Different Time Gain and Amplitude-Color Arranging for Ground Penetrating Radar Data: Applied Samples

Selma KADIOGLU
Ankara University Engineering Faculty
Geophysical Engineering Dept.
06100 Tandogan-ANKARA/ TURKIYE
Ankara University Earth Sciences Application and Research Center (YEBIM)
06100 Tandogan-ANKARA/ TURKIYE
kadioglu@eng.ankara.edu.tr

Jeffrey J. DANIELS
Ohio-State University
Geological Sciences Dept.
Columbus OH 43210-1308, USA
daniels.9@osu.edu

Abstract- **We introduced a simple time gain approximation with a functioned amplitude-color range to image all amplitudes or only selected amplitudes. First, we reduced ground wave amplitudes near to the maximum reflected / diffracted wave amplitudes of the data. Thus amplitude range of the two dimensional (2D) GPR profile section (radargram) was rescaled by maximum reflected/ diffracted wave amplitude values only for displaying the radargram. Second, we re-arranged amplitude-color range with a functional approximation which was very important as well as time gain application to pick events according to the aim of the research. Third, we functioned an opaque range to obtain transparent three dimensional (3D) image of the aligned 2D radargrams. We presented 2D and 3D applications to show our approximations.**

Keywords- amplitude-gain; amplitude-color; amplitude-opaque; GPR; radargram

I. INTRODUCTION

GPR signal (very high frequency electromagnetic (EM) wave) suffers attenuation as the result of absorption and dispersion, besides spherical divergence [1] as it propagates in the underground medium. The quality of GPR images is strongly dependent on an adequate correction of the attenuation effects, usually supplied by time-varying gain. However, amplitude gain as a basic processing for GPR data has been historically very subjective and also very much displaying methodology [2]. There are various ways of amplitude gaining for the GPR data. Traditional time-varying gain is carried out by using linear, exponential etc. functions including ground wave amplitudes. However, this operation is not linear. The time gained GPR data can not recover the original information. Selection of the gain function depends on mostly the user and the quality of the GPR data. Both linear and exponential time gain change not only amplitude range for each time step but also amplitude shape. In fact the exaggerated time gain to image 2D GPR data can result with a wrong interpretation especially to image them in a 3D volume.

A second approximation concerns 2D or 3D image simplification especially for determining buried archaeological remains and vertical discontinuities like fractures. Assigning a new amplitude-color range and/or opaque range picked anomalies and displayed data set on 2D profiles and 3D imaging. We showed a functioned amplitude-color range and opaque range to pick different anomalies such as differentiate buried caves and fractures on the same radargram. We used GPHYZGPR program developed by [3] and Reflex-Win ver.5.0 [4] during the studies.

Knowledge of the spatial distribution of the buried objects is fundamental for the researcher. Defining buried anomalies and mapping the location of high-quality undisturbed structures can indicate the best way in which to advance the digging front to minimize excavation costs.

This study presents these processing on different data.

II. TIME GAIN APPROXIMATION

GPR data $f(x,t)$ contain directly coupled ground signal $d(x,t)$ between transmitter and receiver and the reflected/diffracted signals $r(x,t)$ coming from underground, where x indicates location of a survey line, t is recording time. When we acquire the data on a profile with fixed antenna separation, the ground condition does not change. Therefore, $d(x,t)$ has a strong amplitude and comes to receiver in the early time [5]. $r(x,t)$ at great depth in the late time are very small when compared to $r(x,t)$ from shallower depth [5]. Simultaneous display of these signals requires conditioning before visual display [6]. Equalizing amplitudes of the GPR signals by applying a time dependent gain function compensates for rapid fall off in GPR signals from deeper depths. Display of the GPR data versus time must accommodate low and high attenuation extremes [6].

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A GPR signal is

$$f(x,t) = d(x,t) + r(x,t), \qquad (1)$$

and time gained signal is

$$s(x,t) = [d(x,t) + r(x,t)]h(t), \qquad (2)$$

where $h(t)$ is a time gain function. The ground wave amplitude dominates amplitude scale on radargram. Therefore, firstly the ground wave amplitude must be reduced in order to enhance the image of the other waves. However, other amplitudes must not be destroyed during this process. Therefore, time gain can be realized in two parts like

$$s(x,t) = d(x,t)h_1(t) + r(x,t)h_2(t) \qquad (3)$$

and

$$h_1(t) = \left| \frac{r_{\max}}{d_{\max}} \right|, \qquad 0 \le t \le t_d \qquad (4)$$

$|r_{\max}|$ is a maximum amplitude of the reflected/diffracted wave $r(x,t)$, $|d_{\max}|$ is a maximum amplitude of the ground wave $d(x,t)$ and t_d is the maximum travel time of the ground wave. Therefore $d(x,t)$ has been reduced to $|r_{\max}|$. If GPR data quality is good, this process will be enough to enhance 2D and 3D image. The other original part of the signal can be protected. In fact the exaggerated time gain can result with a wrong interpretation. Both linear and exponential time gain changes not only amplitude range for each time step but also amplitude shape. Therefore, our second aim is to protect the reflected/diffracted amplitude relation with increasing time (Fig. 1). If a constant time gain is applied to the $r(x,t)$ part, processed data can be recovered with the original information. Then,

$$h_2(t) = a\,,\ a \le \left| \frac{r_{\max}}{r_{\min}} \right|, \quad t_d \langle t \le t_{\max} \qquad (5)$$

We prefer to protect original $r(x,t)$ by assigning a constant value a between 1 and 2 with a decimal number. $h_2(t)$ could also be a linear function between 1 and a. Another process to enhance weak amplitude signal is a functioned amplitude-color range.

III. A FUNCTIONED AMPLITUDE-COLOR RANGE AND OPAQUE APPROXIMATION

2D GPR data, acquired on a karstic area (Fig. 2a), processed and time gained with Fig.1b, first displayed with a selected linear amplitude-color range (Fig.2b). The aim of the second approximation is to develop imaging of 2D and 3D data. Therefore, we applied a function for the linear amplitude-color range according to the aim of the image. Horizontal axis of this function is amplitude scale of the GPR data, vertical axis represents color from 0 to 255.

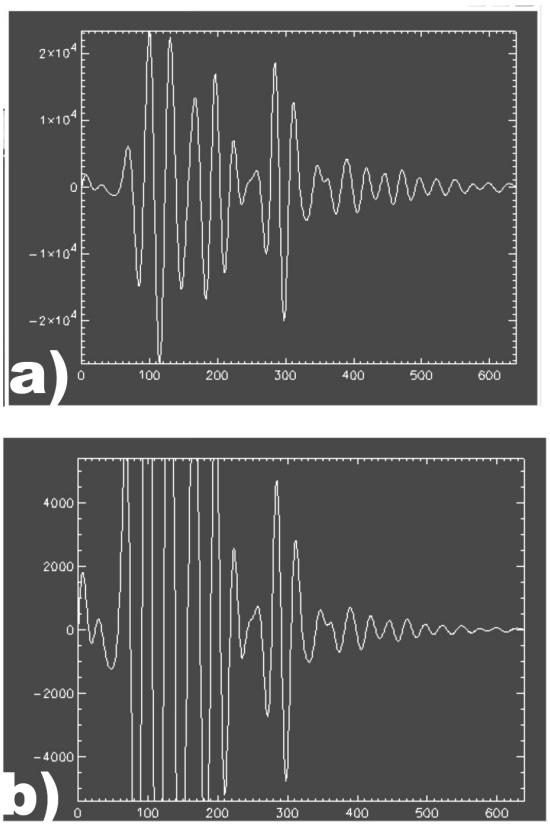


Figure 1. a) ungained signal, b) gained signal with decreased ground wave amplitude.

A color scale indicates amplitude range, which begins with maximum negative polarity and ends with maximum positive polarity (Fig. 2c).

We applied a new approximation for image simplification to eliminate the weak reflections by assigning a new color scale for the amplitude range of the processed profiles with an amplitude-color function instead of linear amplitude-color function (Fig. 3). When Fig.2a and Fig.3b were compared to each other, Fig.3b was simplified to show cavities and especially vertical fractures. If only cavities had wanted to show on the radargram, then maximum and minimum amplitude range represented black and red colors would have been more narrow. While amplitude-color arranging was important to image 2D data or solid 3D visualization, an opaque function of the amplitude-color range was important to reveal only buried objects in the 3D volume, called transparent 3D visualization [7] [8]. A solid 3D volume has linear opaque function to visualize amplitude range. Therefore the user can control slices of the volume to decide the location and depth change of the anomaly caused by an object. However, a transparent 3D volume can image the object more efficiently with a functioned opaque of the amplitude-color range. We showed a solid 3D volume and a transparent 3D volume representing ancient area and including buried remains for the first 0-0.5 m depth range with its linear amplitude-color range

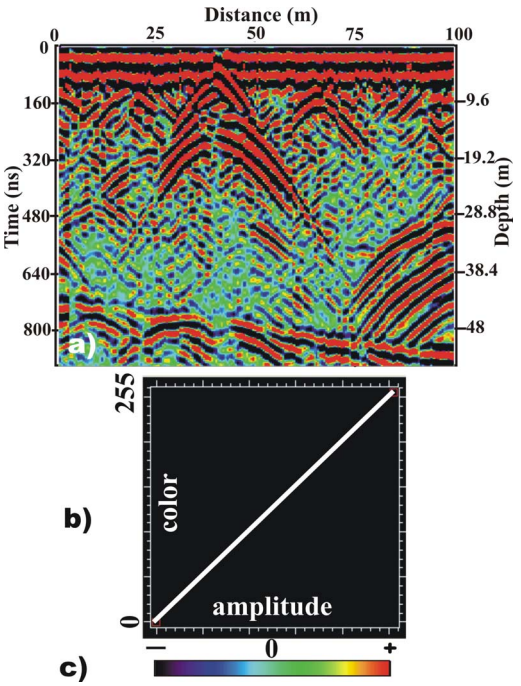


Figure 2. A 2D radargram acquired on a karstic area imaged with b) linear function of c) amplitude-color range.

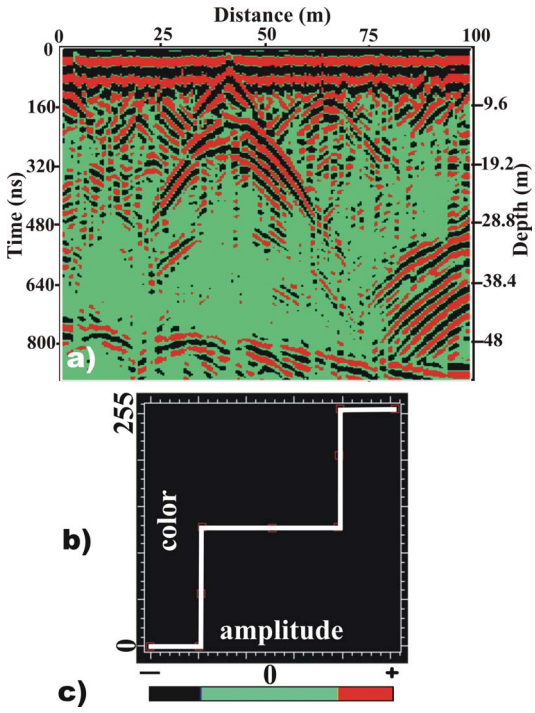


Figure 3. Same profile of Fig.2a imaged with b) a new constructed function of c) amplitude-color range. This function activates only maximum amplitude range with black and red color. Green color represents weak amplitude range.

and linear amplitude-opaque function (Fig. 4) and a reconstructed amplitude-opaque function (Fig.5). First the full data block could be divided into sub-data blocks in time or depth. Because it was known that the maximum amplitudes represented the objects, weak amplitude range around the zero amplitude was eliminated by giving zero opacity value like

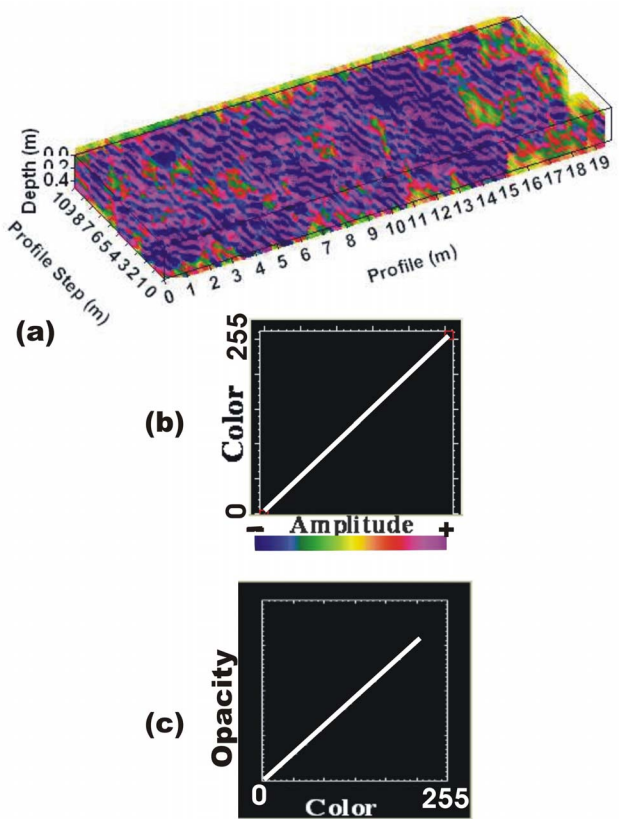


Figure 4. A solid 3D GPR data volume acquired archaeological area imaged with b) functioned linear amplitude-color range and c) linear amplitude-opaque range revealing all amplitude range.

constructing of amplitude-color range and transparent 3D imaging was obtained., Horizontal axis of the opacity function represents amplitude-color scale of the GPR data set, and vertical axis of which represents opacity coefficients (Figs. 4c and 5c).

IV. CONCLUSION

As a result, the new amplitude gain approximation and image simplification with amplitude-color function increased the visualization quality of the radargrams and protected the real amplitude rates of the GPR data. The transparent 3D imaging with an opaque function proved successful in specifying changes in the structures underground.

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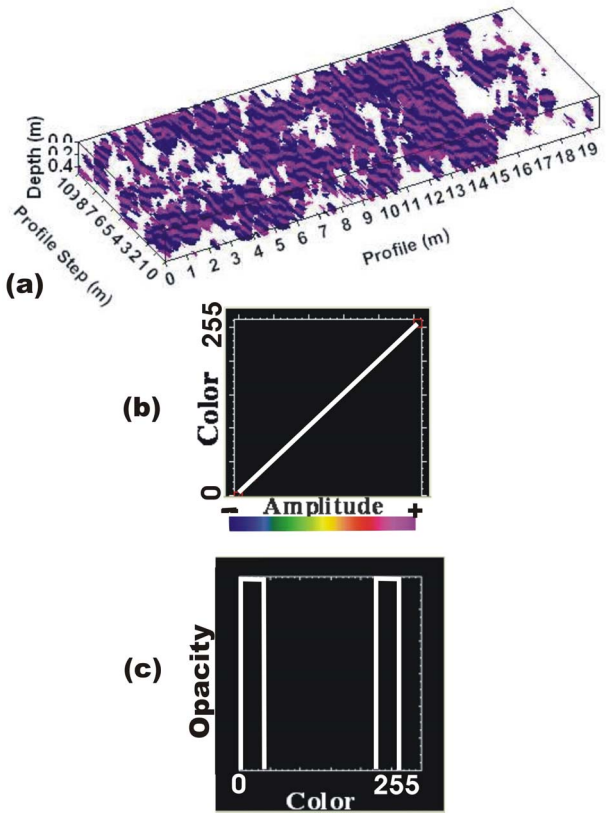


Figure 5. a) A transparent 3D GPR data volume of the same data of Fig.3 with b) functioned linear amplitude-color range and c) functioned amplitude-opaque range activating only maximum negative and positive amplitude range.

REFERENCES

[1] P.X. Neto and W.E. Medeiros, "A practical approach to correct attenuation effects in GPR data," Journal of Applied Geophysics, vol. 59, issue 2, pp. 140-151, 2006.

[2] A.P. Annan, "Practical processing of GPR data," Proceedings of Second Government Workshop on Ground Renetrating Radar, Sensor and Software Inc., 1999.

[3] J. J. Daniels, "Ground penetrating radar for imaging archaeological objects in the subsurface", Proceedings of the New Millennium International Forum on Consideration of Cultural Property, Kongju-Korea, 242-265, 2000.

[4] Reflex-Win: Ver.5.0. Sandmeier software. info@sandmeier-geo.de

[5] M. Sato, "Fundamantels of GPR data interpretation", Text Document, Tohoku University, January, 2001.

[6] M.H. Jol, Ground penetrating radar: Theory and applications, Elsevier:Oxford,UK. 2009, pp. 34-35.

[7] S. Kadioglu, "Photographing layer thicknesses and discontinuities in a marble quarry with 3D GPR visualisation", Journal of Applied Geophysics **64**, 109-114.

[8] S. Kadioglu and J.J. Daniels, "3D visualization of integrated GPR data and EM-61 data to determine buried objects and their characteristics,", Journal of Geophysics and Engineering. Vol. 5, 448-456, 2008.