Microwave frequency combs in superconducting circuits

T. Weissl, S. W. Jolin[a], and D. B. Haviland[a]

Nanostructure Physics, KTH-Royal Institute of Technology, Roslagstullsbacken 21, S-10691 Stockholm, Sweden

We present a new experimental method to syntesize and analyse frequency combs in the microwave regime. The combs are generated by up-conversion of a frequency comb digitally synthesized at intermediate frequencies. Measurements are performed by down-conversion using the same local oscillator. The core of the experimental setup is a multi-frequency lock-in analyzer (MLA)[1]. It synthesized/analyses the frequency combs at intermediate frequencies in the kHz or MHz range by Fourier composition/decomposition using a field-programmable gate array (FPGA).
A nonlinear system, strongly driven at one tone of a frequency comb, will create two-mode squeezing, and eventually entanglement, between tones symmetrically spaced around the drive. We observe two-mode squeezing of up to 10 pairs of tones in our experiments. Extending this scheme to multiple drives should lead to highly entangled states that would provide a resource for one-way quantum computation[2].
When a non-linear system is driven with two drive tones, intermodulation between the two-drives will create a broad frequency comb. Measuring amplitudes and phases of these intermodulation products enables precision characterization the nonlinearity present in the system.

[1]Tholén, Erik A. et al., Rev. Mod. Phys. 82, 026109 (2011)
[2]Roslund, Jonathan et al., Nature Phot., 8, 109–112 (2014)