Electromagnetic Inversion

A. Peter M. Zwamborn
TNO Physics and Electronics Laboratory
Oude Waalsdorperweg 63
P.O. Box 96864
2509 JG 's Gravenhage
The Netherlands

1. INTRODUCTION

1.1 The Land Mine Pollution Problem

The pollution of areas with large quantities of anti-tank and anti-personnel land mines, especially in countries of former armed conflicts, like Afghanistan, Angola, Cambodia, Iraq, Kuwait, Somalia, Vietnam and Yugoslavia, is a major problem. According to United Nations estimates, the number of uncharted buried anti-personnel mines exceeds 100 million, in over 60 countries around the world. The rate of new mines being laid is about one million per year, which surpasses the number of mines cleared by a factor of twenty. Some 2 million mines have been deposited in the war-torn areas of former Yugoslavia alone. Whole areas of countries, especially Cambodia, have been severely held back from further development [1].

According to the Mine Clearance Planning Agency in Afghanistan, over a period of 15 years an estimated 20,000 civilians have been killed and 400,000 wounded by land mines in that country. The current rate is 4000 killed and another 4000 wounded annually, world-wide. Injuries are horrific and usually result in amputation; returning refugees to conflict zones often find minefields in previously farmed lands, and usually have to clear the land themselves. Methods used at present for locating and clearing mines are painstaking, costly, time consuming and highly dangerous. Those methods include the use of sniffer dogs, magnetic mine detection aids (e.g. metal detectors) and manual probing. These methods are very slow and involve teams of two working their way along rows as narrow as 1 m across. For instance, a team of 30 men with dogs is able to cover only 2000 squared meters per day. The costs of such clearance is reported to lie between $ 200 (US dollars) and $ 1000 per mine. After the food problem, the so called land mine pollution problem is seen as the biggest humanitarian problem in the world [1].

Initial moves have been made towards a world-wide ban of land mines. In December 1993, the United Nations General Assembly passed a non-binding resolution calling for such a ban. In the 1981 United Nations Convention, some rules governing the use of land mines (considering for example the automatic neutralization of land mines and the obligation to record pre-planned land minefields by means of maps) have been agreed upon. This international law regulating the use of land mines, the 1981 Land Mines Protocol, at present only regulates the use of land mines in wars, but not in internal conflicts, and has been ratified by only 39 countries. Meanwhile, new minefields have been created in Georgia, Armenia and Tajikistan, for example, as well as in the territories of former Yugoslavia.

In May 1996, a United Nations Review Conference of the 1981 Convention finished in Geneva. One of the main topics was land mines. Some additional rules to those of 1981 were agreed upon. Internal conflicts are now also covered by the convention. It was further agreed that land mines must have a self-deactivation device and that they must contain at least 8 g of iron, to be detectable by the current types of mine detectors.

The above discussion on the land mine pollution problem demonstrates the need to develop new technologies to increase the efficiency and to reduce the costs of mine clearing operations.

1.2 Electromagnetic Inversion

The detection of objects buried in the ground is in general difficult. An even bigger problem is discrimination or classification of the buried object. The first problem is the ground itself. It is usually very inhomogeneous and has a complicated layered structure, often containing rocks and voids. Moreover, many other objects like metal cans can be present in the ground. Without a reliable identification method, the false-alarm rate of a ground-penetrating-radar system would be so high that the cost of clearing of a minefield would be prohibitive.

The objective of this lecture on inverse methods is to present some methods to carry out detection of buried objects. Subsequently, the reconstructed data is available to dedicated pattern recognition algorithms to obtain classification of the detected object.

In general the electromagnetic data is obtained by using fixed-frequency systems operating at a single or multiple frequencies or ultra-wideband systems. The term ultra-wideband is used in all situations where one deals with pulses of extremely short duration. A pulse of almost zero duration, which approximates a delta function, contains almost all frequencies. Hence, short pulses are ultra-wideband pulses. It has been claimed by some authors that UWB systems have many advantages compared to fixed-frequency systems when used for probing the ground [2], [3]. In a UWB system, like a ground-penetrating-radar system, a large amount of individual frequencies are applied towards the object of interest.

1.3 The EM-Inversion Methods Presented in this Lecture

The first method that is presented is denoted as "Microwave Image Reconstruction Methods" by S. Primak *et. al.* This method uses a special mapping of gathered data and in this paper a tutorial type overview of microwave tomographic imaging is given. The second method that is presented is denoted as "Two-Dimensional Inverse Profiling: Nonlinear Optimization and Embedding" by A. Tijhuis *et. al.* In this

Paper presented at the RTO SET Lecture Series on "Advanced Pattern Recognition Techniques", held in Bristol, UK, 14-15 September 1998; Rome, Italy, 17-18 September 1998;

paper, a method is presented to solve nonlinear inverse scattering problems. This approach is based on the availability of efficient iterative solvers to carry out the electromagnetic computations. The last method discussed in this lecture is denoted as "Non-linear Inversion Based on Contrast Source Gradients" by van den Berg *et. al.* This method is an algorithm for reconstructing the complex index of refraction of a bounded object. Also, this method incooperates efficient iterative solvers.

REFERENCES

1. EUREL,
International Conference on the detection of abandoned land mines: a humanitarian imperative seeking a technical solution,
Edinburgh, October 7th-9th 1996,IEE conference publication 431,
Institute of Electrical Engineers,London,ISBN 0 5296 669 5.

2. Baum, C.E.,
Signature-based target identification and pattern recognition,
IEEE Antennas and Propagation Magazine,
vol. 36, no. 3, pp. 44-51, 1994.

3. Baum, C.E. and E.J. Rothwell, K.M. Chen and D.P.Nyquist,
The Singularity Expansion Method and its application to target identification,
Proc. of the IEEE, vol. 79, no. 10, pp. 1481-1492, 1991.