MODELLING THE SIGNATURE VULNERABILITY OF A MAIN BATTLE TANK

Simon J. King and Mark A. Richardson

Abstract. If commanders are to have the freedom to move around the battlespace to locations where they can best influence the battle at the critical time and place they must be sure in the knowledge that they can do so undetected. Infrared (IR) sensors, with ever increasing sensitivity, are now well established in the land environment. IR signature management is therefore becoming evermore pertinent in that environment. Innovative design and the use of modern materials can reduce the external temperature range of a vehicle but can be expensive. It is therefore paramount that vulnerable areas on a vehicle are identified so that appropriate thermal camouflage can be applied in the most cost-effective manner. High-fidelity thermal signature models are available but are time consuming to run and heavy on computer processing power. A simple, easy to use thermal signature model would provide a ready alternative to the more exacting complex models. Whilst not attempting to replace the high-fidelity models for the detailed analysis of thermal signatures, a simple model would have utility as a first filter of trials data and the initial testing of signature reduction concepts. A single temperature difference model of the Main Battle Tank for input into a Minimum Resolvable Temperature Difference (MRTD) model is presented. The model is used to predict detection range reduction and thereby identify the areas on a MBT that require thermal signature reduction.

INTRODUCTION

In modern warfare commanders must have the freedom to move around the battlespace to locations where they can best influence the battle at the critical time and place [1]. An essential component to achieving this freedom to manoeuvre is the capability to detect; discriminate; identify (through active or passive, non-cooperative methods); and prioritise both ground and aerial platforms at ranges in excess of the effective ranges of the threat's detection and weapon systems, and inside the threats detection and response time. The capability must be effective day or night in adverse weather, in cluttered background environments, and in the presence of threat countermeasures. The achievement of this goal is initiated with the exploitation of the electromagnetic spectrum to provide surveillance information of the battlespace.

Infrared (IR) sensors, with ever increasing sensitivity, are now well established in the land environment. IR signature management in that environment is therefore becoming evermore important. The IR radiation is generated by a combination of solar radiation, reflection and heating and by heat generation by the object. This radiation can be observed as an apparent temperature difference between the object and its surroundings. Detection can result from either a positive contrast when the object radiates more than the background or a negative contrast when the background radiation is higher. The detection of objects therefore depends on a number of factors, such as operating environment and activity of the object. In the case of a Main Battle Tank (MBT) this creates a wide range of thermal signatures varying from the negative contrast of a wind-chilled stationary MBT to the positive contrast of a MBT on the move.

Signature management in the IR region is complicated by the environmental conditions, such as solar heating, wind chill, rain or snow, which can cause unpredictable thermal contrast. The thermal contrast is a function of the external temperature and emissivity of the object. Innovative design and the use of modern materials can reduce the external temperature range of an object but can be expensive. It is therefore paramount that vulnerable areas are identified so that appropriate thermal camouflage can be applied. This paper presents a method of generating a single temperature difference model for input into a Minimum Resolvable Temperature Difference (MRTD) model. The model was used in a case study based on a contemporary MBT to predict detection range reduction and thereby identify the areas on the MBT that require thermal signature reduction.

THERMAL CONTRAST

In a normally lighted visual scene there is no shortage of contrast variations between the objects in the scene. The contrast arises from the surface properties of the materials of which the objects are made. In visual images there is colour contrast as well as brightness contrast. Colour contrast results from the variation of energy between spectral wavelength bands, whereas brightness contrast results from the energy variation between the objects and the surrounding environment. This contrast mechanism applies equally to infrared or thermal scenes as it does to visual scenes. Planck's radiation law states that every object at a temperature above absolute zero emits electromagnetic radiation, and the higher the temperature the higher is the emitted intensity. This equally applies to the background of a scene. Therefore for an object to be detectable there must be a difference in the radiated energy originating from the object and the radiated energy originating from the background. This thermal contrast can equally be positive, object energy greater than background energy, or negative and can be expressed as:

$$C = \frac{M_{Object} - M_{Background}}{M_{Object} + M_{Background}} \qquad (1)$$

where M_{Object} = Power per unit area from the object

$M_{Background}$ = Power per unit area from the background.

This thermal contrast expression accounts for the brightness contrast in a scene. The colour or spectral variation is defined by Planck's law, which represents the power per unit area per unit wavelength as:

$$M_{\lambda} = \frac{c_1}{\lambda^5\left[\exp\left(\frac{c_2}{\lambda T}\right) - 1\right]} \qquad (2)$$

where M_{λ} = Spectral Radiant Emittance ($Wm^{-2}\mu m^{-1}$)