Simulation and Analysis of Electromagnetic Interference Effects with 900 MHz Frequency on Various EMI Protection Model

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Abstract: - Electromagnetic interference possesses potential hazard towards equipment in an oil and gas refinery plant. Installing mesh common bonding network with high conductor density underneath the equipment is known to be an effective protection method against this thread. Nevertheless, using more conductor would require higher cost. Henceforth, a series of simulations has been executed to determine the optimum mesh configuration. The modelling and simulations were carried by using COMSOL software. In the simulations, the mesh diagonal (D) were varied from 6.9mm to 70.5mm. The results show that the electromagnetic interference was less for mesh with smaller D. However, the total cost rose exponentially when D was decreased to a certain value. All but all, this study found that mesh configuration with D 14mm is the most optimum option.

Key-Words: - Electromagnetic interference, individual mesh diagonal, mesh common bonding network

1 Introduction

Electromagnetic field consists of time-varying electric and magnetic field that are mutually coupled [1]. EM field exists and transmits its energy through space, forming a propagation of energy known as the electromagnetic radiation. Over the past few years, the wireless communication technology has developed rapidly. Consequently, the extensive use of electromagnetic wave as information carrier is inevitable, causing a potential thread of electromagnetic interferences (EMI) [2]. Other than that, EMI can also be emitted from indirect lightning strikes, power supply, power transmission line, power electronic devices [3-7].

EMI possesses potential thread towards human body, electrical devices, and communication lines [8,9]. In an oil and gas refinery plant, the substations host various electrical device, power lines, bus ducts, switching devices, and communication lines. Those objects can be both potential EMI victims and sources [10]. Hence, a certain protection method should be installed around those devices.

2 Problem Formulation

2.1 Types of Electromagnetic Interference

There are two types of EMI, low-frequency (LF) interference and high-frequency (HF) interference. The LF interference has frequency between 0 to 5 MHz, while HF interference frequency is more than 5 MHz [11]. Some of them are deliberately produced, while some others are unintentionally generated, such as short circuits, sudden earthing, switching, gas discharge, and fluorescent lamps. Meanwhile, the intended emitted EMI usually comes from communication wave, which is frequently used anywhere.

A study by Y. Karan et al investigated the electromagnetic radiation that was emitted from mobile using third generation long term evolution (3G/LTE) [12]. From the result in Table 1, it can be seen that the EMI from 890-915 MHz frequency was significantly higher than the other 3G frequencies.

2.2 Protection against Electromagnetic Interference

An electromagnetic protection can be intended both for protecting devices inside the EM zone from EM disturbances outside, as well as preventing EMI generated by the device to spread outside the zone [13].

Table 1 3G/LTE mobile phones electromagnetic interferences [12].

Freq.		EFS					
min.	max.	dwelling #1		dwelling #2		dwelling #3	
[MHz]		max.	avg.	max.	avg.	max.	avg.
791	821	0.024	0.014	0.029	0.014	0.028	0.015
832	862	0.024	0.013	0.024	0.013	0.024	0.014
876	880	0.020	0.011	0.023	0.012	0.022	0.012
880	890	0.067	0.016	0.024	0.015	0.057	0.007
890	915	0.116	0.014	0.092	0.014	0.055	0.015
921	925	0.016	0.007	0.020	0.011	0.017	0.007
925	935	0.019	0.011	0.024	0.011	0.018	0.007
935	960	0.029	0.018	0.029	0.023	0.029	0.014

In 2012, Keith Armstrong mentioned that shielding and radio frequency (RF) reference can be applied as EMI mitigation measures [14]. Furthermore, a MESH-CBN behaves as both shielding and RF reference. The EM radiation would be weakened when it tries to pass through the mesh shielding. However, there are few parameters that need to be considered while designing a MESH-CBN.

The first parameter is the largest diagonals or diameters of an individual mesh (D). In order to provide any use in EMI mitigation, D (in meter) should be less than $50/f_{max}$, with f_{max} (in MHz) as the maximum frequency that is intended to be controlled by the shielding. On the contrary, when the value of D is more than $150/f$, it can instead cause a resonation, worsening the EMI impact. Fig. 1 shows the graph of recommended maximum D for each f_{max}.

The mesh can be constructed using whichever conductive material exist although certain type of conductor would brought better performance as a shielding. Oppositely, rubbers and plastics are non-conducting and transparent to EMI [15]. The EMI attenuation itself comes from three schemes: absorption, reflection, multiple reflections; combined to determine the shielding effectiveness (SE) [16].

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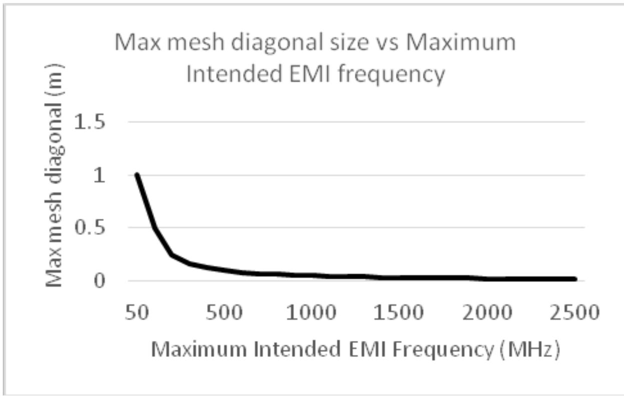

Fig. 1 Recommended value of maximum individual mesh diagonal respective to maximum EMI frequency controlled by the shielding.

3 Modelling and Simulation Parameters

In this study, the modelling and simulations of MESH-CBN as a shielding against electromagnetic interference were done by using COMSOL software.

3.1 Simulation Parameters

Based upon the explanation in the previous subsection, the emitted EMI was set to have 900 MHz frequency. The type of enclosure that was modelled in this study was a real enclosure, meaning that it there were certain gap between each side of the enclosure. Fig. 2 shows the 3D modelling of the simulation in COMSOL.

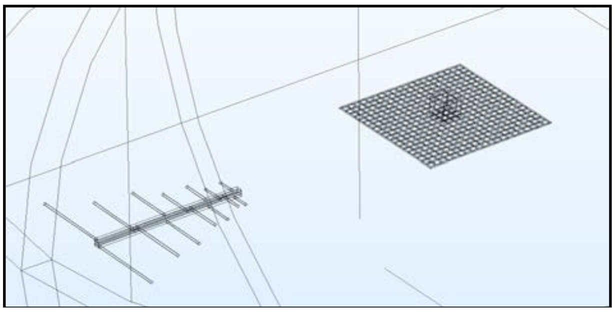

Fig. 2 3D modelling of the equipment, mesh, enclosure, and antenna.

A model of antenna as the EMI transmitter was located one meter away from the mesh. The mesh was placed underneath the enclosure, with side length of 0.1m.

There were four kinds of materials involved in this modelling: iron for the equipment, aluminum for the enclosure, copper for the mesh, air for the surrounding space. Electrical conductivity of air, iron, aluminum, and copper are 0 S/m, 1.12×10^7 S/m, 3.774×10^7 S/m, and 5.998×10^7 S/m respectively.

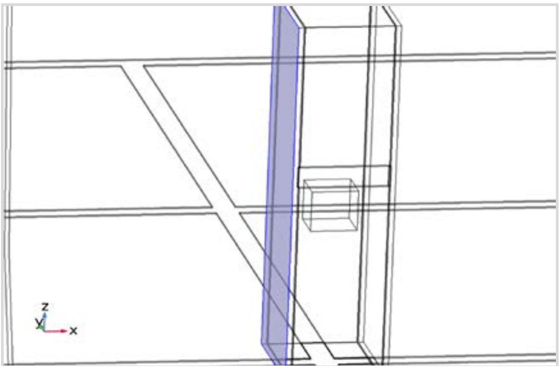

Fig. 3 Simulation output point, on the surface of enclosure.

In this study, the effectiveness of the shielding was examined. The analysis was done by comparing the measured EMI between various shielding configurations. Fig. 3 and 4 show the points of the observation, which are the surfaces of the enclosure and the equipment.

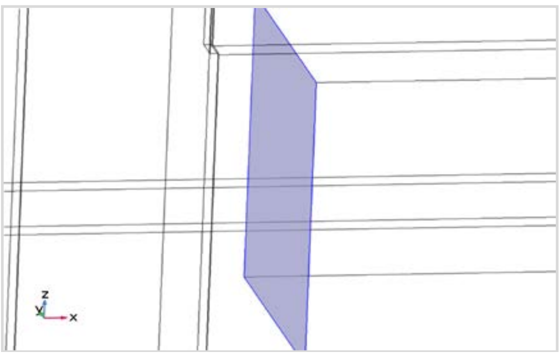

Fig. 4 Simulation output point on thesurface of equipment.

3.2 Simulation Variations

In this study, the simulations were done under mesh size variations. In subsection 2.2, it was explained that the individual mesh diagonal length should not be more than $50/f_{max}$. By substituting f_{max} with 900, it was obtained that the maximum D value was 55.5mm. Hence, the variations were done with D less than 55.5mm.

Five variations of mesh sizes were simulated to see the effectiveness of each shielding, compared to the required cost for each configuration. Additionally, a variation of mesh with D>55.5mm was also simulated to observe the result of surpassing maximum D value. Overall, Table2 summarizes the mesh size variations that were done in this study.

Table 2 Mesh size variations for simulations.

Mesh configuration	D (m)
20x20	6.9
16x16	8.7
10x10	14.0
4x4	35.2
2x2	70.5

4 Problem Solution

Overall, the results were divided into two major division, electric field and magnetic field. The whole simulation results are shown in Table 3 and 4.

Table 3 Electric field measurement result on simulations.

D (m)	Electric Field (V/m)	
	Enclosure	Equipment
6.9	0.39747	9.11E-09
8.7	0.41133	1.13E-08
14.0	0.42988	1.19E-08
35.2	0.53422	1.46E-08
70.5	0.79817	2.52E-08

Table 4 Magnetic field measurement result on simulations.

D (m)	Magnetic Field (A/m)	
	Enclosure	Equipment
6.9	4.5E-03	7.25E-09
8.7	5.0E-03	8.76E-09
14.0	5.1E-03	8.25E-09
35.2	7.1E-03	1.07E-08
70.5	1.5E-02	1.85E-08

Overall, all of the data show that the measured electric and magnetic field decreased when the mesh had higher density. Furthermore, Fig. 5 to 8 show the graph that were generated from the results.

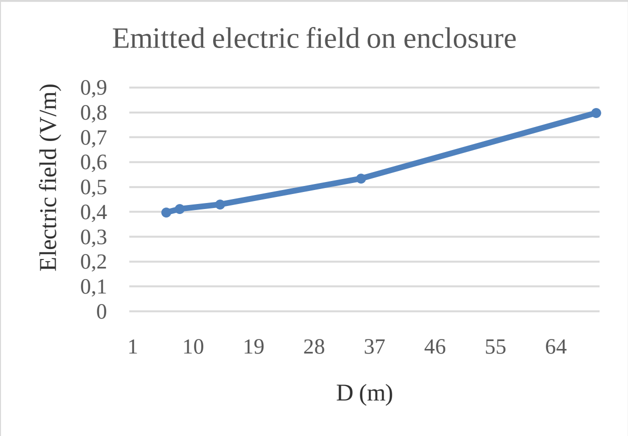

Fig. 5 Electric field on the surface of enclosure results graph.

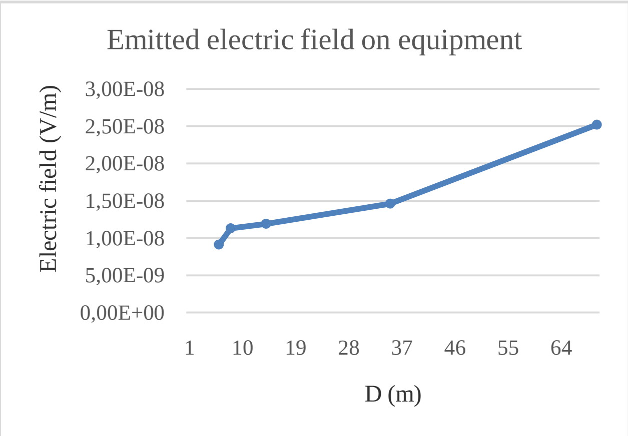

Fig. 6 Electric field on the surface of equipment results graph.

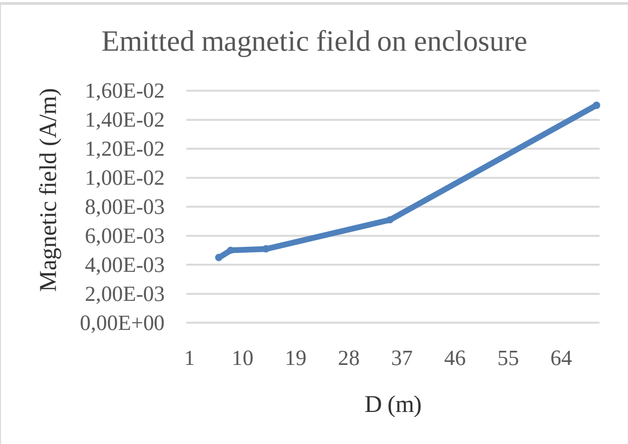

Fig. 7 Magnetic field on the surface of the enclosure results graph.

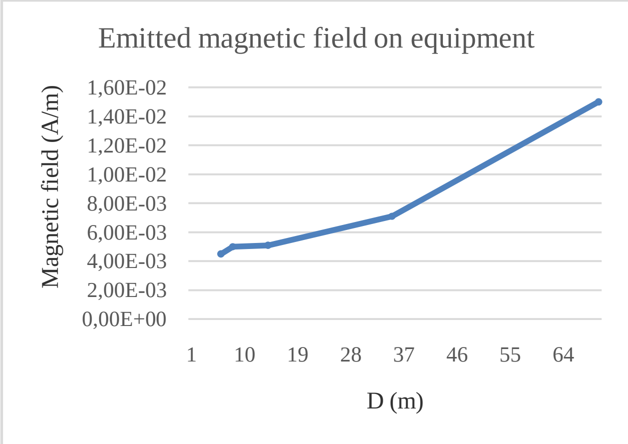

Fig. 8 Magnetic field on the surface of the equipment results graph.

From all the graphs, it can be observed that the EMI inclined rapidly when the mesh diagonal was increased from 35.2mm to 70.5mm. Hence, using mesh with D more than the maximum value is highly not recommended. Moreover, increasing the D from 14 to 35.2 also made a significant rise on every simulation results. Meanwhile, there were no significant difference between 6.9, 8.7, and 14 mm mesh diagonals. Furthermore, Fig. 9 depicts the comparison between total conductor length used and D.

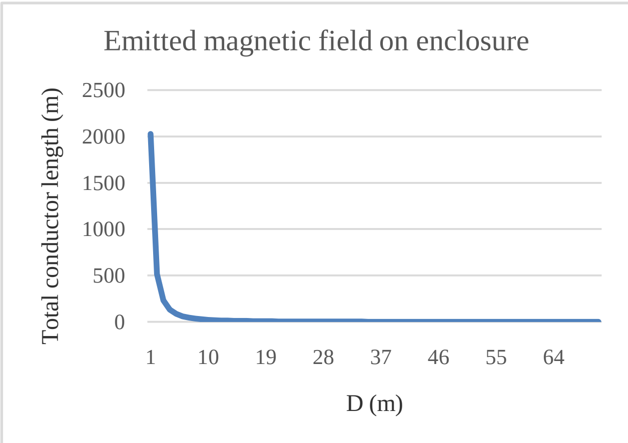

Fig. 9 Total conductor length vs individual mesh diagonal length (D).

It is obvious that the total cost would be in linear with the total conductor length. As depicted in Fig. 9, the total conductor length rose exponentially as the D was decreased. Hence, having a mesh protection with very small D proves to be not advantageous in term of the cost. Based on these results and comparisons, a mesh protection with D around 14 m provided with the most advantageous and effective protection against 900 MHz EMI.

5 Conclusion

The MESH-CBN protection in oil and gas refinery plant has been modelled with various mesh diagonal length (D) in order to evaluate the electromagnetic field caused by a 3G/LTE transmitter with 900 MHz frequency.

The simulation results show that for D of 6.9, 8.7, 14, 35.2, and 70.5, their electric field on enclosure were 0.39747, 0.41133, 0.42988, 0.53422, and 0.79817 V/m respectively. In term of electric field on equipment, the measured values were $9.11x10^{-9}$, $1.13x10^{-8}$, $1.19x10^{-8}$, $1.46x10^{-8}$, and $2.52x10^{-8}$ V/m. Meanwhile, the emitted magnetic field on enclosure were 0.0045, 0.005, 0.0051, 0.0071, and 0.015 A/m. Last, the magnetic field on equipment are $7.25x10^{-9}$, $8.76x10^{-9}$, $8.25x10^{-9}$, $1.07x10^{-8}$, and $1.85x10^{-8}$ respectively.

The graphs show that mesh with D 35.2 and 70.5mm gave significantly less protection compared to 14mm. In the other hand, the cost did not differ much. Oppositely, the protection provided by mesh with D 6.9 and 8.7mm show no significant difference to 14mm mesh. Meanwhile, decreasing the D to 8.7 or 6.9mm resulted in exponential cost rise.

Mesh with higher density gave better protection, because the induced electromagnetic interference was dissipated faster through more conductor. Henceforth, the equipment was exposed to smaller electromagnetic interference.

In conclusion, this study suggests the mesh configuration with D 14mm as the most advantageous and effective protection against 900MHz electromagnetic interference in oil and gas refinery plant.

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