Front End Hardware for Future Generation Wireless Communication System

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AGENDA

- WTEC Study
- Device
- Packaging & Integration
- Amplifiers
- Antennas
- Future Issues & Directions

Background

- State of the Art Hardware at Industries in the US, Europe and Japan
- Improvement vs. Emerging Technologies
- What We Can Learn for the Future

Observation

Research Opportunities Worldwide

- **Devices and Materials**
  - **New Materials and Components (GaN, SiGe, MEMS, etc)**
  - **Higher f_t & $f_{\max}$,Higher Linearity**
  - **New 3D-Oriented Process Technology**
  - **Higher Performance Passive Devices & Antennas**

Observation (cont'd)

- **Architecture**
  - **Amplifier Linearization and Efficiency**
  - **Interconnect & Packaging**
  - **Mixed Signal IC (Baseband/RF)**
  - **Front-end Architecture for Software Oriented Radio**
  - **RF for Smart Antennas**
  - **Multifunction/Reconfigurable Devices/Circuits/Antennas**
  - **MEMS**

Observation (cont'd)

- Frequency

  10, 30, 60, 77 and 90
- CAD

  Global CAD (Ckt, EM, Device, Ant, Thermal, Mechanical, Packaging)

DEVICES

Figure of Merit of ADC

$$= \log_2(\textit{Sampling Speed}) + \text{Resolution}(\textit{Effective No. of bits})$$
$$\approx 38 \sim 40\ (\textit{State of the art})$$

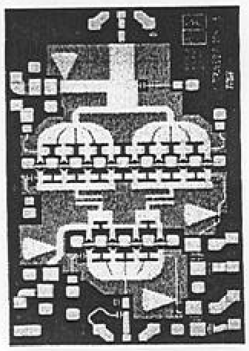
$$e.g. \quad \log_2(1\,GHz) + 10\,bits = 40$$

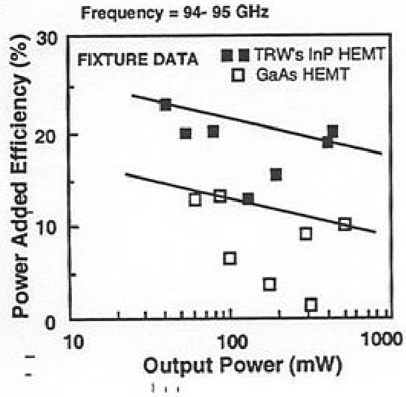
Wireless Communication Technology

TRW

Record-Breaking Performance of InP HEMT MMIC Power Amplifiers at 94-95 GHz

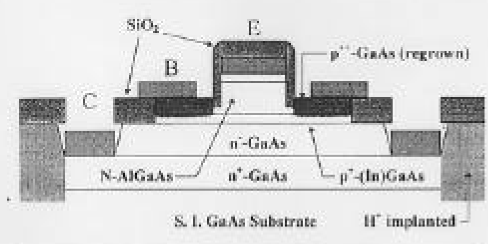
Output Power = 427 mW
PAE = 19 %
Associated Gain = 8.2 dB

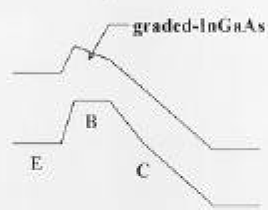




9802193-1002-8 NT

High f_{max} (>200GHz) HBT Technology





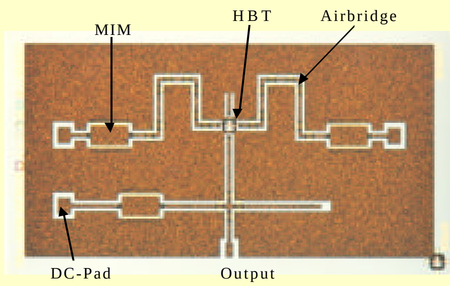
- MOMBE regrowth of base contact layers
  - Base resistance reduced to 1/4
  - Carbon doping density: 2-4E20 cm^{-3}
- Pseudomorphic $In_xGa_{1-x}As$ graded base (x:0.1-0)
  - Very short base transit time: τ_B~0.14ps

NEC

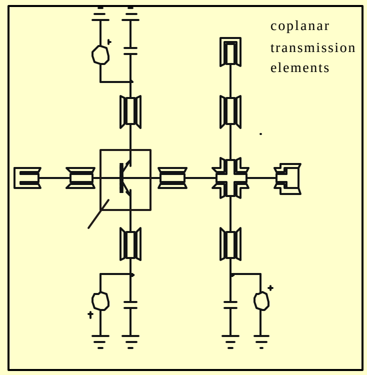
SiGe SIMMWIC: Modules

Ka-Band Moduls for Minilinks

Layout of coplanar Oscillators



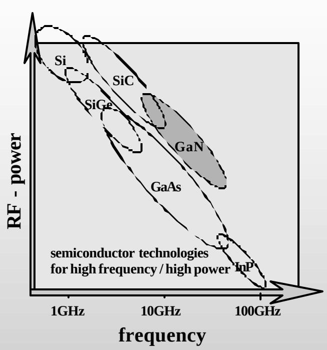
Circuit diagram
coplanar Oscillator

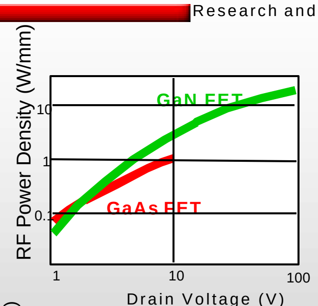


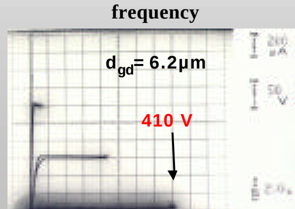
DaimlerChrysler

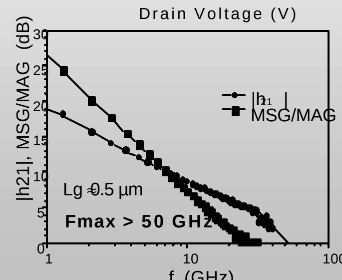
GaN - Power Technology

Research and Technology









DaimlerChrysler

Luy, Lab 13, Folie 12

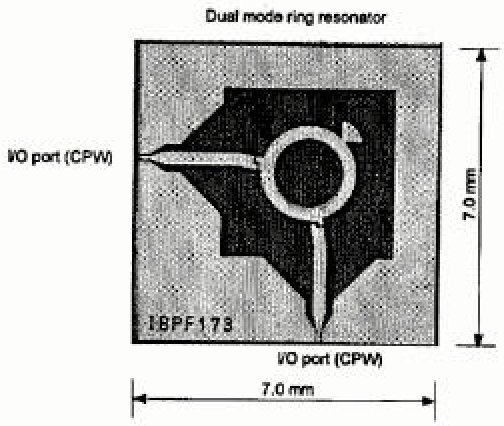
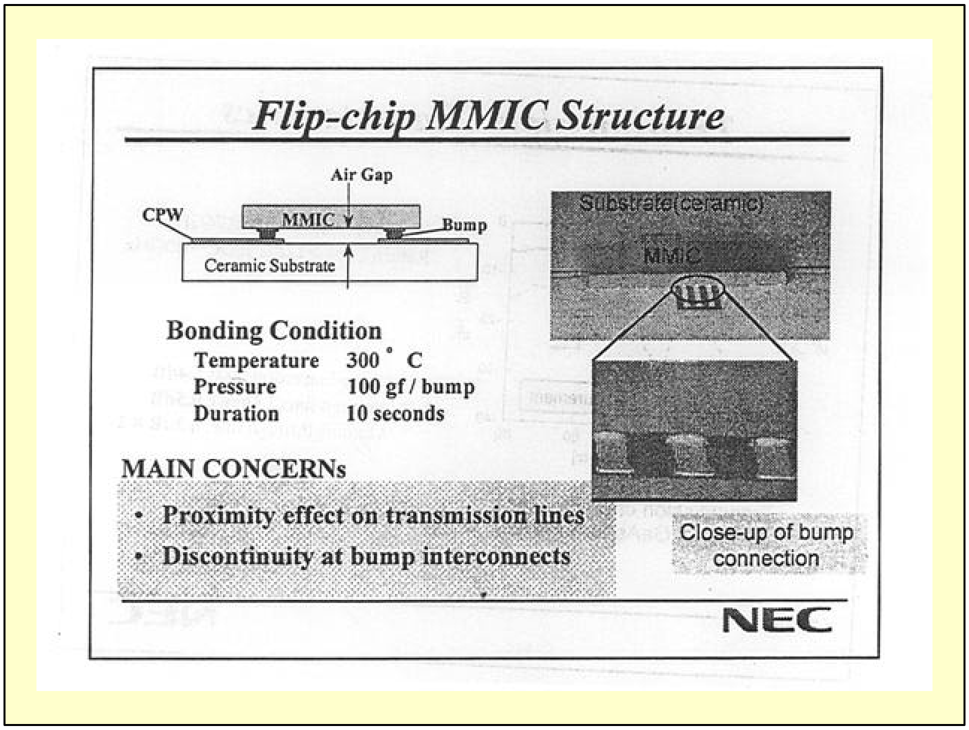
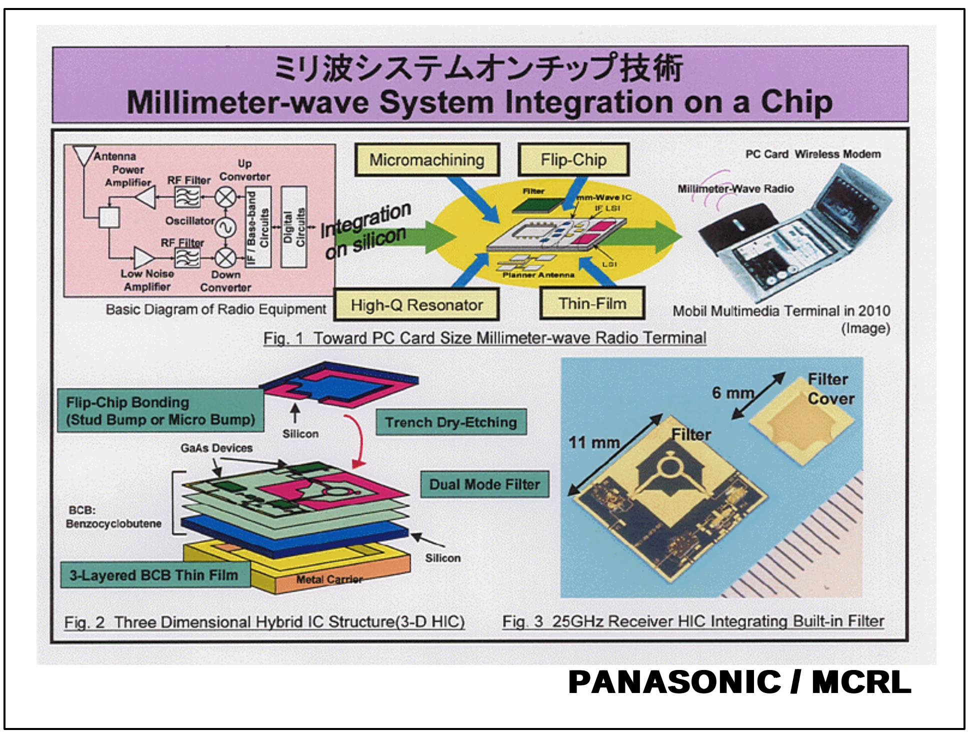


Figure 4 Microphoto of the experimental dual mode filter on the silicon substrate (without micromachined silicon cover)

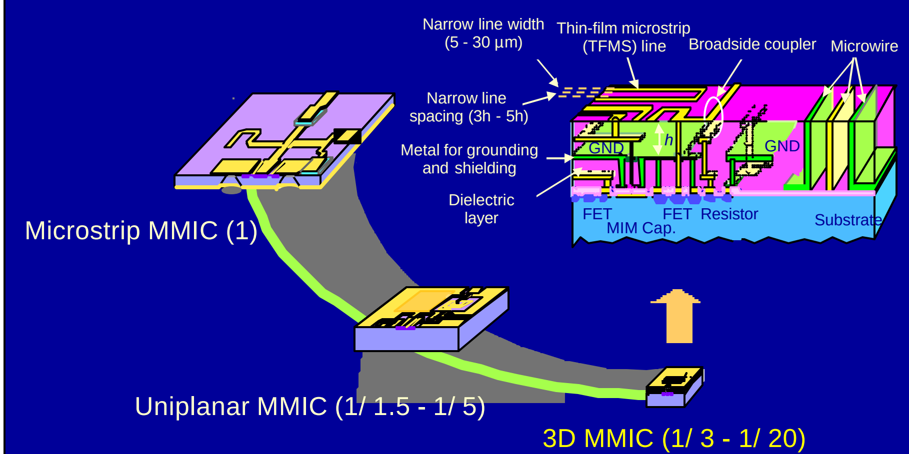
Packaging and Integration


Flip-chip MMIC Structure
Air Gap
CPW
MMIC
Bump
Ceramic Substrate
Substrate(ceramic)
MMIC
Bonding Condition
Temperature 300 ° C
Pressure 100 gf / bump
Duration 10 seconds
MAIN CONCERNs
• Proximity effect on transmission lines
• Discontinuity at bump interconnects
Close-up of bump connection
NEC


ミリ波システムオンチップ技術
Millimeter-wave System Integration on a Chip
Antenna
Power Amplifier
RF Filter
Up Converter
Oscillator
RF Filter
Low Noise Amplifier
Down Converter
IF / Base-band Circuits
Digital Circuits
Basic Diagram of Radio Equipment
Integration on silicon
Micromachining
Flip-Chip
High-Q Resonator
Thin-Film
Filter
mm-Wave IC
IF LSI
LSI
Planner Antenna
PC Card Wireless Modem
Millimeter-Wave Radio
Mobil Multimedia Terminal in 2010 (Image)
Fig. 1 Toward PC Card Size Millimeter-wave Radio Terminal
Flip-Chip Bonding (Stud Bump or Micro Bump)
Silicon
Trench Dry-Etching
GaAs Devices
Dual Mode Filter
BCB: Benzocyclobutene
3-Layered BCB Thin Film
Metal Carrier
Silicon
Fig. 2 Three Dimensional Hybrid IC Structure(3-D HIC)
6 mm
Filter Cover
11 mm
Filter
Fig. 3 25GHz Receiver HIC Integrating Built-in Filter
PANASONIC / MCRL

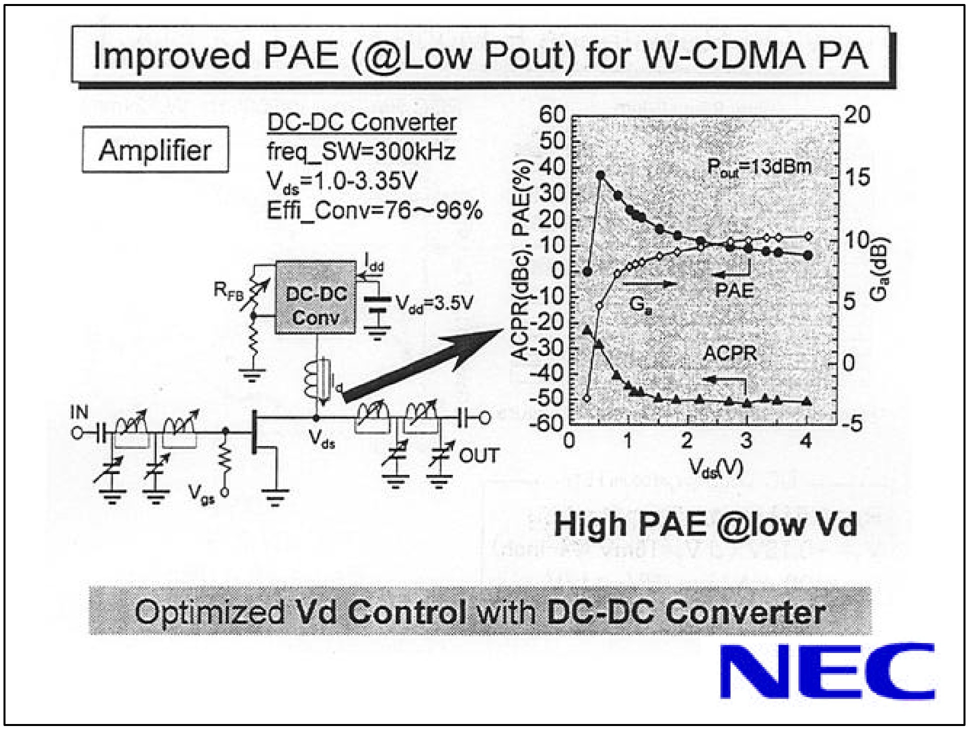
Miniaturization of MMIC

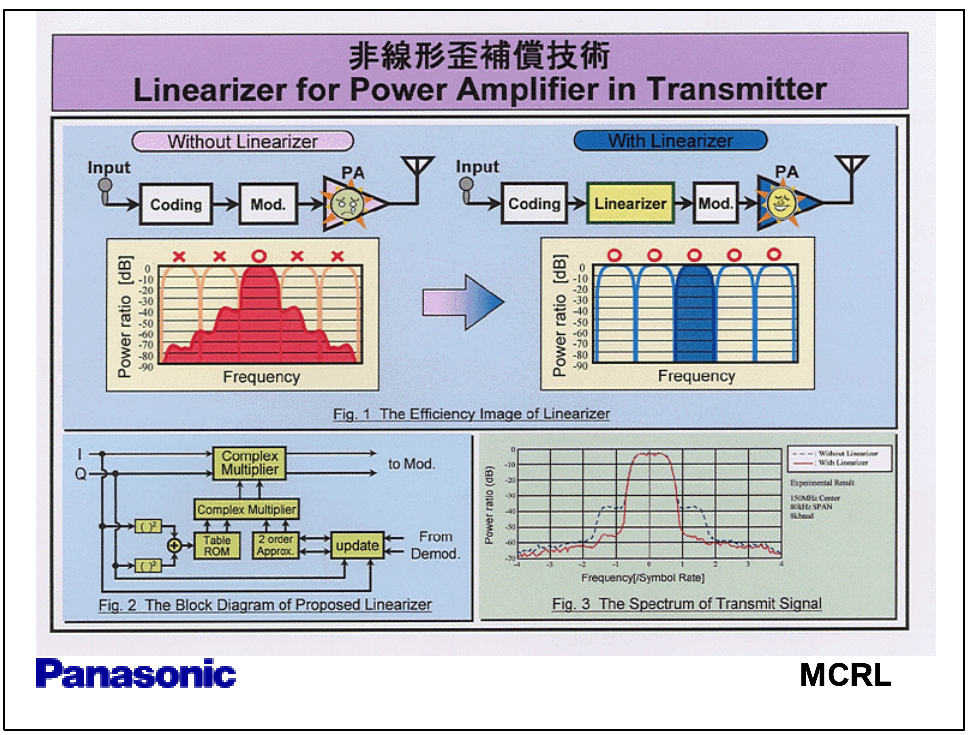
NTT



3D MMIC Technology *Wireless Systems Laboratory*

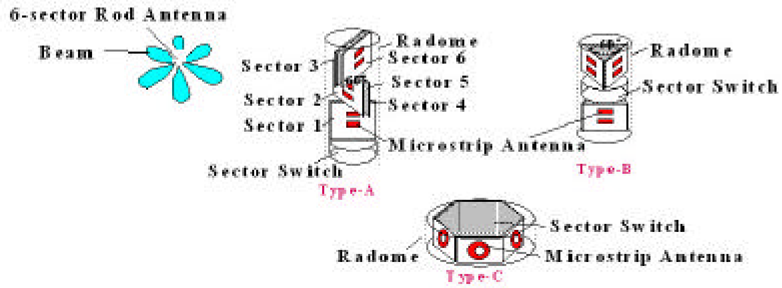
Amplifiers


Improved PAE (@Low Pout) for W-CDMA PA
Amplifier
DC-DC Converter
freq_SW=300kHz
Vds=1.0-3.35V
Effi_Conv=76~96%
Idd
RFB
DC-DC Conv
Vdd=3.5V
Id
IN
Vds
OUT
Vgs
Pout=13dBm
ACPR(dBc), PAE(%)
Ga(dB)
Ga
PAE
ACPR
Vds(V)
High PAE @low Vd
Optimized Vd Control with DC-DC Converter
NEC


非線形歪補償技術
Linearizer for Power Amplifier in Transmitter
Without Linearizer
With Linearizer
Input
Coding
Mod.
PA
Linearizer
Power ratio [dB]
Frequency
Fig. 1 The Efficiency Image of Linearizer
I
Q
Complex Multiplier
to Mod.
Table ROM
2 order Approx.
update
From Demod.
Fig. 2 The Block Diagram of Proposed Linearizer
Power ratio (dB)
Frequency[/Symbol Rate]
Fig. 3 The Spectrum of Transmit Signal
Panasonic
MCRL

Antennas

Rod Type Printed Antennas



NTT

FUTURE ISSUES
&
DIRECTIONS

Amplifier Efficiency and Linearity

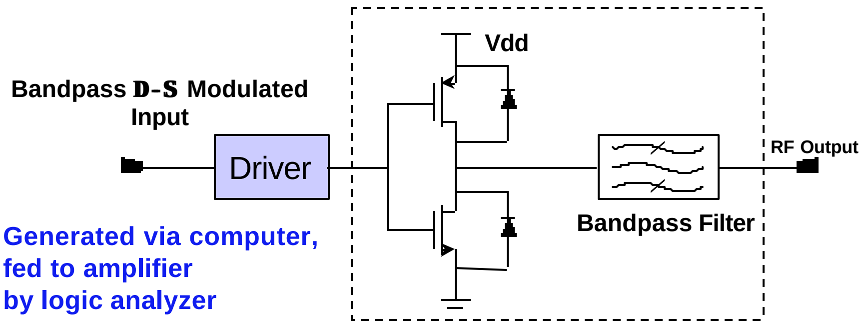
- Synergistic approach
- Good devices are needed (SiGe HBT?)
  - By architecture as front-end
  - In combination with digital technique

Mixed Signal IC

- Toward One-chip Radio or System on a Chip
- Good devices are needed (SiGe HBT?)

Class S Amplifier
for Bandpass D-S Modulator

Preliminary Implementation: Complementary MOSFETs
(low frequency demonstration: 10MHz)

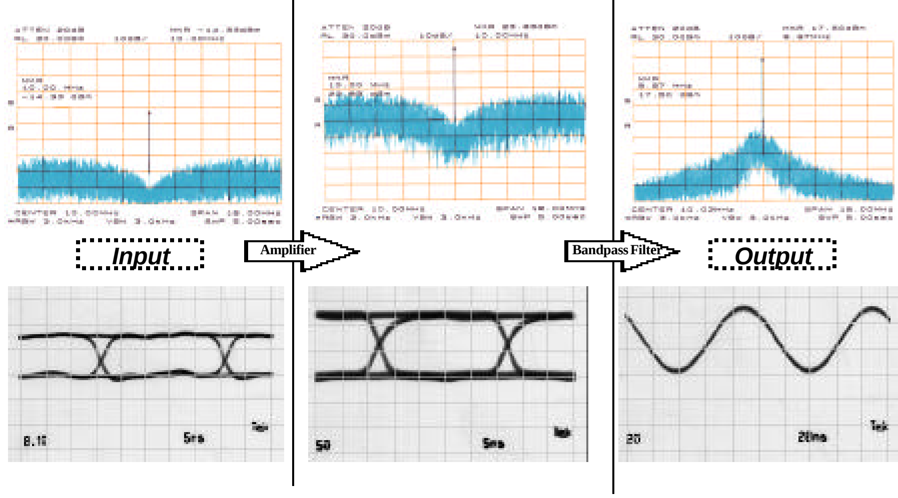


Generated via computer,
fed to amplifier
by logic analyzer

Class S Amplifier

Class S Amplifier
for Bandpass D-S Modulator

Bandpass D-S Modulated Input (50W)	Class S Amplifier Output (50W)	RF Output (50W)



Applications of DSP in Power Amplifiers

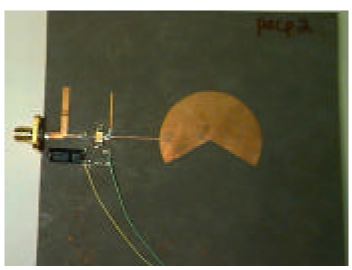
* Generate input signals at baseband
? Generate reference signals (eg: envelope)
? Generate control signals for PA (eg: Vgg control)
? Predistort input signal (at baseband)
? Generate waveforms for PWM converter
? Generate rf waveforms

Instead of **"High Efficiency and Linear Power Amplifier"**

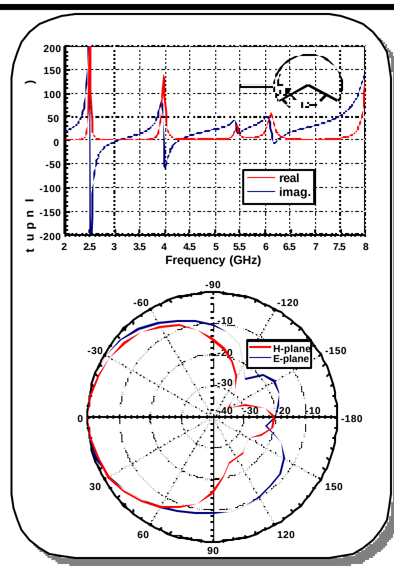
===> *Focus Becomes* "High Efficiency and Linear Transmitter"

Need to integrate PA design into overall transmitter design

Class F Amplifier Integrated with Antenna



- Class F power amplifier requires tuning of 2nd and 3rd harmonics
  - Used circular segment microstrip antenna
- Real part of input impedance is almost zero at 2nd and 3rd harmonics
- Measured Antenna Gain = 5.8 dB
- Cross-Polarization < -16 dB



Front End Architecture for Software Oriented Radio

- Hardware aspects should not take a back seat in research

RF for Smart Antenna

- Need antenna with smart function electronics

Multifunction/Reconfigurable Devices/Circuits/Antennas

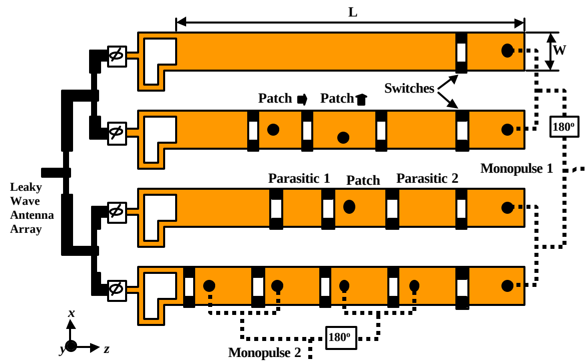
- Even if everything else becomes digital, antenna will not be.

Reconfigurable Leaky Mode/Multifunction Patch Aperture

Leaky-Mode Antennas & Arrays Find Wide-Range Applications in Radars and Wireless Communications

- Relatively high gain
- Easy Realization of Fan Beam
- Frequency Scanning for Beam-Steering Arrays

Proposed UCLA Structure



University of California, Los Angeles

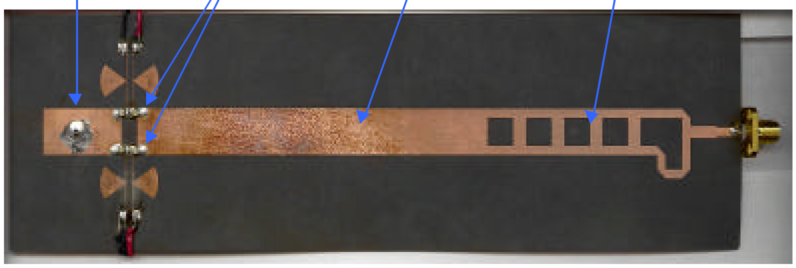
Reconfigurable Antennas

Patch antenna aperture and feed

PIN diode switches

Leaky mode antenna aperture

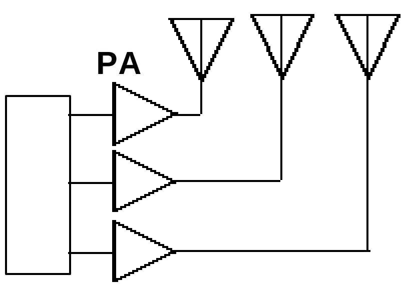
First higher order mode launcher



University of California, Los Angeles

Another Future Challenge

Phase distortion must be minimized for proper operation of "smart antennas"



AM/PM distortion of PAs will produce pointing error, sidelobes, and incomplete nulls

Can be more stringent than specifications on ACPR

Technology Assessment

	US	Japan	Europe
Millimeter Wave	2	5	4
Packaging/Interconnect	5	4	3
CAD	5	2	3
SiGE	4	3	5*
III-V	5	5	4
GaN	5	4	3
Antennas	4	4	4
Passive Components	5	5	4
Amplifier Technique	5	4	4**
MEMS	4	3	2

*Germany Only

** UK