2009
International Technology Roadmap for Semiconductors

Radio Frequency and Analog/Mixed-Signal Technologies for Wireless Communications Working Group

On behalf of the RF and AMS WG

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ITRS Winter Meeting

2009 Membership

Name	Affiliation	Name	Affiliation
Pascal Ancey	STMicroelectronics	Yukihiro Kiyota	Sony Corporation,
Herbert S. Bennett	NIST	Sebastian Shyi-Ching Liau	Industrial Technology Research Institute
Volker Blaschke	Jazz Semiconductor	Ginkou Ma	Industrial Technology Research Institute
Bobby Brar	Teledyne Scientific and Imaging	Jan-Erik Mueller	Infineon Technologies
Wayne Burger	Freescale Semiconductor, Inc	Takashi Nakamura	Omron Corp
Pascal Chevalier	STMicroelectronics	Hansu OH	Samsung Electronics Co., Ltd.
David Chow	HRL	Jack Pekarik	IBM Corporation
Julio Costa	RFMD	Ed Preisler	Jazz Semiconductor
Stefaan Decoutere	IMEC	Marco Racanelli	Jazz Semiconductor
Jonathan Hammond	RFMD	Mark Rosker	DARPA
Erwin Hijzen	NXP Semiconductors,	Bernard Sautreuil	STMicroelectronics
Digh Hisamoto	Hitachi Ltd.,	Tony Stamper	IBM Corporation
Dave Howard	Jazz Semiconductor	Alberto Valdes-Garcia	IBM Corporation
W. Margaret Huang	Freescale Semiconductor, Inc	Sorin Voinigescu	University of Toronto
Matthias Illing	Bosch	Dawn Wang	IBM Corporation
Anthony A. Immorlica Jr.	BAE Systems,	Albert Wang	University of California
Jay John	Freescale Semiconductor, Inc	Dennis Williams	WinSemi
Alvin Joseph	IBM Corporation	Peter Zampardi	Skyworks Solutions, Inc
Mattan Kamon	Coventor, Inc.	Herbert Zirath	Chalmers University
Tom Kazior	Raytheon RF Components	Alex Kalnitsky	TSMC

* Inactive this year

2009 Organization

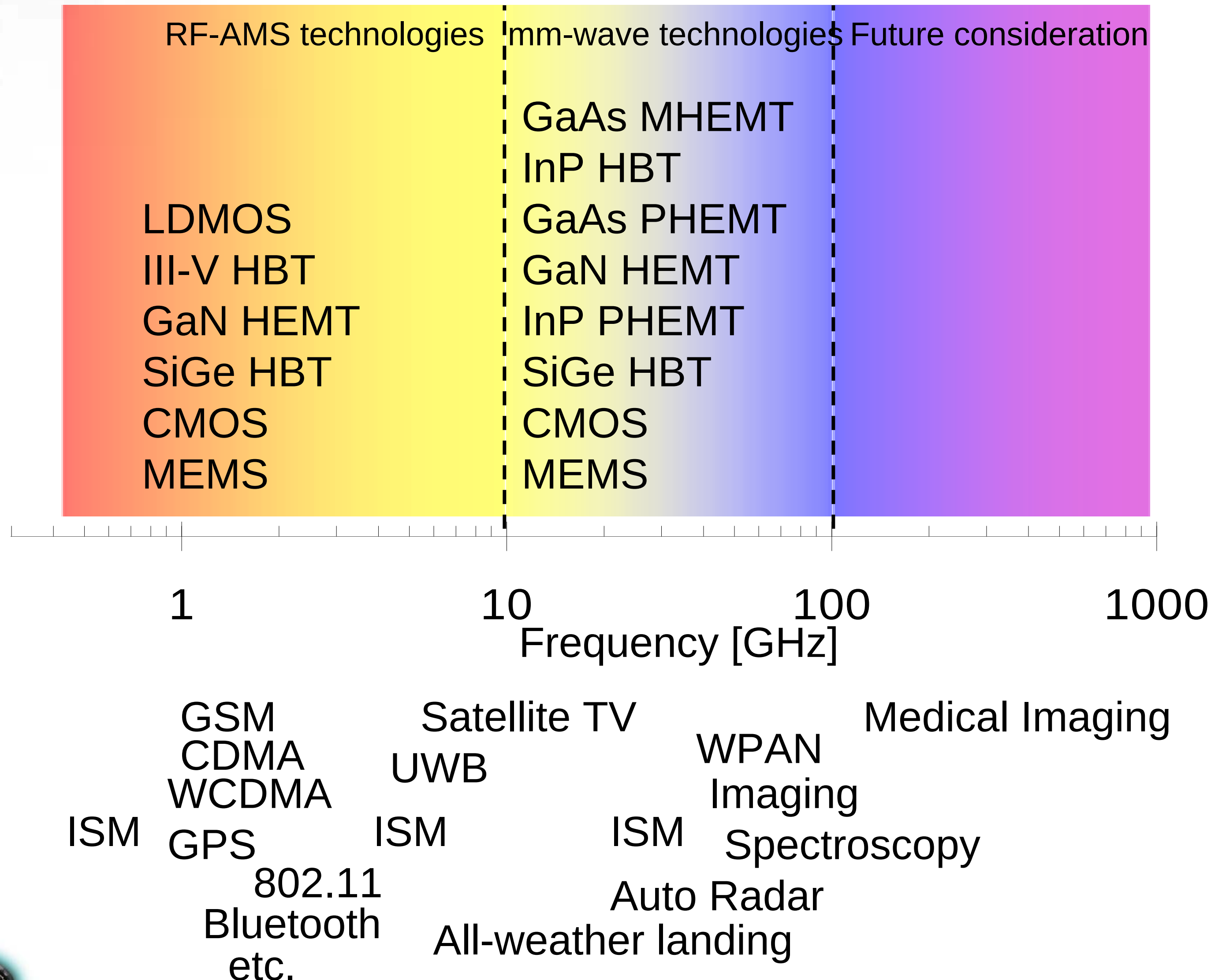
Chair:	**Jack Pekarik, IBM**	**40 Members in 2009 / 43 Members in 2008**
Co-chairs:	**Jan-Erik Mueller, Infineon**	**25 NA, 70 EU, 7 AP**
	Sebastian Shyi-Ching Liau, ITRI	
	Margaret Huang, Freescale	
Editor:	**Herbert Bennett, NIST**	

• **Subgroup CMOS**	**Jack Pekarik, IBM**
• **Subgroup Bipolar**	**Pascal Chevalier, ST**
• **Subgroup Passives**	**Sebastian Shyi-Ching Liau, ITRI**
• **Subgroup PA**	**Peter Zampardi, Skyworks**
	Wayne Burger, Freescale
• **Subgroup mm-Wave**	**Tony Immorlica, BAE Systems**
• **Subgroup MEMS**	**Dave Howard, Jazz**

Wireless ITWG Background

- Scope of work remains the same; wireless transceiver IC as technology driver, with active contribution to ITRS-defined More than Moore thrust.
- Chapter subdivided into <10GHz applications and mm-wave applications.
- 5 technology subgroups cover <10GHz applications: CMOS, bipolar, passives, power amplifier and MEMs. A mm-wave subgroup focuses on higher frequency applications, considering power and low-noise using III-V and silicon-based devices.
- Some portions of the roadmap reflect prototype capability more than volume production. Production requires applications (especially emerging mm-wave connectivity and imaging) that currently lag technology capability.

Wireless Communication Application Spectrum



Wireless Working Group Key Considerations

Traditional Roadmap Drivers:

- Cost (scaling, die size, part count)
- Power consumption
- Chip functionality

Non-traditional Roadmap Drivers:

- Government regulations determining system spectrum and specifications
- Standards and protocols drive frequencies, power and performance
- Color coding “Manufacturing solutions exist” does not imply product volume shipment per ITRS definition
- RF module form factor (size and height requirements)

Cost / Performance Drives Integration:

- Multi-band & multi-mode system applications (embedded passives, filter, switch integration)
- Signal isolation and integrity
- Analog shrink (power supply, area, design innovations)

RF&AMS Chapter Change Overview

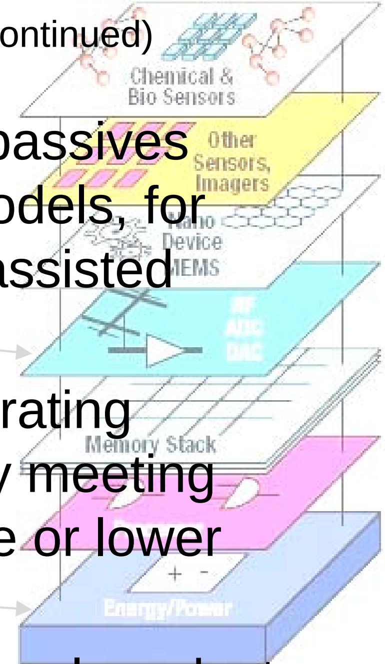
- **Overview**
  - Micro-electro-mechanical systems (MEMS) now in a separate section of the chapter. In 2007, they were part of the More-than-Moore Section
  - 3-D integration trends are affecting many RF and AMS technologies.
- **RF AND AMS CMOS**
  - Many product families skip nodes entirely when migrating to new application versions.
  - Optional devices to support Power-management and analog since the 90nm node.
  - Millimeter-wave CMOS technologies are moved to the mm-wave section
- **RF AND AMS BIPOLAR DEVICES**
  - High-speed HBTs underwent a major update to reflect higher fMAX / fT ratios..
  - High-voltage HBTs were removed & High-speed PNP transistors were added
  - Power-amplifier HBTs were update to anticipate changes in battery-voltages.
- **ON-CHIP AND OFF-CHIP PASSIVES FOR RF AND AMS**
  - On-chip: 3D integrated circuits enable improved performance of passive devices.
  - Off-chip: includes inorganic substrates to reflect 3D integration and passives-only integration.
- **POWER AMPLIFIERS (0.4 GHZ–10 GHZ)**
  - 4 major trends in handsets - 1) Lower end-of-life battery voltage, 2) More complex biasing schemes, 3) Demand for CMOS PAs, and 4) More modes supported by PA modules.
  - 2 major trends in basestations – 1) GaN has supplanted GaAs 2) Very-efficient architectures
- **MILLIMETER WAVE (10 GHZ–100 GHZ)**
  - Maximum current (Imax) was removed for low noise devices .
  - Maximum available gain (MAG) at 60 and 94 GHz was added to the SiGe HBT and CMOS tables.
  - The production of mm-wave GaN power HMETs was delayed to 2010.
- **MEMS**
  - Bulk acoustic wave (BAW) devices, resonators, metal-contact and capacitive-contact switches.
  - Acknowledges emerging MEMS e.g. gyroscopes, etc. and growing interests in sub-THz applications.
  - Need to develop appropriate quantitative metrics in tables.

Examples of Key Challenges

- **CMOS** - New materials (e.g., high-permittivity gate dielectrics, embedded structures to induce channel strain, and metal-gate electrodes) make predicting trends uncertain for transistor mismatch and for 1/f noise.
- **Bipolar HS-NPNs and HS-PNPs** - Increasing f_T by more aggressive vertical profiles and still maintaining FOMs, manufacturing control, and punch-through margins.
- **Bipolar PAs** - Improving the tradeoff between f_{MAX}/f_T and breakdown voltages to provide voltage handling and power densities at performance levels that can effectively complete with alternative technologies.
- **On-Chip Passives** - Integrating new materials in a cost-effective manner to realize compact high quality factor (Q) inductors and high-density metal-insulator-metal (MIM) capacitors demanded by the roadmap for increased RF performance.

RF & AMS

Examples of Key Challenges (continued)



- **Off-Chip Passives** - The large variation in embedded passives options increase complexity and cost. And accurate models, for process tolerance and parasitic effects, and computer assisted design (CAD) tools.
- **Handset PAs** - Increasing functionality in terms of operating frequency and modulation schemes and simultaneously meeting increasingly stringent linearity requirements at the same or lower cost.
- **Basestation PAs** – Enhancing performance with continual product price pressure. And Improving amplifier efficiency.
- **mm-Wave** - Thermal management for high power density circuits, multi-level integration and E/D mode transistors. And reduction of leakage current and understanding of failure mechanisms, particularly for GaN materials which are piezoelectric in nature

Examples of Key Challenges (continued)

- **MEMS** - Incorporating the great process diversity of MEMS into specific ITRS processes. And developing design tools, packaging, performance drivers, and cost drivers for each MEMS device type.

Thank You !