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An Innovative Design of Landmines Detector Using High Power Microwave Source and IR Camera

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***Abstract*— The statistics indicate that every year about 110 Million of landmines kill about 12 thousand persons and in Iraq only, about 25 million landmines. Furthermore, the landmines affect bounds the usage of land for agriculture purpose in more than 60 countries. Inappropriately, the present approaches of landmines detection have disappointing detection, high false alarm amounts, and are time consuming. This article defines a remote sensing with mobility design of landmines detector based on microwave source and improved IR imagery, which includes enlightening hidden and buried landmines according to the thermal signature at the soil surface. This method complements the passive infrared remote-sensing method for mine detection. The main advantages of this method include the simplicity of the underlying principle of target detection, remote-sensing operation, ability to detect targets under cloudy conditions with little dependence on solar diurnal cycle and ability to detect both metallic and non-metallic mines.**

Index Terms*— *Landmine, IR Camera, HP Microwave.

I. Introduction

It is an underestimation if the global landmines problematic postures a danger to the persons in the infected countries. The goal of many non-governmental organizations, for example The Canadian Red Cross [1] [2] is to clear the landmines fields and terminate stockpiles. The current global agreement to ban the use of Anti-Person (AP) mines by most countries has promoted support to develop enhanced approaches of demining. For this reason, research is being done to find fast, simple, inexpensive and reliable ways to improve or replace the present methods of demining. The furthermost communal technique for distinguishing different varieties of buried landmine is by the usage of manual prober. This technique is unsafe and requires extra time.

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The second method for detecting mines develops typical electromagnetic initiation methods. A second issue associated with metal detection is that some mines contain little or without metal, thus generating a supplementary undetected hazard for the de-miners. The most promising new techniques for landmines detectors include a Ground Penetrating Radar (GPR) [3], passive IR remote-sensing [4], Thermal Neutron Activation (TNA), Radiometry [5], a chemical detector, as well as other electromagnetic [6] and acoustic methods [7].

The technique of passive IR has been considered and is presently used for military landmines field detection [8]. This method detects the infrared power assumed off by the solar heating special effects to create a thermal signature at the external surface of the soil area. The landmine signature is formed outstanding to the variance in the heating amounts among a buried mine and the nearby soil. It is reliant on on the quantity of solar illumination, variations in soil temperature, soil nature, and surface clutter, and the penetration depth of the mine [9]-[12].

The main benefit of this technique is that microwave radioactivity causes a volumetric heating rather than only heating the surface of the soil and depend on transmission to extent the heat to the buried mine. The required time to necessarily heat the mine to producing a thermal signature is critically decreased using microwave illumination. As a continuation of the previous study, the present work includes the proposed design for landmine detection system carried by small vehicle using a 2450 MHz microwave generator as a heating source and high sensitivity IR camera.

II. General System Design

In this Section, we will describe the principle of the HPM/IR method for mine detection and point out the differences between this method and the passive infrared method for the detection of the buried mines, and the basic structure shown in Fig.1.

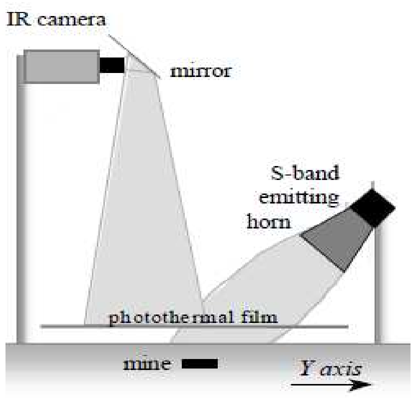

Fig. 1 HPM/IR general system design

The HPM/IR method is based on the fact that in general the complex dielectric constant of a mine is different from that of the soil surrounding it. When a mined area is radiated with high power microwaves, a fraction of the incident HPM radiation is reflected back to the atmosphere and the balance is transmitted into the ground. The transmitted component is attenuated within the ground at a rate which is dependent on the dielectric properties of the soil. Further, when the transmitted component is incident on an interface, such as a soil/buried mine interface, it is partly reflected back into the soil and the balance is transmitted into the mine.

The HPM components incident at and reflected from the soil/mine interface interfere and produce an interference pattern in the soil above the mine which leads to alternating hot and cold areas in that region. Further, a fraction of the HPM radiation transmitted into the mine is absorbed by the mine. As a result, the mine will be warmer or colder than the soil surrounding it dependent on the relative values of the complex dielectric constants. Both of these phenomena, the microwave interference above the mine and the microwave absorption by the mine, lead to a thermal signature of the mine on the soil surface which can be detected in the thermal infrared region. The thermal signature of the mine at the soil surface due to the reflection of microwaves at the soil/mine interface occurs in near real- time from the start of HPM irradiation. The thermal signature at the soil surface, due to microwave absorption by the mine followed with a thermal conduction process, occurs after a small time delay following HPM irradiation. At any instant, the thermal signature of the mine at the soil surface is a sum of these two components. The infrared detector detects only the resultant temperature contrast at the soil surface above the mine.

III. Estimation of System Parameters

To establish the mathematical model, we can say that when f is the magnetron frequency and is equal to 2450MHz and if we use a waveguide of WR340, then:

λ =wave length

c= signal speed

= 300 000000 m/sec

$c = \lambda * f$

or :

$\lambda = c/f$

= 0.1224 m

= 12.24 cm

If the distance R from the open waveguide to the air/soil satisfies and D is the maximum dimension of the waveguide aperture:

$$R \geq \frac{2D^2}{\lambda} \tag{1}$$

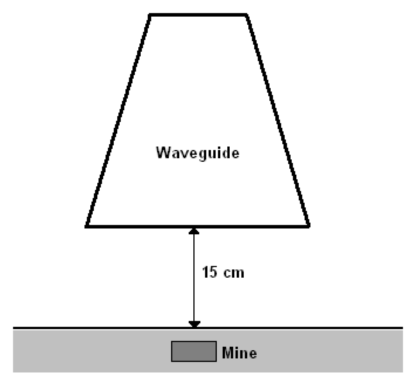

Fig. 2 Distance R from waveguide to the soil

In WR340 Waveguide, Fig. 3, D= 9.35 cm, when D is the largest dimension of the waveguide aperture the largest open (Diagonal) of the waveguide.

Then R ≈ 15 cm

When,

a: longest side of the waveguide

b: smallest side of the waveguide

In WR340, Fig. 4,

a= 8 cm , and b= 4 cm

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The microwave power density at the surface of the sand:

$$D_T = 0.81\frac{4\pi ab}{\lambda^2} \qquad (2)$$

The waveguide dimensions used were a and b:

a=8.636 cm and b=4.318 cm

The estimated transmitted power used is:

$$D_T = 2.53 \text{ w/cm}^2$$

Or:

$$D_T = 1\text{-}3 \text{ w/cm}^2$$

Then, the power density, estimated to be 1 to 3 W/cm².

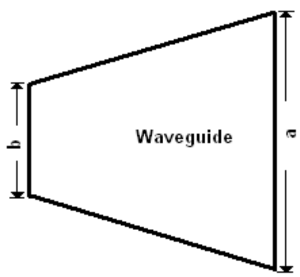

Fig. 3 WR340 waveguide dimensions

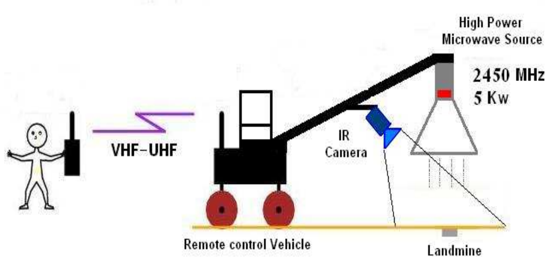

Fig. 4 Proposed System Units

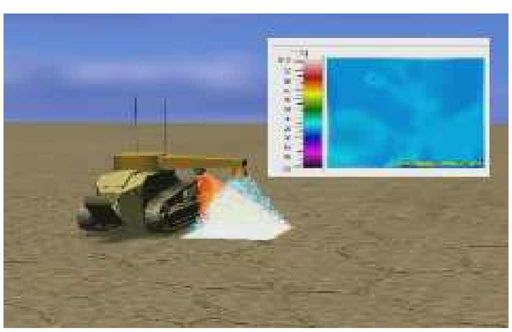

Fig.5 The proposed system animation

IV. The Proposed Model

The proposed model is shown in Fig. 5 while Fig. 6 shows the model animation. A hybrid remote sensing apparatus is grounded on an active high power microwave illuminator and a passive infrared for the detection of shallow buried landmines. A 2.45 GHz, 5 kW microwave source is used for illumination and the thermal signature at the soil surface and also is used to detecting the mines in 3 fan zones in real time.

Another thermal signature is produced once temperature differences outstanding to difference microwave preoccupation by a landmine and the nearby soil are directed upwards from the landmine place to the soil surface. The both signatures are reliant on the composite dielectric coefficients of landmines and the soil. These signatures can be used to define the location of different kinds of non-metallic and metallic landmines surrogates, dummy landmines (without explosives) and live landmines with explosives.

In Fig.5, the main elements of the proposed system model are shown. The basic system components abed on three main parts or units, the HPM source, IR Camera, and the positioner unit as explained below:

- High power microwave source with magnetron of 2450 MHz and power of 5 Kw.
- IR camera with sensitivity less than 0.1 C.
- Mines locator system, supported by GPS system to points landmines positions.
- Remote control system using VHF-UHF transmitter and receiver to control the vehicle motion.
- Remote sensing vehicle to carry the detection units.

V. Results and Discussion

The main indication of any object in the sand happened at least for three minutes in each experiment. An optimum procedure was studied by performing experiments with a few different waveguide heights and with or without a horn. The thermal signature images obtained by the IR camera of a buried object are shown in Figures 8 to 10. The graphical evaluation of these objects signature with the heating spot is enclosed in Fig. 8 and exposes that there is very little to differentiate between a object (mine) signature and a thermal image with no mine. For this and other motives, recommendations are prepared for additional studies in IR image processing in order to improve the effectiveness of this method.

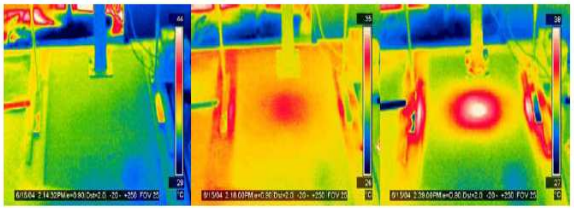

Fig. 6 Microwave heating source with buried mine buried in depth of 1 cm and after 0, 3, and 13 minutes

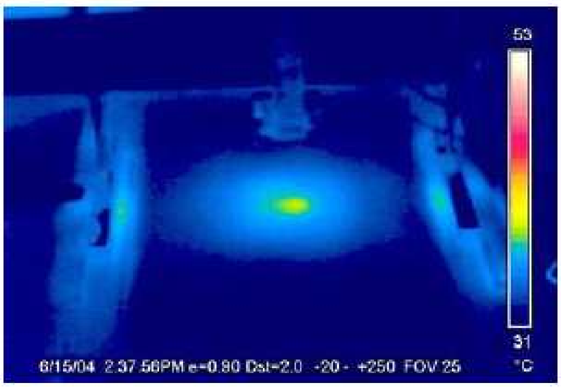

Fig. 7. Microwave heating mine buried in depth of 1 cm and 23 minutes

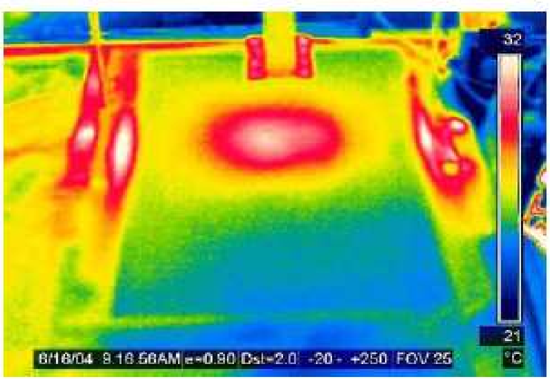

Fig. 8. Microwave heating without mine and after 15 minutes

In Fig. 9, there is a very clear thermal image of the object (mine) taken in the equivalent experiment shown in Fig.8. This was consummate by manually modifying the temperature rate of the IR camera from a 27- 38 ºC range to 31-53 ºC. As shown, even a simple regulation expressively advances the images. Furthermore, it should be expected that the spot diameter of this particular 2450 MHz assembly was considerably smaller than the 915 MHz type.

It is not clear at this point as to which spot size would be optimal for buried object detection. One could argue that a larger spot size might cover more area and perhaps with the correct power density would be better than such a confined arrangement.

VI. Conclusion

This article provides an experimented model to detect the landmines using a novel technique. This technique based on using high power microwave source to increase the mines thermal in soil and then use IR camera to get clear image that can assist to detect the mine place in specific area. The final model should be carry by remote control vehicle to avoid using the humans in the detection process. Furthermore, the proposed model not so expensive and can achieve high detection ratio with high accuracy but the use of this technique may require extra time with wet soil or when the minefields includes mines deeply buried in the soil.

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