Electromagnetic Simulation for Education on Antenna Engineering

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Abstract: For the purpose of the teaching of antenna for the undergraduate students, the time domain response of near field distribution of dipole antenna excited by Gaussian monocycle pulse generator is shown. Then a centrally fed slot antenna on the rectangular conducting plane is calculated and shown how the equivalent magnetic current is induced on the slot. In the numerical analysis, the electromagnetic simulator WIPL-D based on the Method of Moments is used.

Keywords: Slot antenna; simulation; electromagnetic simulator; Method of Moments

References:
He received his B. E. and M. E. degrees from Saga University, Japan in 1975 and 1977, respectively, and a Dr. Eng. Degree from Kyushu University Japan in 1986. In 1996 he was a visiting researcher at the Department of Electrical Engineering at the University of California, Los Angeles. Since 2007, he has been a Professor in Nagasaki University.

His research interests are low profile antennas for mobile communication and the education by using the electromagnetic simulator.

He was a Chair of Technical group of Microwave Simulator in IEICE from 2006 to 2007, IEEE AP-S Fukuoka Chapter Chair from 2007 to 2008, IEICE Kyushu Section Chair in 2013.


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Electromagnetic Simulation for Education on Antenna Engineering

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Outline of Presentation

1. Introduction
2. Animation of electromagnetic wave radiation from dipole antenna
3. Analytical model of slot antenna
4. Numerical results and discussion
5. Conclusion
1. Introduction

Recently, due to the development of the graphics processing unit and the animation tools in the electromagnetic simulators, the user can see the near field distribution or current distribution on the antenna in addition to the input impedance and the radiation characteristics, and understand the antenna characteristics intuitively [1].

Therefore the electromagnetic simulators and the animation tools are useful tool in the education of electromagnetic wave theory and the antenna engineering for the undergraduate students.
We have analyzed the time response of the near field distribution of the dipole antenna excited by the Gaussian monocycle pulse generator, and showed how the electric and magnetic fields are excited near antenna [4].

Since the dipole and the slot are the element antennas of the circularly polarized antenna [5], the phenomenon of electromagnetic field on slot antenna have to be shown.
In this presentation,

The time domain response of near field distribution of dipole antenna excited by Gaussian monocycle pulse generator will be shown [4].

A centrally fed slot antenna on the rectangular conducting plane will be calculated and shown how the equivalent magnetic current is induced on the slot [6].

In the numerical analysis, the electromagnetic simulator WIPL-D based on the Method of Moments is used [7].
3. Animation of electromagnetic wave radiation from a dipole antenna [4]

Half-wave dipole antenna

Gaussian mono cycle pulse voltage is fed. (Center frequency: 500 MHz)
Gaussian mono cycle pulse voltage

\[ f(t) = A \frac{\sqrt{e}}{\sigma} (t - t_0) \exp \left\{ -\frac{(t - t_0)^2}{2\sigma^2} \right\} \]

\[ A = 1.0, \]
\[ \sigma = 0.318 \text{ nS}, \]
\[ t_0 = 2.0 \text{ nS} \]

Center frequency: 500 MHz
Time response of electric field

1.0nS   1.2nS   1.4nS   1.6nS   1.8nS   2.0nS   2.2nS   [V/m]
2.4nS   2.6nS   2.8nS   3.0nS   3.2nS   3.4nS   3.6nS
Time response of magnetic field

<table>
<thead>
<tr>
<th>Time (nS)</th>
<th>Magnetic Field (mA/m)</th>
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</table>
Near field distribution

Electric field

Magnetic field

Strongly excited

[V/m]

[mA/m]

Strongly excited
Fresnel and far-field region

Electric field

Magnetic field

Boundary between Fresnel and Far-field region

$$r = \frac{2D^2}{\lambda} \approx \frac{\lambda}{2}$$

Electric field is proportional to magnetic field in far-field region
3. Analytical model of slot antenna

Fig. 1. Slot antenna.

Frequency: 500 MHz

model 1: \( w=3\,\text{mm}, \quad L=280\,\text{mm} \)
model 2: \( w=6\,\text{mm}, \quad L=270\,\text{mm} \)
model 3: \( w=12\,\text{mm}, \quad L=250\,\text{mm} \)
4. Numerical results and discussion

Current distribution on conducting plane.

(a) Model 1
Maximum value of current amplitude = 3.69 A/m.

(b) Model 3
Maximum value of current amplitude = 2.17 A/m.

Fig. 2. Current distribution on conducting plane.
Z component of magnetic field

Feed point

Model 1

Model 2

Model 3

[A/m]
Amplitude distribution of magnetic field on central axis of slot
X component of electric field

Feed point

Model 1

Model 2

Model 3

[V/m]
X component of electric field along x axis

Amplitude is inversely proportional to slot width. Directivity is almost same in three models.

Directivity
Model 1: 5.672 dBi
Model 2: 5.666 dBi
Model 3: 5.656 dBi
Amplitude distribution of electric field (x component) on central axis of slot
Electric field at \((r, \theta, \varphi)\) in Far-field region

\[
E(r, \theta, \phi) = \frac{\exp(-jkr)}{r} D(\theta, \phi)
\]

\[
D(\theta, \phi) = -\frac{j\omega\mu}{4\pi} \int_S \left\{ J - (J \cdot i_r) i_r + \sqrt{\frac{\varepsilon}{\mu}} J_m \times i_r \right\} \exp(jk\rho i_\rho \cdot i_r) dS'
\]

\(J\): Current on conducting plane

\(J_m = E \times n\): Equivalent magnetic current on slot

\(n\): Unit normal vector on slot

\(i_r, i_\theta, i_\varphi\): Unit vectors along \(r, \theta, \varphi\) direction

\(\rho i_\rho\): Position vector of source point
Electric field $E_s$ is induced within slot.

Equivalent magnetic current $J_m$ is defined by

$$J_m = E_s \times n.$$
Current vector distribution of Model 3.

Fig. 3. Current vector distribution of Model 3.
Current flows on circumference of slot.

Currents on opposite sides flow opposite directions each other. This means that current on conducting plane does not contribute to radiation field.

Electric field is expressed in terms of integration of equivalent magnetic current.
5. Conclusion

The slot antenna on the rectangular conducting plane is calculated and the current distribution on the conducting plane and the equivalent magnetic current within slot are shown for the purpose of the teaching of antenna for the undergraduate students. In the slot antenna, the current flowing along the slot edge decides the equivalent magnetic current within slot.
REFERENCES


