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Mutual phase-locking and frustration in arrays of interacting spin-torque nano-oscillators ANDREI SLAVIN, VASIL TIBERKEVICH, Oakland University — We developed a perturbation theory describing collective dynamics of spin-torque nano-oscillator (STNO) arrays in a weak-coupling limit. In this limit each STNO is described by a single dynamical variable – effective phase ϕ_j, which satisfies the equation $d\phi_j/dt = \omega_j + \sum_k \lambda_{j,k} \sin(\phi_k - \phi_j + \beta_{j,k})$. Here ω_j is the free-running (unperturbed) frequency of the j-th oscillator, $\lambda_{j,k}$ is the effective coupling amplitude of j-th and k-th oscillators, and $\beta_{j,k}$ is the *frustration angle* of the oscillators' interaction. The frustration angles $\beta_{j,k}$ are determined by the intrinsic nonlinearity of STNO and by the delay of coupling signals. The frustration angles can be controlled by changing the distance between STNOs and/or by adding reactive elements to the STNO circuit. We have analyzed collective dynamics of STNO arrays in the case of global coupling, i.e. when coupling amplitudes and frustration angles for all STNOs are equal, $\lambda_{j,k} = \lambda$, $\beta_{j,k} = \beta$. We have shown that STNO array mutually phase-locks only when $\cos(\beta) > 0$. The critical coupling amplitude λ_{cr}, at which phase-locking starts, has a minimum for $\cos(\beta) = 1$ (i.e., for $\beta = 2n\pi$) and increases with the decrease of $\cos(\beta)$. For $\cos(\beta) < 0$ the mutual phase-locking of more than two STNOs is impossible, and the STNO array enters a *frustrated state*, in which the output power becomes vanishingly small due to the destructive interference between individual STNOs.

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