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Analysis of acoustic imaging using wide-spread infrasonic sensor network array

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ABSTRACT

A kind of wide-spread sensor network array consisting of broadband infrasound microphones (0.001Hz~20Hz) which was used by observing and studying low-frequency atmospheric infrasonic waves was provided. Each unit of this network array was distributed in a large area, and could monitor the local infrasonic waves effectively. According to continuous observations and statistic analyses, it could be hard to analyzing and acquiring the exact information of infrasonic waves source from the random infrasonic array signals observed, for the reason that disturbance caused by influence factors, such as wind, temperature, turbulent flow and so on, which existed in atmosphere and in the long distance propagation paths of infrasonic waves which comes from some places of hundreds of kilometers away. Therefore, a method of Rainbow graph based on the acoustic imaging analyzing of array signals observed by the wide-spread sensor network array, which could indicate the amplitude and frequency of infrasonic waves varied in its propagation paths by the changes of colors in the Rainbow graph, was provided. Propagation laws of infrasonic waves and its sources information could be studied by this method. The wide-spread sensor network array and Rainbow graph method provided in this paper may propel the study of atmospheric infrasonic waves and its propagation laws.

INSTRUCTIONS

There are multifarious sound waves in the atmosphere, including audible sound, infrasonic wave and acoustic-gravity waves with acoustic characteristic similar to infrasonic wave, and so forth. As for the ultrasound existing in the atmosphere has very short propagation distance due to the strong attenuation in the air.[1]

Due to the large wavelength, the infrasonic wave can propagate very large distance, Infrasound signals in nature are closely related to natural events and human activities.

Infrasound microphone can effectively detect infrasound changes in the atmosphere. The infrasound microphone array monitoring atmospheric infrasound can obtain more information about infrasonic waves sources and propagation rules. and since the 1940s, rocket is used to high atmosphere detection for the study on very long distance propagation rule of infrasound in stratified atmosphere medium.

At presents, Comprehensive Nuclear Test Ban Treaty Organization (CTBTO) has established a worldwide infrasound monitoring stations network with monitoring frequency of 0.01-20Hz, which is mainly used to locate nuclear test site and estimate explosive yield.

In addition, the infrasound monitoring array is able to locate bolides and flight track and impact point of rocket. It also can detect the infrasonic waves brought by volcanoes, earthquakes, tsunamis and other natural activities, in order to study their activities laws, explore its occurrence mechanism, predict the occurrence time, to reduce the harm.

Institute of Acoustics, Chinese Academy of Sciences (IOACAS) dedicated to infrasound studies since the 1950s and achieves many research results in infrasound monitoring, infrasound propagation in the atmosphere, infrasound damage effects and protection against infrasound.

In recent years, large amounts of data were monitored during the continuous infrasound signal data observation, especially before and after the earthquake many unusual infrasound. The method of infrasound array acoustic imaging gives a good way to study the abnormal infrasound signal sources and propagation mechanism.

WIDE-AREA INFRASOUND MONITORING ARRAY

Each station of the wide-area infrasound monitoring array located in Beijing, Hubei Province, and Taiwan. The station's main equipment is composed of: wide band plays acoustic measurement capacitive microphones and plays acoustic measurement network transmission apparatus. The main equipments of each station are broadband absolute infrasound microphones and digital network transmission device which are placed in the room, and all data are directly transmitted to the central server in IOACAS located in Beijing via the Ethernet.

InSYS2008 broadband infrasound microphone and network transmission device

The capacitive broadband infrasound microphone was developed by IOACAS, with frequency range of the 0.001Hz-100Hz, dynamic range of 108dB (0.001Pa-300Pa), the consistency error of 1dB and the temperature drift 0.01mv /℃.

Due to its working principle and metal shield, the microphone is not sensitive to vibration and electromagnetic interference. Therefore it can fulfill the need of long-term uninterrupted infrasonic waves monitoring.

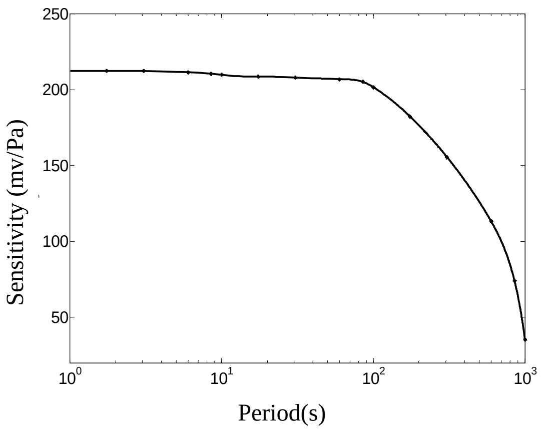


Figure 1. Sensitivity curve of infrasound microphone

Figure 1 shows the 0.001-1Hz part of sensitivity curve of broadband infrasound microphone. It can be seen from figure that this microphone is of high sensibility and larger frequency response range. Its sensibility is 25mv/Pa at the frequencies of 0.001Hz. It could monitor long period infrasonic waves even atmospheric gravity waves.

InSYS2008 network transmission device can transmitted the data monitored by infrasound sensor via wired network and 2.5G and 3G wireless networks to a central server preconfigured. And through built-in GPS module, the array can achieve large area array clock synchronization. It provides synchronization of array, and the geographical information, including latitude and longitude, height. Transmission apparatus and the network also provide remote software update feature.

This infrasound monitoring stations can be increased to improve the accuracy of array detection, for its high environmental adaptability and low cost, wide arrangement.

Figure 2. InSYS 2008 Infrasound microphone and network transmission device

Central server and database signal analysis software

The center server is composed of a workstation computer and two web servers. Database analysis software can operated on the platform of workstation, which can find data files interesting of any time or place to analysis and display on the screen.

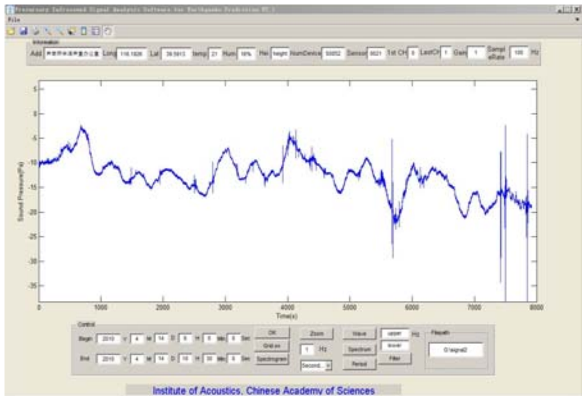


Figure 3. Interface of database signal analysis software

Structure of infrasound detection array

5-10 infrasound monitoring stations compose sub array in each city, and all the sub array of cities compose the wide area infrasound array. With incease density of infrasound monitoring stations, the distance between each sub-array will be reduced.

The distance between each infrasound monitoring station of sub-array is about 10km. infrasound signal sources could be located and directed by using time delay estimation algorithm and the accuracy of estimation could be improved with the increase number of sub-arrays.[2]

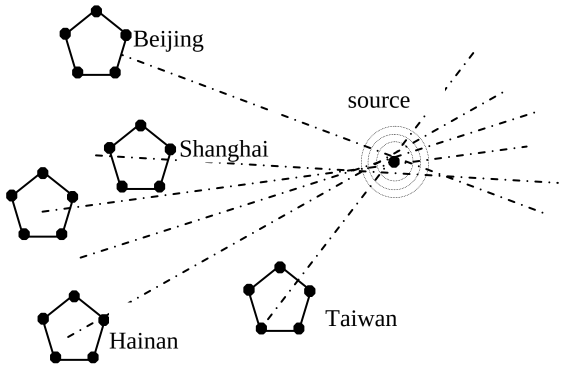


Figure 4. Wide area infrasound monitoring array

Figure 4. is wide-area infrasound monitoring array composed of regular pentagon sub-arrays and locating method by using several subarrays.

IMAGING METHOD OF WIDE AREA INFRASOUND MONITORING ARRAY

Beamforming algorithm is always used in area of audible sound imaging. The sound intensity distribution in small areas can be calculated by using beamforming algorithm.

However, with reducing of the monitoring frequency sound waves, especially in band of infrasound, due to the large monitoring spatial scale and the long distance propagation of atmospheric acoustic waveguide, the calculation using beamforming algorithm will be less accurate. But in the spatial range of sub-array, propagation of infrasound is a straight line, the beamforming algorithm can be effective.[3]

When using a large area of infrasound monitoring of the wide-area range (more than 100Km), especially studying of long-distance propagation of atmospheric infrasonic, a method of Rainbow is proposed, which could express variation of amplitude and frequency in long-distance propagation and its propagation paths.

With the combination of monitoring area map, this method that shows the local infrasound signal amplitude and main frequency by the variation of colors, can express variation of amplitude and frequency in long-distance propagation and its propagation paths.

According to amplitude and main frequency of infrasound signal, software can adjust the image RGB value. For example, Along with the color changing from red to black, the frequency and amplitude change from low to high.

The variation of color in Rainbow graph shows the infrasound dispersion and atmospheric attenuation in its propagation path. In addition, interpolation method is used to realize the smooth transition of colors in the different infrasound stations between the geographical areas to form a rainbow-like image.

Figure 5.and 6. are the sketch maps of Rainbow graph of 100km × 100km area. It illustrates that the frequency and amplitude of infrasound have significantly decreased while the propagation distance increases. Combining the rainbow graph with map of measured area, and the weather of this area, how weather and geography effected the propagation of infrasound wave will be known.

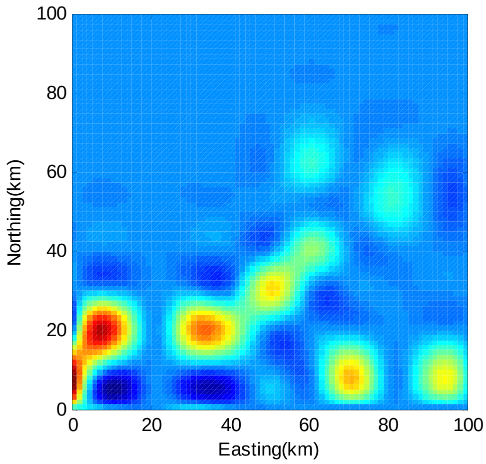
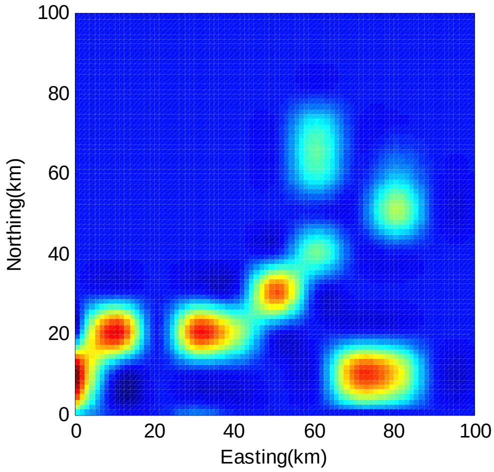


Figure 5. sketch map of Rainbow graph(signal frequency)



Source: (Author, 2006)

Figure 6. sketch map of Rainbow graph(signal amplitude)

CONCLUSION

The normal method is that a number of infrasound microphones compose a single small-aperture array to locate the source using time delay estimation algorithm, and more stations work together to improve accuracy. However It is assumed that the propagation path of infrasound is a straight line.

However, in fact, infrasound propagation path is not a straight line. It would be effected by temperature, humidity, high altitude wind. For this reason, the accuracy of positioning need to be improved. The method of Rainbow can show the variation of amplitude and dispersion to study propagation rules of atmosphere infrasound to find features of its source.

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