Nonlinear Self-phase-locking in an Array of Current-driven Magnetic Nano-contacts

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Recently it was shown that spin-polarized current passing through a thin magnetic layer can excite microwave magnetization precession in this layer. It was also demonstrated experimentally that the frequency of microwave generation in a current-driven magnetic nano-contact can be phase-locked to the frequency of a small external sinusoidalcurrent added to the constant bias current. In this work we theoretically investigate the possibility of self-phase-locking of an array of magnetic nano-contacts by self-induced dipolar magnetic field. First, we consider an isolated nano-contact driven by a constant bias current and determine the conditions of its phase-locking to the frequency of a small external microwave signal, which can be created either by microwave magnetic field or by microwave modulation of the bias current. We show that, in contrast with the case of a usual microwave oscillator, the mechanism of phase-locking in a nano-contact is strongly nonlinear: due to the strong dependence of the precession frequency on the precession amplitude even small changes in the oscillation amplitude can result in matching of the generated frequency to the frequency of the external signal. This nonlinear frequency matching mechanism leads to a significant increase in the frequency bandwidth of phase-locking D (up to $\sim$ 300 MHz). Bandwidth D has a non-trivial dependence on the magnetization angle, showing a well-pronounced minimum for the magnetization angle at which the coefficient of the nonlinear frequency shift is zero. We used the results obtained for an isolated nano-contact to determine the conditions for self-phase-locking of an array of nano-contacts, and found that the self-phase-locking in an array is practically possible when the distance between individual contacts is ~ 10 times larger than the nano-contact radius even if the inhomogeneous distribution of the frequencies generated by individual nano-contacts is as large as 10%.