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Original Article

# Plastic landmines detection enhancement in non-homogeneous environment

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***Abstract***
Mine detection techniques require extremely high detection rates. In this paper, enhancement in a signal processing algorithm is applied in the ground penetrating radar (GPR) in an ongoing research. In GPR microwave signals penetrate into the ground until a buried object reflects them back and the reflected signals are processed in order to extract information about the target. The main purpose of this paper is to apply an algorithm that provides a solution to the main problem of GPR application, which is the strong reflections from non-homogeneous clutter and other reflections from underground rocks and other materials. In this work the synthetic aperture radar (SAR) processing is applied to enhance resolution and SAR matrix is formed as GPR moves to the next position, followed by adaptive reference subtraction. Afterwards, a sand surface removal, reference subtraction and transition detection are applied in order to emphasize the weak reflections from the buried plastic landmine only and remove other reflections. The results obtained show that the algorithm worked well in the presence of high noise and non-homogenous clutter environment.

## I. INTRODUCTION

The detection and identification techniques for buried objects have been a great interest to researchers for many years. There are many techniques have been studied and many signal processing techniques involved to achieve the required results. In this paper a solution is offered to the main problems associated with the GPR which are the strong unwanted reflections[1]. In this paper, a signal processing algorithm is used which makes use of the synthetic aperture radar (SAR) processing in order to improve the cross range resolution. To overcome the problems cited before a sand surface removal is applied followed by reference subtraction and transition detection in order to obtain the required results. The results obtained show an enhancement in removing the unwanted non-homogenous clutter and emphasize the weak reflections from the buried landmine. Thus, it can be implemented and work efficiently in the non-homogenous sand environment. In this paper a stepped frequency continues wave radar (SFCW) is used to overcome the problem of high instantaneous bandwidth and high sampling rate of the pulsed systems[2, 3]. This paper is organized as follows; section 2 summarizes the main processing algorithm. Section 3 includes survey on the techniques used to overcome the strong reflections from unwanted buried objects, associated with the results obtained in the presence of strong unwanted signals from buried unwanted materials. Conclusion comes at the end of this paper.

## II. THE MAIN SIGNAL PROCESSING ALGORITHM

In this paper, enhancement has been applied to an algorithm that has been tested and verified by me in aprevious paper in order to achieve the purpose of detecting buried plastic landmines. The processing algorithm makes use of the synthetic aperture radar (SAR) processing and adaptive subtraction to emphasize the responses of the buried plastic landmines[4, 5]. The results obtained showed the effect of applying these techniques to create an image of the buried plastic landmines[4]. However, application of algorithm for the case of rough sand surface and high nonhomogeneous clutter emphasizes a drawback of the first difference, as shown in figure 1, the high values of the differences obscure the weak responses of the plastic mine. This simulation result was done for a SNR of -20 dB as an investigation for the case of high non-homogeneous clutter. Measuring the Peak Signal to Noise Ratio (PSNR) of the obtained image, gives a value of 0 db, which is a low quality and gives an indication that the algorithm didn't work effectively in detecting the buried plastic landmine.

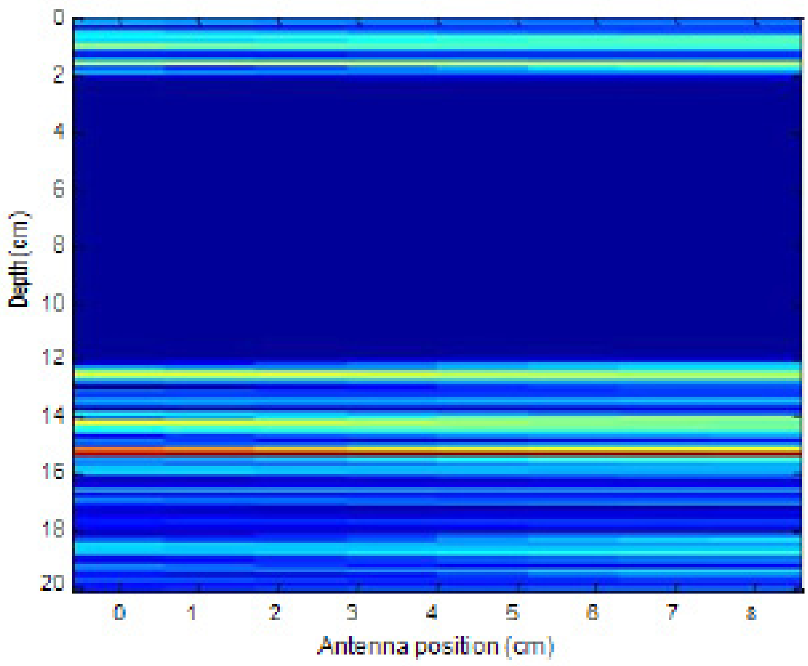


**Fig. 1:** The obtained image with non-homogeneous clutter and SNR = -20 dB.

To enhance the quality of the obtained image of the buried plastic landmine, these unwanted responses must be removed. The figure shows the unaccepted result after applying SAR processing with adaptive reference subtraction in the presence of nonhomogeneous contribution, such as rough sand surface and other buried objects. Thus, there was a need to modify this algorithm to be able to enhance the obtained results in the presence of non-homogeneous clutter contribution.

## III. REMOVAL OF THE NON-HOMOGENEOUS CONTRIBUTION

The algorithm under consideration is modified in three aspects; sand surface removal, transition detection, and reference subtraction.

### A. Sand surface removal

In order to overcome the problem of using the first difference with a rough surface, an early range window can be used to remove the strong surface reflections[6]. This would be effective if the rough surface of the sand never crosses the boundary of the window, which is not likely to happen all the time. In this work, an adaptive time window is applied, in which the surface bin is tracked at each GPR cross-range position. The location of the surface is estimated by specifying a fixed distance dz, measured downwards from the antenna as shown in figure (2).

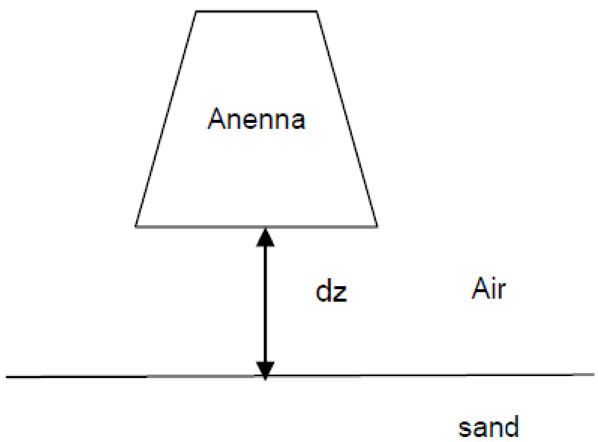


**Fig. 2:** Distance dz in which the surface bin is searched.

For each incoming complex data colum, the first range bins contained in the distance dz, arc examined in order to find the bin with the maximum value, which is assumed to contain the maximum response of the sand surface. Once surface bin (sbin) is obtained, it is set to zero together with all the bins above it, and a set of neighbor range bins below it which obscure the response of the buried objects.

### B. Transistion detection

Once the sand surface bin sbin has been estimated in data and removed, now the idea is to search for transitions in the responses under the surface of the sand as the GPR moves along in the cross-range direction. This is performed by computing the power of the difference vector sdern,m, which is equivalent to obtaining the Mean Square Error (sMse) between the two adjacent columns.

$$\text{sMSE m} = \frac{1}{N-sbin} \sum_{n=sbin}^{N} |\text{scder}(n,m)|^2$$

Where N is the number of rows and sbin indicates the row corresponding to the surface response. The MSE is helpful as an indicator of the power changes from the current GPR position with respect to the previous one. A threshold T1 is defined in order to detect significant changes. The threshold can be defined by analyzing its Probability Density Function (PDF) as shown in figure (3) and figure (4).

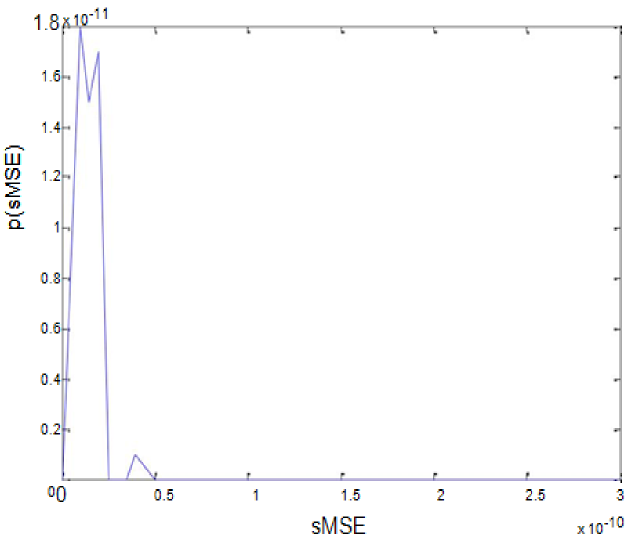


**Fig. 3:** Estimated Pdf for the sMSE of the data with sand cnly

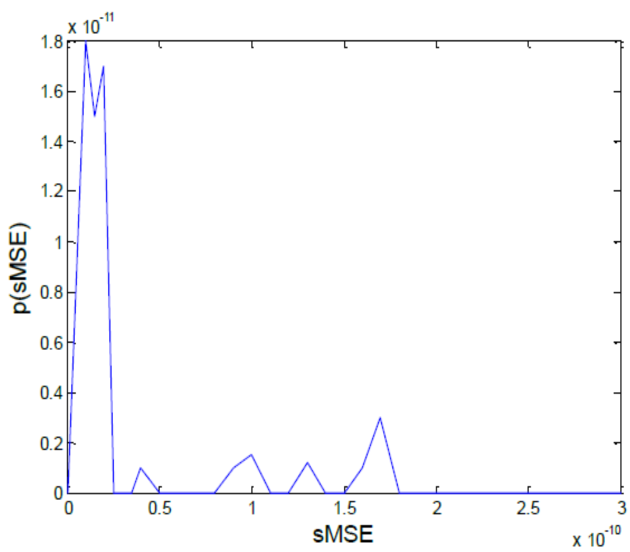


**Fig. 4:** Estimated pdf for the sMSE of the data with a buried plastic mine.

Figure (3) shows the MSE plot for sand only with no buried objects. In Figure (4.13), the data with buried landmine plot, shows MSE values up to $0.18x10^{-10}$ 'hen a Threshold can be hosen at T1 = $0.5x10^{-10}$. Hence, all the columns scder(n,m) with sMSE values above T1 will be considered as candidates to contain a buried object response. C. Reference subtraction A reference subtraction approach is followed in this thesis, in which the received signal is viewed as the sum of different contributors as follows:

S(n.m) = Ca(n.m) + Cb(n,m) + t(n,m)

Where Can.m is a homogeneous clutter (i.e. sand), Cbn,m is a non-homogeneous clutter contributor (i.e. rocks.), and tn,m is the contribution of a known target under search (i.e. Plastic mine). A reference column srefn is defined as an approximation of the homogeneous clutter response. It is initialized with the first incoming scmpn.m column as srefn = sn.m, which is generated by performing a scan with the GPR over a surface position in which it is assumed that no buried object is present. A reduction of the response contribution from Can.m is performed by applying the subtraction

sub(n,m) = s(n.m) – sref(n)

The obtained sub(n,m) column contains the combined responses of the desired target tn,m and the non-desired targets Cb(n,m) that can be any object which is not sand nor a plastic mine. The absolute value of subn,m is appended as a new column into the final image, srefn is stored in memory and the GPR is moved to the next position. Besides knowing that a power change occurred by monitoring sMSE as explained before, it is necessary to indicate whether the response belongs to the buried plastic mine or to other unwanted buried objects. This can be done by comparing how similar the new incoming column S(n.m) is to the stored reference srefn, which is an "object-free" column. Hence, in order to have a similarity indicator, the mean square error rMSE is computed from subn,m as follow:

$$\text{rMSE m} = \frac{1}{N-sbin} \sum_{n=sbin}^{N} |\text{sub}(n,m)|^2$$

Where sub is the difference between each new column and the reference column. So, a threshold T2 is defined for rMSE in the same way as T1.

## IV. SIMULATION RESULTS

After modification of the algorithm to include techniques of sand surface effect removal, transition detection, and reference subtraction, it was applied in the presence of other unwanted targets. Consider SNR = -20 db as shown in figure (1). The result has been enhanced as shown in figure (5). Measuring the PSNR of these results shows an enhancement from 0 dB to 30 dB which is a good indication of the enhancement achieved.

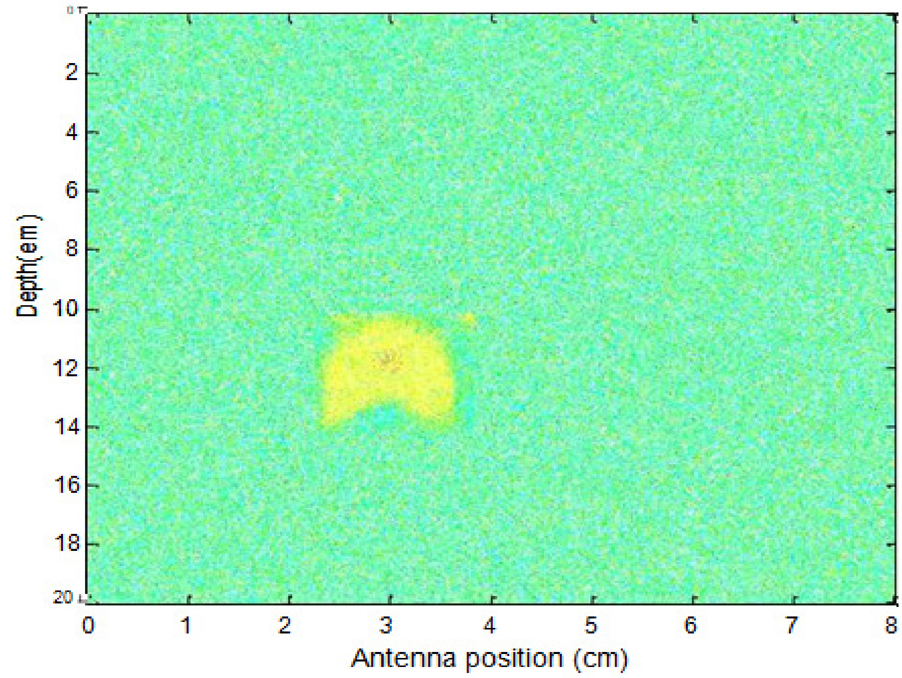


**Fig. 5:** Image obtained after applying transition detection and reference subtraction for SNR = -20 dB

At this point, sMSE and rMSE are two indicators that will be used in order to detect transitions in the sand as well as differences with respect to an object free.

The algorithm is applied in the case of two closely buried objects. Two cases have been simulated; the first one is the case of two buried plastic mines at different depths, the one is the case of two buried mines at the same depth. The model shows a promising results in the two cases as shown in the figure (6) and figure (7). So, by achieving these results, this algorithm can be applied practically to create a two-dimensional image of the buried landmines, even in the presence of rough surface and other unwanted buried objects.

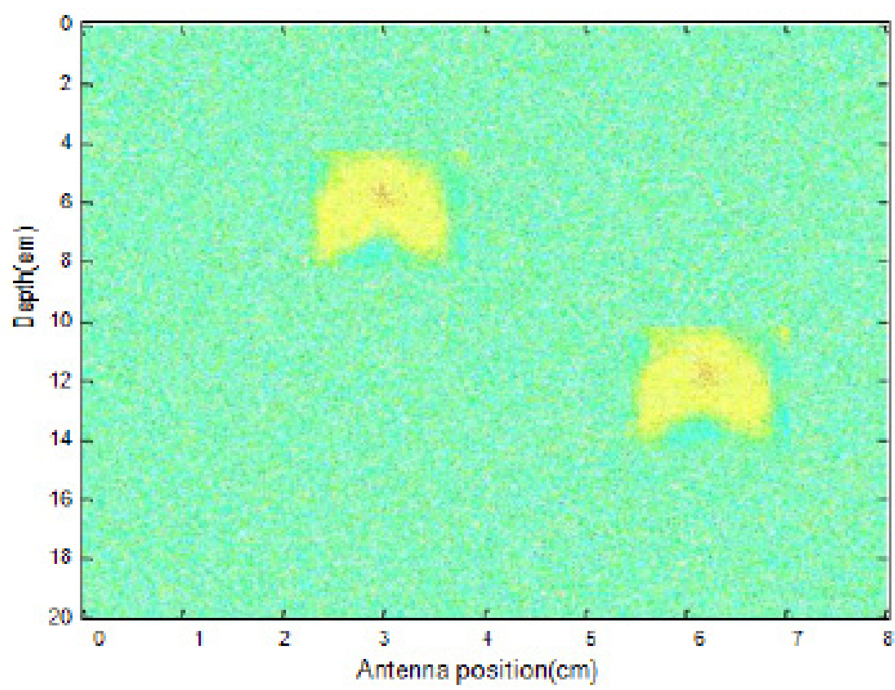


**Fig. 6:** Image obtained for 2 buried plastic landmines at different depths for SNR = 20 dB

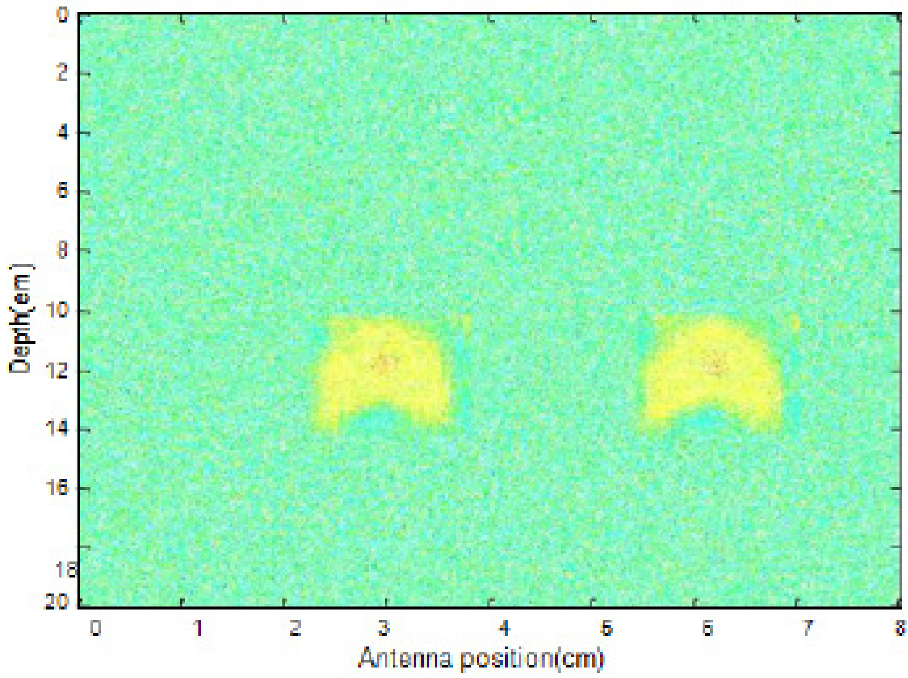


**Fig. 7:** Image obtained for 2 buried plastic landmines at the same depth for SNR = -20 dB.

## V. CONCLUSION

In this paper, a modified signal processing algorithm has been applied to create a 2 dimensional image of a buried plastic landmine. The results obtained showed that it worked efficiently even after increasing the non-homogeneous contribution of other unwanted targets. The PSNR of the images obtained also has been enhanced from 0 dB to 30 dB in the case of SNR = -20 dB, which indicates good quality of images obtained. The proposed algorithm also shows a promising results even in the presence of two closely buried landmines. The ongoing research after applying these results is to implement this algorithm and enhance it to create 3-D GPR images.

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