ANTENNA INTEGRATION FOR WIRELESS MODULES

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OUTLINE

Introduction

Design of active antenna package for 60 GHz
  ▶ Antenna performance
  ▶ Low interconnect loss between chip and antenna elements
  ▶ Shielding of chip and interconnect

Conclusion
INTRODUCTION
WHY INTEGRATED RF SYSTEMS?

Integrate *miniaturised, truly autonomous* systems for *ambient intelligence*

- **Size reduction:**
  - Planar “as thin as possible”
  - Cubic “small footprint”
- **Hetero-integration**
  - Reduction of amount and size of passives
  - Actives in different technologies
- **ULP requirements**
- **Modularity**
- **Antenna integration**

5.2GHz WLAN Front-End
INTRODUCTION
17 GHZ SYSTEM INTEGRATION

Miniaturized 17 GHz wireless rf-front end module for a wireless autonomous sensor

Project goals:
• Realize compact hybrid integration of microcontroller, radio chip and passive devices
• To be integrated with antenna patch, sensors, power and power-management components

P. van Engen et al. “3D Si-level integration in wireless sensor node” SSI2009
INTRODUCTION

60 GHz band for wireless HD

- Unlicensed band between 57 and 66 GHz
- Unidirectional link to High-Definition (HD) screen
INTRODUCTION

Characteristics of 60 GHz band

▸ Available bandwidth is large
  - High data rate applications

▸ Strong attenuation (e.g. by walls)
  - Frequency reuse
  - Antenna gain should be sufficiently large

▸ Wavelength about 5 mm
  - Phased array antenna possible to improve link budget
PROBLEM STATEMENT

Design of small active antenna package with integrated phased-array antenna and 60 GHz CMOS chip

▸ Good antenna performance
  - Bandwidth
  - Gain

▸ Low interconnect loss between chip and antenna elements

▸ Shielding of chip and interconnect
LTCC ANTENNA PACKAGE (1)

Cross-section

Stripline fed waveguide antenna

Ground

Solder ball

Microstrip to stripline transition

60 GHz CMOS chip

Printed-Circuit Board

Antenna package
LTCC ANTENNA PACKAGE (2)

Top view for transmit module
- Size: 9.5 mm x 9.5 mm
LTCC ANTENNA PACKAGE (3)

Pictures of transmit module

Microstrip feed lines

Open waveguide antennas
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OPTIMIZED ANTENNA SUBSTRATE

Material: Ferro A6-M

- Low dielectric loss: $\tan\delta@60\ GHz<0.002$
- Dielectric constant: $\varepsilon_r@60GHz=5.7-6.1$

Open waveguide antenna

- No surface wave loss
OPEN WAVEGUIDE ANTENNA
SINGLE ELEMENT

Inductive posts

Waveguide aperture

Microstrip feed of open waveguide antenna

3.4 mm

1.4 mm

X

Y

Z
SETUP FOR WAFER PROBED ANTENNA MEASUREMENTS IN V-BAND
OPEN WAVEGUIDE ANTENNA
SINGLE ELEMENT

Antenna matching

- Coplanar contact pad deembedded from measurement

![Graph showing antenna matching with measured and designed data for frequency range 50 to 67 GHz](Ansoft/HFSS simulation)
OPEN WAVEGUIDE ANTENNA
SINGLE ELEMENT

Radiation pattern at 61 GHz (E-plane = XZ)

- Ripple due to diffraction at edges of small test sample (9.8 mm x 9.8 mm)

(Ansoft/HFSS simulation)
OPEN WAVEGUIDE ANTENNA
SINGLE ELEMENT

Radiation pattern at 61 GHz (H-plane = YZ)

> Ripple due to diffraction at edges of small test sample (9.8 mm x 9.8 mm)

(Ansoft/HFSS simulation)
OPEN WAVEGUIDE ANTENNA ARRAY
4 ANTENNAS FED IN-PHASE
OPEN WAVEGUIDE ANTENNA ARRAY
4 ANTENNAS FED IN-PHASE

Antenna matching
- Coplanar contact pad deembedded from measurement

(Ansoft/HFSS simulation)
OPEN WAVEGUIDE ANTENNA ARRAY
4 ANTENNAS FED IN-PHASE

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OPEN WAVEGUIDE ANTENNA ARRAY
4 ANTENNAS FED IN-PHASE

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INTERCONNECT LOSS BETWEEN CHIP AND ANTENNA

Picture of test sample

- TRL structures for microstrip and stripline

136 μm wide microstrip lines

80 μm wide striplines
INTERCONNECT LOSS BETWEEN CHIP AND ANTENNA

136 µm wide microstrip lines (Zc≈50 Ohm)

- Extracted line loss: 0.08-0.12 dB/mm
PROBLEM STATEMENT

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SHIELDING OF CHIP AND INTERCONNECT FROM RADIATION

Electrical field intensity (dB) in E-plane

Maximum
-20 dB
-40 dB
-60 dB
Minimum

Radiated field
Low field intensity at backside of antenna (except at feed)

microstrip feed

(Ansoft/HFSS simulation)
SHIELDING OF CHIP AND INTERCONNECT FROM RADIATION

Electrical field intensity (dB) in H-plane

Maximum
-20 dB
-40 dB
-60 dB
Minimum

Radiated field
Low field intensity at backside of antenna (except at feed)
(Ansoft/HFSS simulation)
CONCLUSION

An active phased array antenna is realized in a 9.5 x 9.5 x 0.8 mm$^3$ LTCC package

The antenna package has
- good antenna performance
- low interconnect loss between chip and antenna
- excellent shielding of chip and interconnect