INFRASONIC MONITORING

RODNEY W. WHITAKER
LOS ALAMOS NATIONAL LABORATORY

Abstract

Infrasonic monitoring is a relatively low cost and robust means of monitoring for atmospheric explosions, which was used from the early 1950s through the mid 1970s by the US for monitoring purposes. Source yields anticipated under a Comprehensive Test Ban Treaty monitoring regime are lower than they were during the years of atmospheric testing, with the result that the frequency range of interest is moved to higher values. We present a brief review of infrasound physics and propagation and review the results of recent DOE supported research at Los Alamos National Laboratory. Recent data from large surface explosions is discussed with regard to current monitoring interest. Considerations of synergy among infrasound and other monitoring technologies are presented. Results from earlier work are in good agreement with more recent measurements for kiloton sized explosions. Infrasound continues to be an excellent technology for inclusion in the International Monitoring System for a Comprehensive Test Ban Treaty.

Infrasonic Monitoring

Rodney W. Whitaker

Los Alamos National Laboratory

Infrasound Review and Background

Infrasound signals are regular acoustic signals in that they are longitudinal pressure waves albeit at rather low frequency. Many researchers would place infrasound frequencies in the range of 0.1 to 10.0 Hertz, with corresponding wavelengths of 3300 to 33 meters. As with most wave phenomena, absorption decreases with decreasing frequency and infrasound propagates well in the earth's atmosphere, with geometric loss dominating other losses. This makes infrasound useful in remote monitoring activity such as the CTBT International Monitoring System (IMS). Atmospheric explosions generate a wide spectrum of acoustic frequencies; those in the audible domain are absorbed in the atmosphere and do not propagate to large distance. Lower frequency components are also present, and these do propagate to great distance. As the yield of the explosion decreases, the acoustic energy is concentrated at higher frequency than that for higher yield sources.

Infrasound can be generated by natural and manmade processes; moreover, many sources of audible sound are also sources of infrasound. Some known natural sources include: winds, large scale weather systems, volcanoes, earthquakes, meteors, aurora, and avalanches. Some manmade sources include explosions, helicopters, other aircraft, rockets, and large machinery. Measurements in the Los Alamos infrasound program, working around 1 Hz, have established databases on the acoustic signals from underground nuclear tests, earthquakes and large surface explosions[1-3]. Other organizations have obtained measurements of the acoustic signal from meteors, which can penetrate to lower altitudes where the kinetic energy may be explosively deposited. Meteors are a natural impulsive source and would look like an atmospheric explosion. Large eruptive volcanoes also would appear impulsive; however many would be of large size and would have additional information on origin from the seismic network.

At large range, infrasound signals are oscillatory acoustic signals detected as small pressure variations about the ambient value. Thus in time, a signal would look like positive and negative pressure variations around a zero mean value. The microphone is then a high quality differential pressure sensor not an absolute pressure sensor. In a quiet background, the sensor should be able to measure 0.1 microbars (1 microbar = 1 dyne/cm^2 = 0.1 Pascals). In character, infrasound data is similar to seismic data. For the IMS, sampling rates of no more than 20 samples per second will be sufficient. These are rather low data rates and present no significant data handling or transmission problems.

Detection is accomplished generally with arrays of microphones, and standard array/signal processing techniques are applied to determine source bearings, source power spectra, and correlation coefficients. The sensor can be one for infrasonic frequencies or one for lower frequencies, generally referred to as a microbarograph. Microbarographs were used extensively during the 1960s and 1970s in global networks for detecting atmospheric nuclear explosions, often at much larger yield than is of interest currently. Infrasound arrays operated by Los Alamos employ a system of porous hoses at each sensor to aid in low level wind noise reduction[4]. This system can be viewed as a generalization of the Daniels pipe used in earlier systems, which emphasized lower frequencies. For a wide band sensor (0.01 to a few hertz) as considered for the IMS, the exact design of the front end noise reduction still needs to be studied to achieve optimum design. The low level wind noise power rises rapidly with lower frequency below a few tenths of a Hertz.

Notional site locations have been made in an expert group report for the Ad Hoc Committee on a Nuclear Test Ban.[5] As final site selection proceeds, it is useful to note that there are some obvious features that one would like to avoid in the selection process. Persistent low level winds of moderate velocity (several meters per second) would have a large background noise level and should be avoided. Locations with ground cover, wooded or shrubs and grass are useful. Sites removed from heavy industry, mining and significant civilization noise are to be preferred. Power requirements are modest and Los Alamos has operated two of its arrays with solar panels and battery backup for several years with minimum maintenance problems. At these locations the analog data are RF transmitted back to a central site for recording using low power (a few watts) VHF transmitters. Snow is generally not a problem and can aid in the wind noise reduction.

In atmospheric wave physics, attention must be given to upper (> 10 km) atmospheric winds, because the wind speed at these heights can be a significant fraction of the sound speed. They can exert an appreciable influence on propagation speed and on surface bounce locations. Northern hemisphere stratospheric winds follow a seasonal pattern, blowing to the east in winter and to the west in summer. Received signal strength is enhanced to the east in winter and degraded to the east in summer. The opposite behavior is seen for propagation to the west. Southern hemisphere stratospheric winds show similar seasonal behavior, with roughly opposite phase. Absolute speeds can be higher in the southern hemisphere in mid summer and mid winter. Work at Los Alamos has provided a normalization procedure to account for the wind effects on measured pressure amplitudes[6].

Recent Surface Explosion Data

As part of the Los Alamos program, long range infrasound measurements of large surface ANFO (ammonium nitrate and fuel oil) explosions have been routinely made[1-3]. We have data from eight tests with charge weights of 24 tons to 4880 tons and ranges of 250 km to 5300 km. These events provide a uniform source set for propagation studies, and our analysis incorporates our wind normalization, giving the amplitude for a zero wind condition. In the attached Figure, the peak to peak normalized amplitude, p_{wca}, microbars, is given as a function of scaled range, where scaled range is actual range, R km, divided by charge weight, W, tons, raised to the 0.5 power. The regression curve is given by

$$p_{wca} = 4.69X10^{4}(R/W^{0.5})^{-1.36}.$$

Interplay with other Technologies

It is not surprising that costs are a significant issue in planning the IMS. Cost saving measures are sought in deployment and operations. Co-location is seen as an obvious method of saving costs in the deployment phase as well as in operations. It will be possible to co-locate two or more technologies at the same location in some instances. There are factors that would prohibit co-location in other instances. Consider for illustration a seismic station and an infrasound station. With seismic using buried sensors and infrasound sensors sitting on the surface, true co-location is possible. However, at a given location the best seismic site may be unsuitable for infrasound because of lack of ground cover and/or low level winds. Low level winds and local topography could make a good seismic site bad for infrasound. With islands where a hydroacoustic ground station might be, one would like to be inland from beach areas to avoid sea breeze and surf noise. In such cases a move of 5 km or so may provide a suitable alternative. This should still be considered co-location and cost savings would still be possible in installation, operations, and data handling. The older global networks did utilize island sites which operated successfully.

For sites that may be rather remote, such as certain island sites, specific dedicated transportation of equipment for initial installation might be expensive. With careful attention to shipping and air schedules, and a little flexibility in deployment schedules, one may be able to use vessels or aircraft which are going to the region of interest anyway, i.e. ships and planes of opportunity. Equipment, for one or more technologies, may be shipped in such cases at some cost savings over dedicated carriers.

It is anticipated that co-location of two sensor types will have benefits in event detection, location and discrimination. Because this type of operation has not been common to date, we must realize that only actual operations can establish the full range of cooperative benefit. With acoustic and seismic paired, each data type can help the other in some background characterization and event identification. This is true when one sensor type sees a suspicious event but the other sensor identifies the event as uninteresting. Differences in travel times for seismic, hydroacoustic and infrasonic data can be exploited to improve event location, when the event is seen by two or more sensor types. The characteristics of infrequent but recurring signals on two different sensors can be learned with time and used to identify (and dismiss as uninteresting) such events. It is likely that the value of such intercomparisons will vary from one site to another and that actual operation will suggest other applications.

Acknowledgment

This work has been supported by the US Department of Energy, Office of Nonproliferation and National Security, NN-20.

References

1. "Infrasonic Observations of the Minor Scale High Explosive Test", R. W. Whitaker, J. P. Mutschlecner, S. S.Bunker, and C. A. Painter, 1986, paper J2-6, Proceedings of the 12th International Congress on Acoustics, Toronto, Canada.

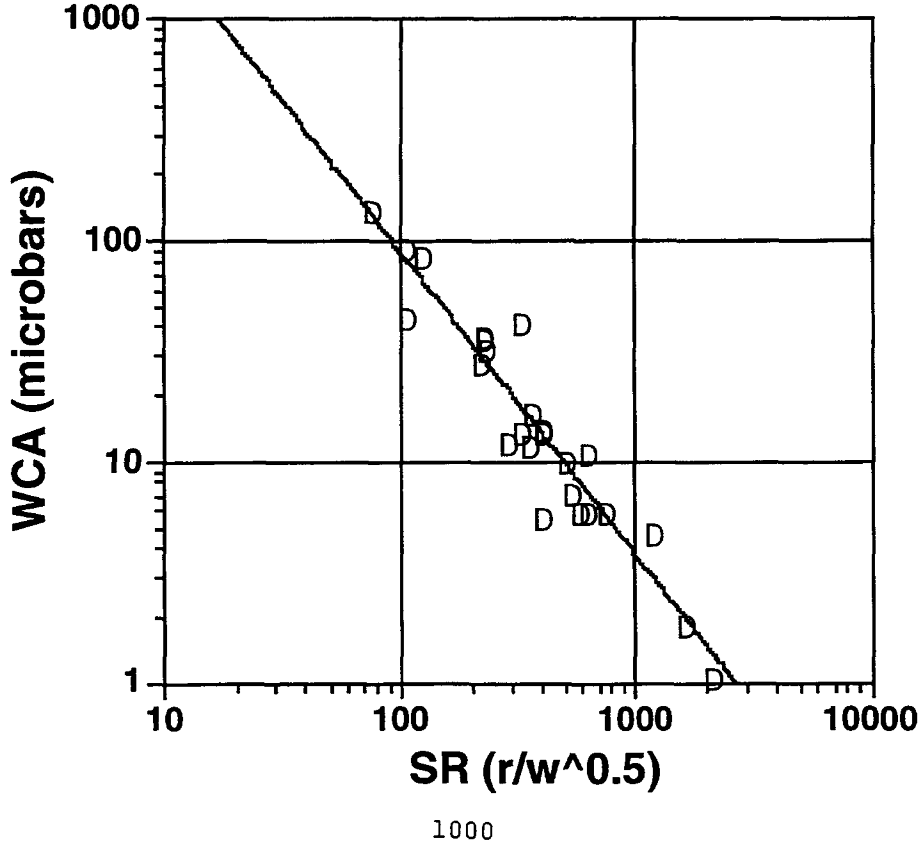
2. "Infrasonic Observations of Large-Scale HE Events", Rodney W. Whitaker, J. Paul Mutschlecner, Masha B. Davidson, and Susan D. Noel, 1990, Fourth International Symposium on Long-Range Sound Propagation, NASA-CP-3101.

3. "Miser's Gold", Marie Davidson and Rodney W. Whitaker, 1992, LA-12074-MS.

4. "Comparisons of Noise Reduction Systems", S. D. Noel and R. W. Whitaker, 1991, LA-12008-MS.

5. "Working Group 1 - Verification. International Monitoring System Expert Group Report based on Technical Discussions held from 6 February to 3 March 1995, Part I, Infrasound Monitoring," Ad Hoc Committee on a Nuclear Test Ban, 16 March 1995, Conference onDisarmament, Geneva, Switzerland, CD/NTB/WP.224.

6. "The Correction of Infrasound Signals for Upper Atmospheric Winds", J. Paul Mutschlecner and Rodney W. Whitaker, 1990, Fourth International Symposium on Long-Range Sound Propagation, NASA-CP-3101.



1000