SiGe HBT Amplifiers Replace GaAs for Wireless and Broadband Applications

Silicon Radio Platform

October 2007

Introduction

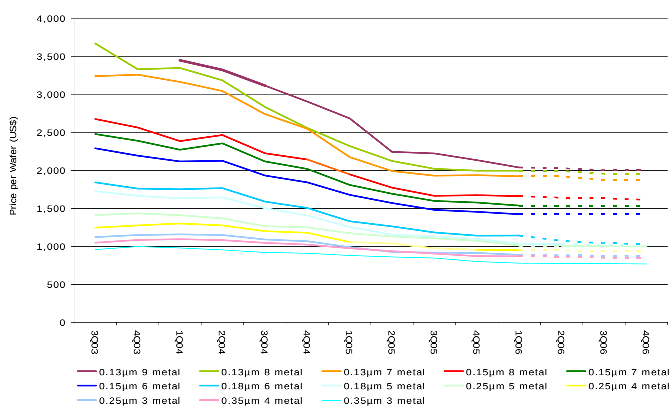
While the cellular handset market is experiencing growth, service providers and consumers expect low cost handsets. Handset complexity and features have grown significantly while maintaining the expectation for lower cost. Traditionally, reducing cost in electronics subsystems and modules has been achieved by leveraging low-cost CMOS Silicon processes to integrate as many discrete devices as possible. However, in the case of the RF radio modules found in all wireless systems, the need for discrete and exotic GaAs devices in the radio subsystem has limited the ability to cost reduce. Now, with Jazz Semiconductor's 0.18-micron Silicon Radio Platform, complete radio integration can be achieved in today's wireless applications using CMOS process technology.

The 0.18-micron Jazz Silicon Radio Platform allows complete integration of the radio in a wireless device on a single piece of Silicon integrating the transceiver, antenna switch, power amplifier (PA), and controllers eliminating the need for expensive discrete GaAs devices. Jazz's 0.18-micron RF CMOS process (CA18) and its 0.18-micron SiGe BiCMOS process (SBC18) include an SOI option that enables the integration of the antenna switch, but, unlike other solutions, also enables the integration of the PA. This new technology promises to deliver higher levels of integration for future cell phones, wireless LANs, and WiMAX systems while displacing chips today built in more expensive GaAs, reducing die costs up to fifty percent.

This white paper examines one of the key areas of cost reduction in the Silicon Radio Platform, the PAs. CMOS-based Silicon Germanium (SiGe) HBT amplifiers provide an alternative to present GaAs based amplifiers. Handset PAs are dominated by GaAs /AlGaAs /InGap HBT amplifiers. These were introduced to replace earlier generations of MESFET amplifiers based on discrete and integrated designs. Newer wireless protocols such as WCMDA, UMTS, 802.11n, and WiMAX are increasing in complexity and power requirements. In addition, multiple protocols are being integrated into a single solution that include cellular, WiFi, and Bluetooth thereby increasing the number of radios and hence PAs. While their performance is adequate, the cost and space of discrete GaAs amplifiers in these new devices is undesirable to today's designers. This white paper explores aspects of the performance, size and cost of the SiGe HBT amplifiers within a wireless transceiver.

Cost

Silicon based wafers and processing technology are cheaper than GaAs based wafers due to the cost of substrate material and overall processing tools. The wafers used in Silicon based processes are 8 inches in diameter versus 6 inches of GaAs wafer thus yielding almost two times more die per wafer. When comparing GaAs based and SiGe based PAs overall die size is comparable, hence the lower cost for a SiGe based amplifier.

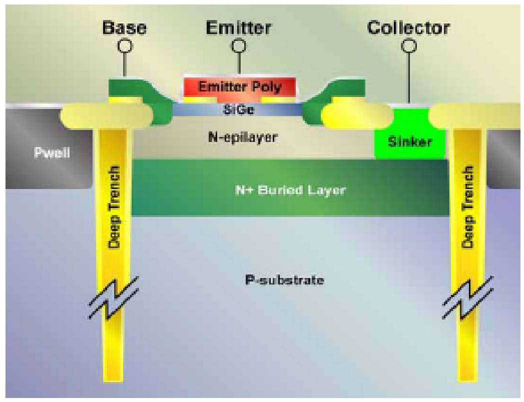


Source ** Semico

Active Device Performance

Pivotal to the successes of any amplifier design is the active device capability. NPN device performance is based on several factors, namely the process technology doping profiles, structure and the physical layout. The picture below is a cross section of a SiGE NBT NPN RF transistor. Below are some attributes the physical device along with characterization results.

FIGURE 4.2 Cross Section of High Voltage NPN



Breakdown

There are several causes that contribute to the breakdown of a transistor such as Zener , Punch trough (overrun basewidth) and avalanche breakdown. Common base and common emitter breakdown of a transistor are measured in common base configuration with base open (BVcbo) and in common emitter configuration (BVceo). Jazz RF NPN transistors are designed to withstand breakdowns seen in wireless applications exhibited by reflected VSWR (10:1 ruggedness). Process technologies for amplifiers offered by Jazz Semiconductor provide an option for 3.5/6v BVceo as well as 8V Bvceo devices.

Cutoff Frequency (Ft)

Ft is the cutoff frequency of a bipolar transistor where gain drops to unity thus no longer able to amplify. A rule of thumb determining the effective bandwidth of an amplifier for circuit design is an Ft ten times the band of operation. Below are Ft plots of SiGe HBT NPN unit cell devices.

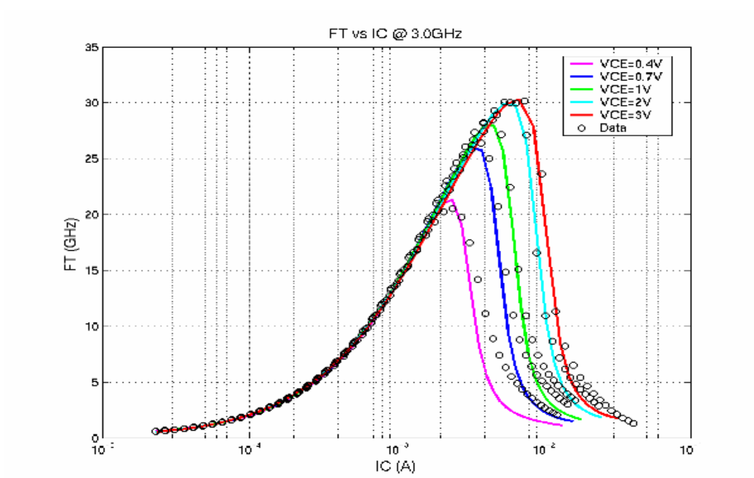
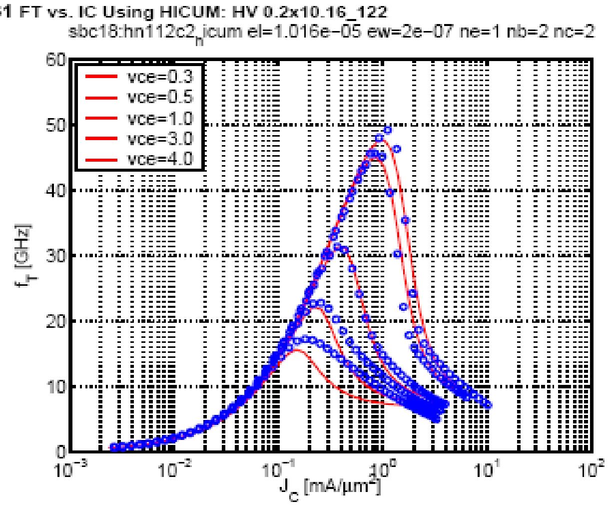
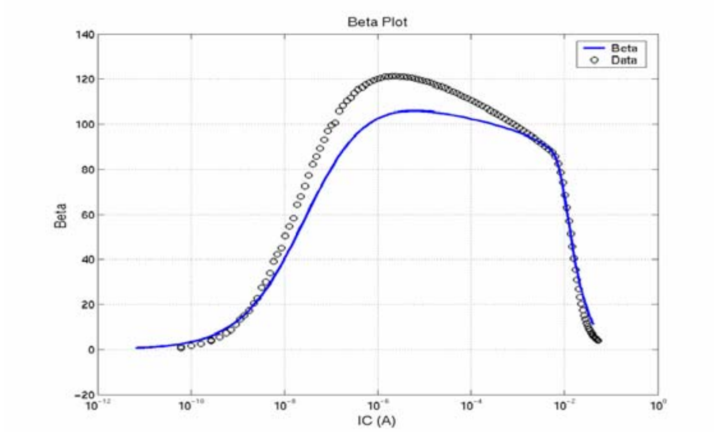


FIGURE 4.31 FT vs. IC Using HICUM: HV 0.2x10.16_122



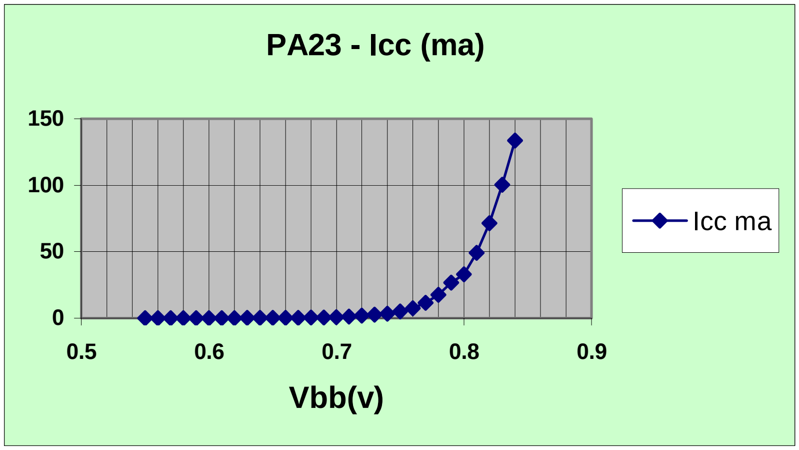
Beta

Beta is commonly known as the current gain of a bipolar transistor and is given as the ratio of collector current relative to base current. This current gain is heavily dependent on the doping concentrations in the emitter and base. The viewgraph below shows a typical beta for SiGe NPN transistor fabricated on the Jazz SBC18 process.



Biasing

Present biasing techniques used in GaAs HBT transistors are based on current mirrors requiring reference voltages to be generated externally in order to supply the transistor with ~1.2V for Vbe unlike SiGe transistors which require ~0.76 V. This eliminates any external circuitry used for the reference voltage. The viewgraph below is a sweep of collector current vs. base voltage. (SBC18QTD – NPN 658um^2 emitter area,p1db = 20dBm).

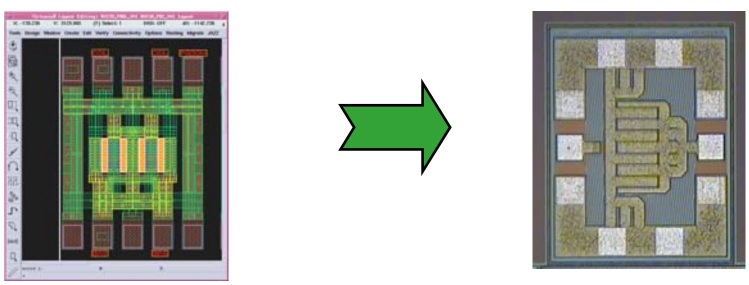


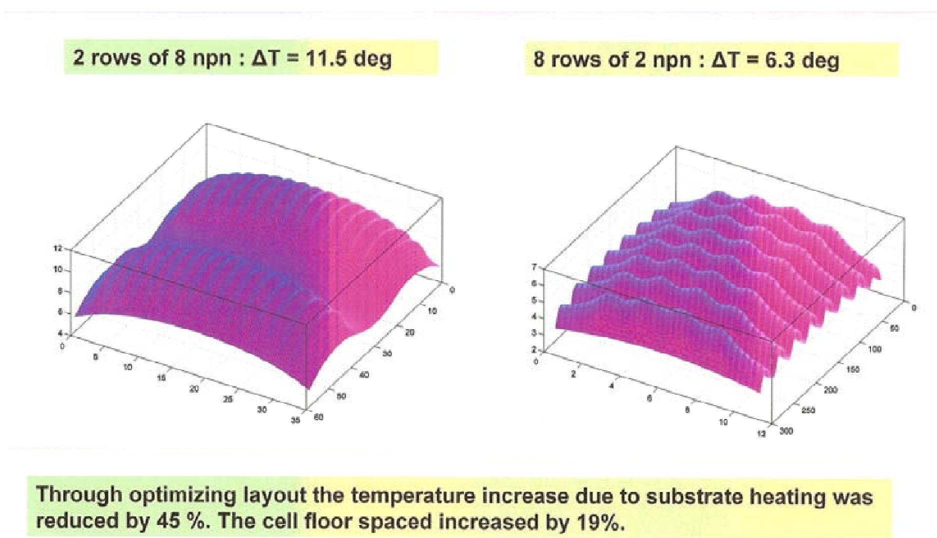
Thermal Rise

Thermal rise within the active device can impact performance significantly and it can be controlled through appropriate layout techniques and metallization. The viewgraph below shows how optimized layout can affect the thermal rise within the device. Analytic computation of the temperature fields by the source (device emitter) is used to optimize the layout. Additional power was delivered by the device with the optimized layout while maintaining low temperature rise with reduction of the overall area.

A0238: P1dB = 28dBm (631mW)
270 * 410 microns

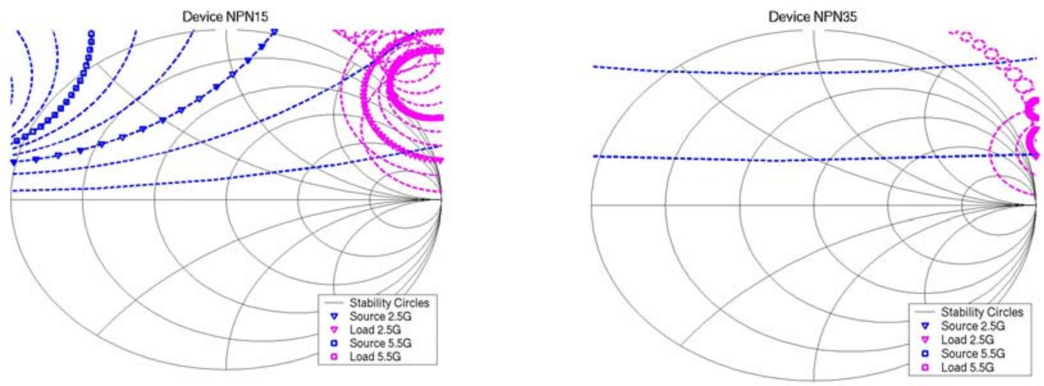
A0608:p1dB= 31dBm (1.35 W)
210 * 382 microns





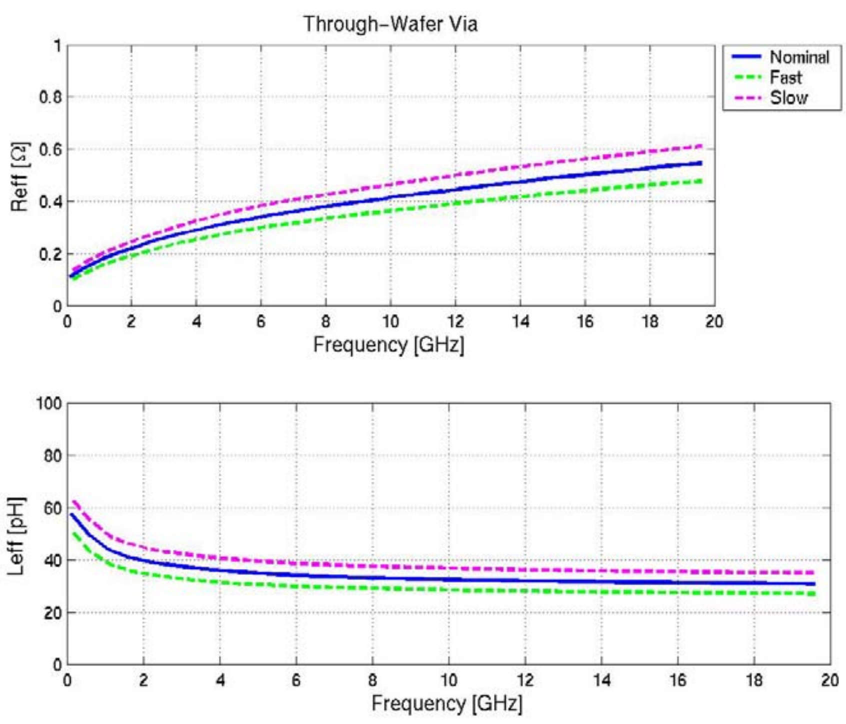
Stability

Amplifiers require unconditional stability of transistor cells which can be achieved using ballasting techniques. The following viewgraph compares transistors that incorporate ballasting in the base and the emitter. It was concluded by simulation that emitter ballasting did not contribute significantly to stability while base ballasting was most effective.

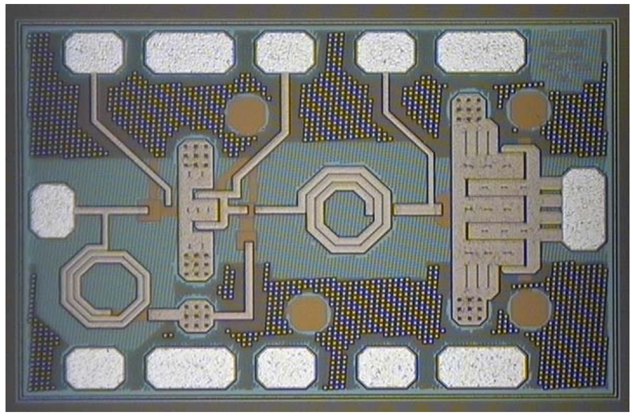


Through Wafer Via

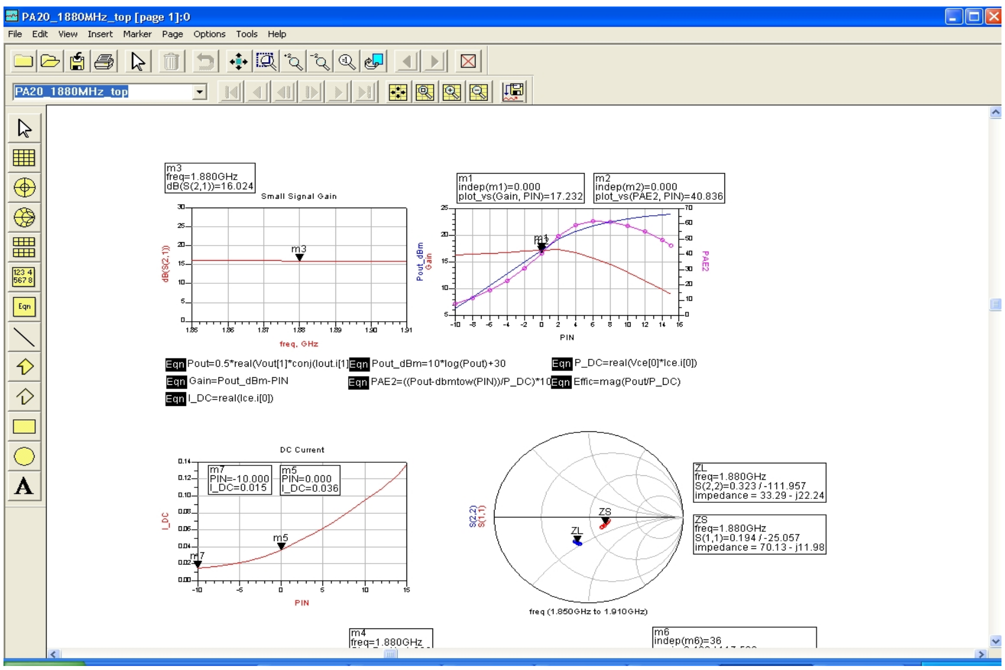
Another important factor is the Through Wafer Via (TWV) which provides short lead inductance by connecting directly to ground reducing inductance of the bond pads and wires and provides additional thermal dissipation. Traditional TWV process technology is generally from the back side of the wafer by tunneling a copper post. Jazz Semiconductor's SiGe TWV process uses tungsten plugs, a less complex method connecting the via to a conductive substrate layer.



Below is a picture of a two-stage WCDMA power amplifier driver design incorporating TWV.



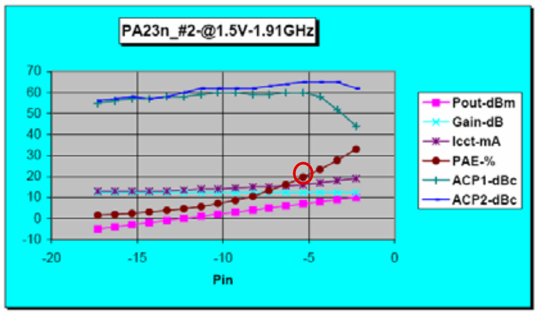
ADS Simulation results of the above amplifier are provided below.



Linearity

Generally, the most critical performance factor of a linear amplifier is efficiency as battery drainage impacts talk time and is undesirable for consumers and service providers. In addition, data heavy protocols such as Code Division Multiple Access (CDMA) require an efficiency premium due to linearity requirements. Below is a viewgraph comparing a “low power mode” PA driver prototyped in Jazz Semiconductor’s SiGe HBT SBC18QTD process versus a best in class GaAs WCDMA based amplifier. Although the view graph compares a single amplifier with a two-stage cascaded amplifier, it is expected to match the performance of a commercial amplifier despite all the parasitic effects of the additional stage and the package. For high data rate 802.11b/g amplifiers, good linearity and low Error Vector Magnitude (EVM) are required.

The characterization data below demonstrates both EVM and Spectrum mask compliance utilizing the single power cell as an output power stage in PA34 SBC18QTD with P1dB of ~ 28dBm @3.3v.



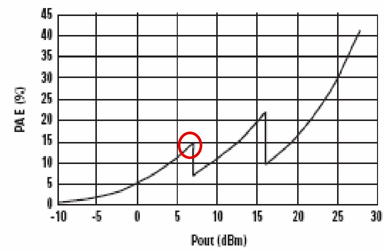
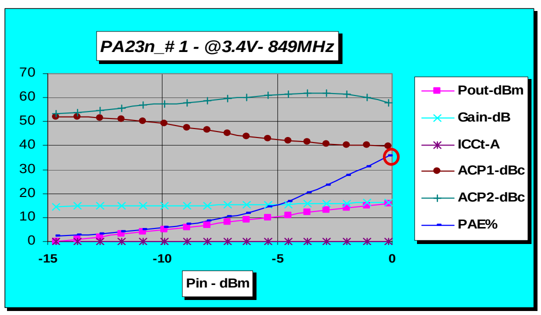


Figure 3. Power Added Efficiency vs. Output Power.



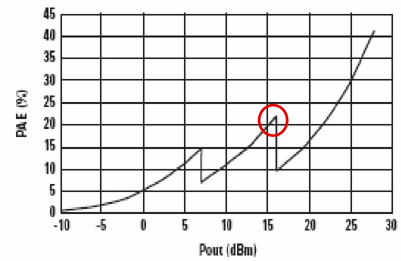
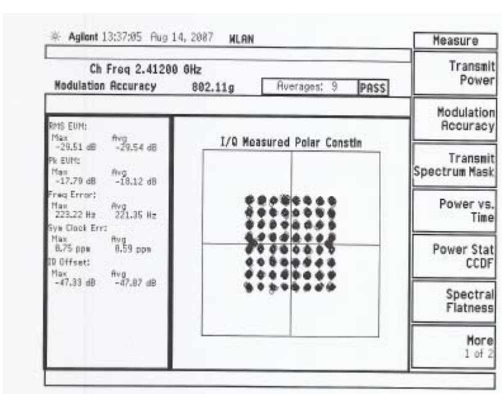
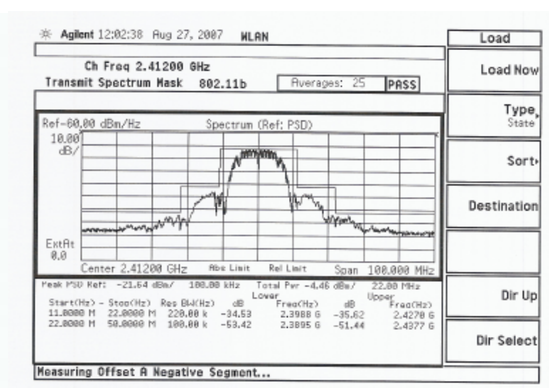


Figure 3. Power Added Efficiency vs. Output Power.

*** source Avagotech.

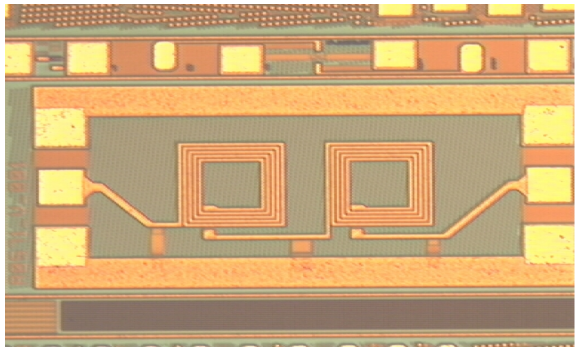
The plots below demonstrate the linearity compliance of the SBC18QTD based power cell in 802.11b/g – EVM compliance in "g" mode and spectrum mask in "b" mode 19 and 23dBm respectively.

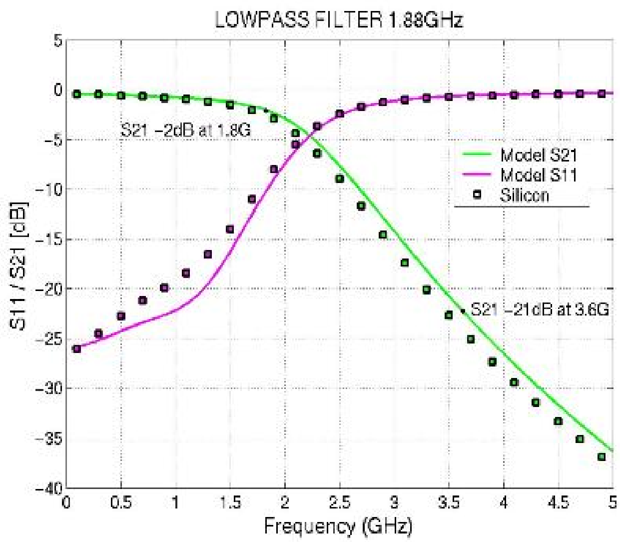




Integration

Integrating the transceiver with the PA further makes Jazz Semiconductor's SiGe technology attractive in applications such as a WLAN 802.11 a/b/n power module and an EGSM Front End Module. Integrated passive devices performance in SiGe SBC18 is comparable to GaAs as well as Silicon, enabling on die harmonic filtering and partial matching.





Conclusion

Design of multistage amplifiers or front end modules incorporating Jazz's SiGe process technology meets commercial market specifications while providing an excellent linearity and efficiency tradeoff as well as a significantly reduced die cost. A WiFi 802.11 a/b/g PA implemented in this technology can be designed to incorporate all features matching the performance of GaAs. Design of an amplifier as standalone or integrated with a transceiver provides further flexibility unlike GaAs based amplifiers. The dream of a true all Silicon based radio is now a reality with the introduction of Jazz Semiconductor's 0.18-micron Silicon Radio Platform.