Modeling the EM Field Distribution within a Computer Chip Package

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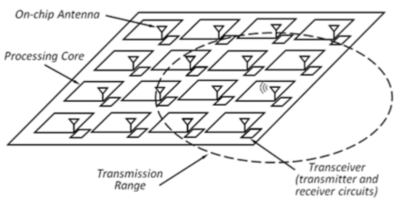
I. Solution for the intra-chip channel study limitations

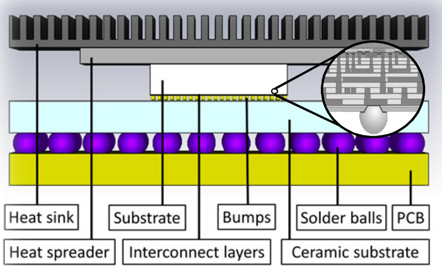
Motivation

- **Network-on-Chip** (NoC) is the paradigm of choice to interconnect cores and memory within a Chip MultiProcessor.

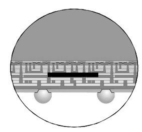


- The **wireless** network in a NoC helps **escalating** the number of cores, but it is crucial to know the **channel** behavior of the chip.

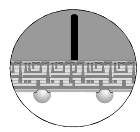
Structure of the chip package



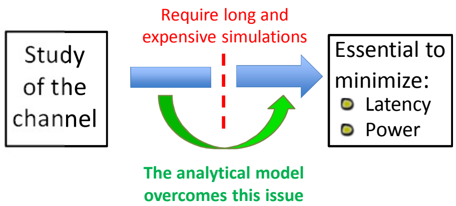
Aperture antenna



Monopole antenna



Problem and solution

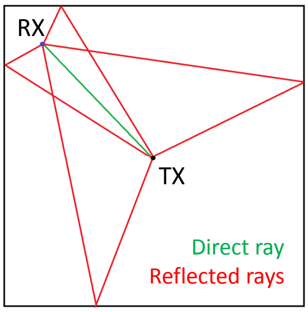


- We propose an analytical model based on **ray tracing**.
- The results will be accurate enough to perform **massive** parametric simulations before going to fine-grain studies.
- To simplify and **accelerate** the computation, only the most important **multipath components** are considered.

II. The Model

Multipath components

- **Direct ray:** Strongest and most important component.
- **Reflected rays:** reflected **once** at the heatsink or lateral boundaries of the chip.



Model equations

We modeled the Electric field magnitude as:

$$E_{mag,d} = e^{-\alpha d} e^{-j\beta d}$$

The constants α and β can be expressed as:

$$\alpha = \frac{\pi\sqrt{\varepsilon_r}}{\lambda} tan(\delta) \qquad \beta = \frac{2\pi}{\lambda_0}\sqrt{\varepsilon_r}$$

The field magnitude of the reflected rays can be expressed as:

$$E_{ref,heatsink} = T_{SiO_2\_Si}\, R_{Al}\, T_{Si\_SiO_2}\, E_{direct}$$

Transmission coefficient between SiO_2 and Si — Reflection coefficient of Aluminum — Transmission coefficient between Si and SiO_2

Near field region

- In the near field region of the transmitting antenna, the prior equations do not hold.

$$\frac{\lambda_0}{\sqrt{\varepsilon_r}} \approx 1.3\ mm$$

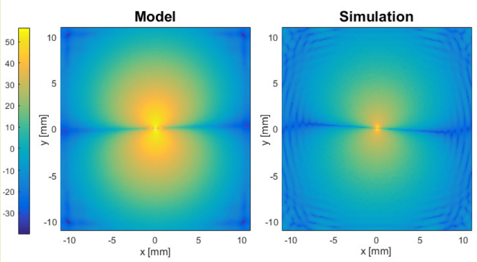
- **Near field laws** dominate the propagation in this area
- Specific near-field **equations** were used in the region $d \leq 1.3\ mm$

$$P_{RX} \sim |E^2| \sim \frac{1}{(kd)^2} + \frac{1}{(kd)^4} + \frac{1}{(kd)^6}$$

Propagation constant

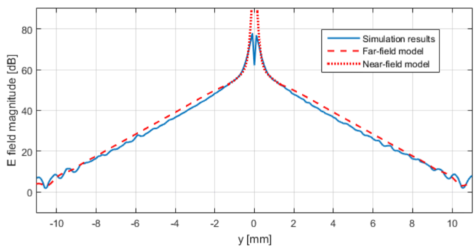
III. Matching with simulation results

E-Field magnitude



- The predicted E-field magnitude matches well **except** for the **near field region**.
- The near field region is corrected using the near-field **model**.

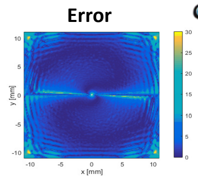
Far and near field convergence



E-field magnitude at the intersection of X=0 and Z=0 planes

- Combining the two models for their corresponding regions of application, the results match with **high accuracy**.

Conclusion



- This model could compute the electric field intensity inside the chip reducing the computational time **several orders of magnitude** with an average mismatch of only **1.7 dB.**

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