2013 8th International Conference on Information Technology in Asia (CITA)

Ambient Noise Analysis on Sound For Use in Wireless Digital Transmission

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***Abstract*—Ambient noise is present everywhere in varying degrees of frequencies and amplitudes. This paper tries to analyse the ambient noises in various environments ranging from quiet room to busy public places to remote jungle type locations in order to study the impact of noise while using sound as a low frequency wireless carrier for digital data. We try to find the suitable frequency band for text transmission using soundby identifyingthe sound spectrum band least susceptible to ambient noise and do some test communication.**

***Keywords*—noise analysis;ambient sound noise; digital transmission, wireless, data communication**

I. INTRODUCTION

In response to the need for lower power wireless network signals, a proposal to evaluate use of sound as a network signal carrier was examined and we were able to successfully complete short rage communication between low powered smart devices using sound signals as the data carrier. However, even as the ubiquitous nature of sound makes it an adequate candidate for use as carrier signals, the same nature also presents a good amount of "noise", in the form of ambient sounds present in various environments. This is a challenge with potential to become a strong obstacle in using sound as the wireless carrier signal in real life practical scenarios. This paper attempts to analyse the ambient noise conditions in different environments ranging from quiet office room, busy street, quiet streets (in-roads), busy shopping malls, market place, normal household, quiet jungle terrains, etc. It will first evaluate the possible effect of such noise over normal data communication and try to find a suitable frequency band for text transmission using sound by identifying the spectrum band least susceptible to ambient noise.

II. RELATED WORKS

Mathew and Issac proposed making use of sound as carrier for low bandwidth, low power communication in the ubiquitous paradigm [1]. The paper attempted ubiquitous data communication using existing hardware in smart devices and sound as the carrier signal. Successful data transfer was achieved as a proof of concept and future work on furthering this towards practical application was suggested. M Weiser, proposed in 1991 pervasive computing as technologies which disappear as they ubiquitously blend into everyday life so that they are indistinguishable [2]. The concepts called tabs, pads and boards were introduced, and also opened up the networking challenge the nature of the devices will present.

Madhavapeddy, Scott, and Tse worked on audio networking which was a forgotten technology [3]. Theysuccessfully sent and received data and over sound using common computing platforms to do high frequency (ultrasonic) communication.

Chen and Leesubmitted a bibliographic study on Ubiquitous Computing looking at inter-relationships among major research themes in ubiquitous [4].

Jurdak, Lopes and Baldi proposed an acoustic identification scheme for location systems [5] which uses acoustic signals to uniquely identify and locate a user.

Madhavapeddy, Scott, and Sharp presented context aware computing with sound [6]. A number of location aware applications, namely, pickup and drop interface, digital attachments in voice, etc. were analysed.

Mandalet.et al. presented indoor positioning with 3D multilateration algorithms using audible sound [7]. It gave accuracy levels of about 2 feet in about 97% times using cheap consumer use hardware.

III. SOUND – THE NOISY SIGNAL

Close range transmission of data using sound as the carrier signal was tested to be possible in the real life scenario [1] and the transmission was accomplished using the Android smart devices with their standard built-in microphones and speakers.

Sound is a good choice in an attempt to identify a ubiquitous wireless signal, because of its low frequency, ubiquitous presence and low power requirements. The fact that sound is a ubiquitous signal also brings with it a challenge, that is, the good amount of sound present in most environments, which translates as noise when attempting data transfer. The challenge is to ensure successful data transmission even when noise is present.

The noise profiles in various environments are also expected to be different, which is analysed in this paper. We collected sound samples, from the Free Sounds website [9] from various environments including quite office, home, shopping mall, market, roadside, etc. and did a comparative

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study, enumerated in the ensuing section. The white noise is included as the last case as control signal for reference.

IV. THE EXPERIMENT AND RESULTS

The following sections show the analysis of the various ambient conditions explored. It is not comprehensive, but is indicative areas of application. We look at the power spectrum and the spectrogram in order to view the frequency spread and power of the signal over time. Additional parameters analysed are the Standard Deviation (Sigma), Mean (Mu), Peak - crest (Q) and Dynamic Range (D), all computed from the sample signals using the Matlab tool using the equations 1 to 2.

The audio data was downloaded from the internet [12]. The downloaded audio samples were trimmed to about 5 second for standardisation of the profiling. Each of the scenes under analysis is as from figures 1-10 and Table1.

A. The Quiet Office

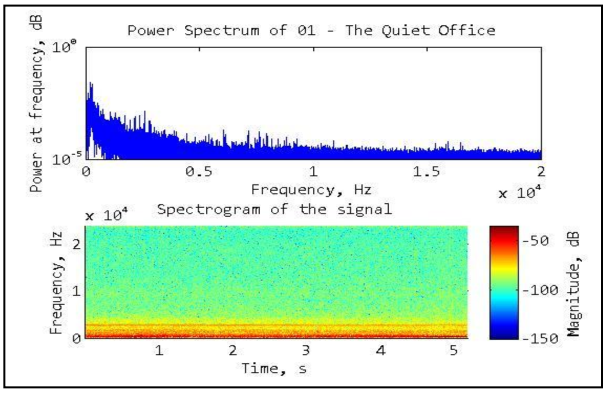

Fig. 1. Data Analysis – The quiet office

We observe strong low frequency which weakens around 1 kHz and 17.5 kHz. The spread over time is fairly consistent.

B. The Quiet Home

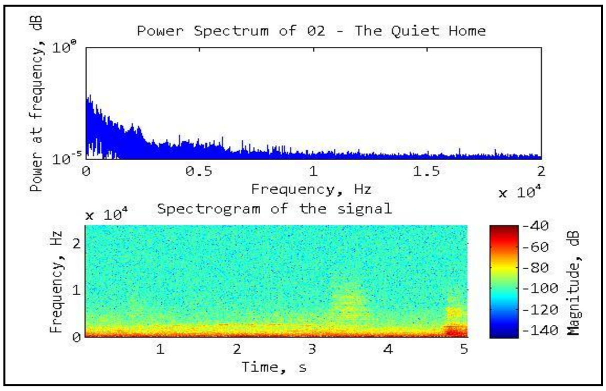

Fig. 2. Data Analysis – The Quiet Home

We observe strong low frequency signal which weakens around 8 kHz. The spread over time is not consistent.

C. The Busy Cafeteria

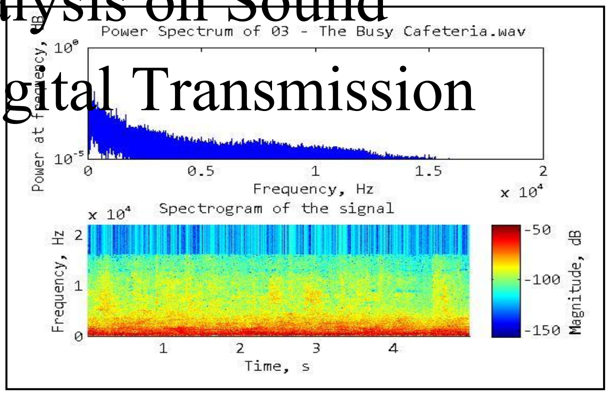

Fig. 3. Data Analysis – The Busy Cafeteria

We observe strong low frequency signal which weakens around 15 kHz. The spread over time is not consistent, as noticed from the spectrogram.

D. The Shopping Mall

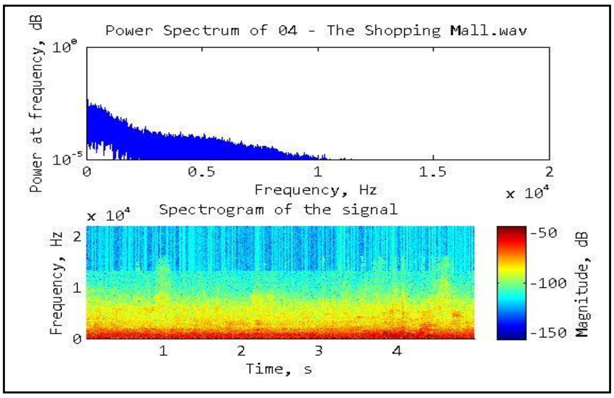

Fig. 4. Data Analysis – The Shopping Mall

We observe strong low frequency signal, weakens before 11 kHz. The spread over time is relatively consistent.

E. The Market

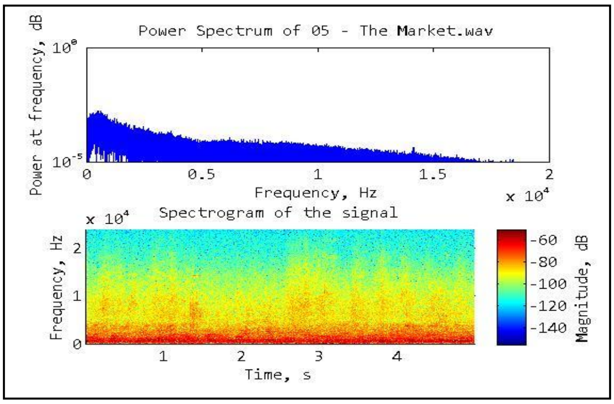

Fig. 5. Data Analysis – The Market

We observe strong low-mid frequency signal, weakens around 15 kHz. The spread over time is not consistent.

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F. The City Roadside in Traffic

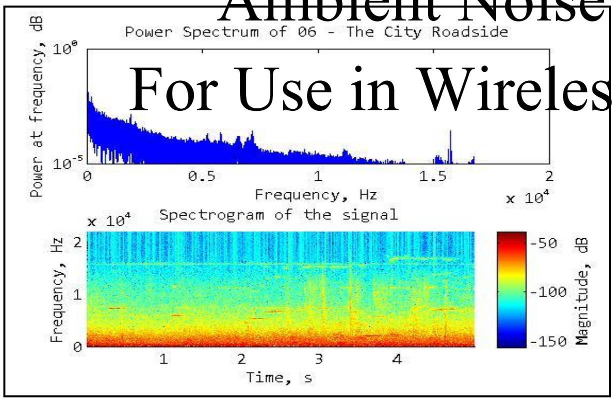

Fig. 6. Data Analysis – The City Roadside

We observe strong low frequency which weakens around 14 kHz. The spread over time is not consistent.

G. The Suburban Roadside

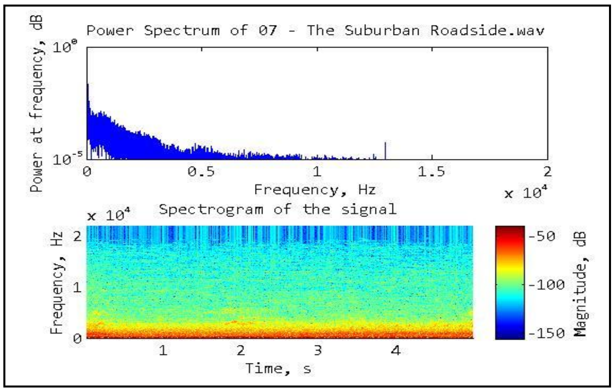

Fig. 7. Data Analysis – The Suburban Roadside

We observe strong low frequency which weakens around 13 kHz. The spread over time is fairly consistent.

H. The woods

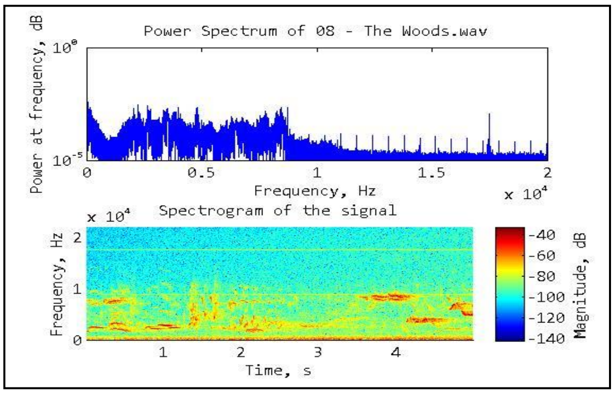

Fig. 8. Data Analysis – The Woods

We observe strong low-mid frequency which weakens around 12 kHz. The spread over time is not consistent.

I. A Rainy Day

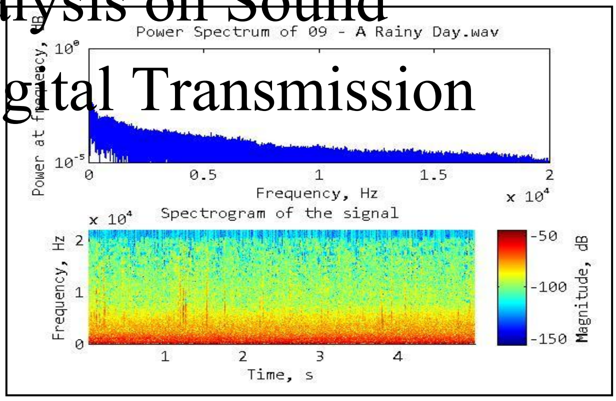

Fig. 9. Data Analysis – A Rainy Day

We observe low to high freq rollover as in a “pink noise”. The spread over time is fairly consistent.

J. White Noise (control signal)

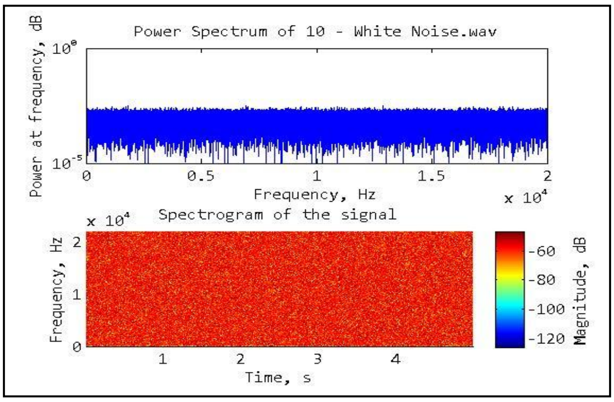

Fig. 10. Data Analysis – White Noise

We observe white noise as a control signal for referential comparison. White noise gives consistent strength throughout the spectrum & time.

The spectrogram was plotted using the built in spectrogram function in Matlab. To compute the power, we used the FFT function to calculate the values and plotted them against frequency. The Table 1 compares some of the other parameters of the clips that were generated using the Matlab tool on which the experiment was carried out. Standard deviation (Sigma), mean (Mu), peak-crest (Q) and dynamic range (D) was calculated as:

Use the norm fit function to compute Sigma & Mu

Peak (crest) factor Q

\- (1)

Dynamic range D

\- (2)

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TABLE I. AMBIENT NOISE PROPERTIES COMPARISON

Scenario	Noise Properties Comparison			
	Sigma	***Mu***	***Q (dB)***	***D (dB)***
A.	0.0[illegible]5704	2.3515e-05	12.7382	53.1316
B.	0.036529	5.1988e-05	19.7477	81.3094
C.	0.040365	7.2657e-07	13.0013	75.4303
D.	0.049696	9.7926e-06	15.0469	79.2824
E.	0.028277	7.2574e-06	13.5749	72.9124
F.	0.063095	-4.28e-07	15.0027	81.3116
G.	0.050741	0.018188	12.0411	76.9822
H.	0.060877	3.3152e-06	18.9953	84.9933
I.	0.041024	2.7176e-05	18.35	80.9198
J.	0.21329	-0.00019247	9.3998	86.2883

V. THE APPLICATION: COMMUNICATION USING SOUND

A simple Android application to do data transmission using sound was created as a proof of concept. It receives input text from the user, converts it to ASCII and sends it over the air as audible beeps to a peer application. The peer listens to this beep, identifies the fundamental frequency using FFT, translates it back to ASCII and displays it to the user as text. The beep was sounded using built in speakers on the Smartphone and built in microphones would listen for incoming beeps.The experiment was done on a range of devices from version 1.6 to 4.1 of the Android OS. The initial experiment showed that the frequency gap needs to be sufficiently wide (about 8 Hz or more) to accommodate for standard errors in the mass consumer devices and still correctly identify the transmitted frequency. It transmitted basic alphabets and numbers in short sequences in a quiet office environment. The results of some of the testing are as shown in Table2.

TABLE II. DATA TRANSMISSION OVER SOUND

Transmission Text	Successful Transmission percentages	
	Success	***Failure***
1. Alphabets	100%	0%
2. Random Characters	99%	1%
3. Digits	100%	0%
4. Short Text	96%	4%

[a] Transmission was done with a frequency gap of 10Hz between each character code

Transmission using lower harmonic frequencies had higher failures. So we shifted transmissions to a higher frequency band, using formula (3) for data encoding and was quite acceptable above 500Hz.

- (3)

where f = frequency of the signal; asc = ASCII value of the text; s = frequency band shift factor; g = frequency gap

The experiment reveals that the influence of the noise in this type of signal is high. Hence the study detailed in this paper was carried out to identify quieter channels that are less susceptible to noise.

VI. CONCLUSION AND FUTURE WORK

We can observe as a trend from the above experiment that the quieter signal is towards the higher frequency bands. The common pattern through most signals, we observe the signals quieting down to a good extent around the 12-15 kHz mark. This can lead us to think that the better candidate for a lesser noisy channel for data communication using sound as the carrier signal should be more towards the higher frequency spectrum. With the only exception of scenario H (The woods), we can see that the signals are very strong at closer to the low frequencies tapering down towards the higher frequencies and the most interesting being I (A rainy day), very closely resembling the pink noise. The noisiest of these environments can be observed as the (H) The Woods and (I) the rain. Both of these signals also register a relatively higher peak (crest) value and range, as observed in Table 1. Scenario (A) The Quiet Office is relatively the quietest of the environments considered for this experiment. This need not necessarily mean that the lower frequencies cannot be used, but rather indicates that it needs to be more resilient to noise. A possibility is to use a stronger signal that is "louder than noise" so that the signal is "heard" above the noise. Another approach can use a higher frequency sound, above the 15 kHz mark to take advantage of less interference due to noise. Both options imply a slightly higher power requirement, to generate a louder signal or to generate a higher frequency signal. Further studies are neededin order to identify an efficient design.

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