



Columbia University  
EE Department

# DESIGN OF ROBUST FREQUENCY GENERATION AND MODULATION CIRCUITS FOR LOW-VOLTAGE MOBILE IOT

As future wireless systems utilizing advanced CMOS technology demand not only low power but also low-voltage design, robust frequency generation and modulation have become more crucial than ever. In particular, sub-0.5V frequency synthesis and modulation are essential for enabling battery-free operation in mobile IoT devices, as they can be directly powered by energy harvesters without the need for additional DC-DC converters. However, designing a low-voltage fractional-N PLL is highly challenging, as both matching and linearity degrade significantly when the supply voltage is scaled down. The first part of this talk will discuss the extensive use of a 1-bit  $\Delta\Sigma$  modulation method to develop robust frequency modulation systems by mitigating nonlinearity issues. Then, a low-voltage BLE transmitter based on a bias-current-free hybrid fractional-N PLL with voltage-mode phase detection will be presented. Lastly, other energy-efficient wideband transceiver designs from my research group will be briefly introduced.

## Woogeun Rhee

*School of Integrated Circuits  
Tsinghua University  
Beijing, China*



Woogeun Rhee received the B.S. degree in electronics engineering from Seoul National University, Seoul, Korea, in 1991, the M.S. degree in electrical engineering from the University of California, Los Angeles, CA, USA, in 1993, and the Ph.D. degree in electrical and computer engineering from the University of Illinois, Urbana-Champaign, IL, USA, in 2001. From 1997 to 2001, he was with Conexant Systems (now Skyworks), Newport Beach, CA, USA, where he was a Principal Engineer and developed low-power, low-cost fractional-N synthesizer products. From 2001 to 2006, he was with IBM Thomas J. Watson Research Center, Yorktown Heights, NY, USA, and worked on clocking area for high-speed I/O serial links. He was a Visiting Professor at Seoul National University, Korea, from August 2022 to February 2023. He is currently a Professor with the School of Integrated Circuits, Tsinghua University, Beijing, China. He has published more than 180 IEEE papers and holds 24 U.S. patents. His research interests include energy-efficient short-range radios for mobile IoT, UWB transceivers for secure wireless connectivity, and mixed-signal circuits including phase-locked loops. Dr. Rhee currently serves as the Editor-in-Chief for IEEE OJ-SSCS. He has served on the AdCom of the IEEE Solid-State Circuits Society and the BoG of the IEEE Circuits and Systems Society, as a SSCS Representative. He was an SSCS Chapters Steering Committee Member from 2021 to 2023, a Distinguished Lecturer from 2016 to 2017, and an Associate Editor for OJ-SSCS, JSSC, and TCAS-II. He has served on the TPC for IEEE conferences, including ISSCC, CICC, and A-SSCC. He was the TPC Chair of A-SSCC 2021 and has been the Steering Committee Member of A-SSCC. He is an IEEE Fellow.

**April 11th | 2:00 PM - 3:00 PM**  
EE Conference Room | 13th Floor