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Comparing the Frequencies of 450 Mhz and 750 Mhz using GPR in Investigating Archaeological Features in (Borsippa) Site, Babylon, Iraq

Hamza A. Kareem*, Najah A. Abd

Department of Geology, College of Science, University of Baghdad, Baghdad, Iraq

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Abstract

Mala GX (Ground Explorer) conducted the survey using two different antennas: 450 MHz and 750 MHz. Data for the 450 MHz antenna were collected in a grid, while data for the 750 MHz antenna were collected in parallel profiles at the same location above the 450 MHz profiles. After processing the data using GPR slice software, possible reflections of archaeological walls buried at different depths and with different extensions of 13 m, 7 m, 6 m, 5m, 3 and 2 m were identified. The reflections were clear and high in the 450 MHz antenna with a depth penetration of 3 meters and unclear and weak in the 750 MHz antenna with a depth penetration of 1 meter. When comparing the two antennas, it is possible to notice a match in the reflections of the walls, and some reflections are not identical in the 750 MHz antenna due to the high noise.

Keywords: Ground Penetrating Radar; archaeological feature; Borsippa

مقارنة ترددات 450 ميغاهرتز GPR في التحقيق في المعالم الأثرية في موقع (بورسيبا) بابل العراق و 750 ميغاهرتز باستخدام

حمزة علي الكريم* نجاح عبد الحسن

قسم الجيولوجيا ، كلية العلوم ، جامعة بغداد ، بغداد ، العراق

الخلاصة:

جرى استخدام جهاز Mala GX (Ground Explorer) في مسح راداري ارضي باستخدام هوائيين مختلفين: 450 ميغاهرتز و 750 ميغاهرتز. تم جمع بيانات هوائي 450 ميغاهرتز في شبكة ، بينما تم جمع بيانات هوائي 750 ميغاهرتز في ملفات تعريف متوازية في نفس الموقع فوق ملفات تعريف 450 ميغاهرتز. بعد معالجة البيانات باستخدام برنامج شرائح GPR ، تم تحديد الانعكاسات المحتملة للجدران الأثرية المدفونة على أعماق مختلفة وبامتدادات مختلفة من 13 م ، 7 م ، 6 م ، 5 م ، 3 م و 2 م. كانت الانعكاسات واضحة وعالية في هوائي 450 ميغاهرتز مع اختراق عمق 3 أمتار وغير واضحة وضعيفة في هوائي 750 ميغاهرتز مع اختراق عمق 1 متر. عند المقارنة ما بين الهوائيين يمكن ملاحظة تطابق في انعكاسات الجدران وبعض الانعكاسات غير متطابقة في هوائي 750 MHz بسبب الضوضاء العالية.

1. Introduction

Ground penetrating radar (GPR) is helpful in modern archaeological investigations. It is a high-resolution, non-destructive geophysical method for investigating archaeological sites [1].

*Email: ly664850@gmail.com

It is generally known and proven that ground penetrating radar is a handy tool in engineering, environmental geology, archaeology, and mining [2]. GPR probes lossy dielectric materials with electromagnetic fields to detect structures and changes in the properties of materials [3]. The signal of GPR sent out goes through the material and is scattered or reflected by changes in impedance, which causes events that look like the signal sent out [4]. Several research projects have benefited from incorporating GPR-based geophysical analysis in geological and archaeological studies [5]. Sediments that have been buried can be investigated alongside limited excavations and exposures. Ground penetrating radar's ability to generate 2D and 3D images of soils and sediments at depths of interest to archaeology (from a few centimeters to three and four meters) enables the production of complex images of geological materials associated with archaeological deposits. Standard GPR antennas in geoarchaeology send out radar waves with a frequency range of about ten megahertz (MHz) to 900 MHz. Some uncommon applications in small-scale, high-resolution studies employ frequencies above 900 MHz. The 400 MHz antenna can typically transmit radar energy to depths of 2–3 m, with a resolution of smooth surfaces of features as low as 20 cm or so. High-frequency antennas, like the 900 MHz, are very good at surveying near the ground's surface, up to about 1 meter, and can see details as small as 10 cm wide. Moreover, if high-frequency antennae are used in even moderately electrically conductive ground, their transmitted energy is attenuated within 30–40 cm of the ground surface [6]. The main objective is to use the GPR method to determine the positions and depths underneath archaeological structures in study sites and compare 450 and 750 MHz antennas to see which is better for detecting archaeological features.

2. Location of the study area

Borsippa is an archaeological site located in the Babylon Governorate, Iraq. Borsippa was an important ancient Sumerian city. It was built on both sides of a lake about 17.7 km (11.0 mi) southwest of Babylon on the eastern bank of the Euphrates river (Figure 1). The research area is covered by Quaternary sediments from the flood plain and aeolian sediments, as reported by [7].

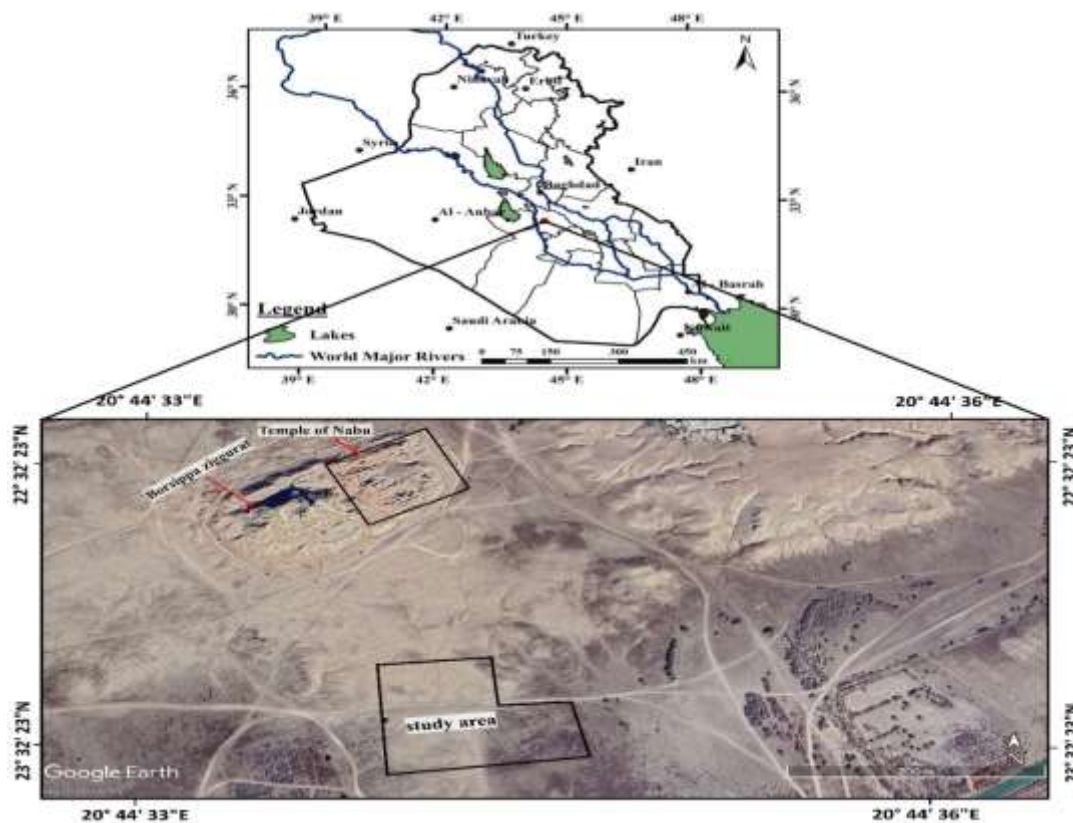


Figure 1: The location map of the study area.

2. Fieldwork

2.1 Data acquisition and processing:

The fieldwork was carried out in February 2022 by the Mala GX (Ground Explorer). The 450 MHz antenna was collected to cover an area of about (130m x 90m), 130 m in the y-direction, with an inline spacing of 10 m between every two profiles, and 90m in the x-direction, with an inline spacing of 5m between every two profiles. Where 36 profiles were collected as a grid (Figure 2), data from 750 MHz antenna were used to survey the same area with only 16 profiles in the same location of the 450 MHz antenna profiles in the x-direction with an inline spacing of 5m between every two profiles (Figure 2).



Figure 2: Google Earth Maps displays the locations of 450 MHz antenna profiles and 750 MHz antenna profiles.

The two antennas data were processed in the following sequence using GPR slice software to processing the GPR profiles:

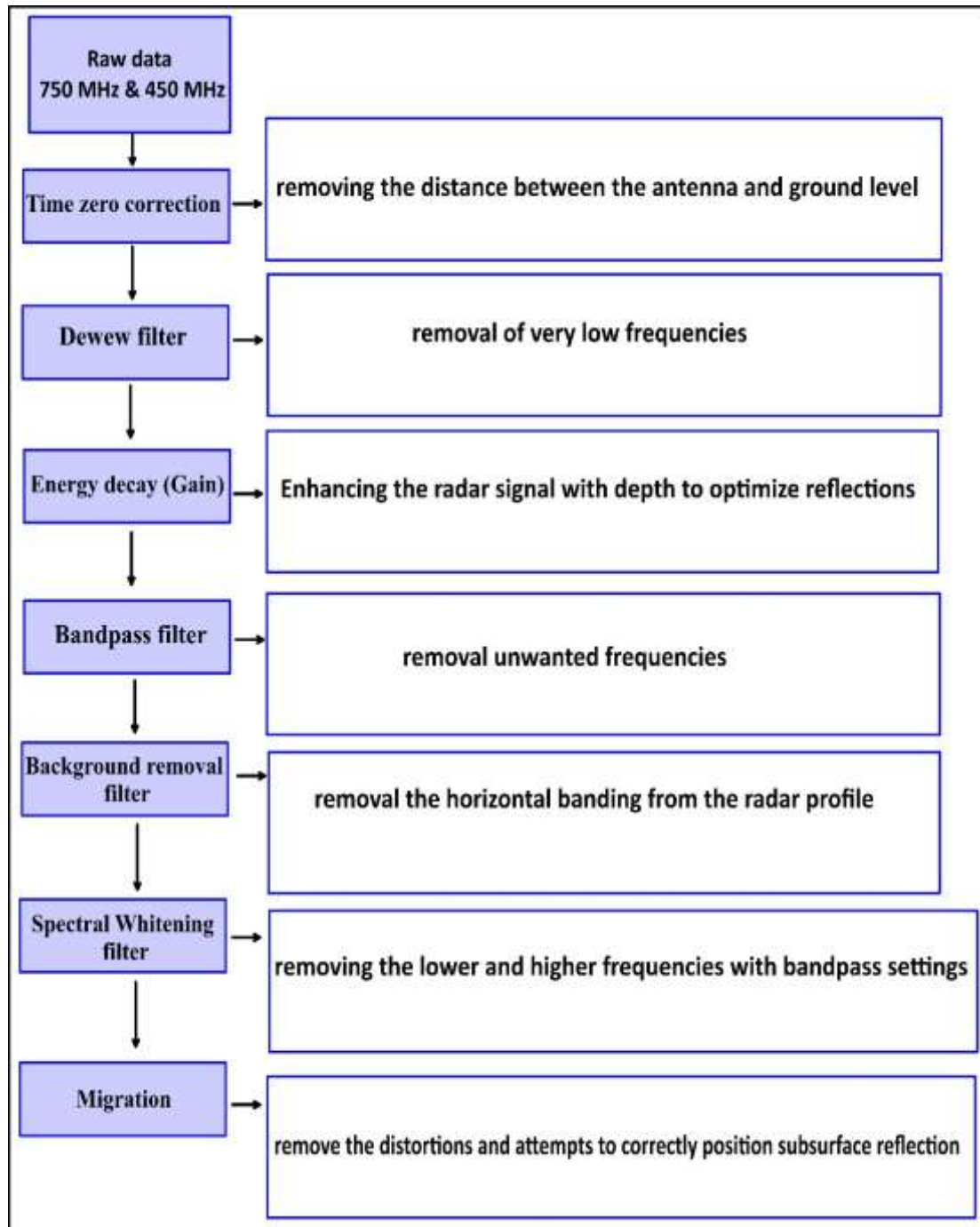


Figure 3: The processing sequence of the two antennas (450 MHz and 750 MHz).

The processing steps depend on the collected profiles and the goal of the survey [8]. The processing sequence (Figure 3) begins with time-zero correction and ends with the migration of two antennas, 450 MHz (Figure 4) and 750 MHz (Figure 5), which is the final image ready for interpretation. All GPR profiles are times-to-depths converted at a velocity of 0.1 m/ns (0.1 m/ns values are the default for the device).

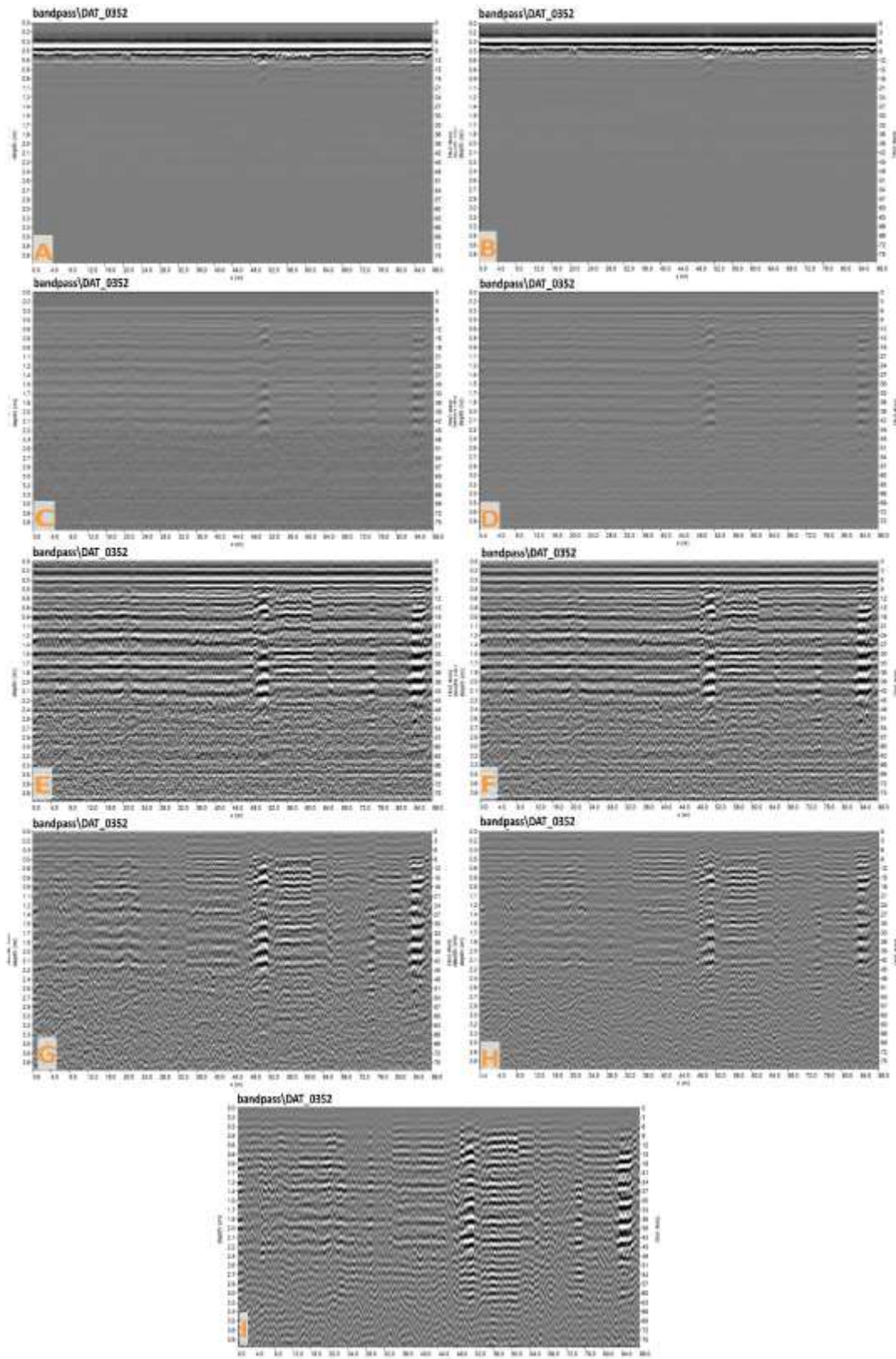


Figure 4: Processing sequence for the 450 MHz antenna profile 352. A) Raw data, B) Following zero correction, C) Before applying the deweathering filter, D) After applying the deweathering filter, E) After applying the gain filter, F) After applying the bandpass filter (the low-frequency cutoff is 200 MHz, and the high-frequency cutoff is 600 MHz), G) After applying the background removal, H) After using the Spectral Whitening filter, I) After using the Migration filter.

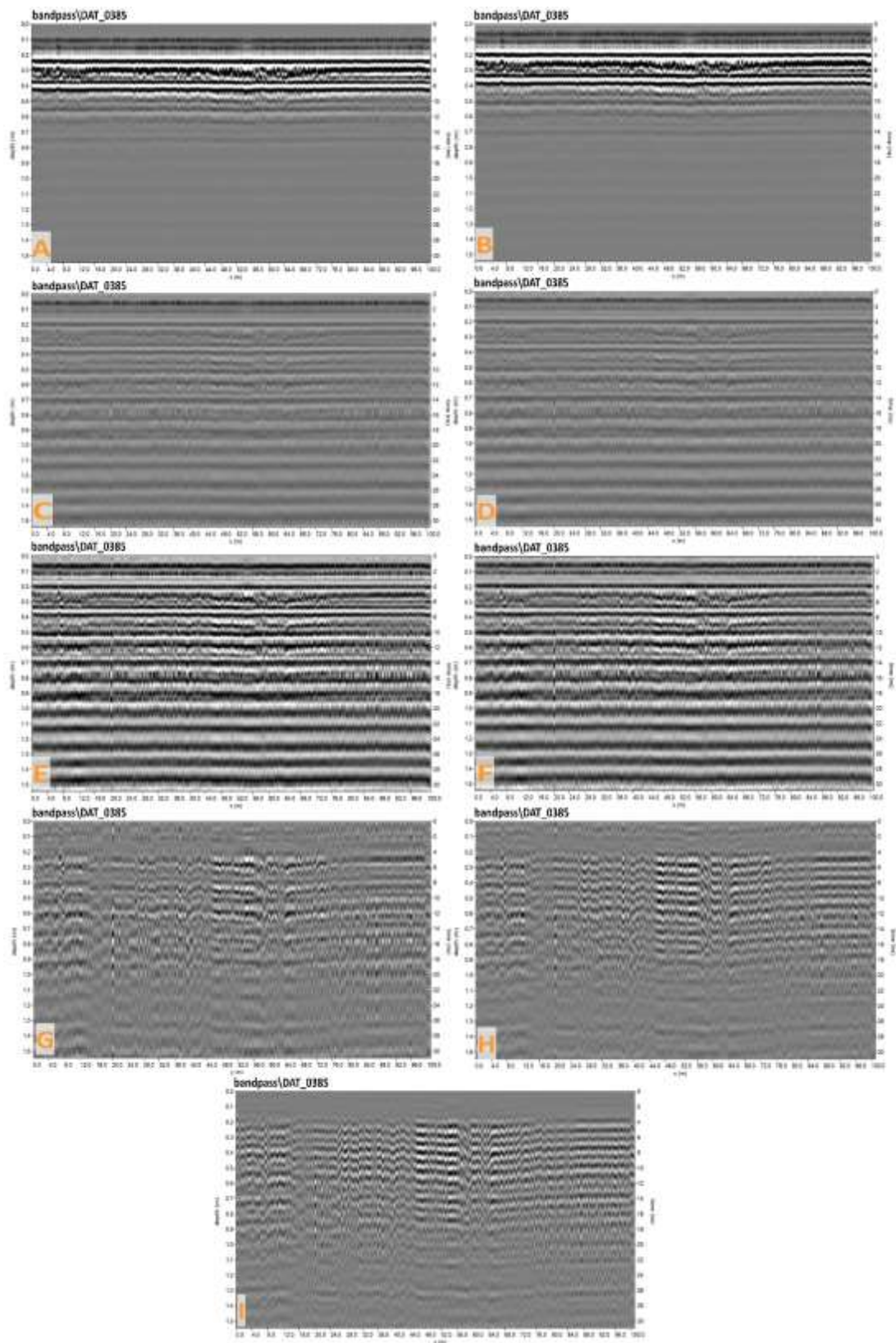


Figure 5: Processing sequence for the 750 MHz antenna profile 385. A) Raw data, B) Following zero correction, C) Before applying the dewew filter, D) After applying the dewew filter, E) After applying the gain filter, F) After applying the bandpass filter (the low-frequency cutoff is 350 MHz, and the high-frequency cutoff is 1000 MHz), G) After applying the background removal, H) After using the Spectral Whitening filter, I) After using the Migration filter.

3. Results and discussion:

3.1 450 MHz antenna data interpretation

Profile 366 (Figure 6) 450 MHz has a few high reflections that might be ancient walls with different lengths and depths of burial. Low-amplitude wave regions often represent soils with no contrast. The contrast is between two adjacent media, one of which, for example, has a high amplitude and the other a low amplitude, while the same material does not have a high contrast, such as buried archaeological features or substantial changes [9]. Beginning at the start of the profile and running for 6 m. the first wall was buried at a depth of 0.3 m. The second wall is buried at a depth of 0.3 m at a distance of 19 m extending to 18 m. The third one is buried at 0.8 m deep with a space of 64 m, extending to 2 meters. The fourth wall is buried at a depth of 0.8 meters at a distance of 69 meters and extends to 11 meters. As with the first and fourth walls, Profile 366 shows that the depth of penetration reaches more than 3 meters, with areas where reflections weaken the archaeological wall, as in the reflection of the first wall at a depth of 1.1–1.5 meters in Profile 366 because the wall material resembles a burial environment. The wall (target) must have the size and dielectric properties that contrast with the host material to be observed by the GPR systems [6]. In addition, the radar signal contains less noise than the significant archaeological reflections.

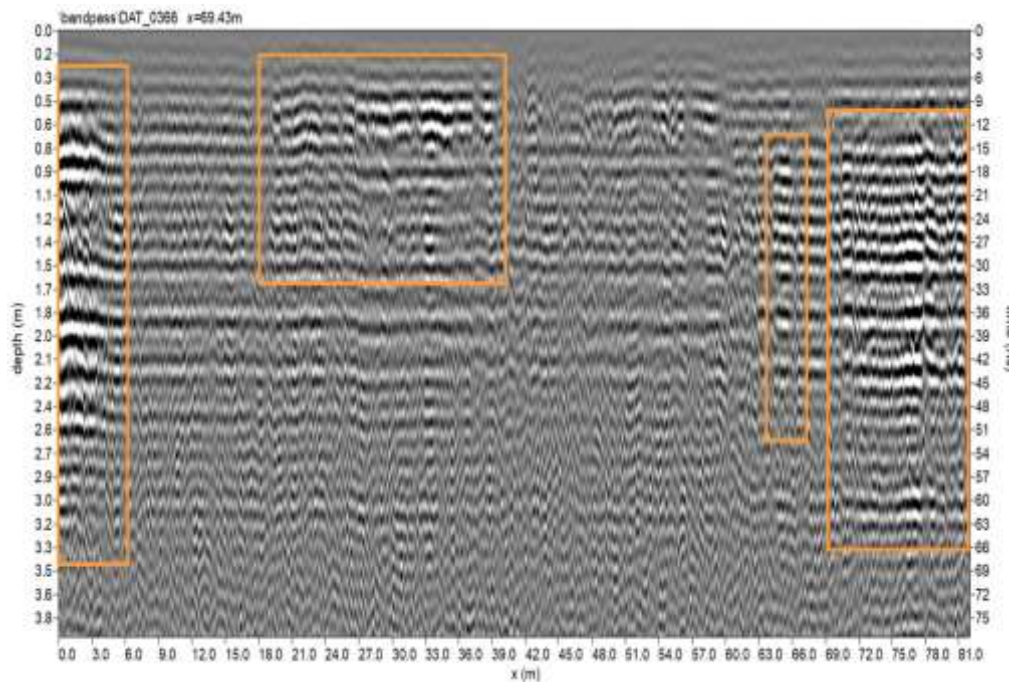


Figure 6: Profile 366 showing reflections of possible archaeological walls with varying extensions and burial depth.

3.2 750 MHz antenna data interpretation

Profile 380 (Figure 7) 750 MHz contains two possible reflections of ancient walls, the first wall at a distance of 2 meters buried at a depth of 0.2 meters and extending to 6 meters, and the second wall at a distance of 57 meters buried at a depth of 0.2 meters and extending to 5 meters. There are also several reflections of ringing noise due to buried metal and fuzzy reflections that may be noise. These reflections are prevalent in all profiles collected by the 750 MHz antenna.

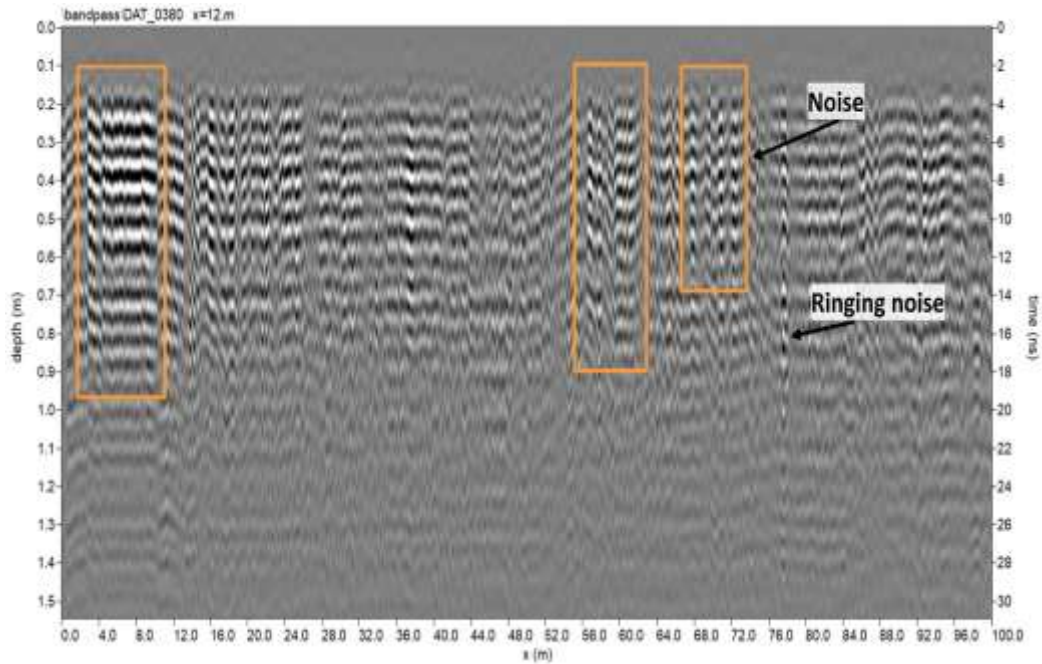


Figure 7: Profile 380 showing reflections of possible archaeological walls with varying extensions.

3.3 Comparison between two antennas

When comparing the data of the two antennas, as in Figure 8, Profile 368 used 450 MHz, and Profile 381 used 750 MHz (both profiles are in the same location and direction). The reflection of the first wall, which extends for 11 meters, is identical between the two profiles and the second and third walls. However, there are two reflections between the first and second walls (red color) in Profile 368 that we did not get clearly in Profile 381 because of the high noise, where the high-frequency signal contains a lot of chaos or unwanted signals that lead to partially obscuring or hiding the features that we desire [10]. The penetration depth of the 450 MHz antenna is about 3 meters, while that of the 750 MHz antenna is about 1 meter with high noise. It is possible to notice a difference in the burial depth between the antennas. In the 450 MHz antenna, the burial depth ranges between 0.3 and 0.5 meters, while in the 750 MHz antenna, reflections of the same walls appear at a depth of 0.2 meters. This might result from the 750 MHz antenna's excellent resolution at shallow depths below the surface.

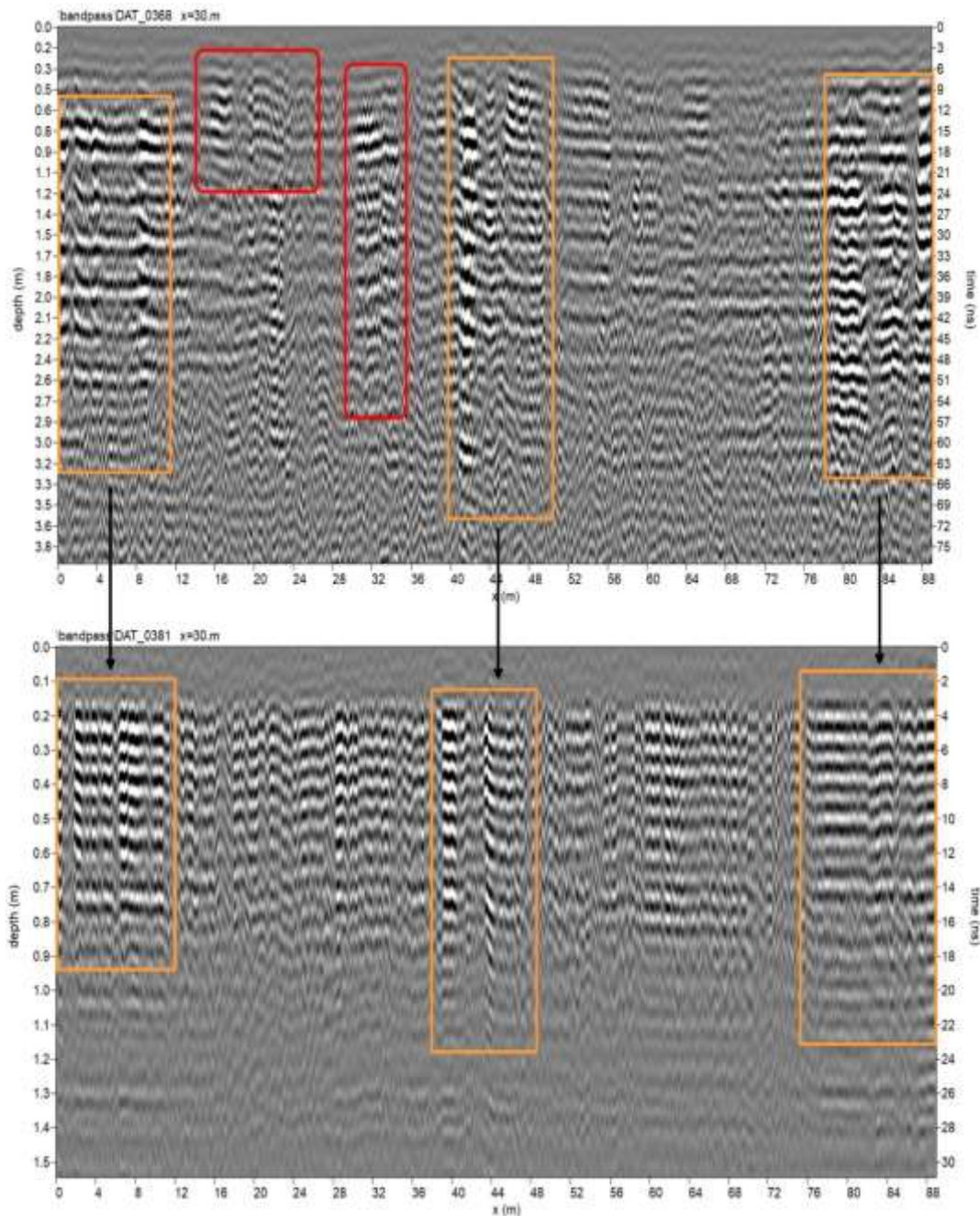


Figure 8: comparison of the 450 MHz antenna (Profile 368) to the 750 MHz antenna (Profile 381).

Some GPR profiles of the two antennas were taken at the same location (9 profiles from each antenna), and the GPR slice software was used to make time slice maps so that they could be compared (Figure 9). In the time slice at a depth of 0.3 to 0.4 meters for both antennas, it can be observed that the reflections in the 750 MHz antenna have greater extensions than those of the 450 MHz antenna. As the reflections located at a distance of 25 to 40 meters in the X-direction on the time slice of the 450 MHz antenna are present on the 750 MHz antenna but with larger extensions, they do not represent the actual buried archaeological features because these reflections are caused by the high noise distributed in the GPR profiles of the 750 MHz antenna.

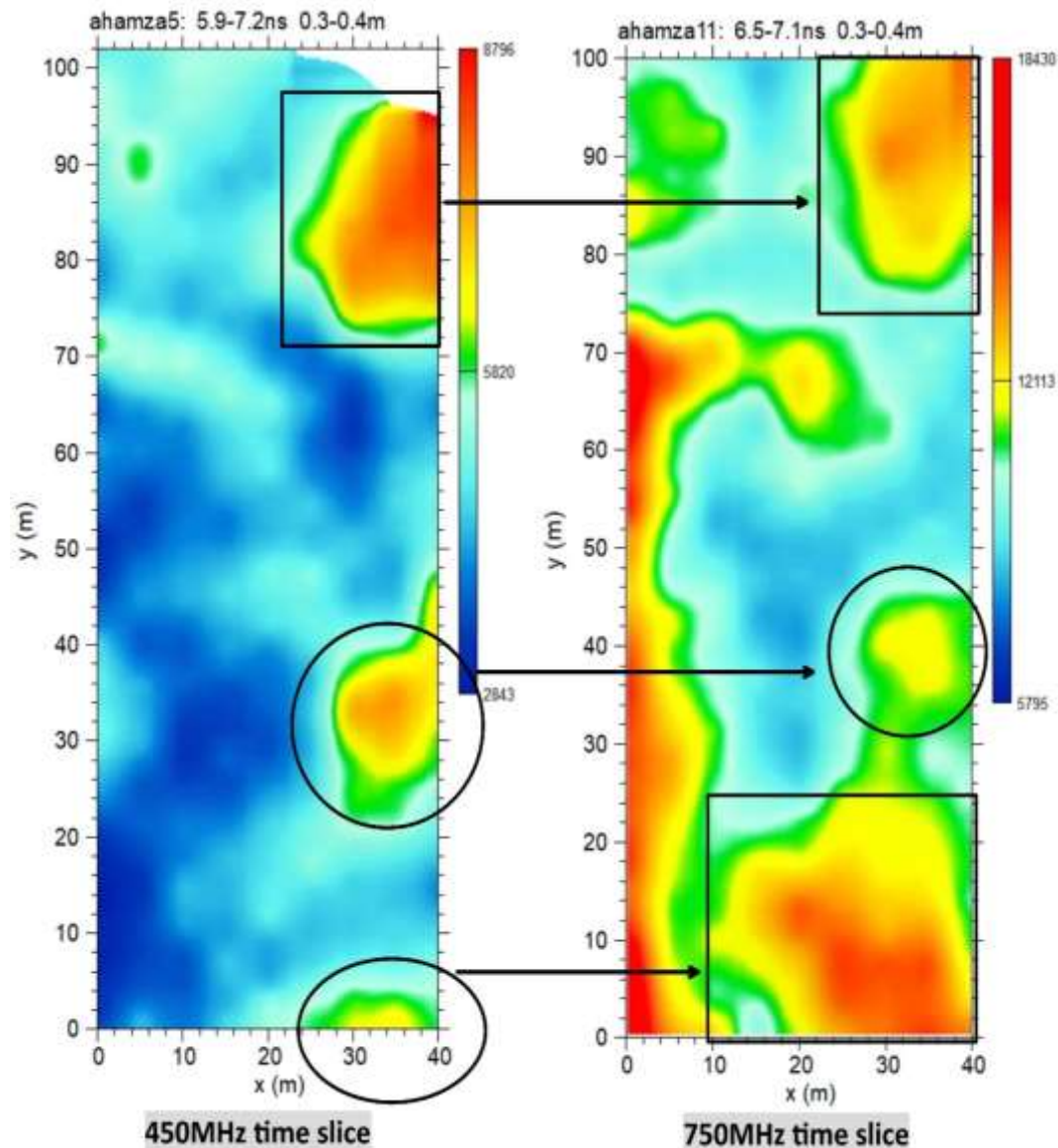


Figure 9: Time-slice comparison at 0.3–0.4 m for both 450 and 750 MHz antennas.

4. Conclusions:

A GPR survey using two types of antennas (450 and 750 MHz) revealed that the results of the 450 MHz antenna are better in horizontal and vertical accuracy than those of the 750 MHz antenna for investigating buried archaeological features. The results of the 450 MHz antenna showed a penetration depth of up to 3 meters, with clarity of possible archaeological wall reflections and little noise. In contrast, the results of the 750 MHz antenna showed a penetration depth of up to 1 meter, with some reflections of the possible archaeological walls lacking clarity due to the high noise that accompanied the reflections of the possible archaeological walls. There is a match for the reflections of some archaeological walls between the two antennas. However, due to the noise spread along the 750 MHz antenna profiles, it is exceedingly difficult to produce time slice maps to determine the extent and shapes of the buried archaeological structures.

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