Detection of high frequency cyclostationary third moment of current fluctuations in a tunnel junction

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**INTRODUCTION**

In electronics, the term "current noise" often refers to the variance $S_2$ of current fluctuations defining an effective temperature for a system. However, since fluctuations are in general not Gaussian, a lot of information can be extracted from the measurement of higher order moments. For example, in mesoscopic conductors, the existence of a third moment of current fluctuations $S_3$ stems from the binomial statistics of charge transfer [1], and correlations between current and emitted photons [2]. It can also probe internal timescales [3], electronic interactions [4], or charge multiplication in avalanche diodes [5]. In this work we present a new tool to study high frequency fluctuations in conductors. We measure the cyclostationary third moment of voltage fluctuations, i.e. the dynamical response of the third moment to an external drive. We demonstrate the possibility to detect the modulation of the skewness of current fluctuations at timescales shorter than 1ns. This opens the possibility to measure for example diffusion times in nano-wires, or to address the quantum limit where noise variance is dominated by vacuum fluctuations.

**METHOD**

High frequency measurements of $S_3$ are difficult for a conductor in the stationary regime due to the to a stringent constraint on the frequency bandwidth $\Delta f$, which must be at least of one third of the measurement frequency $f_0$. This condition relaxes in the cyclostationary regime, when the conductor is excited by a periodic signal at three times the measurement frequency. In this case there is no constraint on the bandwidth besides signal-to-noise considerations.

Using an homodyne setup [6], we detect the two quadratures of voltage fluctuations $X$ and $P$ at $f_0 = 4.85$GHz with a bandwidth of $\Delta f = 450$ MHz generated by a tunnel junction placed at low temperature $T = 3K$. The phase and magnitude of the third moment are calculated from the histograms of $(X, P)$ which are recorded for various dc and ac biases of the junction, see figure 1.

**RESULTS**

Our experimental data show that the total signal contains signatures of the Poissonian statistics of charge transfer in the junction, with contributions from environment through its impedance and noise temperature. These contributions however differ from the case of stationary detection [7]. In particular, some involve the environmental impedance at multiples of the measurement frequency $f_0$.

![Fig. 1. Probability density $P(X, P)$ of the quadratures of voltage fluctuations of a tunnel junction under cyclostationary excitation (after subtraction of the phase insensitive contributions). The existence of a third order moment is directly related to the rotational symmetry clearly visible in the data. Different plots correspond to different dc bias. The histogram rotates with dc bias, as a consequence of environmental feedback.](image)

**REFERENCES**


