A Miniaturized Identification System for the Dismounted Warrior

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ABSTRACT

The paper is presenting a novel concept for identifying friend or foe (IFF) ground troops, without target cooperation The idea is based on the principles of Non-Cooperative Target Identification (NCTI), which has been applied so far mainly to combat aircraft. The main objective of NCTI is the elimination of fratricide, which may occur due to a possible malfunction of standard, active tagging systems. The interrogator does not require any signal, originally emanating from the target, in order to make a decision. On the contrary, the target classification depends on the scattering of a waveform, initially radiated from the interrogator, and backscattered from the target outer surface. The decision is made by comparison of the backscattered field to samples from a stored data base. For the ground troops case, to amplify the backscattered field, relatively large, conducting surfaces should be exploited, such as the soldier's helmet. The form of the scattered field can be suitably tailored, by attaching miniature cavities, or reflectors, to the helmet surface. Scientifically documented results of electromagnetic scattering analysis from inlets will be taken into account.

1.0 INTRODUCTION

Non-cooperative target identification (NCTI) has always been a crucial research area for the military. Its purpose being fratricide reduction, it is currently the main focus of several SET task groups, including SET068/RTG ("*Modeling, Analysis and Recognition of Radar Signatures for Non-Cooperative Aircraft Identification*"), and SET-053/RTG29/RFT ("*Ground Target Automatic Recognition by Radar*"), while its importance triggered recently the creation of at least one spin-off group, namely SET 085 RTG49 on "*Radar Signature Prediction of Cavities on Aircraft, Vehicles and Ships*". All these groups study the electromagnetic response of a military target to RADAR illumination, and investigate the possibility of using its features to identify it as friend or foe, without necessarily requiring its active cooperation. NCTI has been related so far to aircraft, vehicles and vessels, but its basic concept may be applicable to dismounted troops. A directive antenna could be attached to the soldier's rifle, with its main, narrow lobe aligned with the aiming direction. Since the range of the system would not normally exceed a few hundred yards, the antenna power could be sufficiently low, allowing small size to the radiating structure, and also posing no health threat to the user. The same antenna should be designed to be functioning as a receiver, too. To facilitate troops' identification via this antenna, the helmet of allies may be covered with an array of miniscule inlets or reflectors, amplifying and beam-forming the backscattered field. Alternatively, ally uniforms can be equipped with some special fabric, e.g. embedded metallic fibers, that would guarantee an extraordinary electromagnetic return to the interrogating antenna, thus notifying the aiming soldier that the target is not hostile. A warning mechanism, such as a red light, and/or a buzzing sound, would prevent the soldier from shooting.

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2.0 ELECTROMAGNETIC SCATTERING AND INLET MODELING

NCTI is basically exploiting electromagnetic scattering, to determine, roughly at least, the geometrical form of the target. A specific RADAR waveform is produced by the interrogator's transmitting antenna, and is directed towards the object to be identified. The electromagnetic radiation is scattered towards all possible directions, and a portion is directed back to the interrogator, subsequently intercepted by its receiver. By analyzing the parameters of the backscattered field, several important features of the target can be extracted, in addition to range and velocity, for which RADAR is widely known. In principle, an approximate image if the target can be reconstructed, revealing the identity of the target. However, such images are still very coarse and inaccurate, and hence unreliable for definite identification. Alternatively, the values of the measured, backscattered field are compared to a data base, which has already been generated for an array of known targets, via measurements and/or mathematical predictions. The algorithm, that compares the receiver input with the data base, is called a *classifier*. Its goal is to identify the target, by determining whether its signature resembles any one belonging to the data base.

To quantify the discussion above, let the transmitter power be P_t, the antenna gain be G, the radiated wavelength be λ, and the distance of the target be R. The received power P_r is given by the well-known RADAR equation, namely [1]

$$P_r = \frac{P_t G^2 \lambda^2 \sigma}{64\pi^3 R^4} \quad (1)$$

where σ is the Radar Cross Section (RCS) of the target, which has dimensions of area (square meters in SI), and characterizes its scattering properties. In general, the RCS, whose formal definition in three dimensions is given by

$$\sigma \equiv \lim_{R\to\infty} 4\pi R^2 \frac{P_r}{P_t} \quad (2)$$

is not a constant parameter, but is a function of the incoming and outgoing directions, frequency, the shape and the substance of the target. Hence, the geometric and physical properties of the target are contained in σ, and therefore can, in principle, be extracted from the values of the received power P_r in (1). Furthermore, by intervening to the shape and material features of the target, it is possible to increase or decrease its RCS, according to specific requirements. Stealth design, for example, minimizes σ for the widest frequency band possible, suitably shaping the target, and covering it with a radar absorbing material (RAM). Similarly, appropriate treatment of the scatterer may maximize the RCS, to increase its detectability.

Among all types of scatterers, inlets and cavities have been receiving special attention for more than twenty years [2]. The main reason is the mathematical complexity involved in their analysis, along with their frequent occurrence on aircraft, which complicates the overall RCS prediction of the latter. A few, simple inlet geometries have been fully characterized via rigorous mathematical techniques, and their scattering behavior is completely understood. For instance, the cylindrical cavity, shown in Fig. 1, has been analyzed via mode matching [3]. The most interesting property of such a cavity is that its RCS pattern (see Fig. 2) varies drastically with the following parameters: outer radius b, inner (hub) radius a, and lengths l_1 and l_2. Therefore, by choosing suitable values of four different degrees of freedom, the RCS of the cavity can be tailored in such a way that backscattering, for specific incidence angles, can be much more significant than a flat target of similar size. Also, scattering can be designed to be substantial for only a narrow frequency band. The selectivity of the scattering properties for this inlet can be tuned, by modifying its dimensions, and especially lengths l_1 and l_2, which may even become continuously variable, via a suitably designed mechanism. Additionally, several inlets of the same type may be gathered together, to form an inlet array. In that case, additional degrees of freedom for a suitable design will be the distances among the arrays elements (single inlets).

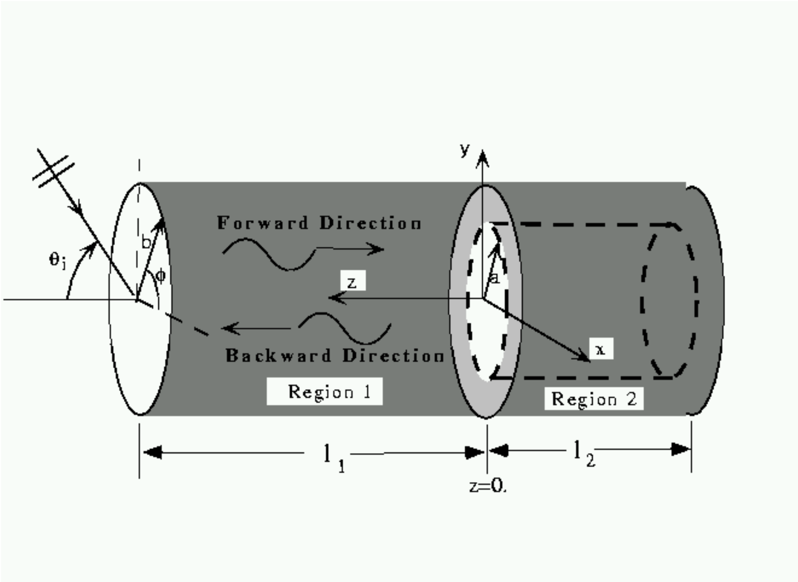

Figure 1: A cylindrical inlet containing a cylindrical hub

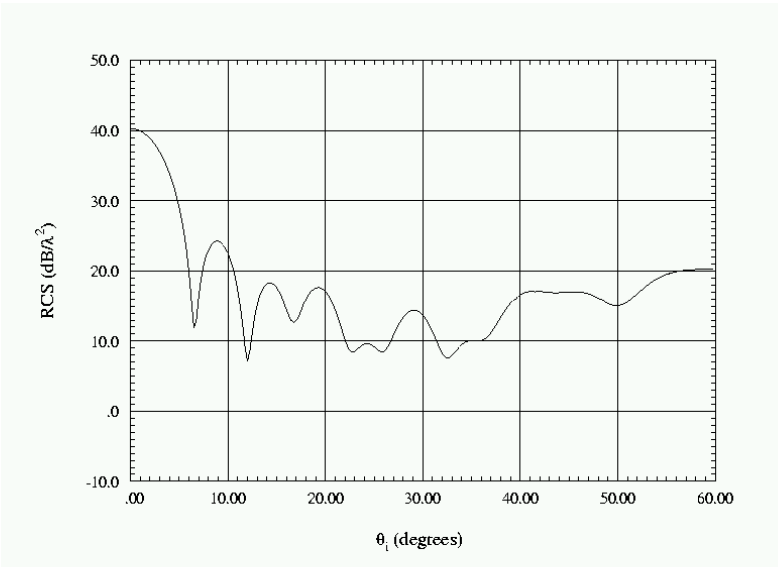

Figure 2: Typical RCS pattern as a function of incidence angle, for an inlet shown in Fig. 1

3.0 APPLICATION TO THE SYSTEM CONCEPT

The basic idea of an electromagnetic-based identification system is to classify targets (soldiers under interrogation), as friends or foes, according to their scattering signature (RCS value). The interrogator's weapon should be equipped with a suitable transmitter (e.g. a small horn antenna) (see Fig. 3), radiating a narrow beam parallel to the aiming direction. After bouncing off the soldier, the backscattered field is received by the same, or similar antenna, and serves as a classification tool. To distinguish between friends and foes, care should be taken a priori, so that the RCS of friends be completely different from the RCS of foes. A possible way to achieve this goal, is to cover the helmets of friendly troops with arrays of inlets, similar to the types discussed in the previous section (see Fig. 4). The dimensions of the inlets should clearly be such that the helmet would demonstrate very substantial backscattering for a particular frequency only. At that, secret frequency, friendly helmets will backscatter a much stronger field than enemy helmets. This field will be transformed to a strong signal at the receiver input, which will, in turn, notify the interrogator of the target's identity, so that the latter holds fire.

To achieve a highly directive beam, so that the system focuses on a particular target without disruptions, a suitable lens, or a metamaterial slab at the horn aperture may be utilized. The power required would not be excessively high, since the system's functionality would be oriented towards short-range applications (urban battle, for example). Therefore, the power supplier would not be particularly bulky, and hence it would not be a burden to the interrogator. The frequency should also be chosen high enough, to facilitate the use of a relatively small antenna, for the same reason. An additional salient feature of the inlet array would be possible tuning to various frequencies, by varying the inlet depth, for example, for additional secrecy.

The system proposed herein has not been developed yet, but it was presented at the meeting mainly to provoke fruitful discussions and exchange of ideas.

4.0 REFERENCES

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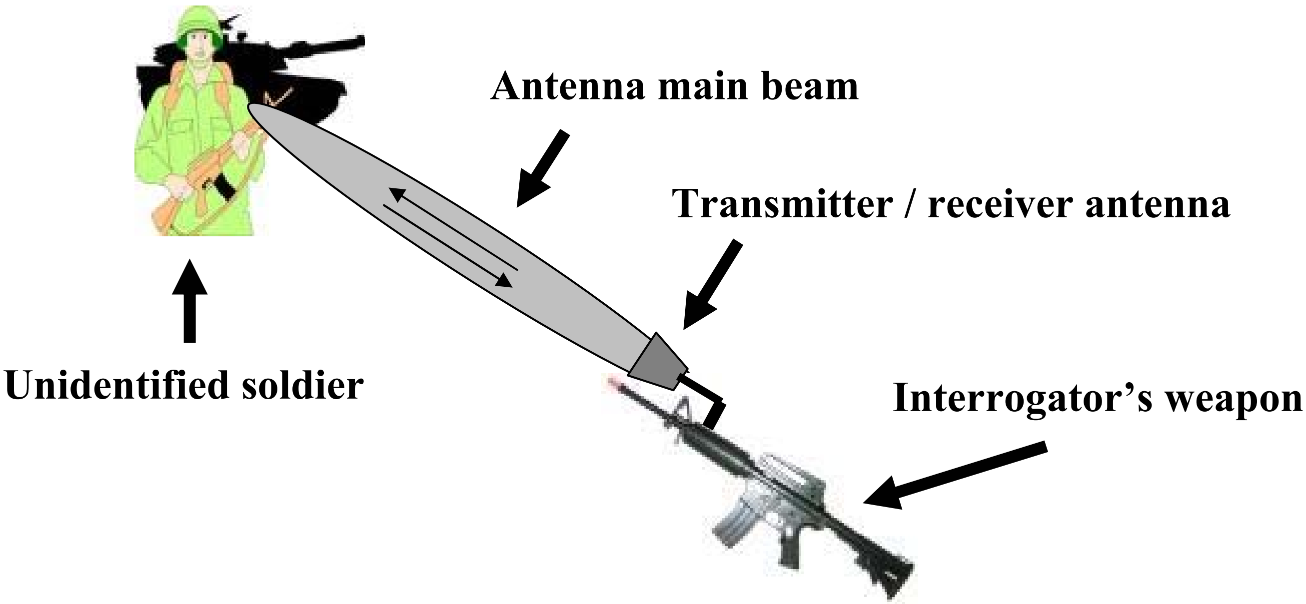

Figure 3: The main concept of the identification system

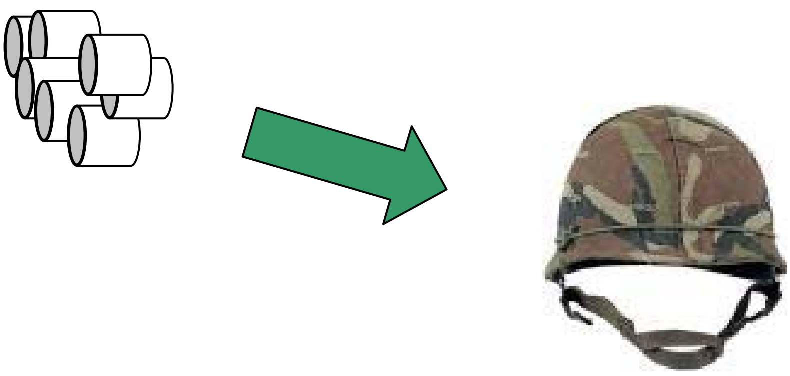

Figure 4: Helmet coverage with inlet array