

¹ Detection of Fracture Zones for Groundwater Investigation from
² Interpretation of VLF-EM Anomalies of Kwara State Polytechnic
³ Ilorin and its Environs

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7 Abstract

8 The Very Low Frequencyâ???"Electromagnetic (VLF-EM) geophysical methods have been used
9 to map selected settlements in Kwara State Polytechnic (Permanent Site) and its environs,
10 Ilorin, Northcentral Nigeria with a view to determine the groundwater potential of the area. A
11 total of thirteen (13) profiles were covered during VLF data collection with 20m sample
12 interval along each profile with spread length of between 100m. The VLF data were collected
13 using ABEM WADI instrument. The data were interpreted using KHFFILT software. The
14 qualitative interpretation of the acquired VLFâ???"EM data identified areas of hydro-geologic
15 importance. The results further showed that the EM anomalies vary greatly. Some of the
16 anomaly peaks are narrow and sharp while others are broad with varying width extent. The
17 values of the filtered real range from -0.9 to 22.5 across the study area. The study area is
18 adjudged, based on the VLF data interpretation which indicates the presence of
19 interconnected fracture zones, to have potentially good prospects for groundwater
20 development; while recommendation is made for further geophysical methods to be employed
21 in order to detect suitable locations for productive and sustainable borehole.

Index terms— very low frequency electromagnetic (VLF-EM), moro lga, abem wadi, em anomalies, fracture zones, groundwater.

25 1 Introduction The VLF-EM technique was developed in the
26 1960s

with the use of the transmitted signals of the already established powerful radio communication stations (in the 10-30 kHz band). The transmitters of these stations generate primary fields with horizontal magnetic components ($y H$), and vertical electric component ($z E$). Both components are perpendicular to the direction of propagation (X). At great distance, their wave front is considered uniform and plane. It is known that the induction caused by the primary magnetic field in a homogenous earth modifies the $y H$ component and creates a horizontal electric component $x E$, and when a subsurface conductor is encountered, a secondary magnetic field will be generated ??Mahemedet al., 1998). In recent times, the VLF EM method has been applied successfully to map the resistivity contrast at boundaries of fractured zones having a high degree of connectivity ??George et al., 2013). Also VLF method yields a higher depth of penetration in hard rock areas because of their high resistivity (McNeill and Labson, 1991). VLF method is capable of delineating fractures in lateral direction effectively compared to resistivity sounding (Sharma and Baranwal, 2005), characterize aquifer structures in a complex environment ??Ozeginet al., 2012), underground water contamination by solid waste (Deborah and Ayobami, 2013) and examination of the fault pattern of industrial estate (Theophilus and Lukman, 2012).

The Very Low Frequency Electromagnetic (VLF -EM) method has found useful application in groundwater investigation in basement terrain, most especially as a reconnaissance tool (Amadi and Nurudeen, 1990; Olorunfemi et. al., 1995). It is an accepted fact that most of the ground VLF-EM anomalies are caused by the galvanic

5 RESULTS AND DISCUSSIONS

43 effect (McNeil, 1985) where the influence of frequency may be neglected ??Guerin et al., 1994). This method of
44 geophysical prospecting was primarily developed for the delineation of sheet -like metallic conductors, which are
45 often concentrated within fault and fracture zones which are known to be good groundwater aquifers, particularly
46 when the fracture frequency is high (Olorunfemi et. al., 1995). The technique may be applied indirectly to the
47 location of sites with appreciably thick overburden to the mapping of geological structures such as fault and
48 fracture zones that are favourable to groundwater accumulation ??McNeil, 1980;Palacky et. al., 1981; ??diat et.
49 al., 2009).

50 The mapping of fracture zone which is a break in crystalline basement rock due to tectonic forces or intrusion of
51 magmatic bodies is important for civil engineering and hydrogeological applications. In civil engineering, it helps
52 to locate the safest depth to lay the foundation of buildings. This study was driven by the desire to investigate
53 water bearing fracture zones in the area under investigation using very low frequency (VLF) electromagnetic
54 method. Most boreholes drilled in the past in the area are unproductive and due to this failure, it is therefore
55 necessary to use an appropriate geophysical method to locate the fracture zones. This became important as
56 the inhabitants of the study area depend solely on streams, lakes and groundwater for their domestic needs and
57 otherwise.

58 2 II.

59 The Study Area Kwara State in its entirety is located in the North-Central part of Nigeria. It lies between the
60 Longitude 3 0 and 6 0 E and Latitude 8 0 and 10 0 N respectively (Fig. 1). It covers an area of over 32,500 square
61 kilometer and bounded by an international boundary with Benin Republic in the West, in the North by Niger,
62 in the East by Kogi and to the south by Oyo, Ekiti and Osun. The progressive population growth in Ilorin, the
63 nearest major town to the study area, has led to severe shortage of portable drinking water for the area which
64 poses a great challenge to both the citizens and the government. It is therefore obvious that the demand for
65 reliable and consistent water supply is high. Certainly the use of water is beyond mere domestic as virtually all
66 the industries, companies and governmental establishments are in dare need of water. Such high demand can only
67 be achieved through viable boreholes. The drilling of viable boreholes can be obtained by carrying out adequate
68 geophysical studies to empirically ascertain areas or sites where long term steady supply can be achieved.

69 Furthermore, rapid industrialization recently witnessed by the Ilorin metropolis has resulted in population
70 increase and has led to the urbanization of satellite villages and settlements of which the ancient Eleko, Kwara
71 Poly. (Permanent site), Ara and Akwo settlements, all of which fall in the study area. The people of these
72 settlements depend solely on surface water from streams and hand dug wells for their domestic use. However,
73 these sources of water are highly vulnerable to pollution thereby making the people to be susceptible to water
74 borne diseases. Moreover, fast increase population growth of this region occasioned by the influx of people
75 from nearly congested city of Ilorin, coupled with the location of government institutions such as Kwara State
76 Polytechnic and University of Ilorin Teaching Hospital has also made these sources of water inadequate for its
77 dwellers, and the need for good quality and readily available portable groundwater in this area forms the basis
78 for this research.

79 3 III.

80 4 Materials and Methods

81 The ABEM WADI VLF-EM Instrument used to measure the EM response is a portable instrument which
82 measures the electrical properties of the subsurface, using EM induction as detailed in ??cNeil (1980a). In
83 this work, thirteen EM profiles were made using a 20m coil spacing, with an expected maximum depth of
84 investigation of about 15m for the horizontal dipole (HD) mode ??McNeil, 1983). The EM data were collected
85 at 20m interval along thirteen profiles (Fig. 3) with lengths ranging from 300 to 1700m. The VLF-EM data were
86 presented as profiles figures by plotting raw real (quadrature) measured on the field and the filtered real while
87 their corresponding Karous-Hiljet (K-H) pseudo sections are shown in Figures respectively. The The VLF WADI
88 instrument displays the filtered real anomaly on the screen, and this anomaly can be roughly interpreted on site.
89 This feature of the instrument is used to select sounding locations for resistivity surveys. For further detailed
90 information of the subsurface, the measured real anomalies were rediscertized at 1 m interval and filtered using
91 the approach of ??arous and Hjelt (1983). This process yields pseudo-section of relative current density variation
92 with depth. A higher value of relative current density corresponds to conductive subsurface structures.

93 IV.

94 5 Results and Discussions

95 It is observed that apparent current density cross-sections using real and imaginary anomalies show almost similar
96 features. Therefore, for simplicity only the real component results are presented below (Fig. 4

97 Figure 4a Figure 4b Figure 5a

98 Figure 6b

99 At location VLF 06 with traverse oriented in the E-W direction, a well-fractured zone with positive Fraser
100 filter was identified (Fig ??a). It is located at a horizontal distance between 11-13m, along the profile at depth
101 of between 2-6m. Similar was the case at location VLF 07 with a prominent fracture zone located at a horizontal
102 distance between 28-34m (Fig 10a), along the profile at depth between 2-6m. At VLF 08 with traverse oriented
103 in the N-S direction, two probable and another two not wellfractured zones were identified. They were located
104 between 5-8m, 32-34m, 50-52m and 68-70m respectively along the profile (Fig 11a). The depth of each fracture
105 zone was between 0-40m, 0-35m, 0-30m and 0-30m respectively all with orientation sat NE-SW (Fig 11b).

106 **6 Figure 7a**

107 Figure 7b

108 **7 Figure 8a**

109 Figure 8b

110 Figure 14b Figure 15a Figure 15b

111 **8 Figure 16b**

112 The EM anomalies vary greatly. Some of the anomaly peaks are narrow, sharp while others are broad with
113 varying width extent. The values of the filtered real range from -0.9 to 22.5 across the study area. The profiles
114 for the EM sections contain significant maxima in the filtered real part. Zones with peak positive filtered real
115 anomalies are considered priority areas for electrical sounding, since they often correspond to zones with high
116 conductivity, characteristic of water-filled fractures or faults ??Alvin et. al., 1997), or effect of appreciable
117 depth to bedrock or lithological variations within the unconsolidated regolith ??White et al., 1988). In other
118 words, VLF-EM anomalies were delineated as fairlyconductive, conductive, highly-conductive, fairlyresistive and
119 resistive responses at different locations across the study area. Positive anomaly is indicative of steeply-dipping
120 linear features such as fractures. These features serve as channels for migrating fluids and minerals. These points
121 are zones of interest in groundwater abstraction in basement complex terrain. These results therefore form the
122 basis for Vertical Electrical Sounding (VES) investigation that may subesquently be carried out on any portion
123 of the study area.

124 V.

125 **9 Conclusion**

126 The study area has good prospects for groundwater development due to the presence of fracture zones which are
127 interconnected in nature. Further investigations for groundwater in the study area is therefore recommended;
128 these should however be aimed at searching for fracture zones where overburden is relatively thin and any
129 borehole drilled in the study area should be made to pass through as many fracture zones as possible. Finally,
130 it is recommended that for productive and sustainable boreholes to be drilled on any location in the study
131 area, relevant electrical resistivity methods should be employed for the Vertical Electrical Sounding (VES) of all
132 areas of interests (as suggested by the results of the present study) along each of the thirteen profiles that were
133 traversed.

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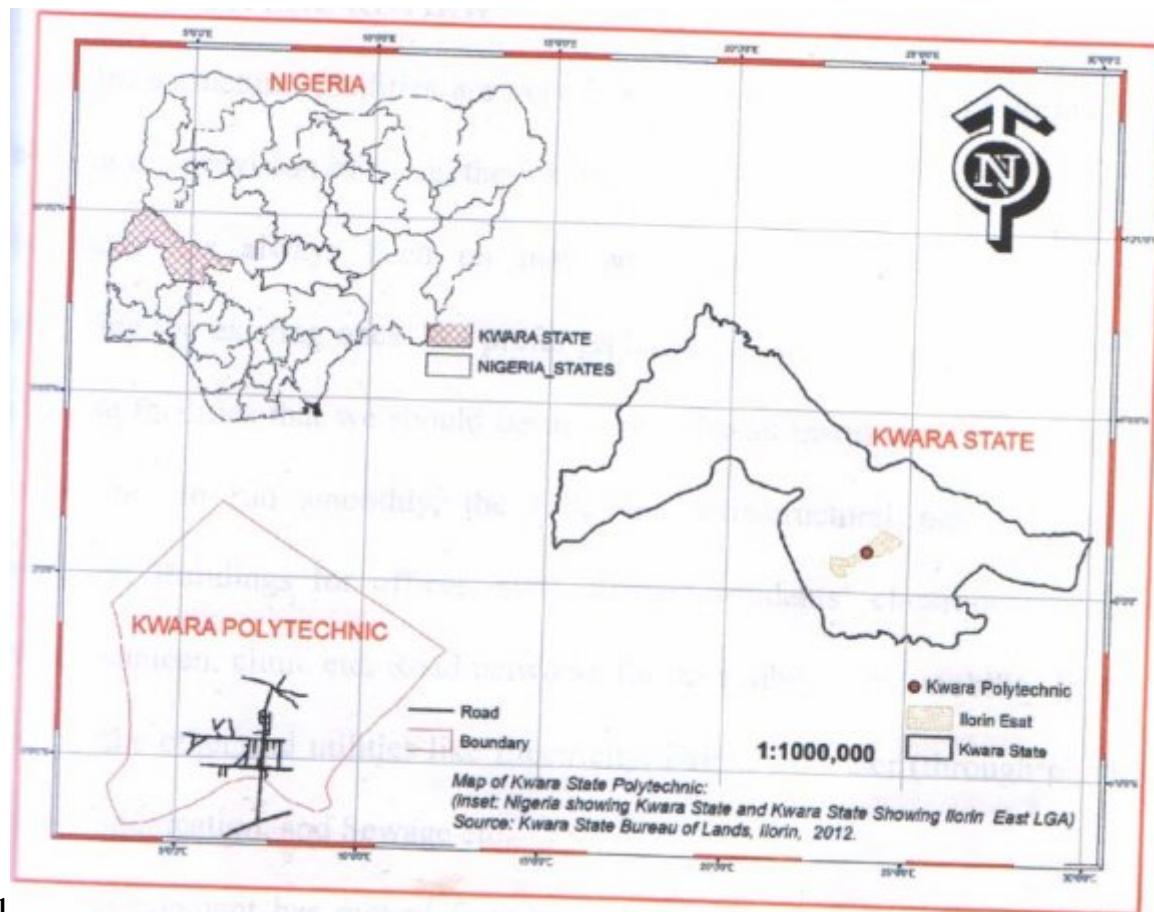


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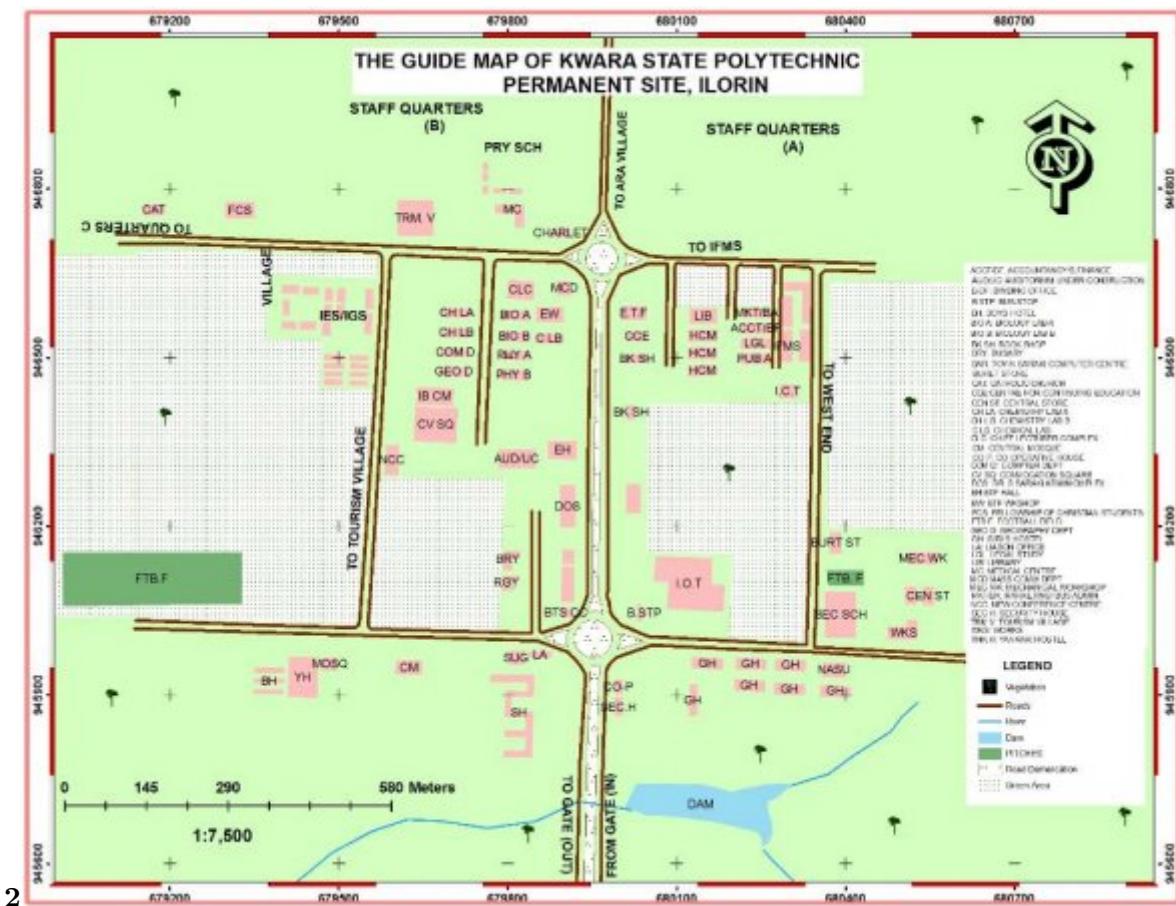


Figure 2: Figure 2 :

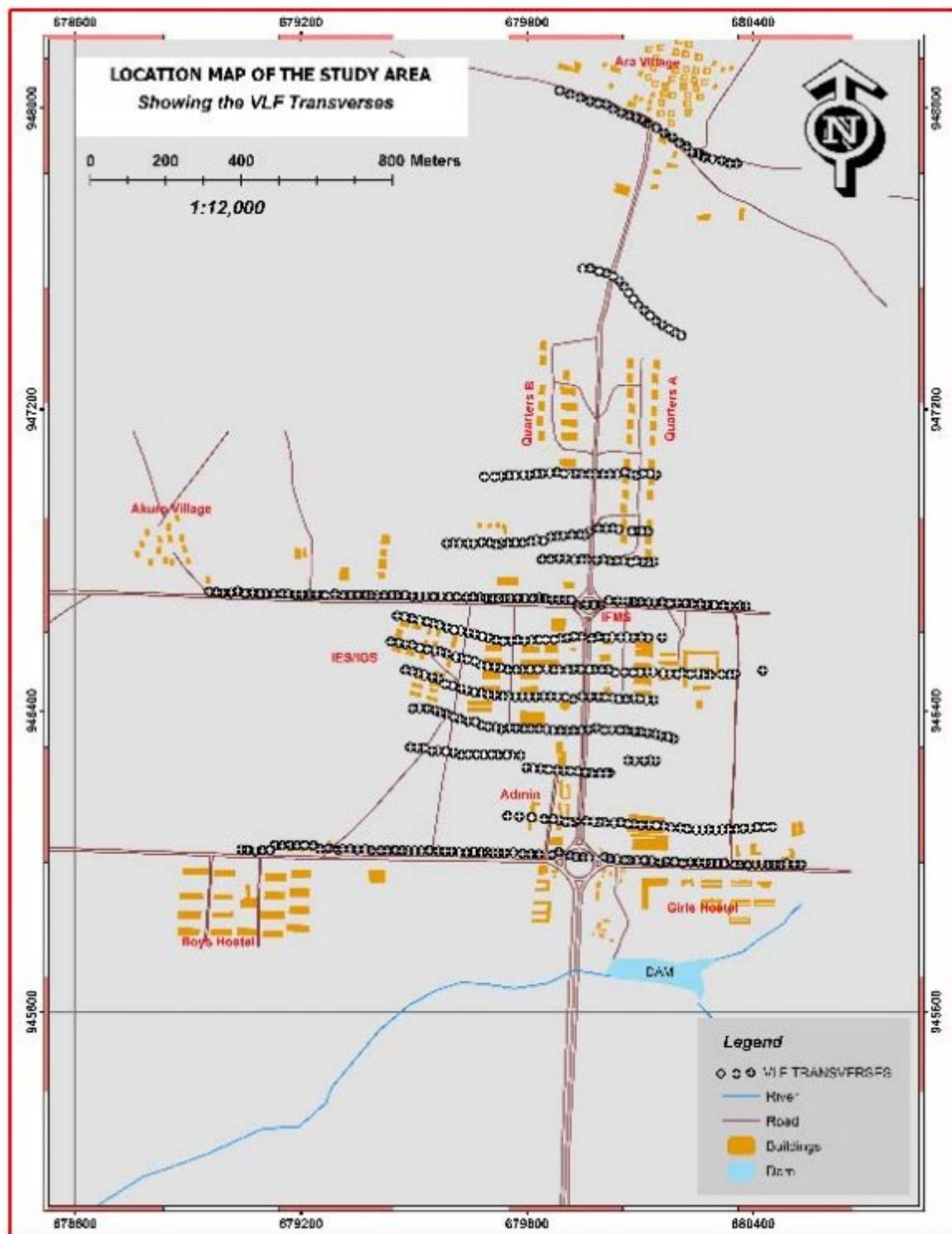


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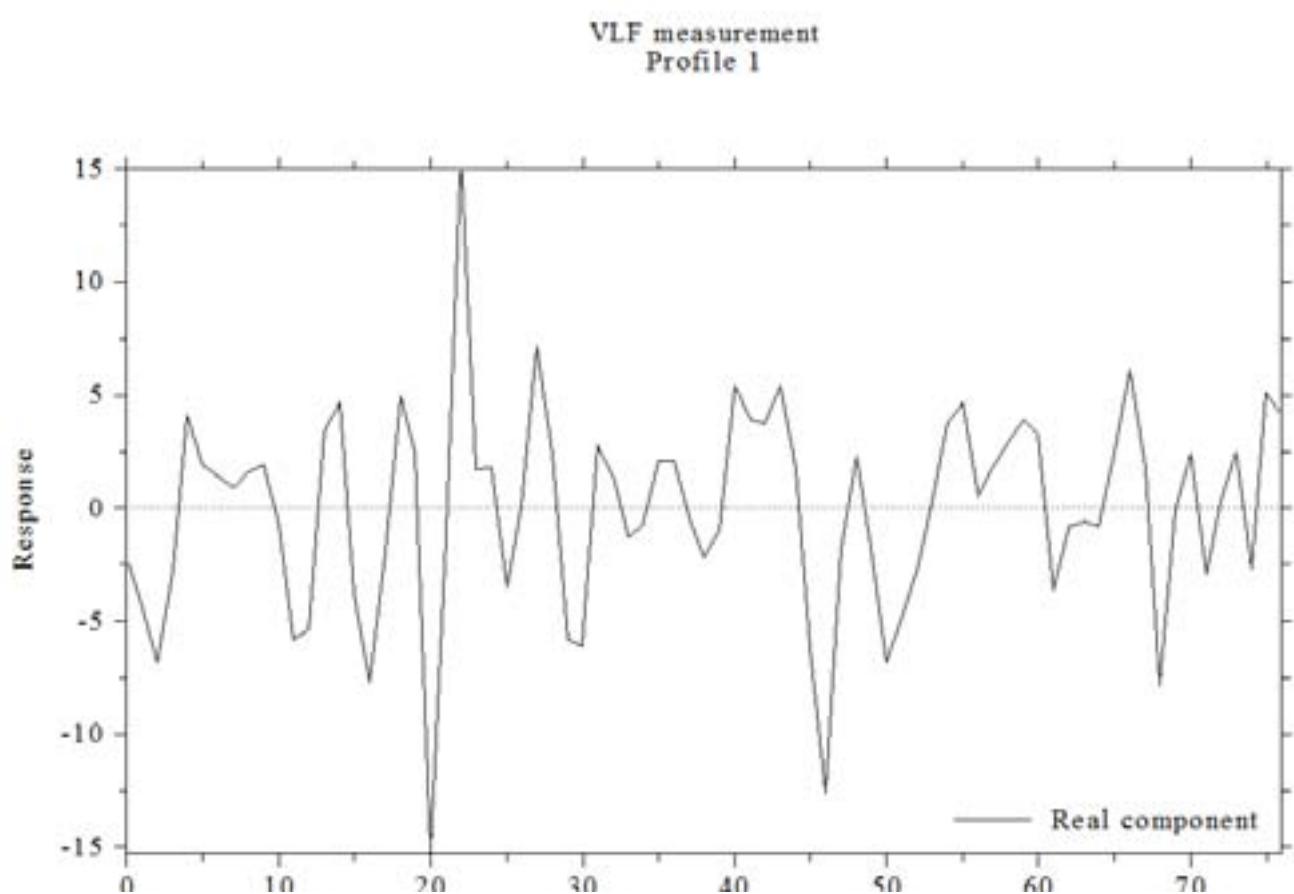


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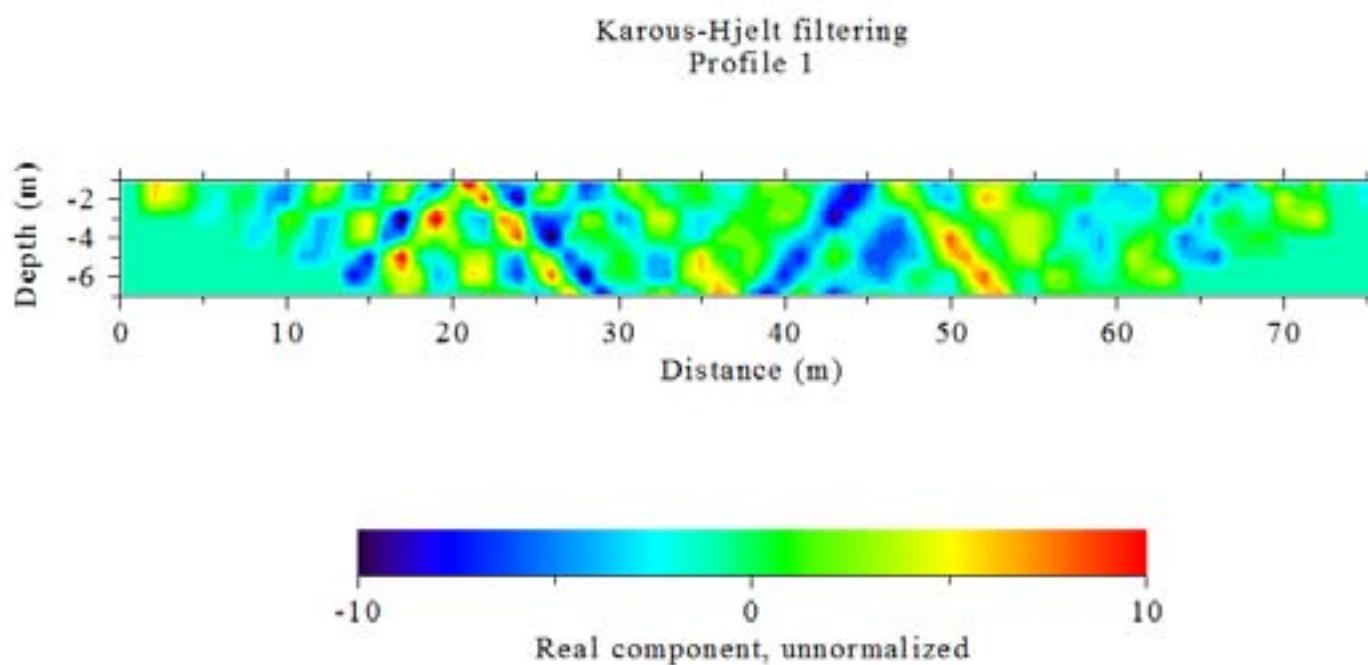


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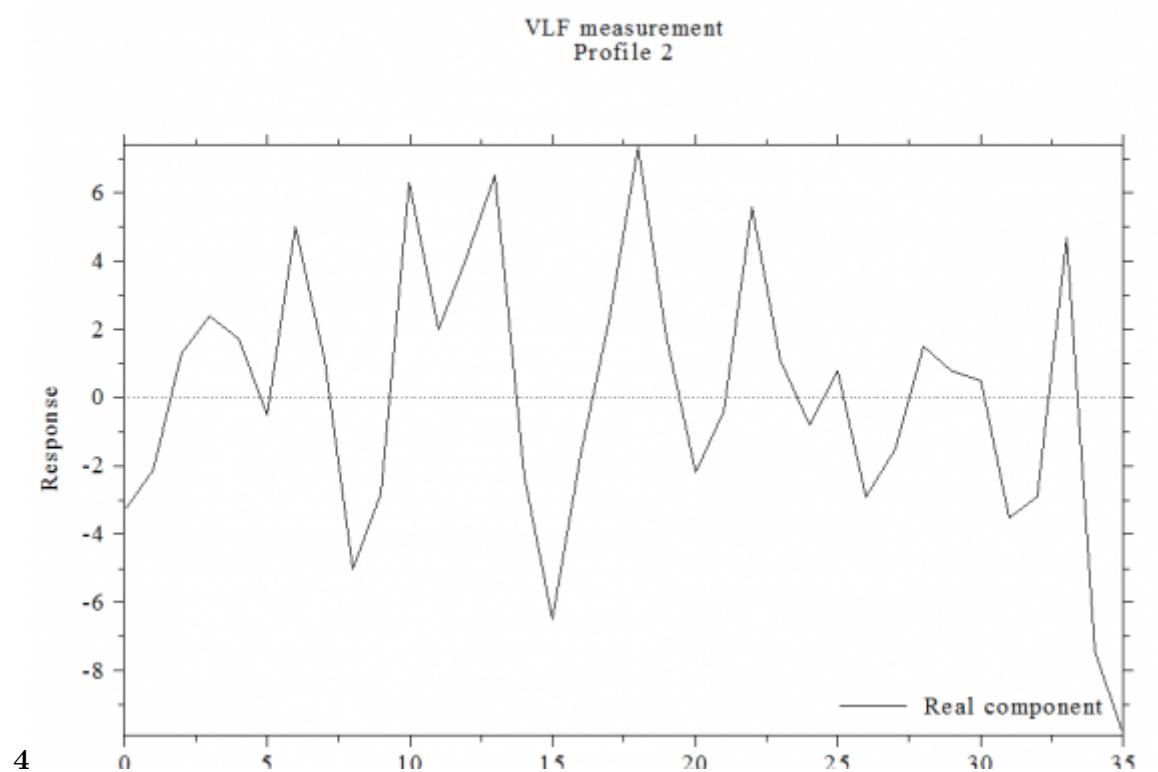
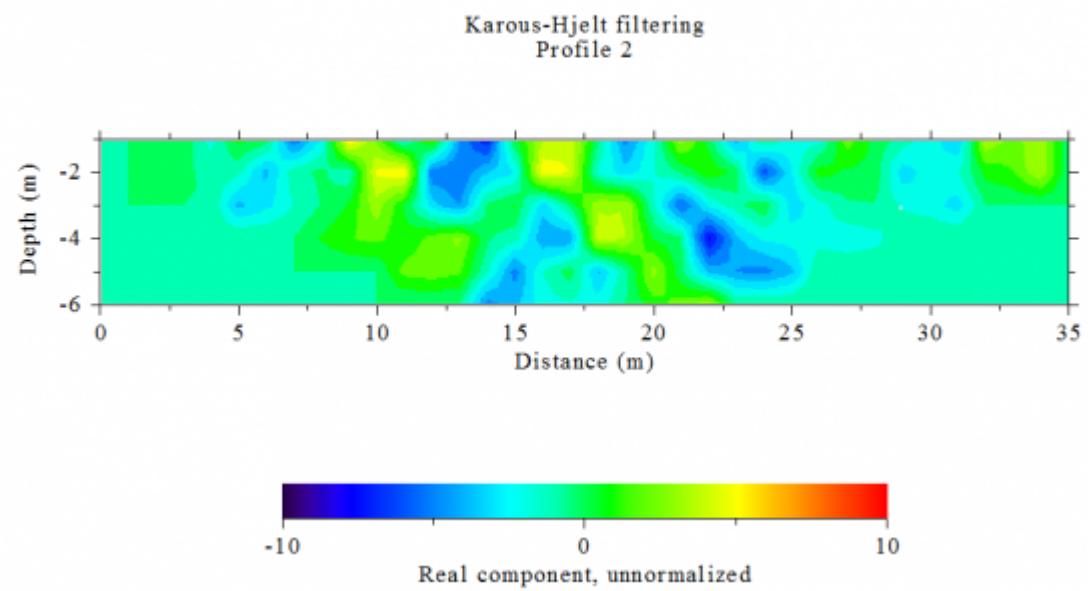


Figure 6: Figure 4



6a

Figure 7: Figure 6a

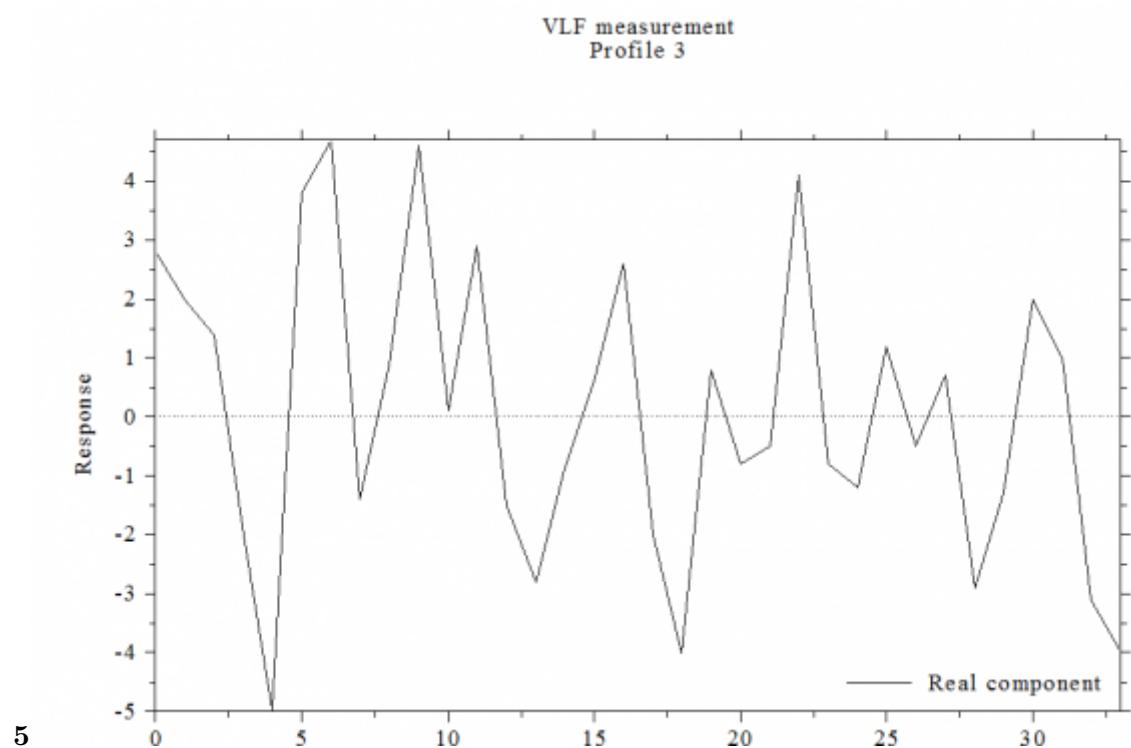
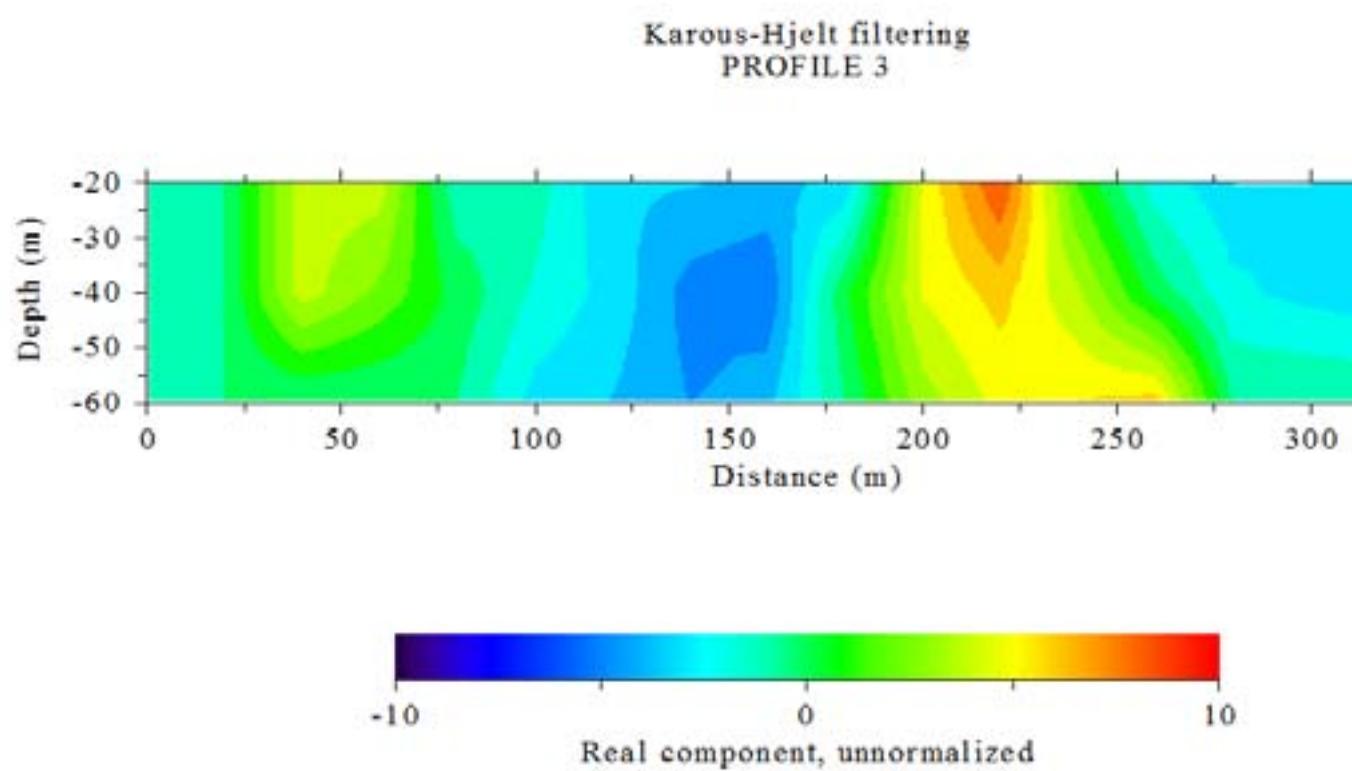


Figure 8: Figure 5



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Figure 9: Figure 6 Figure 7

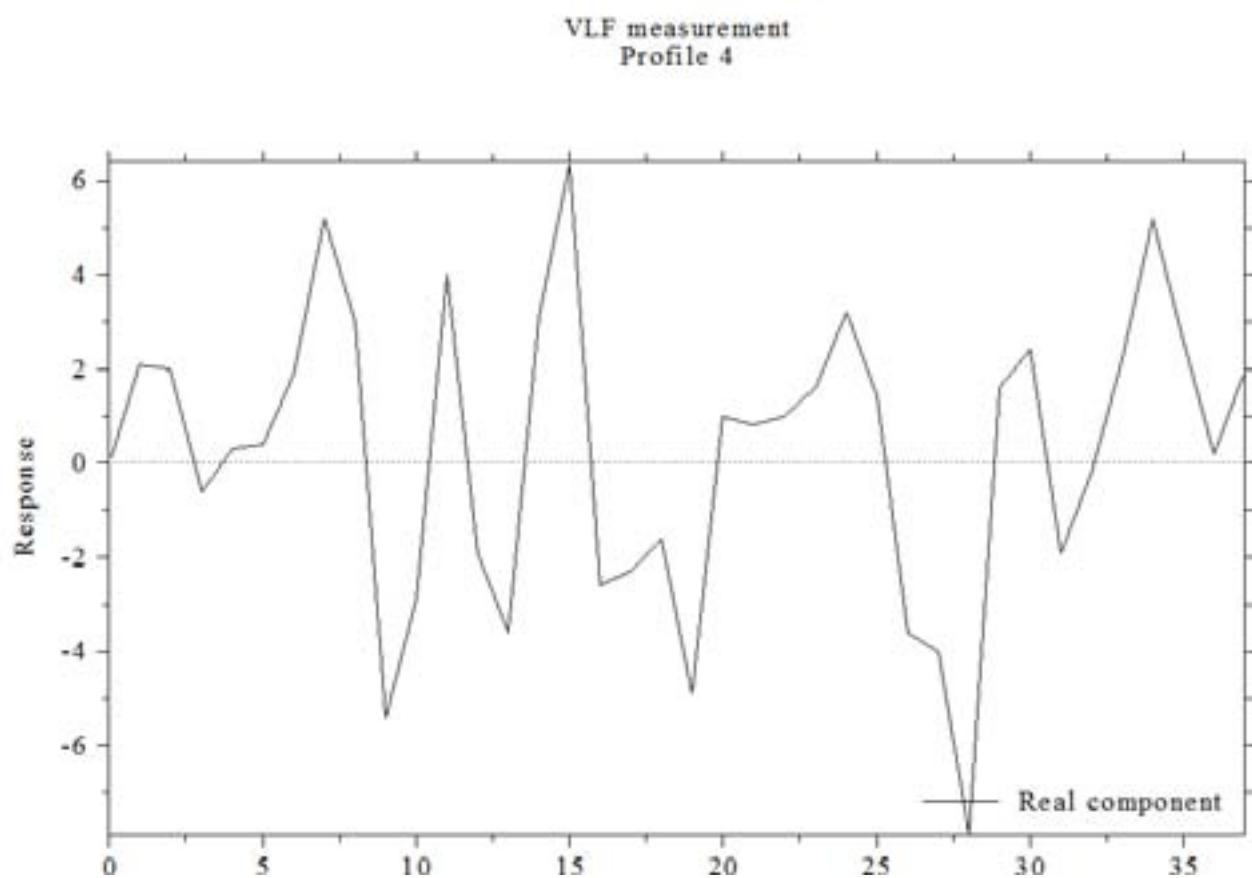


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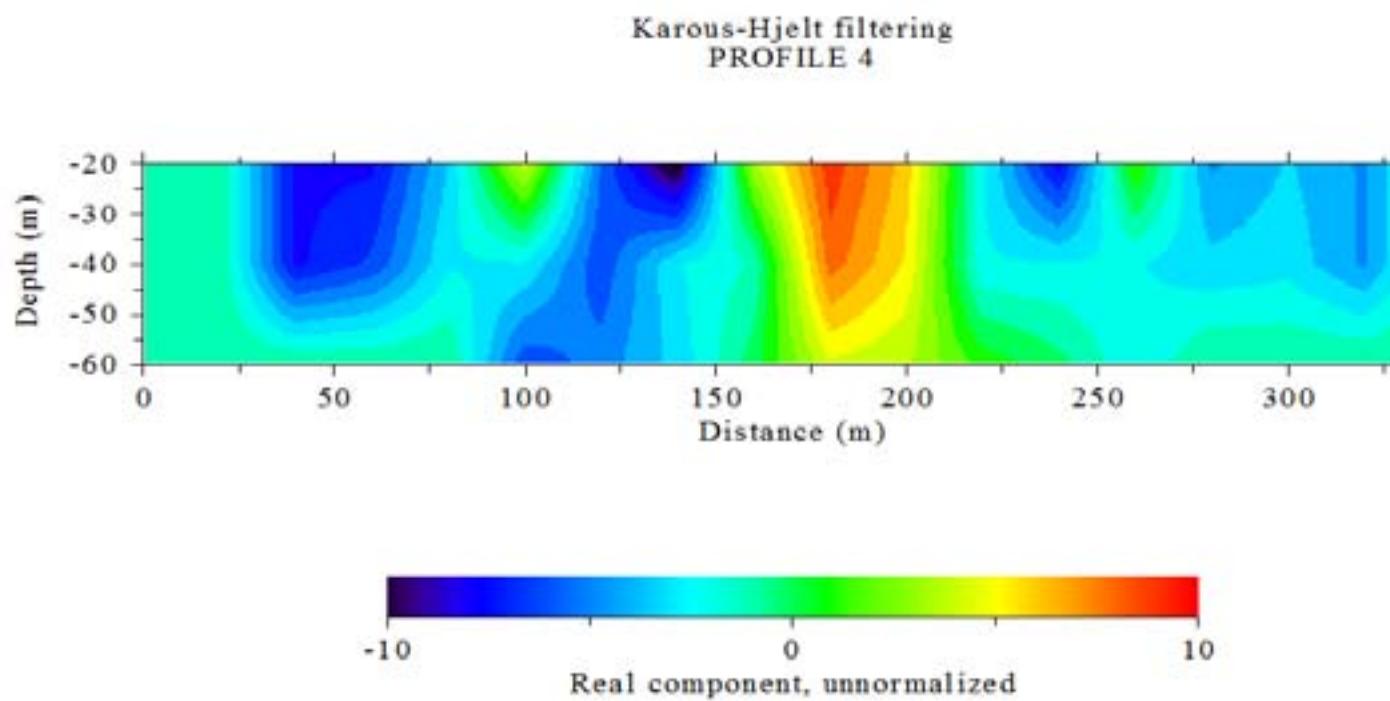


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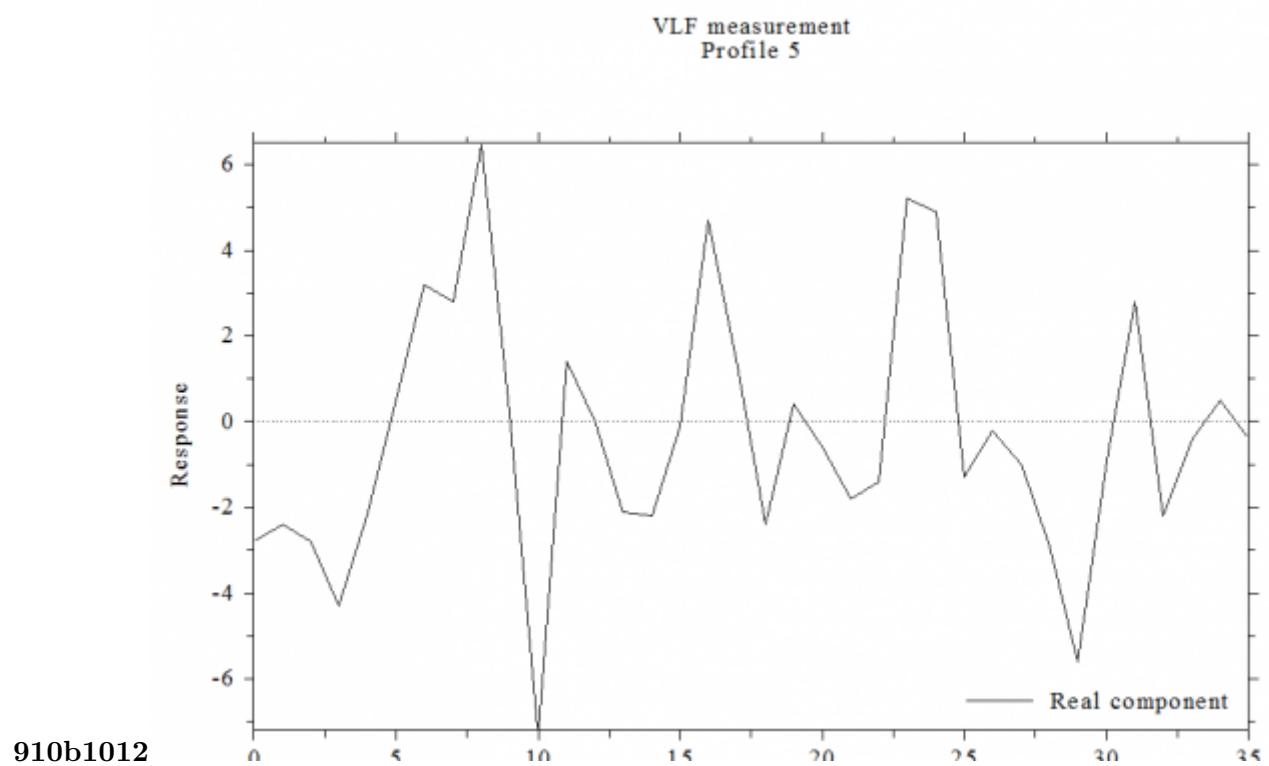
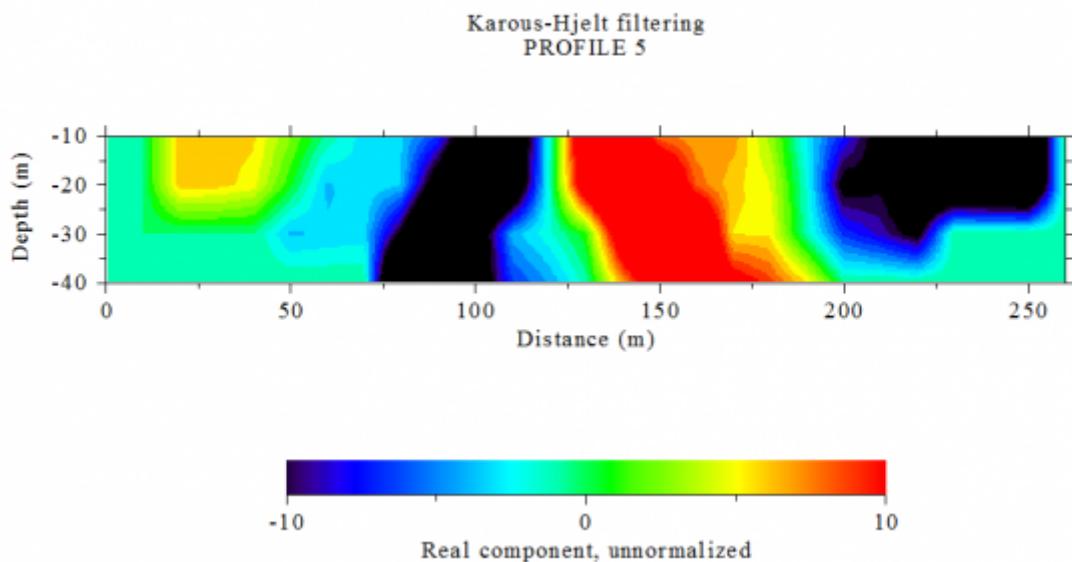
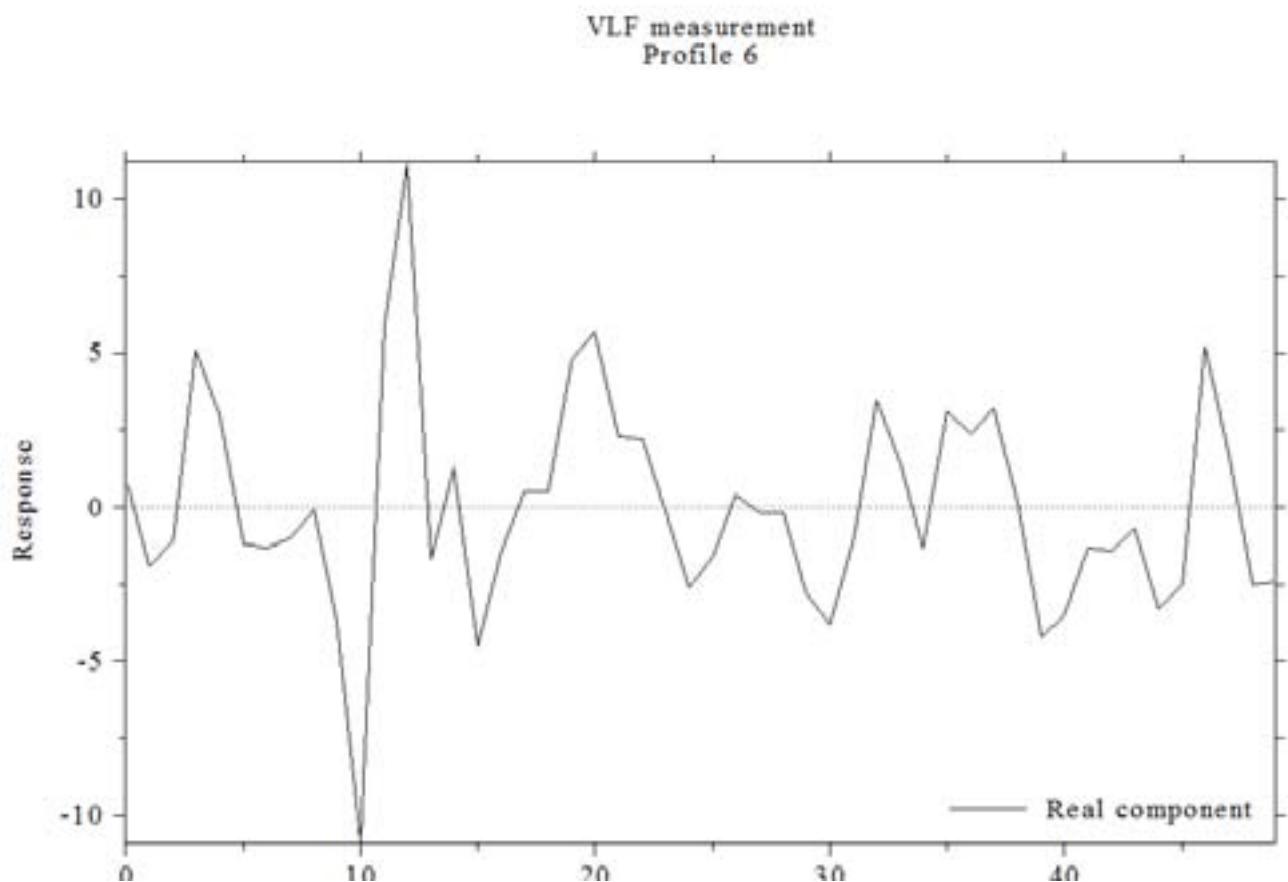


Figure 12: Figure 9 Figure 10b Figure 10 Figure 12



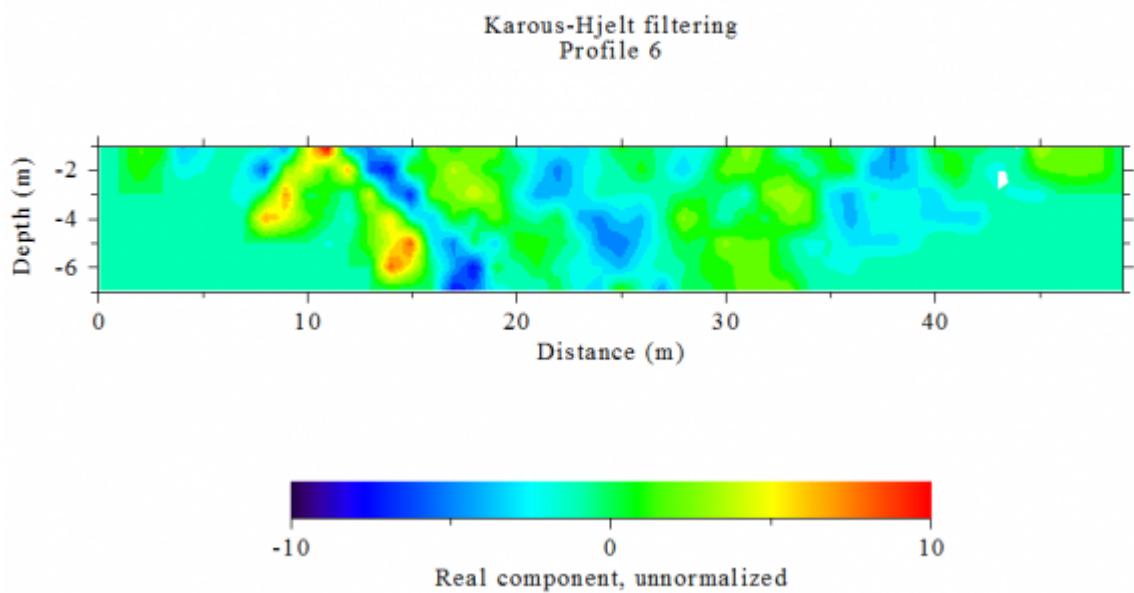
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Figure 13: Figure 14a



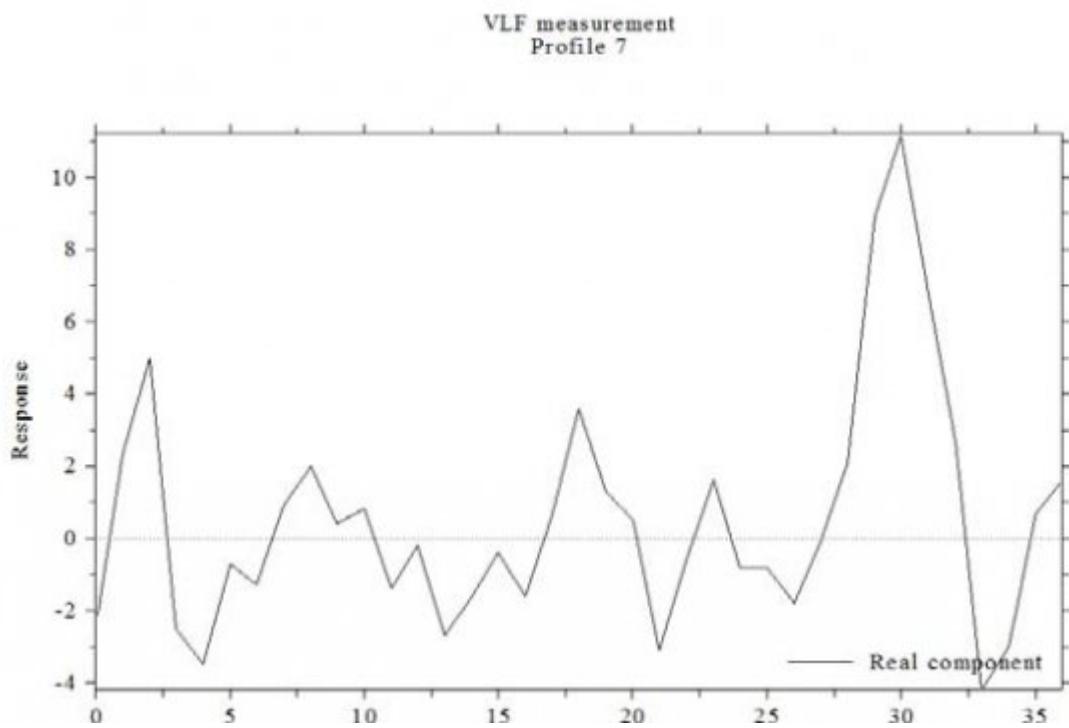
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Figure 14: Figure 13 (



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Figure 15: Figure 14 (



16a16

Figure 16: Figure 16a Figure 16

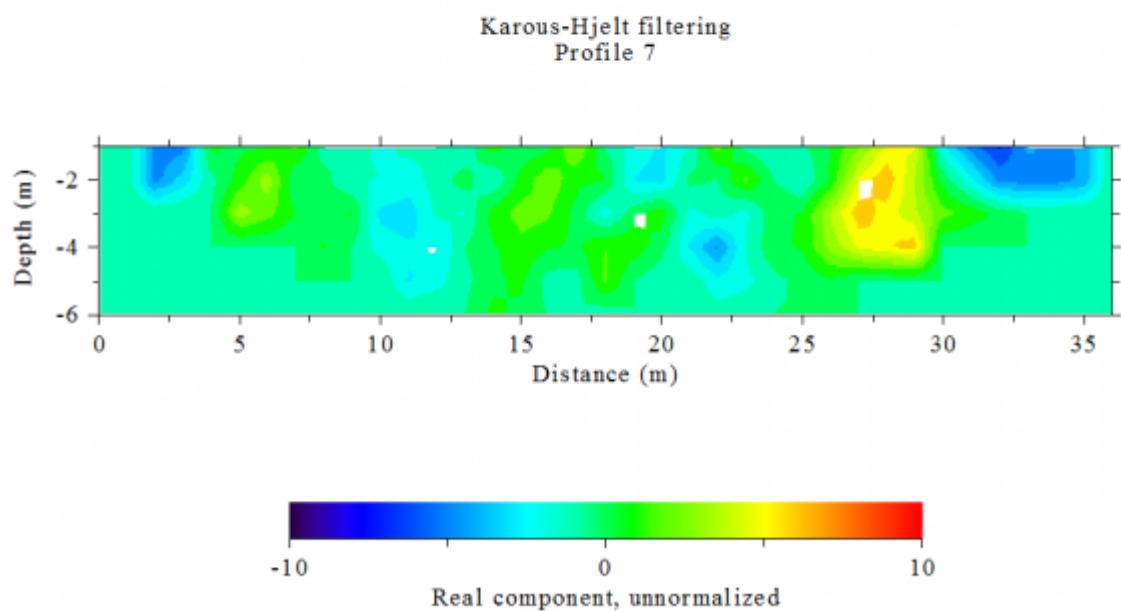


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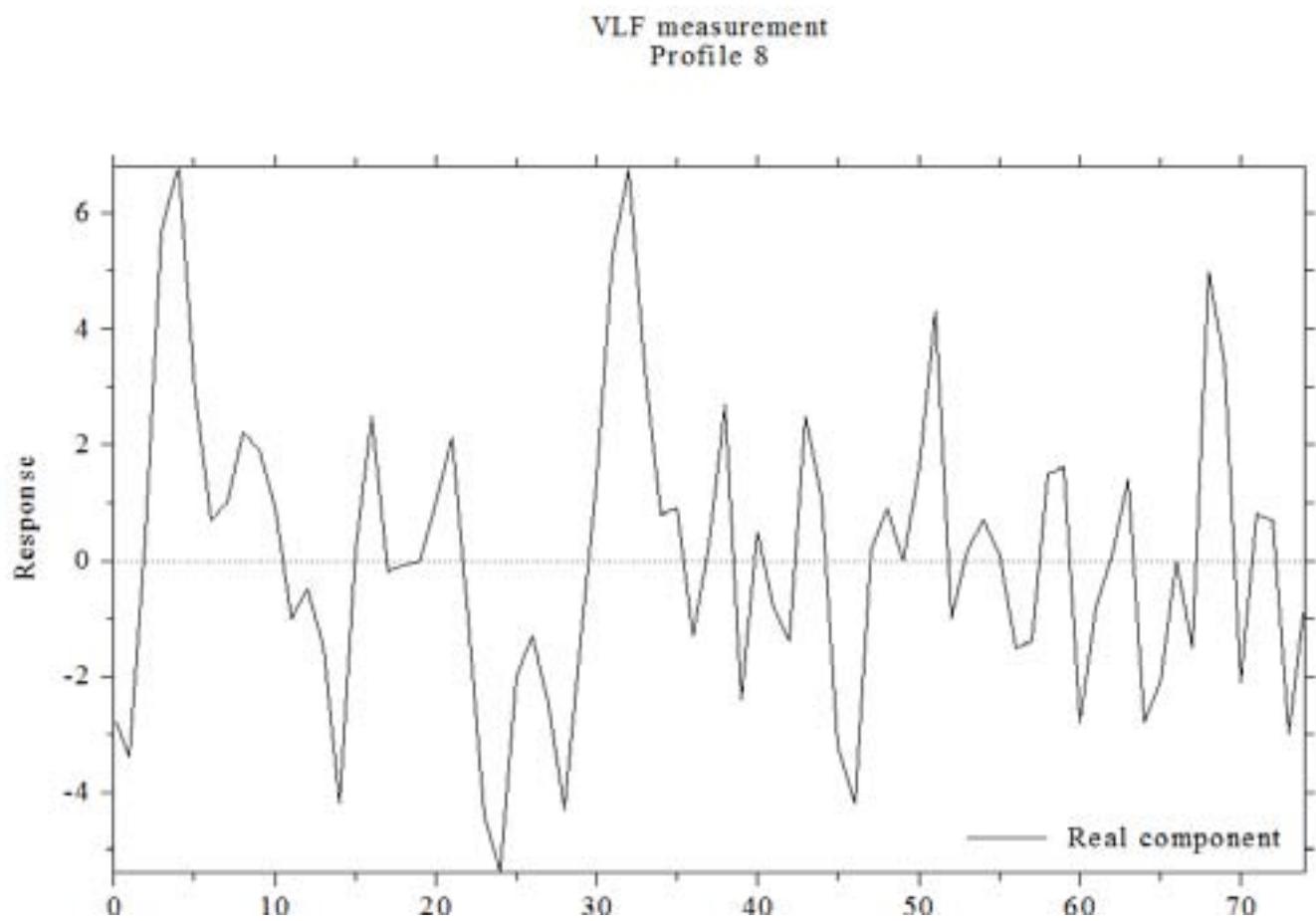


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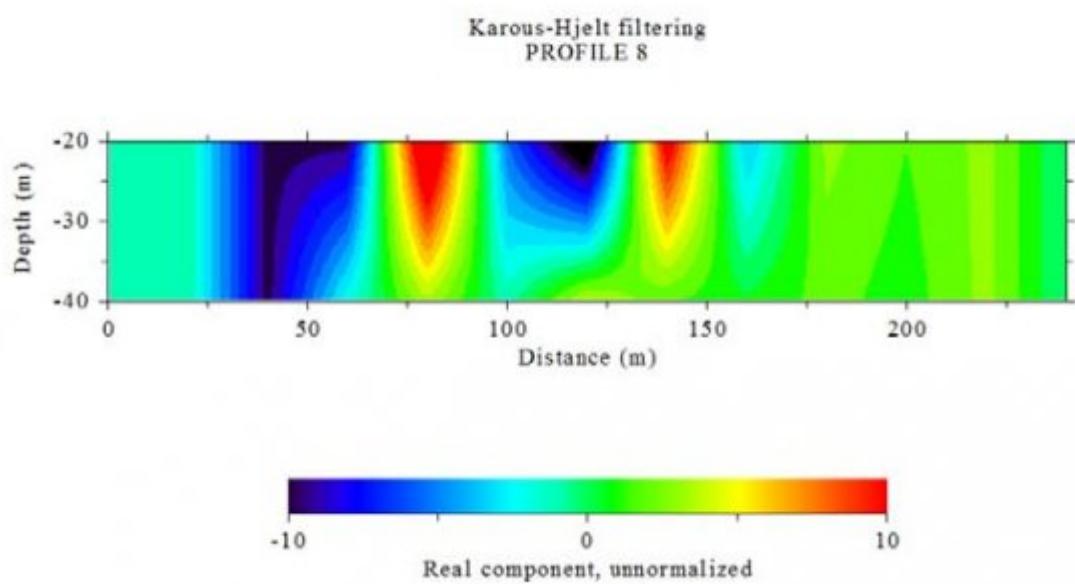


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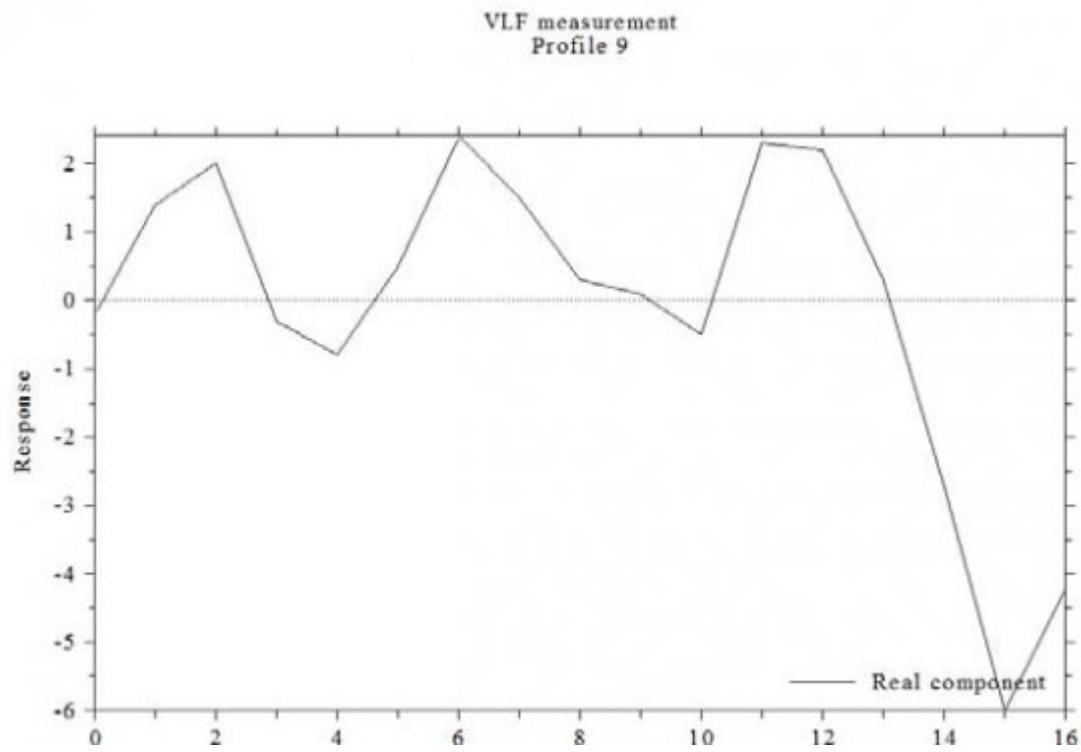


Figure 20:

Detection of Fracture Zones for Groundwater
Investigation from Interpretation of VLF-EM
Anomalies of Kwara State Polytechnic Ilorin
and its Environs

[Note: competency]

Figure 21:

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