

Traffic Noise: 1/f Characteristics

K. B. Patange, Deogiri College Aurangabad, Maharashtra, India

A. R. Khan, Maulana Azad College, India

S. H. Behere, Dr. Babasaheb Ambedkar Marathwada University, India

Y. H. Shaikh and Shivaji Arts, Commerce, Science College, India

ABSTRACT

In this paper, the study of traffic noise is presented from the point of view of 1/f noise. Samples of Traffic Noise are collected from selected locations from busy roads of Aurangabad city in Maharashtra state (India) and data is analyzed. It is observed that in many cases the traffic noise possesses pink noise (1/f noise) prevailing over appreciable range of frequency. The log log plot of noise power versus frequency results in a straight line with a slope approximately equal to unity confirming the presence of pink noise. After certain frequency, the noise power no longer behaves like pink noise (1/f noise) and becomes more or less constant with random fluctuations. Plots of noise power versus frequency on log log basis for different locations studied are presented and the inferences are discussed.

Keywords: 1/f Noise, Frequency Spectrum, Noise Power, Pink Noise, Traffic Noise

INTRODUCTION

Traffic noise is considered as one of the important sources of noise pollution that adversely affects human health in residential urban areas (Onuu, 2000; Martin, 2002; Gambart, Myncke, & Cops, 1976). Low frequency noise is common as background noise in urban environments arising due to many artificial sources like road vehicles, aeroplanes, industrial machinery, artillery and mining explosions and air movement machinery. This includes wind turbines, compressors, and indoor ventilation and air conditioning units etc. (Tempest, 1985; Leven-

thall, 1988). Low-frequency noise or flicker noise has been found in many systems (Li, 2009). Intense low frequency noise may produce clear symptoms like respiratory impairment and aural pain (Von Gierke & Nixon, 1976). The $1/f$ behavior generally persists over low frequencies (Sinha, 1996). The power spectra of large variety of complex systems exhibit $1/f$ behavior at low frequencies. It is widely accepted that $1/f$ noise and self-similarity are characteristic signatures of complexity (Gilden, Thornton, & Mallon, 1995; Wong, 2003). Self-similarity, scale invariance and fractal nature are found to be characteristics of many natural phenomena (Shaikh, Khan, Pathan, Patil, & Behere, 2009; Shaikh, Khan, Iqbal, Behere, &

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Bagare, 2008). $1/f$ noise refers to the phenomenon of the spectral density, $S(f)$ of a stochastic process (Ward & Greenwood, 2007) having the form

$$S(f) = \text{constant}/f^\alpha$$

Where f is frequency, on an interval bounded away from both zero and infinity. Spectral density (power distribution in the frequency spectrum) is such a property, which can be used to distinguish different types of noise (Wikipedia, n. d.). This classification by spectral density is given “color” terminology. The spectral density of white noise is flat ($\alpha = 0$), while pink noise has $\alpha = 1$, and brown noise has $\alpha = 2$. During last 80 years since the first observation by Johnson (1925), long-memory processes with long-term correlations and $1/f^\alpha$ (with $0.5 \leq \alpha \leq 1.5$) behavior of power spectra at low frequencies have been observed in physics, technology, biology, astrophysics, geophysics, economics, psychology, language and even music (Wong, 2003; Press, 1978; Hooge, Klempner, & Vandamme, 1981; Dutta & Horn, 1981; Kogan, 1985; Weissman, 1988; West & Shlesinger, 1990; Van Vliet, 1991; Zhigalskii, 1997; Milotti, 2002) and in traffic flow too (Yale University, n. d.).

The frequency spectrum of pink noise is flat in logarithmic space; it has equal power in bands that are proportionally wide (Li, 2009; Press, 1978; West & Shlesinger, 1990; Milotti, 2002; Gardner, 1978). This means that pink noise would have equal power in the frequency range from 40 to 60 Hz as in the band from 4000 to 6000 Hz. Since humans hear in such a proportional space, where a doubling of frequency is perceived the same regardless of actual frequency (40–60 Hz is heard in the same interval and distance as 4000–6000 Hz), every octave contains the same amount of energy and thus pink noise is often used as a reference signal in audio engineering. That is, the human auditory system perceives approximately equal magnitude on all frequencies. The power density, compared with white noise, decreases by 3 dB per octave (proportional to $1/f$).

Materials and Methodology

To study the frequency distribution of the noise power, the noise recorded was analyzed using FFT (Fast Fourier Transform) technique. For the implementation of FFT, we used MathCAD 11. The audio files were opened in MathCAD for reading in the data and the characteristics of the recorded file such as sampling rate, number of channels, resolution etc were found. This is necessary for deciding the frequencies present based on sampling rate.

A program was written for this purpose, after reading in the data this displays the plot of amplitude versus time just like the wave representation of sound in any sound editing software like wave editor or wave pad. The amplitude data in time domain was then subjected to Fast Fourier Transform using the built in function FFT of MathCAD. We used 8192 (2^{13}) points for Fourier transform. Total number of frequencies resulting from the Fourier transform of the signal as described above is 4096. This allows a range of frequencies of up to about 22 KHz which is more than sufficient. In fact power at frequencies greater than about 10 KHz is marginal in general as compared to that at lower frequencies.

Fourier transform of the signal gives amplitude of noise at different frequencies. The amplitude resulting from the Fourier transform is a complex quantity with both real and the imaginary parts. Power can be found from the amplitude by taking its square, resulting data is written to text files for further use.

Results and Discussion

Having analyzed plenty of data from wave files recorded at selected locations under different traffic conditions it was observed that the noise power is higher at lower frequencies in most of the cases and as one goes to higher frequencies, the noise power rapidly falls down. Later a stage is reached where the noise power is found to be more or less same with random fluctuations. A typical recording of noise level spectrum is shown in Figure 1. The noise was recorded at

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