# Analysis of Noise Signal with Simulation by Cross Sectional Area Distortion of Steam Generator Tube

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Background

- Steam generator (SG) tubes in nuclear power plants (NPPs) have U-bend regions of various radius. The bending may cause the variation in tube dimensions of wall thickness, ovality and may also affect the trajectory of the probe motion which can be distortion.

<U-bend region strip chart>
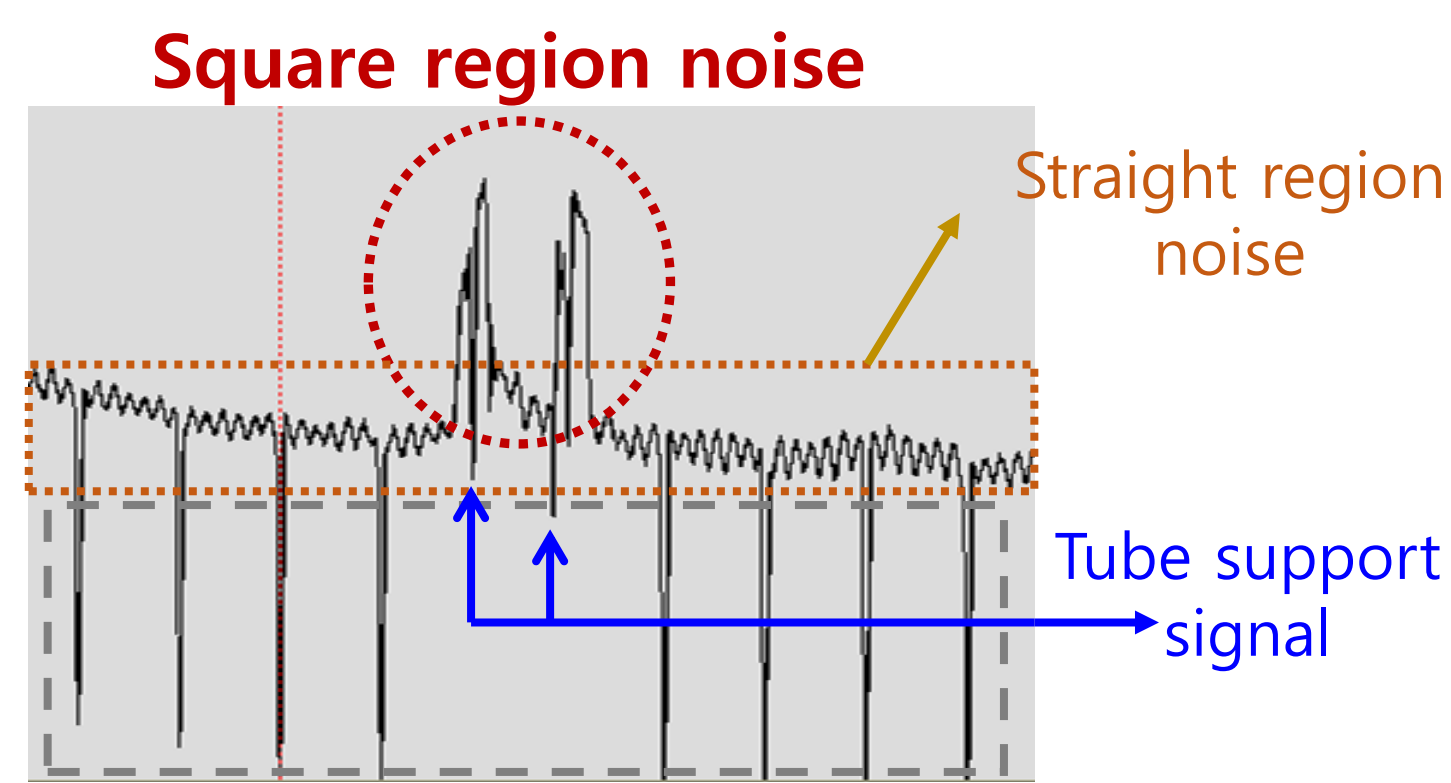
- **Purpose**
  - Analysis of variable cross-section shapes of U-bend tubes using CT
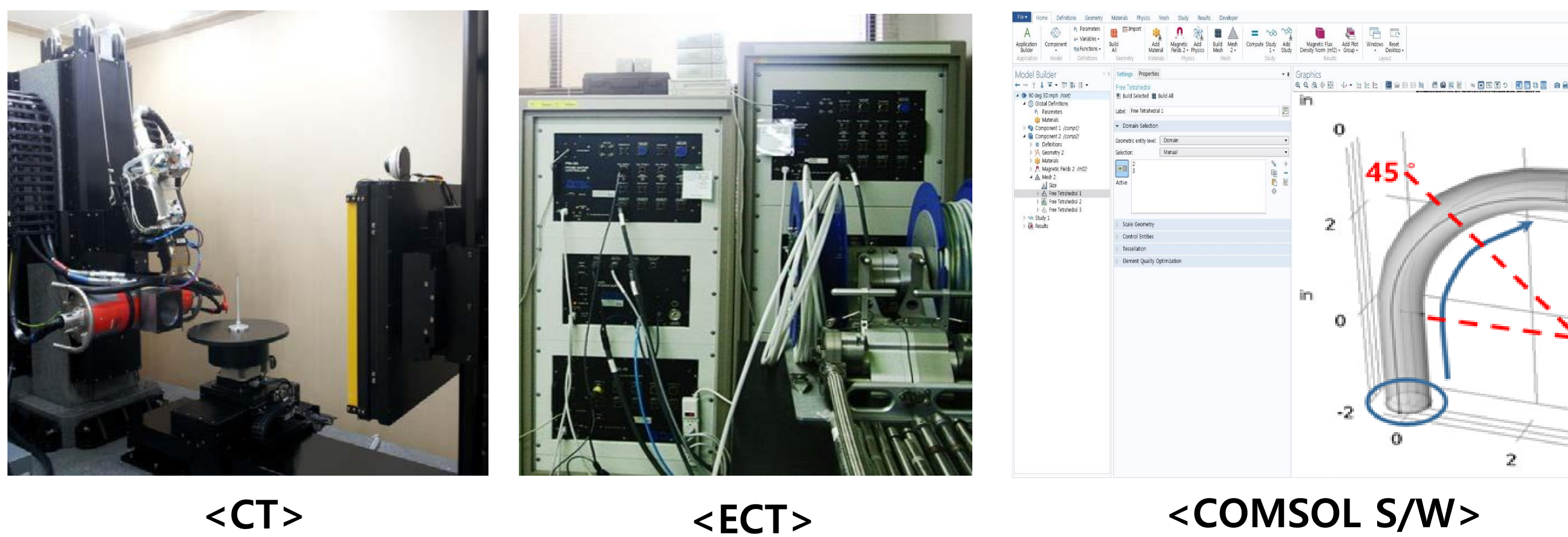 - Theoretical prediction and acquisition of various noise signals using simulation

Experiments

- **Instrument**
  - CT(Computed Tomography) instruments
    : High power X-ray tube (Tube voltage 450 kV/ Tube power 700 W)
    : VG studio max 3D (Analysis software)

- **Simulation**
- COMSOL Multiphysics 5.5 (AC/DC module)

- Electromagnetic numerical analysis
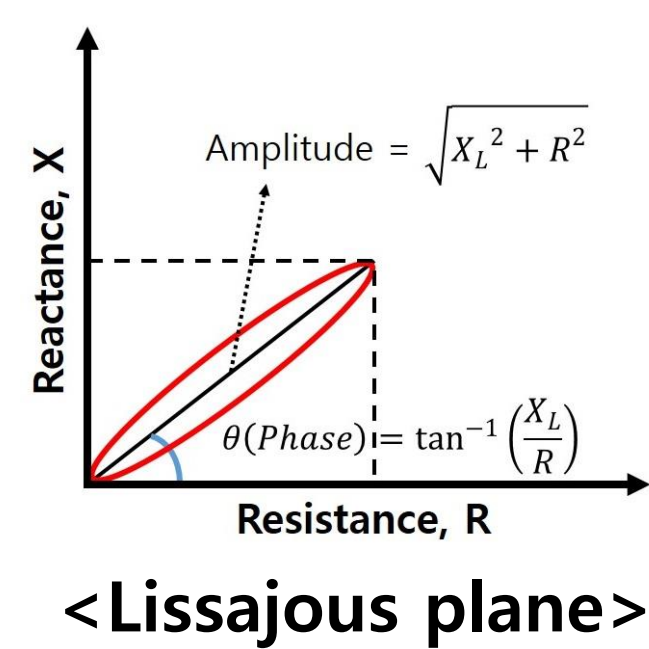 - Maxwell-Ampere's Law formula
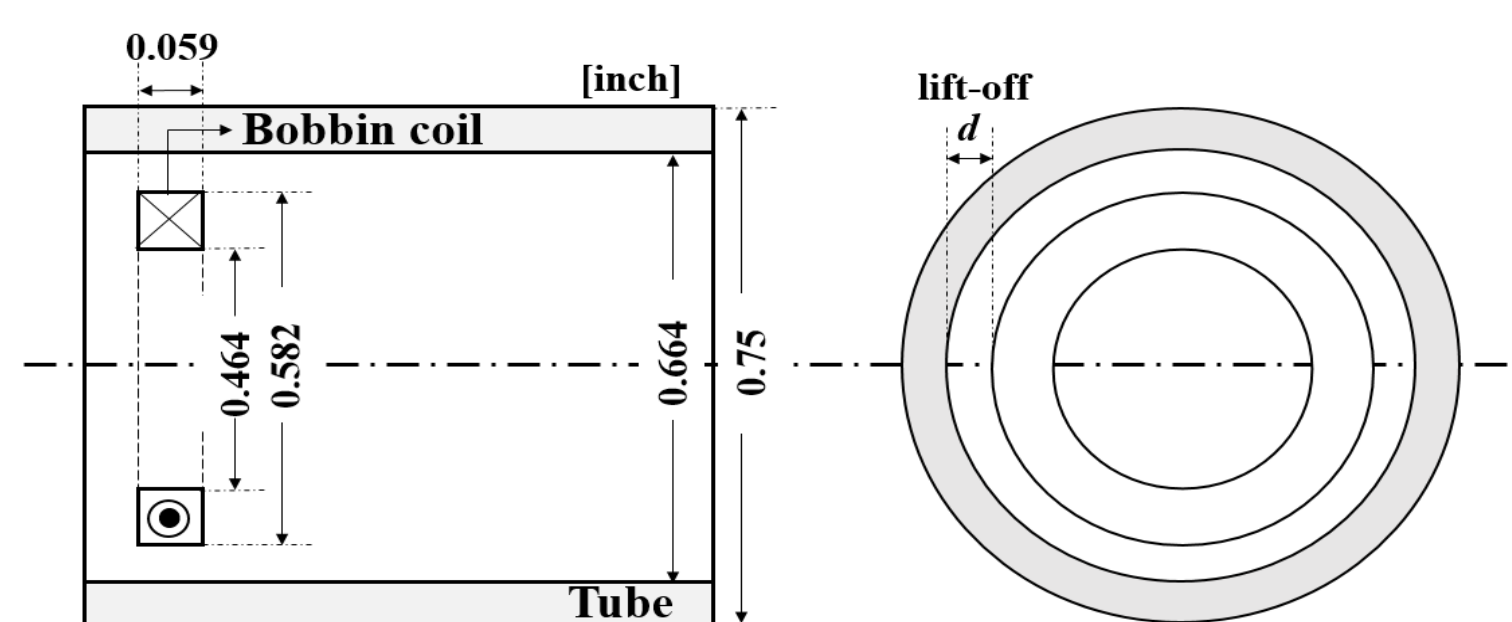 $$\Delta \cdot H = J$$

<CT>   <ECT>   <COMSOL S/W>

- **Materials boundary conditions**

	Relative Permeability	Relative Permittivity	Electrical Conductivity (S/m)
Air	1.00000037	1.000536	3×10^{-15}
Coil (Copper)	0.999994	0.9999996	5.96×10^{7}
Tube (Inconel 690)	1.01	1	6.7567×10^{6}

- **Definition Phase & Amplitude**

$$Amplitude = \sqrt{X_L^2 + R^2}$$
$$\theta(Phase) = \tan^{-1}\left(\frac{X_L}{R}\right)$$

<Lissajous plane>

- **The schematic diagram of SG tube**

<The schematic diagram of the ECT bobbin coil probe>

Results

- ❖ **Results from CT**

<CT results of straight pipe and U-bend tube>

- Diameter of pipe cross-sectional area

[mm]	Straight	45°	90°
Vertical	16.88	16.20	16.15
Horizontal	16.94	16.98	16.87
Ovality*	0.3	4.6	4.2

$$* \, Ovality \, [\%] = \left[\frac{(Max.\,I.D. - Min.\,I.D.)}{nominal\,I.D.}\right] \times 100$$

(nominal I.D. = 16.91 mm)

- Results of current density

* The error range for measurement = ± 0.03 mm
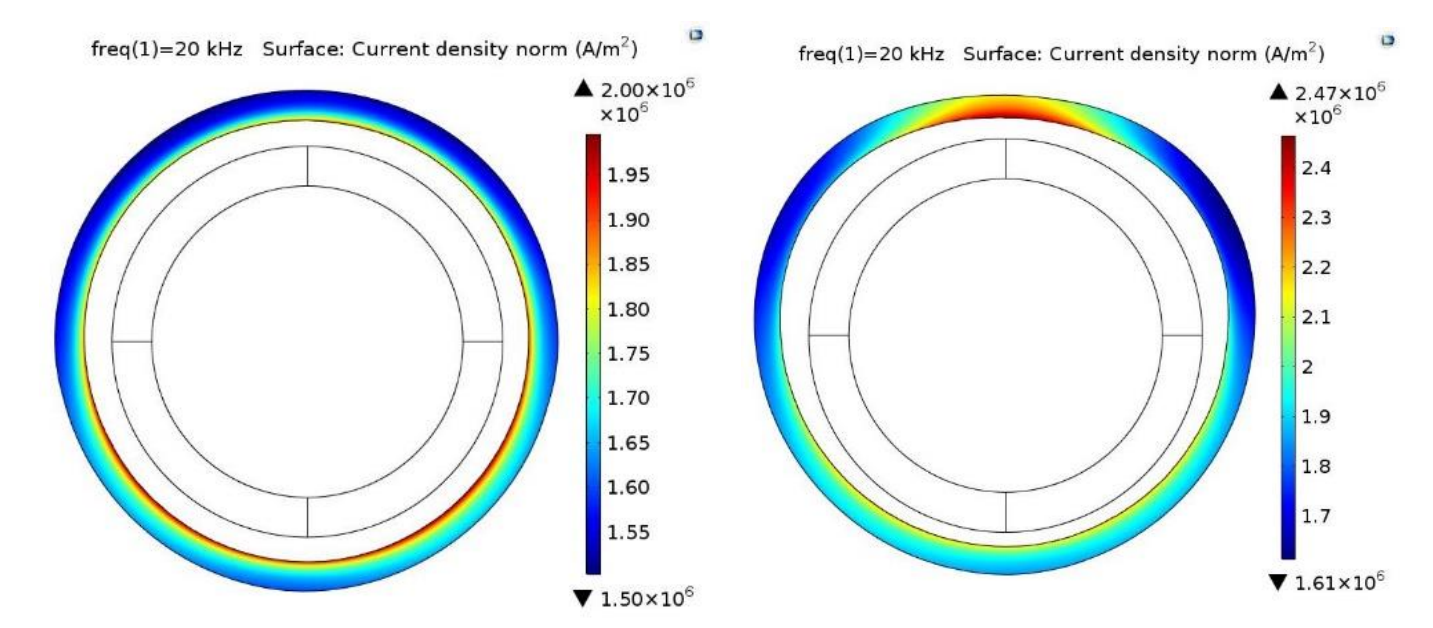
⇒ The ovality of tube due to the bending process is about 4.6%.

⇒ The error range of real OD measurement value and CT results is ±0.05 mm

⇒ CT analysis is a reliable tool for dimension measurement, and provides more accurate values.

- ❖ **Results from Simulation**
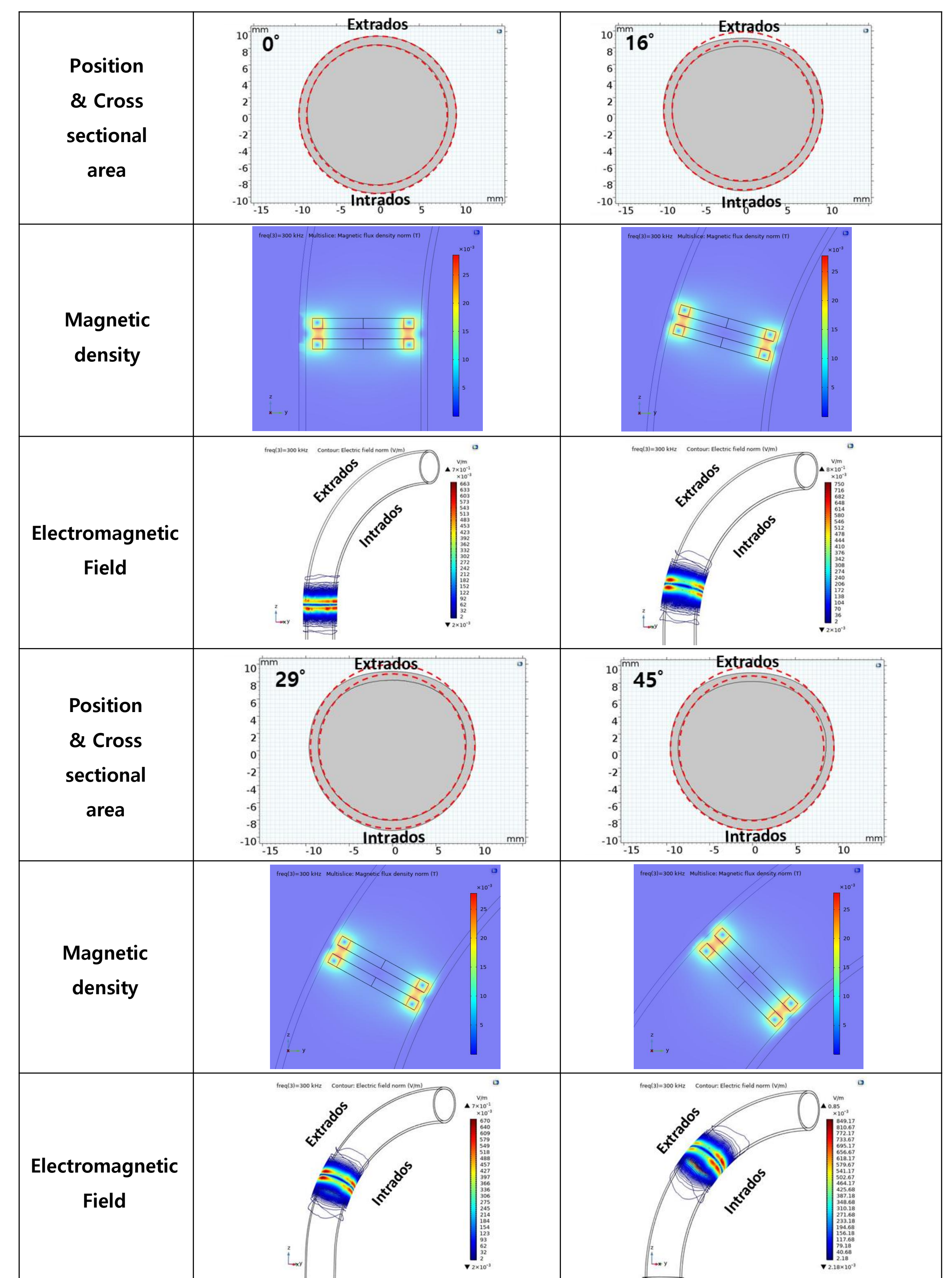
⇒ In the straight section, it was confirmed that the concentration of the current density was evenly concentrated along the coil.

⇒ The electro-magnetic field is concentrated inside/outside the pipe at the location where the cross-sectional distortion.
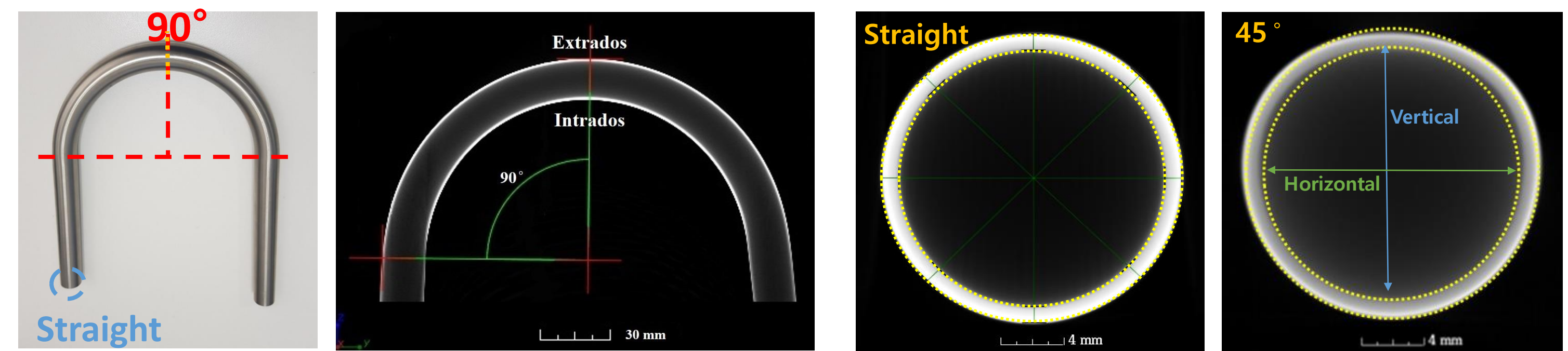
Summary

- The electromagnetic variations by the cross-section area shapes were theoretically predicted through the FEM simulation.
- The distortion of the cross-sectional area was confirmed to vary the physical distance between the coil probe and the inside of the pipe, and the simulation analysis was performed using COMSOL.
- It was verified that current density was concentrated when the pipe was adjacent to the coil probe due to distortion of the pipe, and it was possible to additionally verified that changes slightly depending on the position of the curved pipe.
- This effect is also considered to be associated with the effect of tilting the coil in integrity piping.

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