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RESEARCH ARTICLE

INFRASOUND SOURCE AND CALIBRATION METHODS IN SEISMIC INTERPRETATION

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Abstract

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Worldwide research and recordings discovered that low-frequency acoustic waves are inaudible sound, travels around the globe up to four times with modernization of data analytics and infrasound sensor network systems. Seismic interpretation is a critical process in subsurface exploration with infrasound sensor network systems. The evolution aims at identifying structures or environments of significant importance in various applications. Study in this paper attempts to understand behaviour of infrasounds and determine measurable procedures with digital microbarometer . Furthermore, this will be a key practice for understanding and calibration mechanisms , characterization of the infrasound sensors.

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Introduction:-

Acoustics is the physics of sound, including all of the multiphysics disciplines concerned with the production, transmission and detection of the sound signal. Human ear is sensitive to sounds of frequency lying between 20 and 20,000 cycles per second. The sound less than 20 Hz are called infrasonics or infrasound and more than 20,000 are called ultrasonics. The definition of sound also includes the propagation in media other than air. Additional analysis of the worldwide recordings revealed that these low-frequency acoustic waves, i.e., inaudible sound, travelled around the globe up to four times with modernization of data analytics and systems.

This could be elastic waves in solids (vibrations) pressure waves in liquids, like underwater acoustics or the combined propagation in porous materials (poroelastic waves). Numerous natural and anthropogenic sources emit infrasound, sound at frequencies below human hearing (< 20 Hz) and Known sources include severe storms [1,2], Explosions or rocket launches [3,4,5,6], earthquakes [7,8,9], ocean waves [10] and volcanoes [11] .

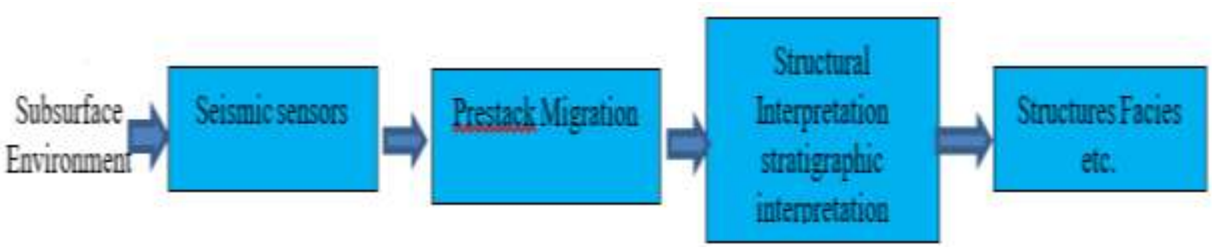

Fig 1:- Seismic interpretation.

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Figure 1 explains seismic interpretation many image processing theories and algorithms which are commonly employed in many scenario . The fast progress in MEMS technology and statistical signal processing as well as related areas of neural network, machine learning and computer vision provides higher level of automation in seismic interpretation. The spatial distribution of infrasonic sensing systems may vary from meters to kilometers.

In the remainder of this paper , Section II focus on wave motion . Section III introduces emerging a standardized methods for estimating the energy, or intensity, of an observed infrasonic pressure signature with substantial energy below 20 Hz. Section IV discusses data acquisition system for infrasound sensor. Section V concludes the review and provides recommendations for further research and actions.

Progressive wave motion and attenuation

The propagation of acoustic wave through a material medium is analyzed with wave equations.For the wave propagation medium must posses three important properties like elasticity, inertia and small frictional resistance. Elasticity may tend to recover its position or condition on being disturbed ,inertia may able to store up energy. The waves can be propagating, standing, or a combination of both. Wave crests are the pressure maxima, while the troughs represent the pressure minima. The particle velocity in the case of a plane progressive wave is known as the speed of sound . Its value is related to the compressibility β_s and the density ρ of the material in which the waves propagate, by $c = \sqrt{\frac{1}{(\beta s \rho)}}$. The speed of sound in air is about 343 m/s and 1485 m/s in water. The precise value depends on ambient temperature and pressure, as well as other variables. Earth's complex atmosphere and diverse topography conspire against linearity which leaves the more interesting problem of quantifying how the source energy spectrum is repartitioned along the propagation path to the receive[12] .

BASICS OF Sound measurements

One of the most fundamental acoustic measurements is pressure amplitude . Since acoustic signals can span over 12 orders of magnitude in sound intensity, it is useful to adopt the SPL logarithmic scale. For humans, sound is best understood as the sensation, as detected by the ear, of very small speedy changes in the acoustic pressure **p** above and below a static value. This static value is the atmospheric pressure which is about 100,000 pascals at sea level. The amplitude of the small pressure variations that can be detected by the human ear vary from roughly $20 \cdot 10^{-6}$ Pa at the hearing threshold to 600 Pa for jet engine noise. The amplitude at normal speech levels is about 0.02 Pa. The values described here are often given on the logarithmic decibel scale, relative to the hearing threshold of $20 \cdot 10^{-6}$ Pa (or 20 µPa), in units of dB SPL. The logarithmic scale follows naturally from how the human auditory system experiences loudness.SPL logarithmic scale for root- mean-square (rms) pressure prms is

$$SPL = 10log_{10}\left[\frac{p_{rms}^2}{p_{ref}^2}\right] = 20log_{10}\left[\frac{p\_{rms}}{p_{ref}}\right] \quad \square\square\square$$

Where

$$p_{rms}^2 = \langle p^2 \rangle = \frac{1}{T_s}\int_0^{T_s} p^2\,(t)dt$$

and pref = 20 µPa is the reference rms pressure, p is the acoustic pressure time series over a specified frequency band, and Ts is the signal duration or the chosen time interval for integration. Root-mean-square pressure (prms) estimates are robust when the acoustic signal is stationary, so that its statistical properties do not change substantially over the period of integration.

Noise free data can never be realized in the laboratory because some types of noise arise from thermodynamic and quantum effects that are impossible to avoid in measurement. It is important for the analyst who uses a particular instrumental method to be aware of the sources of noise and the instrument components used to minimize this noise because noise determines both the accuracy and detection limits of any measurement. Noise enters a measurement system from environmental sources external to the measurement system FIG 2. or it appears as a result of fundamental, intrinsic properties of the system. It is usually possible to identify the sources of environmental noise and to either reduce or avoid their effects on the measurement. Such is not the case with fundamental noise because it arises from the discontinuous nature of matter and energy. Thus, fundamental noise ultimately limits accuracy, precision. and detection limits in every measurement. To avoid losing data ,according to the equal energy principle, the effect of a combination of noise events is related to the combined sound energy of those events. Thus, measures such as the equivalent continuous sound pressure level (LAeq,T) sum up the total energy over some time period (T) and give a level equivalent to the average sound energy over that period. Such average levels are usually based on integration of A-weighted levels. Thus LAeq,T is the average energy equivalent level of the A-weighted sound over a period T.

The signal to noise ratio is a representative marker it that is used in describing the quality of an analytical method or the performance of an measuring instrument. The magnitude of signal to noise is conveniently defined as the standard deviation, s, of numerous measurements of the signal strength, and the signal is given by the mean, X, of the measurements. Thus, S/N is given by:

S/N = Mean/Standard Deviation = X/s.

It is often desired to measure the maximum level (LAmax) of individual noise events. For cases such as the noise from a single passing vehicle, LAmax values should be measured using the *Fast* response time because it will give a good correlation with the integration of loudness by our hearing system. However, for very short-duration impulsive sounds it is often desirable to measure the instantaneous peak amplitude to assess potential hearing-damage risk. If actual instantaneous pressure cannot be determined, then a time-integrated level with a time constant of no more than 0.05 ms should be used (ISO 1987b). Such peak readings are often made using the C- (or linear) frequency weightings.

Alternatively, discrete sound events can be evaluated in terms of their A-weighted sound exposure level . The total amount of sound energy in a particular event is assessed by the SEL. One can add up the SEL values of individual events to calculate a LAeq,T over some time period, T, of interest. In some cases the SEL may provide more consistent evaluations of individual noise events because they are derived from the complete history of the event and not just one maximum value. However, A-weighted SEL measurements have been shown to be inadequate for assessing the (perceived) loudness of complex impulsive sounds, such as those from large and small weapons [13]. In contrast, C-weighted SEL values have been found useful for rating impulsive sounds such as gun shots.

Parseval's Theorem provides a relationship for the variance and the power spectral density (PSD) of a digital pressure signal [13], with units of Pa2/Hz. The PSD can be readily computed by the FFT over a finite time window and provides an estimate of the mean squared acoustic pressure per frequency band in the time window. The decibel unit for PSD is dB relative to (20 μPa)2/Hz, which is referred to as the spectral level. A spectrogram is a time-stepping PSD, and is useful for interpreting time-varying signals. To convert spectral levels to sound pressure levels, a particular frequency band has to be defined. Suppose the unilateral PSD of a signal has al-ready been calculated [14]. The SPL in a frequency band Δf12 can be estimated from the PSD P(f) from:

$$p_{rms}^{2}(\Delta f_{12}) = \int_{f_1}^{f_2} p(f)df \qquad (2)$$

$$SPL(\Delta f_{12}) = 10log_{10}\left[\frac{\int_{f_1}^{f_2} p(f)df}{p_{ref}^{2}}\right] \qquad (3)$$

If P(f) is very slowly varying or nearly constant over a fractional octave band, we can estimate the sound pressure level on band n from

$$SPL(f_{cn}) = 10log_{10}P(f_{cn}) + 10log_{10}P(\Delta f_n) + 94dB \qquad (4)$$

where f_{cn} is the center frequency, Δf_n is the bandwidth of the nth frequency band and pref = 20 μPa (−94 dB) is the reference rms pressure

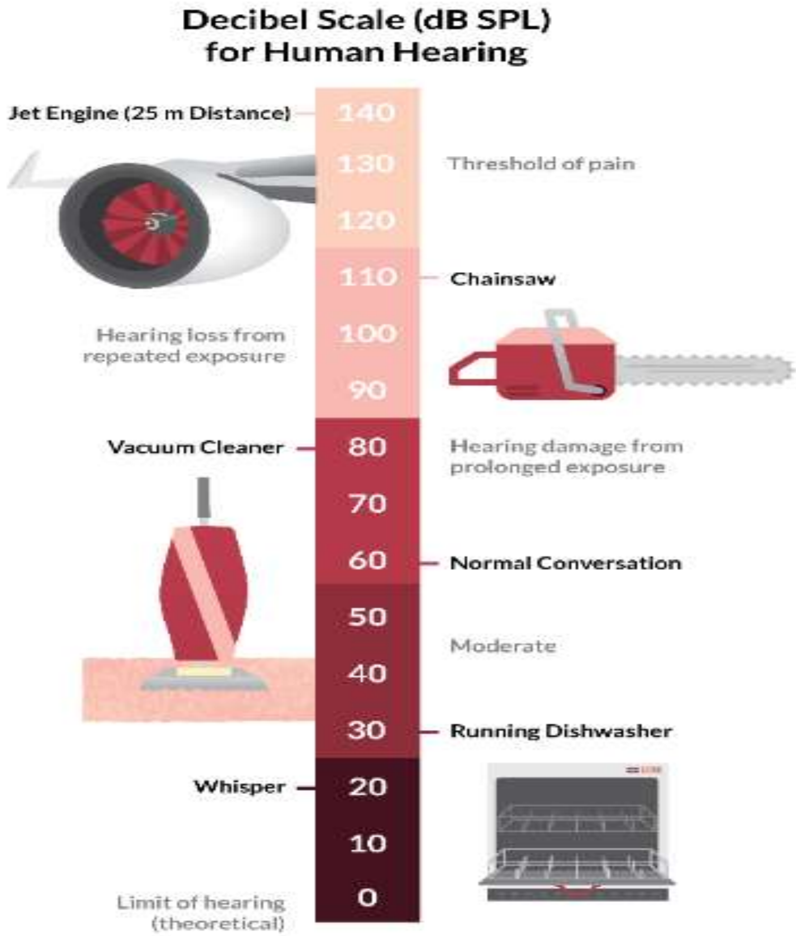

Fig. 2:- A decibel scale that illustrates the sound pressure level associated with different situations.[15].

Data Acquisition System For The Ifrasound Sensor
Infrasound Sensors



Fig 3 a:- (NCPA ANALOG SENSOR). **Fig 3.b:-** NCPA digital sensor.

NCPA (National Center for Physical Acoustics) Infrasound sensorsoperates in the range 0.01 Hz- 500 Hz and sensitivity = 150 mV/Pa Seismic sensitivity 1 m/s2 less than 0.04 Pa equivalent signal in seismically decoupled version and highly ruggedized. Approximate 750 mW power consumption, and can drive very long cable lengths (at least 500-m).

The 5113/A infrasound sensor is a new revision of the 5000 series intended to meet the infrasound application requirements for use in the International Monitoring System (IMS) of the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO). The Chaparral 50A infrasound sensor developed by the Geophysical Institute of the

University of Alaska is an example of a capacitor transducer used for IMS purposes. In recent years, improvements upon legacy infrasound sensors have resulted in digital versions. These newer generations perform analog-to-digital conversion of the transducer electrical output inside the sensor itself, meaning the digitizer (acquisition unit) is embedded and not externally connected to the sensor with wiring[16] .Examples of these digital sensors include the MB3 digital microbarometer(MB3d), which includes a digitizing block attached to the analog transducer block, and the Hyperion model 5200 series.

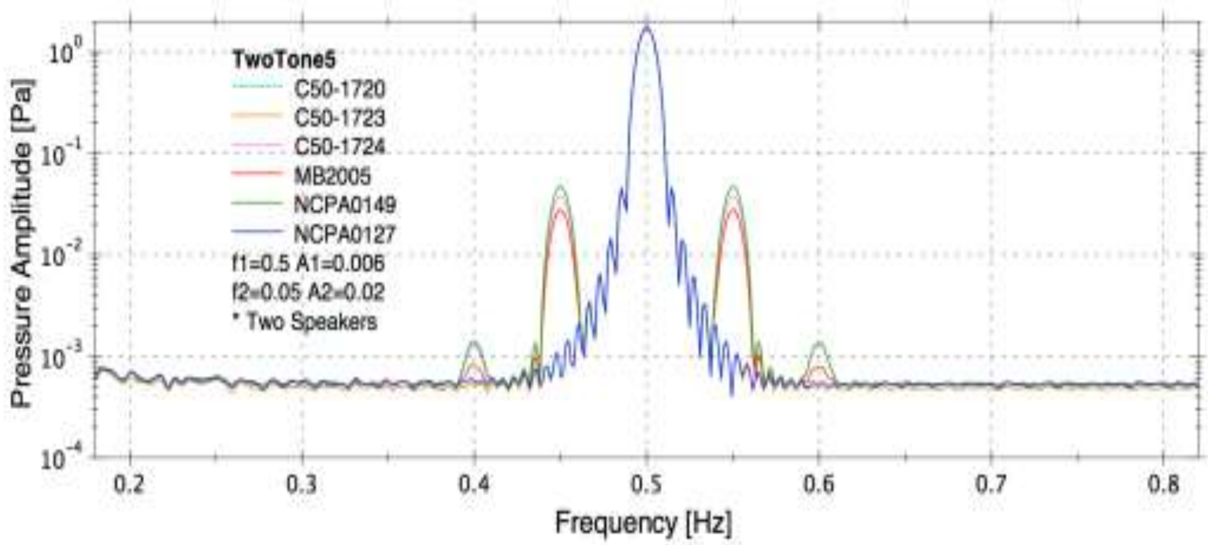

Fig 5:- Comparison of two-tone measurements.

Calibration Of Infrasound Sensors

The calibration of infrasound sensors against their predecessors is crucial to the modernization of conventional technologies. This section describes the characterization of the infrasound sensors and measurement parameters. The Several references sensors are usually used throughout the infrasound microphone test. Main parameters like isolation noise ,dynamic range, dynamic noise and amplitude and phase responses of the microphones are included in the calibration method. The purpose of the isolation noise test is to provide an environment that is free from the influence of atmospheric background, allowing for the evaluation of the sensors electronics and transducer noise under conditions of minimal excitation. The purpose of the dynamic range test is to determine the ratio between the largest and smallest possible signals that may be observed on the sensor. Normally dynamic range is defined as the ratio between the RMS of a full-scale sinusoid at the calibration frequency, typically 1 Hz, and the RMS noise present in the self-noise of the sensor across an application pass band.The purpose of the dynamic noise test is to evaluate the sensors' electronics and transducer noise under conditions of significant excitation as shown in Fig (5) [14].An MB2000 SN 1380 was co-located within the isolation chamber to provide a reference measurement for the testing of the 5113/A sensors.[17]. A Vaisala PTU300 SN D1050016 temperature and pressure sensor was recorded to provide a record of the ambient conditions throughout the testing[18] . The sensitivities of the 5113/A sensors were observed to be between 0.1377 and 0.1393 V/Pa. The observed power consumption of the Hyperion 5113/A was between 1.407 W and 1.602 W at 13.24 V.The stated power consumption from the sensor specifications was 1.5 W. The 5113/A noise, the Bowman Low Noise Model (LNM), the IMS requirement, and a noise model provided by Hyperion.[19].

C Outdoor Installation And Wind Screen Protection.

A fundamental difficulty in the detection of outdoor infrasound is the so-called "wind noise" problem. Because of ever-present wind-generated turbulence, the atmosphere is inherently noisy at frequencies of interest (typically between 0.1 and 20 Hz). Accordingly, effective wind screening is vital to the success of outdoor infrasonic measurements. Past methods of screening a microphone from the wind include a piped array, a barrier, or an open-mesh (e.g., cloth or foam enclosure). Over the years, researchers at NASA Langley have developed and field tested different types of compact and structurally sound windscreens [20,21].The windscreen principle is based on the high penetrating capability of infrasound through barriers, which is dependent upon the acoustic impedance ratio (wall-to-air) and wall thickness

The principle of the windscreen is based on the great penetrating capability of infrasound through matter. The sound power transmission coefficient from medium 1 to medium 2 is

$$|T| = \frac{1}{cos^2x+\frac{1}{4}\left[\frac{z2}{z_1}+\frac{z1}{z2}\right]^2 sin^2x} \quad (5)$$

Where

$$x = \frac{2\pi fW}{c_2}$$

and f is the frequency, W the wall thickness, z_1 the acoustic impedance of air, z_2 the acoustic impedance of the wall material, and c_2 the speed of sound in the wall.[22]

Conclusion:-

In many research the sensorarrays are located within a seismic zone and it is possible for identification local infrasonic arrivals.Meteorological data should also be collected to support in the understanding of the acoustic propagation. Data from each of the arrays are telemetered in near-real-time to the near by monitoring station where they will be processed and archived.With the available meteorological data, sound propagation can be modeled in the linear acoustic approximation.Any future active source experiments, whether the explosion is on the surface or grossly overburied, should deploy both seismic and acoustic technologies.The deep learning algorithms have become incredibly good at analyzing and identifying pieces of objects from massive data and should not only effectively reject the white noise but also identify the migration artifacts contained in the seismic data.

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