Noise Performance of Phase-coherent Oscillators Arrays

Archita Hati[(1)], Marco Pomponio[(1, 2)], and Craig Nelson[(1)]
(1) National Institute of Standards and Technology, 325 Broadway, Boulder, CO 80305, USA e-mail: archita.hati@nist.gov; marco.pomponio@nist.gov; craig.nelson@nist.gov
(2) University of Colorado, Boulder, Colorado 80309, USA; e-mail: marco.pomponio@colorado.edu

Low-phase modulation (PM) noise oscillators are at the core of many applications, including but not limited to radar, communication systems, medical imaging, wireless technologies, instrumentation, and precision metrology.

In this work, we discussed a method for achieving low PM noise and amplitude modulation (AM) noise signals by utilizing a phase-coherent array of oscillators [1]. While this approach is well-known for its effectiveness in reducing phase noise [2, 3], our primary focus has been on addressing the challenge of minimizing AM noise resulting from PM-to-AM conversion and to emphasize the importance of precisely aligning the phase of oscillators in the array.

For the array configuration, we employ a total of six oscillators each capable of generating 10, 100, and 1000 MHz. All six oscillators are synchronized to a common 10 MHz reference, as depicted in Figure 1. Initially, each set of three oscillators are combined in a 3-way power combiner, and the final composite signal is derived from the Σ-port of the 180º hybrid. We mainly use the Δ-port of the hybrid for measuring PM and AM noise utilizing a carrier suppression technique. Achieving precise phase alignment among the individual input oscillators is crucial for optimizing noise at the output. Through careful phase alignment, we attain extremely low single-sideband white PM noise of -182 dBc/Hz and -191 dBc/Hz for 10 MHz and 100 MHz, respectively and the corresponding white AM noise are approximately -191 dBc/Hz and -194 dBc/Hz. These noise levels are about 7.8 dB lower than those of a single oscillator, which corresponds to the anticipated reduction of 20log10(k), where k is the number of oscillators present in the array. The experimental results presented in this study demonstrate state-of-the-art performance. An analysis of AM-to-PM and PM-to-AM noise conversions, and a method for minimizing these conversions using a new type of digital Armstrong modulator will also be discussed.

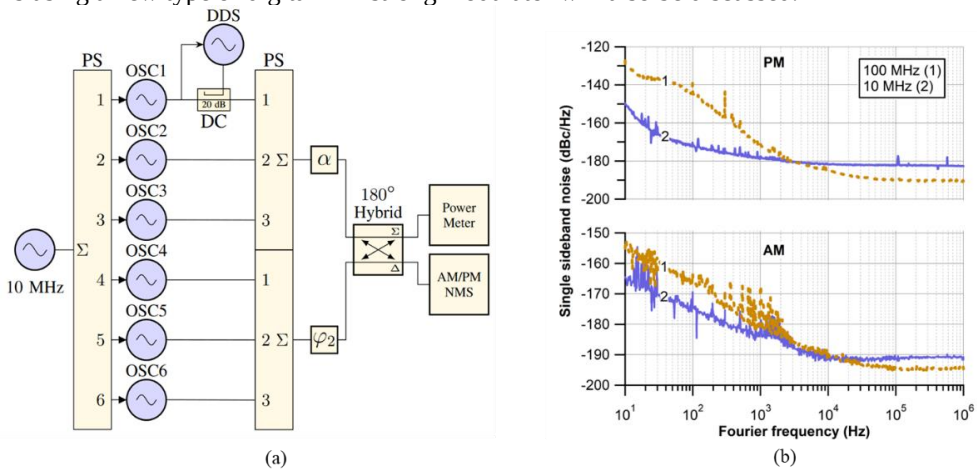

Figure 1. (a) An array of six phase-coherent oscillators. (b) PM and AM noise at 10 MHz, and 100 MHz. DDS – Direct Digital Synthesizer, DC – Directional Coupler, NMS – Noise Measurement System, OSC– Oscillator, PS – Power splitter/combiner.

1. A. Hati, M. Pomponio, and C. Nelson, "Ultralow PM and AM Noise Generation with an Ensemble of Phase-Coherent Oscillators," IEEE Trans. Ultrason., Ferroelectr., Freq. Control, Dec. 2023, doi: 10.1109/TUFFC.2023.3341726
2. H.-C. Chang, X. Cao, U. Mishra, and R. York, "Phase noise in coupled oscillators: theory and experiment," IEEE Transactions on Microwave Theory and Techniques, **45**, 5, May 1997, pp. 604–615.
3. M. Pomponio, A. Hati, and C. Nelson, "Ultra-Low Phase Noise Frequency Division with Array of Direct Digital Synthesizers," IEEE Trans. Instrum. Meas., Dec. 2023, doi: 10.1109/TIM.2023.3346538.