

Development of Multi-channel data logger for passive acoustic measurements

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Abstract

Recording of passive acoustic data involves a listening device along with an instrumentation system. The passive listening device transforms mechanical disturbances to electrical signals. The subsequent sampling and logging of the transformed data is accomplished by employing the instrumentation system. One such system is the Low cost "Multi-Channel Data Logger" (MCDL) that is indigenously developed at CSIR-National Institute of Oceanography with a capability to record 8- channels of passive acoustic signals simultaneously. Here we have presented the designed and developed MCDL system interfaced with a six channel hydrophone array to log ambient noise data from the underwater environment and also connected with dual low cost high sensitivity microphones for recording terrestrial ambient noise signals. The laboratory tests & field trials along with the data analysis results are presented to demonstrate the MCDL's multi-platform functionality.

Keywords: Ambient noise, passive acoustic, multi-channel, data-logger, soundscape

I. INTRODUCTION

In marine environment the sound signals are generated by various sources (surface as well as undersea) and are collectively called as marine ambient noise (AN). AN is sometimes classified as geo-phonic, bio-phonic and anthro-phonic. These underwater ambient noise signals may travel longer distances and therefore can be studied for number of applications such as underwater object detection, tracking of marine habitats and identification etc. Moreover, the terrestrial applications include forest soundscape studies using animal/bird sounds, for species identification, quantification studies and protection. The birds migrate due to the effects of climate change, reaching at their breeding grounds sooner as global temperature rise [1]. Hence birds migration pattern does provide the signatures of climate change. However, long term monitoring of environmental parameters may be used for climate research [2]. The Study of traffic and pollution data can be used to comprehend the environmental parameters. All the above mentioned research studies can be undertaken by implementing economically low cost data loggers within the region of interest.

In this work, we present the low cost Multi-channel Data Logger (MCDL) system and the passive acoustic data acquired from laboratory tests to field trials held within the Goan boundaries, along with a demonstration data recorded at Radhanagri wildlife sanctuary, Maharashtra. It may be stated here that the developed low cost instrumentation system can be employed at different locations for monitoring species (marine as well as terrestrial) and also the marine traffic by utilizing multi-channel facility of the MCDL.

II. MATERIALS

The self contained battery operated autonomous Multi-Channel Data Logger (MCDL) designed around Teensy 3.6 cortex-M4F ARM (Advanced RISC Machine) processor board (www.pjrc.com). The Teensyduino software provides integrated support for Teensy microcontrollers within Arduino IDE software platform by adding microcontroller specific libraries and the compiled program download utility that loads the program to the microcontroller memory. The C program compiled either on Linux using GNU gcc compiler or Windows is utilized to convert the recorded binary formatted data to ASCII file format. The microcontroller is interfaced with 8- channel Successive Approximation Register (SAR) - Analog to Digital Converter (ADC) using byte transfer mode that transfers data from ADC to microcontroller. At the time of acquisition every sample ensemble of 8- channels, 16 bytes are transferred from ADC to microcontroller. In this mode a sampling rate of 100 kHz was obtained. The MCDL block diagram demonstrates the total system functioning protocol (fig.1). The system is powered through 8D cells each of 1.5V alkaline batteries having total capacity of 7.2AH, may provide approximately 40 hours of continuous sampling of 8 channels at a maximum sampling rate

of 100 kHz. In active mode, it consumes maximum of 150 mA, while the sleep mode consumption is less than 0.5 mA approximately.

For field trials and the demonstration, the sample rate of 25 kHz was preferred for recording of bio-phonic and anthropogenic process generated acoustic signals. The marine AN data was acquired using single wideband C55 hydrophone (www.cetaceanresearch.com) for sampling duration of 30 seconds in every 1 minute. However, the laboratory test data was acquired for duration of 10 seconds in every 1 minute. The terrestrial ambient noise was also recorded by interfacing locally available low cost high sensitivity condenser microphones with the above mentioned configuration. The system is designed for short term deployments, however long term monitoring is also possible by upgrading the main power bank and its casing. The signal conditioning card consists of eight dual op-amps pairs configured in DC servo amplifier mode to enhance the electrical signal and to reduce the possibility of noise contamination from ancillary environmental factors. The precision Real-Time Clock (RTC) is provided to monitor sampling and recording time intervals together with time stamping the data. The precision RTC is synced with GPS time in every 24 hrs. During acquisition, the incoming signals are sampled, digitized and stored in the storage media of size 64 GB (upgradable up to 128 GB). The system features flexible and user customizable configuration with sample rates as high as 100 kHz with a file size of 96 MB for 60 seconds. The main 16-bit logger board along with GPS, signal conditioning and main power bank are packed in water proof enclosure. The water-proof interface is also provided on the enclosure. The system is fully water-tight and therefore can be installed on any fixed/floating platform for the acquisition of AN data.

III. METHODS

After successful initial tests of the MCDL system that were carried out by interfacing sine signals to each channel, the laboratory tests were performed, interfaced with single wideband C55 hydrophone deployed in water contained glass aquarium of dimension 50cm x 25cm x 25cm approximately. The aerator was installed and adjusted to generate air-bubbles in water medium, producing signals that are transformed and stored within the logger memory. During second phase of testing at the pool site, the Vertical Linear Array (VLA) of 6-channel hydrophones together with dual microphones were connected to MCDL for a short period of time, so as to check system's versatility. However, during tests and trials, the data was acquired leaving unused channels opened. The field trial at Dona Paula jetty was executed by interfacing single wideband C55 hydrophone (leaving unused channels opened), deployed at 2.5 m below the water surface and configured to record 30 seconds of sampled data at 25 kHz for every 1 minute. However due to shallower depths and higher currents at Cortalim jetty, the hydrophone depth was limited to 1.5 m approximately.

Subsequently, the system demonstration was also arranged in the month of March, 2017 at Radhanagri wildlife sanctuary to study forest soundscape by capturing terrestrial ambient noise (birds, animals and wind generated sounds) data employing low cost higher sensitivity microphones. At dusk, the MCDL was placed at the irrigation department guest house with in the sanctuary with the intention to record early morning bird sounds, but the cricket chorus sound was evident during the period. However, at dawn many birds sound signals were observed. The marine AN data was also logged (as a part of the demonstration) by interfacing single wideband C55 hydrophone, placed approximately at 1 meter below the water surface in the Radhanagri dam for a short span of time. The analyses of the logged data were performed by utilizing Matlab (www.mathworks.com) computational platform employing basic signal processing tools.

IV. RESULTS AND DISCUSSION

The design of 16-bit MCDL composed of integrated sensor (channel) interface, ADC & signal conditioning circuit board along with Teensy 3.6 cortex-M4F ARM micro-controller and storage. The system utilizes 8- channel SAR - ADC that employs byte transfer mode for data transfer from ADC to microcontroller. At the time of acquisition every sample ensemble of 8- channels, 16 bytes are transferred from ADC to microcontroller. In this mode a sampling rate of 100 kHz was obtained. The system has better features particularly towards sample rates, data storage capabilities and improved signal conditioning per channel. The configuration (config.txt) file is simple text format file that holds the settings (File prefix; sampling interval; sample rate; recording interval) and can be easily altered by the user using available text editors. However in the present data, the configuration file was set as per the requirement and unaltered for most of the tests except for file prefix & sampling interval. The MCDL is powered through 8 D cells each of 1.5V alkaline batteries having total capacity of 7.2 AH. In active mode, it consumes maximum of 150 mA, while the sleep mode consumption is less than 0.5 mA approximately. The system presently provides 64 GB microSD card (data storage media) that may be upgradable upto 128GB. Moreover it features flexible and user customizable configuration with sample rates as high as 100 kHz with a file size of 96 MB for 60 seconds.

The analyses of the data recorded in laboratory condition have shown the train of bubble blast sound signals Fig.2(a). The spectrogram i.e., Short Time Fourier transform (STFT) of the laboratory recorded time series acoustic data acquired using the Multi-Channel Data Logger is presented in Fig. 2 (b) in terms of frequency (Hz) versus time (sec). Higher signal strengths of 132.7 dB are observed at 147 Hz. It was also observed that varying the bubble size produces variation in the signal strengths and also to its peak frequency [3]. In the second phase of testing, the MCDL was operated with an VLA of 6-hydrophones and dual microphones as an experiment to record

underwater as well as land based AN signals. The logged array data have not shown much variations, however the microphones have recorded human talks and bird chorus.

The AN data acquired during field trials at Dona Paula jetty has shown jet skis underwater broadband sound signal, overlain with harmonically related tonals (ranging from 300 Hz to 5kHz that can be seen from Fig. 3(b)[4] and also the snapping shrimp noise, which is a dominant source of mid- frequency ambient noise [5]. The trial data recorded at Cortalim floating jetty has provided indication of piling information which was from the piling station positioned diagonally (~500 m) across the Zuari river banks, having signal strengths of 133 dB at the lower frequency of 48.83 Hz, observed through spectrogram (STFT) and Welch's power spectral density estimate (Fig.4)[6]. Furthermore the demonstration data acquired at Radhanagri wildlife sanctuary has shown significant improvement in capturing birds sound signals despite of rough windy conditions [7]. Moreover, the logged data have revealed the low amplitude signatures from birds which were otherwise ignored due to heavy noise induction. As it was equipment demonstration, other parameters were not necessary and hence the spot weather data was not collected. The terrestrial ambient noise data recorded at other locations within the sanctuary provided better results due to stable weather conditions or may be for the reason that the system installation was at lower elevation (Fig.5). However the source identification is not the purpose of this study. The recorded ambient noise during the transition period from dusk to night, the cricket noise signal was observed [8 &9]. The cricket generates the sound pulse by the effect of scissoring movements of the two wings having a series of harmonically related frequency components that were noticed at 3.5 kHz, 6.7 kHz and 10.4 kHz (fig. 6)[8]. However the peak of the spectrum was found to be at 6.7 kHz.

V. CONCLUSIONS

In this study, we presented indigenously developed Multichannel Data Logger (MCDL) that was employed to acquire AN data at various locations. The results were demonstrated through specified figures. The VLA of 6-channel hydrophones together with dual microphones were connected to check MCDL's flexibility in recording underwater as well as land based AN signals, however logging of weather data was not attempted. The SAR-ADC & signal conditioning board has provided better results as can be seen from the figures (oscillograms and spectrograms). The AN data acquired during system demonstration at Radhanagri wildlife sanctuary have shown the evidence of small farm birds. Additionally, the cricket noise sounds were also observed. Finally, the results have illustrated that the system is capable of recording quality data under the effects of moderate weather conditions.

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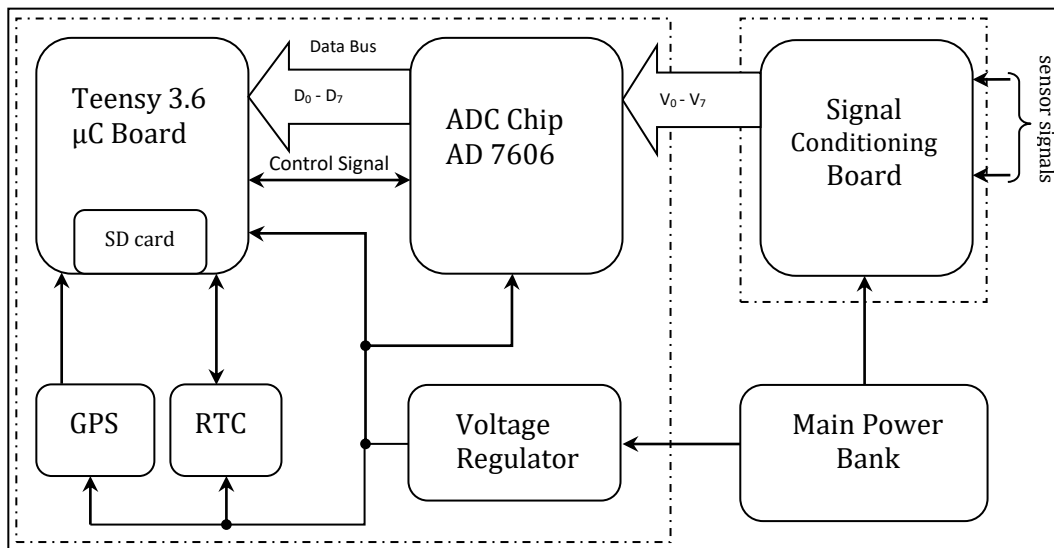


Fig. 1: Showing MCDL functional block diagram.

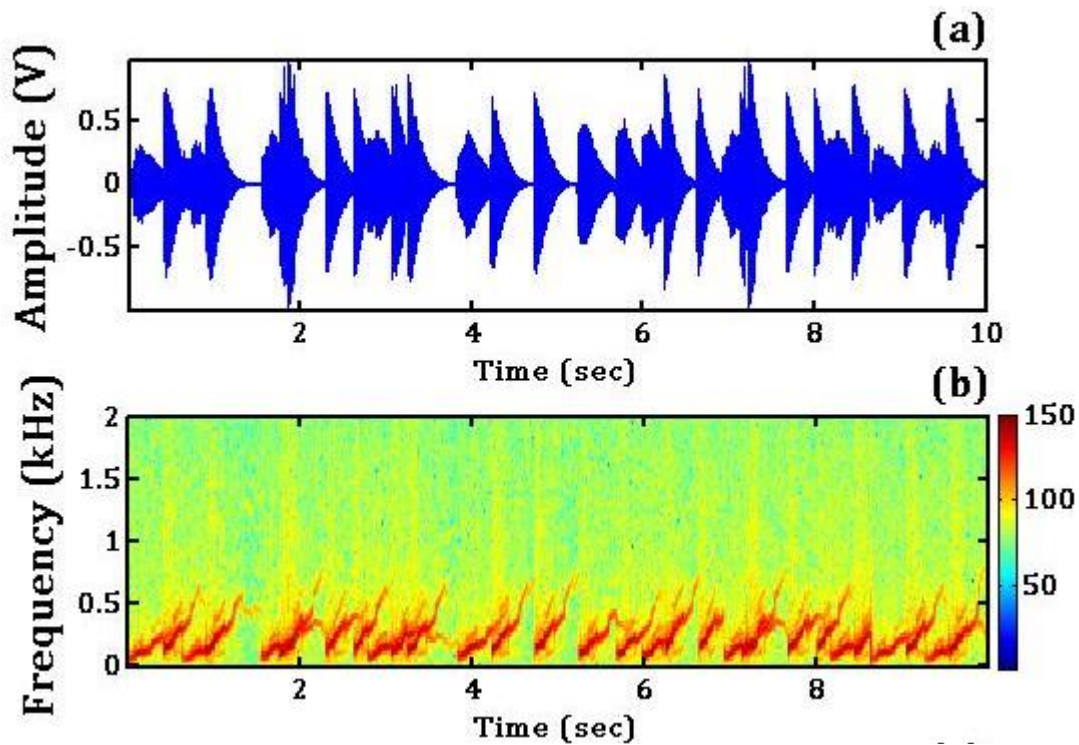


Fig. 2: Showing (a) Time series and (b) frequency spectrum of the bubble blast sounds recorded in laboratory.

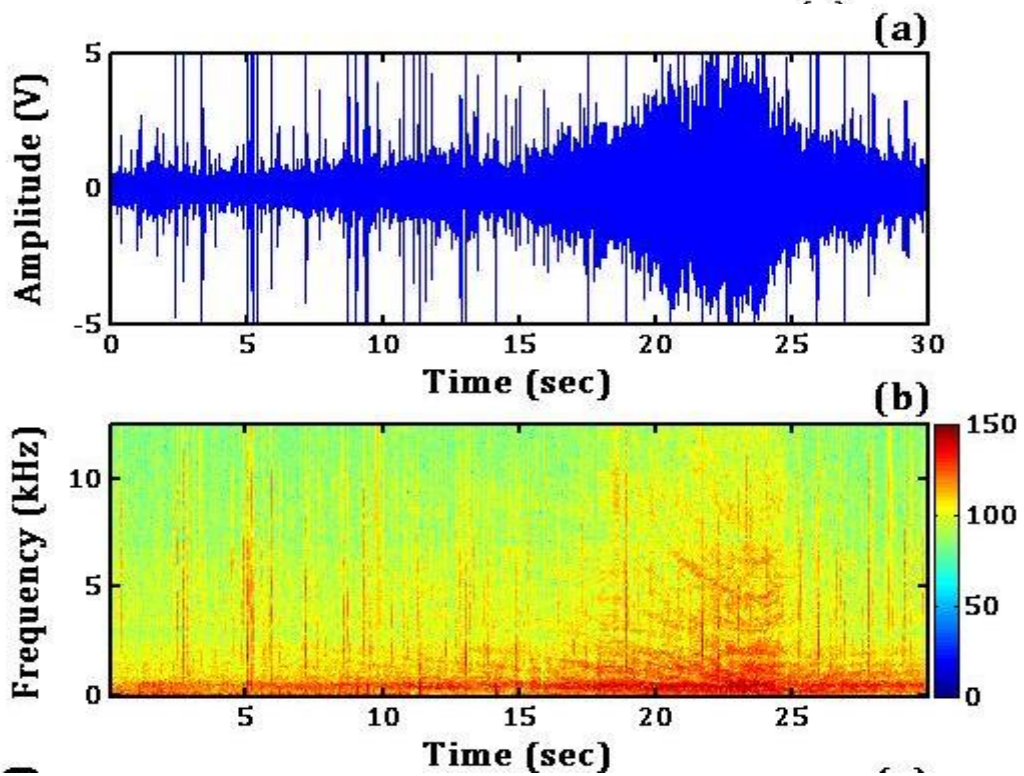


Fig. 3: Showing (a) Time series and (b) frequency spectrum of the Jet skis recorded at Dona Paula jetty

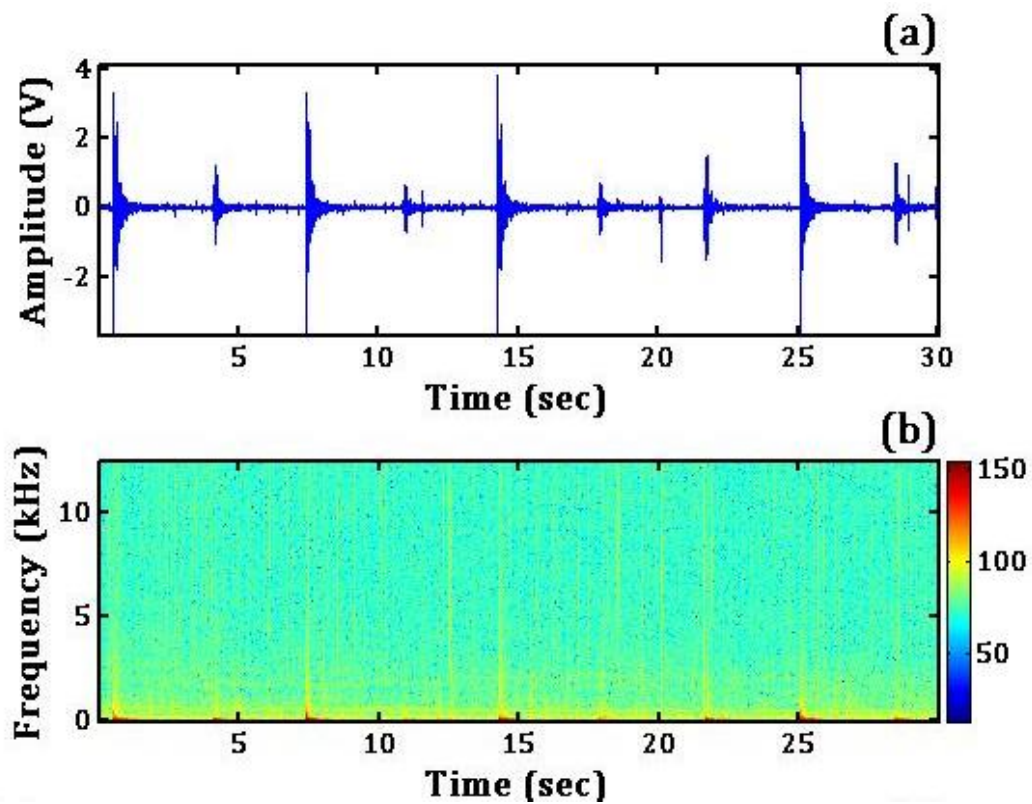


Fig. 4: Showing (a) Time series (b) frequency spectrum of the pile driving noise signals recorded at Cortalim private jetty.

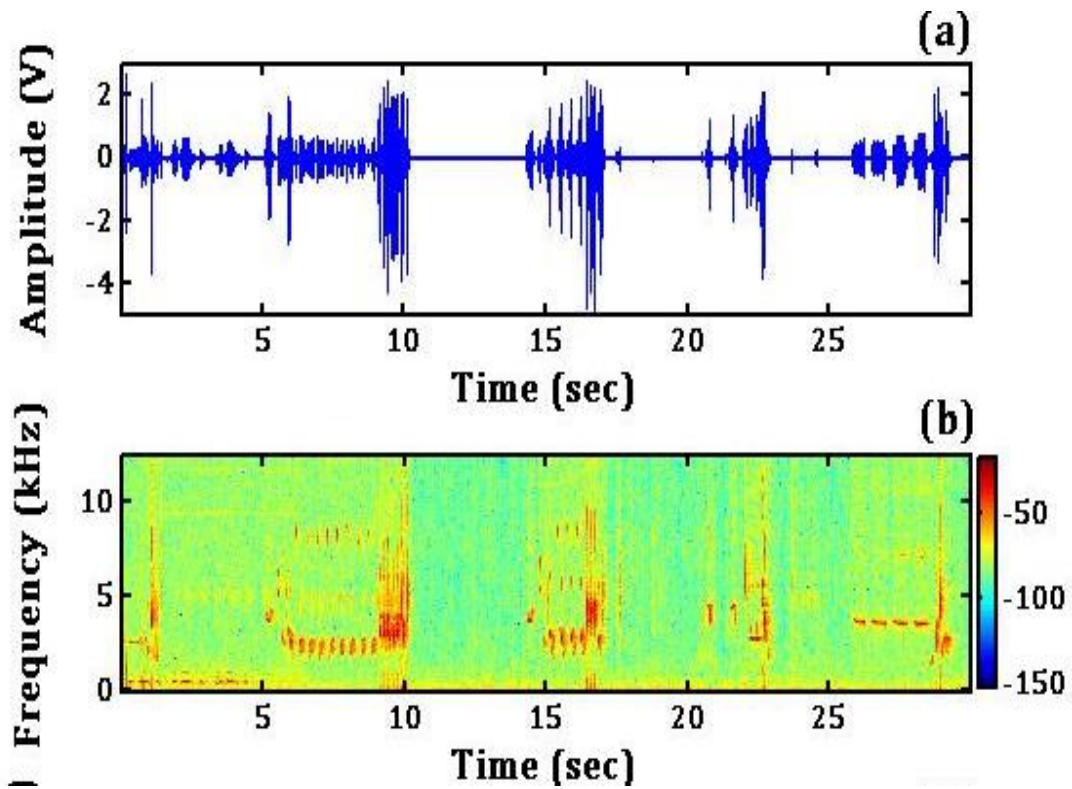


Fig.5: Showing Time series & Frequency Spectrum of the small farm birds sound signal acquired at Irrigation department guest house, Radhanagri

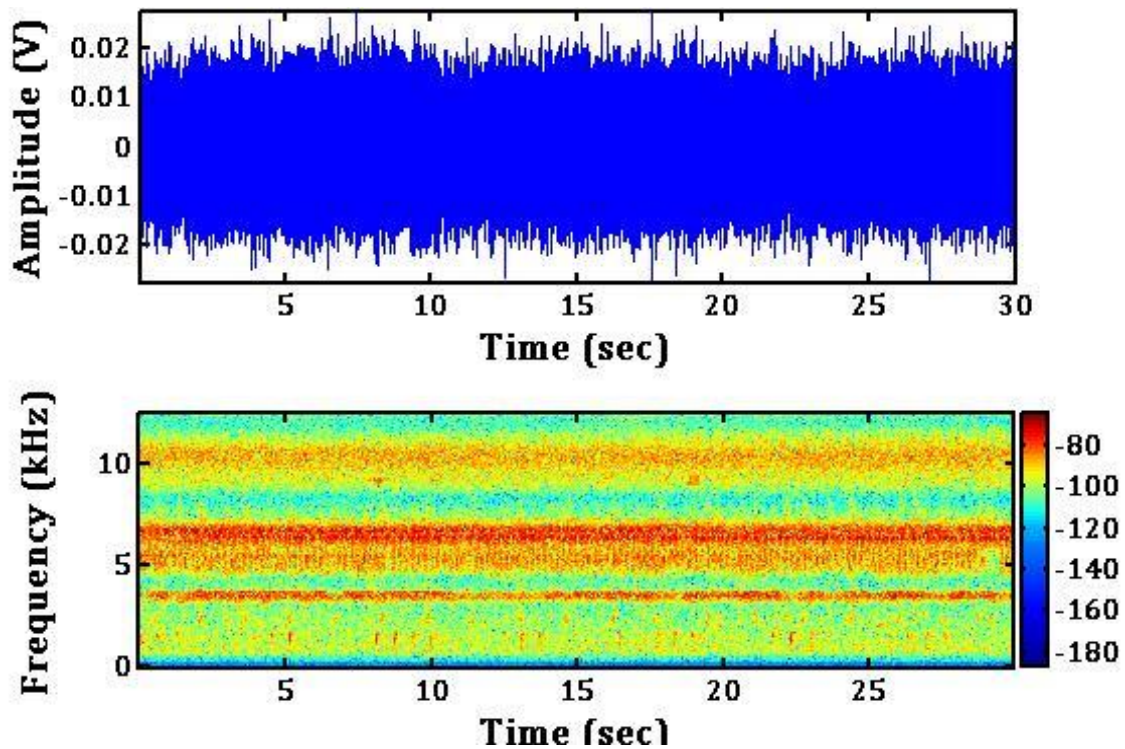


Fig.6: Showing Time series & Frequency Spectrum of the cricket noise signal acquired at Irrigation department guest house, Radhanagri.