A High Shielding Effectiveness Waveguide Window Designed for Modern Combat Vehicle

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Introduction

With the extensive use of electronic equipment in modern warfare and the intensified confrontation of electronic warfare, the strong electromagnetic pulse (EMP) technology, which is mainly used in weapons such as high-power microwaves, is also developing rapidly. The electromagnetic pulses generated by electromagnetic pulse bombs can cause extensive damage to the electronic equipment in modern combat vehicle systems in a short period of time with the enormous energy. The electromagnetic pulses will be coupled into the interior of the vehicle through the gaps and the holes, and induce currents on the cables. The induced current, propagates along the wiring harness, affecting the internal circuits and components, and even destroy the electric circuits. Therefore, it is necessary to study the EMP prevention methods of the modern combat vehicles under complex electromagnetic environment. However, the high-voltage supply system and electric system of the modern combat vehicles will generate a certain temperature under dynamic conditions, if there are no sufficient heat dissipation measures, a high-temperature alerts will be triggered, and the vehicle will be stopped urgently. Therefore, for temperature sensitive electrical systems, ventilation and EMP prevention issues need to be considered at the same time.

In order to effectively suppress the electromagnetic coupling of EMP to the vehicles and meanwhile guarantee the heat dissipation performance of the vehicle, a novel waveguide which cascades a rectangular waveguide filter and a cut-off ventilation waveguide array is proposed in this paper, The proposed structure can improve the electromagnetic shielding effectiveness to 40dB while achieving a larger area of effective heat dissipation.

the Heat-dissipating Waveguide Structure

The proposed heat-dissipating waveguide structure is designed as a rectangular cavity consisting of two parts. The first part is the rectangular waveguide filter with a high-order mode suppression ridge, which can achieve a 30dB attenuation at the frequency region from 800MHz to 2GHz; The second part is the ventilation waveguide array, which can achieve a 35dB attenuation at the frequency region below 800MHz. The rectangular waveguide filter is designed as a rectangular waveguide structure consisting of four resonant cavities, each cavity is coupled by the inductance diaphragms. Considering the poor performance of out-of-band attenuation of the traditional rectangular waveguide filters, the ridge structure is added inside the cavities to improve stopband attenuation. The aim is to suppress the high order modes of cavity resonance, thus effectively suppressing the electromagnetic fields of high frequencies .

In order to realize the optimal suppression of high-order modes by the filter, the parameters of the inductance diaphragms and the ridges of the rectangular waveguide are optimized. The final optimized structure dimensions are expressed as follows. The cavity length l_1, l_2, l_3 and l_4 are 64mm, 44mm, 44mm and 64mm, respectively; The ridge length r_1, r_2, r_3 and r_4 are 77mm, 51mm, 51mm, and 77mm, respectively; The side length of the ridges c_1, c_2, c_3 and c_4 are 18mm, 13mm, 13mm and 18mm, respectively; The width of the inductance diaphragms W_1, W_2, W_3, W_4 *and* W_5 are 142mm, 38mm, 108mm, 38mm and 142mm, respectively.

Taking into account the processing difficulty and heat dissipation efficiency, the cell diameter of the ventilation waveguide designed in this paper is relatively large, where the waveguide cell width w is set to be 32mm, and the cell depth h is set to be 30mmThe ventilation waveguide can achieve a 35dB stopband attenuation below 800MHz.

By cascading the rectangular waveguide filter and the ventilation waveguide, a waveguide that can prevent EMP and have heat dissipation efficiency can be realized. The insertion loss of this waveguide is given, indicating that the cascade structure can achieve an insertion loss of 40dB in the frequency range from 100MHz to 2GHz.

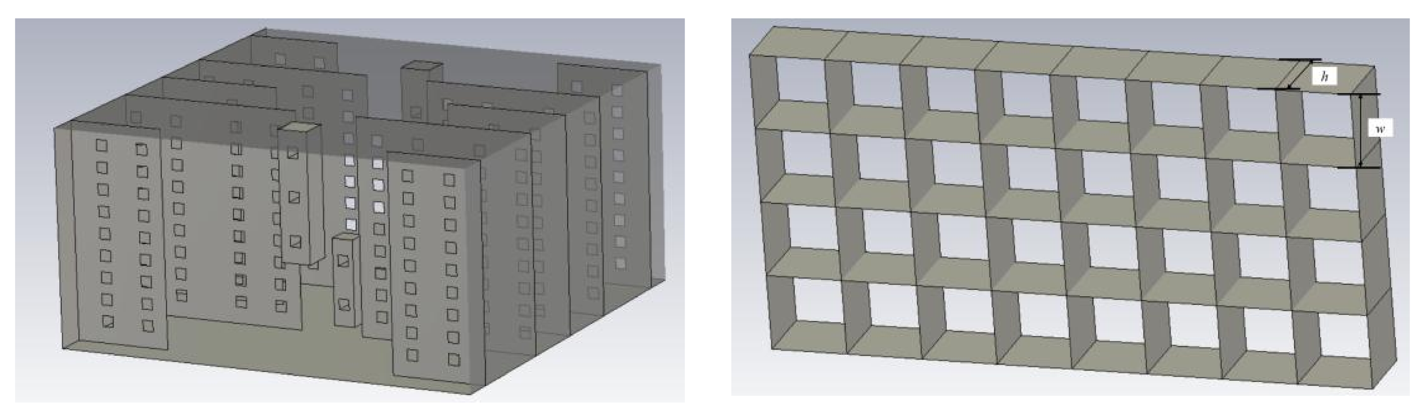


Fig. 3D view of the Heat-dissipating waveguide.

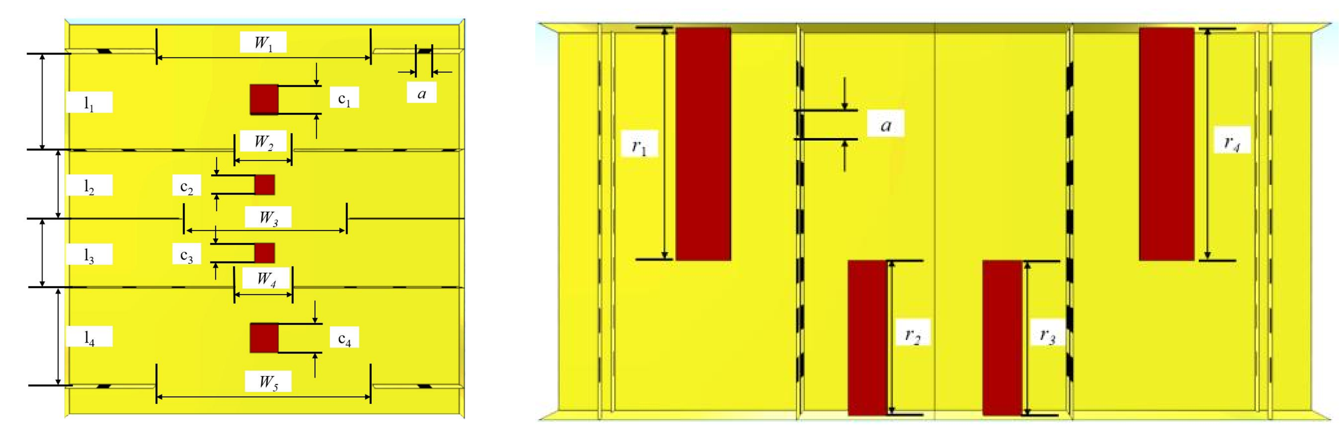


Fig. the Dimensions of the Heat-dissipating waveguide.

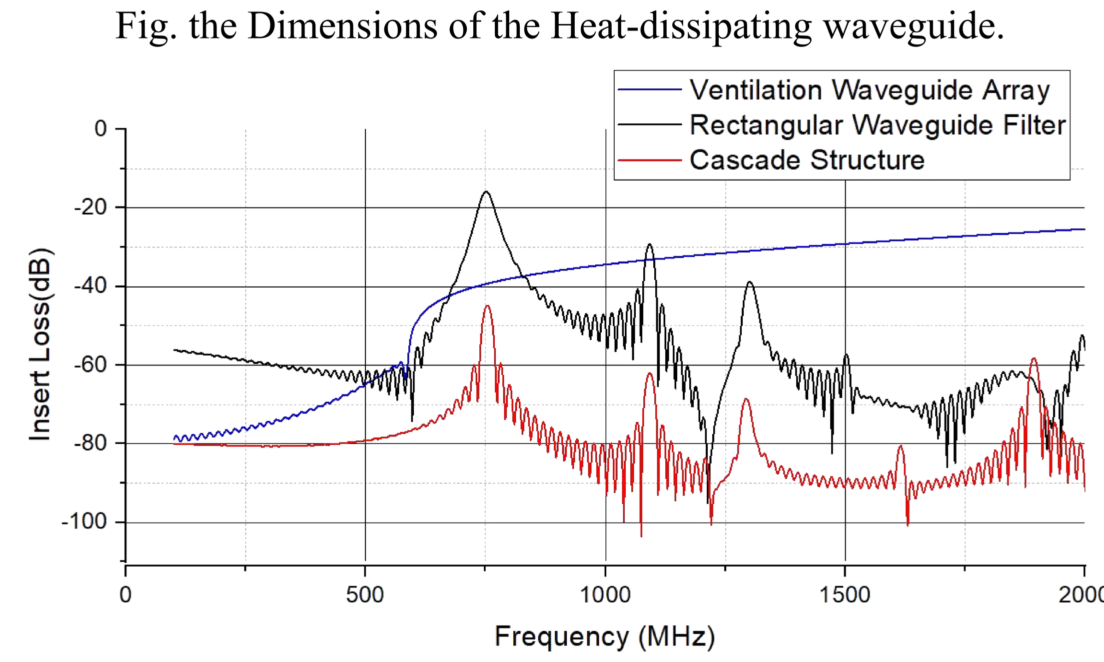
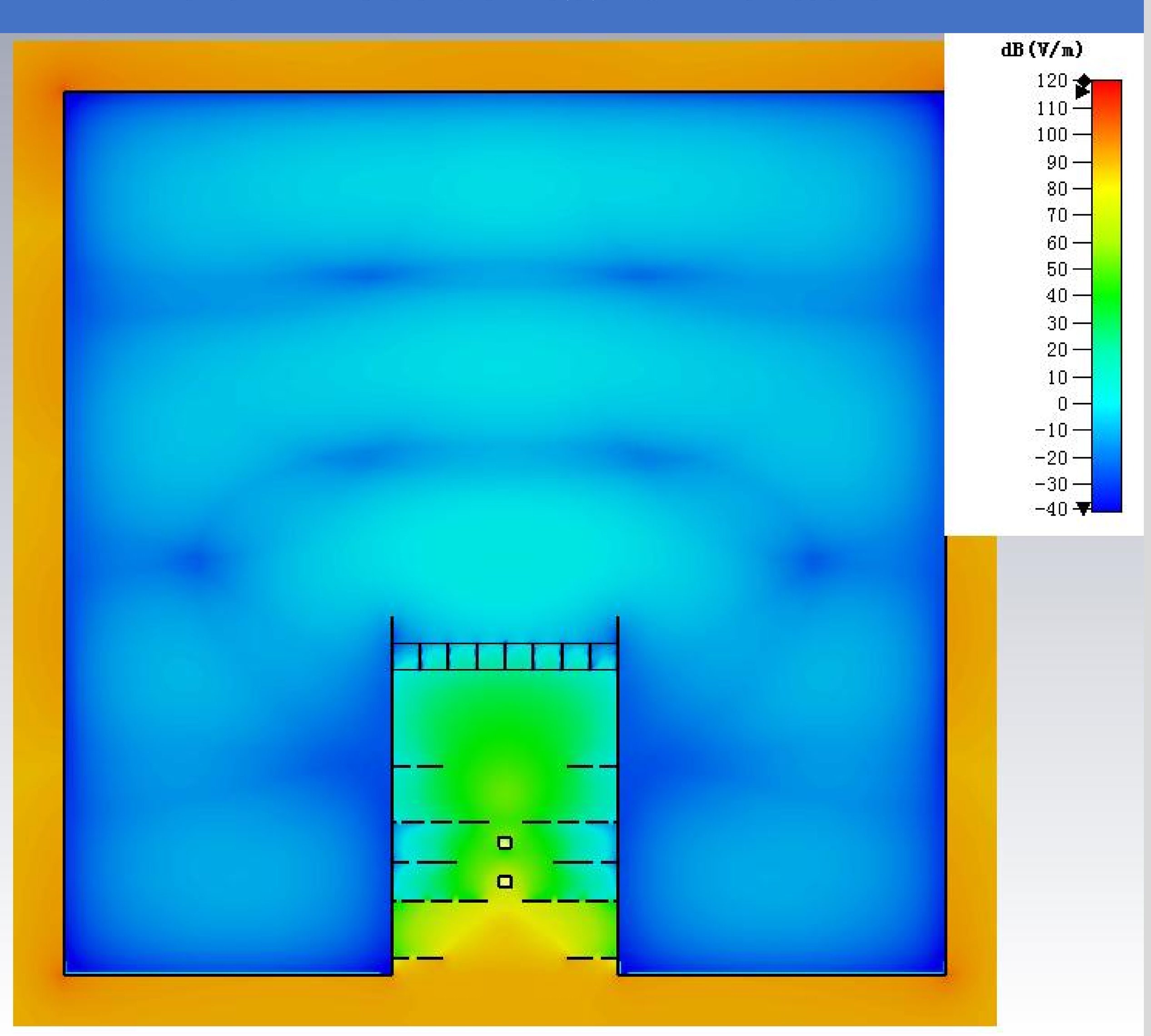


Fig. Insertion loss of the Waveguide Array, Filter and Cascade Structure

Shield Effectiveness Simulation



While the plane wave sweeps across the metal box, the peak magnitude of electric field outside and inside the metal box is approximately 90dBV/m and 10dBV/m, respectively, which indicates a good shielding effectiveness of the cascaded waveguide.

References

[1]K. Yu Sakharov, A. V. Sukhov, V. L. Ugolev and Y. M. Gurevich, "Study of UWB Electromagnetic Pulse Impact on Commercial Unmanned Aerial Vehicle," 2018 International Symposium on Electromagnetic Compatibility (EMC EUROPE), 2018, pp. 40-43.

[2] V. Venkateswarlu and Y. Narayana Rao, "Shielding efficiency measurements under pulsed electromagnetic fields," 1995 International Conference on Electromagnetic Interference and Compatibility (INCEMIC), 1995, pp. 161-165.

[3] M. Camp, H. Garbe and D. Nitsch, "Influence of the technology on the destruction effects of semiconductors by impact of EMP and UWB pulses," 2002 IEEE International Symposium on Electromagnetic Compatibility, 2002, pp. 87-92 vol.1.

[4] M. Camp and H. Garbe, "Parameter estimation of double exponential pulses (EMP, UWB) with least squares and Nelder Mead algorithm," in IEEE Transactions on Electromagnetic Compatibility, vol. 46, no. 4, pp. 675-678, Nov. 2004,.

[5] Y. Liu , L. Zhang, P. V. Klaine, et al. "Optimal Multi-user Transmission based on a Single Intelligent Reflecting Surface," 2021 IEEE 4th International Conference on Electronic Information and Communication Technology (ICEICT). Xian, China, 2021, pp. 1-4.

[6] B. Li, A. Zhang and X. Liu, "Dual Polarization Common Aperture Transceiver Antenna with High Radiation Performance," 2021 IEEE 4th International Conference on Electronic Information and Communication Technology (ICEICT), 2021, pp. 135-137.

[7] D. Zhang, S. Liu, Y. Xue, K. Li, Q. Cheng and X. Shi, "An Ultra-Wideband Circularly Polarized Probe Based on Vivaldi Antenna," 2021 IEEE 4th International Conference on Electronic Information and Communication Technology (ICEICT), 2021, pp. 263-266.

[8] W. A. Bereuter and D. C. Chang, "Shielding Effectiveness of Metallic Honeycombs," in IEEE Transactions on Electromagnetic Compatibility, vol. EMC-24, no. 1, pp. 58-61, Feb. 1982.

[9] S. Kim, Y. Kim, S. Pang and J. Yook, "Electromagnetic shielding effectiveness with multi-layered waveguide-below-cutoff array for improved air flow," 2017 IEEE Asia Pacific Microwave Conference (APMC), 2017, pp. 276-279.