Abstract— The ground bounce noise (GBN) in high-integrative and high-complexity circuit designs is discussed in this paper. GBN doesn’t only transmit its own power and ground plane but also couple to power and ground plane nearby. Therefore, power integrity (PI) will be affected by GBN. I use the segmentation method to cut off the cavity model of PCB. Here, I embed partial electromagnetic bandgap (EBG) structure and Z-shape power bus to isolate the noise power and ground planes. Then, partial EBG structure and Z-shape power bus are implanted to form stop-band characteristics. We can find noise isolation has the same effect as the period EBG structure. Through this modelling method, we can separate the stop-band and pass-band in Z-shape and EBG individually. In the model, the PCB is divided into five segments of different sizes and rectangular power and ground plane. Through the mushroom-shape (Mushroom-like) EBG, these structures are connected as part of a vertical blind hole, rectangular resonant cavity and the transmission line model to describe the Z-shape power bus. From practices and proposed methods, we can effectively improve result of isolating the power and ground noise simulation and implement.

I. INTRODUCTION

In the EBG structure study, high-speed switching frequency integrated system suppresses the power supply noise coupling on the power/ground, such as Simultaneous Switch Noise (SSN) and cross-talk to realize the effective multilayer and high noise isolation printed circuit board (PCB). The EBG structure has played an important role because its small size can maintain the characteristics of power integrity [1]–[4].

In previous study, electromagnetic simulation band-gap structures focus on the forbidden band cut-off frequency prediction [5]. Thus, we only put limited number of EBG cells in the minimize area to ensure the PI and the Z-shape EBG power bus remain the same reference plane. Moreover, we evaluate carefully noise isolation effect and Z-shape part of EBG power channel.

II. SEGMENTATION METHOD FOR Z-SHAPE AND PARTIAL EBG

After using Z-shape power bus and partial EBG structure in multilayer printed circuit boards, we can find the better noise isolation effect. Here, I adapt literature review [4],[6] that uses the partial EBG structure and Z-shape power bus. In the Fig. 1(a), it shows a irregular shaped power/ground plane. In the centre of the power/ground plane, it is embedded Z-shape power bus and partial EBG patch1 and patch2 (Mushroom-like EBG). Using VIAs, the EBG patch1 is connected with Z-shape power bus.
The segmentation method based on Schelkunoff’s field equivalence which deals with the calculation of arbitrarily structure. In Fig. 1(b), we assume that the current source is placed on both sides and the PCB can be divided into five sections. Segment 1 and 5 are a rectangle power/ground plane; segment 2 and 4 are a EBG cell2 structure; segment 3 is EBG cell1 and Z-shape power bus structure.

Next, we can define the group of ports denoted as p, q, r, s and t. The ports are defined vertically the power/ground plane. These segments are connected with the internal ports p2, p3, p4, q1, q2, q3, q4, q5, q6, q7, q8, q9, q10, q11, r1, r2, s1, s2, s3, s4, s5, s6, s7, s8, s9, s10, s11, s12, s13, s14, s15, s16, s17, t1, t2, t3, t4, t5 and t6. Here, port connection is divided as follows: the port pairs of (p2, q1), (p3, q2) and (p4, q3) connect the rectangular cavity of the segment 1 with the partial EBG structure of the segment 2. The port of (q4, r1) connects the partial EBG structure of the segment 2 with the segment 3 of the Z-shape power bus. The port of (r2, s1) connects the Z-power bus of the segment 3 with the partial EBG structure of the segment 4. Finally, the partial EBG structure of the segment 4 path port (s2, t1), (s3, t2), (s4, t3), (s5, t4) and (s6, t5) connect the rectangular cavity of the segment 5. In addition, each EBG cell has four ports connect with on the segment 4 and the segment 2. The port p1 and t6, the external ports, correspond to Port 1 and Port 2.

III. IMPEDANCE MATRICES OF SEGMENT

A. Rectangular Power Plane Structure

To use double summation equation [7], the impedance matrix of the segment 1 and segment 5 can be calculated as following:

\[
Z_{r,\theta} = \frac{q_{out}(h_r + h_t)}{W_{seg} W_{seg}} \sum_{x} \sum_{y} C_{r,\theta} C_{\theta,\theta} (x_{r,\theta}, y_{r,\theta}) P_{\theta,\theta} (x_{\theta,\theta}, y_{\theta,\theta}) \frac{k_{r,\theta}^2 + k_{\theta,\theta}^2 - k^2}{k_{r,\theta}^2 + k_{\theta,\theta}^2 - k^2}
\]  

B. Z-shape power bus and partial EBG Structure

The structure of segment 3 includes a transmission line and partial EBG. EBG cell connects Z-shape power bus with VIAs which shows in Fig. 2. Here, we omit effects came from a transmission line between EBG cells.

Here, \(Z_0\) contains the characteristic impedance and the \(\gamma\) represents the propagation constant. \(Z_A\) impedance matrix is calculated by ABCD matrix [8]. \(Z_B\) impedance matrix model is used to obtain the cavity. The rectangular cavity is formed by metal plates. The segment 2 and the segment 4 can be modeled as the structure of Fig. 3. This structure is composed of the cavity A and the cavity B, and the cavity A includes VIA.
IV. SIMULATION AND MEASUREMENT

To validate the proposed model with the EBG and the Z-shape or not, we use three methods: the model calculation, the HFSS electromagnetic software simulation and the practical measurement. Here, the real board picture is shown in Fig. 4. Noise coupling effect shows on $S_{21}$ from the frequency range 0.1GHz to 10GHz. The dielectric material uses the FR-4 (loss tangent value: 0.012) and the conductive of the copper is $5.88 \times 10^7$ s/m and simulation model of the structure and size of the verification are shown in Fig. 5 and Table 1.

### TABLE I

<table>
<thead>
<tr>
<th>Design parameters and Dimensions (Unit : mm)</th>
<th>$W_{x _seg1}$</th>
<th>$W_{y _seg1}$</th>
<th>$W_{x _seg5}$</th>
<th>$W_{y _seg5}$</th>
<th>$W_{px _seg1}$</th>
<th>$W_{py _seg1}$</th>
<th>$W_{px _seg5}$</th>
<th>$W_{py _seg5}$</th>
<th>$W_{cell1}$</th>
<th>$W_{patch1}$</th>
<th>$W_{cell2}$</th>
<th>$W_{patch2}$</th>
<th>$W_L$</th>
<th>$T$</th>
<th>$T_{0.012}$</th>
<th>$h_1$</th>
<th>$h_2$</th>
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<tbody>
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<td>$W_{x _seg1}$</td>
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<td></td>
<td></td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td>4.2</td>
<td></td>
<td>7</td>
<td></td>
<td>0.6</td>
<td></td>
<td>0.012</td>
<td>0.1</td>
<td>0.9</td>
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According to the result of Fig. 5, the proposed model can suppress the GBN ($|S_{21}| \leq -20\text{dB}$) in the frequency range of 260MHz~940MHz and ($|S_{21}| \leq -30\text{dB}$) in the frequency range of 940MHz~10GHz.

V. CONCLUSIONS

We divide the Z-shape power bus and the EBG structure into five segments to establish individual models. Using the proposed method, it provides accurate results and reduces the calculation time. Meanwhile, we use three layers of the Z-shape power bus and the EBG structure to decrease manufacturing cost. Because this structure only need a small area (the Z-shape power bus and the EBG structure), we can achieve a certain degree of GBN suppression; meanwhile, we can save layout area, too.

REFERENCES