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A RESILIENT METHOD FOR REMOVING MASKING EFFECT IN GPR DATA USING MINIMUM PARAMETER COMPUTATION

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Abstract: This study is concerned with the ground bounce removal and background subtraction algorithms of Ground Penetrating Radar (GPR) return signals. The term ground bounce is often used for the effect caused due to radar wave being reflected at both air and ground interface and at non ideal antenna. Ground bounce often totally dominates the data and masks the shallow buried target. For GPR with antenna positioned very close to the ground surface, the reflections from the ground surface are very strong and can dominate the return from buried utilities. Hence it's a challenging task to remove ground bounce from the return signals and development of non-destructive methodology to detect the thin pavement layers, utility identification and classification using commercially available IMPULSE Ground Penetrating Radar system. A new parameter Singular value decomposition (SVD) is used for removal of ground bounce on GPR Data.
Keywords: Mask, Return signals, GPR, Singular value decomposition (SVD), noise, non-ideal antenna.

I. INTRODUCTION

GPR provides a non-destructive means for testing of the transportation infrastructures, air coupled GPR capable of fast survey at the cost of contaminated data (air coupling effects being major drawbacks), while the ground coupled data being slow in survey provides more accurate data in comparison to the air coupled survey system. Figure 1 shows the difference between air coupled and ground coupled GPR systems, apart from the mentioned GPR configurations there exist an airborne GPR system used for analysis of crop growth and soil moisture content.

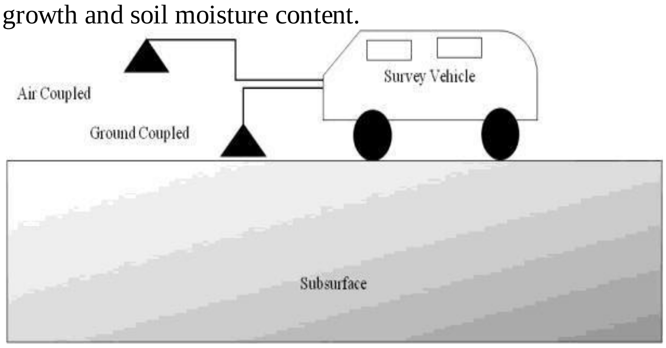

Figure 1. Air coupled and ground coupled GPR systems

Buried utilities possess major threat of getting damaged in any evacuation project, for success of the project it is desirable that minimum cost should be beard on replacing and shifting of the utilities, hence precise location of the buried utilities are required. GPR transmits short pulses to the ground and these pulses after reflection from the subsurface are recorded by the GPR receiver. Different in homogeneity of the ground and man-made waste buried in the subsurface causes distortion of GPR signal, that is called clutter which mainly dominates the background of the GPR radargram. Apart from it due to non-ideal hardware of the GPR system ground bounce and antenna cross talk are the major defects in the initial unprocessed GPR return signals [6]. Non-ideal hardware of GPR often leads to a phenomenon, better known as Antenna crosstalk, when the transmitted wave reaches directly to the receiving antenna without suffering echo, another source of noise in the GPR data is the Ground Bounce, when the electromagnetic waves transmitted from the GPR transmitter gets bounced back to the receiving antenna without penetrating into the medium [1]. Ground bounce and antenna cross talk often dominates the GPR data and results in poor visualization as seen in figure 2.

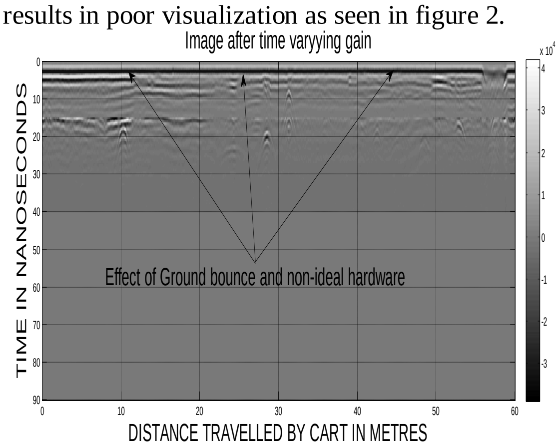

Figure 2. Effect of ground bounce on profile obtained by GPR. (Thick black line dominates the data as seen on top).

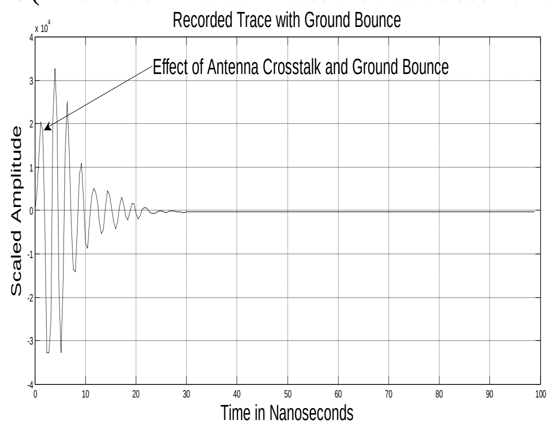

Figure 3. GPR return pulse, effect of ground bounce indicated by arrow

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II. METHODOLOGY

Before applying Singular value decomposition (SVD) algorithm one have to detect the type of layer. Figure 4 shows the flow chart for the detection of thin pavement layer.

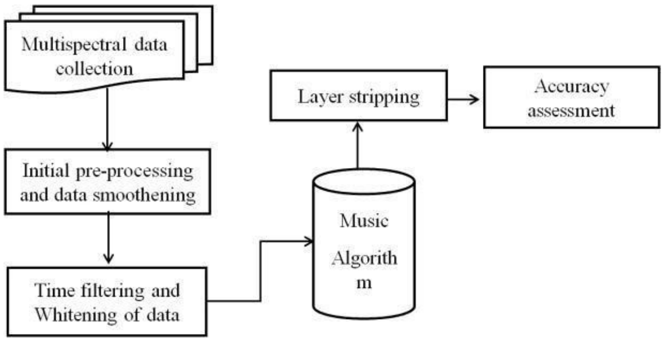

Figure 4. Flow diagram for detection of thin pavement layers

Singular value decomposition has many practical and theoretical values; Special feature of SVD is that it can be performed on any real (m, n) matrix, with minimum parameters to set. Let's say we have a GPR data D with m rows and n columns, with rank r, r ≤ n ≤ m. Then the A can be factorized into three matrices [1].

$$D = RST^T \qquad (1)$$

Where R is an orthogonal matrix

$$R = [r_1\ r_2 r_3\ \ldots.,r_m] \qquad (2)$$

And matrix T is an orthogonal matrix

$$T = [t_1\ t_2 t_3\ \ldots.,t_m] \qquad (3)$$

Here S is a diagonal matrix with singular values (SV) on the diagonal. The matrix s can be shown as:

When a GPR image/Data is SVD transformed, it is not compressed, but the data take a form in which the first singular value has a great amount of the image information. With this, we can use only a few singular values to represent the image with little differences from the original.

D can be shown as outer product expansion:

When compressing the image, the sum is not performed to the very last SVs; the SVs with small enough values are dropped. Sample of GPR data is shown in Table 1.

Table 1. Sample of GPR return signal acquired with 250 MHz antenna (*m*=8, n=5).

Po int	Trace	1	2	3	4	5
	Position (m)	0	0.05	0.1	0.15	0.2
	Time(ns)					
1	-24.8	-246	-249	-267	-260	-256
2	-24.4	-253	-247	-264	-252	-247
3	-24	-245	-262	-258	-264	-244
4	-23.6	-241	-233	-254	-255	-266
5	-23.2	-259	-266	-280	-267	-255
6	-22.8	-254	-260	-258	-273	-245
7	-22.4	-276	285	-269	-270	-281
8	-22	-267	-260	-292	-261	-252

After the matrix has been obtained we subtract from D to obtain a new matrix free from ground bounce and antenna ringing effect i.e. noise getting supressed from the data.

III. RESULT AND ANALYSIS

One Single singular value was selected

$A = \sigma_1 u_1 v_1^T$

Figure 4 shows the return signal with time gain applied in black that contains target signature also, while the plot in red shows the compression of signal so that only ground bounce is present and rest of the information is suppressed.

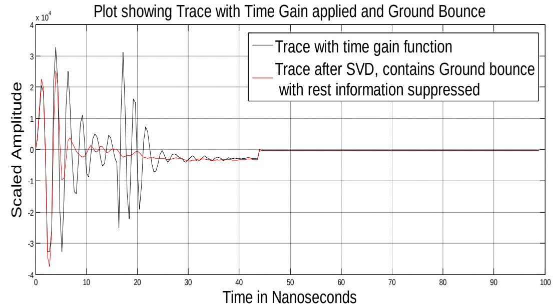

Figure 5. A-Trace plot showing effect of application of SVD

After the SVD is applied to the data, the so obtained data is subtracted from the data obtained in stage a, i.e. after application of time gain function this leads to elimination of ground bounce and effects of non-ideal hardware from the GPR data as shown in figure 5.

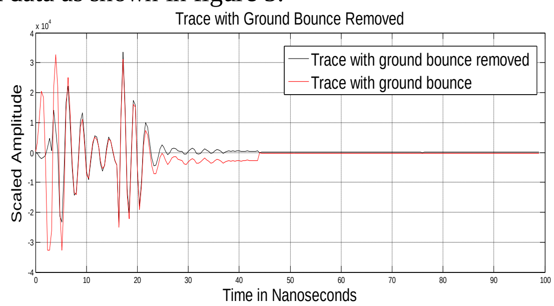

Figure 6. Plot showing removal of ground bounce and effect of non-ideal hardware from the GPR data.

With the elimination of ground bounce and effect of non-ideal hardware, signature of shallow buried objects will not be masked. In figure 6, it is visible that the ground bounce totally dominates the data i.e. a thick black strip at top of the radargram, while after ground bounce has been supressed it can be seen that the thick black strip has been removed i.e. data is now fit for further processing figure 2.

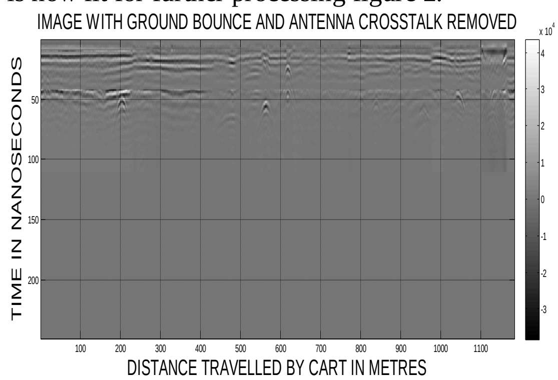

Figure 7. Radargram, after removal of ground bounce and effects from non-ideal hardware

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IV. CONCLUSION

The procedure adopted to suppress the ground bounce from the GPR data and to detect the utility was pretty effective as the result obtained shows a considerable amount of suppression of Ground bounce and antenna crosstalk from the data. The method set minimum parameters to supress the spurious part of the returned signal and minimizing the computation part, as the method is based on statistical decomposition of the initial obtained matrix of return echoes.

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