Success Story

Toshiba Research Europe Innovates Totem Pole RF PA Using NI AWR Software

TOSHIBA

"We use NI AWR software on a daily basis in our research activities, which are projects that are typically five to 10 years away from market. The software enables us to take rough ideas for future products and develop them into prototypes."

Dr. Gavin Watkins, Toshiba Research Europe Limited

Company

Toshiba Research Europe Limited operates Toshiba's Cambridge Research Laboratory and the Telecommunications Research Laboratory in Bristol, UK. Since its inception in 1998, the Telecommunications Research Laboratory has been at the cutting edge of research into technologies such as next-generation wireless networking, reconfigurable device architectures, and "smart" systems for energy, mobile, and medical applications.

Challenge

Wireless communications systems require RF power amplifiers (PAs) to overcome the transmission path loss that exists between transmitter and receiver. The push-pull amplifier offers a simple and convenient way to produce high transmit powers. At RF frequencies, it usually consists of two transformer-coupled common-source devices operating in antiphase. An alternative is the totem-pole architecture, shown in Figure 1, which features two devices of the same polarity driven by an active driver stage. The additional current consumption of this driver stage results in low RF efficiency.

Toshiba designers used NI AWR software to investigate the totem-pole amplifier with the long-term objective of producing an integrated push-pull RFPA in a single package that is the same size as a conventional RF transistor. This would result in a PA size reduction of over 90 percent, suitable for many high-density applications where large numbers of these PAs operate together in a small space, such as phased-array radars and 5G Massive multiple-in-multiple-out (MIMO) communications systems.

In this work, two N-channel field-effect transistor (FET) devices were used, one of which operated in a source-follower configuration, which is not normally covered by the datasheet or the simulation model. Although the low-frequency transistor models complied, moving up in frequency to the RF region led to problems, as the source follower's parasitic components were not sufficiently characterised. The source follower also had a very high input impedance (approximately 1 kΩ). This was significantly higher than the typical 50-Ω domain of RF circuitry, making the circuit layout susceptible to the influence of stray capacitance and inductance.

At-A-Glance

Application
- Amplifier

Software
- NI AWR Design Environment
- Microwave Office

Benefits
- Quality of results
- Ease of use
- Speed of simulation
- Proficient support services

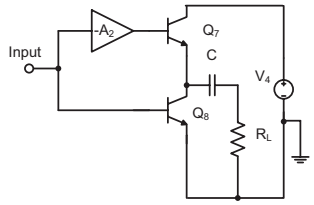

Figure 1: Totem-pole architecture.

Solution

Using the NI AWR Design Environment platform, specifically Microwave Office circuit design software, the designers successfully imported the transistor models and simulated the circuit, as shown in Figure 2. Operation was confirmed by the current waveforms and the suppression of the second harmonic, shown in Figure 3.

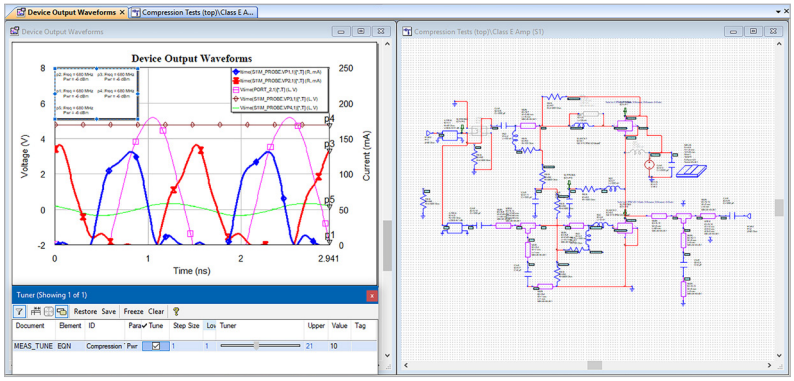

Figure 2: Microwave Office schematics and simulation results.

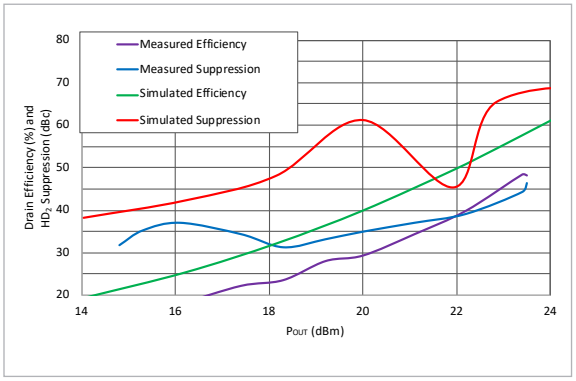

Figure 3: Optimum amplifier performance.

The software enabled the designers to characterize the gain and phase relationship between the two signal paths. This was very important, since the two transistors in the PA must operate in antiphase, but with the same magnitude for correction push-pull operation. It was also clear from the current waveforms that the distortion generated by operating the transistors in two different modes (common source for one and source follower for the other) introduced different distortion profiles. This was previously unknown.

Conclusion

The Toshiba designers successfully proved the feasibility of a totem-pole push-pull PA at RF frequencies with NI AWR software. Using two gallium arsenide (GaAs) N-channel devices in simulation, 69.5 percent DC-to-RF efficiency at a P1dB of 25.1 dBm was achieved. A practical prototype achieved 48.1 percent efficiency at 23.5 dBm P1dB with a second harmonic distortion (HD_2) suppression relative to the fundamental component of -47 dBc.

The lead designer has been using NI AWR software for more than a decade. He commented that the software is easier to use and offers greater coherence between the simulation engines than the alternatives. The most positive feature is the intuitiveness of the software. It is very straighforward to start a new simulation with ideal components and then gradually increase the complexity by adding in realistic models for components and substrates.

Toshiba Research Europe Limited designers use NI AWR software on a daily basis in their research activities. These are projects that are typically five to 10 years away from market, and the software enables them to take rough ideas for future products and develop them into prototypes. Toshiba, like most companies, invests heavily in long term research to ensure that it can release products that offer a better price/performance ratio than competitors.

The original paper for this application, written by Dr. Gavin Watkins of Toshiba Research Europe, can be found at ieeexplore.ieee.org/document/8283349/.

Special thanks to Dr. Gavin Watkins for his contributions to this success story.