Electromagnetic Compatibility Simulation Analysis of Helicopter Engine Irradiated by EMP

ChenHaoyang¹, FanYutang*²
¹Acc Hunan Aviation Powerplant Research Institute, Hunan,412002, China
²Research Institute for Frontier Science, Beihang University, Beijing,100191, China
*Corresponding author’s e-mail: fyt93107@buaa.edu.cn

Abstract. Due to the rapid development of battlefield complex electromagnetic environment research in recent years, electromagnetic pulse (EMP) environment has gradually stepped onto the stage of information war. To make low altitude flying electronic equipment engine plays its normal combat performance in the EMP radiation environment and ensure the integrity of electronic equipment, it is urgent to research in this field. In this paper, according to GJB-1389A and other standards, CST simulation software is used for simulation analysis. Through simulation, field strength and cable coupling with the airborne engine of an armed helicopter under EMP irradiation are predicted. The conclusions have a certain guiding significance of the further study of the protection against the complex electromagnetic environment of the engine.

1. Introduction
At present, the electromagnetic environment effect of EMP is a hot topic in the world. The EMP environment plays a major role in future electronic warfare. EMP is coupled to the target electronic system through the external port, slot, cable, and so on in the electronic system[1]. It breaks with the electronic components, causes interference and damage to the sensitive devices in the system, makes the computer and communication system temporarily confused or destroyed, directly kills the target, or makes the target lose its combat effectiveness[2]. Therefore, it is very important for the normal operation of the engine of air flight electronic equipment Big threat.

Because the simulation of EMP tests needs a lot of human and material resources, the test equipment is vulnerable to external interference, and the test workload is large[3]. Using comprehensive theoretical analysis and simulation to predict the complex electromagnetic environment is an indispensable work for engine development to enhance the adaptability of the electromagnetic environment. Simulation and prediction technology can calculate the complex electromagnetic field by computer, to get the same results as the actual EMP signal electromagnetic field, which greatly reduces the experimental cost and workload, and is easy to realize[4]. The research is very necessary for improving the adaptability of the engine to the complex electromagnetic environments, ensuring flight safety and exerting combat effectiveness[5].

2. Simulation settings
This paper takes an armed helicopter as an example to simulate the EMP effect, to analyze the influence of EMP on the engine cable coupling and the electromagnetic environment inside the helicopter. The EMC model of the helicopter is shown in Figure 1.
A cable bundle is set up in the helicopter engine cabin. The cable types are single-core wire, shielded twisted pair, and RG58 coaxial line. The two ends of the cable are respectively terminated with 50 Ω loads, and the cable length is 2m. The cross-section of the cable and the distribution of electric field probes into the engine cabin is given in Figure 1.
Depending on GJB-1389A, the engine system should meet the functional performance requirements after the EMP environment. Because this paper mainly analyzes the influence of EMP signal on the helicopter in flight, the six sides of the helicopter are all open boundary conditions[6]. The EMP signal is vertically incident from the right side of the helicopter body, and the polarization mode is vertical polarization, and its time-domain waveform is shown in Figure 2. When EMP has injected 5 ns, the peak field strength is 50kV/m. At 24μs, the field strength decays to half of the maximum that the peak field strength is 25kV/m.

![Figure 5. Time domain curve of EMP.](image)

Due to the need for simulation time, at least the half-width time $t = 24$ns should be included. In order to complete the EMP simulation analysis of the helicopter accurately and quickly, the simulation setting time is set to 5us. Since the excitation signal is the national military standard GJB-1389A EMP signal, its energy is mostly concentrated below 30MHz, so the simulation frequency range is 1KHz-50MHz, which can contain the main energy of the EMP signal.

3. simulation result

3.1. Simulation results of fuselage surface current

![Figure 6. Surface current of engine compartment at 5 ns.](image)
In Figures, the red area indicates higher current density, and the blue area indicates lower current density. At 5μs, the peak current of waveform a reaches 50kV/m, and the current density of the fuselage in the engine compartment is the largest, reaching 100A/m. After that, the current density decreases with the decrease of lightning current. At 24μs, half of the maximum current is 25kV/m, and the current injected into the helicopter is smaller than that at 5μs. At 2ns, the surface current of the helicopter disappears. Through the above analysis of the surface current distribution, it can be found that the surface current distribution of the engine compartment is related to its structure, and the structure has an important impact on its electromagnetic environment. Reasonable design of the engine compartment structure can make the helicopter in a better electromagnetic environment. Thus making the flight environment safer[7].

3.2. Simulation of electric field inside and outside aircraft
When EMP signal irradiates the engine compartment, the electric field intensity distribution inside the engine compartment is shown in Figure 9 and 10.
Figure 10. Frequency domain distribution of electric field in engine compartment. （The coordinate of reference point of pink curve is x = 5.9m，Pink curve X = 5.9m）

We can see that the two waveforms of the two observation points are basically the same, and the waveform distribution and peak time of each time period also have a small difference. The electric field intensity at x = 5.2m is slightly higher than that at x = 5.9m. The main reason is that the shielding effect of the whole structure is slightly poor due to the cool holes in the engine compartment, and the electric field intensity near the cool holes is slightly higher[8].

3.3. Simulation of cable coupling in engine compartment
Due to the assembly, welding, and heat dissipation of the engine compartment, the shielding effectiveness of the helicopter is seriously reduced due to the holes, windows, doors, and other components. Preset coupling current distribution of helicopter internal cable within 10KHz-50MHz is shown in Figure 11 and 12.

Figure 11. Time domain curve of cable coupling in engine compartment.. （Comparison between single core wire and shielded wire.）
Figure 12. Time domain curve of cable coupling in engine compartment. (Comparison between coaxial line and twisted pair.)

The maximum coupling current of the single-core wire is about 9mA. The coupling magnitude of the coaxial line and shielded twisted pair is smaller than that of a single-core wire. Maximum coupling values of shielded twisted pair and coaxial line are 35uA and 13uA respectively. EMP has little effect on shielding twisted pair and coaxial line. Due to the simplification of the model, the fuselage is simulated with a precise fully enclosed fuselage, and the cable coupling current is slightly smaller than the actual one. This is explained by the fact that in reality, the gap between the cockpit and fuselage is unavoidable, which has a more severe impact on the cables in the cabin[9]. Therefore, for the protection of the EMP effect, we should try to avoid the appearance of fuselage aperture and other structures, and take the measures of adding shielding partition to the key parts to enhance the electromagnetic shielding effectiveness.

Figure 13. Spectrum curve of cable coupling in engine compartment.

It can be seen from Figure 13 that under the same irradiation conditions, the frequency domain waveform of the coupling current on the single-core cable, twisted pair and the coaxial line is very similar. Except for some resonance points, the shielding performance of the single-core cable is about 30dB higher than that of the single-core cable. The coupling current of the coaxial line is similar to that of the twisted pair, and the shielding effect is about 3dB better than that of the twisted pair[10].

4. Conclusion
In this paper, according to GJB-1389A standards, using the powerful time-domain analysis function of CST, the electromagnetic environment inside and outside the engine compartment and the induced current of cables are simulated and analyzed. According to the simulation results, the coupling value of
the engine compartment under the EMP effect is given, which provides the basis of the optimization design of the engine and the protection for the EMP electromagnetic environment.

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