# 1997 IEEE Radio Frequency Integrated Circuits (RFIC) Symposium

## Denver, CO - June 8–11, 1997

### Digest of Technical Papers

### Digest Editor - James Schellenberg

**Denver Convention Center**
**June 8–11, 1997**

**Sponsored by**
**THE IEEE MICROWAVE THEORY AND TECHNIQUES SOCIETY**
**and**
**THE IEEE ELECTRON DEVICE SOCIETY**

IEEE CATALOG NO. 97CH36095

ISN 0-7803-4603-9

# 1997 IEEE RADIO FREQUENCY INTEGRATED CIRCUITS (RFIC) SYMPOSIUM

## DIGEST OF TECHNICAL PAPERS

Editor: James M. Schellenberg



Sponsored by
THE IEEE MICROWAVE THEORY AND TECHNIQUES SOCIETY
and
THE IEEE ELECTRON DEVICE SOCIETY

97CH36095

Copies available from:
IEEE Service Center

IEEE Catalog Number 97CH36095
ISBN 0-7803-4063-9 (softbound)
ISBN 0-7803-4064-7 (casebound)
ISBN 0-7803-4065-5 (microfiche)
ISBN 0-7803-4066-3 (CD-Rom)
Library of Congress: 97-72646

# 1997 IEEE Radio Frequency Integrated Circuits Symposium Schedule

The 1997 IEEE Radio Frequency Integrated Circuits (RFIC) Symposium will be held on Sunday, Monday, Tuesday and Wednesday, June 8–11, 1997, in conjunction with the International Microwave Symposium (IMS), at the Denver Convention Center (DCC). Sessions open to attendees of both symposia include the workshop on Sunday, three joint sessions on Tuesday, and the Open Forum on Wednesday where several RFIC papers will be presented.

**Sunday, June 8, 1997**

| | |
|---|---|
| 7:00 am–9:00 pm | Workshop Registration—CC Lobby A |
| 5:00 pm–9:00 pm | IMS/RFIC Registration—CC Lobby A |
| 7:00 pm–10:00 pm | RFIC Reception—Marriott Colo. Ballroom |

**Monday, June 9, 1997**

| | |
|---|---|
| 7:00 am–5:00 pm | IMS/RFIC Registration—CC Lobby A |
| 7:00 am–8:00 am | Speaker's Breakfast—CC Exh. Hall B2 |
| 7:00 am–8:00 am | Continental Breakfast—CC Exh. Hall B2 |
| 7:00 am–5:00 pm | Speaker's Prep Room—CC A210/A208 |
| 8:30 am–5:00 pm | Technical Sessions—CC C201/205, C207, C209 |
| 12:00 noon–1:15 pm | Panel Session—CC C201/205 |
| 6:00 pm–10:00 pm | Microwave Journal Reception—Natural History Museum |

**Tuesday, June 10, 1997**

| | |
|---|---|
| 7:00 am–5:00 pm | IMS/RFIC Registration—CC Lobby A |
| 7:00 am–8:00 am | Speaker's Breakfast—CC Ballroom 1 |
| 8:00 am–5:10 pm | Technical Sessions (Joint with IMS)—CC A201 |

**Wednesday, June 11, 1997**

| | |
|---|---|
| 7:00 am–5:00 pm | IMS/RFIC Registration—CC Lobby A |
| 2:00 pm–5:00 pm | Open Forum—CC Ballroom 4 |

# Message from the General Chairman

On behalf of the Steering Committee, I would like to welcome you to the 1997 IEEE Radio Frequency Integrated Circuits (RFIC) Symposium. This new and exciting Symposium expands from our previous Microwave & Millimeter-wave Monolithic Circuits (MMWMC) Symposium. The MMWMC Symposium was created in 1982 to provide a focused forum for emerging MMIC technology. For the past 15 years, this Symposium encouraged the rapid advancement of the technology and facilitated its application in DoD and commercial systems. Today, approximately half of all papers presented during Microwave Week are related to the monolithic technology. We are very pleased that the MMWMC Symposium has served our society and membership well and has made a significant impact on our technology development.

After observing the technology and business changes in the wireless industry and the high-volume production community, the Steering Committee began to implement the re-foucs of the Symposium two years ago. The feedback we received from previous attendees and our membership is that there is a need for more emphasis on Si and GaAs RFICs for commercial applications. With all of this input taken into account, we decided to expand the MMWMC Symposium in several ways: to cover both Si and GaAs technology instead of GaAs only, to provide the high volume and low-cost technique emphasis, and to include both R&D and production development.

To reflect this expansion of the Symposium's scope, we changed the symposium name to Radio Frequency Integrated Circuits (RFIC) Symposium. We expect to bring you the newest developments in highly integrated ICs; ICs for wireless communications, GPS and automotive radars; Si bipolar, CMOS, BiCMOS and GaAs design techniques; design for manufacturability; and RFIC packaging.

This is the first year of the RFIC Symposium. I hope that you will hear the presentations of many interesting papers and learn new technology from the technical sessions, Sunday Workshop and Monday Panel Session. I also hope that you will meet many new friends. To ensure the continued success of this symposium, I would like to receive your feedback on areas that we can improve. If you like this Symposium, please tell your colleagues and invite them to attend and submit a paper. I look forward to seeing you in Denver.

Louis C.T. Liu, General Chairman

# Message from the Technical Program Chairman

On behalf of the Technical Program Committee, it is my pleasure to welcome you to the 1997 IEEE Radio Frequency Circuits (RFIC) Symposium. This new and exciting symposium focuses on highly integrated ICs or subsystems that include RF functions at any frequency.

This year we have put together an outstanding conference for you. Recent advancements in RFICs suitable for wireless and other communication applications are highlighted at this symposium. Original papers describing low cost silicon and GaAs MMICs and subsystems for commercial and military applications are also announced at this conference.

Five invited talks from senior technologists from Europe, Japan and USA will provide additional impetus to this new symposium. These talks cover trends and changes in the wireless communication industry, Radio Frequency Identifications (RFID), Si MMIC applications, RFIC transceivers, and highly integrated ICs for GSM and DECT.

We have also arranged a focused session consisting of six papers on silicon MMICs to bring you the latest in the silicon RFICs.

A total of 26 contributed papers were selected for oral presentations from 51 papers submitted to RFIC. An additional 4 papers were chosen for the Open Forum. International exposure of this conference is evident from the fact that about half of the papers submitted were from outside the continental US.

The technical papers have been arranged into three parallel sessions on Monday. On Tuesday we have joint sessions with IMS subcommittees on Monolithic Technology and Low Noise Amplifiers. Open forum papers will be presented on Wednesday afternoon. Due to the fixed time schedule we could not accommodate many good papers. I thank all the authors who submitted the papers to this symposium and encourage them to continue to submit papers in the future as well.

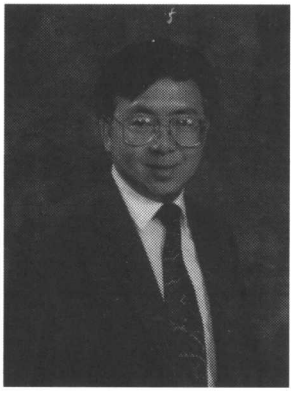
This year we are co-sponsoring three workshops, two on Sunday and one on Friday. The Sunday workshops are on 'Low Voltage Low Power Consumption RFICs for Wireless Communication Products' and 'Measurements for Silicon and GaAs Telecommunications ICs.' Friday workshop addresses 'Epitaxial Material Manufacturing for HEMT and HBTs.' The panel session on Monday discusses device technology choices for commercial portable power amplifiers.

The TPC members contributed significantly to bring you a top quality program for this symposium. I extend my sincere thanks and appreciation to each member of the TPC. Last but not least, I want to thank the authors, the invited speakers, and the panelist for enabling us to present you an exciting symposium.

I look forward to seeing you in Denver, Colorado.

Vijay Nair
Technical Program Committee Chairman
1997 IEEE RFIC Symposium

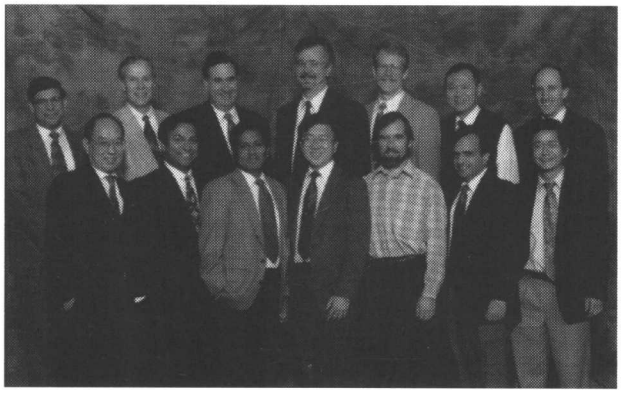
# 1997 RFIC Committees



**Louis Liu**
**Chairman**

**Vijay Nair**
**Co-Chairman**

## Steering Committee



back row: I. Bahl, J. Schellenberg, E. Cohen, M. Calcatera, E. Strid, H.-C. Huang, D. Williams
front row: R. Kagiwada, F. Ali, V. Nair, L. Liu, C. Kermarrec, M. Kumar, T. Tokumitsu

## Technical Program Committee

back row: J. Moniz, S. Heinen, D. Lovelace, J. Schellenberg, E. Strid
front row: M. Kumar, R. Kagiwada, V. Wair, H.-C. Huang, I. Bahl

back row: L. Liu, J. Mandal, M. Calcatera, E. Cohen, S. Kiaei
front row: T. Tokumitsu, F. Ali, M. Madihian, A. Adar, C. Kermarrec

# Table of Contents

## Technical Program

**MONDAY, JUNE 9, 1997**

**8:30 am–10:00 am**
**C201/205**

**Session I: ADVANCEMENT OF WIRELESS TECHNOLOGY AND ITS APPLICATIONS**
**(Invited Session)**
**Chair:** V. Nair, *Motorola*
**Co-chair:** L. Liu, *TRW*



**MONDAY, JUNE 9, 1997**

**10:30 am–11:50 noon**
**C201/205**

**Session II: SILICON RF TECHNOLOGY**
**Chair:** C. Kermarrec, *Analog Devices*
**Co-chair:** J.M. Moniz, *IBM*

**MONDAY, JUNE 9, 1997**

**10:30 am–11:50 noon**
**C207**

**Session III: GaAs TECHNOLOGY**
**Chair:** M. Kumar, *Lockheed Martin*
**Co-chair:** T. Tokumitsu, *NTT*



**MONDAY, JUNE 9, 1997**

**10:30 am–11:50 am**
**C209**

**Session IV: RF CIRCUIT TECHNIQUES**
**Chair:** I. Bahl, *ITT GTC*
**Co-chair:** H.C. Huang, *AMCOM Communications, Inc.*

**MONDAY, JUNE 9, 1997**

**1:30 pm–2:30 pm**
**C201/205**

**Session V: RFIC TRANSCEIVERS**
**(Invited Session)**
**Chair:** F. Ali, *Nokia Mobil Phones*
**Co-chair:** D. Lovelace, *Motorola, SPS*



**MONDAY, JUNE 9, 1997**

**2:50 pm–5:00 pm**
**C201/205**

**Session VI: MM Wave RFICs**
**Chair:** J. Mondal, *Northrop Grumman*
**Co-chair:** M. Madihian, *NEC Corp.*

**MONDAY, JUNE 9, 1997**
**2:50 pm–5:00 pm**
**C207**

## Session VII: SILICON BASED TECHNOLOGIES FOR RF MONOLITHIC ICS
**(Focused Session)**
**Chair:** L.B.P. Katehi, *The University of Michigan*
**Co-chair:** G. Ponchak, *NASA Lewis RC*

**MONDAY, JUNE 9, 1997**
**2:50 pm–5:00 pm**
**C209**

**Session VIII: HIGHLY INTEGRATED TRANSCEIVERS**
**Chair:** S. Kiaei, *Oregon State University*
**Co-chair:** S. Heinen, *Siemens AG*

**TUESDAY, JUNE 10, 1997**

**8:00 am–10:00 am**
**A201**

**Session IX: AMPLIFIER TECHNOLOGY**
**(Joint RFIC and IMS Session)**
**Chair:** J. Schellenburg, *Schellenburg Associates*
**Co-chair:** S. Weinreb, *University of Massachusetts*

**TUESDAY, JUNE 10, 1997**

**1:20 pm–3:00 pm**
**A201**

**Session X: MONOLITHIC WIRELESS TECHNOLOGY**
**(Joint RFIC and IMS Session)**
**Chair:** N. Camilleri, *Advanced Micro Devices*
**Co-chair:** Z. Bardai, *Hughes Aircraft*

**TUESDAY, JUNE 10, 1997**

**3:30 pm–5:10 pm**
**A201**

## Session XI: MILLIMETER-WAVE MONOLITHIC CIRCUITS
**(Joint RFIC and IMS Session)**
**Chair:** H.A. Hung, *TRW*
**Co-chair:** S.S. Bharj, *Princeton Microwave Technology*

## WEDNESDAY, JUNE 11, 1997

**2:00 pm–5:00 pm**
**CC - Ballroom 4**

### RFIC Open Forum 1: PAPERS
### (Joint with IMS)

(Invited)

# Wireless Portable Communications Trends and Challenges

John S. Escher, Senior Member IEEE
Motorola
Phoenix Corporate Research Laboratories
2100 E. Elliot Road, Tempe, Arizona 85284

## ABSTRACT

The electronic wireless communications age has its earliest origins with Thomas Edison and Guglielmo Marconi about 100 years ago. Early R&D on portable communications systems was carried out over forty years ago at AT&T Bell Labs, who led much of the earliest development in communications in the United States. Motorola pursued mobile wireless communications research beginning in the 1960s resulting in the first mobile cellular telephone service in the early 1980s. Decades of continuous cost / performance improvements from the semiconductor and IC packaging industry have had a dramatic impact on reducing the costs, and hence affordability, of all forms of commercial electronics and communications systems. Furthermore, the recent decade has seen an increased desire for personal and business communications mobility, security and access to information at any time, anywhere. Many of these factors have launched numerous commercial wireless communications systems, such as paging and cellular phone systems from a relatively high-end niche market into the multi-billion dollar consumer electronics businesses of today.

## I. THE MARKET

Currently there are about 145 million analog and digital cellular phone customers in the world. About one third of these customers are in the United States. They average about one hundred air time minutes per month. Growth rates of wireless communication products such as cellular phones are very significant. From now through the year 2000, CAGR forecasts for digital cellular phone service is at about 30%. Analog cellular phones will continue to be in demand for many years to come as the lowest - cost solution for emerging and lower volume markets. However only two percent of all phone calls in the US. are currently made using a cellular phone.

As the cost of ownership and usage of wireless communications has come down there has been a dramatic expansion of wireless communication products into the newly developing countries of the world as well. There is a significant demand for reliable phone service in the poorer countries around the world. Wired phone service can not meet this demand fast enough. A paging system, for example, can be installed and made operational in only a few weeks time, giving reliable communications to



0-7803-4603-9/97/$5.00 © IEEE