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Challenge Problem Update: PEEC and MOM Analysis of a PC Board with Long Wires Attached

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Abstract: At the 2000 IEEE International Symposium on EMC, a paper was presented that compared the application of PEEC and MOM techniques to the analysis of one of the EMC Society/ Applied Computational Electromagnetics Society special challenge problems [1]. Good agreement was obtained between the two codes at 2 out of the 3 measurement ports. At that time, no definite explanation was provided for the discrepancy at the third port. This paper will show that the problem was (at least partly) related to assumptions made about the signal source.

I. INTRODUCTION

Several EMC modeling problems have been proposed by the IEEE EMC Society TC-9 Committee and the Applied Computational Electromagnetics Society. This set of problems was created to highlight the strengths and weaknesses of various computational modeling techniques and to evaluate modeling software for EMC applications. In a paper presented one year ago at the 2000 IEEE International Symposium on EMC [1], the Partial Element Equivalent Circuit (PEEC) method and the Method of Moments (MOM) were employed to analyze one of the more complex challenge problems.

In that paper, good agreement was obtained at 2 of 3 measurement ports. However, the voltage waveforms obtained at a third measurement port were different for the two techniques.

Figures 1 and 2 illustrate the configuration being analyzed. A rectangular plate resembling a printed circuit board ground plane has three 0.2-mm wide traces routed 0.8 mm above its surface. The center trace is connected to a voltage source at one end and a 55-ohm load at the other end. The other two traces are connected to 55-ohm loads at one end and wires that extend off the surface of the board on the other end.

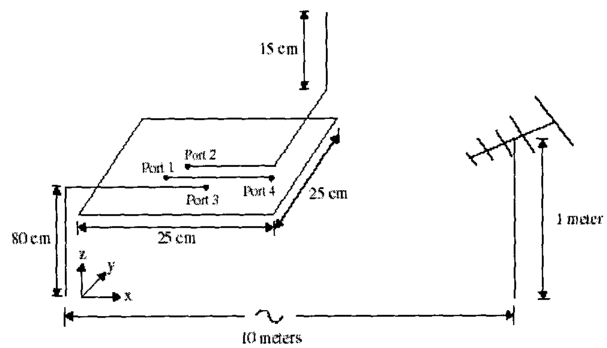

Figure 1. The 3D view of a PCB geometry

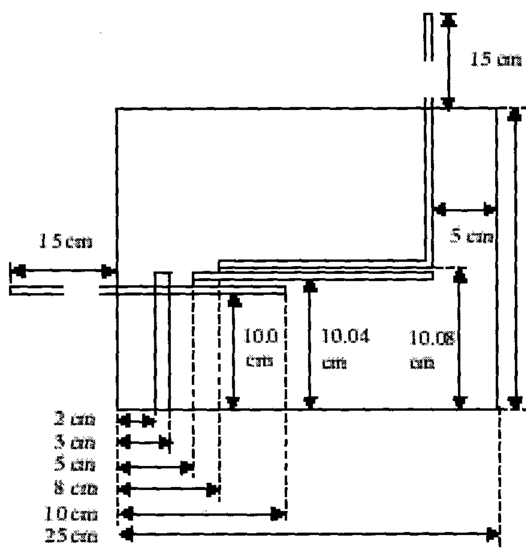

Figure 2. Top view of the PCB geometry

To simplify the problem, the relative permittivity of the dielectric was set to 1.0. There is a gap on the board ground plane in the original problem, however in this study, the gap was removed to simplify the

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analysis. The source waveform, as defined in the problem is illustrated in Figure 3.

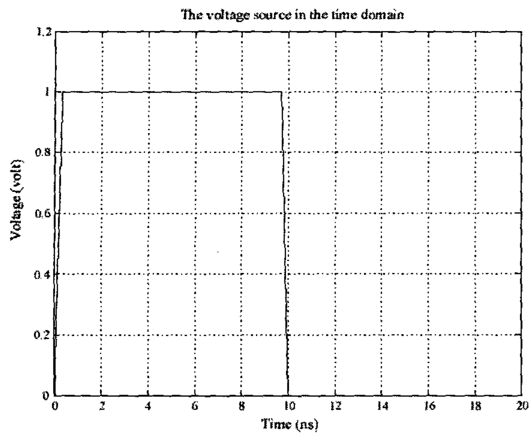

Figure 3. Voltage waveform at Port 1

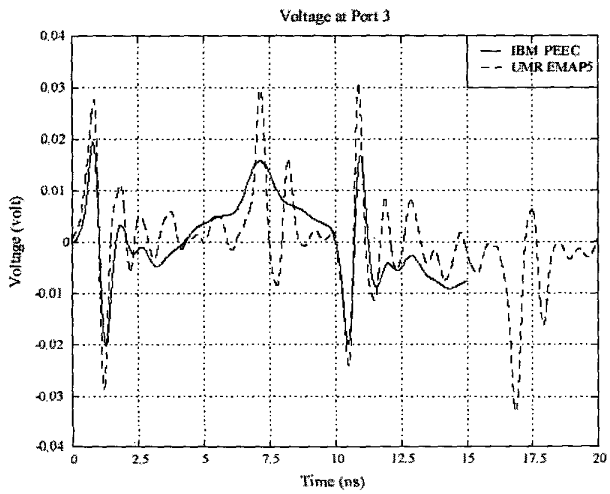

Figure 4. The voltage at Port 3 in the time domain

II. NUMERICAL RESULTS

The calculated results for the voltage at Port 3 that were presented in the previous paper are shown in Figure 4. The PEEC results appear to be damped relative to the MOM results (calculated using a code called EMAP5). Several explanations were offered for this discrepancy. One explanation was that there was some inherent loss that was being modeled by the PEEC code, but not by the MOM code. It was later discovered that the PEEC code did indeed model the plane and traces with a finite conductivity (equal to that of copper) while the MOM code modeled the plane and traces as perfect conductors. However, this difference in the amount of conductor loss was not great enough to explain the entire discrepancy in the results.

Since only one port was exhibiting a significant discrepancy, and that port was connected to the longest wire, it was decided to model the board without the wire and then the wire without the board.

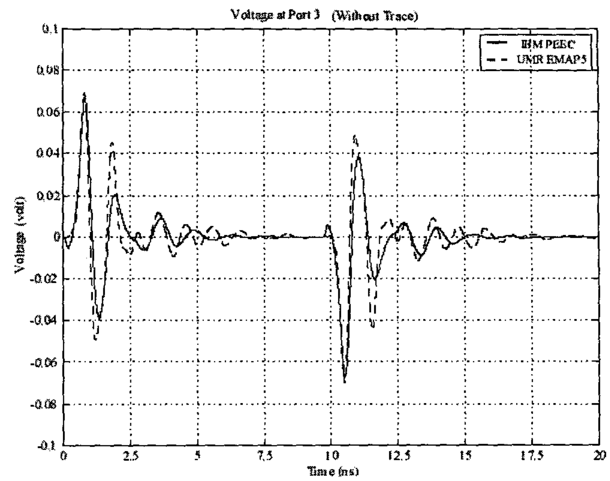

Figure 5. The voltage at Port 3 in the time domain (The board is without the wire)

Figure 5 shows the calculated results for the voltage at Port3 when the long wire is cut off at the edge of the board. Agreement between the results for the board without the wire was better, but there was still a significant discrepancy.

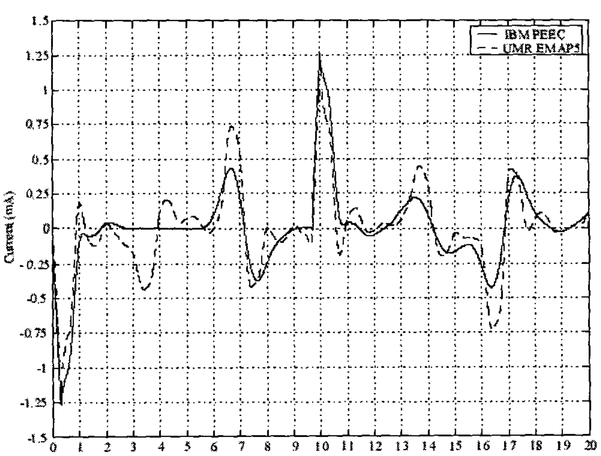

Figure 6. The current provided by the source

In order to model the wire without the board, a wire consisting of an 80-cm vertical section connected to a 25-cm horizontal section was modeled. A voltage source was placed 10 cm from the open end of the horizontal section.

Figure 6 shows a plot of the current provided by the source as calculated by the two codes. Despite the simple nature of the problem being modeled, there is a very significant discrepancy in these two results. Both plots exhibit an initial peak at 0.3 nsec corresponding to the rise in the source waveform. Both plots exhibit a peak at approximately 1.0 nsecs corresponding to the reflection returning from the open end of the horizontal section of wire and both plots exhibit peaks at approximately 6.8 and 7.5 nsecs corresponding to the reflection from the open end of the vertical section and the second reflection from the horizontal section, respectively. Peaks are also observed at 10.0, 10.7, 16.3 and 17.0 nsecs corresponding to the respective reflections of the falling edge of the source pulse. The two peaks at 13.6 and 14.3 nsecs are due to the second reflection of the rising edge from the vertical section and the third reflection of the rising edge from the horizontal section, respectively. These peaks are calculated by both codes. Peaks due to the corresponding reflections of the falling edge should occur at 23.0 and 23.7 nsecs. However, this is beyond the 20-nsec period of the source, so these peaks wrap around to the beginning of the time-harmonic response and appear at approximately 3.5 and 4.2 nsecs in the MOM result. Note that they do not wrap around to the beginning of the PEEC response! At this point, a key difference in the way this problem was modeled by PEEC and MOM is revealed. The PEEC input was a single pulse, not a steady-state waveform. PEEC is a time-domain method, hence it is easier to model time-limited sources. The MOM technique used was a frequency-domain method, hence it was easier to model a time-harmonic source. Since the challenge problem statement was not specific about the nature of the source, the modelers using each code made an assumption that was most natural for the type of code they were using.

Figure 7 shows the results obtained using PEEC for a single 10-nsec pulse compared to results obtained using MOM for a 10-nsec pulse that repeated every 80 nsecs. This time, the agreement between the two methods is much better, though still not perfect.

It is clear that one source of discrepancy between the two methods was the fact that they were modeling different source waveforms. A time-domain code can be used to model a time-harmonic problem if enough time steps are calculated in order to ensure a steady-state response. A frequency domain code can be used to model a time-limited problem if enough frequency points are calculated to ensure that the time-domain response has died out. For electrically small or lossy geometries, this is generally not a problem. However the long wire combined with the lack of significant loss, resulted in a significant difference between the pulse response and the time-harmonic response at Port 3 in this challenge problem.

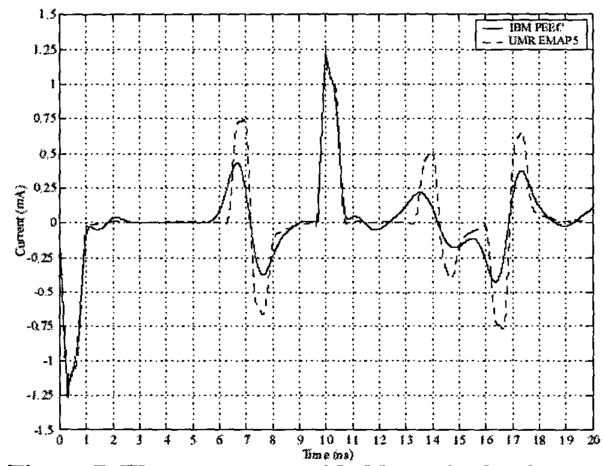

Figure 7. The current provided by a single 10-nsec voltage pulse

Why did the initial results look good for 2 out of 3 ports if the sources were not the same? Because, these ports were not significantly influenced by parts of the geometry that were far from the source. As a result, their initial response (calculated using PEEC) was very similar to their steady-state response (calculated using MOM).

Although the source of the discrepancy became obvious when a simple configuration was modeled, it was difficult to deduce based on the original modeling results. The fact that good agreement was obtained for 2 out of 3 measurement ports seemed to suggest that the source and loads were being modeled correctly.

III. CONCLUSIONS

The results obtained so far, do not rule out another source of error, since we have yet to model the whole configuration using the same source and get the same results. However, one significant difference between the PEEC model and the MOM model has been identified.

This experience illustrates how the details in the description of a complex problem can have a significant effect on the results. The more complex a problem becomes, the easier it is to lose track of exactly what you are modeling. The people modeling this problem had a great deal of experience using numerical modeling tools and were using their respective tools correctly. However, they were not modeling exactly the same problem. That fact was lost due to the sheer number of details and was not easy to track down due to the complexity of the response.

Ultimately, by modeling progressively simpler geometries until an intuitive response could be obtained, the source of the discrepancy became clear. The primary conclusion of this study is that people modeling time-harmonic problems with time-domain codes must ensure that a steady state has been reached. People modeling time-limited events using a frequency domain code must similarly be sure that enough data points are collected to ensure that the time domain response has effectively died out.

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[1] Y. Ji, B. Archambeault and T. Hubing, "Applying the Method of Moments and the Partial Element Equivalent Circuit Modeling Techniques to a Special Challenge Problem of a PC Board with Long Wires Attached," *Proceedings of the 2001 IEEE International Symposium on Electromagnetic Compatibility*, Washington, DC, August 2000. [*Paper was presented in 2000, but appears in this Proceedings.*]