Sonification for the Analysis of Plasma Bubbles at 21 MHz

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Abstract. This research explores sonification - the assigning a sound to a data stream - as a useful tool for space science data exploration. In this research the authors use the xSonify Java-based tool, developed to explore space data using sound, to analyze radio data at 20.1 MHz for the formation of irregularities in the ionosphere. The data was audified in real time, and the power spectra sonified to expose discrete resonances, combs and bands. Since our telescopes are relatively insensitive, a time series analysis will not reveal much about the ionosphere, but a frequency domain analysis, especially over a particular range, will reveal some very interesting features interpretable in terms of radio twinkling. Sonification lead the authors to notice changes at ionospheric recombination time (3Z) that were characterized using FFT algorithms.

Keywords: sonification; data analysis; space physics

Introduction

Plasmas of the ionosphere, of interplanetary space and of the interstellar medium all contain irregularities. Propagation of electromagnetic waves, like optical or radio waves, through a medium with random fluctuations in refractive index results in amplitude and phase fluctuations [1]. These variations may be displayed via sonification, using changes in sounds to represent the data variations [2]. This is particularly useful extending science to the visually impaired [3].

Data sonification - assigning a sound to a data stream - is a tool with potential for studying complex sets of scientific data. Sonification provides the researcher with the ability to perceive variations and trends that are invisible to some data analysis techniques. Sonification offers the capability of seeing and listening to one or multiple data sets. Sonification is the representation of data by using (mainly non-speech) sound [4]. It is the auditory analogue to data visualization. Auditory displays extend (or in some cases replace) visual displays, and basically make use of the highly developed human listening skills for detecting patterns and regularities [5]. This paper describes the sonification techniques applied to the analysis of plasmas at 20.1 MHz. For this purpose the authors use the sonification prototype **xSonify** [6], (http://spdf.gsfc.nasa.gov/research/sonification/sonification_software.html), developed at NASA Goddard Space Flight Centre (GSFC) and FFT algorithms for data characterization.

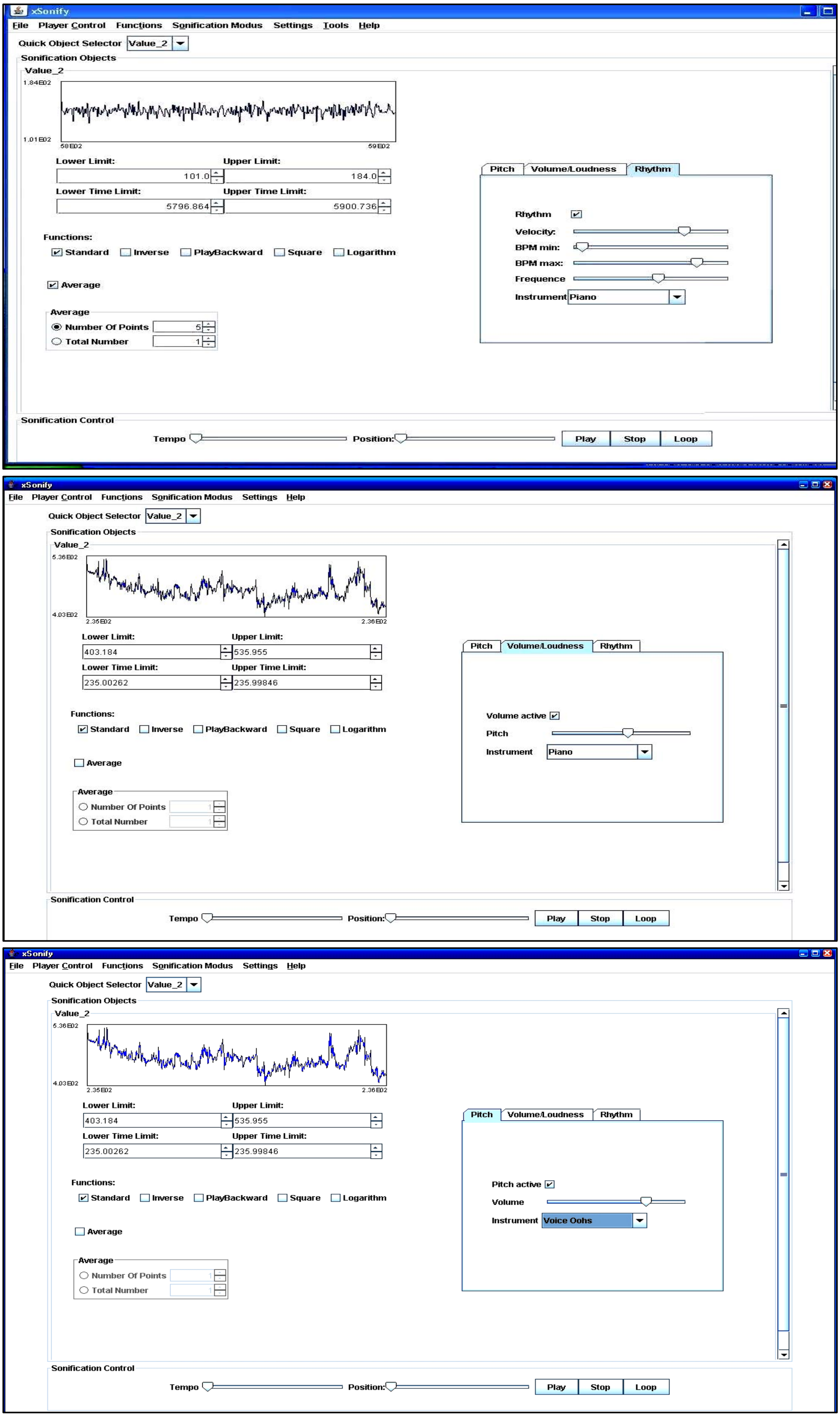
Method and instrumentation

xSonify is a data analysis program developed at NASA GSFC, code 672 by Anton Schertenleib and Robert M. Candey in 2005. The program permits the user to use data as text files and those from NASA data web services such as CDAWeb. xSonify uses the Java Sound package to create MIDI output. Any computer with Java (1.5 or greater) installed and a sound card can run the application.

xSonify is still in the prototype stage. We are working on the ways to analyze space physics data and to improve the human – computer interaction with the software. The xSonify has built in speech support that facilitates for the visually impaired people and the general user to download and sonify the data. Examples of different xSonify GUI are presented in Fig.1.

xSonify opens a world of possibilities for mathematics/science/physics teachers of sighted and visually impaired students and for amateur radio astronomers, such as the users of the NASA Radio JOVE project.

Data presented in this paper were collected by means of the improved Radio Jove receiver, RF-2001A, located at the grounds of the Rosa Cecilia Benitez elementary School in Caguas, Puerto Rico. The students performed an experiment suggested by Dr. John Mannone, collaborator from the University of Tennessee, for the detection of plasma bubbles in the ionosphere. A local oscillator generates a waveform at frequencies around 20.1 MHz (19.950-20.250 MHz). The incoming signals are amplified by a factor of 10. The receiver input circuitry is designed for a 50 Ohm antenna. The double dipole antenna (Radio Jove) is 10 feet above the ground, aligned east-west, in-phase, so the beam is directly overhead. The maximum gain for a horizontal dipole is 7.3 dBi, beam width is 115 degrees.



(a)

(b)

(c)

Fig. 1. Examples of different xSonify GUI: a) with Rhythm active; b) with Volume active; c) with Pitch active.

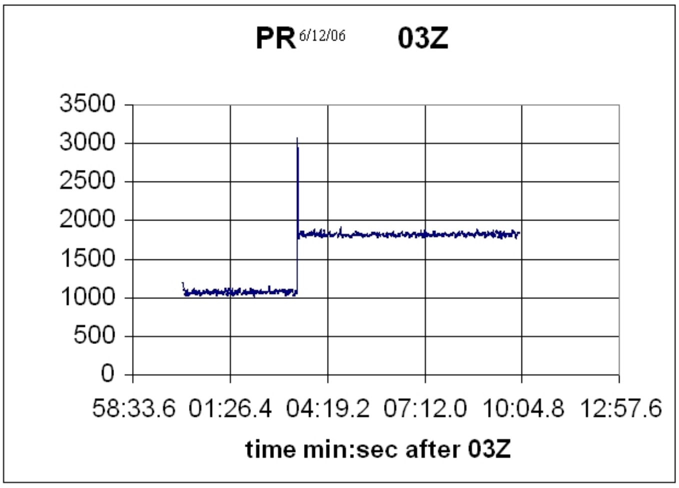


Fig.2. 20 MHz Radio Background Noise; Shirohisa Ikeda Observatory Puerto Rico, December 6, 2006, 11 pm local time. Signal Strength vs. Time Graph Reconstruction in Excel; 10 minutes time series sampled at 1 Hz (990 +/- 7 mHz.) during "herd "event.

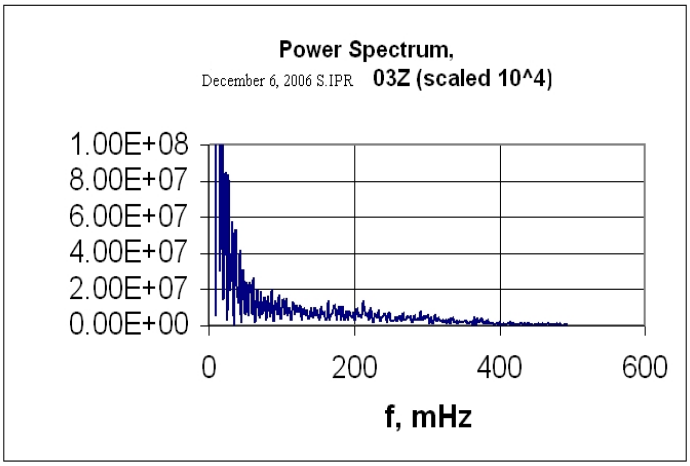


Fig. 3. Typical power spectral density (Power vs. Frequency); not very revealing except for ringing. Frequency plot more revealing is displayed in Fig. 6.

The experiment: radio data at 20.1 MHz

On December 6, 2006 we gathered data for the detection of charge deficient holes (plasma bubbles) in the ionosphere. Data were collected hourly for a period before sunset to after sunrise (6 pm to 6 am Atlantic Standard Time (AST)). Arbitrarily, the antenna signal was sampled for the first 10 minutes of each hour. The sampling rate was 1 Hz. 12 sets of base line were collected. Fig. 2 shows the sample recorded at 11 pm AST.

The data were collected, and the power spectra sonified in the frequency space, as is in the frequency analysis where discrete resonances, combs and bands are exposed [7] by holding the volume constant and the pitch active. We used these settings for sonification based on the fact that exited cavity modes lead to resonant lines: fundamental vibration and its harmonics that might be picked by the ear. The volume range was kept at 70 of its 100 range, the tempo was at 4 of 100 and an observation log was filled during the hearing of the sonification.

Various types of scintillation lead to different spectral indices [8]: the quiet sky - 0.65; typical ionospheric scintillation - 8/3; plasma bubbles - range 2-8 with average 4; tropospheric scintillation - 11/3; interstellar scintillation - like ionospheric without seasonal or geographic restrictions. The power spectrum in Power vs. Frequency plot – an example shown in Fig. 3 – is not very informative. The spectral index p is obtained from log Power vs. log Frequency plot; the spectral behavior is examined from the range 100-1000 milli-Hertz.

On sonification an increase in the baseline pitch was recorded at 11:00 pm local time (03Z), coinciding with ionospheric recombination time [9-11]. Though the plasma bubbles only survive around 30 minutes, the antenna is seeing numerous irregularities (future experiments will acquire more data over a shorter time interval and at higher sampling rate). Fig. 4 presents the examined spectral regions before and after this event.

Conclusions

In the context of this research frequency domain analysis using sonification especially over a particular

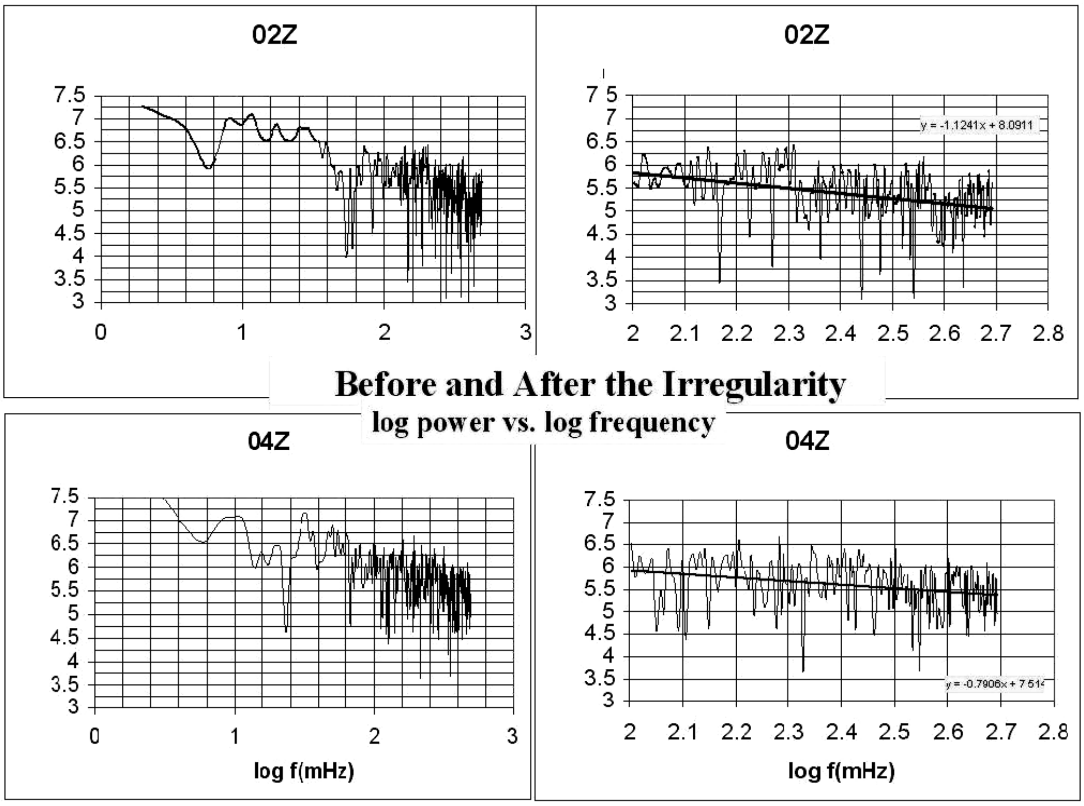


Fig.4. Power spectra of regions before and after the irregularity confirms the pitch changes heard.

range, revealed some very interesting features interpretable in terms of radio twinkling. More baseline studies, acquired at higher sampling rates have to be done to corroborate our findings. Sonification is an alternative and adjunct to visual displays for data exploration. Auditory exploration of data via sonification and audification is promising for complex or rapidly/temporally changing visualizations, for data exploration of large datasets (particularly multidimensional datasets), and for exploring datasets in frequency rather than spatial dimensions. The latter has opened the field of science to the visually impaired as well to the general public.

The use of sound is especially valuable as an assistive technology for visually impaired people and can make science and math more exciting for high school and college students [8, 9].

Listening to turbulent data can only be meaningfully done in frequency space and might also be possible to detect the differences in phase velocity. The power spectrum is difficult to listen to but restricting your hearing to decade windows between 10-1000 milli-Hertz, then you would probably detect frequency-averaged level and descending tones or other changes in slope. These would correspond to spectral indices, which in turn, tell us something about the physical processes in the plasma.

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