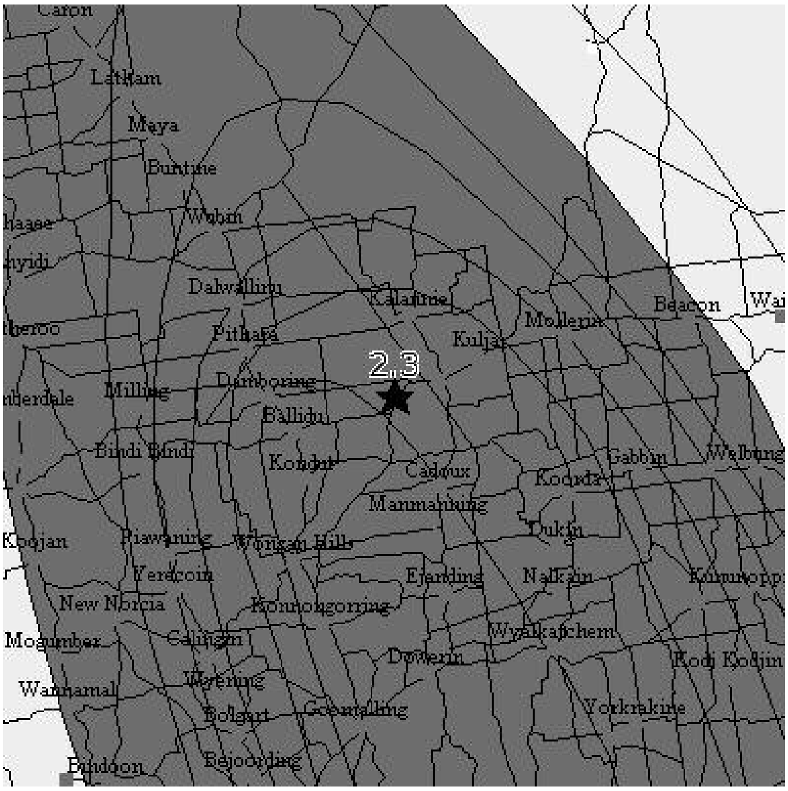


Fig. 4


From 0700 till 2100local 16 to 18may 03
P-H pulses/min
600
500
400
300
200
100
0
1
3
5
7
9
11
13
15
from 0700 local till 2100
16-May-03
17-May-03
18-May-03


Latham
Maya
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Kondut
Cadoux
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Gabbin
Manmanning
Dukin
Koojan
Piawaning
Wongan Hills
Yerecoin
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Mogumber
Calingiri
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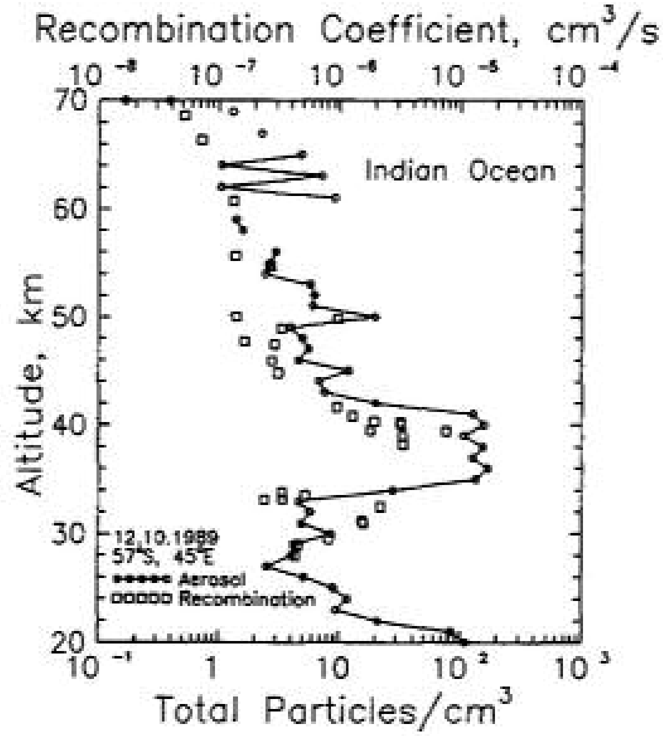
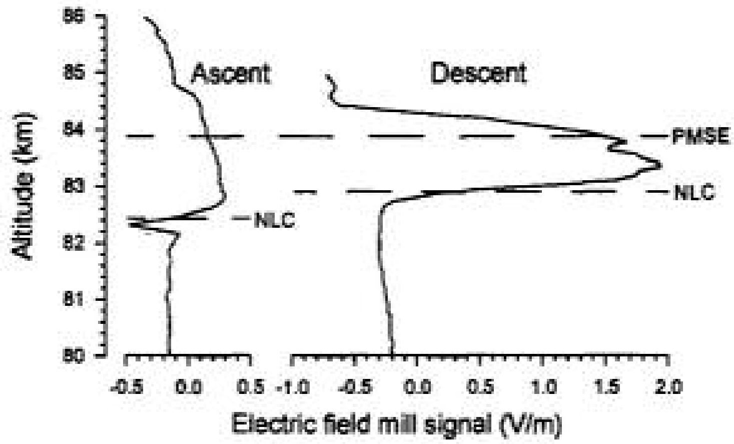
Fig. 5



The dust (aerosol) content and the ion-ion recombination coefficient derived from the rocket data. The rocket dust and ion measurements were carried out in an interval of about 1.5 h (Zadorozhny et al., 1994).



The vertical component of the electric field mill signal measured during the NLC-91 campaign (Zadorozhny et al., 1993). The dashed lines show where the peaks of the NLC and PMSE layers were detected.

Fig. 6

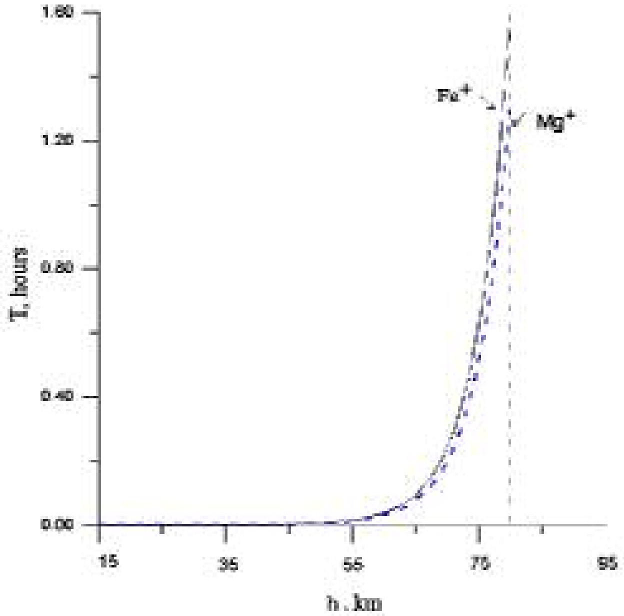


Fig. 7

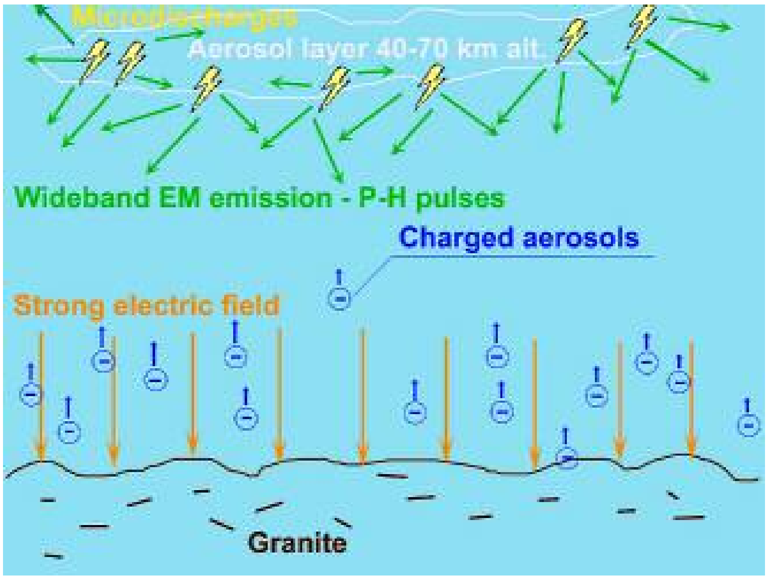

Microdischarges
Aerosol layer 40-70 km alt.
Wideband EM emission - P-H pulses
Charged aerosols
Strong electric field
Granite

Fig. 8

Figure captures

Figure 1. Western Australia map with indication of main seismically active area near Burakin (asterix) and receiving points positions (lily)

Figure 2. Latitude-longitude seismic activity distribution at Burakin area from 1966 up to March 2003

Figure 3. Schematic diagram of experimental setup for P-H pulses registration

Figure 4. P-H pulses examples: top panel – high temporal resolution showing the P-H pulses shape, middle panel – quiet seismic condition – low pulse rate, bottom panel – before earthquake, high pulse activity

Figure 5. Top panel – 3 consecutive daytime registrations of the P-H pulses repetition rate, bottom panel – area map with epicenter position of seismic shock registered on 17 of May 2003

Figure 6. Upper panel: aerosol content (points) and ion-ion recombination coefficient (squares) measured in rocket experiment in Indian ocean. Bottom panel: altitude position of the polar mesospheric summer echo traces (PMSE) and noctilucent clouds (NLC) – dashed lines and vertical component of the electric field measured in rocket experiment (from Zadorozhny, 2001)

Figure 7. Time versus altitude dependence calculated for Fe^+ (solid line) and Mg^+ (dashed line) ions rise by the strong vertical electric field.

Figure 8. Shematic presentation of the physical mechanism of P-H pulses generation.