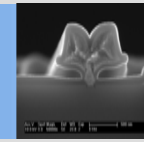
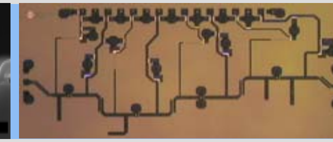




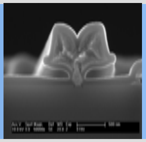
60GHz SoP Design using LTCC

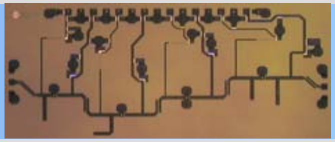
2006. 10. 13

Dong-Young Kim

Microwave Devices Team

Outline





I Motivation

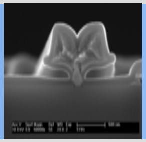
- Wireless Landscape
- Characteristics of WPAN(IEEE802.15.TG3c)
- Schematic diagram of our system

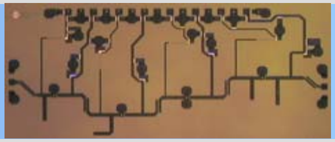
II LTCC SoP at 60GHz

- Characteristics of LTCC Substrate
- Characteristics of transmission line
- Characteristics of wire bonding
- Chip interconnection solution

III Summary

Wireless Landscape continually evolving





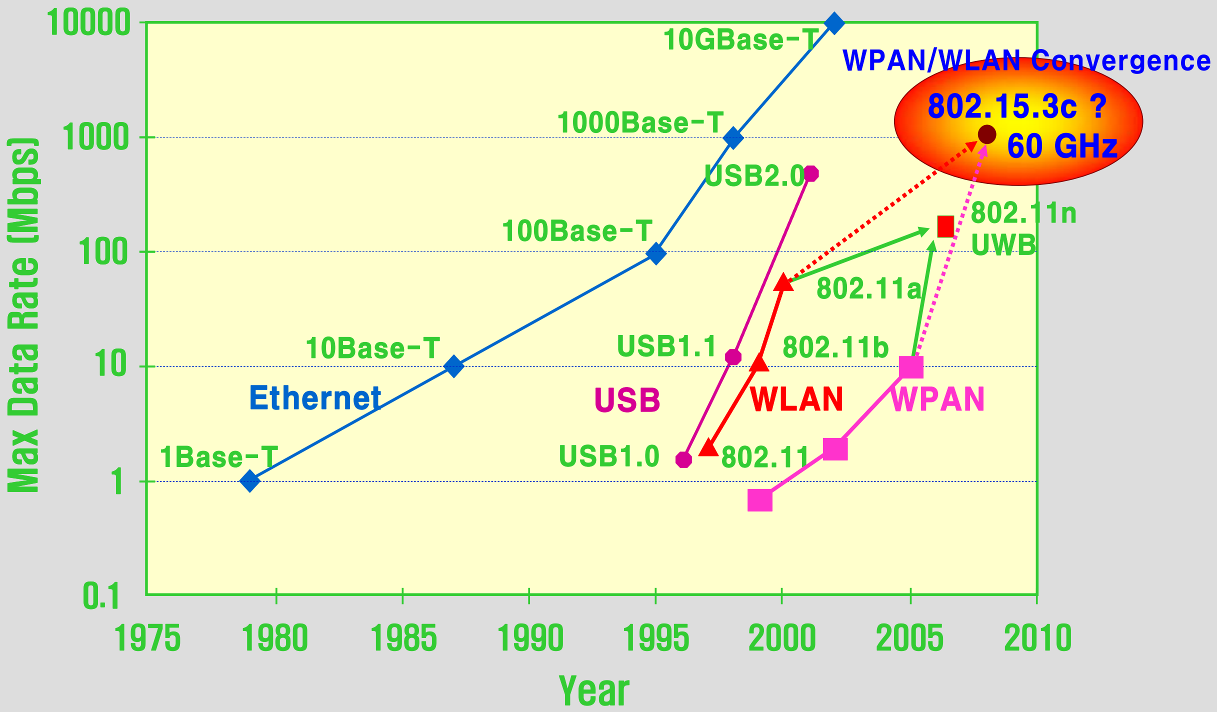
IEEE standards addressing high data rate transmission at mm-Wave, especially 60 GHz band

◆ IEEE 802.15.3c

- Standard Working Group
- Participation of over 15 companies

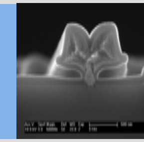
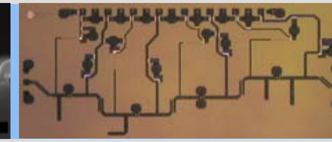
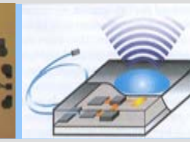
◆ 60 GHz band

- World wide band allocations
- 7 GHz bandwidth
- 100Mbps to multi-Gbps rates



Drivers include: Frequency allocation WW, bandwidth, capacity, power, cost, and reliability

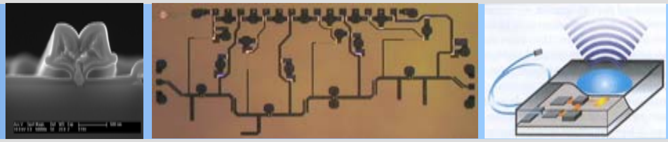
Characteristics of mmW WPAN

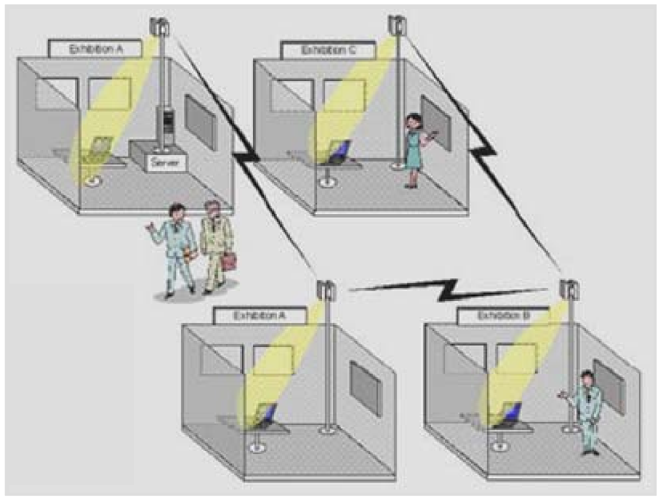
- Wireless transmission
- New unlicensed 60 GHz band
- Short range < 10 meters
- High data rate > 100Mbps
- Multimedia capability

→ 60 GHz is best solution for short range high data rate applications

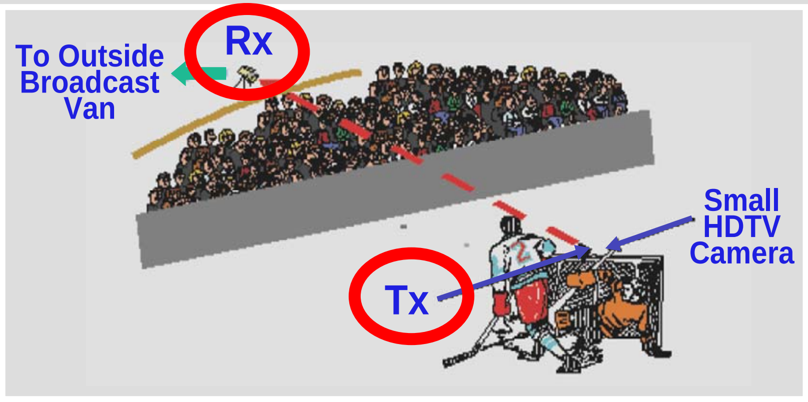
Potential WPAN Applications



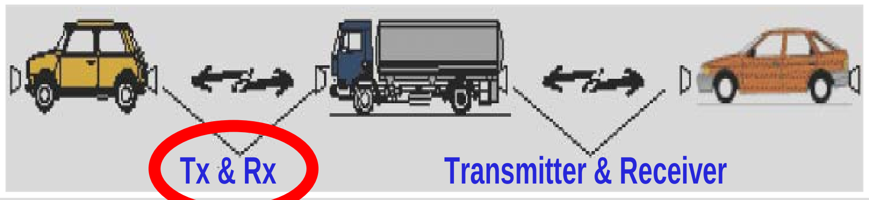
- **Ad-hoc information distribution with Point-to-Point network extension :**
  - *Easy and immediate construction of temporal broadband network such as in exhibition-site for… Advertisement information distribution or Contents downloading service*



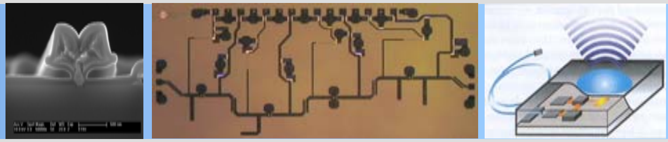
- **Broadcasting video signal transmission system in sports stadium : ~1.5Gbps**



- **Inter-vehicle communication system :**

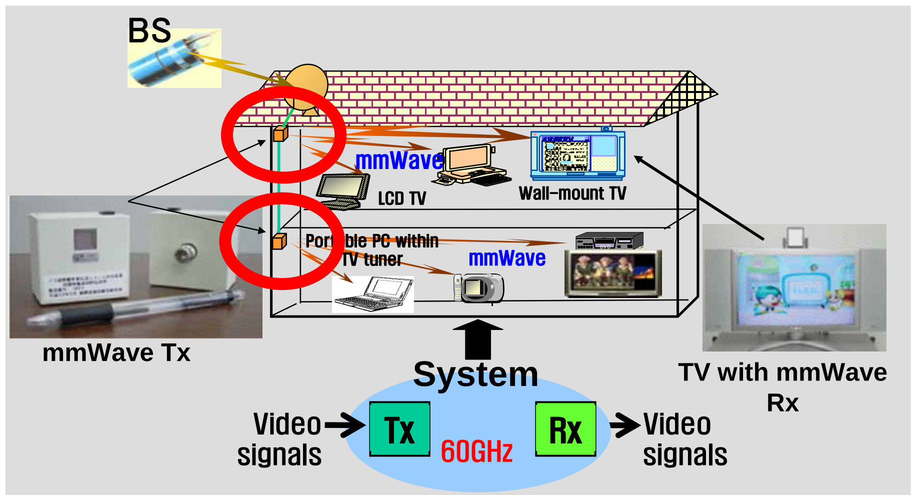


WPAN Applications (continued)

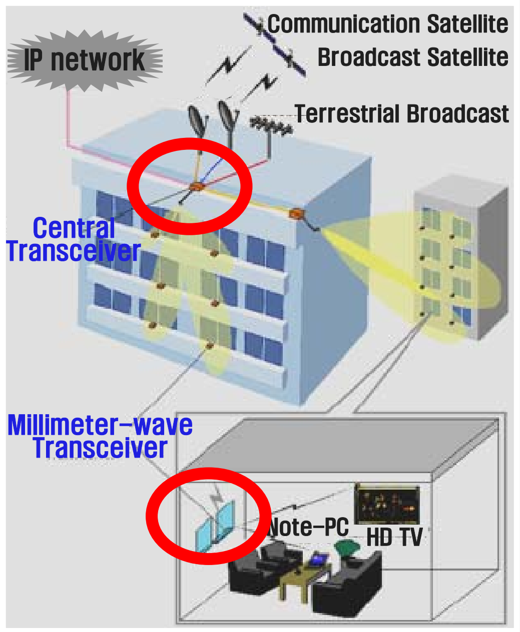


- **Huge data file transmission :**
  Ultra high speed download system

- **mm-Wave video-signals transmission system :**

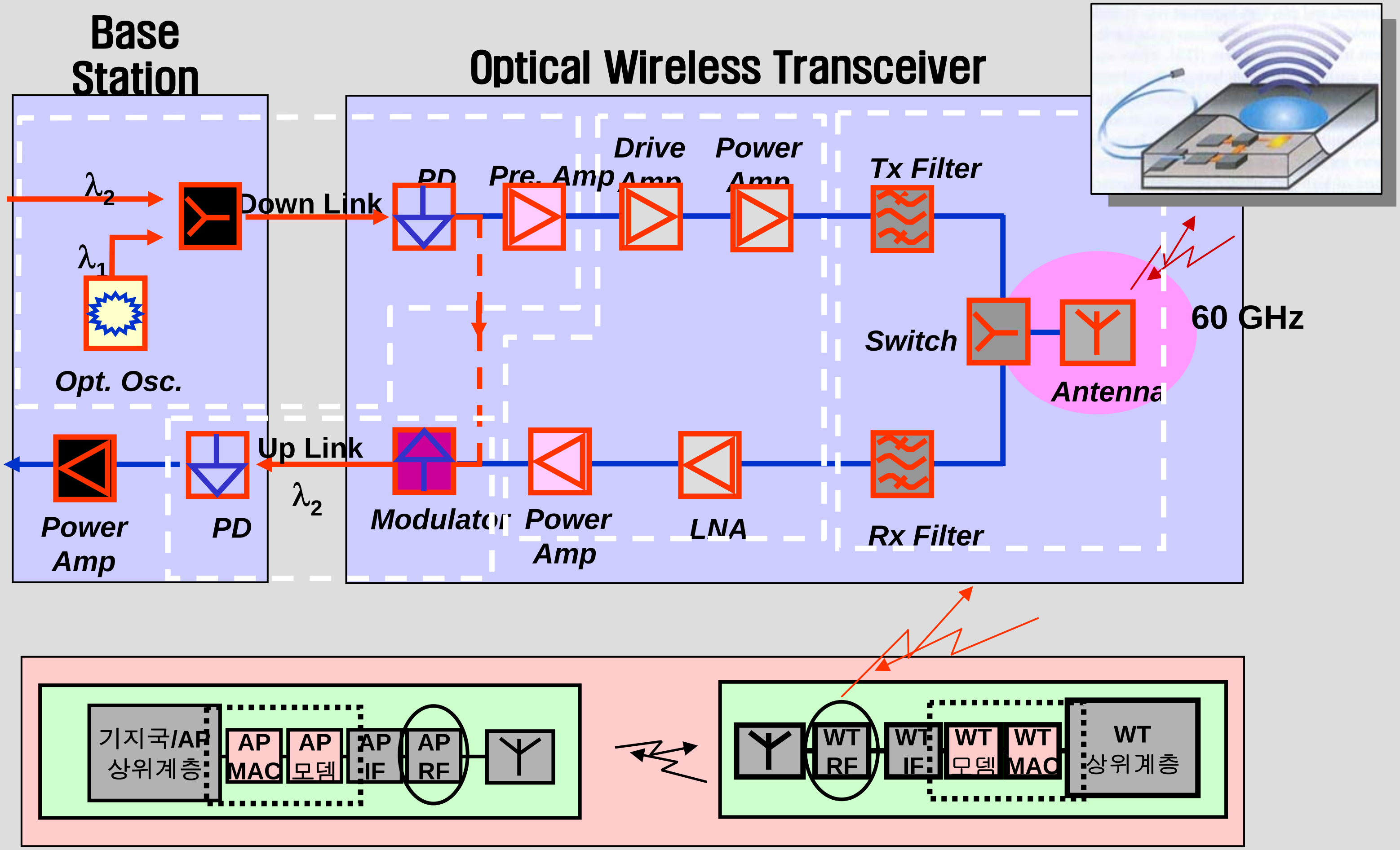


Conceptual Image



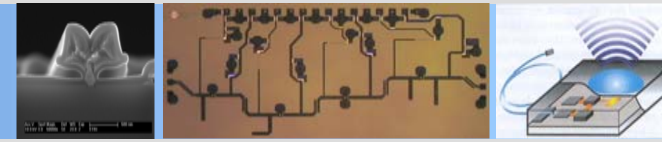
- **Data Distribution at Apartments/condominiums :**
  mm-Wave PAN for on-demand transmission or/and re-broadcasting of video and data signal for ad-hoc terminals

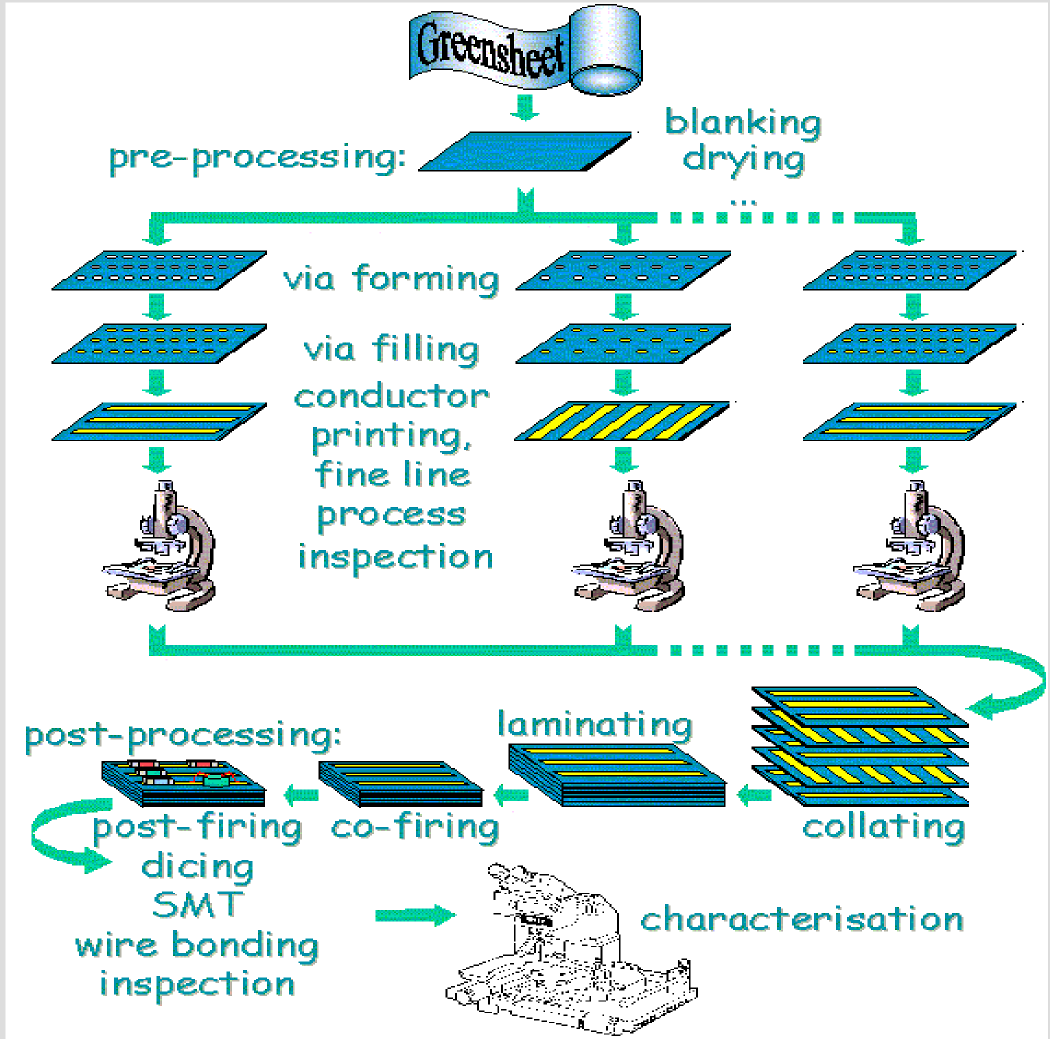
Schematic Diagram of mmW WPAN

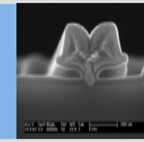


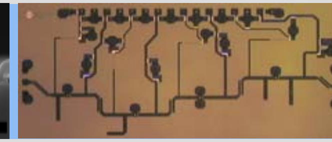
60GHz Wireless LAN

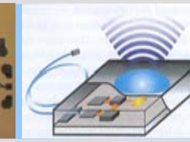
LTCC (Low Temperature Cofired Ceramics)





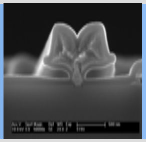


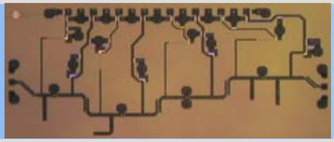




Key Issues

- Loss
  - dielectric and conductor loss increase with frequency
- Substrate solution
  - Low dielectric loss at mmW-band, at 60 GHz
  - Low cost packaging materials
- Transmission Line solution
  - low loss transmission at 60 GHz
- Chip interconnection solution
  - Low loss flip-chip or wire bond
  - Microstrip or CPW transmission line

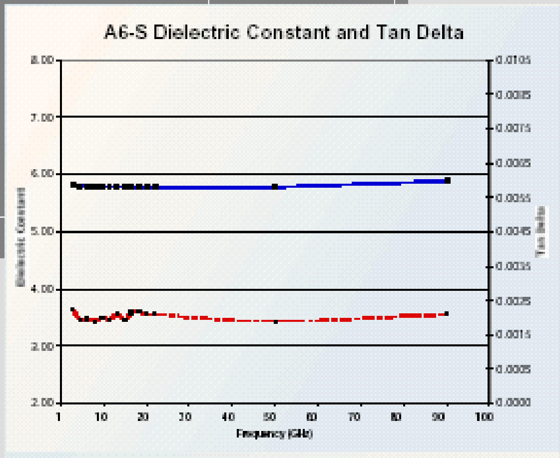




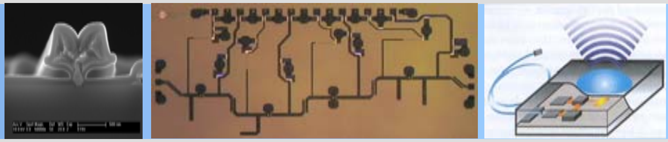
Substrate(LTCC) issues

Ferro A6S [$CaSiO_3$, $(Na,Mg)SiO_3$, SiO_2, CaB_2O_4]

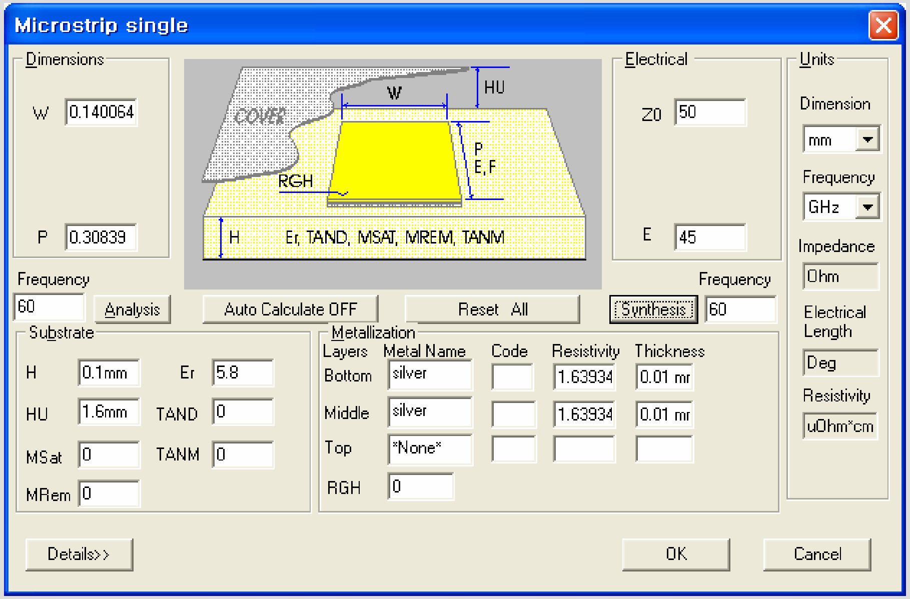
Typical Fired Physical Properties		Typical Fired Electrical Properties	
Thermal Coefficient of Expansion (25 - 300°C)	8 ppm/°C	**Dielectric Constant (1-100 GHz)**	5.9 ± 0.20
Tape Shrinkage		**Dissipation Factor (1-100 GHz)**	<0.2 %
X,Y	15.3 ± 0.2 %		
Z (unlaminated to fired)	24 ± 0.2 %	**Insertion Loss (10 GHz)**	<0.18 dB/in
Fired Density	2.45 g/cm^3	**Bulk Resistivity**	>10^{12} Ω/cm
Flexural Strength (3 point bend)	>160 MPa		
Thermal Conductivity	2 W/mK		
(With Thermal Vias)	>50 W/mK		



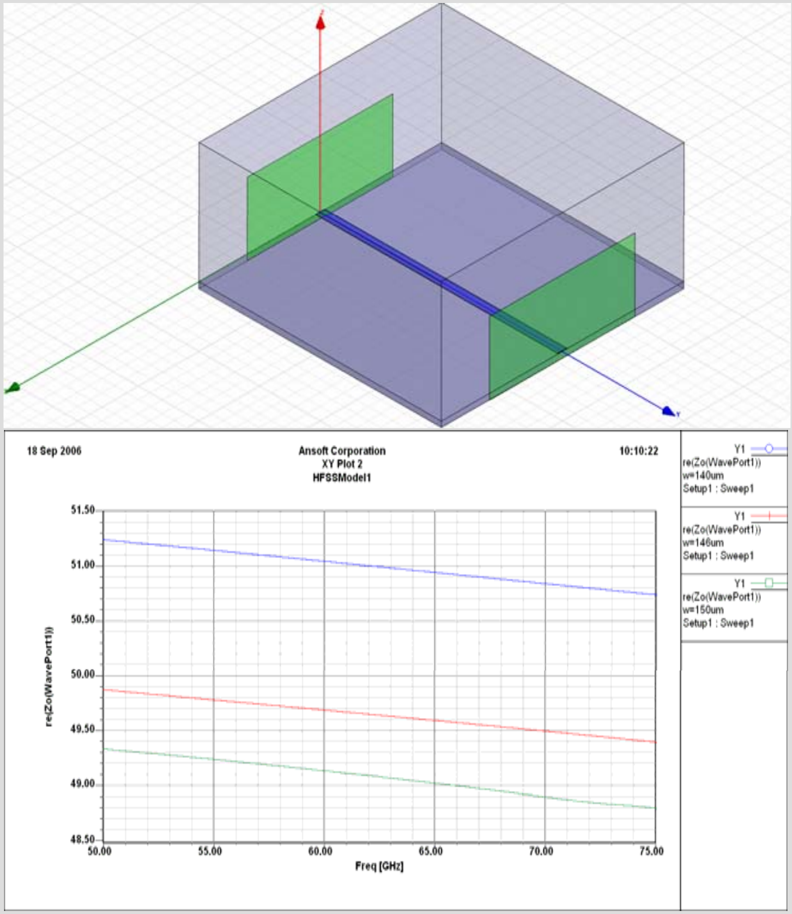
Design of 50 Ω Line (microstrip: 100μm)



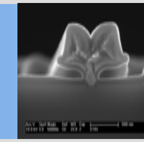
Ansoft Designer (calculation of line width)

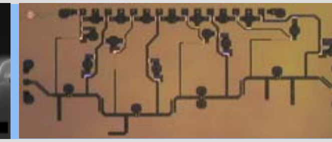


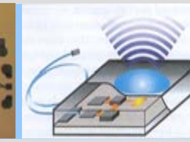
Ansoft HFSS (Simulation of line width)



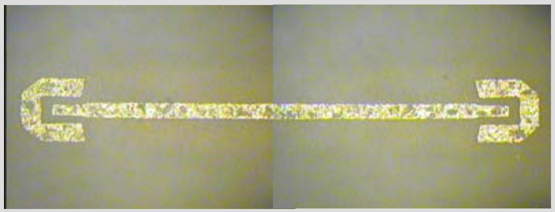
Transmission Line (Microstrip line)

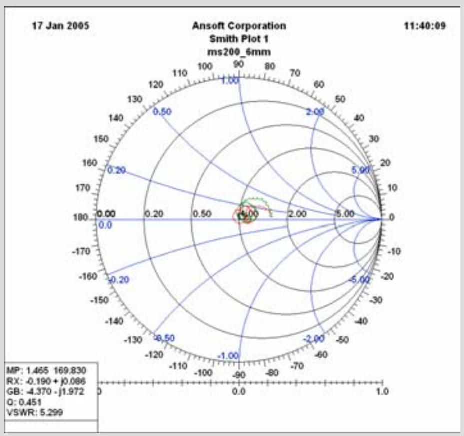


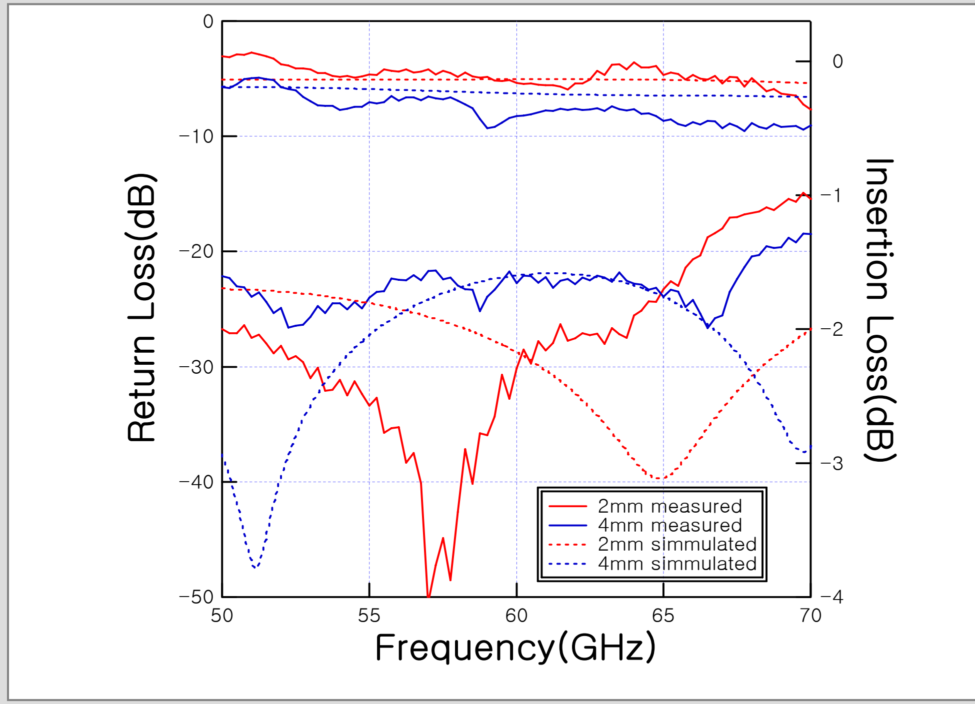




- Dielectric Thickness: 100 μm

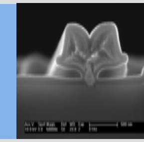


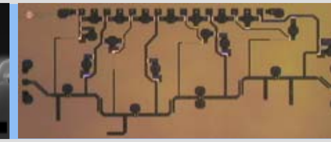


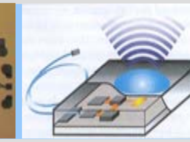


Sub. height	Line length	S11[dB]	S21[dB]	S12[dB]	S22[dB]
1st layer(100μm)	2mm	−31.1	−0.16	−0.18	−29.7
	4mm	−22.8	−0.41	−0.42	−24.3

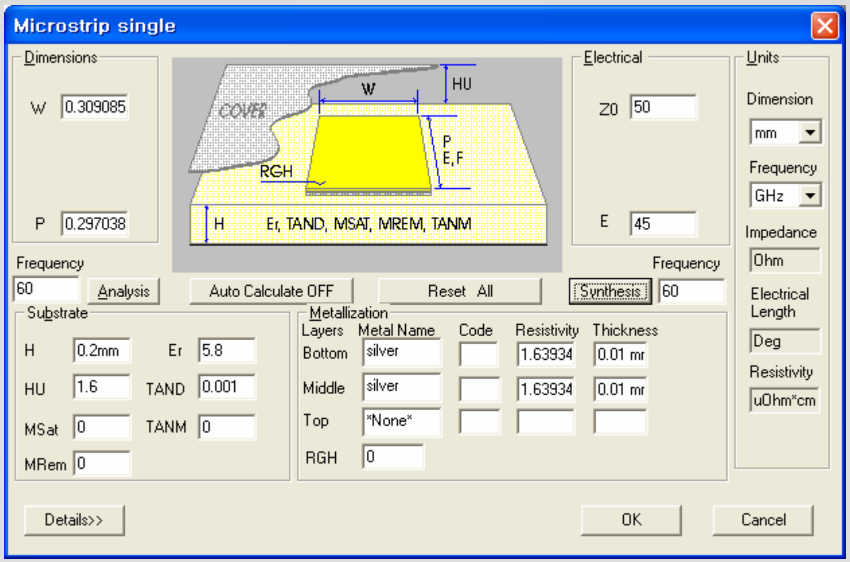
Design of 50 Ω Line (microstrip: 200μm)



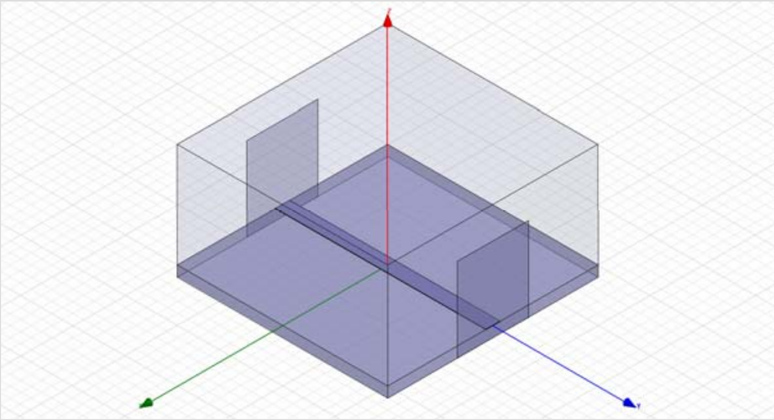


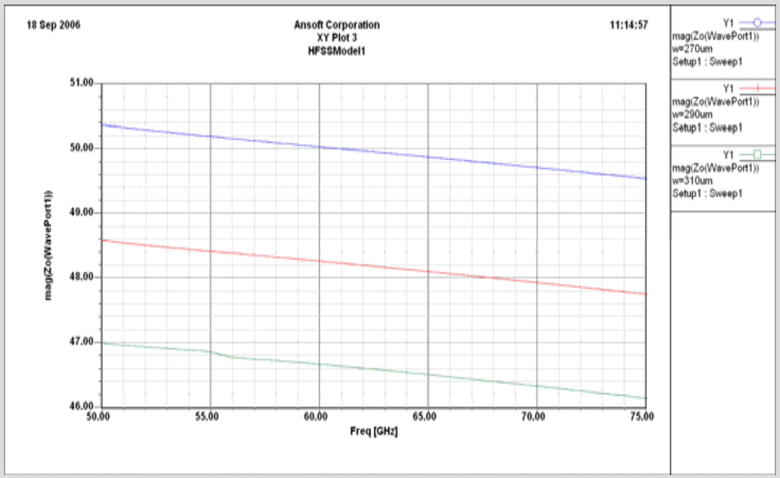


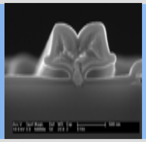
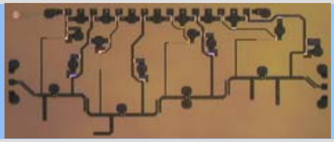
Ansoft Designer (calculation of line width)



Ansoft HFSS (Simulation of line width)

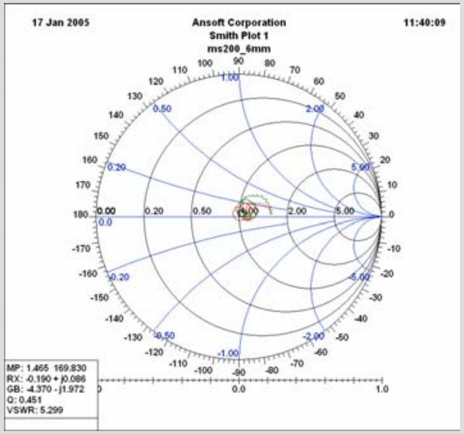


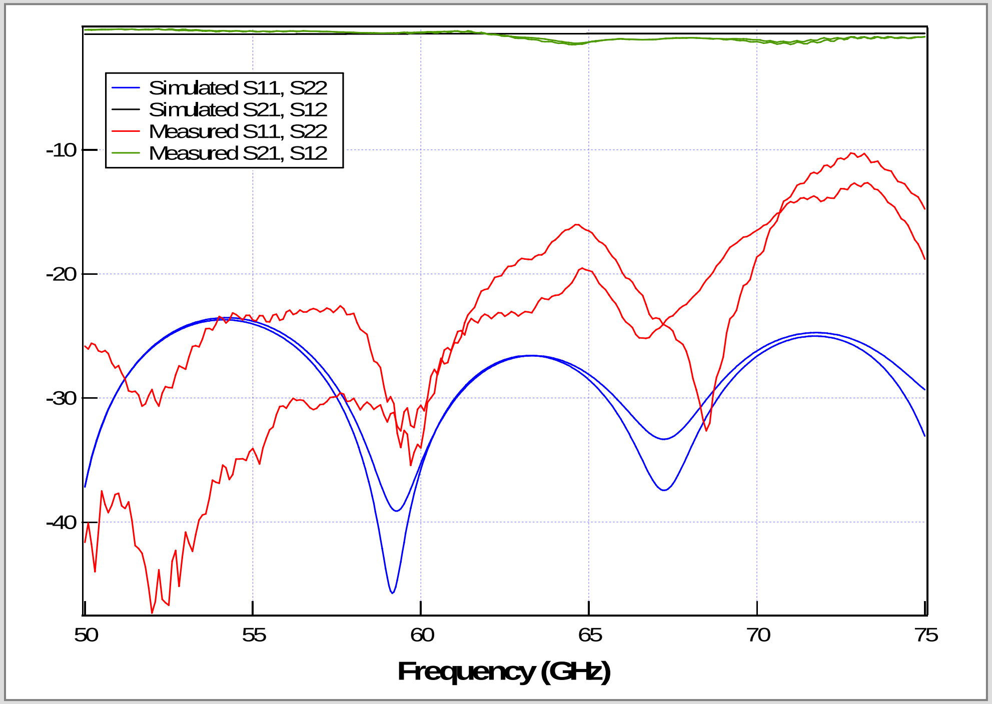


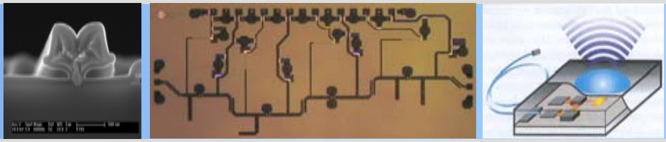

Transmission Line (Microstrip line)

- Dielectric Thickness: 200 μm



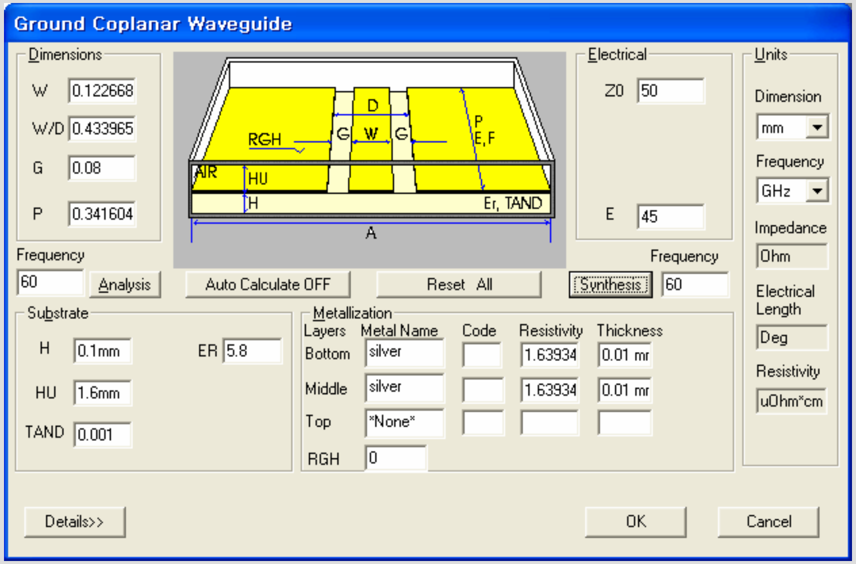


Sub. height	Line Lenght	S11[dB]	S21[dB]	S12[dB]	S22[dB]
2nd layer(200μm)	4mm	−23.9	−1.25	−1.18	−17.3
	6mm	−30.6	−0.58	−0.52	−34.0

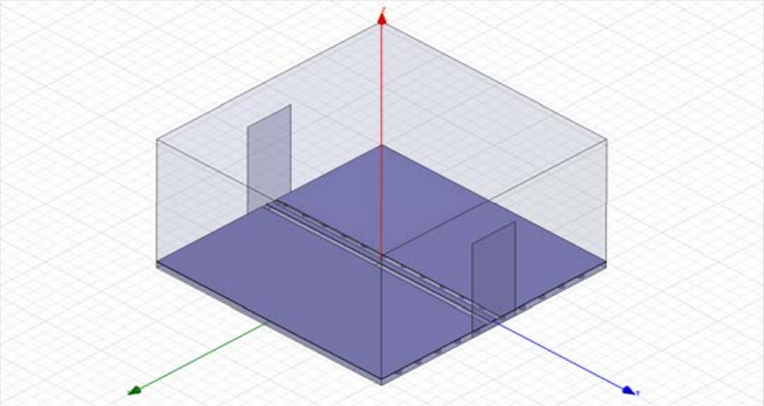


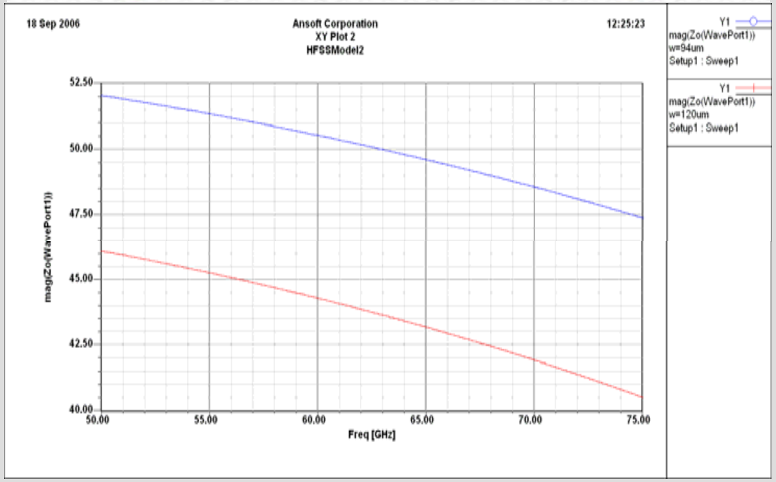
Design of 50 Ω Line (CBCPW: 100μm)

Ansoft Designer (calculation of line width)

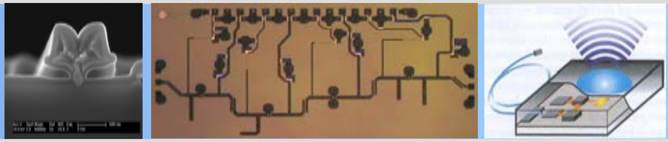


Ansoft HFSS (Simulation of line width)

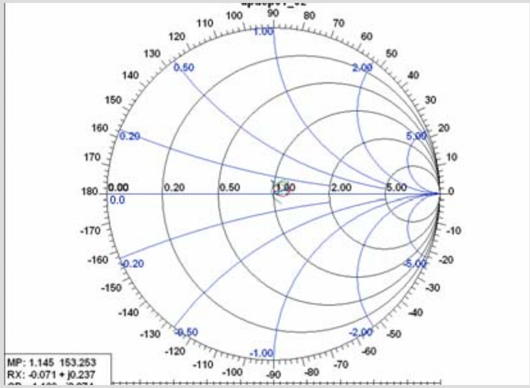


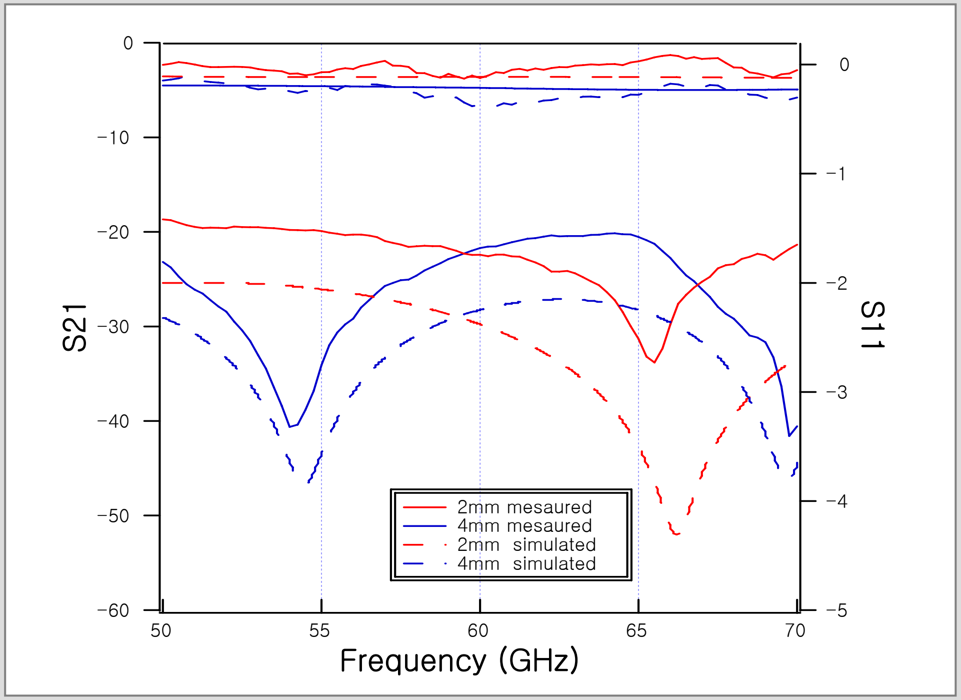


Transmission Line (CBCPW line)



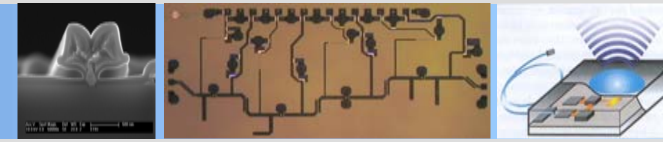
- Dielectric Thickness: 100 μm



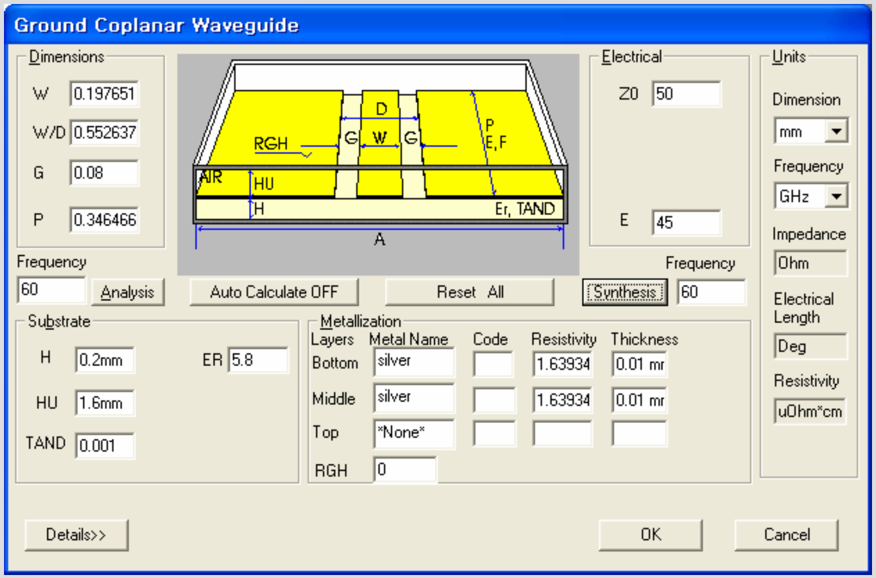


Sub. height	Line lenght	S11[dB]	S21[dB]	S12[dB]	S22[dB]
1st layer(100μm)	2mm	−22.4	−0.15	−0.12	−20.4
	4mm	−21.7	−0.40	−0.37	−22.4

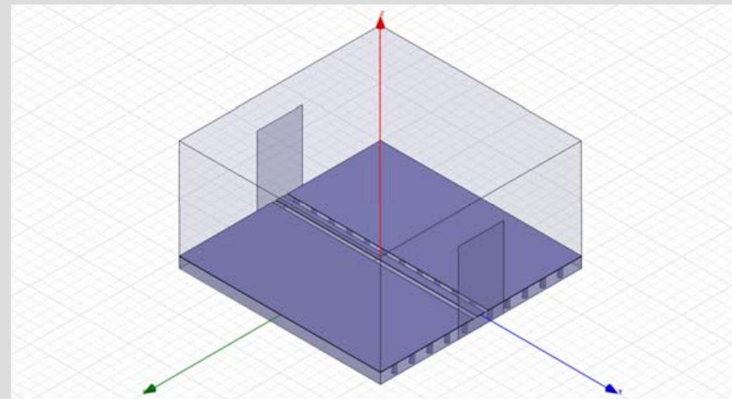
Design of 50 Ω Line (CBCPW: 200μm)

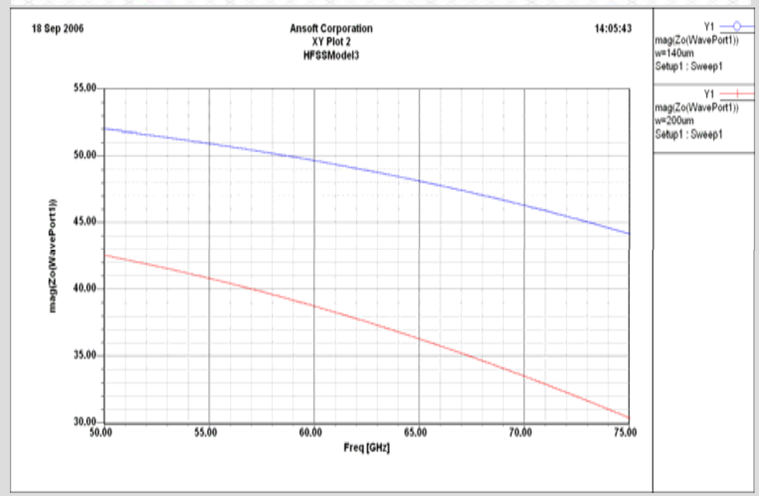


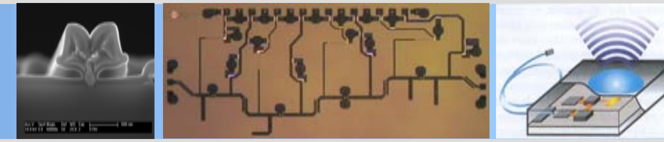
Ansoft Designer (calculation of line width)



Ansoft HFSS (Simulation of line width)

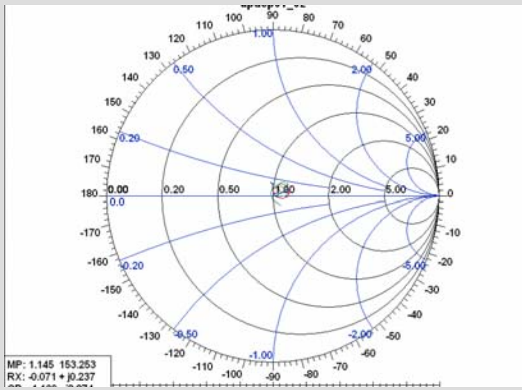


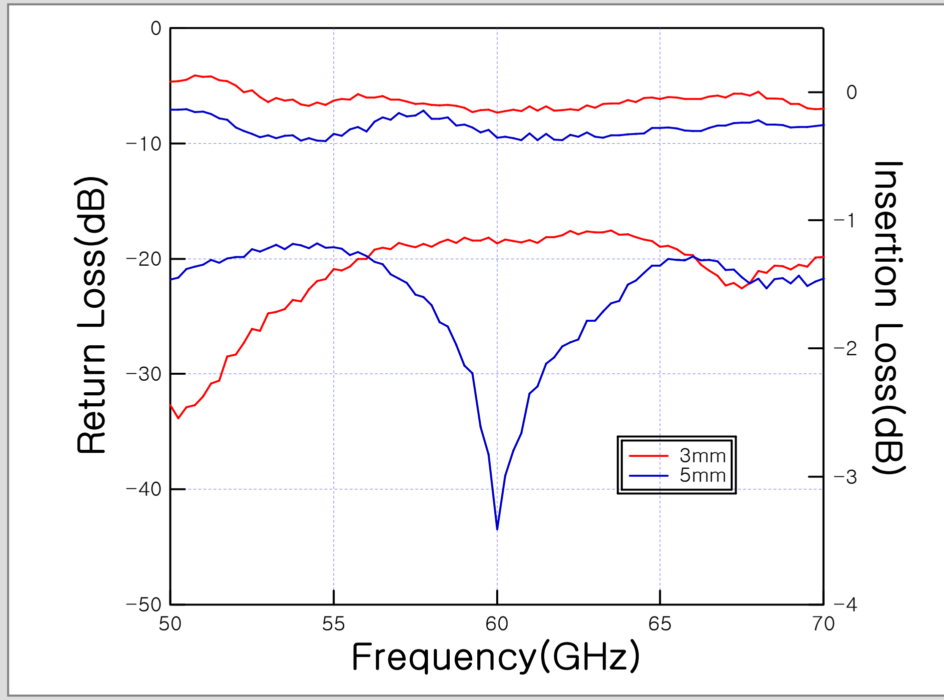




Transmission Line (CBCPW line)

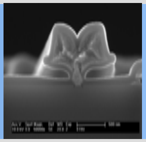
- Dielectric Thickness: 200 μm

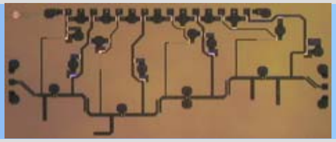




Sub. height	Line length	S11[dB]	S21[dB]	S12[dB]	S22[dB]
2nd layer(200μm)	3mm	−18.6	−0.16	−0.17	−19.1
	5mm	−43.5	−0.35	−0.39	−27.3

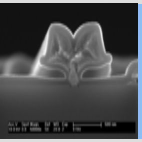
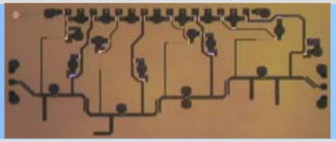
Transmission Line (summary)



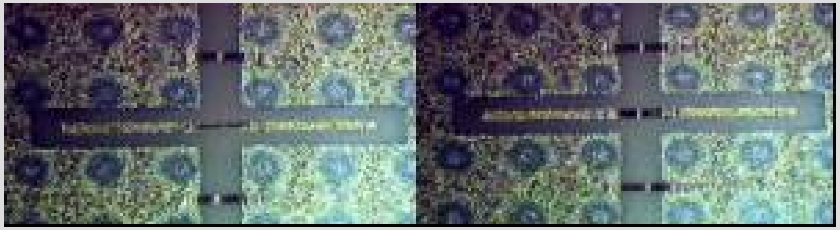


- Design of 50Ω transmission lines
  - using Designer and HFSS
- Simulated value is coincide with measurement.
- Microstrip or CBCPW line is suitable for transmission lines at 60GHz.
  - low loss (0.1dB/mm)

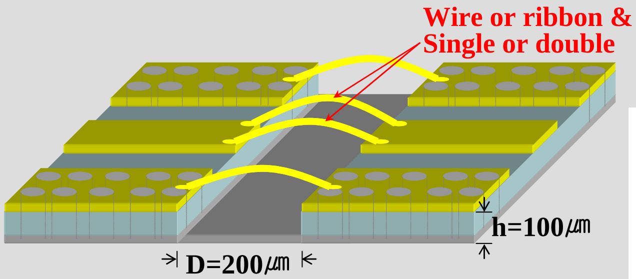
Interconnection (wire bonding)

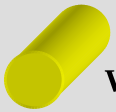




CBCPW Line (Dielectric thickness :100μm)

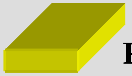


Bonding Type	S11	S12
single wire	– 21.6dB	– 0.17dB
double wire	– 28.6dB	– 0.10dB
single ribbon	– 27.4dB	– 0.10dB
double ribbon	– 24.3dB	– 0.09dB

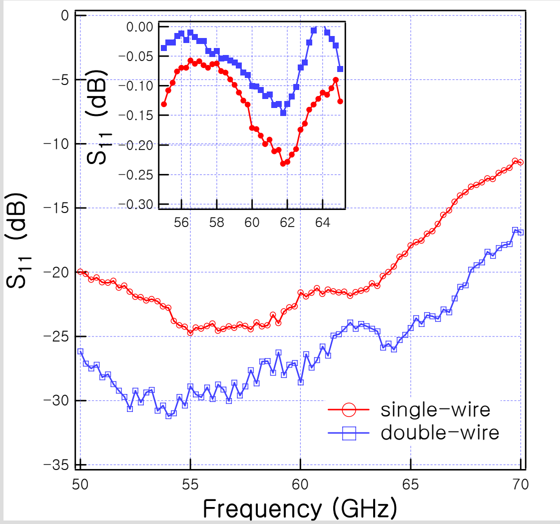


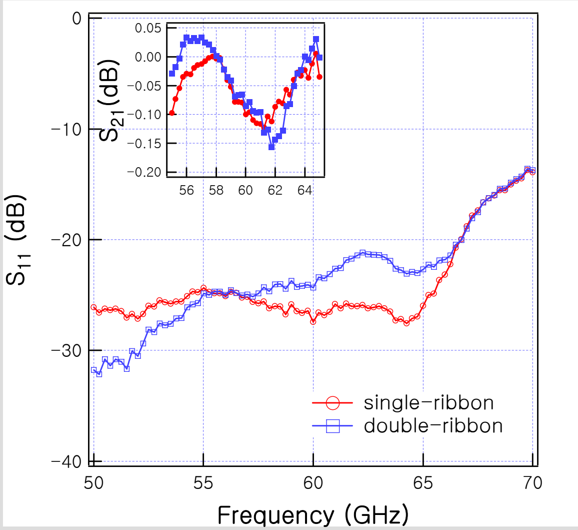


Wire, dia.=1mil (25㎛)



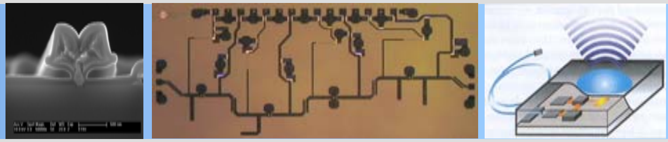
Ribbon, size=2x0.5mil^2



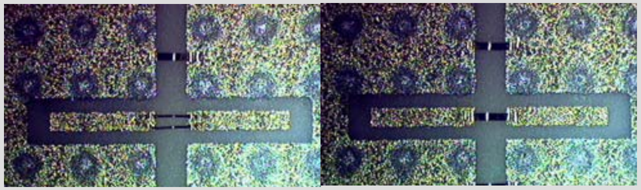


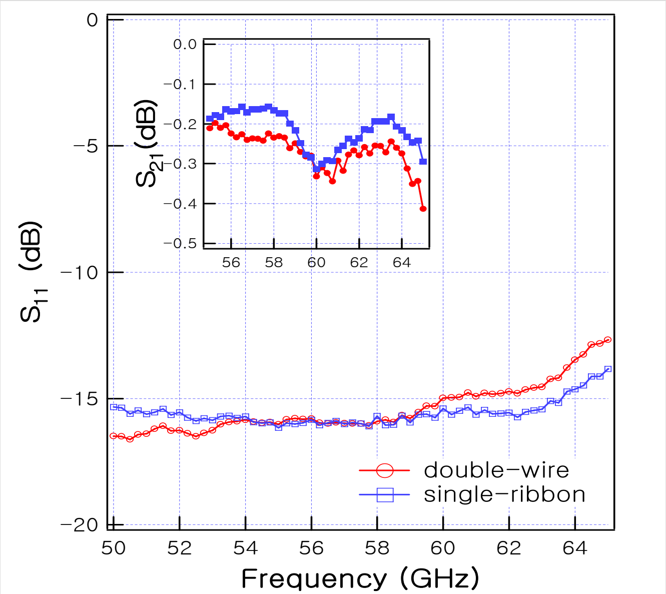
ETRI Microwave Devices Team

Interconnection (wire bonding)

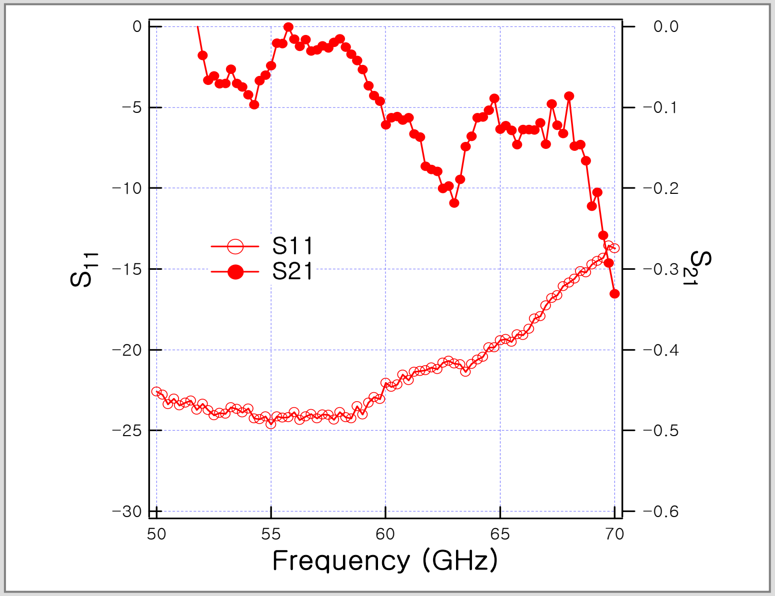


CBCPW Line (Dielectric thickness :200μm)

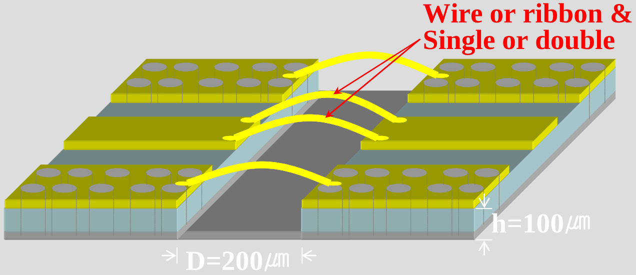


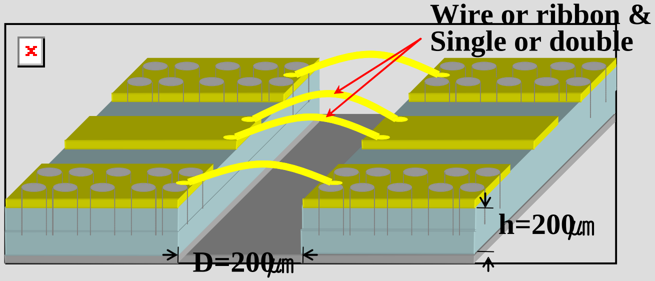


Bonding Type	S11	S12
single wire	− 9.19dB	− 0.75dB
double wire	− 14.5dB	− 0.35dB
single ribbon	− 15.4dB	− 0.31dB
double ribbon	− 22.1dB	− 0.12dB



Interconnection (wire bonding)



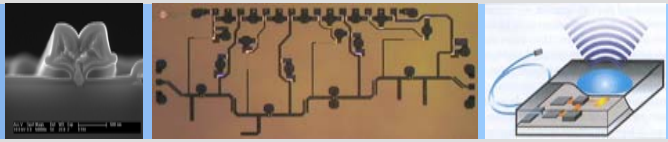


Dielectric thickness (100μm)

- Single ribbon or double wire bonding
  - nearly 50 Ohm at 60GHz
- Low loss transmission
- S_{21}=~-0.1dB and S_{11}=~-20dB

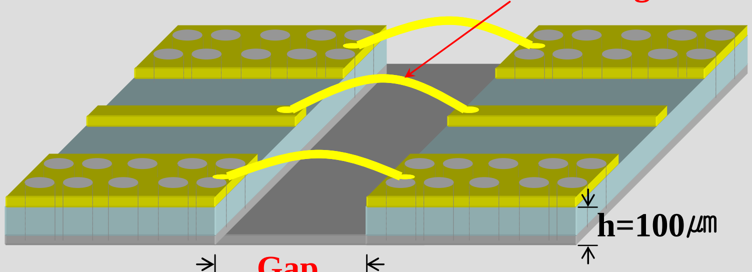
Dielectric thickness (200μm)

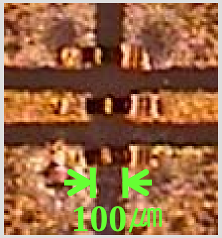
- Single ribbon or double wire bonding
  - high Impedance state
- To match 50Ω, Increase the line width.
- Double ribbon bonding is required.
- Low loss transmission
- S_{21}=~-0.1dB and S_{11}=~-20dB



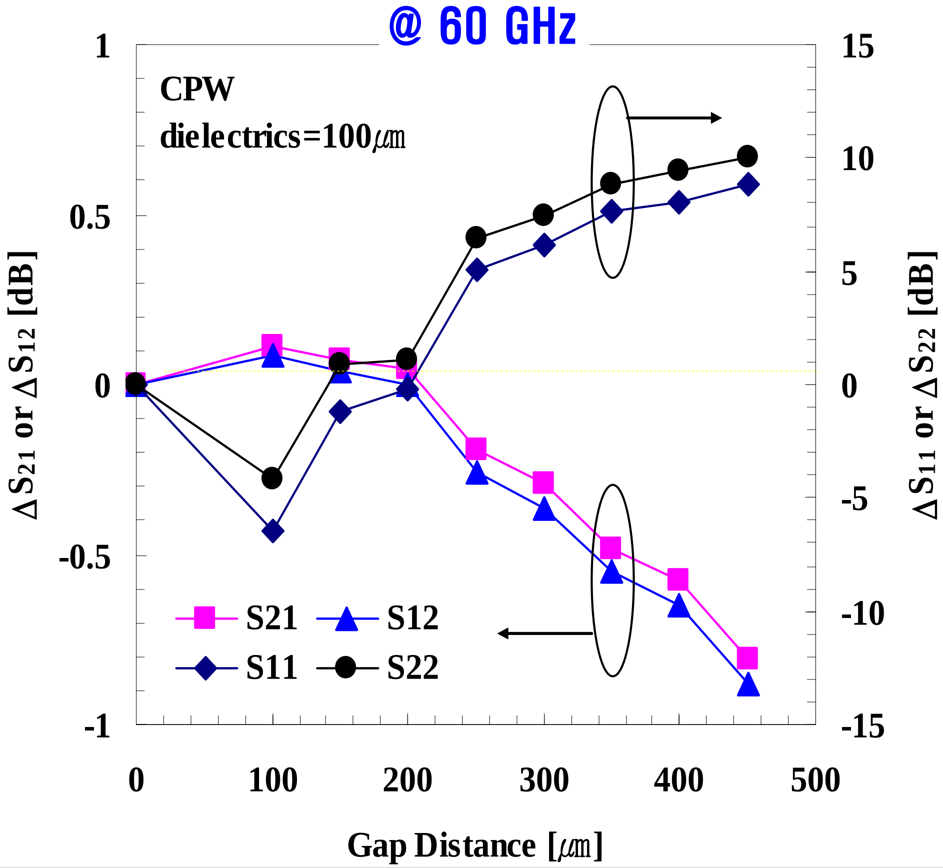
Wire length v.s. Line loss

- Gap distance : acceptable RF degradation during the interconnection

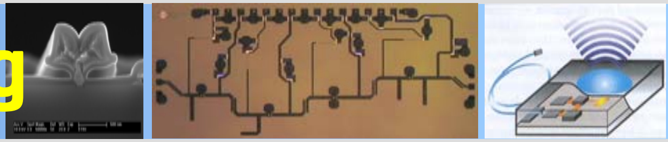




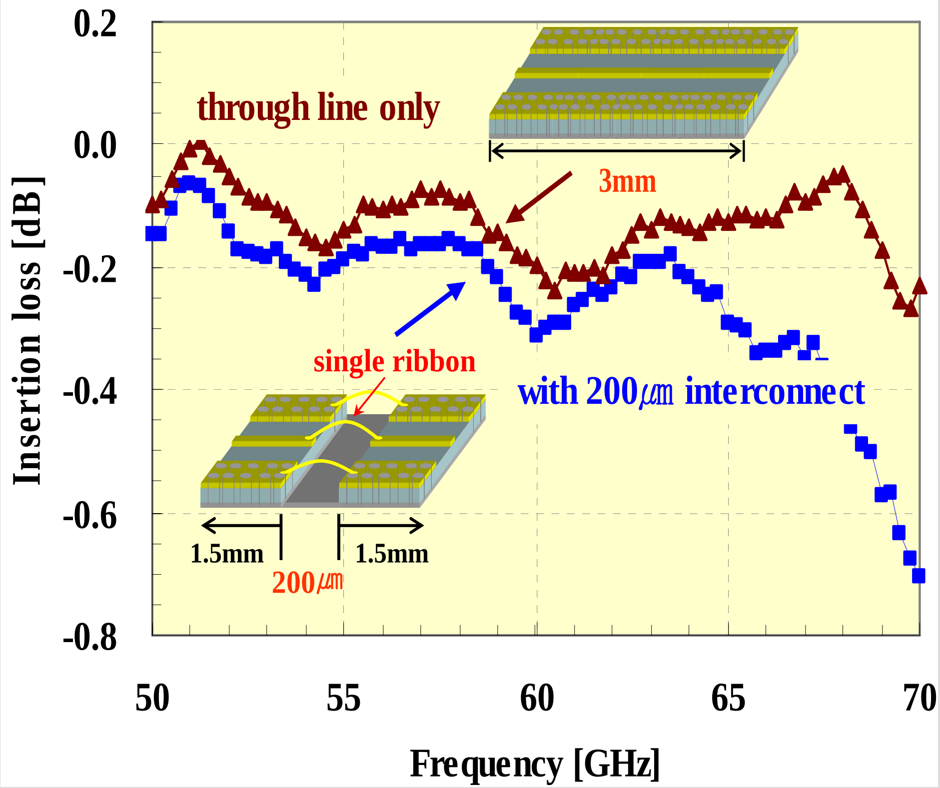
Photograph of 100㎛ gap



Interconnect loss of wire-bonding

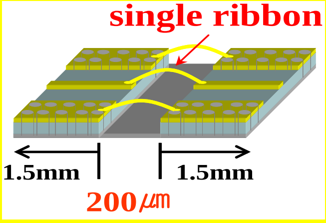


- Low loss and Simple Process : Wire-Bonding technique
- Symmetric performance($S_{11} \fallingdotseq S_{22}$) of Wedge bonding method



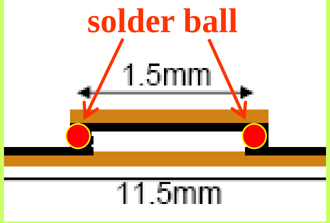
Wire-bonding v.s. Flip-chip bonding

• ETRI(2006)



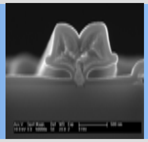
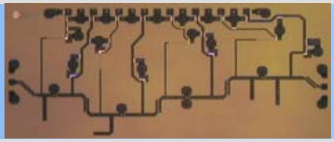
- Ribbon wire loss 0.11dB @ 60 GHz

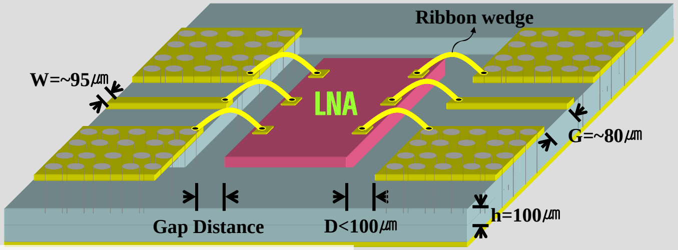
• IBM(2005)



- Solder ball loss 0.7dB @ 60GHz

Amp module

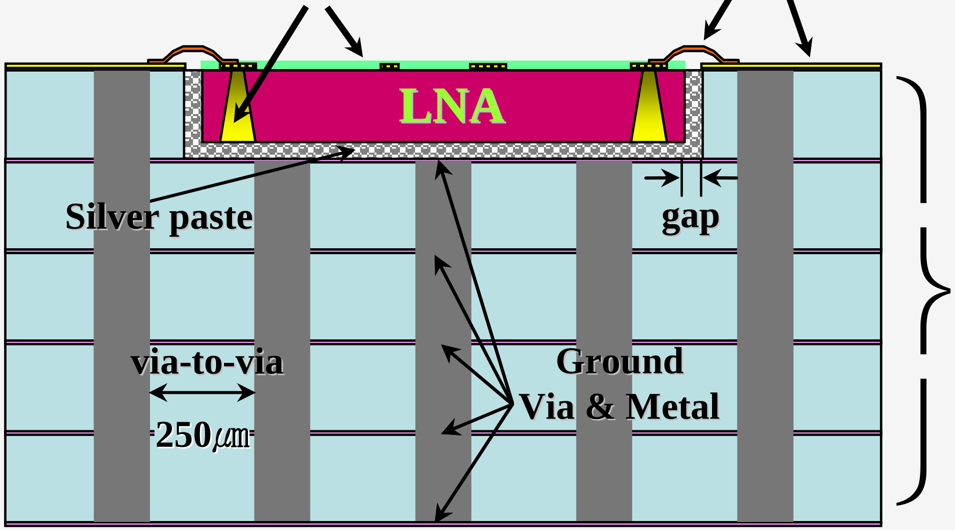



Chip interconnection Solution

- CPW line
- Cavity structure,
- Ribbon Wedge bonding technique

Chip set Solution

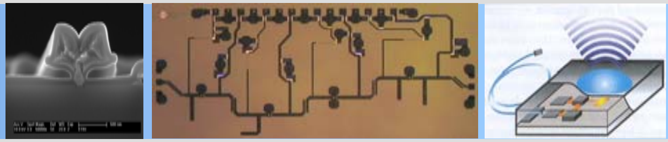
- 0.12 ㎛ pHEMT LNA
- Via-hole ground



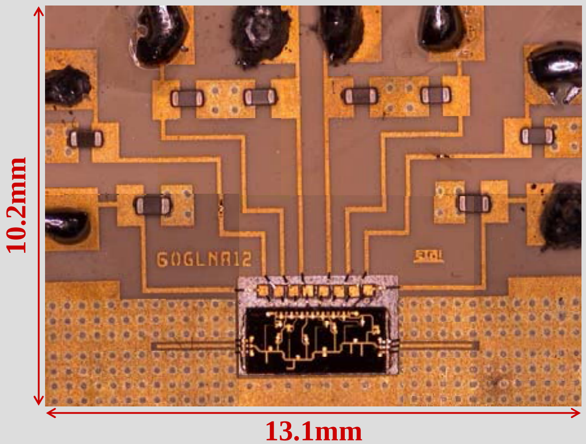
Substrate Solution

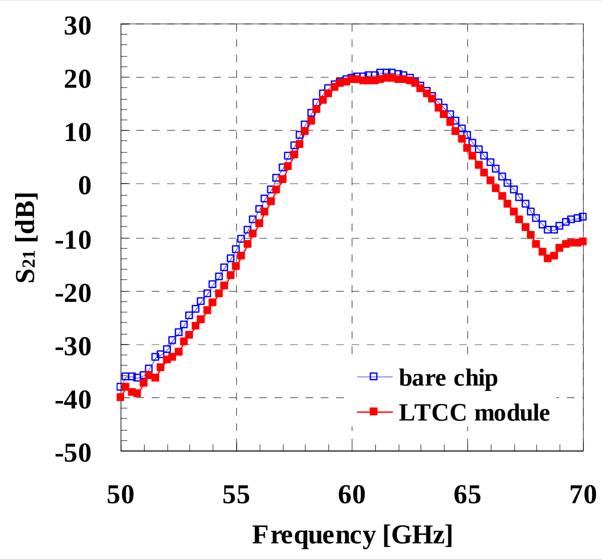
- Ferro A6-S LTCC
- Internal silver conductor
- External gold conductor

Amp module (LNA)

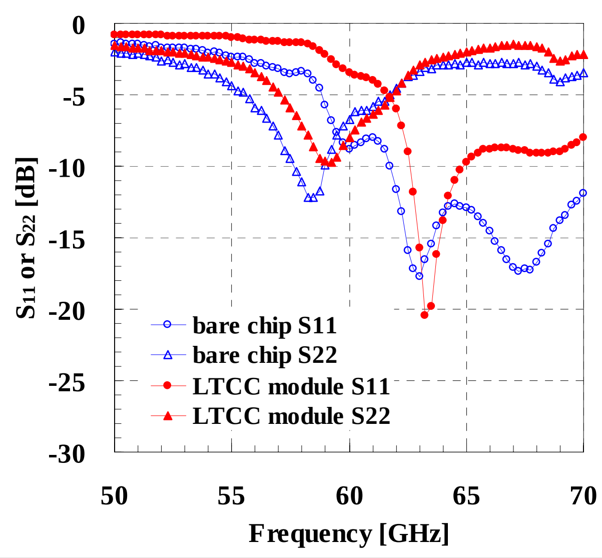


LNA module S-parameters

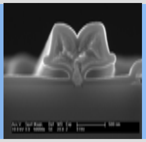


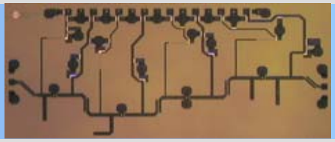


- hp8720C N/A
- freq.=50~70GHz
- S_{21}=~19.4dB and ΔS_{21}=-0.4 dB
- S_{11}=~-3.5dB and ΔS_{11}=-5.3 dB
- S_{22}=~-7.9dB and ΔS_{22}=1.2 dB



Summary





- Design of 50Ω transmission lines
  - using Designer and HFSS
- Microstrip or CBCPW line is suitable for transmission lines at 60GHz.
  - low loss (0.1dB/mm)
- Single ribbon bonding is adequate for interconnection
  - simple
  - low loss (0.1dB/bonding)
- Characteristics of Amp module
  - ΔGain (S_{21}) : 0.4 dB