Analysis of Electromagnetic Wave Propagation in Automobile

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Outline

1. Background

2. Electromagnetic Wave Propagation in Simple Model

3. Measurement of Poynting Vector

4. Electromagnetic Wave Propagation in Actual Automobile

5. Conclusion
Back Ground

- Field Immunity
- Automotive Antenna
- Electric Vehicle

Electric field

Magnetic field
Poynting Vector

Poynting vector

\[ S_p = \frac{1}{2} \mathbf{E} \times \mathbf{H}^* \]

* Complex conjugate

Real Part  \rightarrow  Effective power

Imaginary Part  \rightarrow  Reactive power

Complex Poynting Vector around Automobile

f = 200MHz
(Yz-plane)

Simple model

Real Part

Imaginary Part
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Simulation model

- Vehicle model
  - Full length 3750
  - Overall width 1695
  - Overall height 1350

Dipole antenna
Incident wave $f=110\text{MHz}$: Vertical Polarized Wave

Electric field

Magnetic field

Pointing Vector
Incident wave $f=110\text{MHz}$: Horizontal Polarized Wave

Pointing Vector

Electric field

Magnetic field
Poynting vector $f=110\text{MHz}$

Vertical polarized wave
- Real part
- Imaginary part

Horizontal polarized wave
- Real part
- Imaginary part
Incident wave $f=200\text{MHz}$: Vertical Polarized Wave

Electric field

Magnetic field

Pointing Vector
Incident wave \( f=200 \text{MHz} \): Horizontal Polarized Wave

Electric field

Magnetic field

Pointing Vector
Poynting vector $f=200\text{MHz}$

Vertical polarized wave
- Real part
- Imaginary part

Horizontal polarized wave
- Real part
- Imaginary part
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Calculation method of Poynting Vector

Maxwell equation (feather form)

\[
\text{rot} \mathbf{H} = j \omega \varepsilon_0 \mathbf{E} \\
\mathbf{E} = \frac{1}{j \omega \varepsilon_0} \text{rot} \mathbf{H}
\]

(phasor expression)

Electric field can be calculated from magnetic field using Yee cell

Poynting vector

\[
S = \frac{1}{2} \mathbf{E} \times \mathbf{H}^* = \frac{1}{2} \frac{1}{j \omega \varepsilon_0} \text{rot} \mathbf{H} \times \mathbf{H}^*
\]

* Complex conjugate

Measurement Setup

Dipole antenna

Triaxial Magnetic field probe

Xz plane

Xy plane

500mm (step 25mm)

Antenna

f=200MHz
### Poynting Vector near Dipole Antenna

#### Simulation vs. Measurement

<table>
<thead>
<tr>
<th>Plane</th>
<th>Simulation</th>
<th>Imaginary Component</th>
<th>Absolute Value</th>
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<tbody>
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<td><img src="image2" alt="Imaginary Component" /></td>
<td><img src="image3" alt="Absolute Value" /></td>
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</table>

- **f = 200 MHz**
- **Xz-plane**
- **Xy-plane**
- **Xy-Plane**

- **DB**

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Measurement of Actual Automobile

Vertical Plane (xz)

Antenna

Xyz -stage

VNA
Simulation model

Model accuracy: less than 30mm

Antenna
Electromagnetic Field

Magnetic field

Electric field

Simulation

Measurement

f = 200 MHz
Poynting vector $f=200\text{MHz}$

Real part

Imaginary part

Simulation

Measurement

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Conclusion

1. From Poynting Vector, it was possible to grasp the energy transmission which is a characteristic of propagation inside the automotive cabin, which cannot be seen from measurement of the E/M field,

2. Using a triaxial near-field probe and a vehicle as a case study, we were able to visualize the real and imaginary part of Poynting vector from the magnetic field in automotive cabin.

3. The next step will be to clearly identify the electromagnetic wave propagation characteristics of various vehicle models