MAR14-2013-020029

Abstract for an Invited Paper
for the MAR14 Meeting of
the American Physical Society

Theory of injection locking and mutual synchronization of non-isochronous auto-oscillators in the presence of noise[1]

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A theory of injection locking and mutual synchronization of non-isochronous (having oscillation frequency dependent on the oscillation amplitude) auto-oscillators (AO) in the presence of thermal noise is developed and illustrated on the examples of spin-torque and spin-Hall nano-oscillators. It is demonstrated that all the characteristics of the injection locking and mutual synchronization of AO (such as phase-locking and synchronization frequency bands and transition times to a phase-locked state after application of a driving signal) are determined by the non-isochronous parameters of an AO : damping rate of amplitude fluctuations Γ_p and dimensionless nonlinearity coefficient ν (see Eqs. (27b) and (33) in [1]). It is also shown that the influence of the thermal noise leads to the appearance of an apparent threshold amplitude of the driving signal in the process of injection locking. The developed theory is used to quantitatively explain the phenomena of fractional [2] and parametric [3] synchronization observed in strongly non-isochronous spin-torque [2, 3] and spin-Hall [4] microwave nano-oscillators based on magnetic nano-structures and driven by either spin-polarized charge current or pure spin current.

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[1]This work was supported by the NSF , DARPA, and U.S. Army TARDEC
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