# Effective HEMP Hardening Shelter Design Tool

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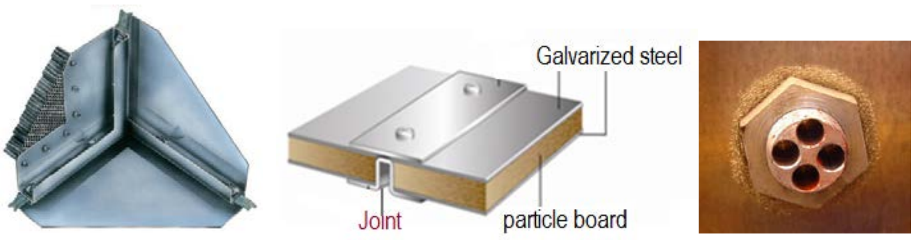
**Abstract.** This paper aimed to find an effective tool which enable ones to design HEMP (High Altitudes Electro-Magnetic Pulse) hardening shelter because a couple of existing formulas are not coincident with the actual SE(Shielding Effectiveness) test results which are measured on the site after shielding room construction. In this paper, we present the reasonable solution which has a coincident tendency between the theoretical calculation and SE test results on the site.

**Keywords:** HEMP(High Altitudes Electro-Magnetic Pulse), SE(Shielding Effectiveness)

## 1 Introduction

Basically, two kinds of formulas regarding SE estimation were introduced. The first one is calculated by intrinsic material constants [1] using conductivity σ, permeability μ and dielectric *constant* ε. The second one is calculated by the cavity with waveguide or slots [2]. Now we proposed the new concept [3] of the SE calculation adapting the effective conductivity, permeability, dielectric constant. These acted to reduced their intrinsic value through the structural configuration for the PAN and panel type shielding room, which has a number of pin holes and its dimensions for the welding type shielding room.




a) PAN type b) Panel type c) wave guides/ pin holes

**Fig.1.** various holes and slots on the HEMP hardening shelter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## 2. Theory

There are main factors shown on table 1. These caused the discordance between theoretical results and SE test on the site. This study applies parameters (1)-(3) into the HEMP hardening shelter design tool.
For the 3rd formula [4], first term is a SE formula of the cylindrical wave guide, second term is the reduction of incident angle and number of holes, 3rd term is the reduction rate of the open area. Where, $a$ is the transverse dimension of waveguide [mm], $d$ is the length of waveguide [mm], $k$ is the wave number and R is a rate of $3.18/g$. For the 4th formula, SE could not be higher than filter insertion loss even so there is no definition on the MIL STD 188-125. Cavity resonance frequencies of the shielding room dimension are also effective on the SE result that is described on the IEE 299-1997 and is corresponding to Meinke and Gundlach [5] (1968).

## 3. Verifications

It's so difficult to get the exact variable into the formula because it is depends on the shielding room construction. However, we found the overall curve and trend of SE simulation results which coming to the actual SE test. Fig.2 a) is a main view of the simulation tool and Fig. 2 b) is a SE test result of the very complicated shielding structure which consists of welding and jointing. We have a plan to evaluate again for the ideal shielding structure in future. In the Fig.2 a), I : SE simulation results using a pure materials, II : considering the reduction factor of structural configuration, III: considering a wave guide and unknown pin holes on the wall

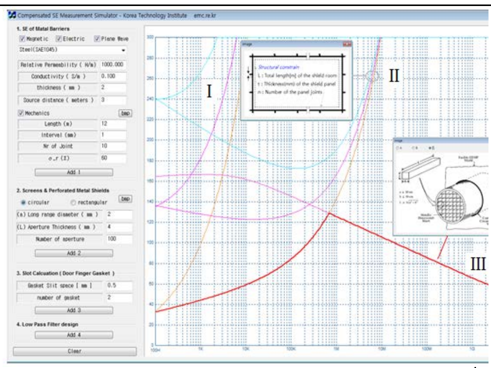
## 4. Conclusion

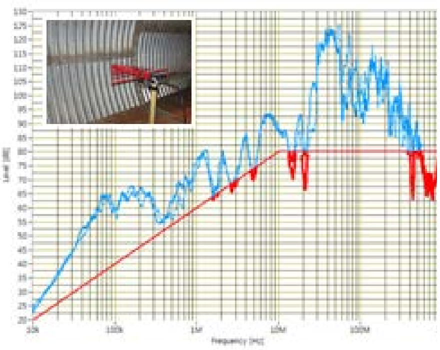
This tool was studied as a sub-project of the ***KTI-HEMP cord*** development and will be improved in the close future. However we found possibility to apply these algorithms which is very useful to estimate the shielding room SE test composed by the waveguides, various air vent and optimal diameter decision of liquid pipe. The result produced by this study enables constructors of shielding room, anechoic chamber and HEMP hardening shelter.

**Table.1.** SE calculation formulas of the newly proposed [3]

| Factors | Normal SE formula | Structure |
|---|---|---|
| 1)Intrinsic material Constants[1]; (I) | $SE[dB] = 20\ log\frac{\eta_0}{4\eta_s} + 20\ log\ e^{\frac{t}{\sigma}}$ <br> $\eta_0 = \sqrt{\frac{\mu_0}{\varepsilon_0}} \approx 377\Omega,\ \sigma \approx \frac{1}{\sqrt{\pi f \mu \sigma}}$ | Ideal perfect welded shielding room |
| 2)Reduction factor of Structural configuration[3] ; | -Applied a percent rate into the upper formula <br> -Calculation of the effective permeability by way ; | PAN and panel type shielding room |

| | | |
|---|---|---|
| (II) | $$R_{mo}=\frac{l_c}{\mu S}(1+\frac{l_g}{l_c})$$ Where, $R_{mo}$=magnetic resistance when material has a gap, $l_c$=total length of the shielding room, $l_g$= length of jointing gap, S=cross section of the shielding wall<br>-Apply the nominal effective conductivity considering the gasket conductivity and torque. | |
| 3)Cylindrical wave guide and unknown pin holes on the shielding wall [4]; (III) | $$SE_{dB}=31.95\ \frac{d}{2a}\sqrt{1-[\frac{2af}{175800}]^2}-20\ log_{10}\frac{4k}{\pi}\cos\phi-20\ log_{10}\frac{4R}{f}$$ | Common to<br>all type of shielding room |
| 4) Others;<br>-Filter insertion loss<br>-Rectangular cavity resonance frequencies | $$f_{cut}=\frac{c}{2\pi}\sqrt{k_x^2+k_y^e}=\frac{c}{2\pi}\sqrt{(\frac{m\pi}{h})^2+(\frac{n\pi}{w})^2}\ ,$$ $$f_{res}=\frac{c_0}{2}\sqrt{(\frac{m}{d})^2+(\frac{n}{h})^2+(\frac{p}{w})^2}\ ;m,n,p\in N$$ | |



| | |
|---|---|
| a) Main view of the SE simulation | b) Some of SE test results on the site |

**Fig.2** An effective HEMP shelter design tool

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