Analysis of Water Pipe Structure Considering EMP Shielding Effectiveness

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***Abstract*—Conventional water pipes used in septic tanks are installed with additional metal shielding to protect against damage from electromagnetic pulse (EMP) events. These shielding structure prevents EMP attacks, but impurities mixed with water cannot pass through the water channel. Thereby losing the original role of the water pipes and requiring additional maintenance workforce is needed to manage this. To solve this problem, a water pipe structure considered the attenuation characteristics of water was proposed. In this paper, effective design guideline that can maintains the function of the water pipe and provides protection from EMP damages without additional shielding structure was proposed.**

***Keywords*—EMP; Shielding effectiveness; Pipe,Water; Attenuation; Scattering**

I. Introduction

Recently, the EMP (Electromagnetic Pulse) attack causes malfunction and breakdown in many electronic devices within a certain range. Therefore, national and military major facilities require the design of EMP shielding facilities. In the case of buildings, shielding facilities are included in water pipes and windows for EMP protection [1].

In Korea, the shielding facilities used in the architectural field comply with the military specification and standard in MIL-STD-188-125-1,2. In order to satisfy the shielding effectiveness criteria specified in the regulations (80 dB at 1 GHz), an additional metal shielding is installed inside the conventional water pipes. At this time, the shielding effectiveness (SE) measurement was calculated as the ratio of the electromagnetic wave intensity between the inlet and the outlet near the metal shielding. Based on this, the metal shielding was designed. However, since this design is very narrow in comparison with the entire drainage system. Also, impurities are accumulated on metal shielding so losing the original role of the water pipes.

In this paper, the water pipe structure considering water attenuation characteristics is proposed instead of the conventional structure. It is proved that the proposed structure can satisfy the shielding effectiveness standard by using ANSYS HFSS.

II. Verification Processes

A. Analysis of Attenuation Characteristics of Water

Before calculating the SE of the proposed water pipe structure, we analyzed the attenuation characteristics of water.

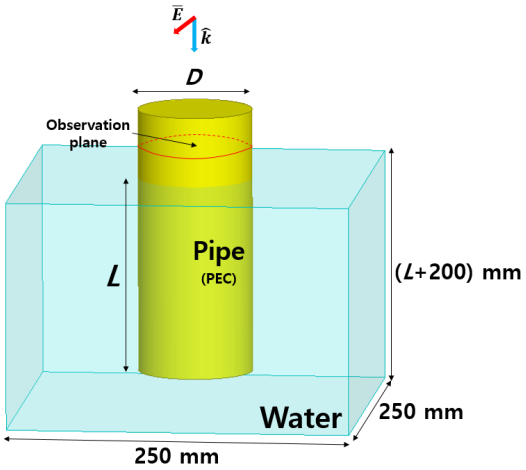

Fig. 1: **Geometric model of proposed pipe structure.**

For the analysis, a Cole-cole model water was used.

When the frequency increases, the loss tangent sharply increases, making it difficult for electromagnetic waves of high frequency components to propagate. Next, when the electromagnetic wave is transmitted through the water form the air, the shielding effectiveness according to the transmitted length can be summarized as (1).

$$SE \simeq 20\log\left(\frac{1}{T}\right) + 20\log\left(e^{2\alpha L}\right) + 20\log\left(e^{2j\beta L}\right) \qquad (1)$$

Where T is the transmission coefficient, α and β are the attenuation and propagation constant, and L is the transmission length of the electromagnetic wave. The attenuation constant α increases with increasing loss tangent. For this reason, when the electromagnetic wave travels the same distance, attenuation is high in the high frequency component as compared with the low frequency component. It can be seen that SE increases as the transmission length L increases.

B. Simulation Result

In this section, we assume the simulation that the water pipe structure is submerged in the septic tank by a certain length. The simulation was carried out using ANSYS HFSS. The water pipe structure is shown in Fig. 1. The air portion of the drain pipe was covered with a perfect electric conductor so that

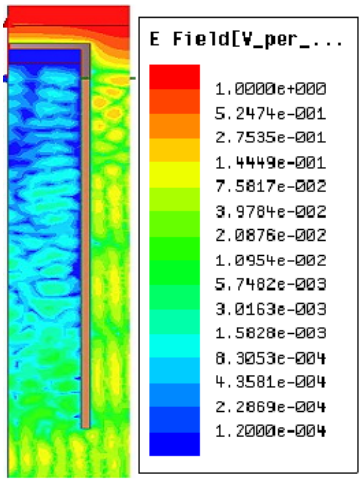

Fig. 2: **Internal electric field distribution of pipe.**

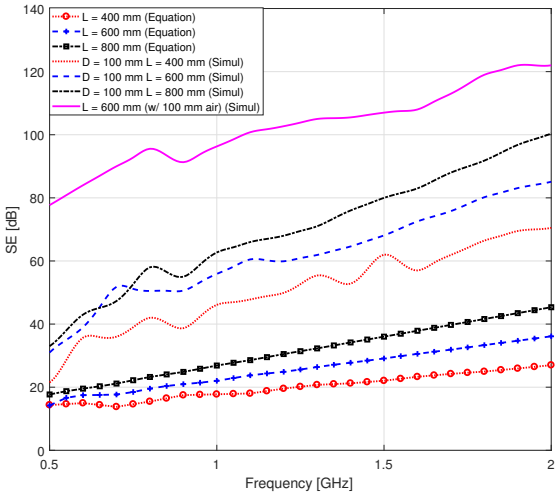

Fig. 3: **Shielding effectiveness result.**

the electromagnetic wave was introduced into the water pipe only through water. The external generated electromagnetic wave was set as a linear polarized plane wave of 1 V/m. The generated electromagnetic wave begins to attenuate from the moment it passes thorough the water in the septic tank and travels for a length of $2L$.

From Fig. 2 the attenuated electromagnetic wave can be visually confirmed to flow into the water pipe. Fig. 3 shows simulation result with calculation result from (1). The tendency of the shielding effectiveness changes when increasing the length L. This shows the same tendency, but shows the difference values in the SE. In the simulation structure, only the electromagnetic waves scattered at the end of the pipe flow into the pipe, which shows a larger SE than calculation result. When the length L of immersion in water is small, it can be seen that the SE is fluctuated in the low frequency region. This is a phenomenon that the SE slightly varies depending on the frequency due to multiple reflection occurring between the air and the water surface. The multiple reflection effect decreases as the water immersion length L or the frequency increases. The inside medium of the water pipe leading from the actual building will have a very long air layer above the surface of the septic tank. Therefore, the electromagnetic wave propagating inside the water pipe is more shielded with passing the air layer comparison with only water. The magenta solid line shows a simulation result of fixing the immersed length L to 600 mm and propagating a further 100 mm of air.

In the same length of air layer condition, SE is 91 dB and 112 dB respectively when L is set to 400 mm and 800 mm. Therefore, designing the water pipe with no metal shielding can be designed with a diameter of 100 mm and underwater pipe length of 600 mm as a guideline have.

III. Conclusion

In this paper, we propose the structure of the water pipe considering the electromagnetic attenuation characteristics of water. In order to satisfy the standard SE level, conventional metal shielding have no problem in terms of EMP shielding. However, impurities that must pass through the water channel along with water can accumulate on the metal shielding and interfere with the flow of water. It is verified through the theoretical equations and simulation results that the proposed water pipe structure does not require installation of additional metal shielding and can satisfy the standard SE. This suggests reasonable guidelines for EMP shielding design in the architectural field.

IV. Acknowledgment

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