LTCC Technology for 60 GHz Applications

Hae-Cheon Kim

(ETRI/Korea)

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Haecheon Kim, Dong Young Kim, Jae Kyoung Mun,
Dong Suk Jun, Hyun Kyu Yu

ETRI
Electronics and Telecommunications Research Institute

Outline

I Motivation
- Wireless Landscape
- 60 GHz Wireless Applications
- RoF based 60 GHz O/E Transceiver

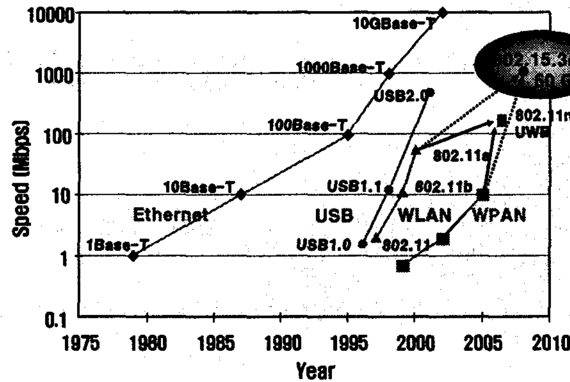
II LTCC for 60 GHz
- Characteristics of substrate
- Characteristics of transmission line
- Characteristics of wire bonding
- Chip interconnection

III Summary

Wireless Landscape

■ IEEE standards headed toward mm-wave WPAN (60 GHz)

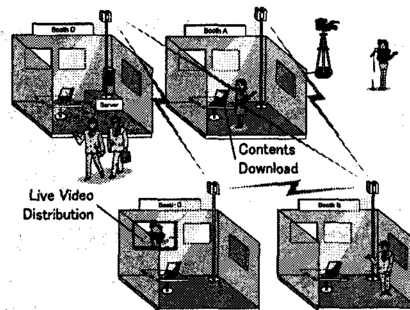
- IEEE802.15.3c
  - Standard Working Group
  - Participation of over 20 Companies
- 60 GHz Band
  - World wide band allocations
  - 7 GHz bandwidth
  - 100 Mbps to multi-Gbps rates



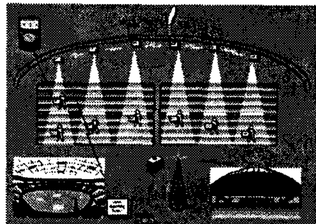
Drivers include: Frequency allocation, bandwidth, capacity, power, cost, and reliability

60 GHz Wireless Applications

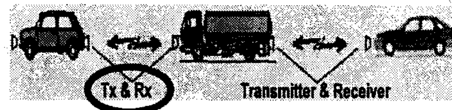
■ Ad-hoc information distribution with Point-to-Point network extension :
- Easy and immediate construction of temporal broadband network such as in exhibition-site for... Advertisement information distribution or Contents downloading service



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

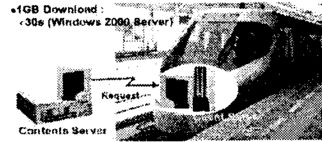


■ Inter-vehicle communication system

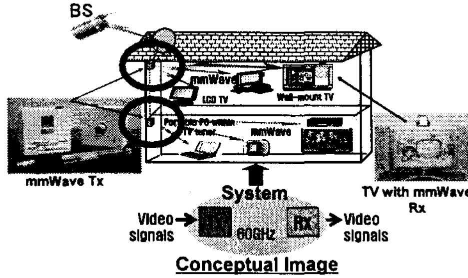


60 GHz Wireless Applications

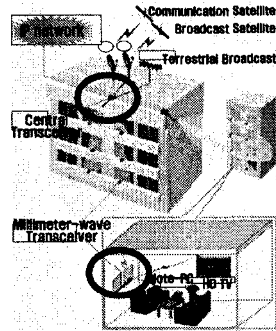
- Huge data file transmission :
  - Ultra high speed download system



- mm-Wave video-signals transmission system :



Conceptual Image

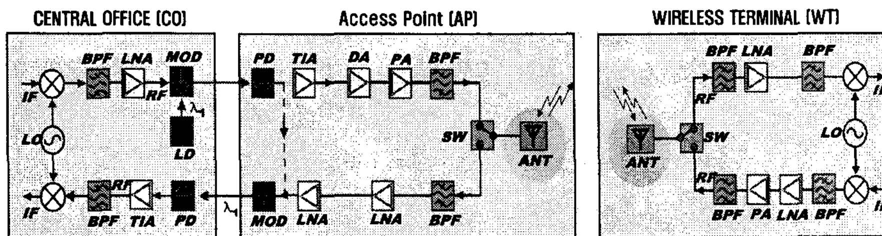


- Data Distribution at Apartments/condominiums :
  - mm-Wave PAN for on-demand transmission
  - re-broadcasting of video and data signal for ad-hoc terminals

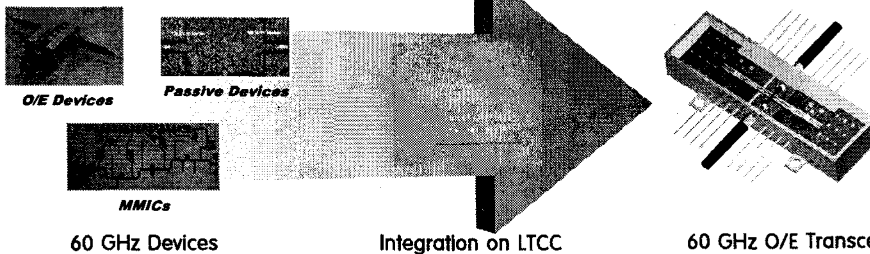
RoF based 60 GHz O/E Transceiver

- RoF (radio-over-fiber) based communication system

CENTRAL OFFICE (CO) Access Point (AP) WIRELESS TERMINAL (WT)



- 60 GHz O/E Transceiver SoP

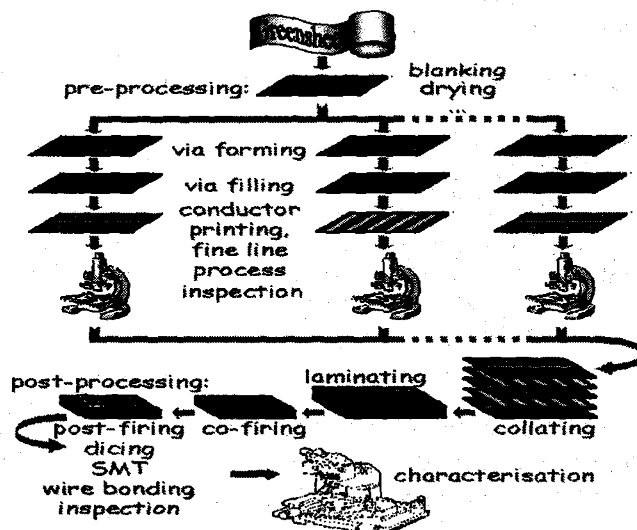


60 GHz Devices Integration on LTCC 60 GHz O/E Transceiver

LTCC for 60 GHz

ISMP 2006

- LTCC (low temperature co-fired ceramics) Technology



LTCC for 60 GHz

ISMP 2006

- Is LTCC suitable for 60 GHz applications ?

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

Characteristics of Substrate

GSMP 2006

■ LTCC Greensheets for millimeter wave

Material Property	Units	A1	A2	B1	B2
Electrical - Dielectric Constant - Dielectric Loss Factor	 (0.1~2 GHz) (0.1~2 GHz)	 7.8 0.0015	 7.4 0.0005	 5.9 0.0012	 5.9 0.0012
Thermal - Expansion Coefficient - Conductivity	 (ppm/K) (W/mK)	 5.8 3.3	 6 4.4	 7 2	 >8 2
Mechanical - Flexural Strength - Young's Modulus	 (Mpa) (Gpa)	 320 120	 230 150	 170 92	 >160 92
Physical - Green Tape Thickness - Fired Tape Thickness	 (mils) (mils)	 4.5/6.5/10 3.6/5.4/8.1	 2/5/10 1.8/4.5/9	 5/10 3.7/7.4	 5/10 3.9/7.8

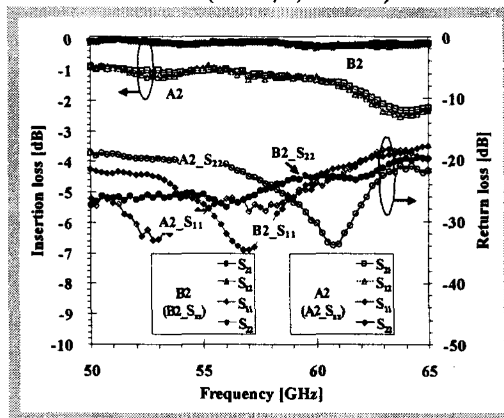
Characteristics of Substrate

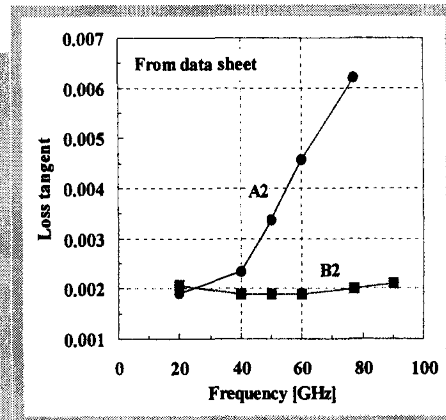
GSMP 2006

■ LTCC for millimeter-wave package

- Low insertion and return losses at 60 GHz and up to 90 GHz
- Low material cost & multi-layer possible

CPW (h=100㎛, L=4mm)

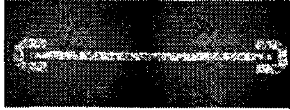


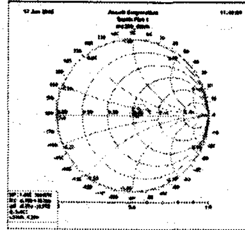


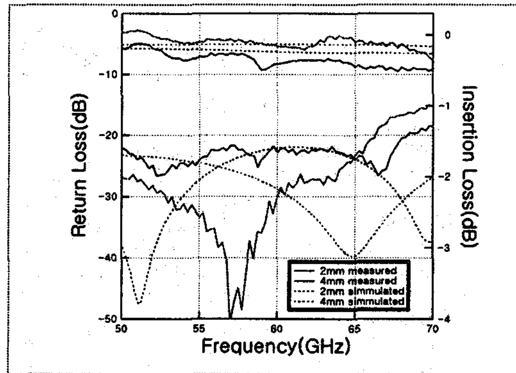
Characteristics of transmission Line

▣ Microstrip line (1 layer)

- Dielectric Thickness: 100 μm





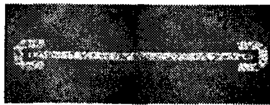


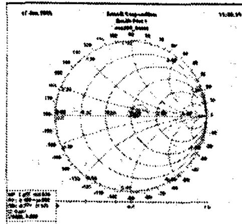
Thickness	Line length	S11[dB]	S21[dB]	S12[dB]	S22[dB]
1 layer (100μm)	2mm	-31.1	-0.16	-0.18	-29.7
	4mm	-22.8	-0.41	-0.42	-24.3

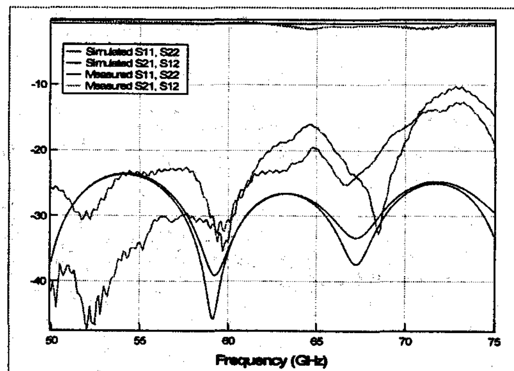
Characteristics of transmission Line

▣ Microstrip line (2 layers)

- Dielectric Thickness: 200 μm





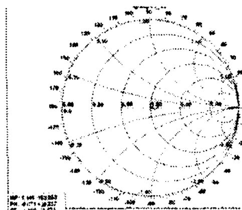


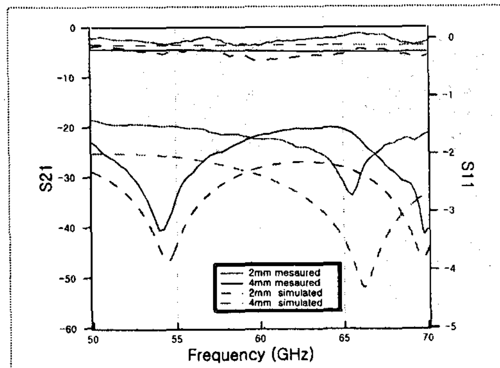
Thickness	Line length	S11[dB]	S21[dB]	S12[dB]	S22[dB]
2 layers (200μm)	4mm	-23.9	-1.25	-1.18	-17.3
	6mm	-30.6	-0.58	-0.52	-34.0

Characteristics of transmission Line

CBCPW line (1 layer)

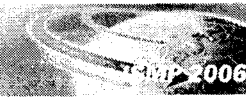
- Dielectric Thickness: 100 μm





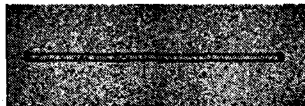
Thickness	Line length	S11[dB]	S21[dB]	S12[dB]	S22[dB]
1 layer (100μm)	2mm	-22.4	-0.15	-0.12	-20.4
	4mm	-21.7	-0.40	-0.37	-22.4

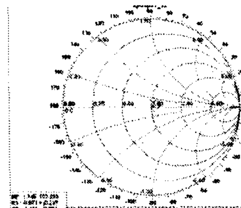
Characteristics of transmission Line

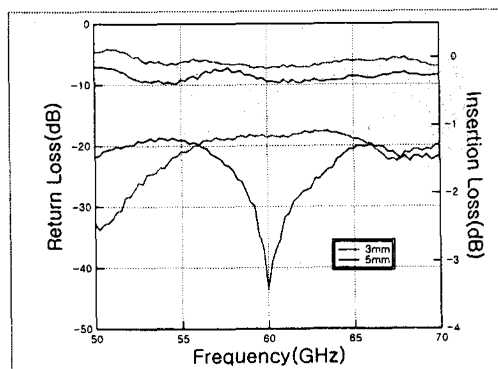


CBCPW line (2 layers)

- Dielectric Thickness: 200 μm

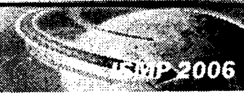






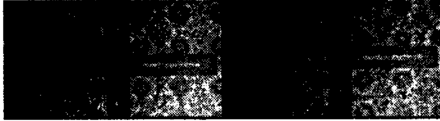
Thickness	Line length	S11[dB]	S21[dB]	S12[dB]	S22[dB]
2 layers (200μm)	3mm	-18.6	-0.16	-0.17	-19.1
	5mm	-43.5	-0.35	-0.39	-27.3

Characteristics of Interconnection

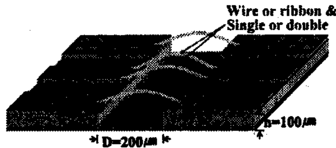


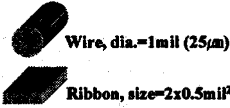
▣ Wire bonding

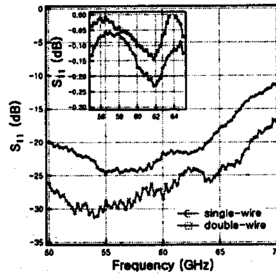
- CBCPW Line (Dielectric thickness: 100 μm)

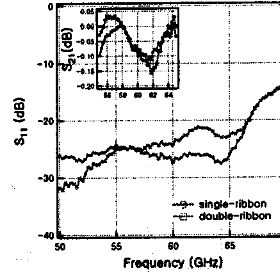


Type of bonding	S11	S12
single wire	- 21.6dB	- 0.17dB
double wire	- 28.6dB	- 0.10dB
single ribbon	- 27.4dB	- 0.10dB
double ribbon	- 24.3dB	- 0.09dB







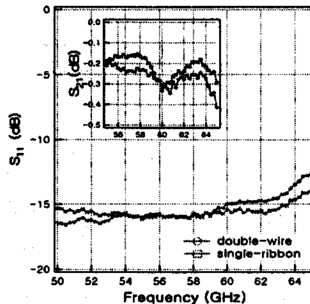


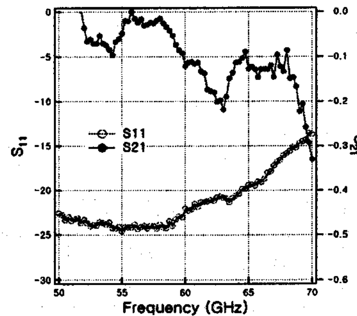
Characteristics of Interconnection

▣ Wire bonding

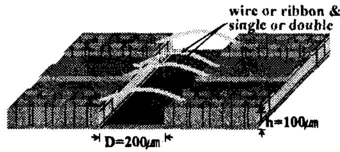
- CBCPW Line (Dielectric thickness: 200 μm)

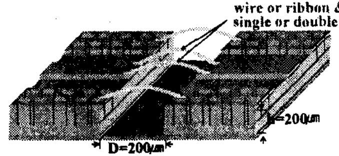
Type of bonding	S11	S12
single wire	- 9.19dB	- 0.75dB
double wire	- 14.5dB	- 0.35dB
single ribbon	- 15.4dB	- 0.31dB
double ribbon	- 22.1dB	- 0.12dB





Influence of dielectric thickness



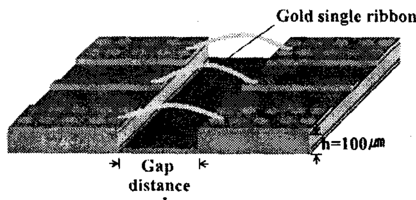


Dielectric thickness (100μm)
- Single ribbon or double wire bonding
  - nearly 50 Ohm at 60 GHz
- Low loss transmission
- S_{21}: -0.1dB, S_{11}: -20dB

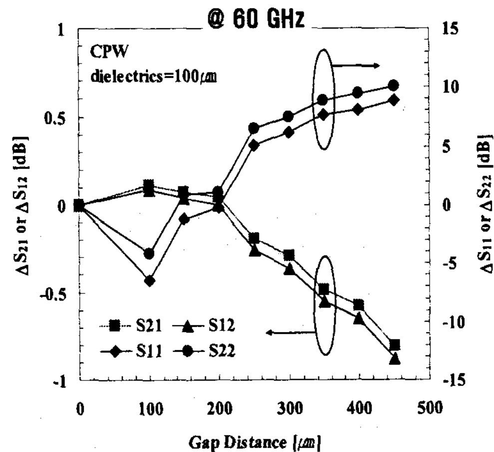
Dielectric thickness (200μm)
- Single ribbon or double wire bonding
  - high impedance state
- To match 50Ω, increase the line width.
- Double ribbon bonding is required.
- Low loss transmission
- S_{21}: -0.1dB, S_{11}: -20dB

Interconnection loss from wire length

- Gap distance : acceptable RF degradation during the interconnection



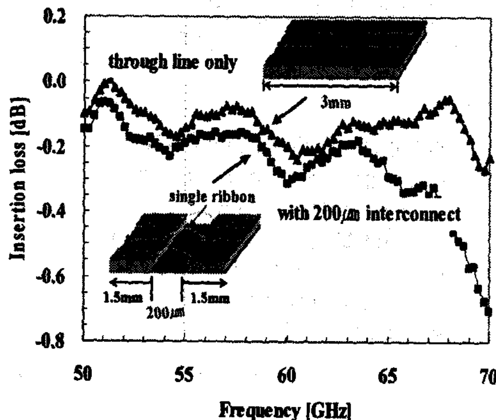
Photograph of 100μm gap



Characteristics of Interconnection

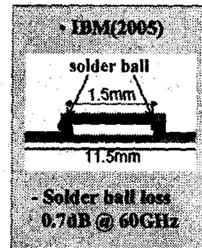
▣ Interconnect loss of wire-bonding

- low loss and simple process : Wire-Bonding technique
- symmetric performance ($S_{11} \fallingdotseq S_{22}$) of wedge bonding method



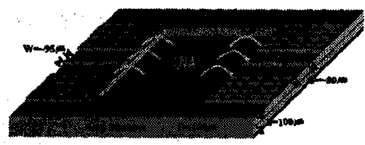
Wire-bonding

Flip-chip bonding



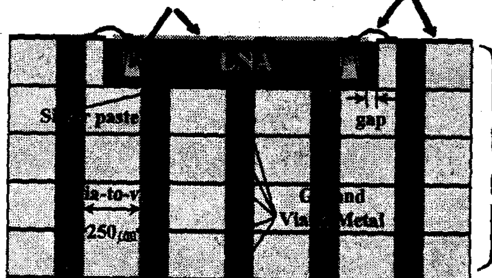
Chip Interconnection

▣ Considerations for MMIC module



Solutions for Mounting
- cavity structure
- via-hole ground connection

Solutions for Interconnection
- CPW line
- ribbon wedge bonding

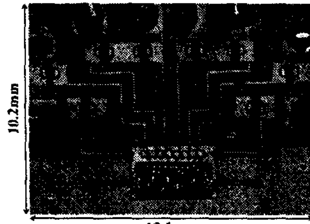


Solutions for Materials
- low loss substrate
- internal silver conductor
- external gold conductor

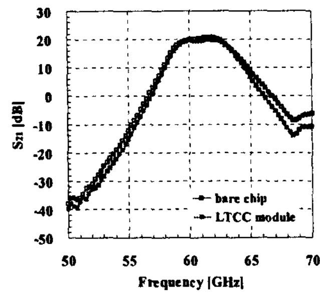
Chip Interconnection

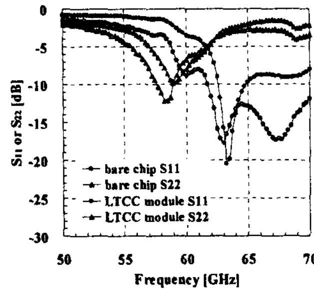
▣ **LNA (low noise amplifier) Module**

- S-parameter measurement
  - by hp8720C N/A
  - frequency: 50~70 GHz
  - 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



LNA Module





Summary

LTCC Technology is very suitable for 60 GHz application

- **LTCC substrate shows low loss at 60 GHz.**
  - low insertion and return losses
- **Microstrip or CBCPW line is suitable for transmission lines at 60 GHz.**
  - low loss (0.1dB/mm)
- **Single ribbon bonding is adequate for interconnection**
  - simple
  - low loss (0.1dB/bonding)
- **Characteristics of MMIC module**
  - Gain difference (ΔS21) : 0.4 dB