HIGH FREQUENCY
ELECTRONICS

Vol. 10 No. 6, June 2011

Editorial Director
Gary Breed
gary@highfrequencyelectronics.com
Tel: 608-437-9800
Fax: 608-437-9801

Publisher
Scott Spencer
scott@highfrequencyelectronics.com
Tel: 603-472-8261
Fax: 603-471-0716

Associate Publisher
Tim Burkhard
tim@highfrequencyelectronics.com
Tel: 707-544-9977
Fax: 707-544-9375

Associate Editor
Katie Landmark
katie@highfrequencyelectronics.com
Tel: 608-437-9800
Fax: 608-437-9801

Business Office
High Frequency Electronics
PO Box 10621
Bedford, NH 03110

Editorial and Production Office
High Frequency Electronics
104 S. Grove Street
Mount Horeb, WI 53572

Also Published Online at
www.highfrequencyelectronics.com

Subscription Services
Sue Ackerman
Tel: 651-292-0629
Fax: 651-292-1517
circulation@highfrequencyelectronics.com

Send subscription inquiries and address changes to the above contact person. You may send them by mail to the Business Office address above.

Our Environmental Commitment

High Frequency Electronics is printed on paper produced using sustainable forestry practices, certified by the Program for the Endorsement of Forest Certification (PEFC™), www.pefc.org

PEFC/29-31-130

SUMMIT Technical Media LLC

The Quest for Power Amplifier Linearity and Efficiency

Gary Breed
Editorial Director

Last month, I discussed the need for signal-to-noise ratio to support effective transmission of broadband wireless signals. This month, I've decided to follow up with comments on a related technical issue.

Similar to the need for strong signals and low noise, the complex signals required for high data capacity also require precise reproduction (linearity) as they are boosted to higher power levels. The distortion added by a less-than-perfect power amplifier (PA), even if very small, can make it more difficult for the signal to be received and demodulated with reliable data recovery.

Unfortunately, the most straightforward methods for highly linear amplification greatly reduce the PA's efficiency. Thus, all the "easy" linearity solutions consume more power, generate more heat, and require larger devices and components. These are, of course, the exact opposite of a design engineer's objectives when designing wireless equipment, whether a base station or a handheld unit. As an example, biasing a power device to class A or class AB, usually with "backoff" from the peak power capability of the PA, will certainly improve linearity, but can consume five times—or more—as much power as a PA that only needs to handle simple analog (FM) or digital (PSK, OOK) modulation.

For those of you who are not directly involved in power amplifier technology, now you can see why there is so much attention given to PA linearity and efficiency. You probably have noticed that we cover PA design topics quite often in *High Frequency Electronics*, including this issue. This is because high power amplifiers such as those used in base stations (or in military communications systems with similar design objectives) are still designed "from scratch" rather than simply copying a device manufacturer's reference design or some other engineer's published design example. Performance requirements and end uses vary widely. Every engineer must understand the design choices, as well as the available selection of power devices and other circuit components. Then they will use their own creative ability to improve performance, reduce size, dissipate heat, etc.

How do we Get Better PA Performance?

The power device is the center of any amplifier design. Today, most devices for linear operation are FETs, but there are may variations, such as vertical or lateral structures or the number and size of cells. Devices may have internal pre-matching, and are offered in a range of different packages chosen for their RF, thermal and mechanical performance.

Different materials offer a variety of performance options—power level, frequency range, temperature, etc.. The designer may choose from silicon, gallium arsenide, gallium nitride or silicon carbide, with each manufacturer having different approaches to the internal design and semiconductor process.

The selection of a device often depends on the external linearization and efficiency enhancement methods that are to be used. The most important spec may be different for each design technique—high breakdown voltage, thermal performance, smallest device-to-device variation, or similarity of devices for different power levels.

There are too many linearization techniques to list here, but today's highest performance PAs use a combination of analog and digital techniques. Typically, one of the various feedforward techniques will provide analog cancellation of distortion products, creating a basic PA building block with good initial linearity. Then digital predistortion provides the necessary additional level of improvement.

Big improvements in efficiency are challenging! The most efficient PAs are highly non-linear—the output waveform barely resembles the input. Methods to use these nonlinear amplifiers for linear signals include envelope elimination and restoration (EER), polar modulation, outphasing, and others.

Sequential techniques such as Doherty PAs and switched amplifier methods allow lower power amplifiers to be used when the signal waveform is at a low level, saving power (and power consumption) when it's not needed. These, and other, high performance linearity and efficiency methods are either very complex or difficult to maintain over temperature, power level, and time (component aging).

The level of engineering creativity that is going into the development of these techniques is remarkable! Most engineers find this type of interesting and challenging work very rewarding. It is important work, and we will continue to cover it regularly in our magazine.

From June 2011 *High Frequency Electronics*