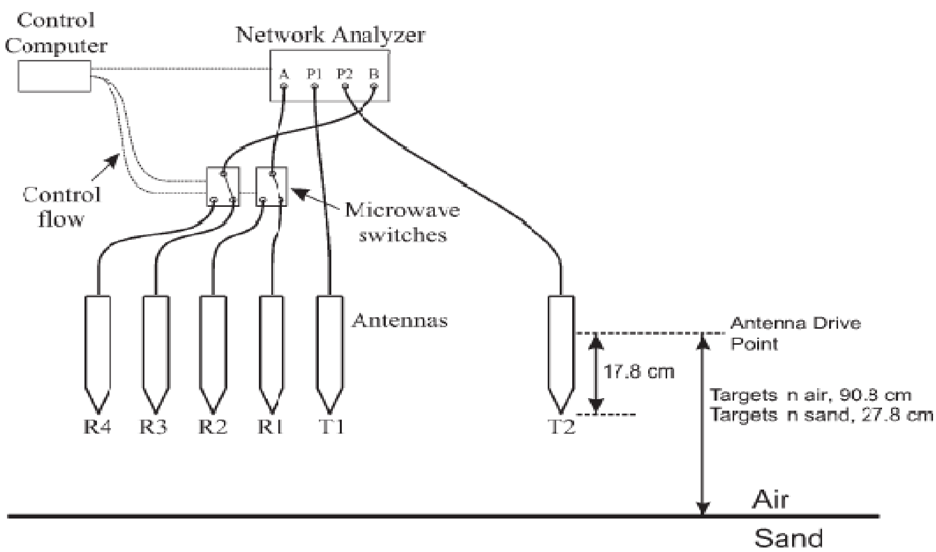


Figure 1: Diagram of the multistatic GPR system and switching network [7].

The data is available in 401×91×91 size for each antenna pair where 401 are the frequency points, 91×91 are the horizontal scanning (scanx) and vertical scanning (scany) positions respectively.

Table 1: Data used for analysis

Data type	*401*91*91 for antenna pair*	*No. of frequency points*	*No. of horizontal scanning points scanx*	*No. of vertical scanning points scany*
Mine clean	T1R1	401	1:91	1:91
	T1R2	401	1:91	1:91
	T1R3	401	1:91	1:91
	T1R4	401	1:91	1:91
	T2R1	401	1:91	1:91
	T2R2	401	1:91	1:91
	T2R3	401	1:91	1:91
	T2R4	401	1:91	1:91

In a similar way as shown in Table 1, data is available for mine rock in which rocks are randomly scattered over the soil in the scan region.

3. Signal Processing of Data

GPR acquire data in frequency domain. The reflected energy is received as a function of frequency and indicates the amplitude of energy scattered from subsurface objects. The return signals are usually having noisy content not suitable for direct interpretation. To solve this problem different signal processing techniques are applied on data to obtain A-scan and B-scan images.

3.1 A-scans

Range profile is obtained from A-scan which will give us information about presence of target as well as location of target. To observe the effect of rock on mine detection, range profiles are obtained with clean surface i.e mine clean data file and cluttered surface (Mine rock data file) using the procedure as shown in Fig.2.

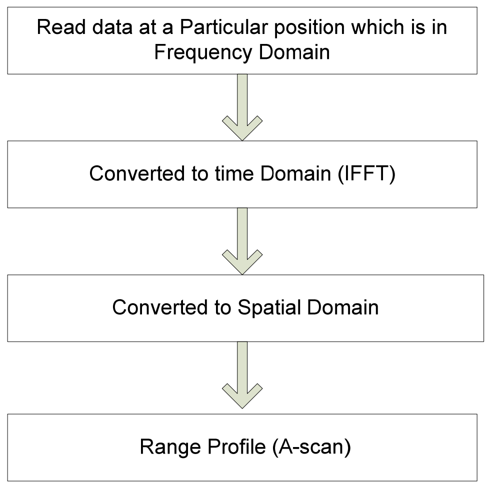


Figure 2: Flowchart for Range profile

The range profile at every point can be obtained from the available data. As it is given that after each switch operation the radar sweeps 401 equally spaced frequency points which are discrete points. Select one of the antenna pair and position of scanning point. Then read data at selected location which is in frequency domain format and convert this data in time domain format by taking IFFT. Now by plotting these data after converting into spatial domain we get range profile.

3.2 B-scan with clutter reduction

Range profiles provides very limited information, therefore the information in more than one scan has to combined i.e it does not indicate number of targets present in cross range. B-scan image provide this information along with their locations. B-scan image is a collection of A-scans recorded along scanning line [9]. To determine the effect of rock on buried object using B-scan, select one of the horizontal scanning positions (scanx) and all vertical scanning positions (scany). Obtain B-scan image using the procedure as shown in Fig.3 for clean surface as well as for rough surface. Observe the B-scan images and note intensity value of target.

An important step towards detection of object is reduction of unwanted reflections (clutter) to a maximum extent as possible. The clutter may include soil reflections, multiple reflections and weak isolation between transmitted and received signals. These clutters should be suppressed or significantly mitigated for detection of target. Researchers have presented techniques by which these clutter effects can be minimized [4]–[6].

The detailed discussion and implementation of clutter reduction techniques using Singular value decomposition (SVD) described initially in our earlier work [10]-[11] and is applied in similar way here.

4. Results and Discussion

4.1 A-scans

For plotting range profile, data T1R2 with horizontal scanning position as 23 and vertical scanning position as 73 is used. Results are not reported for all the data due to limitation of length of paper. In the above Fig. 4 (a), the first reflection is due to surface of soil and the second is due to mine target buried under soil.

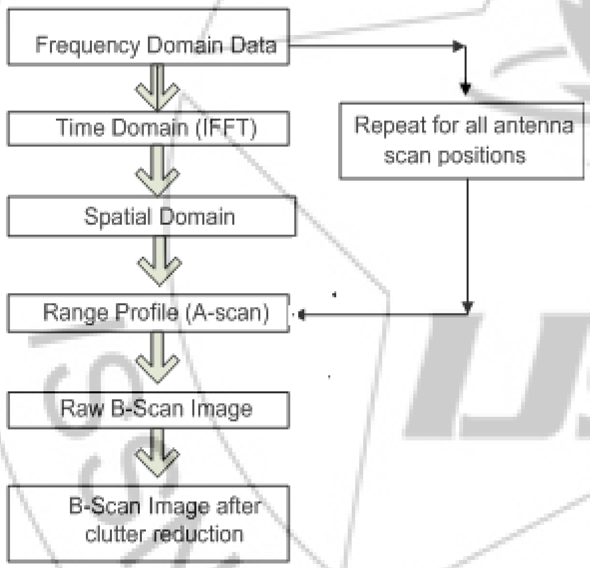


Figure 3: Flowchart for B-scan

This is because when the EM wave interfaces between air medium and soil we get first reflection and when it is incident on mine we get second reflection. Table 2 show the results obtained from range profiles of mine clean and mine rock. The table shows distance and intensity of target measured from surface in mine clean and mine rock, at different horizontal scanning (scanx) position varying from 22 to 25. Only those scanning position are chosen where reflection due to target is strongest. That is if we are considering antenna pair T1R2 for mine clean and mine rock, then by selecting range profile position at 73 and scanx positions 23, the intensity is observed as 0.0007 and 0.0006 respectively.

Distance of target is 0.6187 m for mine clean and 0.6375 m for mine rock. It is observed that distance of target changes in mine rock as compared to mine clean due to presence of rocks in soil surface and also the intensity decreases in mine rock as compared to mine clean. This can be observed for different scanx positions as shown in Table 2. From the Table 2, it is observe that as the antenna pair changes the position of target is moved along x-axis. The reason for this is transmitter T1 is nearest to receiver R1 as compare to transmitter T2 from R1. Due to this arrangement the travel time for T2R1 pair is maximum as compared to T1R1. Hence the intensity of the object in T1R1 is maximum.

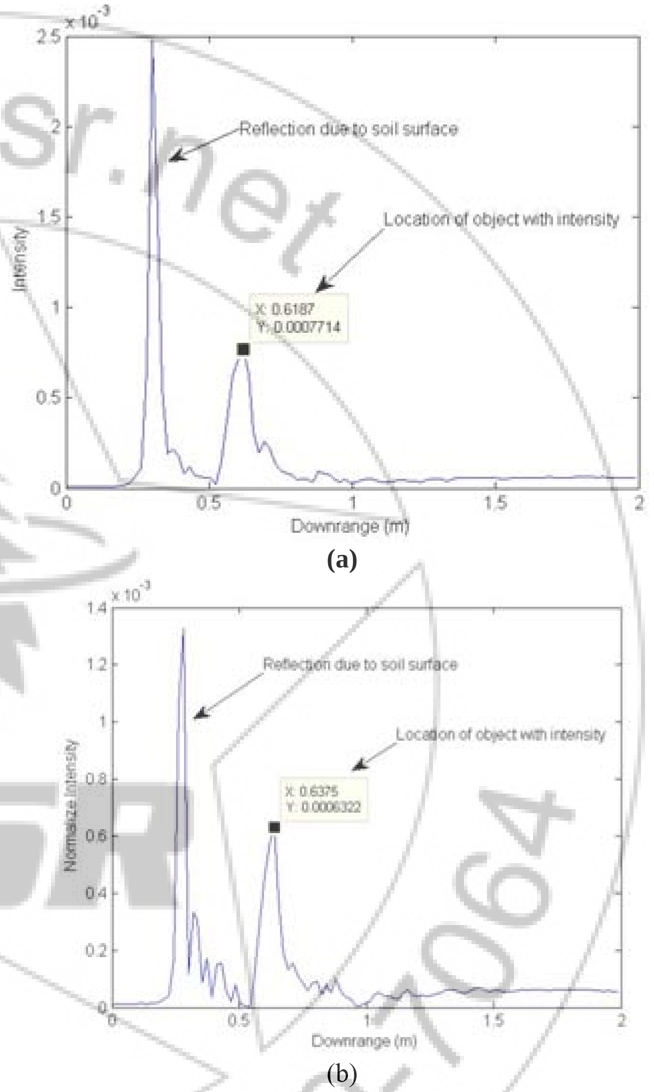
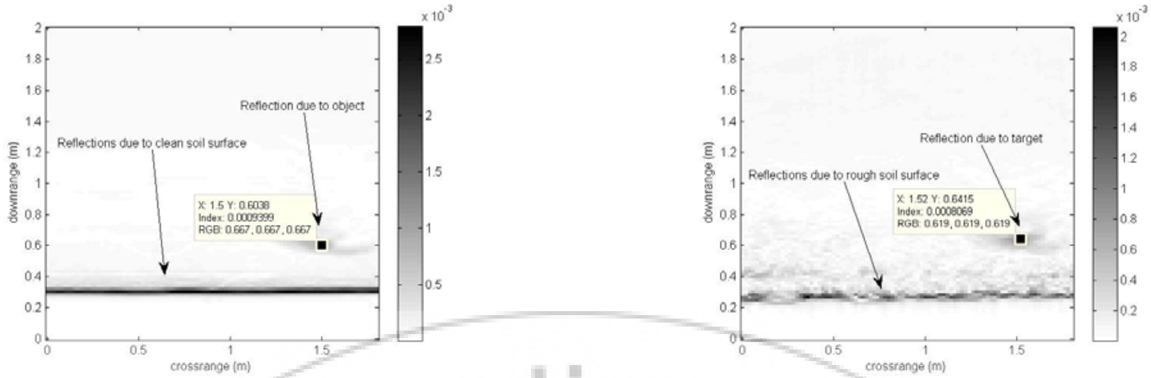


Figure 4: At T1R2 and X-23 (a) Mine clean (b) Mine rock

4.2 B-scans

4.2.1 B-scan Images without using clutter reduction

The processing steps as shown in Fig. 3 except clutter reduction are applied to obtain B-scan image. Horizontal axis represents cross range and vertical axis corresponds down range distance. From Fig. 5 (a) and (b), it is observed that the intensity of the object reduces due to presence of rock on soil surface in comparison to clean surface. It is also observed from Fig. 5 (b) that the reflections due to soil surface is not uniform for all scanning positions due to presence of rocks on surface of soil whereas in Fig. 5 (a) reflections from soil surface is uniform for all scanning position as surface is clean. These results are observed for antenna pair T1R2 at scanx positions 23.



(a) (b)

Figure 5: B-scan image without clutter reduction (a) Clean surface (b) Rough surface

Table 2: Range profile Results for Mine clean

Antenna pair	*Range profile at*	*Horizontan scanning (Scanx) position*	*Mine Clean*		*Mine Rock*	
			Distance of target from surface (m)	*Intensity*	*Distance of target from surface (m)*	*Intensity*
T1R1	73	23	0.5813	0.00131	0.6187	0.0008
		24	0.5813	0.00143	0.6187	0.0010
		25	0.5813	0.00139	0.6187	0.0010
T1R2	73	22	0.6187	0.00070	0.6375	0.0005
		23	0.6187	0.00077	0.6375	0.0006
		24	0.6187	0.00082	0.6375	0.0006
T1R3	73	23	0.6375	0.00049	0.6563	0.0003
		24	0.6375	0.00053	0.6563	0.0003
		25	0.6375	0.00052	0.6563	0.0003
		26	0.6375	0.00047	0.6563	0.0003
T1R4	77	22	0.6755	0.00034	0.6937	0.0001
		23	0.6755	0.00038	0.6937	0.0001
		24	0.6755	0.00039	0.6937	0.0002
		25	0.675	0.00039	0.6937	0.0002
T2R1	55	22	0.7125	0.00022	0.756	0.0001
		23	0.7125	0.00025	0.756	0.0001
		24	0.71250	0.00027	0.755	0.0001
		25	0.7125	0.00026	0.755	0.0001
T2R2	56	23	0.75	0.00016	0.787	0.0000
		24	0.75	0.00017	0.787	0.0001
		25	0.75	0.00017	0.787	0.0000
		26	0.75	0.00016	0.787	0.0000
T2R3	55	23	0.8063	0.00011	0.862	0.0000
		24	0.8063	0.00012	0.862	0.0000
		25	0.8063	0.00012	0.862	0.0000
		26	0.8063	0.00011	0.862	0.0000
T2R4	58	22	0.8625	0.00008	0.918	0.0000
		23	0.8625	0.00009	0.918	0.0000
		24	0.8625	0.000094	0.918	0.0000
		25	0.8625	0.000095	0.918	0.0000

4.2.2 B-scan Images after using clutter reduction

The processing steps as shown in Fig. 3 with clutter reduction are applied to obtain B-scan image. Same locations as taken as above are taken for plotting B-scan image. It is observed from Fig. 6 that the strong reflections due rough soil surface are reduced i.e., clutter and object intensity is increased as compared in Fig. 5 (b) at same location.

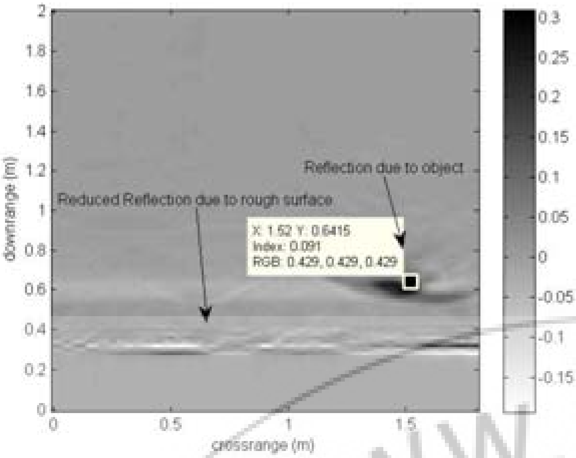


Figure 6: B-scan image after clutter reduction

5. Conclusions

In this paper we present the results obtained by using data which is publicly available on line. Two data files which represents two different measurement environments are chosen for analysis.

In the first file measurement are done when target is buried in relatively homogeneous soil. In second file measurements are done when rocks are placed on surface of sand. The analysis of GPR data for buried object detection is processed to get the distance of the object from surface and measure intensity levels. We observed that intensity of the buried object is more in clean surface as compare to cluttered surface. After clutter reduction technique also the intensity of object in clean surface is high compared to intensity of object in cluttered surface.

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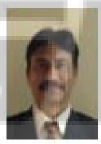

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