AN ANALYSIS OF FEA NOISE MECHANISMS

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ABSTRACT

Noise, due to spontaneous fluctuations in the electron beam, has long been a source of concern for power tube amplifiers. At present, solid state amplifiers (SSA) are limited to a power output on the order of a Watt at 100 GHz or a kiloWatt at 1 GHz: at higher frequency-average power combinations, vacuum electronic devices dominate and are classified as either "slow wave" devices such as traveling wave tubes (TWT's), klystrons, magnetrons, crossed field amplifiers, or, at very high frequencies, "fast wave" devices such as gyrotrons, gyro-amplifiers, and Free Electron Lasers (FEL's). In either case, cathode noise is a concern. Whereas shot noise is due to the discrete nature of electron charge, flicker noise is related to ion bombardment, desorption of materials and (depending on the cathode) diffusion and / or evaporation of low work function coatings or higher work function adsorbates. When the cathode is operated space charge limited, noise from the cathode can be greatly reduced, but such options are not available for FEAs (nor to the magnetron injection guns (MIGs) of gyro-devices).

The time scale of shot noise (discrete electron emission events) is short by comparison to those associated with diffusion and migration of admolecules (flicker noise) for either thermionic or field emitters. In an rf system, after the electrons leave the cathode, they are accelerated into the power extraction region of the device: any noise the beam current carries will modulate the signal, and both sources of noise will receive the same amplification in the interaction region of the device. Because the time scales over which the noise mechanisms operate are different, the mechanisms will be more or less important depending on the frequency regimes (the Shot noise power is frequency-independent). In the present work, those sources of noise generated at the cathode, in particular as they apply to field emitter arrays, are investigated and contrasted with thermionic emission. The mathematical foundation of both noise mechanisms is briefly described, and the descriptions tailored to field emission sources. In particular, an analysis and comparison of shot and flicker noise is made, focusing on characteristic emission times and their relative importance in rf applications. Models of Flicker noise based on diffusion [1,2]and bistable transitions [3] are reviewed and examined in light of a statistical hyperbolic emission model describing Spindt-type field emitters. Even though the processes which contribute to flicker noise come in a variety of time scales and are due to a number of causes, thereby resisting a overarching analysis, we shall describe a few of the mechanisms in relation to experimental data taken on Spindt-type field emitters coated with zirconium carbide, and discuss that data in light of the models.

ACKNOWLEDGMENTS

We thank Y. Y. Lau, C. A. Spindt, W. A. Mackie, P. R. Schwoebel, and D. R. Whaley for useful discussions. KLJ thanks T. Antonsen and P. O'Shea for his stay at the U. of Maryland's *Institute. for Research in Electronics and Applied Physics* while this work was performed.

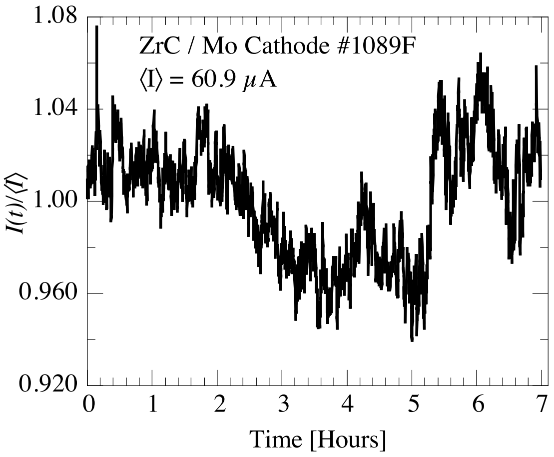

Figure 1: Data taken from an FEA developed by SRI (C. A. Spindt) and coated with ZrC by LRI (W. Mackie).

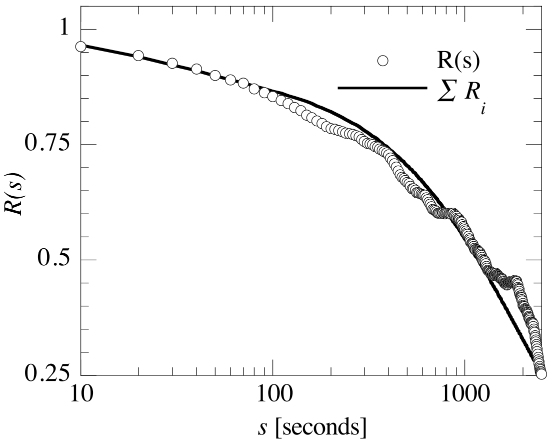

Figure 2: The normalized correlation function *R(s)*, associated with Figure 1 and compared to the sum of three fitted exponential terms.

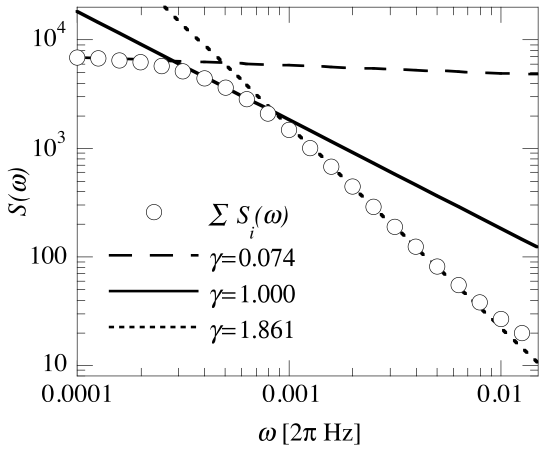

Figure 3: A comparison of the power spectrum $S(\omega)$ with tangent lines ($S(\omega) \propto 1/\omega^\gamma$) at various points, for *R(s)* data shown of Figure (2).

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