Archaeoacoustic analysis of Kanda Hill in Macedonia

Study of the peculiar EM phenomena and audio frequency vibrations

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***Abstract* — Archaeoacoustic and Electromagnetic research of ancient sites is becoming an established discipline. SB Research Group (SBRG) have been developing a new methodology over the last five years using a practical archaeoacoustic standard (SBSA), which helps to explain certain phenomena which are commonly found at "sacred sites".**

Applying this expertise enabled better understanding of the specific EM and acoustic wave emissions present on Kanda Hill, Macedonia. Analyzing these emissions enables better understanding of what lies below the surface. The previous research paper (ARSA 2014) demonstrated evidence of various physical phenomena present at this ancient site and the artificial origin of this hill, which should now be reffered to as a tumulus. At the time of writing the presence of interior cavities in was suspected, possibly consisting of small number of chambers and passageways . This hypothesis is corroborated by the evidence presented in this paper.

Keywords- archaeoacoustics, geoglyph, EM waves

I. Introduction

Archaeoacoustics (the archeology of sound) is a discipline in its own right, but closely linked to archeology in that it can broaden an understanding of the properties of ancient structures. On a number of occasions it was discovered that certain "sacred sites" have specific acoustic and electromagnetic (EM) phenomena.

Through archaeoacoustical analysis it is possible to determine that there was almost certainly some knowledge of acoustic phenomena in the antiquity concerned, which could have been used for very specific and practical purposes. [2,3,4,5,6,7,8,9,10,11].

(*) Note. SB Research Group (SBRG) is an international interdisciplinary project, the team of researchers from (Italy, Croatia, Serbia, Macedonia, England and Finland) research the anthropology and archaeoacoustics of ancient sites and temples throughout Europe (www.sbresearchgoup.eu).

Figure 1. Kanda hill with the deep geoglyph carved on it (photo: survey SBRG)

In the vicinity of Sveti Nikole, Macedonia there is an egg-shaped ritual mound, referred to locally as a Geoglyph with dimensions of approximately 85 x 45 meters. This soil mound is perfectly oriented North-South and bears two oval frames containing a giant symbol/geoglyph which bears a striking resemblance to one of the undeciphered letters of the Mycenaean script known as Linear B. The whole structure, with its shape and symbolism, resembles that of a cosmic egg – the source of primordial creation [12]. This site was investigated over two week long missions, in March and July 2014 [8]. On both occasions very particular types of VLF (Very Low Frequency) radio waves were detected, which is a first, as they have not been detected at other ancient sites investigated by SBRG[2,3,4,5,7,9,10,11]. In the second mission (July 2014), these frequencies and their attenuation were utilised in an attempt to better understand` what lies below the surface. This paper provides the summary of observations and subsequent analysis.

II. Materials and Methods

The SB Research Group Standard for archaeoacoustics (SBSA) [5] , tested at several archaeological sites throughout Europe [2,3,4,5,7,8,9,10,11] , was used in this study.

Due to the fact that archaeological sites can be influenced by electro-magnetic pollution, EM monitoring devices were used to avoid anomalous results.

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The equipment used for investigating the vibrations coming from below the surface consisted of high-end audio recorders extending from the ultrasound to infrasound range with a maximum sampling rate of 192KHz (Tascam DR-680) or sampling rate of 96KHz (Tascam DR-100 and Zoom H4N equipment), 768kHz (Pettersson D1000x ultrasound recorder for bats) and Protools audio recording system. Use of gain control in recording devices is very delicate. In quiet places, the maximum possible gain for recording is used. In more noisy environments gain is determined with 0,775V/0dB AES/EBU standard.

The microphones used have a wide dynamic range and a flat frequency response (Sennheiser MKH 3020, frequency response of 10Hz - 50.000Hz) with shielded cables (Mogami Gold Edition XLR) and gold-plated connectors, Brüel & Kjaer 4006 cond. mics (frequency response 15Hz-30.000Hz) and Pettersson Bat detector´s mic (frequency response 5kHz-290kHz).

Figure 2. Placing the microphone outside the perimeter of the geoglyph

Ultrasensitive omnidirectional hydrophones (Aquarian H2a-XLR Hydrophone, with a frequency response from 10Hz to 100,000Hz) were used to accurately obtain any possible sound information from water sources. These act like an omnidirectional antenna capturing any sound from a wide underground area. This type of microphone has a wide frequency range and is used for submarine detection and by sea biologists listening to whales.

For ultrasounds a Pettersson Elektronik´s D1000x ultrasound detector with a 5kHz-295kHz audio recording range was used. This is a mobile professional device which directly transforms ultrasounds into audible sounds.

A 3D electromagnetic sensor and specially constructed "small" 300Ω sensor (Demiurg) were used to monitor the intensity and direction of electromagnetic waves. These sensors can detect all electromagnetic fields in the 5 – 90 kHz range. Sound vibrations were simultaneously recorded in real time to obtain coherent results. The 3D EM-sensors were always positioned in a north-south direction (X-angle). The graph on the computer screen shows 3 directions (X,Y,Z) of EM waves recorded from each sensor. The ear of an expereinced researcher can distinguish between sound vibrations that originate from different XYZ-sources via the headphones connected to the equipment. The graphic generated by Praat software indicates the direction of sound.

The mission of July 2014 lasted for one week, during this time, measuring equipment was placed within the Geoglyph perimeter for four days and was continuously monitored by different team members day and night.

Most of the equipment was placed under a shelter located on top of the mound to protect it from extreme heat. In order to measure the electromagnetic signal a modified and tested MOTU digital audio interface with eight recording inputs, powered by a car battery was used. This had to be recharged daily through use of a diesel generator.

Figure 3. Recordings using the MOTU interface.

Figure 4. MOTU interface showing cables connected to the sensors and Genelec speakers to “sonify” the EM signals and mechanical waves being reflected from the tumulus

Eight different types of sensors were connected to the MOTU interface, including microphones, hydrophones and a 3D sensor used in earlier research which can determine the direction of a range of signals. This is done to eliminate the possibility that these signals are not spurious signals (from for example a radio or TV station closely). However, with this method it was not possible to eliminate the source of the

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interference, which meant that the process of clearing the recordings had to be done in the studio.

Figure 5. The 3D sensors with a sensitivity of 300Ω used by SBRG during archaeoacoustical research. Built in Demiurg laboratories (Zagreb) by Slobodan Mizdrak, they transform electromagnetic impulses into electrical impulses which can be captured via digital recorder.

Pro Tools ver. 9.06 software for Mac was used to analyze the various recorded tracks, Praat open-source version 5.3.55 from the University of Amsterdam and Audacity open-source program version 2.0.2, both for Windows PC were also used. BatSound software from Pettersson Elektronik, Uppsala, Sweden was used for comparative analysis.

Before recording, a spectrum analyzer (Spectran NF-3010 Aaronia AG) was used to analyze the wide electromagnetic field for comparative calibration of the systems.

Equipment to capture the frequency range of electric and magnetic fields produced by telluric currents was also used: Teslameter TM 40 [H 50Hz, nT], a Trifield meter, 100XE [H, mG; E, V/m], a Digital multimeter Mastech MS8229 [T,o C; Hum, %; Noi, dBrel], a VF- Broadband amplifier, a Digital storage oscilloscope with FFT, 32 02A, 200 MHz, 1GSa/sec.

A. Groundloop measuring method developed by HSS Pro

This method utilizes a specifically designed resonating measurement system in which external electronic interferences are predefined, such as those coming from the switched-mode power supply or "*earth-link*" hum[1]. Essentially, the galvanic ground is connected to the electric ground of the measuring equipment to create a known measurable resonating feedback [1]. The system is designed to detect EM radiation and audio waves in the range 10Hz - 96kHz simultaneously.

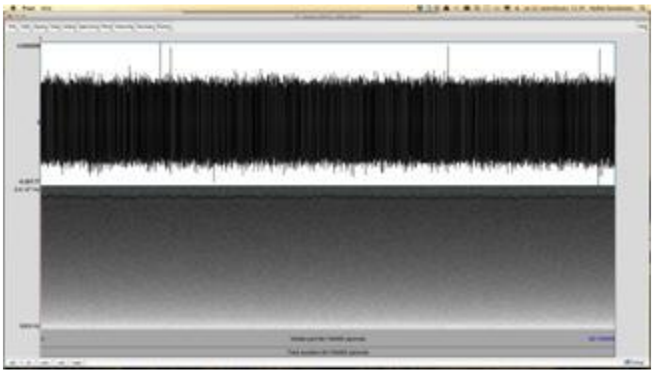

Figure 6a. Baseline 192kHz/16bit spectrum of the measuring system (viewed in Praat software).

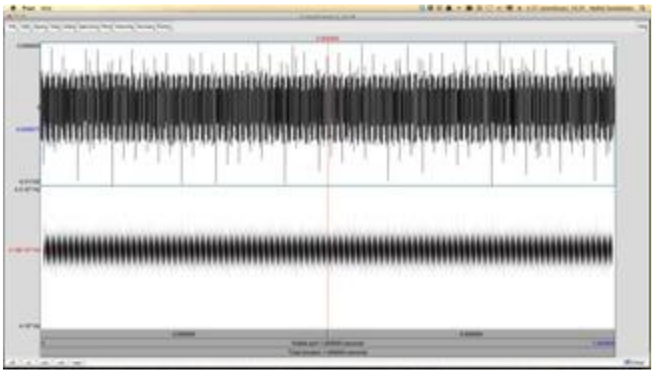

Figure 6b. Original ground loop signal spectrogram without any external interference ~42kHz. Measured using the Demiurg sensors near the field of the switch-mode power supply.

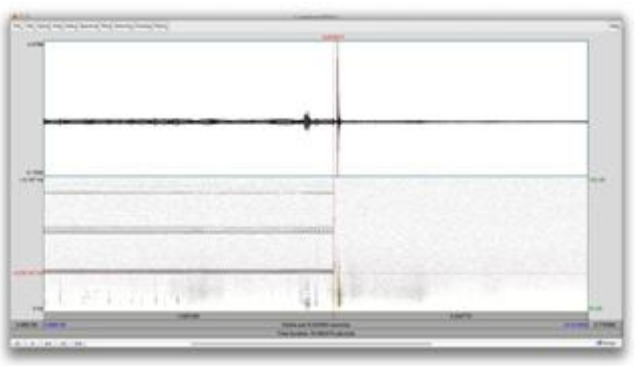

Figure 6c. Fluorescent lamp on/off atmosphere spectrogram with Demiurg sensor detection. While on, the lamp produces strong EM vibrations (left) that disappear when switched off (right). Audio above, EM field below.

B. Groundloop methodology

The nominal impedance of 300Ω for the EM-sensors was used because it is the most common impedance for audio microphones. In this system, EM sensors are connected to the digital audio interface´s preamplifier, which is mainly used with microphones. In a normal recording situation, the microphone membrane detects changes in air pressure, which are heard as mechanical sounds. In the Groundloop system, EM sensors are plugged into the preamp to detect EM radiation variations/oscillations, which move with the average speed of light and have wavelengths of 10-100km.

The Demiurg EM sensors are designed to measure the 5kHz-100Khz range (the very low frequency, VLF range).

The specifically designed 3D sensors geometrically placed on the X,Y,Z axes, produce 3 simultaneous data feeds which make it possible to define the direction of any originating oscillation/diffraction source. This is particularly important because this allows the approximate location and dimension of every echo anomaly to be detected [13]. Single Demiurg 300Ω sensors with hydrophones and B/K microphones were used with this method as in the SBSA standard. [5]

Groundloop in the audio field is considered to be a fault in the 220V electric system [1]. It means that the systems electronic grounding is in contact with the galvanic grounding which can produce a ground signal sinewave loop. It can also be heard as a base 50Hz "hum" sound with harmonics in the system (in the United States 60Hz).

In numerous tests carried out in Finland and the Balkans[2,5,8], SBRG found that this "hum" changes depending on the location of the EM sensor. If the EM sensor is moved around a certain perimeter, differences can be detected and heard through the headphones which are connected to the preamplifier, the effect is similar to touching the tip of an active audio jack.

By using this method, it was discovered it was possible to measure and explain various EM emissions that emanate from or pass through different underground layers and substrate materials. The detection and elimination of environmental interference caused by EM-pollution, such as fluorescent lamps, electric wiring, power supplies, transformers to name a few, has been refined over time. This baseline research knowledge was obtained by SBRG over five years through digital data recording, testing and developing the research equipment.

As for the different media and materials found below the Earth's surface; wet soil has for example, a different frequency spectrum, values and characteristics from dry soil. Solid soil produces different spectrum/values to soil full of holes. This enables the detection of and distinction between solid ground from empty areas, such as underground cavities and water streams. These results can be made audible using "data sonification" i.e. varispeeding the data from its original into the audible frequencies.

However, although this system is relatively reliable, it is not possible to obtain one hundred per cent accuracy at this stage. It would therefore be advisable to check any findings with established geophysical surveying instruments such as Ground Penetrating Radar (GPR).

III. RESULTS

The baseline 3D EM wave measurements alongside those with the infrasound and ultrasound waves was recorded with a sampling rate of 192Khz along the X-Y-Z axes in the frequency range of 10Hz - 96KHz. The same measurements were repeated on top of the Geoglyph shown in Figures 7, 8 and 9 in order to detect the differences and potential underground anomalies in the Geoglyph.

Figure 7. Comparative analysis. Bottom: Baseline X-angle EM spectrogram 700m north of Geoglyph mound. Top: same on top of the Geoglyph mound. The top results showed some interference & diffractions to the groundloop signal which are not found on the baseline results (Praat software).

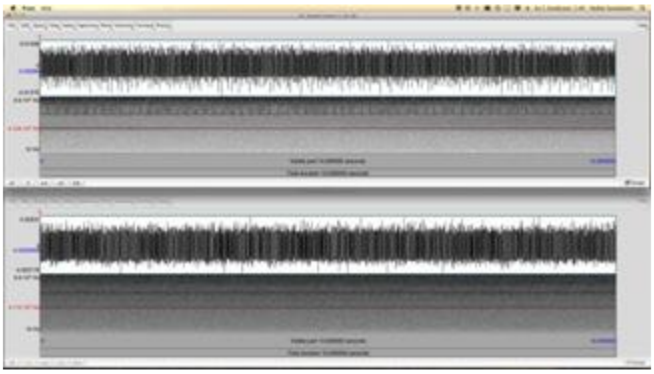

Figure 8. Comparative analysis. Bottom: baseline Y-angle EM spectrogram 700m north from the Geoglyph, above same on the top of the Geoglyph. Top results show some interference and diffractions to the groundloop signal which are not found on the baseline results (Praat software).

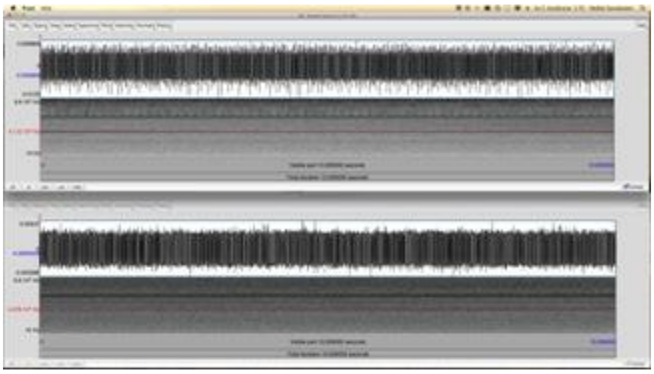

Figure 9. Comparative analysis. Bottom baseline Z-angle EM spectrogram 700m north of the Geoglyph, top same on the top of the Geoglyph. The top results showed some interference and diffractions to the groundloop signal that are not present in the baseline results (Praat software).

The baseline results that were taken outside the perimeter of the Geoglyph mound, did not show any anomalies or unusual behavior in the groundloop signals. In contrast, the same measurements taken on the top of the Geoglyph mound showed odd pulsing diffractions (see Fig. 7, 8 & 9) In order to obtain a clearer understanding of these results, a second set of baseline measurements was taken at Bylazora, an archeological site

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located 2.5 km from the Geoglyph, and were then repeated on the Geoglyph. The detailed results are shown in Figures 10a and 10b.

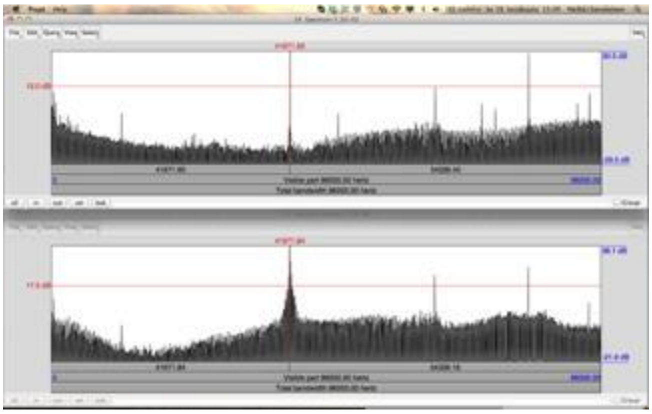

Figure 10a. Top Bylazora full range EM spectrogram, below the Geoglyph, the mound seems to amplify the groundloop signal (Praat software).

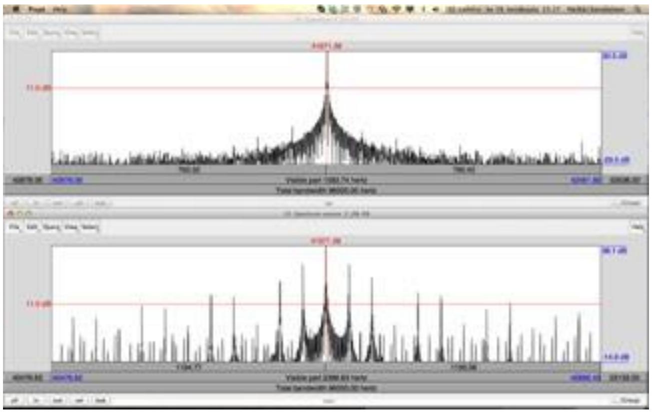

Figure 10b. Top Bylazora EM spectrogram zoomed in (42kHz peak). Bottom Geoglyph zoomed in scale. Visible part ~2kHz. Geoglyph seems to make harmonics of the ground loop signal.

As shown in Figures 10a and 10b the Geoglyph seems to effect the groundloop signal acting as some sort of divergent lens or antenna (cavity resonator).

The ground loop measurements were taken at the so-called entrance point to the Geoglyph (see figure 13). They show an anomalous result coherent with the Y-angle of the 3D measurements from the same spot. The data from the groundloop measurements are presented in Figures 11 and 12.

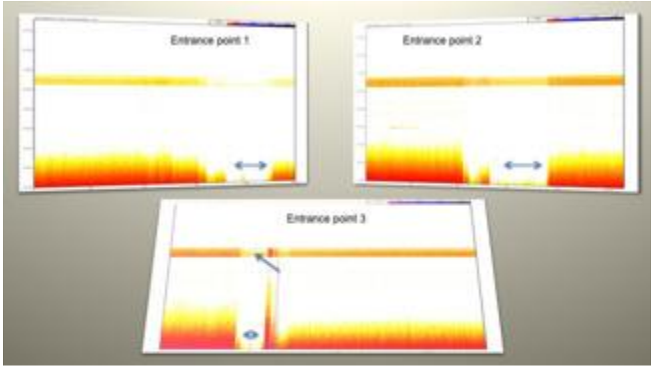

Figure 11. Small sensor data recorded while moving the directional small sensor above the presumed entrance point. The "hole" that's visible in the spectrums refers to a possible empty space (cavity) in the ground (x=frequency/Hz @ 192kHz sampling rate, y=time/secs). The same feature can be seen in the ~65kHz groundloop harmonic reference signal (BatSound software).

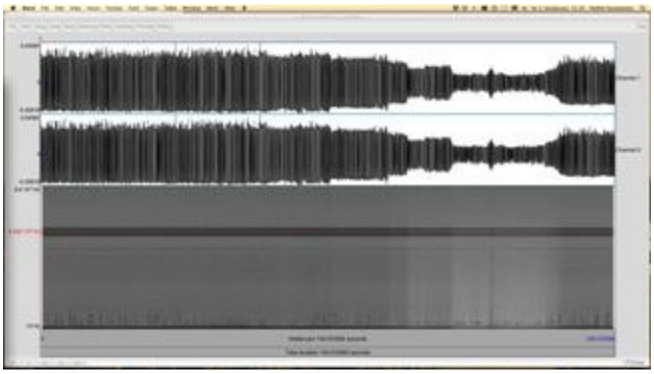

Figure 12. Possible cavity, 3D-Y-angle (vertical direction). Measurement area is the same as Fig. 11. Above sound pressure level dB/Hz vs time, Bottom frequency spectrogram produced with Praat software.

Figure 13. Data measuring points

In order to obtain a clearer understanding of the electric anomalies, a series of 'roundabout' measurements were taken around the Geoglyph using a mobile EM sensor and Tascam DR-680 digital recorder (with a 192kHz sampling rate). The main distinction between the groundloop and the roundabout measurements, is the power source. Without an external power source a ground loop reference signal you cannot be produced. In contrast, the Tascam recorder used for the roundabout measuring was battery operated, as a results there was no groundloop signal present (see Figures 14, 15 & 16).

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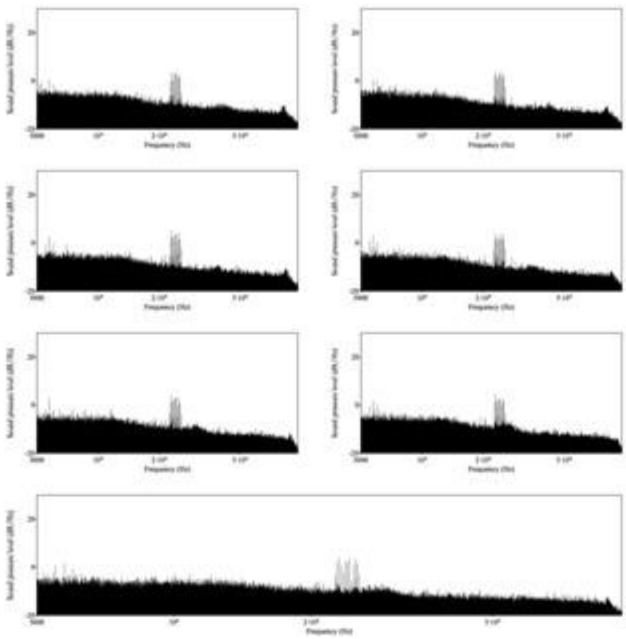

Figure 14. 7 EM measuring points samples (of 4 seconds each) around the Geoglyph perimeter, support the theory of a much larger cavity underneath. Similarities in these samples show that EM diffraction is not limited to a particular place on the Geoglyph.*(Praat software).*

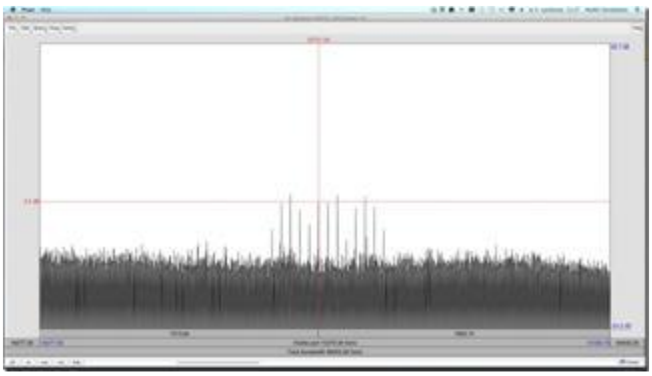

Figure.15. Zoomed spectrogram showing EM emissions ~23,7kHz all 'roundabout' samples had a similar appearance. This is not electrical interference from A/D conversion / anti-aliasing, -10dB peak / power supply / as equipment was battery operated. Visible part 15.3kHz (Praat software).

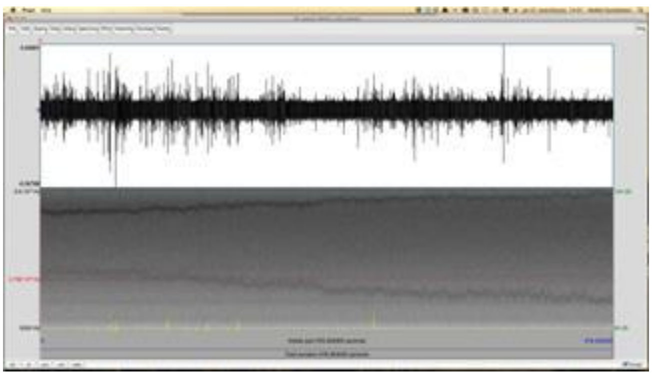

Figure 16. Time (576 secs) based frequency spectrogram from 'roundabout' measurements showing variations in EM radiation while moving around the geoglyph (Praat software).

On the 'roundabout' snapshot we can clearly spot the following emissions:

1) 23, 24 and 25 kHz, with stable frequency and amplitude,

2) Signal around 38 kHz (at 0 sec) with stable amplitude (intensity) with a frequency slowly increasing to 40.5 kHz (at 600 sec).

3) Frequency "package" 38-46 kHz /at 0 sec/ whose amplitude (strength) increases, while its frequency decreases to 20-28 kHz (at 600 sec),

4) Frequency package 78-86 kHz /at 0 sec./ whose amplitude (strength) decreases and the frequency increases up to 86-92 kHz (at 600 sec).

Signals 3 and 4 are mutually "inverse - opposite". One possible explanation is that the resonant frequency of the Demiurge sensor is around 30 kHz, and therefore offers an explanation as to why the amplitude of Signal 3 increases with decreasing frequency whereas the amplitude of Signal 4 decreases with increasing frequency.

The original groundloop signal, which is not visible here (should be a harmonic of ~ 62 kHz [(42 + 82) / 2], is the most likely the cause of the EM disturbance which the sensor registers during the 3rd and 4th emissions. Such large changes in frequency between these two sets of emissions are not typically to be known of technical origin. However, they are more typical of certain "natural" phenomena which appear at many "sacred" sites SBRG have taken measurements at.

The probe which was used to conduct groundloop measurements, is sensitive to both electric and magnetic EM emissions. However, other probes sensitive to only electric or magnetic emissions were also used.

Electric field spectrograms of recordings 37 and 38 show the presence of "E-field" signals with frequencies 17.5, 22, 23.5, 44, 32.5, 51, 80, 87.5 kHz.

Figure 17. Spectrogram of electric field. Sensor: rod antenna, l = 30 cm, 12.5 kHz/div F [kHz]: 6.2; 11.2; 15; **17.5**; 32.5; 51; 80; 87.5

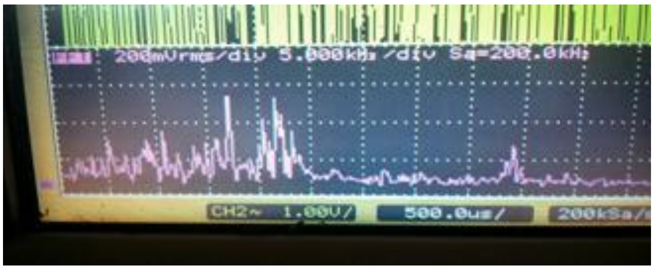

Figure 18. Spectrogram of electric field Sensor: rod antenna, l = 30 cm, 5 kHz/div F [kHz]: 5, 9; 10.5; 12,; 14, 15, 16, **17;** 20.5; **22**; 23.5; 44

All of them are visible in the 'roundabout' sample recordings. Spectrograms of the magnetic fields (see figures 19 and 20) indicate the presence of very strong magnetic emissions at 22.5, 45 and 87.5 kHz, which were also found in the 'roundabout' samples.

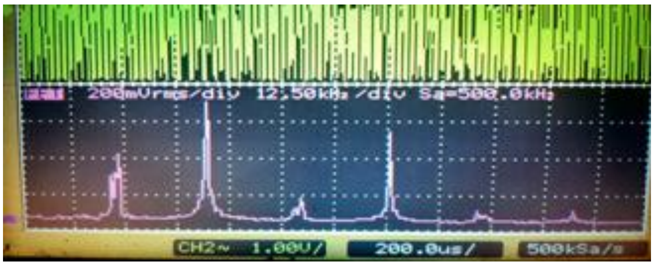

Figure 19. Sensor: open coil antenna, 12.5 kHz/div F [kHz]: 22.5; **45**; 67.5; **87.5**

Figure 20. Sensor: open coil antenna, 5 kHz/div F [kHz]: 16; 23; **44.5**;

A. *Utrasound (audio spectrums)*

Figure 21. Full range (384kHz) ultrasound spectrogram recorded on top of the Geoglyph (using a Pettersson D1000x bat detector). Typical natural sounds including insects exceed 50kHz, no ultrasound anomalies. Sampling rate 768kHz/16bit. Visible part 80 secs. Praat software.

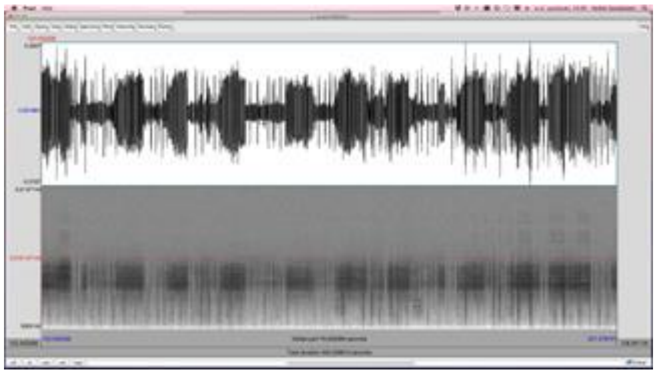

Figure 22. Zoomed (96kHz) ultrasound spectrogram recorded on top of the geoglyph (using a Pettersson D1000x bat detector). Typical natural sounds including insects exceed 50kHz. There are no ultrasound anomalies. Sampling rate 768kHz/16bit. Visible part 80 secs. Praat software.

B. *Infrasound (audio spectrums)*

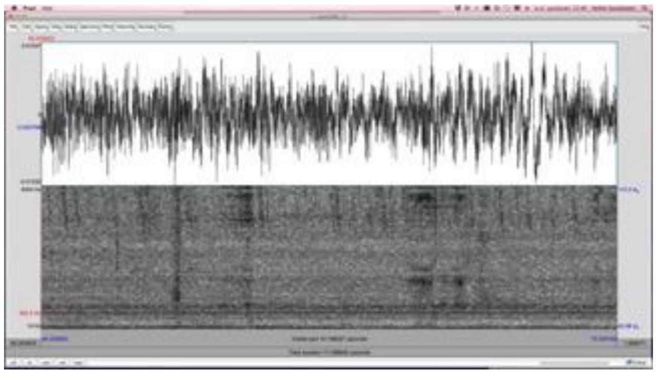

Figure 23. Zoomed (4kHz) infrasound spectrogram on top of the Geoglyph recorded with Brüel & Kjaer 4006 condenser microphone. There is a continuous vibration of around 462Hz which is not usually found in a natural environment. Sampling rate 192kHz/16bit. Visible part 10 secs.

C. *Some notes*

At the end of the results, it is important to resume some peculiarity just cleared in previous paper [8]. Our research of mechanical vibrations gave very interesting results. Throughout the circumference of the geoglyph, a strong subsonic vibration of approximately 16Hz is present, with a peak range between 15Hz and 17Hz. The infrasound is constant with some slight variations of volume depending on the time of day or night, the later was found to be just a little stronger.

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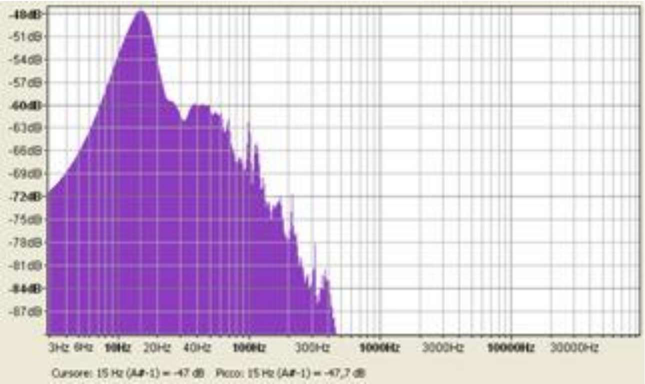

Figure 24. The aspect of infrasound recorded during the night on the hill inside the geoglyph (the other peaks at higher frequencies are normal environment noise).

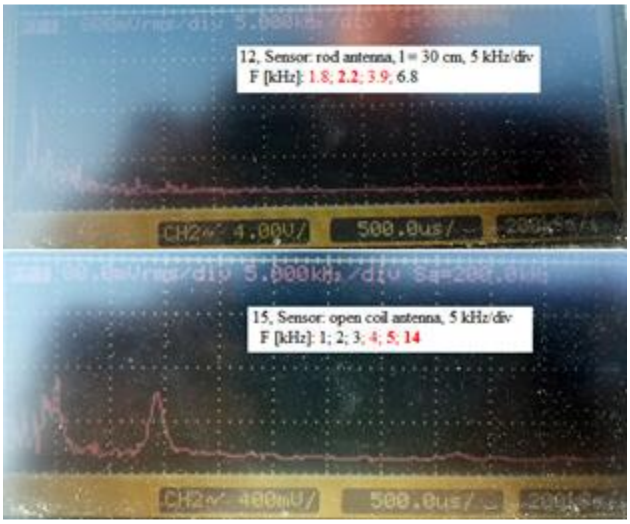

Figure 25. Images of measurements indicating a water flow and a cavity below the geoglyph (photo: survey SBRG)

On some samples on position Nord-East we measured a maximum energy point out on 20 July 2014 at 17:40 hrs (figure 25) and observed a significant non-correlation in the area of 1 to 14 kHz. The significant 'E' and 'H' frequency spectrum content difference is a sign of the lack of coherence between the Electric and Magnetic components of the field, which clearly indicates the presence of a longitudinal waves, i.e. subtle-energy flows on the site [8].

Figure 26. Signals in the range from 2 to 16 kHz with shape that are extremely peculiar and are correlated with the presence of water flow (photo: survey SBRG)

However, as water flows always "follow" important sacral facilities - which provide feeding/recharge energy for that natural or human made -"machines" providing the possibility to create "spatial standing waves" and the constitution of specific scalar fields - the presence of water flow indirectly confirms the importance and significance of this site.

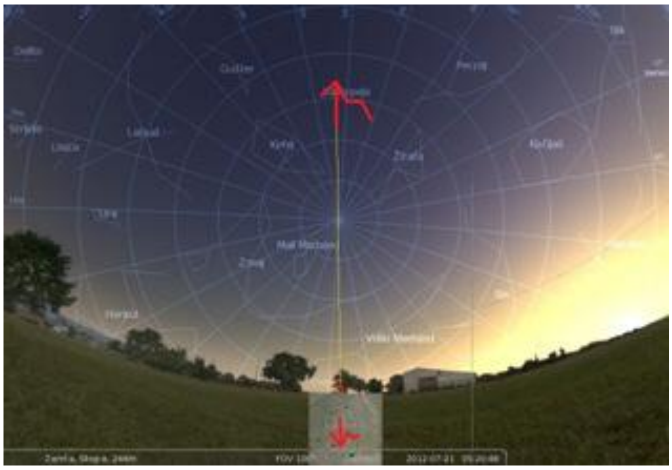

Figure 27. Celestial-earthly mirror: As above so below. Geoglyph shaped like cosmic egg reflecting the celestial picture and the sunrise of White Dawn of Leo. The moment and symbolism coincides with the birthday of Alexander the Great.

IV. Discussion

The EM baseline shows normal environmental EM emissions commonly found in natural environments: these are characterized by randomness, lots of static, radio stations, military communication, a lack of harmonics and EM carrier waves.

When the baseline results are compared with the measurements from the Geoglyph, a heavy dispersion of the original signals is found. The EM spectrum values indicate a high probability that there is some sort of resonant cavity or artificial structure below The scalar wave harmonics that effect the measured signals, suggest the geoglyph acts as some kind of a resonator or reflector. Equally it is possible that there could be several cavities in the Geoglyph. Is it possible that the cavities could be geologic, for example some sort of underground stream? We suppose this is not possible because in the previous paper we demonstrated the different composition of the hill soil respect the surrounding area by UV aerographical analysis. So we concluded that the hill is totally artificial, made by landfill [8]. Because these cavities look to be placed not so deeply, but standing far away from a simple speculation, we could suppose that a building complex could be built there and after was covered by the soil.

Strong and emphasized magnetic components of the recorded emissions also indicate the presence of a longitudinal electro-dynamic vibration (standing waves) within the Geoglyph interior. This points to high probability that resonant cavities (regularly shaped structures) exist within the interior of the Geoglyph. So the infrasound vibrations could indicate the existence of an underground water stream, deeper than the cavities complex.

But it is obvious this is only a hypothesis and we need to confirm the hypothesis by a further step of research using a Ground Penetrating Radar (GPR).

V. Conclusions

Also in this paper, as in the previous paper on the Geoglyph in Kanda [8], these extensive archaeoacoustic methods can inform archaeology due to the non destructive methods employed, in relatively short timescales. It could be considered as an initial approach to study a new or unrecognized archaeological site to discern if there is something below the surface or not, using natural electromagnetism or environmental vibration. Respect digging (stratigraphy) is not costly in terms of time and expense. A small group of people with a limited number of devices can analyze a such as this very quickly.

As stated in the previous paper [8], the Geoglyph almost certainly has some form of resonance cavity. Only more detailed surveying with geophysical equipment can help determine if the structure is artificial or not. Let's not forget, not far from this site is Virgina, modern name of the ancient city of Aigai, where in this place was found the complex of the tomb of king Philip II. The royal tombs were discovered in 1977-8 by the archaeologist Manolis Andronikos. The characteristics of the artificial hill, the cavities placed and the symbol located over, so precious for Macedonian's kings could suggest that an important member of the Macedonian king's family could be buried here.

Figure 28. The tumulus of Philip II in Virginia, Greece (photo: UNESCO)

However, in order to be more certain and before any interior mapping is carried out, a detailed survey should be conducted with suitable geophysical survey equipment such as Ground Penetrating Radar (GPR) or geophone to confirm the presence of some cavities below the surface. The geophone is a device used by geologists to identify different shapes of layers and the presence of natural caves by measuring soil vibrations. Only after this stage is completed, should any excavations or test pits be done after carried out.

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