Optimal Geometry of Holes in a Cable Tray for Offshore Plants

Daehoon Park¹,² · Jangmyung Lee³,*

Abstract

This study analyzes the crosstalk effects caused by the geometry of holes in a cable tray in offshore plants. Using the analysis results, we determine the optimal hole geometry that can effectively reduce the tray weight under minimum crosstalk. It was previously shown that metal cable trays can reduce crosstalk among cables. However, the impact of hole geometry was not considered. This study demonstrates the impact of hole geometry on the crosstalk. In addition, an algorithm is proposed to determine the optimal geometry of holes in the cable tray. The simulation results validate the proposed algorithm and can be useful for the designers of cable trays with holes.

Key Words: Cable Tray, Crosstalk, Offshore Plant, Scattering Parameter, Shielding Effectiveness.

I. INTRODUCTION

Typically, several power and signal lines are installed in offshore plants. Electromagnetic fields (EMFs) produced by high-voltage power lines can affect living organisms; therefore, a guide for determining a safe distance has been suggested [1]. These EMFs generated from the power lines can also affect other cables, resulting in interference among cables, which is referred to as called crosstalk [2]. The shielding characteristics of a cable tray have been extensively studied so far [3]. $S$-parameters were obtained through modeling and simulation, and experiments were conducted to determine the differences in shielding effectiveness (SE) based on the width-to-height ratios of U-shaped cable trays, which are commonly used in the industry [3].

The holes in a cable tray make it easy to attach cables or other fixings. In addition, they can reduce the tray’s weight and enable drainage and ventilation. However, an increased area of holes can cause interference between cables. To minimize crosstalk between cables, holes are designed to have an optimal geometry. In this study, the SE of various shapes and numbers of holes in cable trays were compared through simulations and experiments. Using the analysis results, an algorithm was proposed to determine the optimal geometry of holes in the cable tray for the desired area of holes.

The rest of this paper is organized as follows. The algorithm proposed to find the optimal geometry is presented and validated in Section II. The conclusions are presented in Section III.

II. PROPOSED ALGORITHM TO FIND OPTIMAL GEOMETRY

This paper proposes an efficient algorithm to determine the optimal geometry of holes in the cable tray for the desired area...
of holes. The detailed process of the proposed algorithm is
described in this section.

1. Dataset Collection

To construct a dataset for training the relationship between
the hole geometry in the cable tray and cable crosstalk, the input
and output variables of the dataset must be defined. We chose
width, number of columns, and number of rows of holes as the
input variables. The hole height was fixed at 100 mm because it
had no significant effect on the cable crosstalk. The range of
variables is listed in Table 1, and the number of datasets was
1,323.

To construct a database, the simulation results of the crosstalk
analysis performed with High Frequency Simulation Software
(HFSS) were used. The $S$-parameter of near-end coupling ($S_{21}$)
had different values depending on the frequency. In addition, $S_{21}$
exhibited a similar tendency in the simulations. Instead of using
all $S_{21}$ values at all frequencies, the representative value was used
as the output value of $S_{21}$ for the proposed algorithm. $S_{21}$ at the 1
MHz frequency is one of the values with similar tendency.
Therefore, the difference in $S_{21}$ between cable trays with and
without holes at the 1 MHz frequency was used as the output
value of the dataset.

The low output value of $S_{21}$ indicates a high SE. As shown in
Fig. 1, the expected values of crosstalk at the rest point between
two typical points can be obtained using the crosstalk simulation
results at the typical points.

2. Training Dataset using Neural Network

The dataset was trained using a neural network. The network
had three inputs, 10 hidden layers, and one output and was
trained using the Levenberg–Marquardt backpropagation meth-

3. Finding Optimal Hole Geometry Using Neural Network

In our proposed algorithm, when we enter the value of the
desired area of the holes in the cable tray as input, the optimal
game of holes with minimum expected crosstalk is suggest-
ed based on a trained neural network. The detailed algorithm is
presented as follows:

Step 1: Input the desired area of holes and output possible
cases of geometry with width, height, number of col-
umns, and number of rows of holes.

Step 2: Output the predicted crosstalk based on the neural
network by using possible cases of geometry ob-
tained from the results of Step 1. The possible cases
indicate possible hole geometries in the cable tray for
the desired area.

Step 3: Find the hole geometry with minimum expected
crosstalk from the results of Step 2.

4. Experiments and Discussion

We performed experiments to evaluate the performance of
the proposed algorithm and to determine the optimal geometry
of the holes in the cable tray. All approaches mentioned in this
section were programmed using MATLAB. The training and
testing processes were performed on a PC with an Intel i5-
9400F processor, 32 GB RAM, and a clock rate of 2.9 GHz
using the Windows 10 operating system (64 bit).

For example, to design holes in cable trays with 84,000 mm²
area, we used an 84,000 mm² area as input and then obtained
the optimal hole geometry as the output using the proposed
algorithm. As shown Table 2, when an 84,000 mm² area of holes
is used as the input, we can obtain the possible cases of various
hole geometries, including the optimal geometry of holes.

To verify the experimental results obtained using the pro-
posed algorithm to determine the optimal hole geometry, a sim-
ulation was performed using HFSS.

As shown in Fig. 2, the simulations were performed by vary-
ing the hole height as 13, 15, 24, and 30 mm while maintaining
the width at 100 mm. Moreover, the number of holes was set as
$9 \times 7/8 \times 7/5 \times 7/4 \times 7$ to maintain the total hole area.

As shown in Fig. 3, the simulation results were similar to
those obtained using the proposed algorithm to find the optimal
hole geometry using a neural network.

Table 1. Range of variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Width (mm)</td>
<td>10–30</td>
</tr>
<tr>
<td>Number of rows</td>
<td>1–7</td>
</tr>
<tr>
<td>Number of columns</td>
<td>1–9</td>
</tr>
</tbody>
</table>
Table 2. Experimental results pertaining to the height of parallel holes with similar area (84,000 mm²)

<table>
<thead>
<tr>
<th>Width (mm)</th>
<th>Height (mm)</th>
<th>No. of columns</th>
<th>No. of rows</th>
<th>Expected crosstalk</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>100</td>
<td>4</td>
<td>7</td>
<td>8.14</td>
</tr>
<tr>
<td>28</td>
<td>100</td>
<td>5</td>
<td>6</td>
<td>9.39</td>
</tr>
<tr>
<td>24</td>
<td>100</td>
<td>5</td>
<td>7</td>
<td>7.79</td>
</tr>
<tr>
<td>28</td>
<td>100</td>
<td>6</td>
<td>5</td>
<td>11.31</td>
</tr>
<tr>
<td>23.33</td>
<td>100</td>
<td>6</td>
<td>6</td>
<td>9</td>
</tr>
<tr>
<td>20</td>
<td>100</td>
<td>6</td>
<td>7</td>
<td>7.39</td>
</tr>
<tr>
<td>30</td>
<td>100</td>
<td>7</td>
<td>4</td>
<td>14.51</td>
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<tr>
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<td>7</td>
<td>6</td>
<td>8.37</td>
</tr>
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<td>7</td>
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<td>100</td>
<td>8</td>
<td>4</td>
<td>13.73</td>
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<td>8</td>
<td>5</td>
<td>10.21</td>
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<td>8</td>
<td>6</td>
<td>6.22</td>
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<td>8</td>
<td>7</td>
<td>2.86</td>
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<td>9</td>
<td>4</td>
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<td>9</td>
<td>5</td>
<td>8.7</td>
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</tr>
<tr>
<td>13.33</td>
<td>100</td>
<td>9</td>
<td>7</td>
<td>1.95</td>
</tr>
</tbody>
</table>

Fig. 2. Cable tray modeling of parallel holes with different heights and similar area (approx. 84,000 mm²).

Fig. 3. Simulation results pertaining to the height of parallel holes with similar area (84,000 mm²).

III. CONCLUSION

The SE of cable trays used in offshore plants was analyzed for cable trays with and without holes through simulations and experiments. The SE of the parallel holes was verified by varying the width and length of the holes. Using the analysis results, an algorithm was proposed to determine the optimal geometry of holes in the cable tray and was verified through simulations. These results can be useful for the designers of cable trays with holes.

REFERENCES