RECORDED MUSIC AMPLITUDE STATISTICS REVISITED

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1 INTRODUCTION

In the first reproduced sound conference Allen Mornington-West presented statistics on the amplitudes in recorded music[1]. His work was of necessity limited by the analogue based analysis equipment that was available in 1985. This paper used digital analysis methods to take that work further and will present statistics of much higher accuracy (at the quantisation limit of Compact Discs) for both filtered, as they would be in active crossover networks, and broadband music of diverse genres, from thrash metal through pop to classical. The results are surprising, and it will further present possible functions that model these distributions. It will also discuss their implication in the design of efficient power amplifiers and audio coding systems.

2 METHOD

Complete CD tracks were analysed using Matlab. Note, they were not "topped and tailed" so may have contained run in and run out silence. The two channels were treated as independent samples and merged together. Then each individual sample value occurrence was tallied, and the resulting counts were divided by the number of samples to give a probability density function (pdf). Unlike the earlier results, the fact that samples correspond to accurate time intervals the pdf can be considered an accurate measurement for the number of samples processed.

3 RESULTS

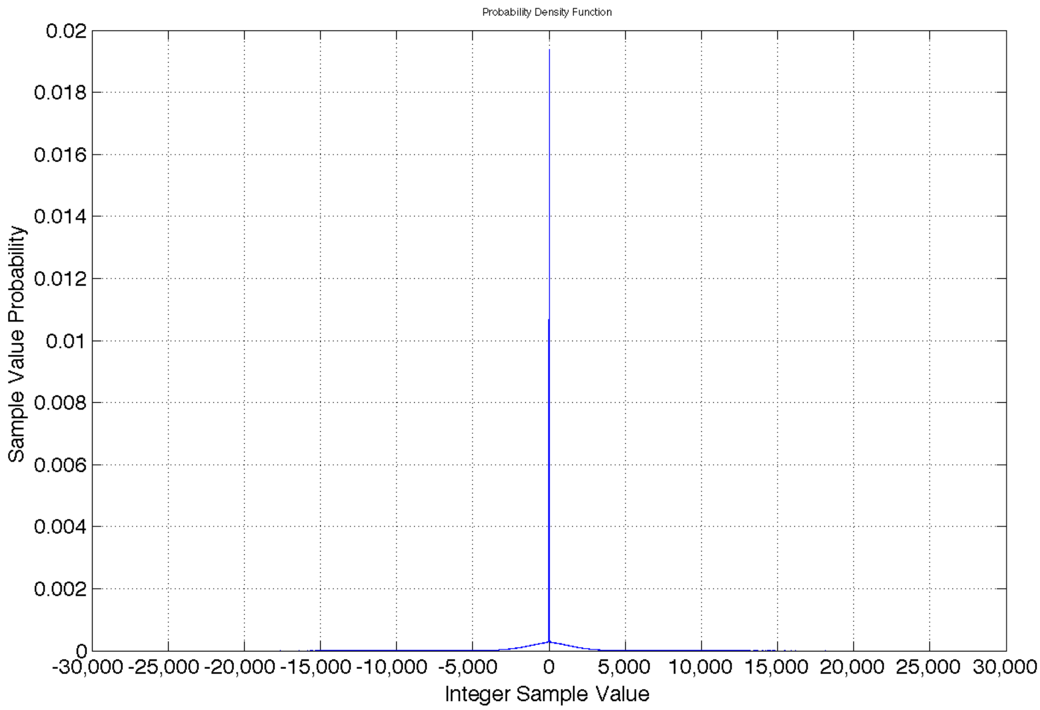

Figure 1 The probability density function of a music track

The probability density function (pdf) of a music track is shown in figure 1. Due to the high number of zero samples it is not particularly informative and figure 2 shows the same data scaled to disregard the zero samples. Its shape is similar to those reported by Alan Mornington West[1]. It is clear that the pdf is not Gaussian, but what law does it obey?

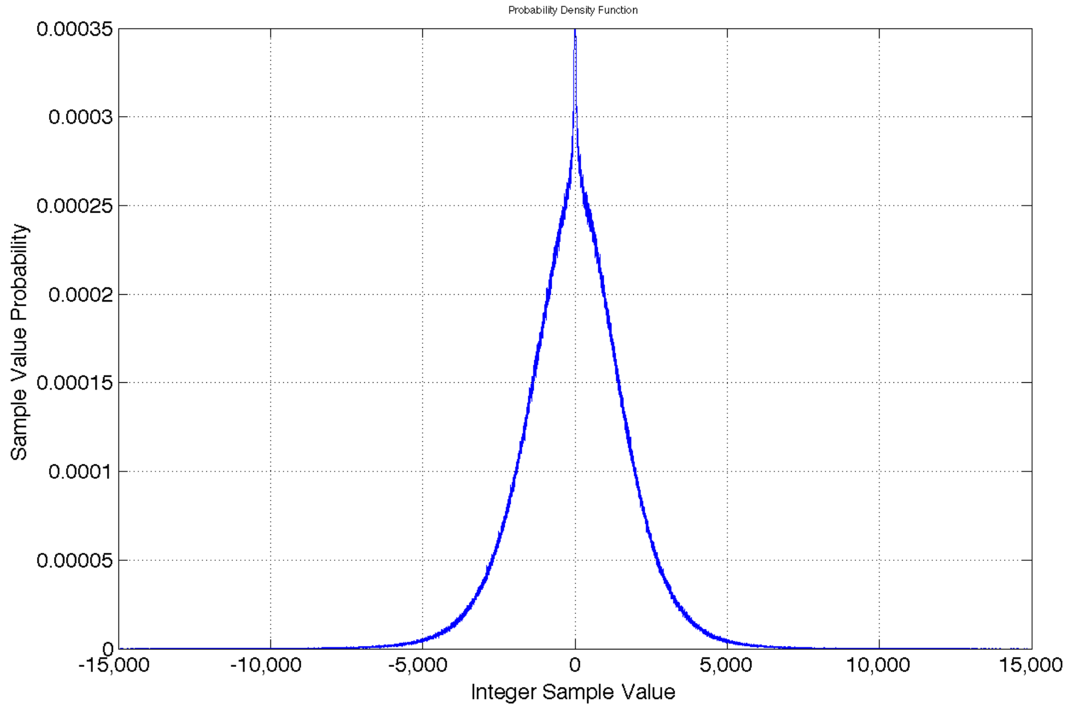

Figure 2 The probability density function of a music track scaled to remove probability of zero.

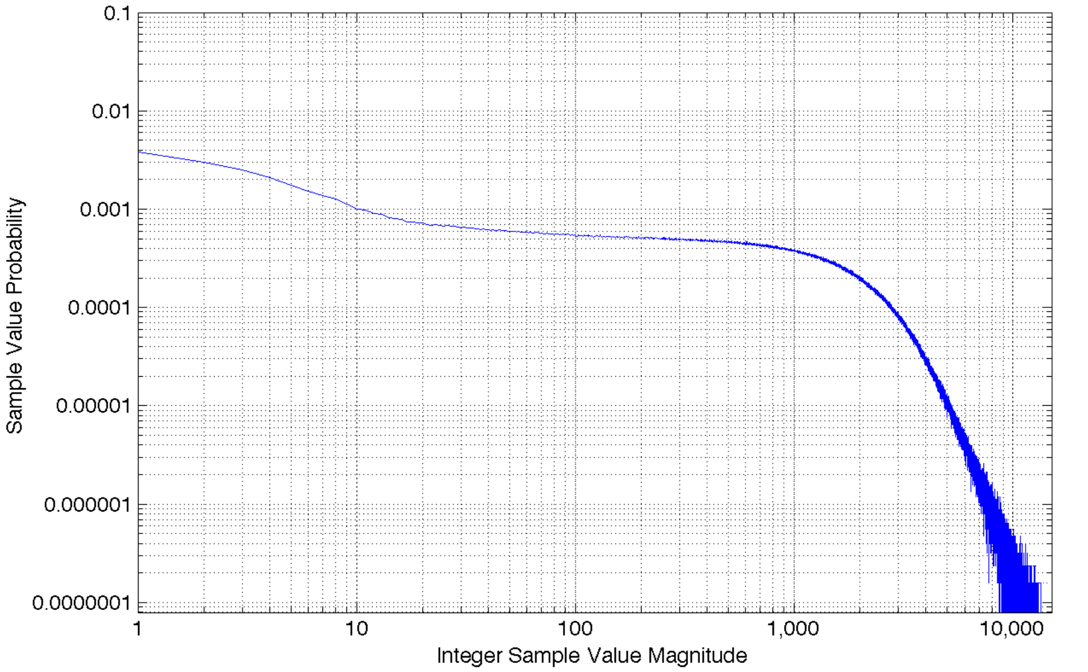

Figure 3 The probability density function of a music track plotted using log-log scales.

A log-log plot of the data in figure 3 clearly shows that the pdf does not obey a power law. However, a linear versus log plot, as shown in figure 4, clearly shows that the pdf corresponds to some kind of negative exponential law as evidenced by the straight-line region at the right hand side of the plot. However near zero the true exponential relationship breaks down somewhat.

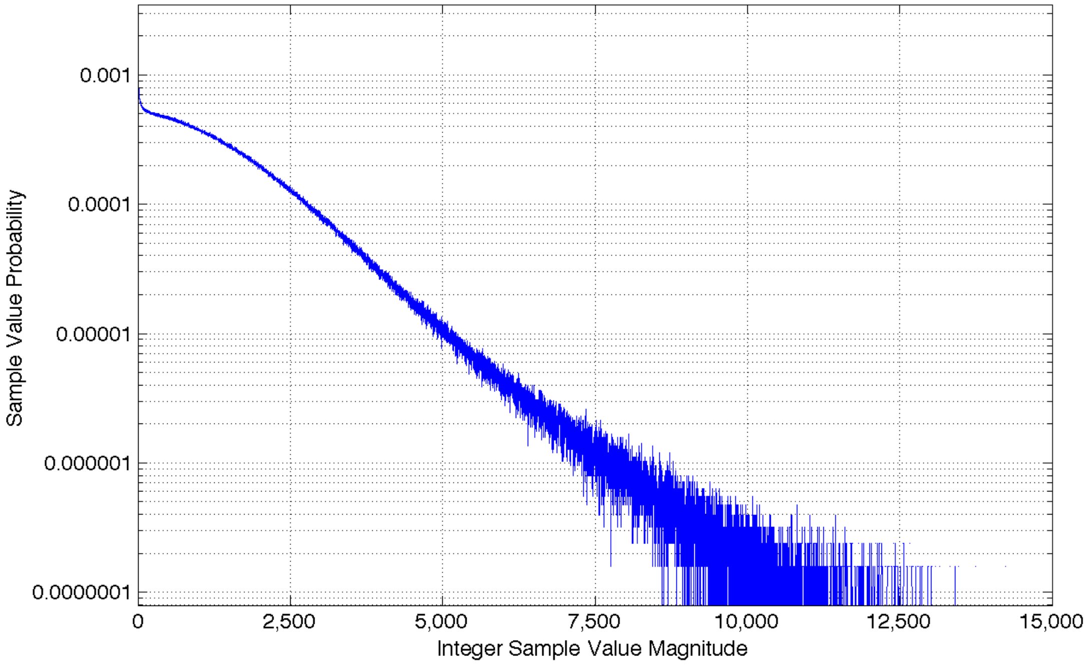

Figure 4 The probability density function of a music track plotted using lin-log scales.

The fact that the magnitude pdf of recorded music is of the form $y = e^{-k|x|}$ means that the music spends surprisingly little time at high amplitude levels. The cumulative probability density function shown in figure 5 indicates that for over 90% of the time the sample values are less than ±3000 compared to a maximum value of ±16500 for this piece of music. Note; this is much lower than the ±32768 range of a CD.

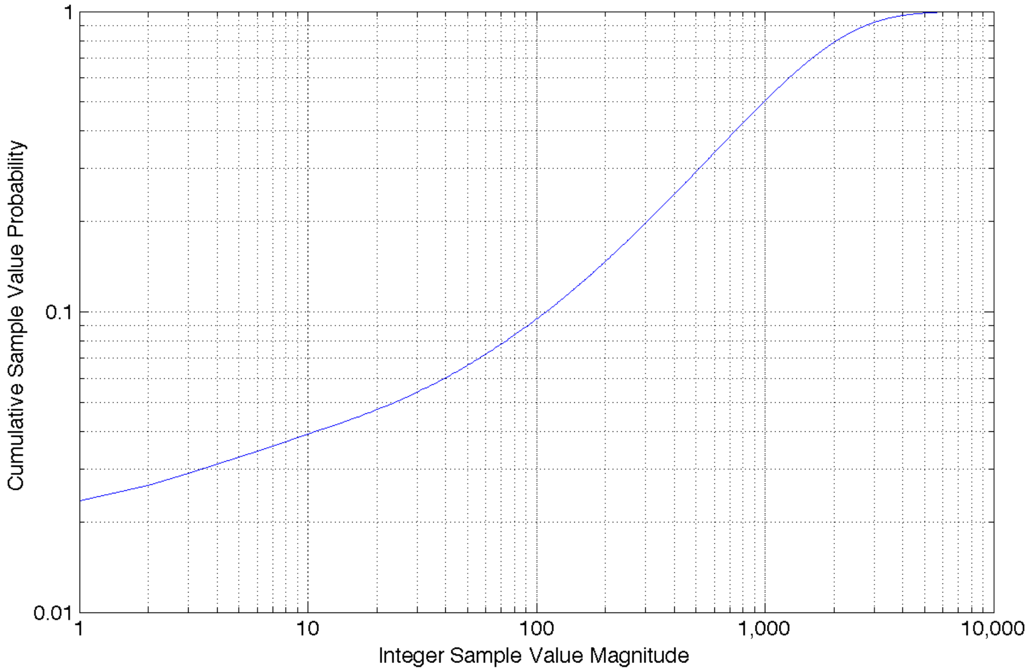

Figure 5 The cumulative probability density function of a music track plotted using log-log scales.

4 DISCUSSION

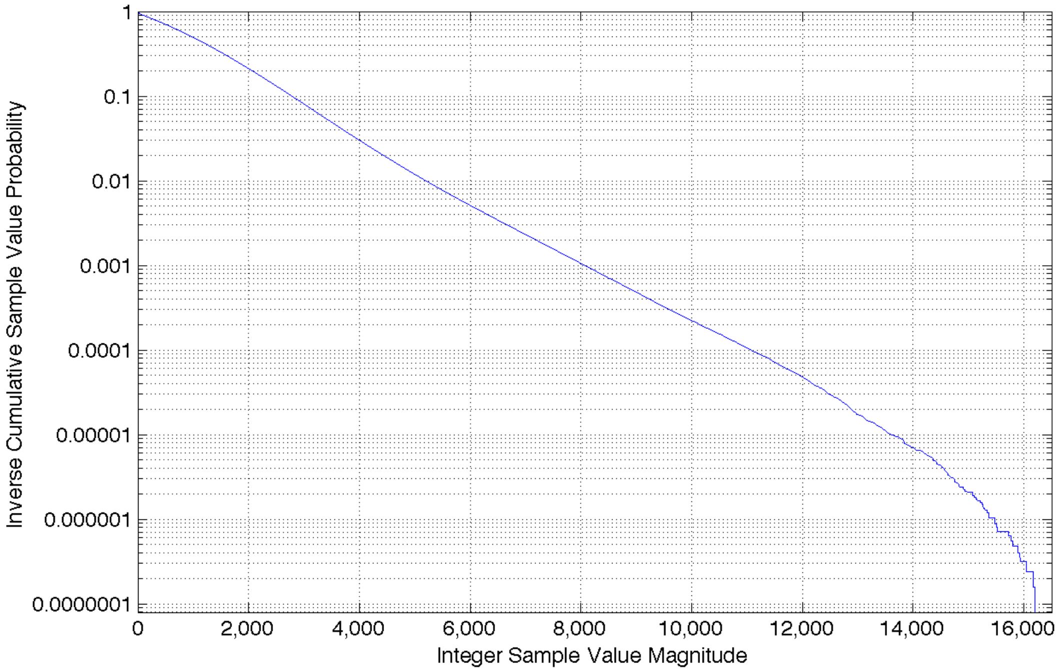

Figure 6 The inverse cumulative probability density function of a music track

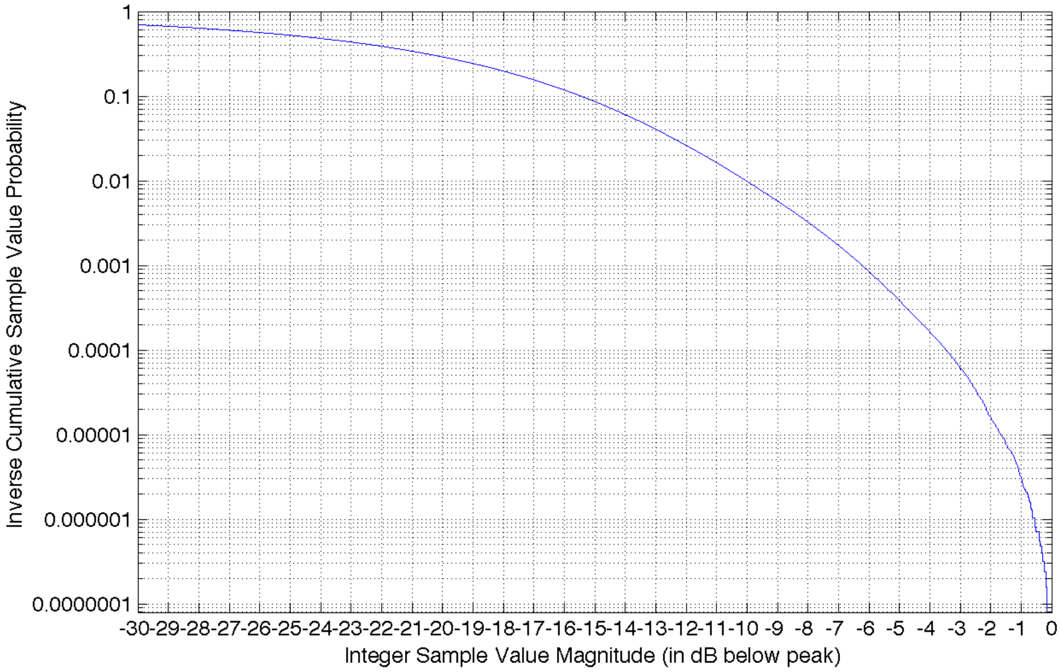

Figure 7 The inverse cumulative probability density function of a music track vs. dB rel peak

Figures 6 and 7 plot the probability that a given level will be exceeded at a given level. Figure 6 again demonstrates the exponential reduction in probability as the signal level increases and one can see that the signal spends 90% of the time at less than ±3000, 99% of the time at less than ±5500, and even less time at higher levels. If one assumes a 100watt amplifier is just passing the peaks then 90% of the time it is producing voltage levels of less than ± 7.27v corresponding to powers of less than 3.3w into 8Ω. Even more surprisingly for 99% the voltage levels are less than ±13.3v corresponding to 11.1w into 8Ω. Such voltages are well within normal op amp voltage ranges and suggest that a class G/class XD type system may have a lot to commend it as the switching points are unlikely to be activated for much of the time. Figure 7 shows that 90% of the time the signal is less than -15dB below peak and 99% of the time it is less than -10dB below peak.

5 CONCLUSION

Music signals have an inverse exponential probability density function that means high signal amplitudes become dramatically less likely. This has significant implications for the design of power amplifiers.

6 REFERENCES

1. A.R. Mornington-West, The distribution of signal amplitudes in recorded music, Proceedings of the 1st Autumn Conference on Reproduced Sound, Proceedings of the Institute of Acoustics, Vol. 7, part 3, 1985, pp137-146