Recent Advances in WLAN Systems

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Outline

- **IEEE 802.11 WLAN Standards Summary**
- **WLAN Integration Technologies**
- **WLAN System on a Chip Tradeoffs**
  - Multi-Band Multimode WLAN Issues
  - Performance, Cost, Size, Process Technology, Time-to-Market Issues
- **Multi Chip Module Approach**
- **RFIC module examples**
- **Conclusions: What Is the Right Approach?**
  - System on a Chip (SOC), or
  - System on a Package (SOP), i.e. Multi Chip Module

WLAN Standards Summary

Standard	Freq	Phy	Thruput	Range	Std Ratified	Chips Avail	Prod Avail
Bluetooth	2.4G	FHSS	721Kb/s	30ft	Partial 2000	Limited	Limited Vol
802.11b (Wi-Fi)	2.4G	DSSS	11Mb/s	200-300ft	1999	Now	High Vol
802.11g	2.4G	OFDM	22-54Mb/s	200-300ft	4Q02	4Q02	1Q03
802.11a	5G	OFDM	54Mb/s	100-150ft	1999	4Q01	1Q02
HiperLAN/2	5G	OFDM	54Mb/s	100-150ft	2Q02	3Q02	??

- **For WLAN systems a single device operating in multimode and multiple bands will be key to success**
- **Active IEEE 802.11 Groups**
  - **802.11e - <u>MAC Enhancement (QoS)</u>**
  - **802.11f - <u>Inter Access Point Protocol</u>**
  - **802.11g - <u>Higher Rate for IEEE Std 802.11b - 1999</u>**
  - **802.11h - <u>Spectrum & Power Management Extensions for IEEE Std</u>**
  - **802.11a - <u>1999 in Europe</u>**
  - **802.11i - <u>Enhancements to the current 802.11 MAC to provide improvements in security</u>**

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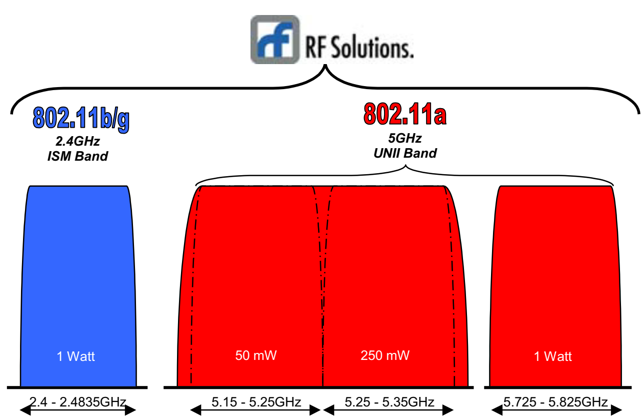
WLAN Standards

RFS Focus is "Dual Band"



- ***83MHz Band***
- ***3 Non-Overlapping Data Channels***
- ***"b"=DSSS CCK (11MB/s)***
- ***"g"= OFDM (54MB/s)***

- ***3 x 100MHz Bands***
- ***12 Non-Overlapping Data Channels***
  - ***(4 in each band)***
- ***"a" = OFDM (54 MB/s)***

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WLAN System and Market Requirements

- **Multimode Operation 802.11a,b,g**
- **High Performance**
  - Long Range – Many Current 802.11a Products Have Low Range at 54 Mbps
  - Low Power Consumption
  - High Data Rates
  - Access Pt. vs. NIC Architectures
  - Additional Features
    - Bridge Products
    - Small Size
- **Low Production Cost**
- **Flexible Architecture**
- **Early Market Entry**

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What does the WLAN Customer Want?

High Performance Dual-Band WLANs Require Multiple Processes

- GaAs HBT for PA
- PHEMT for LNA / Switch
- MCM Technology LTCC / Softbard for Integrated Antenna / PA / Switch / LNA
- NIC Card and Access Point May Have Different Needs
- 802.11b Only WLAN Chips Have Easier Specs for SOC

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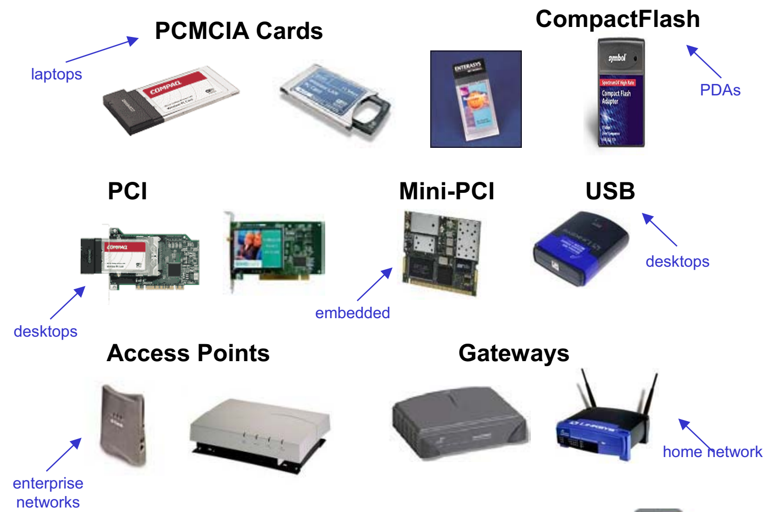
Target Product Platforms

RFS Products Address Wide Array of WLAN Products



Need for Advanced Integration in WLAN Systems

- **WLAN Market Is Large - 50M Units in Next Few Years**
- **WLAN Performance Requirements Are Tough**
  - High Data Rate, Long Range, Low Current, Dual-Band Operation
- **WLAN Cards Have Aggressive Cost Objectives**
  - RF Integration Is Key to Achieving WLAN System Cost and Performance Targets

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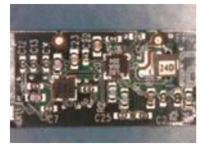
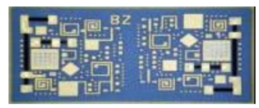
Advanced RF Integration Technologies

- **Functions**
  - RF ICs - LAN, PA, Switch, Up / Down Converter,
  - Other ICs - Baseband, MAC, Power Control
  - RF Passives - Filters, Baluns, Antennas, R, C, L
- **Technologies**
  - Laminate - Low Cost
  - Passive IC Processes - Silicon, Glass - Small Size
  - Low Temperature Cofired Ceramics (LTCC)



WLAN Front End Module With LNA, PA, Switch Using Laminate Technology



LTCC Module

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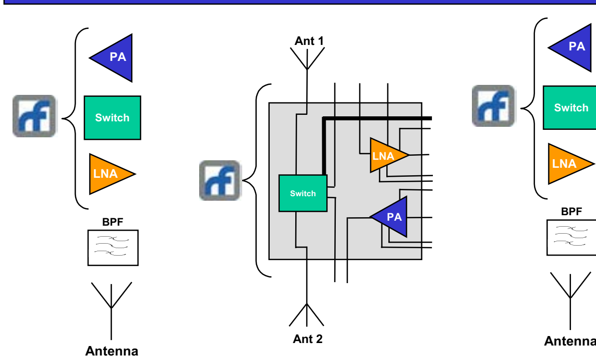
WLAN Front-End Module Approaches

- **Common RF Components**
- **Combine Common Components Into PA/LNA/Sw Module**
- **Increased Integration to Create Dual-Band Front-End Module**

Components	PA/LNA/Sw	Front-End Module

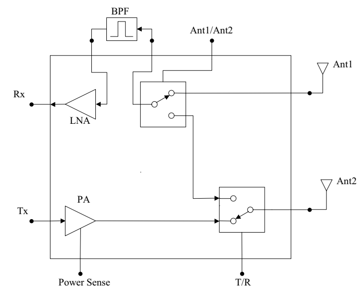


Single module with various configurations of PA, LNA, switches, filters, baluns, etc.

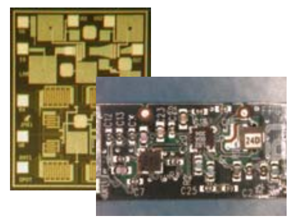
WLAN Front End ICs

- **RF Front Ends**

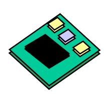
  Integrate LNA, PA, and Tx/Rx Switching on a Single IC
- **Single 3 VDC Supply**
- **2.4 or 5GHz**



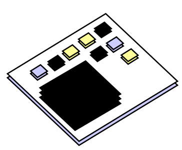
LNA Switch IC



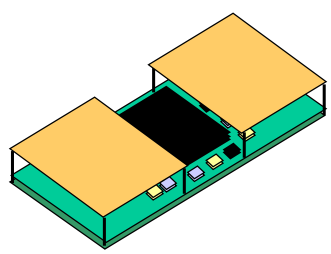
WLAN Module Concepts



PA Module with Passives/bias



PA Module + RF Filter on LTCC



PA Module with PA, LNA, Switch and Diversity Antennas

Single Chip v. MCM Tradeoffs

Parameters	Single Chip	MCM
Cost	Inexpensive	Expensive
Yield	Impacted by Size	KGD, MCM Testing Prob.
Power	Less	More
Application-Specific	More Time	Less Time
Reusability	Poor	Good
Performance	Low	High
Development Cost	High	Low
Testability	Most Difficult	Easier
Design Cycle / ECO	Long	Moderate

How Much Integration?

- **Dependent upon System Architecture / Partitioning**
- **Higher Integration Lowers Cost (up to a point)**
- **High Integration Does Not Allow Flexibility**
  – Access Point vs. NIC Cards
  – Bridge Products
  – Multi Antenna
  – Extra Long Range
- **Dual Conversion vs. Single Conversion Architectures**
- **Should PA, LNA Switches be Integrated on the Same Chip**
- **Integrating High Performance PAs, Tough in CMOS**

What is the Right Process Technology for WLAN RF System?

- **SiGe Bipolar / BiCMOS - Low Cost / High Performance**
  - PLL and Digital Functions Are Better Done in CMOS
  - Multi-Band Architectures Are Better Done in SiGe
- **Si CMOS / BiCMOS – Very Low Cost / Performance Issues**
  - Good for Single Band Architectures and Digital Functions
- **GaAs MESFET / HBT / PHEMT – Low to Moderate Cost / High Performance**
  - High Performance RF Functions, i.e. LNA, PA switch are better done in GaAs
- **What is Best? (lower cost and higher performance)**
  1) High Performance SiGe Process with High Yields; or
  2) Low Performance CMOS Process with Low Yields

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RFIC Technology by Function

Function	BiCMOS	LDMOS	GaAsFET	GaAsHBT	SiGeHBT	pHEMT
LNA	Good	Fair	Very Good	Good	Good	Very Good
Mixers	Good	Good	Very Good	Very Good	Good	Very Good
PA	Fair	Good	Very Good	Very Good	Fair	Good
RF Switch	Poor	Poor	Very Good	Poor	Poor	Good
VCO	Very Good	Good	Fair	Good	Good	Fair
PreScalers	Very Good	Poor	Fair	Good	Good	Fair
Digital Functions	Very Good	Good	Fair	Fair	Good	Fair

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IC Technology Comparison

Multi Chip Module (MCM) Offers Multiple High Performance Technologies in a Single Module

	0.6um GaAs MESFET	GaAs HBT	0.8um SiGe HBT/CMOS
LNA			
Nfmin @ 2 & 6 GHz (dB)	0.6 & 1.0	1.2 & 2.3	1.5 & 2.5
Power Amplifier			
Pmax @ 2 GHz (dBm)	good	excellent	good
Efficiency @ 2 GHz (%)	good	excellent	good
Breakdown Voltage	20	20	5.5-7.4
Single Supply	No	Yes	Yes
External Switch	Yes	No	No
VCO			
Phase Noise	medium	low	low
Mixer			
Linearity	medium	high	low
Other			
On-chip Inductor Q	~25	~25	~8
Integration with baseband	bad	okay	good
Cost			
	medium	high	low

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WLAN Systems Require High Performance

- **OFDM Systems Require High Performance**
  - High Dynamic Range
  - Significant Back-Off in PAs
  - High Performance LAN and Switches
  - Multiband and Diversity Antennas with Switches
  - Low Phase Noise VCOs
- **Multiband / High Power Operation Tougher with Si CMOS – Yield Issues**
- **GaAs HBT Good for High Efficiency Low Current and Low EVM PAs**
- **Bottom Line – WLAN Systems Require High Performance RF with Need for Multiple Process and System on a Package Technology**

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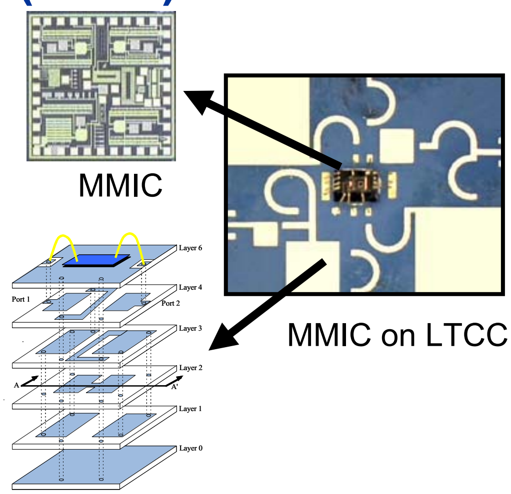
FlexICore Multi Chip Module (MCM)

- Multiple MMICs (GaAs, SiGe, CMOS) on a Passive Substrate (LTCC)
- Flexible Design
- Rapid Prototyping
- Embedded Passives, Filters, Lowers Cost
- Reduction of Device Count (200+ to 6)
- Passive Substrate Technology (i.e. LTCC) is Cheaper than IC Substrates



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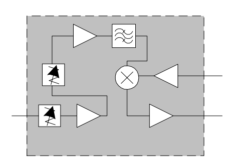
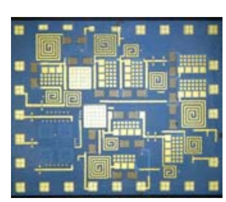
Benefits of MCM / SOP

- **Quick Development Time Compared to Custom IC**
- **Flexible Architecture – Add New Functions Easily – Better for Initial Proto Types**
- **Integration of Filters on the Same Substrate**
- **Low Cost – Use of Existing off the Shelf Chips**
- **Issues – Yield**





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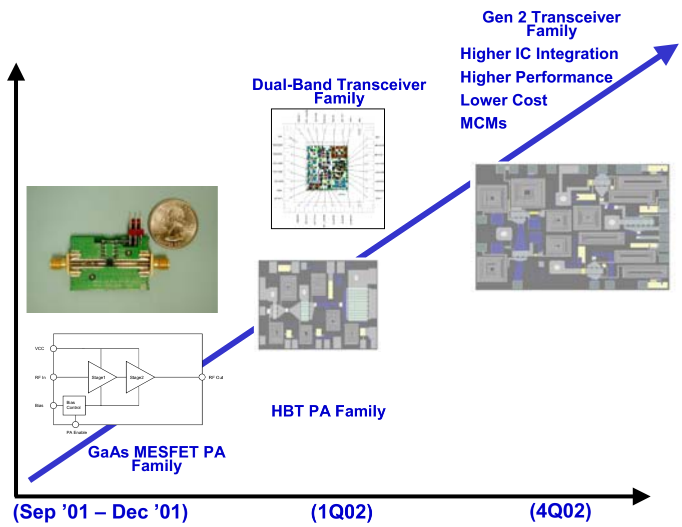
WLAN Product Roadmap



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RFS Power Amplifier Summary

Part Number	Function	Freq (GHz)	Supply (V)	Current (mA)	Gain (dB)	OP1 dB (dBm)	EVM* [EVM] @ 54MBps
RFS 1003	MESFET PA	5.1 - 5.9	7.0 3.0	400 350	20 21	29 24	
RFS 1006	MESFET PA	3.4 - 3.6	7.0	570	21	31	
RFS P2010	802.11b PA 802.11g PA	2.4 - 2.5	3.3	b: 180 @ Pout = 24 dBm g: 95 @ Pout = 18 dBm	21.5	25	meets 802.11b ACPR 1.5% @ Pout = 18 dBm
RFS P2020	802.11b PA 802.11g PA	2.4 - 2.5	3.3	b: 185 @ Pout = 24 dBm g: 100 @ Pout = 18 dBm	30	25	meets 802.11b ACPR 1.5% @ Pout = 18 dBm
RFS P5020	802.11a PA	5.15 - 5.85	3.3	160 @ Pout = 18 dBm	16	25	2.0% @ Pout = 18 dBm
RFS P5021	802.11a PA	5.15 - 5.85	3.3	210 @ Pout = 18 dBm	26	24	2.0% @ Pout = 18 dBm
RFS P5022	802.11a PA	5.15 - 5.85	3.3	175 @ Pout = 19 dBm	23	25	2.0% @ Pout = 19 dBm
RFS P5030	802.11a PA	5.15 - 5.85	3.3	260 @ Pout = 21 dBm	14	26.5	2.0% @ Pout = 21 dBm
RFS P5032	802.11a PA	5.15 - 5.85	3.3	280 @ Pout = 21 dBm	26	26.5	2.0% @ Pout = 21 dBm
RFS P5041	802.11a PA	5.15 - 5.85	3.3	500 @ Pout = 24 dBm	20	32	2.0% @ Pout = 24 dBm
RFS P5920	dual-band PA	2.4 - 2.5 5.15 - 5.85	3.3 3.3	100 @ Pout = 18 dBm 180 @ Pout = 18 dBm	30 28	25 25	2.0% @ Pout = 18 dBm

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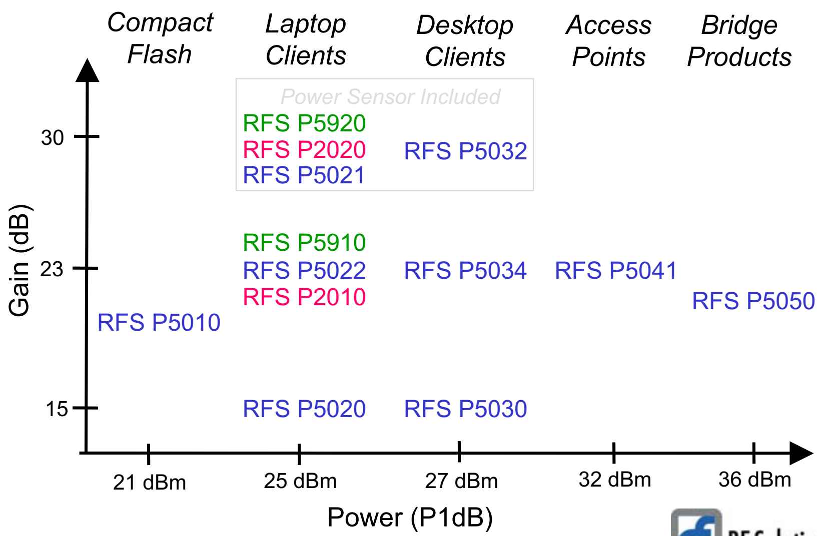
WLAN Power Amplifier Products



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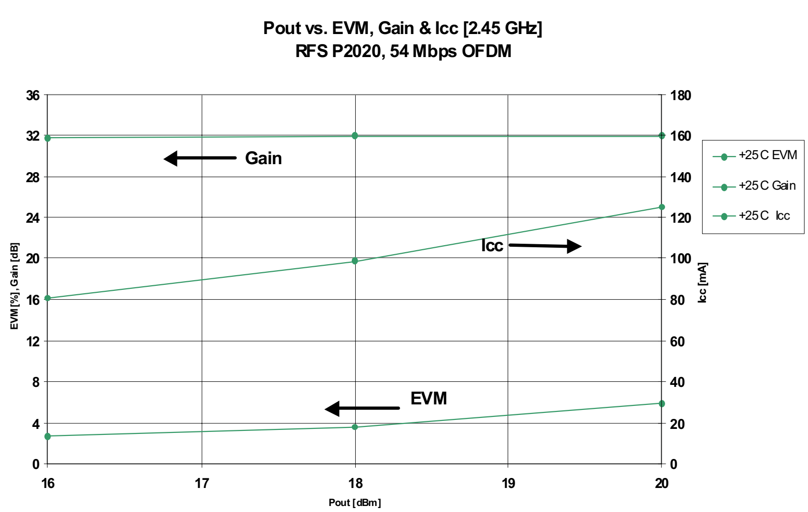
Measured Performance Summary

RFS P2020



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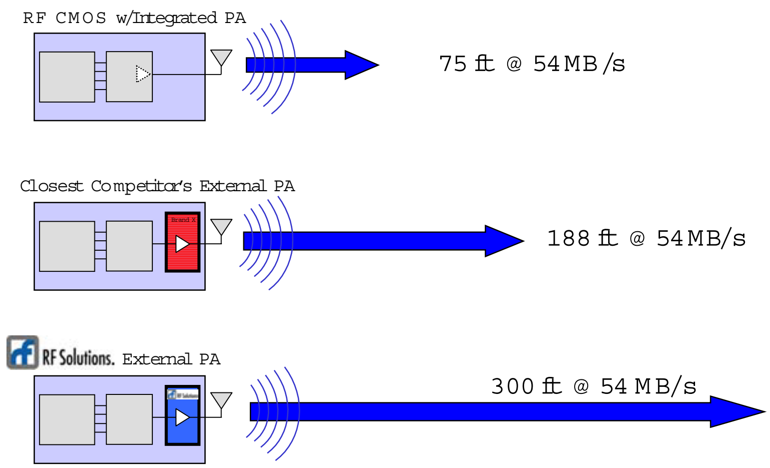
Results of Better PA Performance



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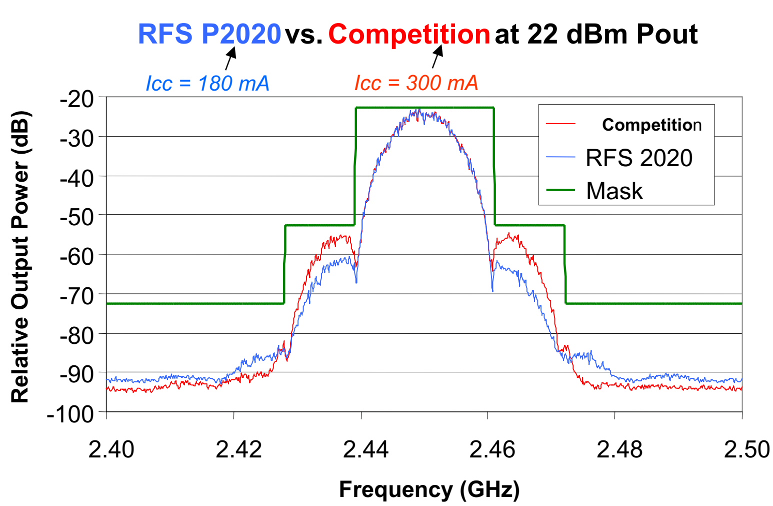
RFS P2020 802.11b Measured Performance Comparison



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Measured Performance Summary

RFS P5022

- **< 4% meas. EVM up to 20dBm Pout, 54MBPS**
- **< 3% meas. EVM @ 19 dBm Pout, 54 MBPS**
- **Typical Performance at 19 dBm Output**
  - > 22 dB Gain
  - > 13.5% Efficiency
  - < 3% Measured EVM w/1.2% Base EVM for 54Mbps
  - < 3 dB Gain Change, -40C to +85C
  - < 2 dB Gain Change from 3.0 to 3.6V with Simple Current Mirror
- **Flexibility: EVM Performance and Gain Can Be Improved by a Simple Resistor Value Change**

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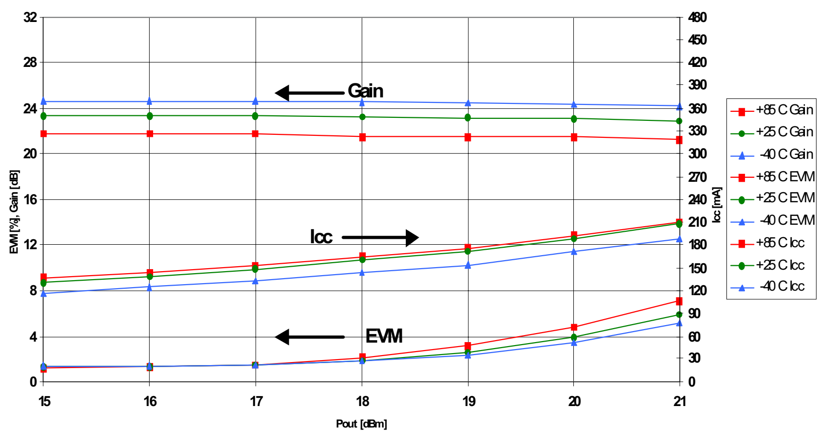
Measured Performance Summary

RFS P5022

Pout vs. EVM, Gain & Icc [5.25GHz]
RFS P5022, 54 Mbps OFDM



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Can You Get High Performance With SOC?

- **WLAN PA Performance Specs Are Tough to Meet With SOC**
  - Good Linearity - Low EVM
  - Low Current
  - High Power
  - Low Cost
- **GaAs HBT PAs Give Better Performance at Lower Cost than Silicon CMOS or SiGe Processes for WLAN Systems**

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RF Solutions' Multi Standard, Multiband Approach

- **History**
  - Cell Phone Examples (TDMA/AMPS/CDMA/GSM, more coming)
  - Ethernet - 10/100 Mbps
  - Seamless Evolution is Required for Acceptance Telephone Modem)
- **RFS WLAN Approach**
  - Multi-Band Multimode Device - 802.11a/b/g
  - CellLan™ - Integrate WLAN with 3G Cellular
- **Applications Have Unique Needs**
  - AP vs. NICs vs. Consumer Electronics
- **Multiple RFIC Technologies Can Improve the RF System**
  - Low DC Power Use
  - RF Output Power
  - High Linearity

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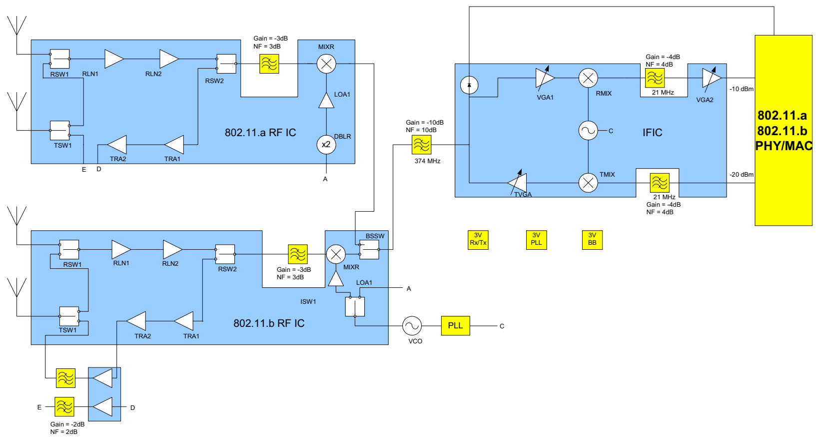
WLAN RFIC

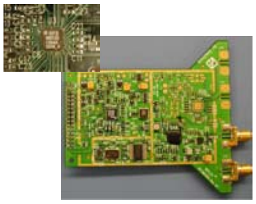
- Dual Conversion, Dual Band



WiFLEX™ WLAN Transceivers

A Highly Integrated, Dual Band WLAN Transceiver Approach

- Integrate All Low Performance RF Components on a Chip – Mixers, Attenuators, Switches, IF Amps, AGC Amp, etc.



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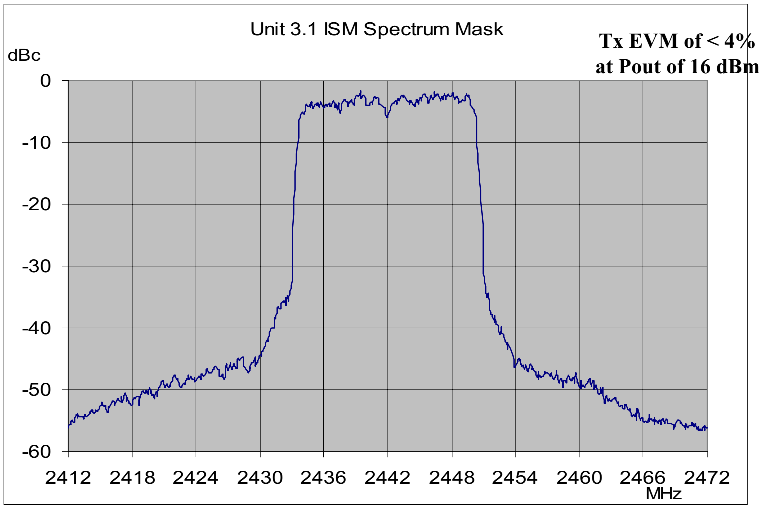
ISM Spectrum Mask (Unit 3.1)



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WLAN Technology Evolution

- **System**
  - Multiband WLANs– 802.11a, b, g Operation
  - CellLAN™ – Cellular and WLAN Functions on Single Chipset
- **IC Technology**
  - Higher Integration, Lower Cost, Higher Performance
    - 3 to 2 to All on One Chip for Most RF Functions
- **Module Technology**
  - Higher Integration, Lower Cost, Higher Performance
  - Integration of Antennas, Filters, Baluns
  - Modules using LTCC, Passive, Glass, Silicon and GaAs
  - Integration of RF and Baseband ICs into a Single System on a Module (SOM) Package

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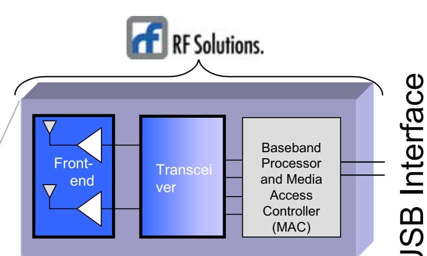
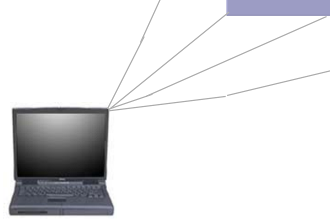
System on a Module (SOM)

The Future of the WLAN Chipset Market

- **WLAN Market Is Quickly Moving From Single Band to Dual Band**
- **Components Moving to Modules**
- **Winners Produce All of the RFIC's Required for a Module (i.e.: PA and Transceiver)**





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CellLAN™ Chipset

- ***CellLAN™***
  - RFIC Front End for WLAN + Cell Phone Mobile Platform
  - GSM/GPRS + 802.11a + 802.11b + 802.11g
  - Enables High Speed Access in WLAN Hot Spots, while Maintaining Connectivity in Rural Areas
  - Lower Cost than Separate Phone, PDA and WLAN Devices
  - Enables Inexpensive 802.11 Overlay for Existing Cellular Infrastructure

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Conclusions

- **Highly Integrated RFIC and MCM Technologies Will Play a Key Role in Future WLAN Systems**
- **For Multiband WLAN Systems - Integrate Most RF Functions Except the Front-End on a Single SiGe, CMOS or BiCMOS Chip**
- **Multi Chip Modules Using Combination of Passive Silicon, Glass, or GaAs, or LTCC, or Laminate Module Technologies is Ideal to Achieve High Performance WLAN System Modules Integrating RFICs Filters, Antennas, etc.**

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