Infrasound & The Paranormal

STP / Para.Science.

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Introduction

Infrasound, is generally considered as audio frequency energy that lies below the range of normal human hearing, typically 20 Hz (Leventhall, Pelmear & Benton, 2003). Ambient Infrasound within the environment is produced by both natural & man-made sources. Natural sources include weather related effects i.e. wind & storms; surf & wave action, volcanic eruptions & upper atmospheric phenomena i.e. the jet stream & meteors (e.g.von Gierke & Parker, 1976; Gossard & Hooke,1975). Man-made infrasound is associated with vehicles & aircraft, machinery & the interactions of weather on buildings & other structures (Blazier, 1981; Stubbs, 2005). Ambient infrasound levels from natural and man-made causes are variable in intensity and there has to date only been a limited number of measurements of ambient environmental infrasound (e.g. Bruel & Olesen, 1973). It is however clear from the few studies and the authors own unpublished survey of ambient infrasound levels at more than 30 locations in the UK that ambient infrasound if often to be found at levels of 50-80dBS in rural locations and frequently exceeds 90 or 100dBS in suburban areas and close to industry & major transport routes. Bruel & Olesen showed that the amount of infrasound rose markedly as a result of increased weather (particularly wind) interactions with structures, a finding that the author also noted in his own measurements. Because of the low frequencies and long wavelengths of infrasound it is capable of travelling long distances with little attenuation. A consequence of the nature of infrasound is that even sources which produce sound energy across the entire sound frequency spectrum will result in much of the infrasound energy being apparent at considerable distances. The infrasound shockwave or sonic boom from Concorde travelling between London & New York have been measured at up to 75dBS in the North of Sweden (Berglund et al, 1996). The infrasound from volcanic & other seismic events can be recorded as it travels around the Earth numerous times losing only a few percent of its total energy on each circuit (Backteman et al, 1983). It is therefore clear that infrasound is not only present at almost every location but it is also present at considerable amplitudes, although it is largely undetectable by normal hearing and un-measurable by the majority of available sound level measuring equipment. In 1975, Westin noted in his review paper dealing with the effects of infrasound on man (Westin, 1975) that the amounts of natural & man-made infrasound that man is subjected to is larger than is generally realised & that few studies have concerned themselves with the physiological effects of moderate-to-high levels of infrasound exposure.

In the past decade, infrasound has captured the attention of paranormal investigators. This interest follows studies that have postulated a causal link between infrasound energy & the appearance of apparitions (*e.g.* Tandy & Lawrence, 1998). Although not the first to link infrasound with paranormal experiences Vic Tandy proposed that exposure to infrasound close to 19Hz was key in the production of psycho-physiological experiences that were subjectively reported as being paranormal in their origin (Tandy & Lawrence, 1998). As a result of Tandy's research, paranormal investigators have taken a keen interest in Infrasound. Tandy's suggestion was based upon existing studies carried out on behalf of the United States space programme & military weapons research (Altmann,1999). These research programmes were set up to study the physiological & psychological effects of infrasound exposure on astronauts and military personnel. Experiments used high infrasound exposure levels (150dBS-170dBS); much higher than would be expected to be found in homes, industry or from environmental sources.

Secrecy surrounding lethal & non lethal acoustic weapons development & the documented effects of exposure to high levels of infrasound has resulted in periodic dramatic & even alarmist claims being made in the media about its effects:

The Silent Sound Menaces Drivers – Daily Mirror, 19th October 1969

Brain Tumours 'caused by noise' – The Times, 29th September 1973

The Silent Killer All Around Us – London Evening News, 25th May 1974

Partly as a result of these claims, infrasound began to develop a popular mythology & was blamed for many ailments & misfortunes for which no other explanation was forthcoming. These have included brain tumours, cot death & road accidents (Tempest, 1971). In 1973, Dr. Lyall Watson published 'Supernature. A natural history of the supernatural' in which he repeated a series of claims originally made by weapon scientist Vladimir Gavreau including; "That in an experiment with infrasonic generators, all the windows were broken within a half mile of the test site" Later adding "That two infrasonic generators focussed on a point five miles away produce a resonance that can knock a building down as effectively as a major earthquake" (Watson, 1973). Gavreau's original claims (Gavreau,1966) have never been substantiated & have been disputed by many subsequent researchers. However, these sometimes extraordinary & frequently misleading claims about the physical & physiological effects of infrasound, combined with a general lack of research into the effects of exposure to both naturally occurring & man-made infrasound have permitted some to perpetuate & develop the idea that infrasound is the cause of many paranormal experiences (Fielding & O'Keeffe, 2006).

Many paranormalists have developed their own theories & explanations of the relationship between infrasound & the paranormal. Some however, are simply bizarre & appear to be the work of a creative rather than a logical mind. On their internet site one well known paranormal group present the following; "Infrasound is caused by ghosts & spirits as they use electromagnetic energy to move things or materialise, just as lightning which is moving energy creates thunder which is infrasound, this can be recorded & used to prove that spirits are present." (Reference withheld). Another respected team of investigators claim to have recorded many infrasonic EVP's (electronic voice phenomena) using handheld digital dictation recorders. (Reference withheld). The use of equipment that is completely incapable of recording or measuring infrasound, together with a generally poor understanding of the original work by Tandy & a lack of knowledge in making infrasound measurements has not prevented investigators presenting their investigation findings in terms of fact & proof by their exponents. This has further lead to a general & gross misunderstanding of any actual relationship between infrasound & paranormal experiences & accounts.

It is necessary that the reader is familiar with the basic principles of sound & terminology of sound & infrasound measurement. Therefore this report will examine some of the physical properties of low frequency sound & consider techniques to detect & measure infrasound. Furthermore, it will consider the perception of infrasound & the psycho-physiological effects of infrasound exposure & examine links to reports of anomalous & paranormal experiences.

1. The physics of sound

Our most common experience of sound is in air, but sound is able to travel through any solid, liquid or gaseous medium. Sound is normally produced by anything that is vibrating & causing the surrounding molecules to vibrate in sympathy with the source. These vibrations travel in the form of a wave which can be defined as a travelling disturbance consisting of coordinated vibrations that transmit energy with no net movement of matter (Ostdiek & Bord, 2000).

Sound waves take the form of alternating compression & rarefaction; this is known as a longitudinal wave. In air, sound waves travelling past a fixed point cause the atmospheric pressure to vary slightly above & below the steady barometric pressure.

1.1 Wavelength, frequency & velocity

The distance between any two corresponding points on successive waves is termed the wavelength. Frequency is the number of successive waves that are emitted from the source in one second. Frequency is stated in units of Hertz (Hz) i.e. 100 wavelengths per second are expressed as 100Hz. In air, under normal conditions, sound waves travel at about 342 metres per second (m/s). In air the velocity of sound varies slightly with the air temperature (Talbot-Smith, 1994). In materials that have a higher molecular density, sound waves will have a higher velocity. For Example:

Water	1480m/s
Glass	5200m/s
Steel	5000 - 5900m/s; depending on the composition of the metal.
Helium Gas	965m/s

Wavelength, velocity & frequency are linked by a simple mathematical formula:

wavelength = velocity divided by frequency.

Using this formula we are able to determine the wavelength for any given frequency i.e. in air, for a frequency of 20Hz & a temperature of 18º C.

The wavelength is therefore: 342.043 / 20 = 17.10 metres.

The same formula allows the calculation of frequency,

frequency = velocity divided by wavelength

The frequency is therefore: 342.043 / 17.10 = 20Hz

1.2 Units of measurement used for sound

Sound waves are oscillations in atmospheric pressure & their amplitudes are proportional to the change in pressure during one oscillation. There are several ways of expressing the amplitude or intensity of sound waves. However, it is commonly expressed as sound pressure. In scientific terms this is defined as the force acting on a unit area. Thus sound pressure waves are normally given as Newtons per square metre (N/m^2). More recently, it has become the official practice to refer to the N/m^2 as the Pascal (Pa). The sound pressure variations that are detectable by a typical human ear are immense. For example, the quietest sound that can be detected by a normal human ear has a sound pressure level (SPL) of 0.00002 Pascal (Pa) & the loudest an SPL of around 200 Pa. In order to simplify the expression of sound pressure levels the decibel (dB) is more commonly used. This is a unit of comparison & thus it must be stated against a reference value to be meaningful. Formally expressed, the number of dB represents a ratio of two powers using the formula dB = 10 log (power ratio). As stated; the human ear at its most sensitive is generally accepted to be able to detect a SPL of 0.00002 Pa referred to as 0dB; this is the reference value against which all comparisons of SPL are expressed.

This standard allows any sound pressure to be quoted as (x) dB above that pressure & is expressed as dB(SPL) or more often simply dBS. Thus; a sound 10 times more powerful than the reference SPL is expressed as 10dBS. A sound 100 times more powerful than the reference is 20dBS. A sound 1,000 times more powerful than the reference is 30dBS etc. An SPL of 140dB (200 Pa) which is 100,000,000,000,000 more powerful than the reference will cause rapid ear damage & aural pain

1.3 Infrasound

In physical terms infrasound is simply sound that has a frequency that is considered to be below the threshold of normal human hearing. It may be described using the same physical definitions.

1.4 Sound waves & structures

Sound waves are absorbed, reflected or diffracted by obstacles in their path. Absorption or reflection of a sound wave reduces the amount of energy it is able to transmit. This will reduce the loudness of subsequent sounds & will also cause an attenuation of the distance that the sound waves can travel. For reflection of the sound waves to occur, the wavelength must be smaller than the dimensions of the reflecting object. For example, if the side of a building is 10m high & 20m long, the dimensions of the building, both in length & height will have an appreciable effect upon the reflection of sounds with wavelengths of less than 10m. This corresponds to frequencies of around 34Hz. Thus sounds above that frequency will be more easily reflected. If sound waves with a lower frequency & correspondingly longer wavelength encounter the same obstacle they will not be reflected but will instead bend around the obstacle, a process called diffraction. If the wavelength is much greater than the obstacle size then there will be marked bending around the obstacle. At infrasonic frequencies the wavelengths are considerable, & therefore very little of the infrasound wave energy is reflected. Absorption of the infrasound wave may also be significantly lower than audible sounds. Therefore infrasound waves are able to travel greater distances from the source without significant attenuation; in air infrasound may be detectable over tens or even hundreds of kilometres & even further through liquid or solid media (Mihan House, 2005)

Acoustic pressure waves reflected & refracted by the structure of a building from infrasound sources such as machinery & vehicles both surrounding & within it, may combine with naturally produced infrasound from wind & weather interactions upon the structure, thus creating regions within the building that have significantly higher & lower levels of infrasound. Such regions may be highly localised & dependent upon the actual acoustic wave / structural interactions. The dimensions, shape & construction materials of a building together with the frequency & amplitude of the infrasound; are all factors that will affect the local levels of infrasound & must be considered. If the infrasound is produced by weather & other natural sources of infrasound these too must be acknowledged. Local infrasound levels will vary over time due to variations in the ambient infrasound sources; natural or man-made, & the resultant change in their structural interactions.

When measuring infrasound within any location a single measuring point will rarely produce an accurate overall result for that location. When measuring human infrasonic exposure, the measurements should be made as close as possible to the position of the percipient as a difference of just a few feet can create a significant difference of the SPL in the local infrasound levels (Para.Science, 2007).

2. Hearing & the perception of low frequency sound

The human ear has a generally quoted frequency range from about 20Hz to around 20,000Hz. However, it has been demonstrated that acoustic stimuli with frequencies as low as 1Hz can not only be heard, but also can de described in terms of loudness (Yeowart et al, 1967).

The actual mechanisms of infrasound detection are not fully understood but is has been suggested that at very low frequencies detection does not occur through hearing in the normal sense. Rather, detection results from nonlinearities of conduction within the middle & inner ear, created as the vibrations pass through body tissues of different densities such as bone & soft tissue, which have different sound conduction properties. This generates harmonic distortion in the higher, more easily audible frequency range (von Gierke & Nixon, 1976). Infrasound waves may also be detected through skeletal bones, bones within the ear, resonance within organs & body cavities & tactile senses (Job, 1993). The inability of most people to 'hear' infrasound means that its effects upon a person are largely unexpected and therefore more likely to be blamed upon other causes and in some instances where the percipient is in a haunted location or involved in the pursuit of ghost hunting such effects are frequently blamed upon a paranormal agent or cause.

2.1 Low frequency hearing thresholds

Although infrasound is normally defined as audio frequency energy that lies below the range of normal hearing, a number of studies have been conducted for the purposes of determining the lowest sound levels which are audible to the average person with normal hearing (Corso, 1958; Lydolf & Moller, 1997; Moller & Andresen, 1984; Watanabe & Moller, 1990). From these studies the average low frequency thresholds can be established (fig. 1):

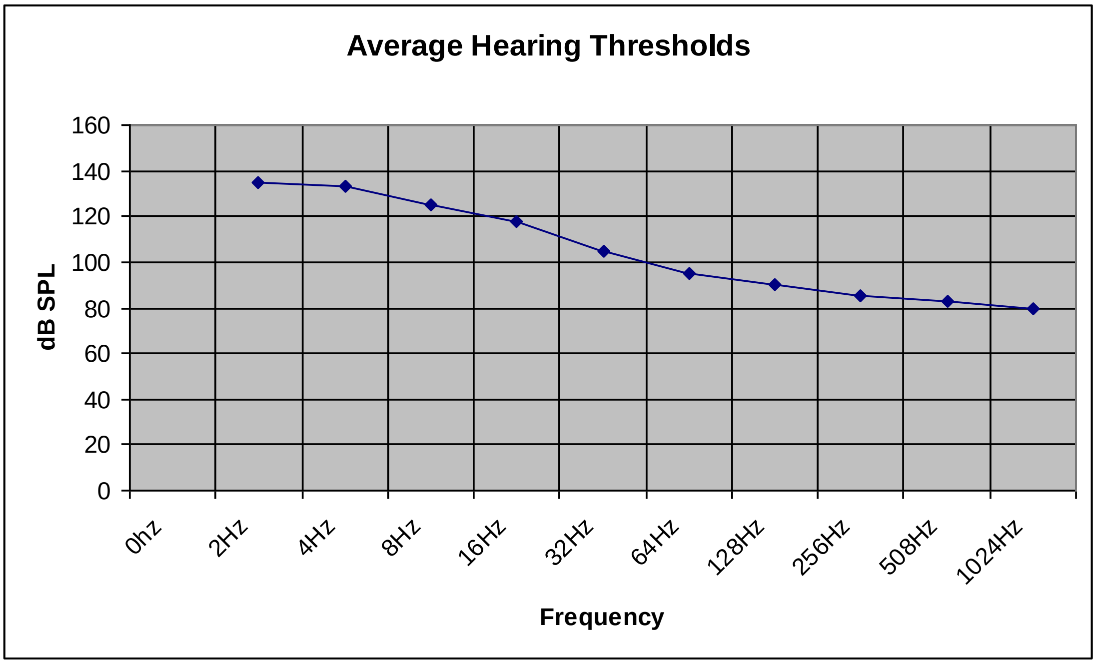

Figure 1. Low frequency Hearing Thresholds.

Thus, using Fig. 1, it can be seen that an average person might be expected to hear a sound with a frequency of 16Hz when the sound pressure exceeds 120dB(SPL) & a sound of 4Hz at a sound pressure exceeding 130dB(SPL). Simply stated, it is perfectly possible for an average person to hear infrasound provided the amplitude is sufficiently high.

2.2 Individual hearing thresholds

The threshold levels described are an average over groups of people. An individual’s threshold may vary considerably from these values. Frost (1987) compared two subjects over a range of frequencies from 20Hz to 120Hz. At 40Hz one individual was 15dB more sensitive that the second. Yamada (1980) reported female thresholds to be around 3dB more sensitive than male thresholds except at the lowest frequencies, below 16Hz.

It was also found that individual differences could be large. In one case, a male subject had a hearing threshold which was 15dB more sensitive than the average. Thus an individual's ability to hear sound, including infrasound will be dependent upon their actual hearing threshold.

2.3 Perception of low frequency sound & infrasound

The function of the auditory system is the perception of objects & events through the sounds they make (Masterton, 1992). The physical dimensions of sound are usually expressed in experiments using perceptual terms, The amplitude, frequency & complexity of the sound vibrations are perceived as loudness, pitch & timbre respectively.

The relationship between the acoustic signals & perception has been tested although the research has concentrated on speech & language i.e. Lisker & Abramson (1970). Studies looking at low frequency & infrasound have mainly been concerned with predicting loudness or annoyance & for the establishment of safe exposure limits (Challis et al 1978: Fields, 2001). The research so far has concentrated on using very high sound pressure levels to establish safe exposure limits e.g. Jerger et al (1966). There is currently no comparable research that has provided data for normal exposures. Data is also not available to indicate the infrasonic sound pressure levels that might normally be expected to be found in the general environment.

In psychophysical terms, the perceived loudness of a pure tone grows as a power function with sound pressure (Stevens, 1975). Goldstein (1994), showed that for a low frequency tone of 20Hz, a doubling in the perceived loudness is achieved with only a 4-5dB increase in SPL for the low frequency tone whereas the SPL of a higher frequency tone of 1,000Hz (1kHz) would need to be increased by 9-10dB to achieve the same perceived doubling in loudness. Pitch discrimination is also affected by low frequency sound. At 25Hz, the ability to discriminate pitch is about three times worse than for sounds at 63Hz (Usher, 1977). The ability to determine from which direction a sound is coming from, known as the Haas Effect is also seriously impaired. Low frequencies can travel great distances without substantial attenuation & can easily penetrate many buildings & structures. Directionality may also be affected by the way low frequency ‘hearing’ involves multiple structures within the body rather than just the ears.

The ability of an individual to perceive infrasound is also affected by the presence of other ambient within the audible frequency range i.e. above 20Hz. The audible sounds having a tendency to mask or reduce the threshold of perception of infrasound by between 6 & 12dB (Yasunao et al, 2009).

2.4 Psychological & Physiological effects of infrasound.

A number of studies have been conducted to study the psychological & physiological effects of infrasound on individuals e.g. Chen & Hanmin (2004) & Moller (1984). Such studies have used a range of pure infrasound tones at high sound pressure levels to examine the effects of infrasound exposure upon subjects.

Individuals subjected to infrasound at high SPL's reported feeling uncomfortable, ear pressure, headaches, tiredness & feeling 'troubled'(Moller, 1984). Karpova et al. reported effects on the cardiovascular & respiratory systems, producing changes within the heart rate, blood pressure & respiratory rate. Although the effects of infrasound exposure have been objectively demonstrated, the results obtained from these experiments have shown highly variable effects with different individuals experiencing different responses to the infrasound exposure (Chen & Hanmin, 2004). Infrasound exposure has also been reported to include effects on the inner ear, leading to vertigo & imbalance; intolerable sensations, incapacitation, disorientation, nausea & vomiting (Hansen, 2007). Subjects exposed to infrasound at 5Hz & 10Hz with levels of 100dB-135dB reported feelings of fatigue, apathy & depression, pressure in the ears, a loss of concentration, drowsiness & vibrations of the internal organs (Karpova et al, 1970). In a study of airline pilots Lidstrom (1978) found that long-term exposure to infrasound of 14Hz-16Hz at levels around 125dB caused decreased alertness, a faster decrease in the electrical resistance of the skin & an alteration in time perception. Other researchers have reported that infrasound exposure produced sensations of apprehension, visual effects, nausea & dizziness (Stephens, 1969) also, depression, fatigue & headaches (Gavreau, 1968). Gavreau (1968) further observed that ordinary man-made sources of infrasound including fans & defective air conditioners etc may produce similar effects.

Anecdotally, there are very many people who report adverse physiological & psychological effects which they claim results from exposure to man-made infrasound. In response to a series of articles (anon, 1977) about the possible dangers of low frequency noise The Sunday Mirror received over 700 letters from readers describing a wide range of adverse health & psychological effects they were blamed on low frequency sounds. These include; severe headaches, nausea, palpitations, dizziness & extreme fatigue. Also reported were visual hallucinations, disturbed sleep, nightmares & suicidal thoughts.

From the various studies of the biological effects it would appear that exposure effects to infrasound may be variable. Studies carried out using animals have reported adverse effects from exposure to infrasound. Male rats exposed to prolonged infrasound at 8Hz at 125dB showed constriction to all parts of the blood vessels in the conjunctiva of the eye after 5 days (Svidovyl & Kuklina, 1985). Infrasound was suggested to influence a rats pituitary adrenal-cortical system as a stressor at SPL's beginning between 100dB & 120dB at a frequency of 16Hz (Nishimura et al., 1987).

3. Measuring low frequency sound & Infrasound

A number of techniques are available to detect & measure low frequency sound & infrasound. At the lowest frequencies i.e. below 1.5Hz, seismometers are normally used for measuring infrasound in the form of structural vibration from tectonic sources such as earthquakes & volcanoes (Garces et al, 1998) & man-made mining explosions (Hegarty et al, 1999). Micro-barometers are preferred for the detection & measurement of infrasound transmitted through the air. These devices are highly accurate & were originally developed for the detection of infrasound generated by atomic bomb tests. They have also been used for the study of meteors, thunderstorms & weather related phenomena mainly in the range 0.1Hz – 5Hz (McKisic, 1997).

For higher infrasound frequencies typically those above 5Hz then microphone based measuring systems are commonly employed such as the *Bruel & Kjaer Type 2209* sound level meter. This meter employs a microphone that is sensitive to 1Hz & can be connected to a Fast Fourier Transform (FFT) analyser such as the *Zonic AND type 3525* to allow spectrum analysis measurements to be made. Many of these systems have been developed to allow environmental noise measurement to be made & the measurements are weighted using electronic filtering in order to replicate as closely as possible normal thresholds of human hearing. This has lead to the development of a series of filters optimised to cover a range of different environmental & acoustic conditions. The most commonly used is the 'A' filter which is designed for general environmental monitoring. However, a major drawback of the A weighting scale is that it underestimates the importance of frequencies below 100Hz (Berglund et al, 1996). Alternative weighting filters have been developed for specialist measurement of sounds having a significant low frequency component, these include the 'C' filter which is recommended for artillery noise (Schomer, 1981) and 'D' filter which is used for aircraft noise measurement. Both of these commonly used filters are based on hand-extrapolations into the lower frequencies & are not based upon empirical low frequency data (Goldstein, 1994). The best noise weighting for infrasound remains to be settled but Bullen et al. (1991) found that equal energy units sometimes called Zero or 'Z' weighting has often provided the most effective predictor for community reaction to infrasound. Such environmental monitoring systems are expensive. Additionally, there is not yet a single standard for the measurement of environmental low frequency sound & infrasound, which can result in difficulties when trying to make comparisons between existing studies.

3.1 Acoustic Research Infrasound Detector

With the advent of powerful personal computers it is now possible to perform measurement & analysis of these low frequency sounds using a laptop computer & suitable software. Microphones that can operate effectively down to as low as 1Hz remain almost prohibitively expensive but it has been possible to adapt existing loudspeaker technology to construct a microphone that will respond accurately at very low frequencies. This concept has been the basis for the author's Infrasound measuring system known as the Acoustic Research Infrasound Detector (ARID). ARID used the principle that a loudspeaker is in effect a microphone operating in reverse. By modifying a pair of large diameter loudspeakers they can be used as large microphones sensitive to frequencies below 1Hz. Signal processing is then carried out using a laptop PC with adapted available FFT spectrum analysis software (Parsons & O'Keeffe, 2008)

Early trials with ARID proved that the concept worked well in practise although the first system was bulky to transport & occasionally excessively prone to structural vibrations being picked up via the stands. The biggest drawback with the ARID system was however a lack of any accepted calibration standard & whilst there was a strong confidence in the resultant data, it was felt that an improved system could be developed. Continued work has resulted in a new system although it is still referred to using the same acronym i.e. ARID 2. This new system replaces the earlier 'loudspeaker' microphones with a pair of 1" diameter dual-diaphragm air pressure transducers housed in modified microphone cases together with an improved Analogue to Digital (D/A) converter & modified software.

The use of microphone cases means that commercial anti-vibration mounts for the transducers can be used thus reducing structural vibration noise affecting the measurements. Improvements to the D/A converter, fully balanced & shielded cables & the improved software has resulted in lower instrument noise levels & therefore improved data sampling & quality. Data sampling can be obtained continuously or at any user selected interval from 1second to 23h & 59m. The biggest advantage the new system offers is that it has been possible to calibrate the data to current (ANSI [1]) sound measurement standards.

Environmental sound measuring equipment is normally designed to measure the peak sound pressure level (Lpeak) or an equalised value (Leq) over a selected period of time. Sudden (impulse) high acoustic pressure sounds; for example the sudden closing of a door, footsteps & wind gusts may cause erroneous high infrasound measurements. Measurement errors can also be caused by short duration & transient events such as passing vehicles or the operation of machinery. In order to minimise any measuring errors resulting from such sounds, measurement of low frequency sound should be made over a period of several minutes or more (DIN: 4560, 1997). ARID measurements are obtained over a 15 minute period which gives an Leq result that should remove measurement errors caused by impulse & transient events.

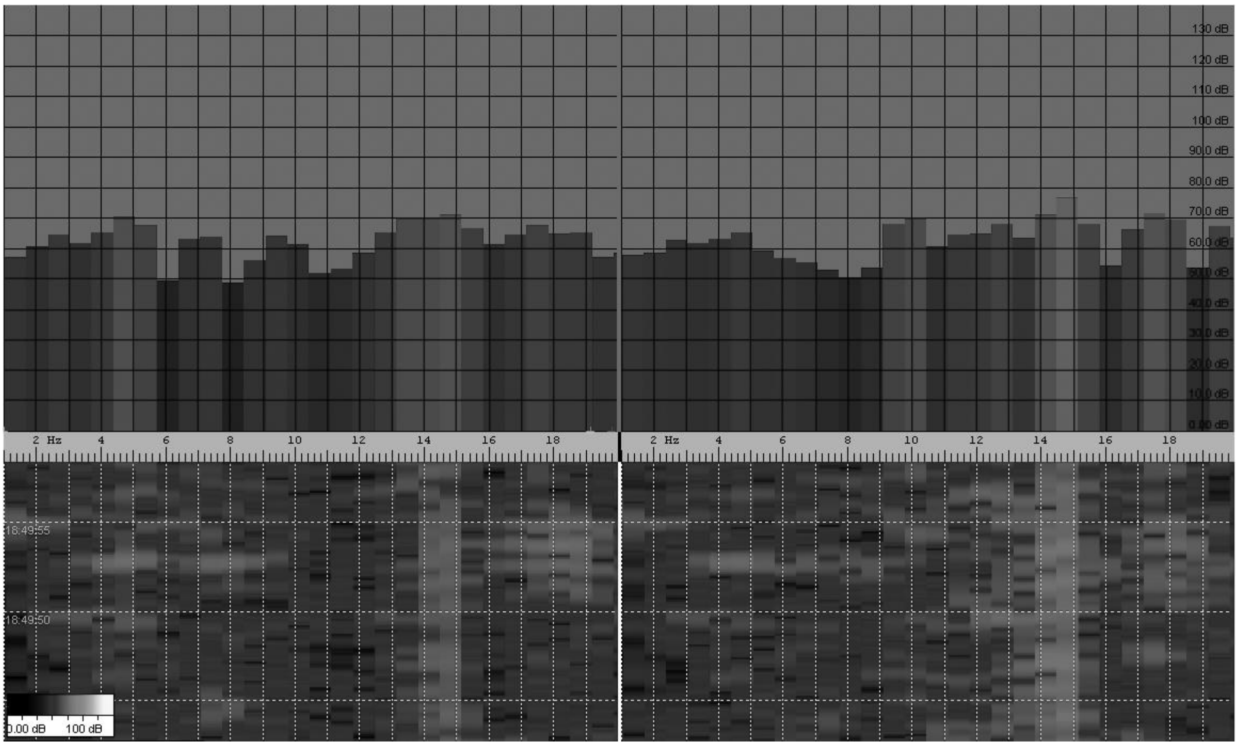

Figure 2. Typical ARID infrasound data screenshot - 0.1Hz-20Hz. 0dBS-130dBS.

4. Infrasound & the paranormal

4.1 Historical links

Early investigators of the paranormal & supernatural recognised that vibrations were a component in some reported haunt & poltergeist cases. Harry Price for example included a bowl of mercury in his personal ghost hunting kit for the detection of tremors in a room or passage (Price, 1974 p31). Price was also aware of the ability of certain notes & sounds to cause a sympathetic vibration in other objects. For example, he observed that in one case a particular pealing of nearby church bells caused the wires of a piano in a haunted house to vibrate in sympathy leading to the residents reporting that ghostly music was at times being played by unseen hands (Price, 1974 p38).

Earlier researchers of psychical reports also noted that sound vibrations played a mysterious part in the production of psychic phenomena (Fodor & Lodge, 1933). None of the early investigators directly mention infrasound as the concept of low frequency sounds existing below the normal human hearing range did not gain general scientific recognition until the

1940s. We now know that low frequency structural & airborne vibrations are produced by & also result from, infrasonic acoustic energy. In an experiment that was set-up to examine vibrations & jolts associated with poltergeist activity Gauld & Cornell (1979) used a powerful mechanical vibrator attached to a group of abandoned houses that were scheduled for demolition. This created powerful vibrations throughout the structure of the building & could be set to vibrate at frequencies between 45Hz & 120Hz. The aim of the experiments was to test the claim that geophysical forces might be responsible for some aspects of poltergeist activity. The experiment would also have produced large amounts of infrasound within the building as the various structures were vibrated by the powerful machinery.

The investigators did not report any anomalous physiological or psychological experiences during any of these experiments & confined their reporting of results to observed physical effects upon the structure.

The first direct claim of a possible causal link between infrasound exposure & reported anomalous experiences was made by Persinger (1974). He stated that "Although little public data has been available for comparison with reports of paranormal experiences. Infrasound, however, is an excellent candidate for at least some types of precognitive experiences. Weak infrasound energy from ambient sources could evoke vague responses & lead to reports of feelings of foreboding, depression of impending doom ahead of natural phenomena such as earthquakes or storms" (Persinger, 1974). Any potential link between infrasound & paranormal experiences was not explored for many years, possibly due to the perceived technical difficulties in properly measuring infrasound energy within a haunt location & the lack of data relating to levels of ambient infrasound within the environment.

4.2 The development of a case for infrasound & the paranormal

Paranormal interest increased followed the publication by Tandy & Lawrence (1998) of their infrasound hypothesis. They suggested a causal role for infrasound in some instances of haunt phenomena & apparitions. The initial suggestion was based upon the observed effects on a metal sword blade & the anecdotal reports of paranormal experiences within the same location. The source of the infrasound was traced by trial & error to a defective fan within the haunted workplace. The actual frequency & amplitude of the infrasound was never directly measured but was estimated from the authors personal experiences, mathematical calculations & the observation of the effects (Tandy & Lawrence, 1998). The authors also noted similarities in psycho-physiological effects reported by workers exposed to low frequency fan noise originally reported by Tempest (1976). A key suggestion of this research was that infrasound at a specific frequency range (around 19Hz) was causing eyeball vibration & leading to visual effects that might be interpreted as apparitional encounters. Tandy later conducted a series of infrasound measurements in a 14^{th} Century cellar beneath a tourist information centre in Coventry (Tandy, 2000). In this experiment objective measurements of the ambient infrasound were made using contemporary environmental monitoring equipment. He observed that a frequency of 19Hz was present within the location. The results confirmed his earlier hypothesis that infrasound close to previously suggested 19Hz range was responsible for the reporting of anomalous experiences by some visitors to the location. Tandy's infrasound hypothesis was quickly picked up by the media & the paranormal community & seems to have been the catalyst for the claims now being made for infrasound involvement in paranormal cases.

Without exception infrasound exposure studies carried by non paranormal investigators have been for the purposes of trying to establish if there are any adverse human health or performance implications in people who are exposed to infrasound in the workplace. These studies have predominantly used pure tone infrasound at high or very high amplitudes or long exposure periods in their experimental design. The use of pure tones in many of the infrasound exposure studies may also result in misleading effects being reported as ambient infrasound from both natural & man-made sources is almost without exception in the form of broadband noise comprising of fundamental notes, harmonics & resonant frequencies. The data from the studies that have been done is strongly indicative of some physiological & psychological effects from prolonged exposure to high amplitude infrasound. These effects are variable & include cardio-vascular & respiratory effects (Karpova et al, 1970), feelings of fatigue, apathy, depression & loss of concentration. In many instances, the reported effects are similar to subjective psycho-physiological effects reported in spontaneous paranormal cases. These include the feelings of anxiety or dread, nausea, sickness & sudden onset headaches. Initially, this similarity of experience may seem impressive & should not be dismissed but a number of problems remain to be addressed. For example, Kawano et al. (1991) found that long distance truck drivers who were exposed to infrasound at around 115dB showed no statistically significant incidence of fatigue, subdued sensations or cardiovascular changes. Chen & Hanmin (2004) reported that different individuals had different responses to infrasound exposure.

Infrasound has increasingly been suggested to be a primary contributing factor in the production of various physiological & psychological effects that are subsequently interpreted as a personal paranormal experience both within books (e.g. Fielding & O'Keeffe, 2006) and also on the websites of many amateur paranormal groups. A search carried out by the author in December 2011 using the simple search words "Paranormal Infrasound" on Google revealed several hundred amateur paranormal groups making various claims about the nature of infrasound and its relationship to paranormal experiences. Reported paranormal experiences that have been frequently linked to infrasound exposure include psychological; such as a sense of presence & foreboding: Psycho-physiological, caused by the vibration of body organs & cavities & Physical; the infrasound creating secondary observable effects upon the structures within a location, leading to movement of objects & anomalous sounds. Such claims are rarely upon empirical observations of infrasound but instead draw upon similarities between the witness reports of paranormal experiences & the reported effects of infrasound exposure in the civilian studies & restricted NASA / military research programmes.

4.3 Is infrasound being measured properly by paranormal researchers & investigators?

It is important to point out that all of the major laboratory based infrasound exposure studies report their results in terms of units SPL without any filter weighting being applied. As has already been described the use of a filter weighting scale when obtaining infrasound measurements of the ambient levels of infrasound within the environment may result in the erroneous under-reporting of the actual levels present if the data is expressed in terms of filter weighted dB i.e. A, B, C, or G. Tandy (2000) reports finding an infrasound standing wave at 19Hz with amplitude of 38dB in the haunted cellar. Unfortunately, he does not specify what weighting filter (if any) was applied to this measurement. Given the type of equipment used i.e. a Bruel & Kjaer type 2209 sound level meter, If one of the standard weighting filters was applied to the data, either the 'C' or more likely the 'A' weighting, its use could lead to a serious underestimate of the infrasound sound pressure levels. Broner (1978) describes a case in a London home where infrasound which was causing annoyance to the wife but not the husband was measured to be only 32dB (A) using 'A' weighting, but the SPL was actually measured at 63dB.

In September 2006, immediately before its closure the author was able to undertake a series of infrasound measurements at the haunted cellar in Coventry. Using ARID to repeat the experiment carried out by Tandy. Replicating Tandy's placement, the microphone was positioned in the centre of the cellar with infrasound measurements being made automatically at one minute intervals by the equipment in the empty cellar. The unpublished measurements did not support his claim of finding a 19Hz standing wave within the cellar, although infrasound was found to be present at a broad range of frequencies. The measurements revealing that all frequencies between 20Hz & 2Hz the infrasound exceeded 30dBS, with a peak at 44dBS at 5.7Hz. However, the variability of location infrasound production due to changes in the ambient sources; not knowing the filter weighting that Tandy used for his measurements & the lack of proper calibration for the prototype ARID system at that time make it difficult to make any further comparisons between the two infrasound surveys.

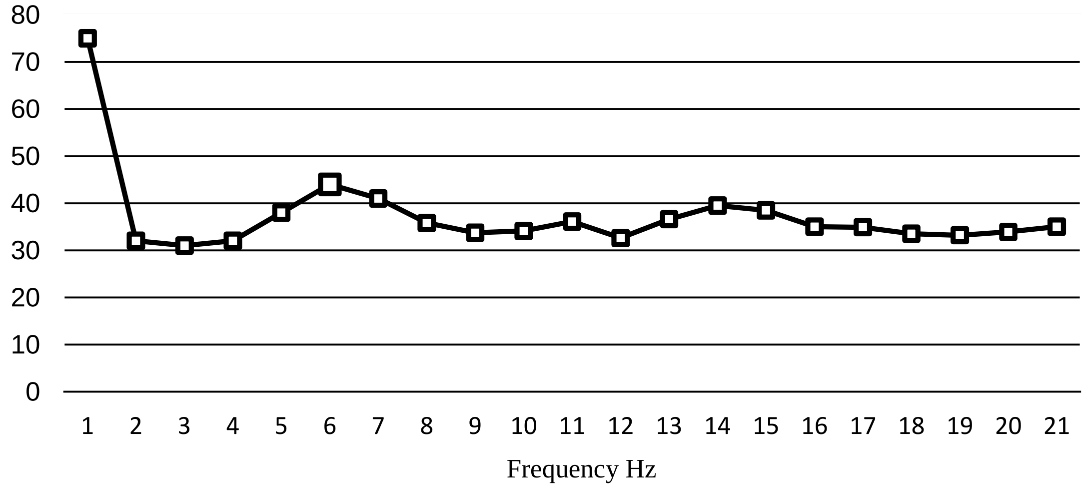

Figure 3. Infrasound levels within the Coventry cellar Sept. 2006

Tandy (2000) acknowledges that his measured value of 38dB within the cellar is substantially lower than those previously reported to create effects within individuals but suggests that as the effects are rather less spectacular this may simply reflect the lower amplitudes found. Braithwaite & Townsend (2006) also make the point that there are no published studies that have found any implications for cognition or experience of infrasound as weak as this. In fact, the actual levels of infrasound present may, as already noted, have been substantially higher & therefore much closer to those demonstrated to have produced effects. This difference in measuring & quoting infrasound levels between field & laboratory studies may also provide an explanation for the results of other experiments where low amplitude infrasound has been suggested to have effects (Brown,1973; Green & Dunn, 1968).

Another difficulty in determining infrasound amounts from field measurements is the sampling period used. In his experiments within the haunted cellar Tandy (2000) describes a sample time of just 20 seconds being used. Although we are informed in that the measurements were repeated a number of times it is not made clear if the resultant data is an average of one sample period or of a number. A short sampling period of 20 seconds would not be sufficient to determine if the measured infrasound was always present at the measured values or simply the result of some transient effect, for example a passing bus or even one parked nearby for a short time with its motor left running. Weather effects such as wind gusts or some other unknown short duration event might also be the cause of the infrasound during the sampling period. A longer sampling period would permit such transients to be taken in account & would permit a more realistic assessment of the true ambient infrasound levels to be made. The author's own measurements at the haunted cellar found that there were indeed short duration infrasound events caused by passing vehicles. It was also discovered that the presence of people within the cellar contributed significantly to the production of infrasound as they moved & walked about. Tandy had vacated the space prior to his measurements being carried out. This step too, may have not have provided an accurate reflection of the nature of the originally reported incidents, which took the form of personal anomalous experiences to visitors during tours of the historic cellar.

Following the death of Tandy there had been little effective research into the possible involvement of infrasound in the production of paranormal experiences. However, since 2006, the author has undertaken a series of broadband infrasound measurements using ARID at a number of locations around the UK together with a number of experiments to study the link between infrasound exposure & reports of anomalous & paranormal experiences. A pilot study was carried out at a former shipyard on Merseyside during 2006 (Para.Science, 2007). The location had a reputation of being haunted with staff & paranormal investigators reporting physiological & psychological effects that might be associated with infrasound exposure. Results of the pilot study suggested a strong causal link between high ambient levels of infrasound (up to 80dBS) at frequencies between 7Hz & 15Hz & the reports of anomalous experiences in the percipients. The source of the powerful ambient infrasound was determined to be generated by the engines & associated equipment of ships berthed in an adjacent dock. A psychic medium also reported changes within the "psychic energies" within the location that closely corresponded to the objectively measured regions of high levels of ambient man-made infrasound.

During 2007, the author et al conducted a pilot study at The Real Mary Kings Close tourist attraction in Edinburgh as part of their annual 'GhostFest' event. A controlled level of Infrasound was produced using the author designed infrasound generator ARIA (Acoustic Research Infrasound Array). Throughout the study period ambient levels of infrasound was measured using ARID 2. Hourly tour groups to Mary Kings Close were unknowingly subjected to either only the ambient infrasound that is normally present or the ambient infrasound plus experimenter produced high level (>100dBS) infrasound at a frequency of 18.9Hz. The route of the tours & the commentary of the tour guides were observed and were consistent for each tour group. The physical conditions such as lighting & temperature within the location were measured & were constant throughout the period of the study. Upon completing the tour the subjective anomalous experiences of 439 individuals were surveyed. The results obtained strongly indicated that infrasound exposure played a significant role in the production of subjective paranormal experiences for around 1/3rd of the total survey. However, the study failed to demonstrate any of the visual disturbances & resulting apparitional experiences that Tandy had suggested would be created by exposure to the frequency range around 18Hz (Para.Science, 2008).

The infrasound generator (ARIA) has also been used in two public performances (Silent Sound, 2006 & 2010) in which a frequency of 18.9Hz was produced at an SPL exceeding 90dBS. Anecdotal accounts from participants & audience members did indicate a significant number of psycho-physiological effects such as feeling ill at ease, anxiousness & physical discomfort were experienced when ARIA was in use. For example, during the first performance with ARIA at the 2006 Silent Sound performance held in Liverpool St. Georges Hall a number of the musicians within the auditorium reported feeling unwell and nauseous & were unable to play their instruments, ultimately abandoning the room during a rehearsal session as the output level of ARIA was being set. During this set-up test infrasound levels of more than 90dBS were measured at 10 metres from the infrasound generator. Following the ARIA test, the author also discovered that three floors below the auditorium on the ground level a security guard had also reported feeling suddenly unwell and had left the building. None of these unfortunate side-effects of the infrasound exposure lasted more than a few minutes and ceased once the infrasound generator was switched off. For the actual performance infrasound levels of 60dBS were used (measured at 10 metres from the infrasound generator). Following the performance audience members and several musicians anecdotally reported unexpected sensations including vertigo, pressure in the ears and the sensation of "having something pressed tightly over the head." Similar experiences were anecdotally reported during the 2010 concert held in Middlesbrough. At neither performance were any visual or apparitional experiences reported.

Tandy's hypothesis that Infrasound may be responsible for inducing anomalous sensations was tested by French et al (2009) 'The "Haunt" Project' used generated Infrasound to investigate the possibility of creating an artificially "haunted" room. Specifically, to investigate whether exposure to infrasound, complex electromagnetic fields or both in combination would lead to an increased reporting of anomalous sensations in the participants compared to a baseline condition. The room was a circular chamber of wood, fabric and canvas built inside an empty room approximately 4 metres x 4 metres (based upon the plans of the experimental area). A pair of electromagnetic coils were hidden outside the chamber along with a single infrasound speaker positioned outside the chamber in a corner of the main room. The Infrasound was generated by "combining two sine waves at 18.9Hz and 22.3Hz" output via a "purpose-built cabinet" These frequencies were chosen to be representative of the Infrasound recorded by Tandy in the Coventry cellar. Participants each spent 50 minutes in the chamber and recorded on a floor plan a brief description of any anomalous sensations they experienced, also noting their position within the chamber and the time the sensation was experienced. The participants were randomly allocated an Infrasound absent or present state in combination with an electromagnetic field absent or present state.

Many of the participants reported having anomalous sensations, a number of which have previously been linked to Infrasound exposure: Dizzy or odd (79.7%), spinning around (49.4%), tingling sensations (32.9%) and pleasant vibrations through their bodies (31.6%). Other sensations linked to Infrasound exposure were also reported including the sense of presence (22.8%), terror (8.9%) and sexual arousal (5.1%). Sensations that may be associated to Infrasound were additionally reported such as hearing a 'ticking sound' (25.3%), this may have been due to changes within the air pressure caused by the Infrasound acting on the ear or acting upon some structural component within the room or chamber and causing resonance. Sensations were reported that have no association with Infrasound exposure such as feeling they were somewhere else (32.9%), feeling detached from their bodies (22.8%), sadness (11.4%) and odd smells (10.1%).

The researchers reported failed to find any support for a link between the presence of infrasound and the experiencing of anomalous sensations; suggesting that "The case for infrasound inducing haunt-type experiences now appears to be extremely weak". However, this experiment fails to properly address a number of issues relating to the physics of infrasound: In order to establish undetectable levels of Infrasound within the chamber a series of pilot trials were carried out, participants were asked to indicate when they became aware of the infrasound stimulus at a range of frequencies; 15Hz, 17Hz, 19Hz, 21Hz, 23Hz and 25Hz. Using this pilot it was determined that "No participant was able to perceive infrasound at a level below 75dB". It is not stated what equipment or method was used to obtain this sound level data or what (if any) weighting was applied to the measurements. As previously discussed It is perfectly possible that significantly higher amplitudes of low frequency ambient sound and infrasound may have been present throughout the entire experiment without being measured by the experimenters. Moreover, the use of two combined sine waves (18.9Hz & 22.3Hz) will result in the production of secondary frequencies as a result of intermodulation between the two primary signals. These secondary tones (harmonics) are equal to the sum and difference of the two primary frequencies i.e. $f_1 \pm f_2$ (3.4Hz & 41.2Hz). Other harmonic frequencies well within the region of normal human hearing might also be expected to be present. The experiment also did not consider interactions of the Infrasound within the room itself caused by reflected and refracted sound waves bouncing off the walls, floor and ceiling and the possible effects upon the participants as they walked through what might have been large variations in both the presented sound frequencies, although interestingly the experimenters noted in relation to the electromagnetic field that "The nature of the field itself can vary infinitely and the participants movements through the field will add an extra level of complexity to the field as experienced" Measurements that were made are stated to be "50dB with all the equipment turned off, 65dB with the air-conditioning switched on and 75dB" when the infrasound was switched on. No information was provided about the sound measuring equipment that was used or any indication if any frequency weighting was applied to the measurements. Without this crucial information about the ambient Infrasound levels present, the experimenters argument against the role of Infrasound being a causal factor in the production of the anomalous sensations reported by the participants must therefore be questioned.

4.4 Should we be interested in 19Hz?

Studies by those interested in the possible links between reported paranormal experiences & infrasound exposure including the author have so far tended to focus most of their experiments at infrasound frequencies of close to 19Hz. Interest in this frequency range comes as a direct result of the papers produced by Tandy & Lawrence (1998) & Tandy (2000). The frequency was identified by mathematical calculation:

"The following day V.T. was entering a fencing competition and needed to cut a thread onto the tang of a spare foil blade so that he could attach the handle. He had all the tools necessary but it was so much easier to use the engineers bench vice in the lab to hold the blade that he went in early to cut the thread. It was only a five-minute job, so he put the blade in the vice and went in search of a drop of oil to help things along. As he returned, the free end of the blade was frantically vibrating up and down. Combining this with his experience from the previous night, he once again felt an immediate twinge of fright. However, vibrating pieces of metal were more familiar to him than apparitions so he decided to experiment. If the foil blade was being vibrated it was receiving energy which must have been varying in intensity at a rate equal to the resonant frequency of the blade. Energy of the type just described is usually referred to as sound. There was a lot of background noise but there could also be low-frequency sound or infrasound which V.T. could not hear. As it happens sound behaves fairly predictably in long thin tubes such as organ pipes and ex-garages joined end to end so V.T. started his experiment. He placed the foil blade in a drill vice and slid it along the floor. Interestingly, the vibration got bigger until the blade was level with the desk (half way down the room); after the desk it reduced in amplitude, stopping altogether at the far end of the lab. V.T. and his colleagues were sharing their lab with a low frequency standing wave! The energy in the wave peaked in the centre of the room indicating that there was half a complete cycle...... Once V.T. knew this he calculated the frequency of the standing wave......." (Tandy & Lawrence, 1998).

The mathematical calculation of the standing wave within the lab is based solely upon a single room dimension, specifically its length, given as 30ft & a wavelength of 2x the length of the room i.e. 60ft.

Tandy uses the formula of: frequency = velocity of sound (1139ft/sec) / wavelength (60ft).

Thus: f = 1139 / 60 = 18.89 Hz.

No account is apparently taken of the height or width of the room, the dimensions of which are not provided. In order to determine the acoustic properties of any space & accurately calculate the frequency of standing waves within the space calculations involving all three dimensions of the space must be used.

Broadly speaking three types of standing wave will exist inside any space, the most powerful being the Axial waves which involves any two parallel surfaces such as walls or floor & ceiling. With Axial waves there are always sound pressure maxima at the walls. (Bruel & Kjaer, 1982).

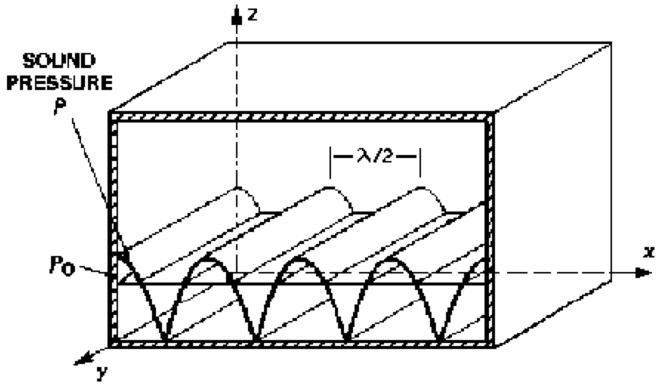

Figure 4. Axial Room Waves (Bruel & Kjaer, 1982)

In addition Tangential waves involve any two sets of parallel surfaces - all four walls, or two walls the ceiling and the floor. These are about half as strong as the axial modes. There are always sound pressure maxima at the walls. (Bruel & Kjaer, 1982).

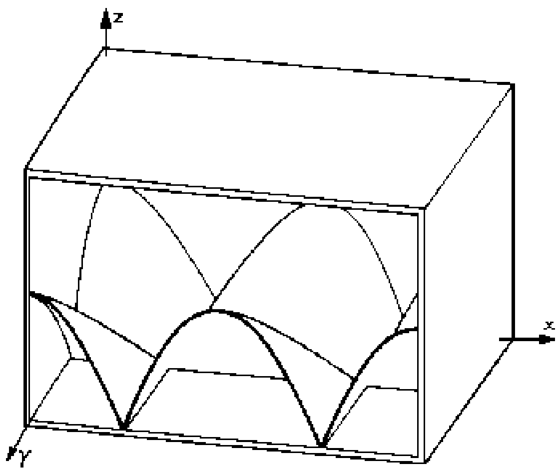

Figure 5. Tangential Room Waves (Bruel & Kjaer, 1982)

Oblique waves involve all six surfaces - four walls, the ceiling and the floor. These are about one quarter as strong as the axial modes, and half as
strong as the tangential modes. Oblique modes are rarely much relevant. There are always sound pressure maxima at the walls. (Bruel & Kjaer, 1982).

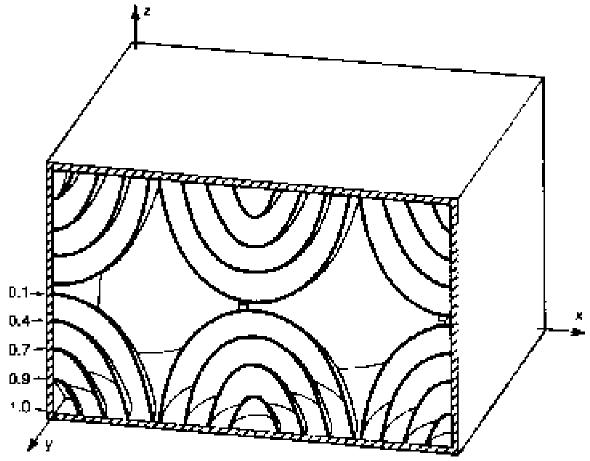

Figure 6. Oblique Room Waves (Bruel & Kjaer, 1982)

It is noteworthy that with all three types of standing wave within a room or space there is always a pressure maxima at the walls something which seems to be contrary to the observation made by Tandy: " *Interestingly, the vibration got bigger until the blade was level with the desk (half way down the room); after the desk it reduced in amplitude, stopping altogether at the far end of the lab."*

To calculate the frequencies of the axial, oblique und tangential modes, the following formula may be used:

$$f = \frac{c}{2}\sqrt{\left(\frac{n_x}{L}\right)^2 + \left(\frac{n_y}{B}\right)^2 + \left(\frac{n_z}{H}\right)^2}$$

f = Frequency of the standing wave in Hz
c = Speed of sound (1139 ft/sec. at 20 °C).
n_x = Order of the standing wave for room length.
n_y = Order of the standing wave for room width.
n_z = Order of the standing wave for room height.
L, B, H = Length, width, and height of the room.

Using the above formula and assuming the stated length of 30ft & estimating a reasonable width of 12ft & a height of 10ft we are presented with a range of fundamental (first order) low frequency standing waves present inside the lab room:

18.8Hz (x axial wave);	50.7Hz (x-y tangential wave);	75.9Hz (x-y-z oblique wave)
47.1Hz (y axial wave);	59.6Hz (x-z tangential wave);	
56.5Hz (z axial wave);	73.5Hz (y-z tangential wave);	

As can be seen, there is not one standing wave existing inside the lab room but several, all of which to a greater or lesser degree may have affected the sword blade. Furthermore, the authors do not provide any information regarding the dimensions i.e. length, width & thickness of the blade that was seen to be vibrating, thus it is impossible for us to calculate the resonant frequency of the blade itself and to know which standing wave/s might therefore be responsible for producing the observed vibrations within it.

Without extensive measurements being undertaken it will be practically impossible to predict the all the various effects that acoustic vibrations might produce within structural systems (Broch, 1980). Tandy's mathematical modelling of the standing wave within the lab also assumes that the source of the infrasound standing discovered was a new fan fitted to the labs extraction system. Turning off fan caused the sword blade to cease vibrating and the untoward experiences also ceased, which might indicate that the that fan was indeed the source of a standing wave. However, this could equally indicate that an infrasound standing wave of unknown frequency/s had formed by the interactions of the fan noise and an external infrasound source which had been interrupted when the fan was stopped. Infrasound has been shown to be capable of travelling large distances without significant attenuation & as no infrasound measurements were made within the lab, both with and without the fan, it is not possible to know which is the case here. Taking the above into consideration It would appear then that there is little to suggest or indicate that experiments & studies based around a frequency of 19Hz are of any particular value to paranormal researchers. This is further borne out by the pilot study in Edinburgh and the concert applications of infrasound, neither of which produced the visual hallucinations or apparitional experiences that Tandy suggested were caused by a 19Hz infrasound exposure.

4.5 Should paranormal researchers be interested in infrasound at all?

The work by Tandy & Lawrence (1998) & Tandy (2000) remains the only real basis for the assumption of an infrasonic involvement in personal experiences at haunt locations. Inevitably, such primary studies are flawed because there is little or no preceding data for the author to make use of when developing their argument. However, there are clear similarities between the reported experiences & sensations of those people who have experienced infrasound and those reporting paranormal experiences & sensations. The author's pilot studies in the former shipyard & in Mary Kings Close, together with the anecdotal reports from the infrasound concerts also strongly suggest that infrasound is a component in the production or enhancing of reported paranormal experiences. The suggestion of a link between infrasound & reported paranormal experiences was also tested in 2003 in a series of 'Soundless Music' concerts that took place in Liverpool & London (Arenda & Thackara, 2003). Questionnaires handed to the audience showed a range of reported experiences; Many unusual experiences were reported during the concerts, ranging from the emotional e.g. ‘sense of sorrow’, ‘brief moment of anxiety’, ‘excited' to the physiological e.g. ‘increased heart-rate’, ‘headache’, ‘tingling in neck and shoulders’, ‘nausea’, ‘sense of coldness’ (Infrasonic, 2003). The 'Soundless Music' concerts used an infrasound frequency of 17Hz but from their own spectral measurements of the infrasound we can readily see that infrasound is present at all frequencies below 20Hz at considerable intensity.

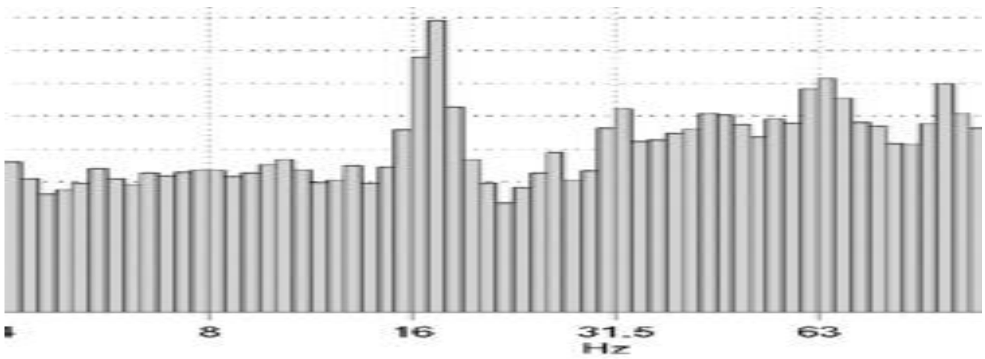

Figure 7. Spectral plot from Silent Sound concert (Infrasonic, 2003)

Susceptibility to psycho-physiological effects of infrasound exposure seems to be linked to both exposure duration & overall sound pressure level (Kitamura & Yamada, 2002). Prolonged exposure to low infrasound pressure levels has been suggested as a likely cause of adverse psycho-physiological effects (Benton, 1997). Although the limited research does not directly indicate it; it might be fair to assume that short duration exposure to high infrasound pressure levels may cause similar effects. Existing research does indicate that exposure to high levels of low frequency sound at concerts or in some industry explosions does cause aural pain & other physical effects; such effects may be temporary or permanent (Fearn, 1973).

A key problem lies with the lack of information about levels of ambient infrasound at haunt locations. Such studies that exist have been made either following noise complaints or for the establishment of safe exposure limits & thresholds within high noise environments. This lack of baseline data is a crucial problem for paranormal researchers seeking to test or develop the case for an infrasound involvement & must be urgently addressed if meaningful research is to continue. The ongoing survey also measures the infrasound at similar or co-located control (non-haunt) sites in order to ascertain if there are any significant difference in the ambient infrasound frequencies & amplitudes at haunt locations compared to the control sites. The survey also undertakes measurements of the ambient infrasound at a wide range of locations regardless of any paranormal association or reports in order to establish a set of baseline ambient infrasound data to support future infrasound studies. The need for such baseline data was also highlighted by Braithwaite & Townsend (2006)

From the limited studies conducted to date & the knowledge that infrasound is produced by so many natural & man-made sources it now seems highly likely that infrasound is just one of many factors that may lead to the reporting of anomalous or paranormal experiences by some individuals. A number of other possibilities are however indicated:

i. Infrasound alone does not produce anomalous & paranormal experiences.
ii. The frequency range around 18Hz does not produce the apparitional experiences as suggested by Tandy & Lawrence.
iii. That infrasound presented at a range of frequencies is more likely to produce reports of anomalous & paranormal experiences than single frequency infrasound.
iv. That a rapid variation in the infrasound frequency & / or amplitude i.e. >1Hz per second or 3dB per second is more likely to contribute to the reporting of anomalous & paranormal experiences than infrasound that is constant or is slowly changing.

v. That a small variation in the infrasound frequency & / or amplitude i.e. +/-2Hz or +/- 3dB is more likely to contribute to the reporting of anomalous & paranormal experiences than greater variations.

A series of experiments & studies are already underway or are being planned to test the indicated possibilities. Further developments of both ARID & ARIA are planned which will permit better measurements of the ambient infrasound to be made & to support further studies of infrasound exposure experiences.

Appendix

A rough & ready test for ambient infrasound

Whilst techniques for measuring infrasound frequency & amplitude can be prohibitive both in terms of the equipment & cost it is possible to undertake a simple test that will act as a rough guide to the presence or otherwise of significant levels of infrasound at a location. Tandy (2002) provides construction details for modifying a standard sound level meter by the addition of a DIY low-pass filter network. This required a considerable expertise in electronics & integrated circuit construction techniques but did provide the user with a general indication of the amplitude of sound at frequencies below about 35Hz. There is however a much simpler method for quickly determining if low frequency sound & infrasound is present at significant levels:

This simple method exploits the filter weighting already built into most sound level meters. Suitable meters can be readily obtained from a number of sources including online retailers for less than £25. The method can even be employed by use of a sound level meter App for the iPhone (3GS, 4, 4S), Ipad 2 & Ipod Touch (4th Gen.) such as 'SPL' (StudioSixDigital), but with a reduced degree of accuracy. In order to carry out this simple test the sound level meter must have both 'A' & 'C' weighting filters. Two consecutive measurements of the ambient SPL are taken: The first measurement is made using the 'A' filter, noting the SPL value; a second measurement using the 'C' filter is carried out, again noting the SPL value. If the SPL value of 'C' is greater than 'A' this indicates that there are increased levels of low frequency sound present. The greater the difference between the 'C' value & the 'A' value, the higher the level of low frequency sound at the measurement location. If the SPL value of 'C' is significantly higher than 'A' i.e. 10dBS or more then it is likely that appreciable levels of infrasound are likely to be present. The technique exploits the difference in weighting between the 'A' & 'C' filters in the low frequency sound region (figure 5)

Although no direct information about either the frequency or amplitude is provided by this technique it does permit the user to make a judgement about the level of low frequency sound & infrasound. The overall accuracy of this technique can be improved by making a series of consecutive measurements over a period of time & / or taking measurements using the time average (Leq) function that some meters provide.

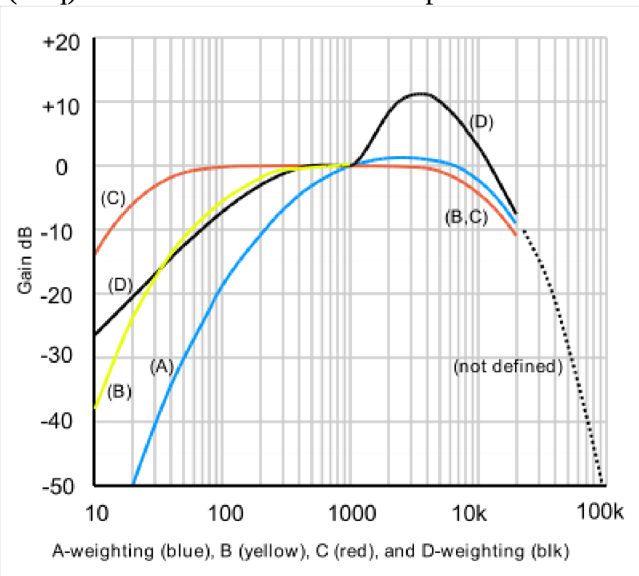

Figure 8. Comparison of sound measurement weighting filters

References:

Altmann, J. (1999). Acoustic Weapons, A Perspective Assessment: Sources, Propagation & effects of Strong Sound. Occasional paper #22, Cornell University Peace Studies Program. New York.

Anon. (1977, 26th June). Hounded by this nagging noise. The Sunday Mirror.

Anon. (1977, 3rd July). Hum – that mystery noise that drives sobbing wife out of the house. The Sunday Mirror.

Arenda, B. & Thackara, D.(2003). Experiment: Conversations in art and science. The Wellcome Trust.

Backteman, O., Kohler, J. & Sjoberg, L. (1983). Infrasound-tutorial review part 2. Journal of Low Frequency noise & vibration. 2. pp. 176-210.

Berglund, B., Hassmen, P., & Soames Job, R.F. (1996). Sources & effects of low frequency noise. Journal of the Acoustical Soc. of America. 99 (5).

Blazier, W.E. (1981). Revised noise criteria for application in the acoustical design & rating of HVAC systems. Journal of Noise Control Engineering. 16. pp. 64-73.

Braithwaite, J. & Townsend, M. (2006). Good vibrations: The case for a specific effect of infrasound in instances of anomalous experience has yet to be empirically demonstrated. Journal for the Society for Psychical Research. 70a. pp211-224.

Broner, N. (1978). The effects of low frequency noise on people. Journal of sound vibration. 58. pp. 483-500.

Brown. (1973). New worries about unheard sound. New Scientist (8th November).

Bruel & Kjaer. (1982). Sound Intensity Part. 1 Theory. Technical Review 1982 (3)

Bruel, P.V. & Olesen, H.P. (1973). Infrasonic Measurements. Presented Paper. Inter-Noise Conference '73. Copenhagen.

Bullen, R. B. Hede, A. J. & Job, R. F. S. (1991). Community reaction to noise from an artillery range. Noise control engineering journal. 37. pp.115-128.

Challis. L.A. (1978). Low frequency noise problems from gas turbine stations. Proceedings Internoise 78. pp.475-480.

Chen, Y. H. Q., & Hanmin, S. (2004). An investigation on the physiological & psychological effects of infrasound on persons. Journal of low frequency noise vibration & active control. Vol.23 1. pp71-76.

Corso, J. F. (1958). Absolute thresholds for tones of low frequency. American journal of Psychology. 71. pp.367-374.

Daily Mirror, 19th October 1969. p.18.

DIN: 4560 (1997). Measurement & Evaluation of Low Frequency Environmental Noise.

Fearn, R. (1973). Pop music & hearing damage.. Journal of Sound & Vibration, 29. pp 396-397.

Feynman, Richard P., Leighton, R., Sands, M. (1963). The Feynman Lectures on Physics. Vol.1. Addison-Wesley. New York. ch.49

Fielding Y, & O'Keeffe C. (2006). Ghost Hunters: A guide to investigating the paranormal. Hodder & Stoughton, London. pp. 316-322.

Fields, J. M. (2001). An updated catalog of 521 social surveys of resident's reaction to environmental noise. NASA Report, NASA/CR-2001-211257.

Fodor, N. & Lodge O. (1933). Encyclopedia of Psychic Science. London. Arthurs Press Ltd.

French, Christopher C., Haque, Usman, Bunton-Stasyshyn, Rosie and Davis, Robert. (2009). The "Haunt" project: An attempt to build a "haunted" room by manipulating complex electromagnetic fields and infrasound. Cortex, 45 (5), pp. 619-629.

Frost, G. P. (1987). An investigation into the microstructure of the auditory threshold & of the loudness function in the near threshold region. Journal of low frequency noise vibration. 6. pp34-39.

Gamberale, F., Goldstein, M.,Kjellberg, A., Liszka, L., & Lofstedt, P. (1982). Perceived loudness & annoyance of low frequency noise. Stokholm. Arbete & Halsa.

Garces, M., Hegarty, M. & Schwartz, S. (1998). Magma acoustics & the time-varying melt properties at Arenal volcano, Costa Rica. Geophysical Research Letters. Vol. 25. 13. pp 2239-2296.

Gaul, A. & Cornell, A. D. (1979). Poltergeists. London. Routledge & Kegan Paul.

Gavreau V. (1966). Infra Sons: Générateurs, Détecteurs, Propriétés physiques, Effets biologiques, in: Acustica, Vol .17, No. 1, p.1–10

Gavreau V. (1968). Infrasound. Science Journal. 4. pp33-37.

Goldstein, M. (1994). Low frequency components in complex noise & their perceived loudness & annoyance. PhD dissertation. Dept. of Psychology, Stockholm University. Arbete & Halsa.

Gossard, E.E., Hooke, W.H. (1975). Waves in the Atmosphere. Elsevier Science Publishers, USA.

Green, J. F. & Dunn, F. (1968). Correlation of naturally occurring infrasonics & selected human behaviour. The journal of the Acoustical Society of America. 44. No.5.

Hansen, C.H. (2007). The Effects of Low Frequency Noise & Vibration on People. Multi-Science Publishing. Essex.

Harris, C. S., Sommer, H. C. & Johnson, D. L. (1976). Review of the effects of infrasound on man. Aviation & Space Environmental Medicine. 47. pp. 582-586

Hegarty, M., Kim, W. & Martysevich, P. (1999). Characteristics of infrasound produced by large mining explosions in Kazakstan. Proceedings of the 21st Annual Seismic Research Symposium: Technologies for monitoring the comprehensive nuclear test-ban treaty. Las Vegas. USA. 1999.

Infrasonic. (2003). Infrasonic - Summary of results 31st May, 2003, Purcell Room, London. http://www.spacedog.biz/extras/Infrasonic/infrasonicResults.htm (Accessed 1st December, 2011).

Jerger, J., Alford, B., Coats, A. & French, B.(1966). Effects of very low frequency tones on auditory thresholds. Journal of Speech & Hearing Research. 9. pp. 150-160.

Job, R. F. S. (1993). Psychological factors of community reaction to noise. Noise as a public health problem, edited by M. Vallet. France. INRETS. Vol 3. pp. 48-70

Karpova, N.I., Alekseev, S. V., Erohkin, V., Kayskina, E. N., & Reutov, R. P. (1970). Early response of the organism to low frequency acoustic oscillations. Noise & Vibration bulletin. 11. pp.100-103.

Kawano, A., Yamaguchi, H, & Funasaka, S. (1991). Effects of infrasound on humans: A questionnaire survey of 145 drivers of long distance transport trucks. Practical Ortology. 84. pp.1324-1325. Kyoto.

Kitamura, T. & Yamada, S. (2002). Psychological analysis of sufferers of low frequency noise & relation between brain structure & psychological response. Proceedings 10th International Meeting Low Frequency Noise & Vibration & its control, York, UK. 2002.

Leventhall, G. Pelmear, P. Benton, S. (2003). A review of published research on low frequency noise & its effects. London: DEFRA Publications. p. 7.

Lidstrom, I. M. (1978). The effects of infrasound on humans. Investigation Report *(UMEA).* 33. pp. 1-42.

Lisker, L. & Abramson, A. (1970). The voicing dimension: Some experiments in comparative phonetics. Proceedings of the 6t International congress of Phonetic sciences (1967). Prague. Academia.

London Evening News, 25th May 1974. p.11.

Lydolf, M. & Moller, H. (1997). New measurements of the threshold of hearing & equal loudness contours at low frequencies. Proceedings of the 8thInternational Meeting on low frequency noise & vibration. Gothenburg. 1997. pp 76-84.

Masterton, R. B. (1992). Role of the central auditory system in hearing; The new direction. Trends in neurosciences. 15. pp. 280-285.

McKisic, J. M. (1997). Infrasound & the infrasonic monitoring of atmospheric nuclear explosions. USAF Technical report, PL-TR-97-2123. Phillips Labaratory, Hanscom AFB. US Dept of Defense. USA.

Mihan House, S. (2005). Infrasonic wave propagation over near regional & tele-infrasonic distances. Ann Arbour, USA. ProQuest Information & Learning.

Moller, H., (1984). Physiological & Psychological effects of infrasound on humans. Journal of low frequency noise vibration. Vol.3, No.1.

Moller, H. (1984). Physiological & psychological effects of infrasound on humans. Journal of low frequency noise vibration. Vol. 3. 1.

Moller, H. & Andresen, J. (1984). Loudness of pure tones at low & infrasonic frequencies. Journal of low frequency noise vibration. 3. pp. 78-87.

Nishimura, K., Kudoda, M., & Yoshida, Y. (1987). The pituitary adenocorticol response in rats & human subjects exposed to infrasound. Journal of low frequency noise vibration. 6. pp. 18-28.

Ostdiek, V & Bord, D. (2000). Inquiry into Physics. Brooks/Cole. USA.

Para.Science. (2007). Cammell Laird Shipyard, Birkenhead. http://www.parascience.org.uk/investigations/laird/laird.htm. Accessed 1st December, 2011).

Para.Science. (2008). Mary Kings Ghost Fest 2007 – Preliminary results. http://www.parascience.org.uk/mkgfr.htm. (Accessed 1st December, 2011).

Parsons, S. & O'Keeffe, C. (2008). Acoustic Research Infrasound Detector. Journal of the Society for Psychical Research, 72.1, pp. 51-57.

Persinger, M. A. (1974). The Paranormal: Part II. Mechanisms & Models. New York. MSS Information Corparation.

Pichon, A. L., Guilbert, J., Vega, A., Garces, M., Brachet, N. (2002). Ground coupled air waves & diffracted infrasound from the Arequipa earthquake of June 23, 2001. Geophysical Research Letters. Vol. 29. 18. pp. 331-334.

Price, H. (1974). Confessions of a Ghost Hunter. Causeway Edition. Causeway Books. New York.

Schomer, P.D. (1981). Community Reaction to Impulse Noise: Initial Army Survey. U.S. Army Construction Engineering Research Laboratory. Technical Report N-100. Champaign Il.

Silent Sound. (2006 & 2010). http://www.silentsound.info/sound_silentsound.html (Accessed 1st May, 2010).

Stephens, R. W. B. (1969). Infrasonics. Ultrasonics. January. pp. 30-35.

Stevens, S. S. (1975). Psychophysics: Introduction to its perceptual, neural & social prospects. New York. Willey.

Stubbs, C. (2005). Tactical Infrasound. JASON, The MITRE Corporation JSR-03-520. Virginia.

StudioSixDigital. www.studiosixdigital.com www.apple.com/itunes/

Svidovyl, V. I., & Kuklina, O. I. (1985). State of the3 hemolymph circulatory bed of the conjunctiva as affected by infrasound. Noise & vibration bulletin. pp. 153-154.

Talbot-Smith, M. (1994). Audio recording & reproduction, Practical measures for audio enthusiasts. London. Newnes.

Tandy, V. (2000). Something in the cellar. Journal for the Society for Psychical Research. 64. pp. 129-140.

Tandy, V. (2002). A litmus test for infrasound. Journal for the Society for Psychical Research. 66. pp. 167-174.

Tandy, V & Lawrence, T.R. (1998). The ghost in the machine. Journal of the Society for Psychical Research, 62, pp. 360-364.

Tempest, W. (1971). Noise makes drivers Drunk. The Observer. 28th November, 1971.

Tempest, W. (1976). Infrasound & Low-Frequency Vibration. London. Academic Press.

The Times, 29th September 1973. p.7.

Usher, N. (1977). Pitch discrimination at low frequencies. Acoustics Letters. 1. pp. 36-37.

von Gierke, H.E. & Parker D.E. (1976). Infrasound. The handbook of Sensory Physiology edited by Keidel W.D. & Neff W.D. Vol.3. pp. 585-624. Springer-Verlag. Berlin.

von Gierke, H. E. & Nixon, C. W. (1976). Effects of intense infrasound on man. Infrasound & low frequency vibration, edited by Tempest W. pp. 115-150. Academic Press. London.

Watanabe, T. & Moller, H. (1990) Low frequency hearing thresholds in pressure field & free field. Journal of low frequency noise vibration. 9. pp. 106-115.

Watson, L. (1973). Supernature. The Natural History of the Supernatural. Hodder & Stoughton, London.pp 91-96.

Westin, J. B. (1975). Infrasound: A short review of effects on man. Aviation space environmental medicine, 46, pp. 1135-1140.

Yamada, S. (1980). Hearing of low frequency sound & influence on the body. Proceedings of the Conference on low frequency noise & hearing. Aalborg, Denmark. pp. 95-102.

Yasunao, M. Yukio, T. Setsuo, M. Hiroki, Y. Kazuhiro, Y. & Jishnu, K.S. (2009). An Investigation of the perception thresholds of band-limited low frequency noises: influence of bandwidth. Multi-Science Publishing. Essex.

Yeowart, N.S., Bryan, M., & Tempest, W., (1967). The monaural MAP threshold of hearing at frequencies from 1.5c/s to 100c/s. Journal of Sound Vibrations, 6 pp. 335-342.