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# Progress in helicopter infrared signature suppression

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**Abstract** Due to their low-attitude and relatively low-speed fight profiles, helicopters are subjected to serious threats from radio, infrared (IR), visual, and aural detection and tracking. Among these threats, infrared detection and tracking are regarded as more crucial for the survivability of helicopters. In order to meet the requirements of infrared stealth, several different types of infrared suppressor (IRS) for helicopters have been developed. This paper reviews contemporary developments in this discipline, with particular emphasis on infrared signature suppression, advances in mixer-ejectors and prediction for helicopters. In addition, several remaining challenges, such as advanced IRS, emissivity optimization technique, helicopter infrared characterization, etc., are proposed, as an initial guide and stimulation for future research. In the future, the comprehensive infrared suppression in the 3–5 μm and 8–14 μm bands will doubtfully become the emphasis of helicopter stealth. Multidisciplinary optimization of a complete infrared suppression system deserves further investigation.



## 1. Introduction

Helicopters play important roles in air-to-ground fire covering and short-distance air-to-air fights, as well as battlefield force transferring and anti-tank missions. Due to their low-attitude and relatively low-speed fight profiles, helicopters are subjected to serious threats from radio, infrared (IR), visual, and aural detection and tracking. Among these threats, infrared detection and tracking are regarded as more crucial for the survivability of helicopters. Firstly, passive detection and tracking by infrared signature seeking missiles are tactically superior to active ones for a comparable detection range. Infrared seekers have exploited techniques to passively acquire and intercept airborne targets by detecting their infrared emitting energy. Developments in infrared detection and tracking have increased the effectiveness of infrared-guided missiles, which are now portable and have proliferated world-wide. The rapid advances in processor and detector array technology have led to enhanced sensitivity, low noise, multi-spectral, and smart detection capabilities.[1–3] On the other hand, with the increase of the ratio of power to weight for turbo-shaft engines mainly equipped in helicopters, the exhaust temperature increases tremendously, resulting in an infrared signature augment intensively. Consequently, infrared signature suppression is an important issue associated with helicopter susceptibility.

This paper reviews contemporary developments in this discipline, with particular emphasis on infrared signature suppression and prediction from helicopters. In addition,

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several remaining challenges are proposed, as an initial guide and stimulation for further research.

## 2. Sources of infrared signature

The sources of infrared signature in a helicopter and their classification are shown in Fig. 1. The important internal infrared sources include plume emission and surface emissions from the following: (a) engine hot parts, (b) exhaust plume, and (c) airframe skin heated by the engine and plume. Besides, the reflected skyshine, earthshine, and sunshine contribute to the total infrared signature.

The attenuation of infrared radiation in the atmosphere is highly dependent on wavelength of radiation, temperature, and composition of radiation participating gases. Mainly two atmospheric windows (3–5 μm and 8–14 μm) are used for surveillance and tracking where the transmittance is high. Tailpipe is the major and reliable source for infrared signature level in the 3–5 μm band because of the large amount of heat produced by combustion inside the gas turbine engine. The helicopter rear fuselage skin is always heated by the flow of hot combustion products in the embedded engine. Though the spectral radiance of the rear fuselage is less than that of the tailpipe, infrared emission from the rear fuselage is important especially in the 8–14 μm band. Meanwhile, the solid angle subtended by the rear fuselage skin is an order of magnitude larger than that of the tailpipe. Unlike surfaces of solids, gases emit and absorb radiation only at discrete wavelengths associated with specific rotational and vibrational frequencies. These frequencies depend on the particular type of molecules, temperature, pressure, and molecular concentration of radiation participating species. In general, the infrared signature level from the plume is much less significant than those from the tailpipe and the rear fuselage skin, especially in the 8–14 μm band.[4]

Thompson et al.[5] presented the infrared signature breakdown of a Bell-205 (UH-1H) helicopter in the 3–5 μm band, as shown in Fig. 2. The signature values shown in this figure were predicted using the infrared signature modeling software developed by DAVIS. The largest contributor to the helicopter infrared signature is the direct view of the 600–700 °C power turbine stages. The next signature component of importance is the hot tailpipe metal. Visible up to 120° off-tail, the tailpipe metal provides a strong target for infrared-guided missiles for all views from behind the helicopter. It is also shown that the engine exhaust plume is the least contributor, followed by the tail boom heated by the plume. When viewed from the front and sides, the plume and the airframe contribute, and when viewed from the rear, the engine hot parts become the major source of infrared radiation.

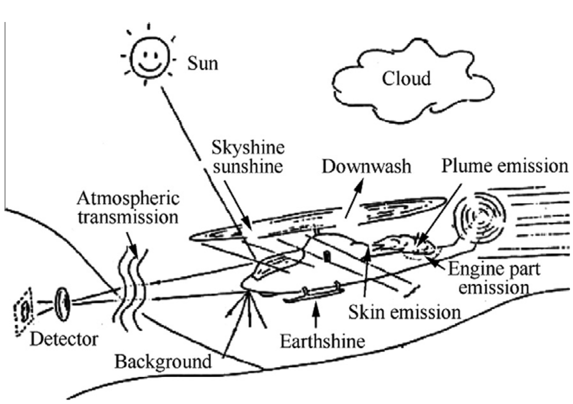


**Fig. 1** Sources of infrared signature in a helicopter and their classification.

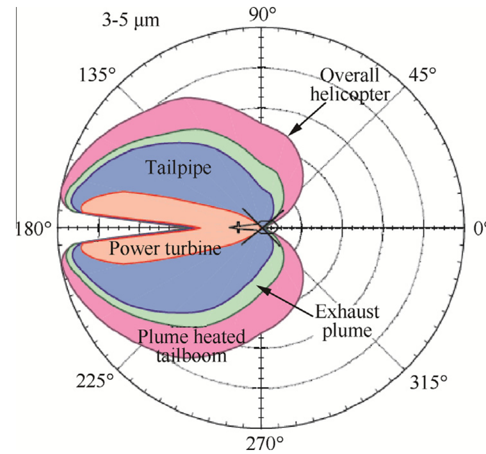


**Fig. 2** Infrared signature variation of a Bell UH-1H helicopter.[5]

## 3. Advances in infrared suppressors

The first generation of infrared suppressors (IRSs) for helicopters typically features an upward-bend nozzle shielded from a direct view by an insulating cowl. It is generally regarded as being adapted for opposing infrared-guided missiles working at the 1.7–2.8 μm band. While this principle holds for radiation of any wavelength, new warheads operating in the 3–5 μm band have the additional capability of locking on weaker signals emitted at relatively lower temperatures. The exhaust plume radiates a detectable amount of energy due to discrete rays in the carbon dioxide spectrum in the 3–5 μm band. Diluting the engine plume with cold ambient air decreases $CO_2$ concentration and temperature and therefore reduces the target detectability. This is most conveniently achieved by means of a passive ejector as has been widely recognized. When the primary jet mixes out to fill the larger area cross-section of the mixing duct, the turbulent shear layer entrains a secondary flow into the mixing duct to dilute the primary flow. Based on this mechanism, several different types of IRS for helicopter engines have been developed, such as cascaded ejector-based IRS, black hole ocarina (BHO) IRS, lobed mixer-ejector IRS, etc.[6–8]

### 3.1. BHO IRS

The BHO system used on the YAH-64 Apache helicopter is a low-cost IR suppressor[6] without any moving part, as seen in Fig. 3. In Fig. 3, $\theta$ denotes the azimuthal angle, $R_I$ is relative infrared intensity. Known as the "black hole" infrared suppression system, the principle revolves around directing the engine exhaust through special ducts which combine the efflux with the air-stream passing over the aircraft. The air-stream thus dissipates the hot exhaust that emerges from the vents evenly, rather than allowing hot spots to appear. Prior to exit, the temperature is further reduced from 574 °C to 304 °C. The engine exhaust ports are angled outward from the airframe to better direct the output into the air-stream. Secondary vents