A Short-Circuit Transmission Line Method for PIM evaluation of Metallic materials

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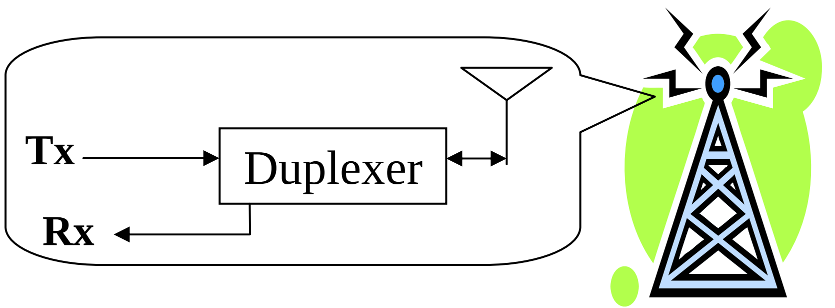
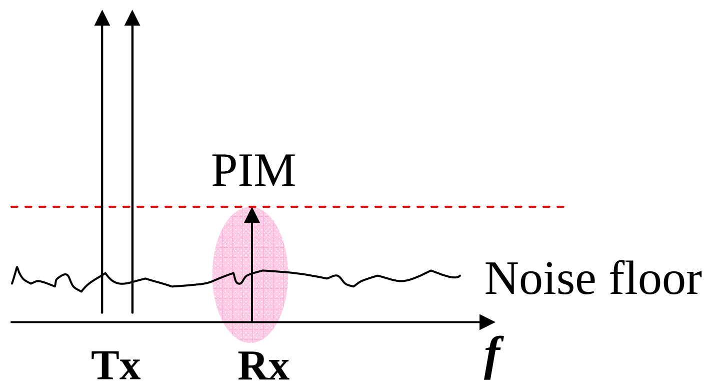
Backgrounds

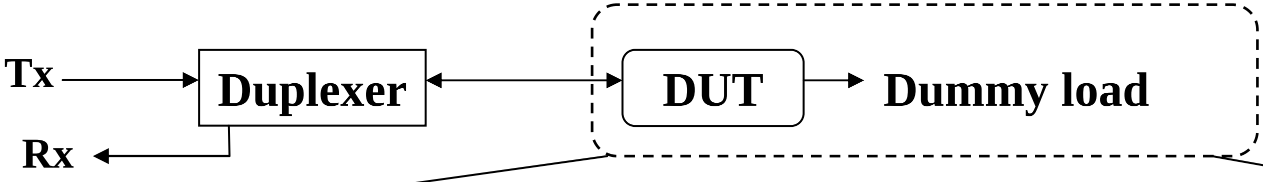
- Intermodulation distortion in passive devices (PIM)
  - Modulation signal･･･f1 + f2 + nonlinearity ⇒ f3
    - Focus on a little nonlinearity that passive components have
      - Example: Metallic contacts, oxidation or corrosion
  - PIM power level： -50 ～ -150dBm
    (Input: 43dBm(20W) ×2tone）

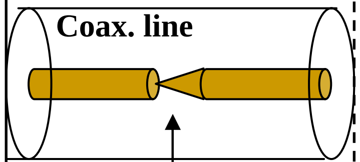
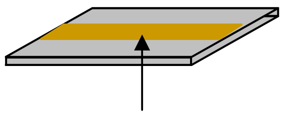
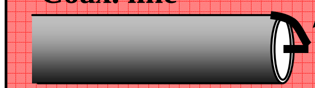


- Typical problems
  - Interference: PIMs at duplexer can not be filtered out
  - Increase of noise floor in the receiver



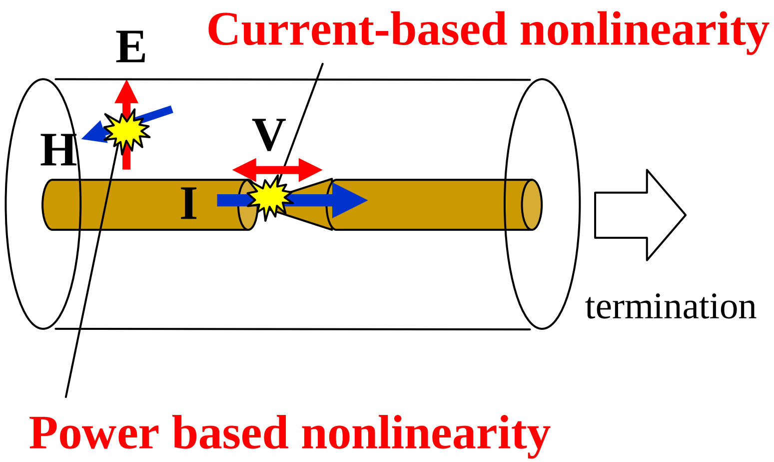
The new measurement method for PIM



	Matched line (termination needed)		Mismatched (standing wave)
DUT Shape	Conventional  Coax. line DUT	 MSL DUT	Proposed  Coax. line DUT
DUT position	The Signal line		Short-circuit conductors
Arbitral shape of DUT	×	△	◎
Control of current density	△	×	◎
Sensitivity (system noise)	△	△	◎ (calibration enabled)

Conventional method

Example:



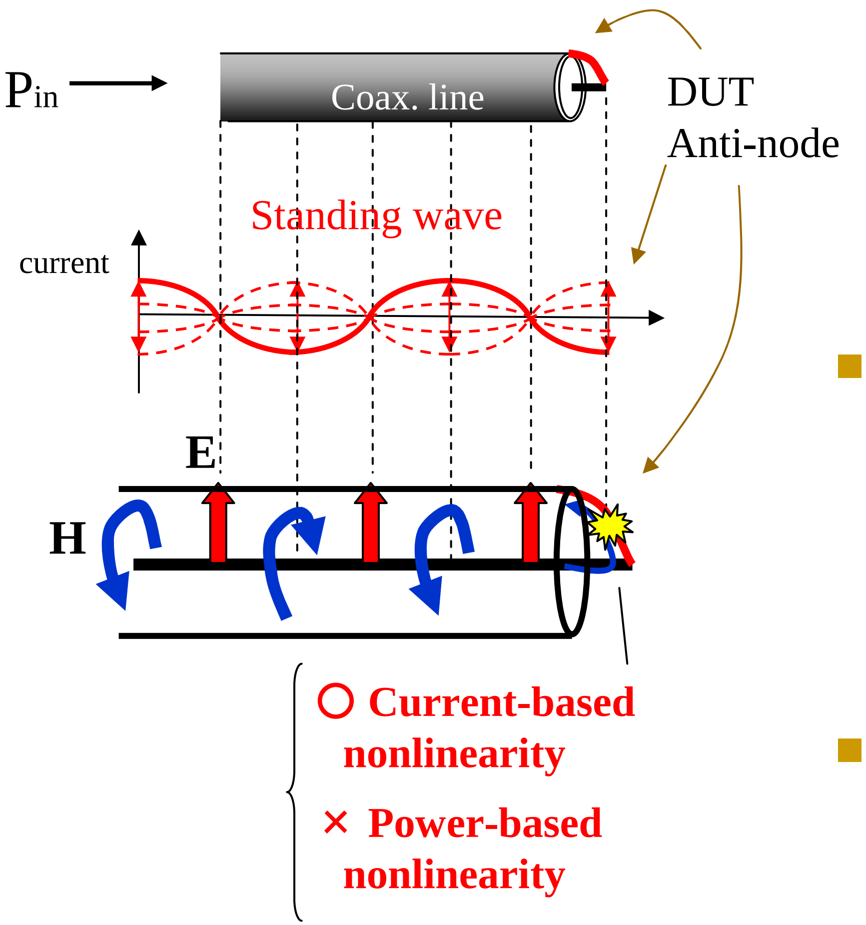
Nonlinearity	Current-based	Power-based
Components	Parallel I // V	Transverse E⊥H
Component relation	V=RI (Resistance)	E=Zc H (Characteristic impedance)
Matching	None	Needed
Sample	Metallic materials Point contacts	Insulator Suppoter

- Measurement has been carried out with matched condition
- Sample: transmission line itself
- **Various nonlinearities are measured**

Conventional:
2 types nonlinearities: Mixed up
It is difficult to separate them

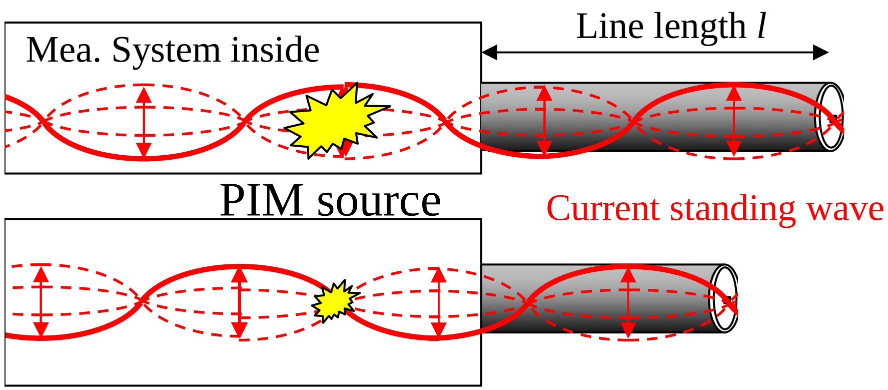
Proposed method: Only current nonlinearity can be measured

Proposed method

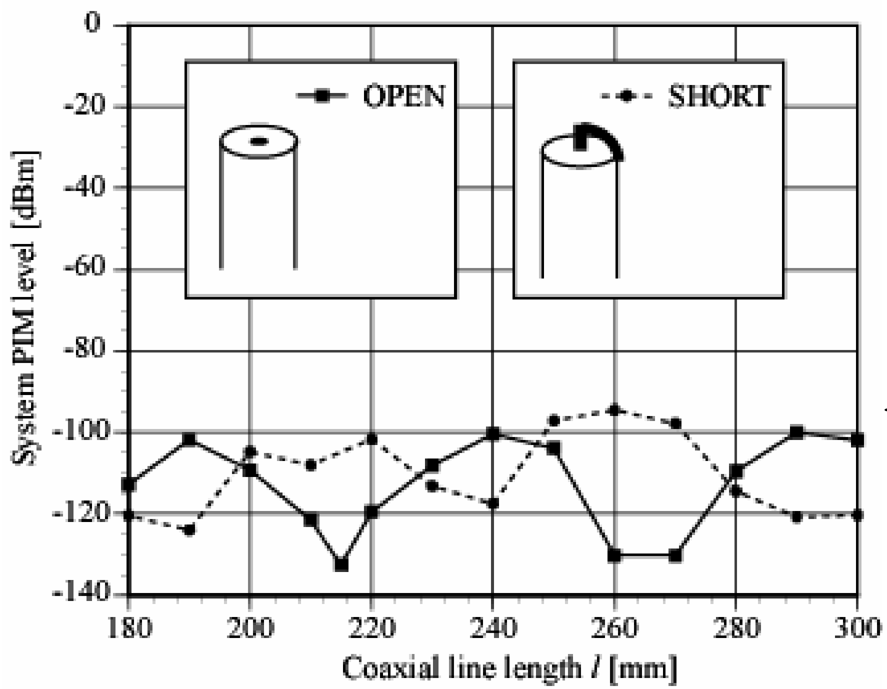


- PIM is evaluated with the short-circuit
  - Mismatch condition makes standing wave in the transmission line
  - Sample: short-circuiting material
    - × transmission line itself
- Avoid the power-based nonlinearity
  - Either electric or magnetic field exists at node/anti-node position
  - Power-based nonlinearity can be negligible
- Advantage: The only current-based nonlinearity can be measured

Calibration of the system noise



- System noise = PIM generated in mea. sys.
- Calibration is carried out with line length *l*
  - Change line length ＝ the position of node/anti-node is shifted together



- System noise level
  - Can be calibrated and minimized
  - Choose the appropriate line length
- The system noise level can be suppressed
- More sensitive measurement
  - Minimized system noise level : about -130 ∽ -120dBm

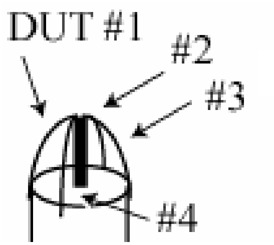
Applications of short-circuit method

- Available in many measurement application
  - the arbitral-shaped sample can be employed

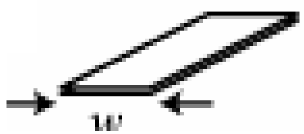
- Examples: metallic material nonlinearity
  - There are no report on material nonlinearity
    - Nonlinearity of a spot contact is well known
  - Sample: Metallic wires
    - Useful to estimate the current density
    - Easy to control the current density
  - Sample: Copper foils
    - Evaluate a metallic material in an actual form including a printed board circuit

Thickness (diameter)

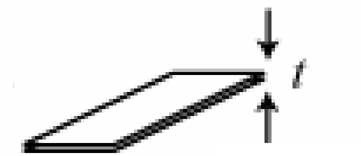
Wire number



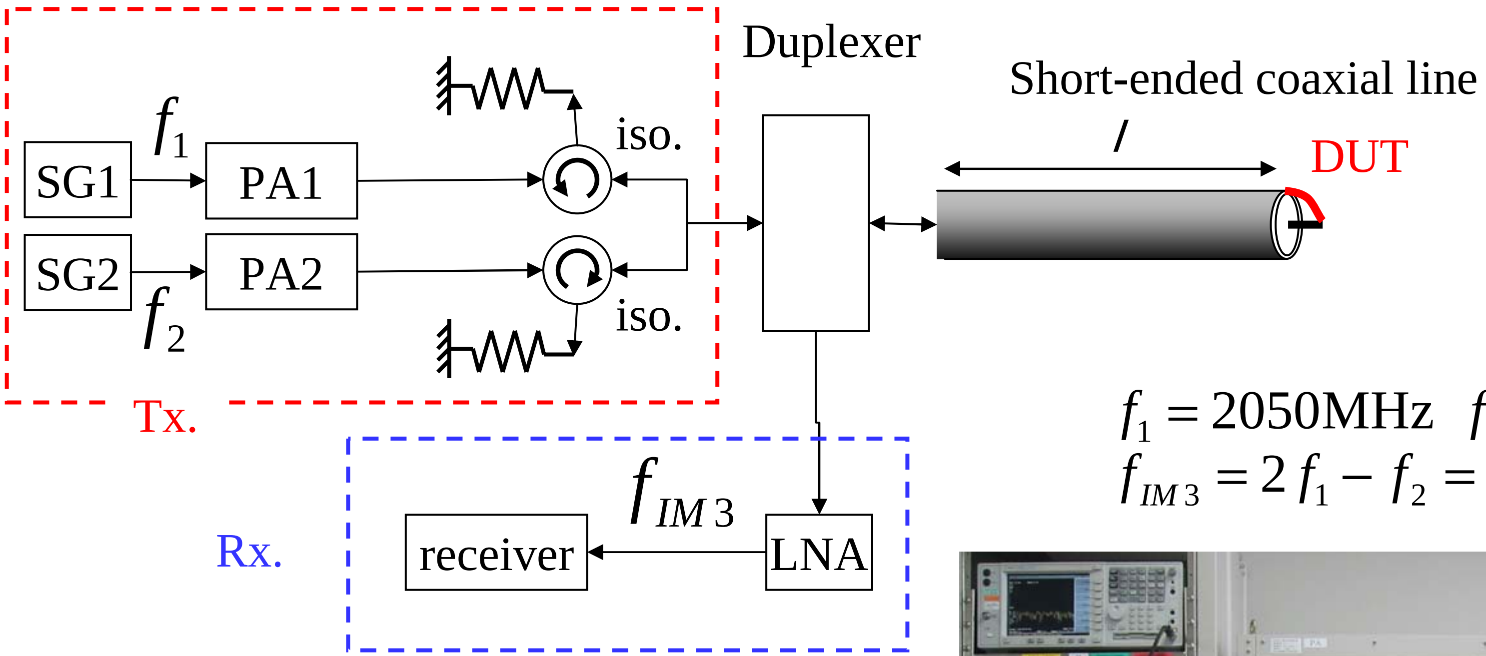
Width



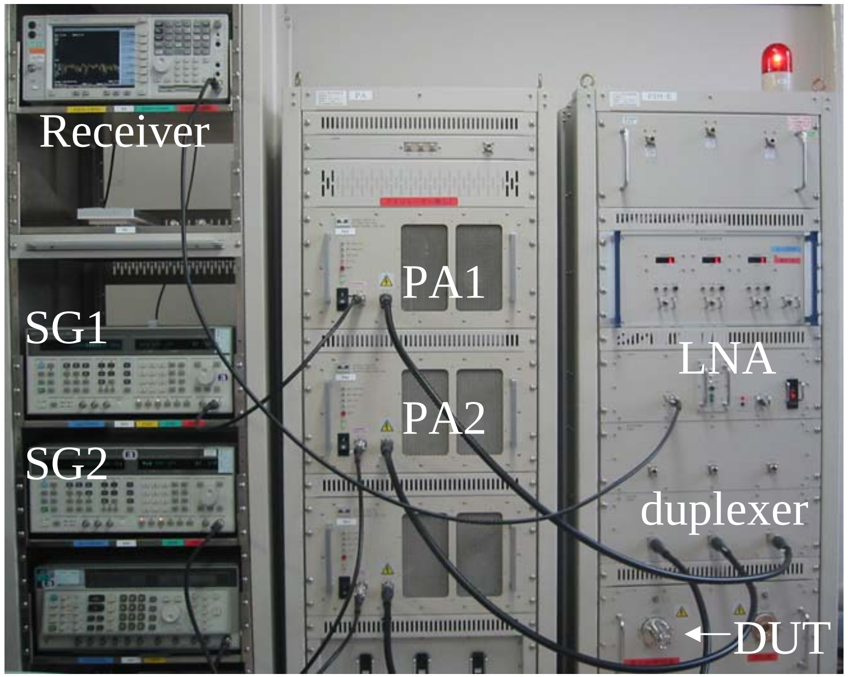
Thickness



Configuration of measurement system



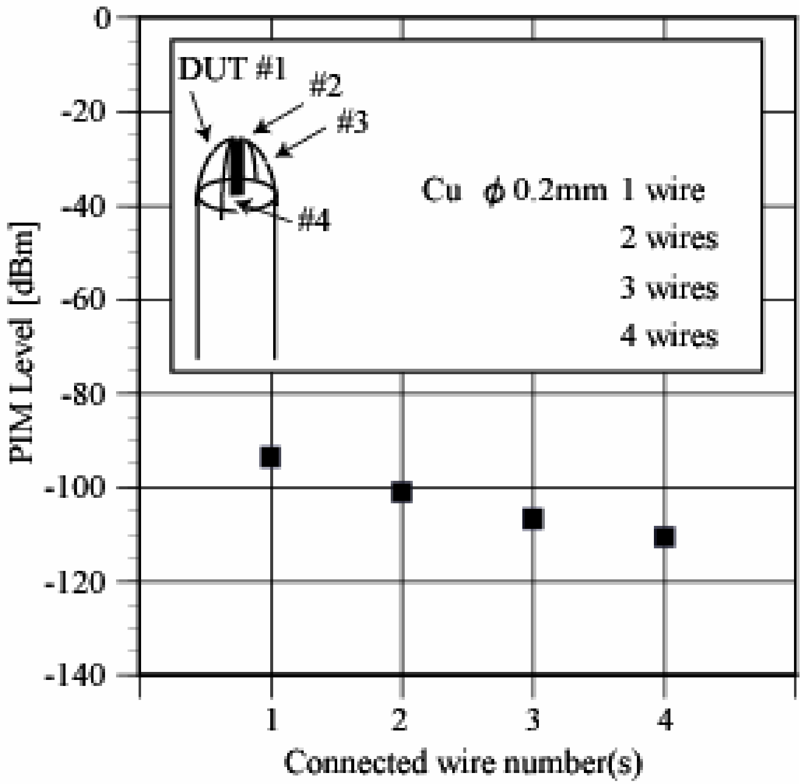
$$f_1 = 2050\text{MHz} \quad f_2 = 2200\text{MHz}$$
$$f_{IM3} = 2f_1 - f_2 = 1900\text{MHz}$$



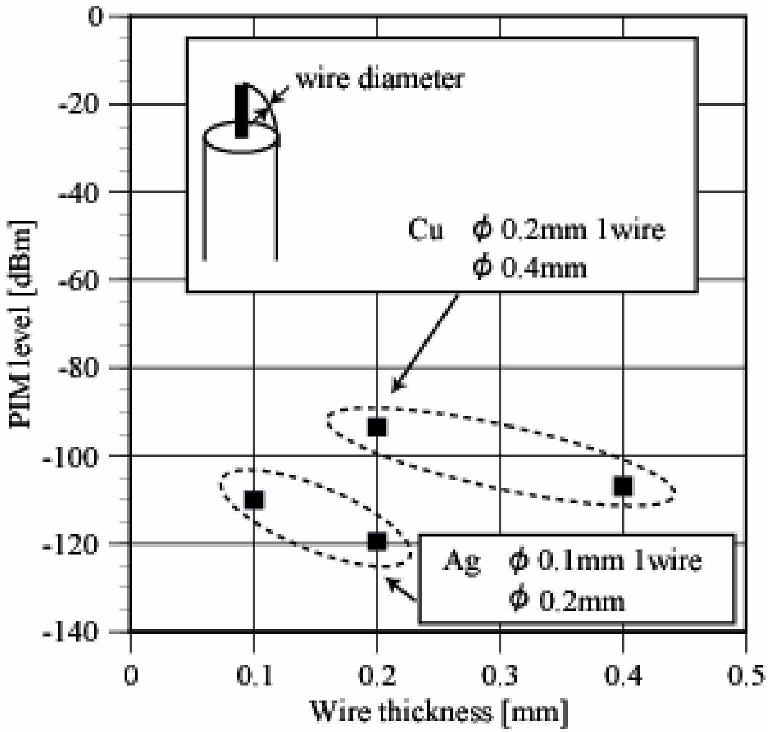
- 2tone-input measurement
  - 43dBm(20W) /tone
  - Input frequency: 2GHz band
  - Measured 3rd-order PIM
- Sys. Noise level: about -120dBm

The results of metallic wire

- Wire number : parameter
  thickness : fixed(0.2mm)



(b) Wire number : fixed(1wire)
thickness : parameter



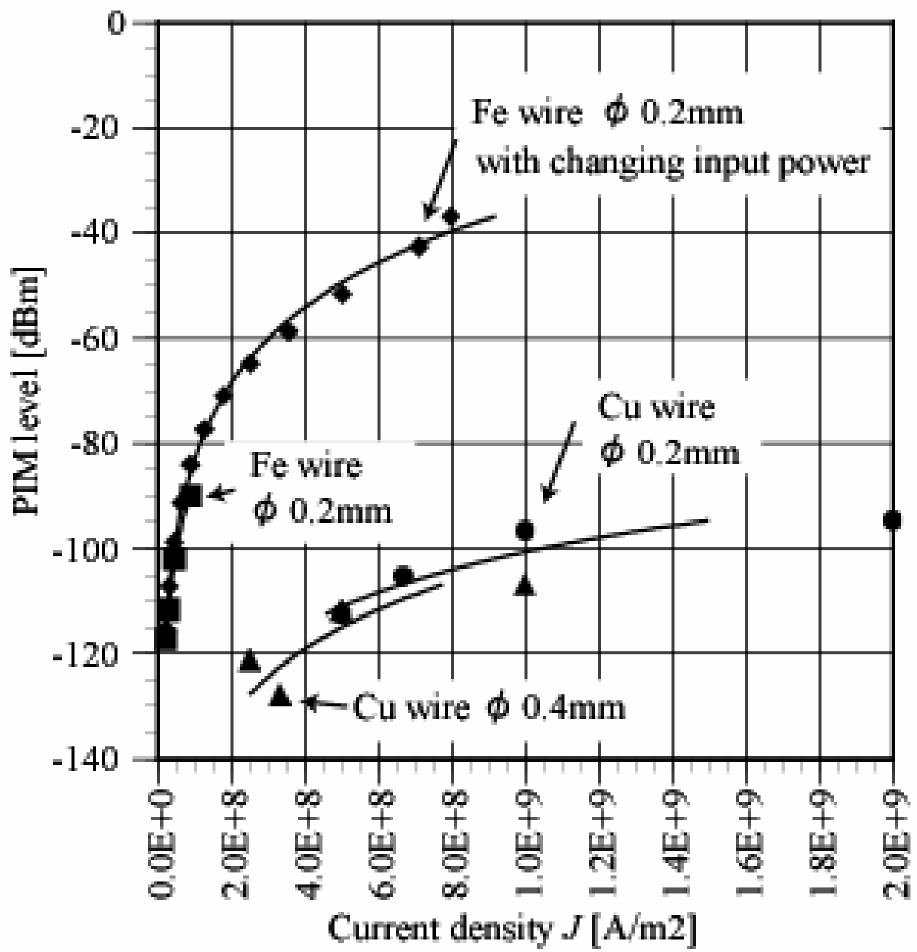
- PIM level becomes lower gradually with the increase of connecting wire number

- Wire thicken → PIM degrease
- Silver generate less PIM than copper

The current density affects on the material-based PIM

The relation between the PIM and current density

- Uniform current distribution
  - Wire form samples…. useful to calculate current density exactly

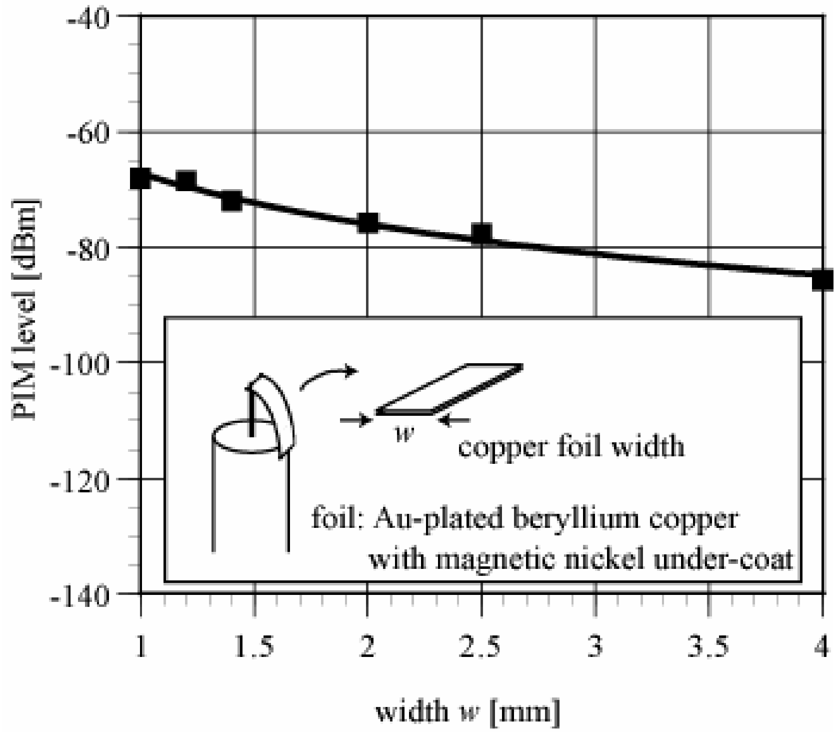


- The PIM characteristics: described as a single-line at each material
  - The results are shown with approximation line
  - Regardless of the wire thickness and the connecting wire number
- Material-based PIM level: controlled by the current density
- The quantitative PIM evaluation is achieved
  - a function of current density

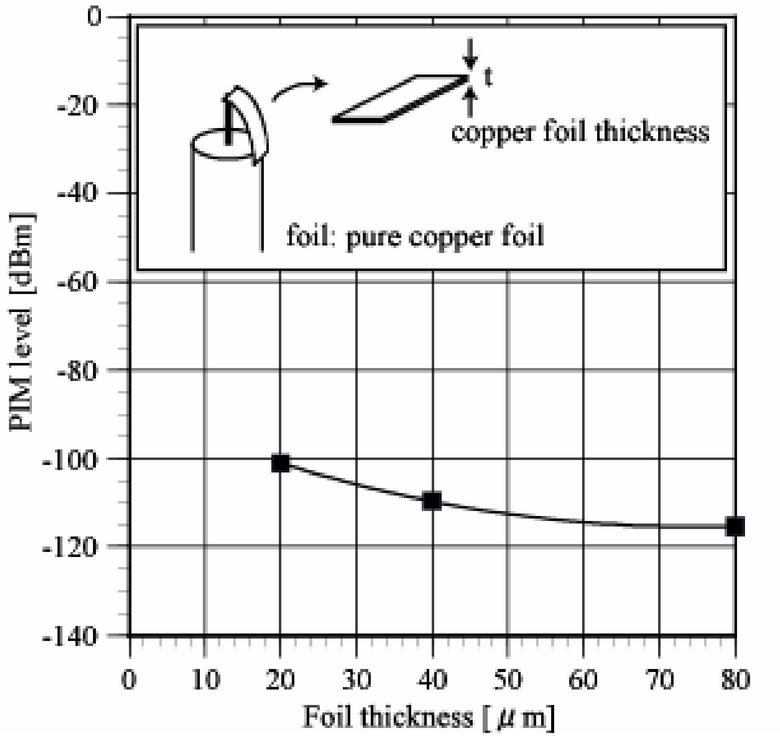
The results of copper foils

- The calculation of the current density is difficult
  - Discontinuity at foil edge

(a) width : parameter
thickness : fixed



(b) width : fixed (w=1mm)
thickness : parameter



- Stripline width 1～4mm
- Conventional: ×arbitral line width

- PIM evaluation for foil thickness: 20, 40, 80μm

The quantitative PIM relation with strip width and thickness is clearly obtained

Conclusions

- A short-circuit transmission line method for PIM evaluation is proposed
  - Current-based nonlinearity evaluation with the exception of power-based nonlinearity
  - More sensitive measurement by system noise calibration

- Example: evaluation results for material nonlinearity
- The quantitative PIM evaluation is achieved with the material-based PIM as a function of current density
  - Experimentally evaluated: PIM characteristics of the metallic wires and foils
  - From the results of foils, the quantitative PIM relation with strip-line width or thickness is also obtained

- Future problems
  - Examining the effect of line length
  - Soldering connection in DUT