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C-CORE Task #2 Report - Support for data processing and image analysis of the Fall 2012 through-wall field trials

B. Yue and J. Chamberland

Defence Research and Development Canada – Ottawa

Contract Report
DRDC Ottawa CR 2013-111
December 2013

Canada

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Abstract

This document contains a description of work carried out under task #2 of contract W7714-125424 for Defence Research and Development Canada Ottawa (DRDC Ottawa). This work consists of processing and examining the data collected during the 2012 Through-wall SAR (TWSAR) data collection. The raw data was examined thoroughly to ensure elimination of data 'glitches' prior to processing, and with the remaining time, the troop-shelter building data was processed and analyzed. The analysis focus was on examining the human targets within the data collected. The report contains a complete set of observations and overviews of the various human targets in the troop shelter data.

Résumé

Ce document décrit le travail accompli sous la tâche #2 du contrat W7714- 125424 avec Recherche et développement pour la défense Canada – Ottawa. Le travail consistait à traiter et examiner des données recueillies pendant les essais de 2012 avec le radar à synthèse d'ouverture aux fins de l'imagerie à travers les murs (TWSAR). Les données brutes ont étés examinées sous tous les angles pour éliminer toutes données erronées aléatoires. Les données de l'édifice appelé refuge des troupes furent ensuite traitées et analysées. L'analyse a été centrée sur l'examen des cibles humaines dans les données recueillies. Le rapport contient un ensemble d'observations et des vues d'ensemble de plusieurs cibles humaines dans les données de l'édifice appelé refuge des troupes.

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Executive summary

C-CORE Task #2 Report - Support for data processing and image analysis of the Fall 2012 through-wall field trials

B. Yue, J. Chamberland; DRDC Ottawa CR 2013-111; Defence Research and Development Canada – Ottawa; December 2013.

Background: The Radar Sensing & Exploitation section of Defence Research and Development Canada – Ottawa has been developing a Through the Wall Synthetic Aperture Radar (TWSAR) system and processing tools. C-CORE has been contracted to help with the processor verifying and to examine issues relating to the data processing. Work under the current call-up examined the new trial data collected in the fall of 2012, and focused on extracting human targets from these data.

Principal results: The primary results of task #2 was extracting and tabulation a set of parameters for humans in through-wall SAR data on the 2012 dataset.

Future Work: Future work will be to extend this analysis and use the tools developed to analyze different buildings and targets in free-space. Some research could also go towards growing the list of parameters that can be extracted from the data that help characterize the target type.

Sommaire

C-CORE Task #2 Report - Support for data processing and image analysis of the Fall 2012 through-wall field trials

B. Yue, J. Chamberland ; DRDC Ottawa CR 2013-111 ; Recherche et développement pour la défense Canada – Ottawa ; décembre 2013.

Contexte : La section Détection & exploitation radar de Recherche et développement pour la défense Canada – Ottawa a developpé un radar à synthèse d'ouverture aux fins de l'imagerie à travers les murs (TWSAR) et ses outils de traitement de données. C-CORE a obtenu un contrat pour aider à la vérification du processeur et pour examiner des problèmes reliés au traitement des données. Le travail pour cette tâche particulière consistait en l'examen des nouvelles données recueillies lors des essais de l'automne 2012, et était centrée sur l'extraction des cibles humaines de ces données.

Résultats principaux : Les principaux résultats de la tâche #2 sont l'extraction et la tabulation d'un ensemble de paramètres des cibles humaines dans les données TWSAR de 2012.

Recherches futures : Les recherches futures consisteront à étendre cette analyse et à utiliser les outils développés pour analyser des édifices différents et des cibles en espace libre. La recherche pourrait aussi se diriger vers l'augmentation de la liste de paramètres qui peuvent être extraits des données pour aider à caractériser le type de cible.

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1 Introduction

Defence Research and Development Canada Ottawa (DRDC Ottawa) has contracted C-CORE for work relating to its Through the Wall SAR program (TWSAR). The current package of work known as task #2 consists of processing and analyzing the trial data collected in the fall of 2012. For this analysis work, emphasis was placed on extracting and comparing human targets within the troop shelter building. The target position in range, azimuth and elevation as well as the dimension of the target 3dB width were extracted and compared for all human targets within the troop shelter building. Due to the time spent analyzing a data acquisition 'glitch' issue, only the troop shelter data was processed during this contract. Matlab tools and functions were developed to extract the desired information during this task. These tools will reduce the effort required to extend the analysis to other buildings.

The first section of the document describes the raw data glitches and shows examples in both delay line and other data acquisitions. The solution was implemented by the scientific authority, thus is not restated here. The second section of the report examines all human targets within fifteen (15) of the troop shelter data acquisitions. This section presents a summary of the features that stood out from the analysis and the most interesting results.

2 Raw Data Glitch Elimination

The visual image generated by the quick pulse compression tool (TWDataChecker) shows some uncharacteristic linear features in the pulsed compressed preview data. Figure 1 and 2 show the resultant pulse-compressed data with the linear features appearing in the range direction. These lines are not expected from the acquisition set-up and are believed to be caused by data glitches within the acquisition system.

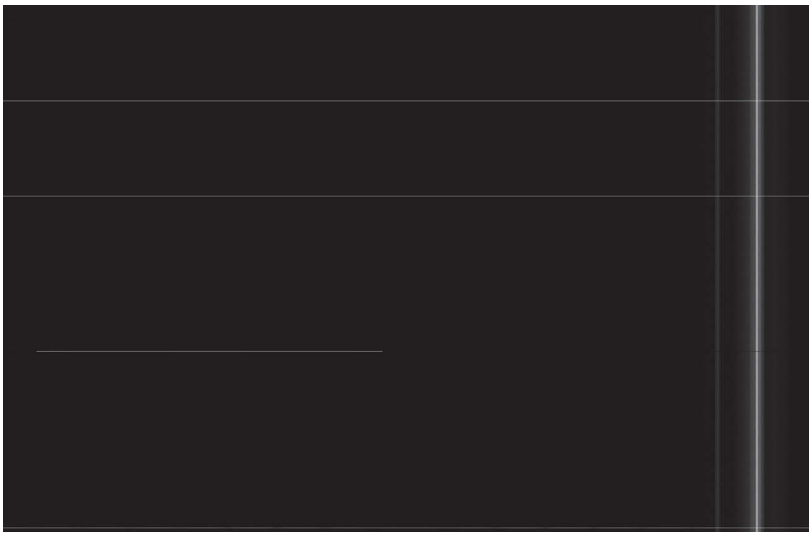


Figure 1: Delay Line quick view PC with linear features

2.1 Locating Glitches

To get a better understanding of the data glitches, both a delay line acquisition and an acquisition of the Troop Shelter were examined. An easy method for locating the glitches is to extract the amplitude value of the DC component of the pulse-compressed data. Figure 3 and 4 show these components for all pulses within the respective acquisition. The higher values of the DC component indicate where there was a glitch within the given pulse.

Using this method 26 glitches were found in the delay line acquisition and 32 in the troop shelter acquisition. The amplitude of the raw data was then examined to see what the cause of the high DC value was within the pulse-compressed data. Figure 5 and 6 show a pulse with a glitch for both the delay line and troop shelter acquisition. These figures also show the raw data of another nominal pulse close to the pulse with a glitch. The glitch in the pulse-compressed data seems to be due to a single sample with an amplitude value much higher than the rest of the samples.

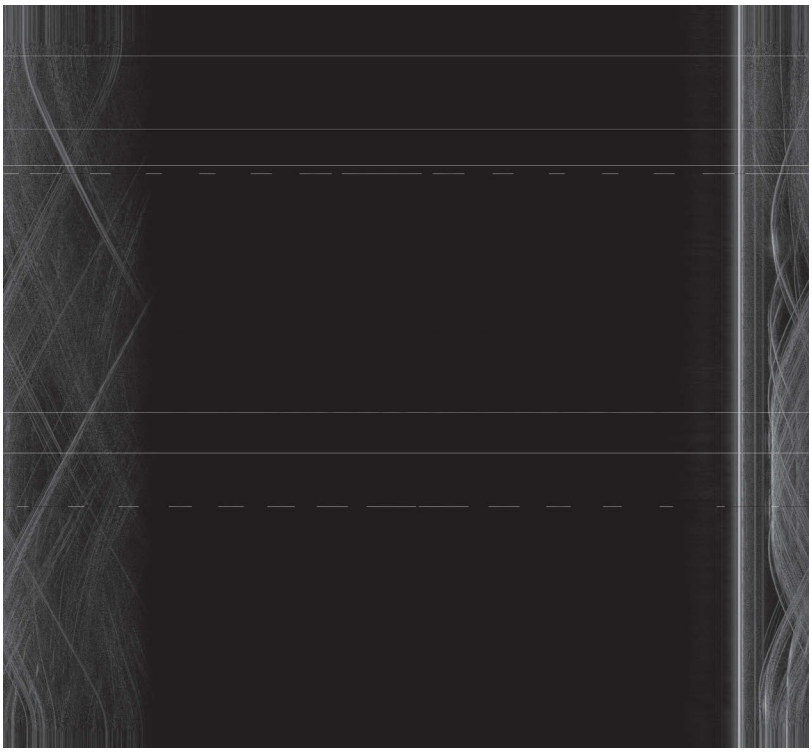


Figure 2: Troop Shelter quick view PC with linear features

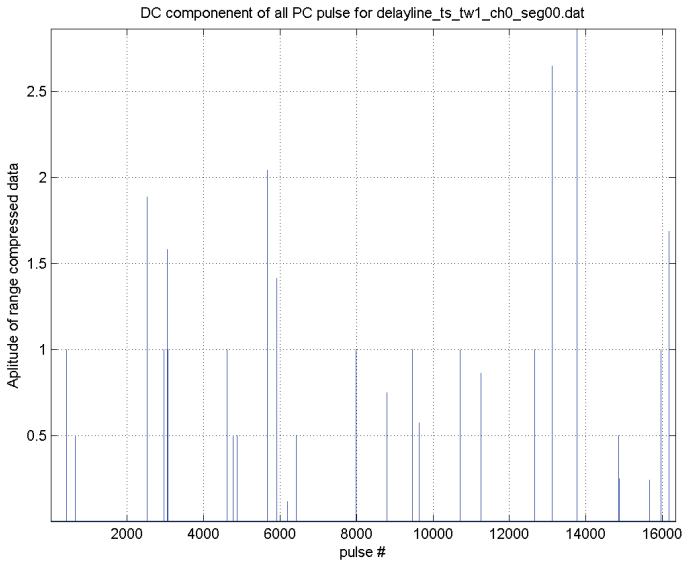


Figure 3: DC component of the PC delay line acquisition

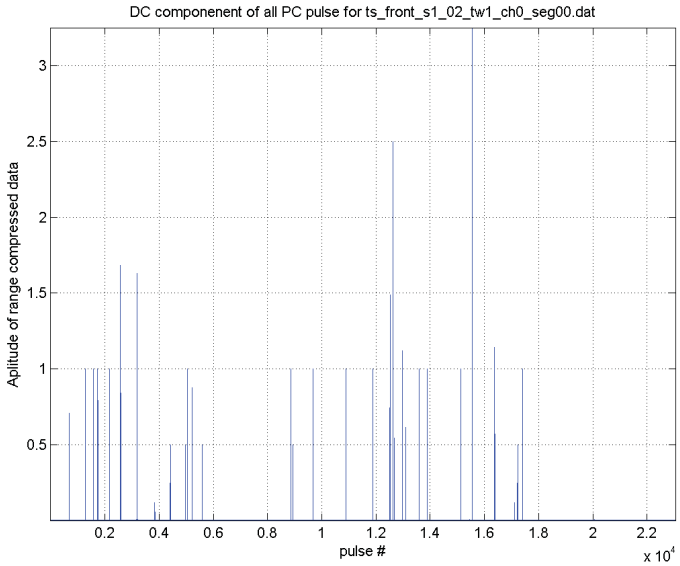


Figure 4: DC component of the PC troop shelter acquisition

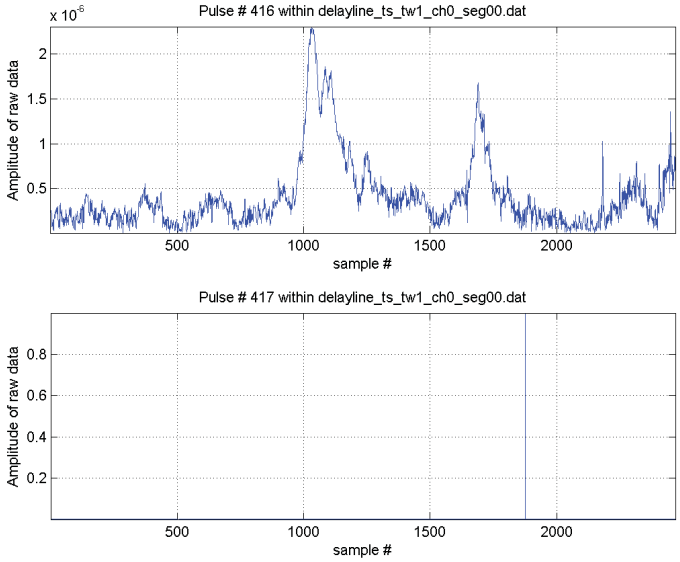


Figure 5: Amplitude of raw samples for pulses 416 and 417

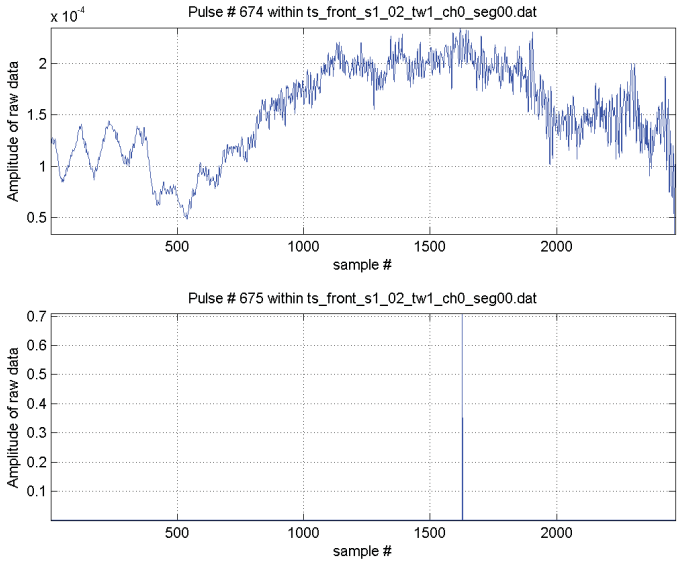


Figure 6: Amplitude of raw samples for pulses 674 and 675

3 Human Target Detection

Table 1 summarizes the images from the troop shelter building that were examined to extract and analyze the human targets. The images in this table are assembled in sections in which the human targets are at the same ground truth location.

To extract the human targets from the processed SAR scene, the ground location of each target is used as a reference point. A data cube surrounding this reference point was then extracted and the pixel with the maximum intensity was found. This point was then cross-checked to ensure that a target was found. The data cube dimensions were set to 1.4m in azimuth and range and 2m in elevation. In most cases, the pixel of maximum intensity within this data cube seemed to be within a human target, however, in some complex scenarios (humans close to walls), this method failed and the location for the human target was corrected manually.

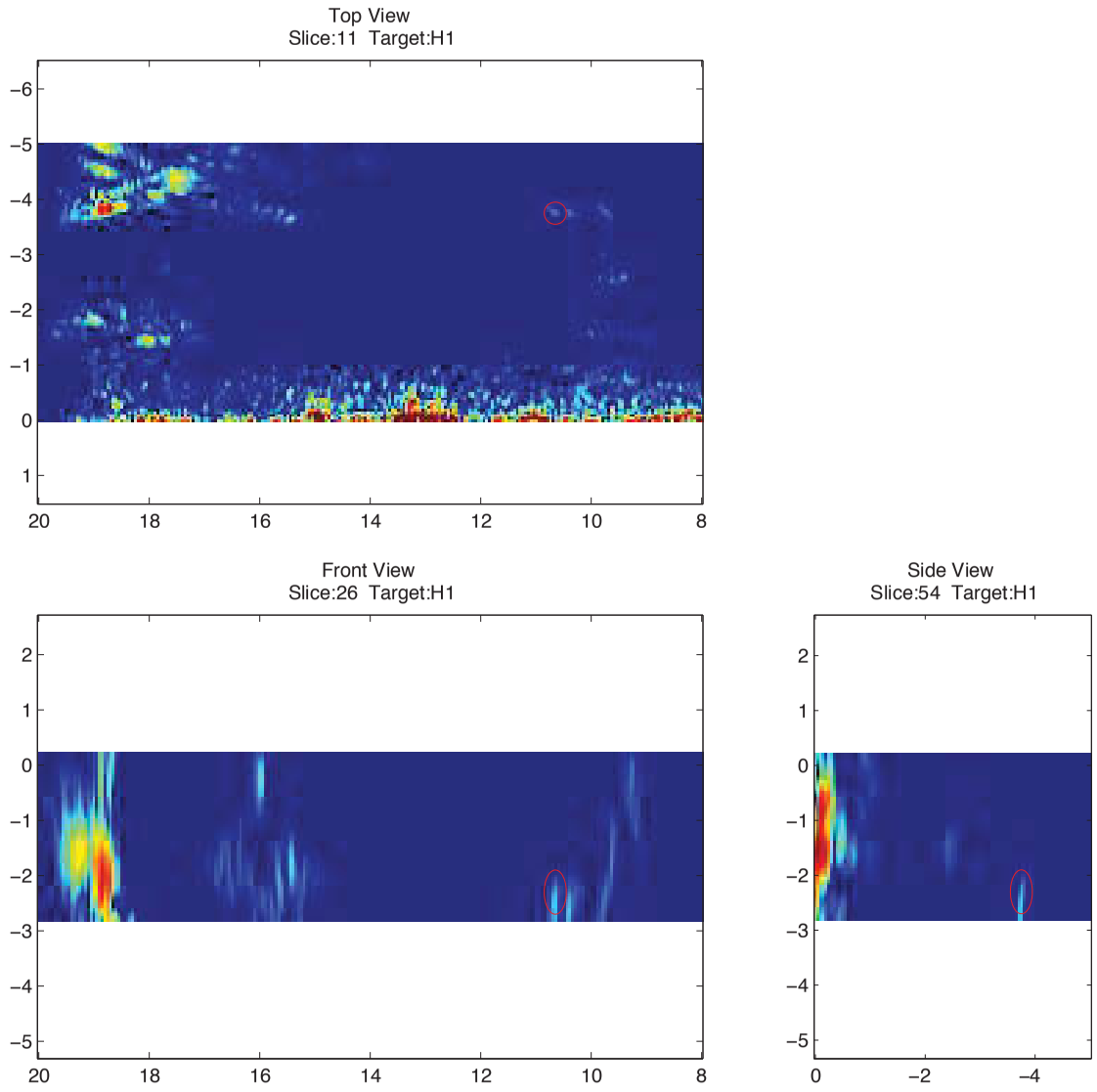
The targets indicated by the italics in Table 1 are the ones that could not be identified. These targets were located very close to the wall, the signal from these targets could not be differentiated from the front wall return. Some filtering was applied to these images and the targets were then easier to pick out.

Table 1: List of Processed Images with Targets

Image	**Targets**	**Same Location Targets**
ts_front_s3_01	H1 H4 H5	H1,H4,H5
ts_front_s4_01	H1 H4 H5	
ts_front_s5_02	H1 H4 H5	H1,H4,H5
ts_front_s6_03	*H1* H4 H5	
ts_front_s7_01	*H2 H3* H6	H6
ts_front_s7_02	*H2 H3* H6	
ts_front_s8_04	H1 *H6*	H1
ts_front_s10_01	H1 H6	
ts_front_s11_01	H1 *H6*	
ts_front_s12_01	H1 *H6*	
ts_front_s14_01	H1	
ts_front_s15_01	H1	
ts_front_s13_01	*H1* H6	

3.1 Detection results for all acquisitions

The detection results for each target listed in Table 1 are displayed in this section. The 3dB power profiles of each target in Azimuth, Range and Elevation direction are also displayed along with the detection results.



tbp

Figure 7: Detection: Target H1, ts_front_s3_01.

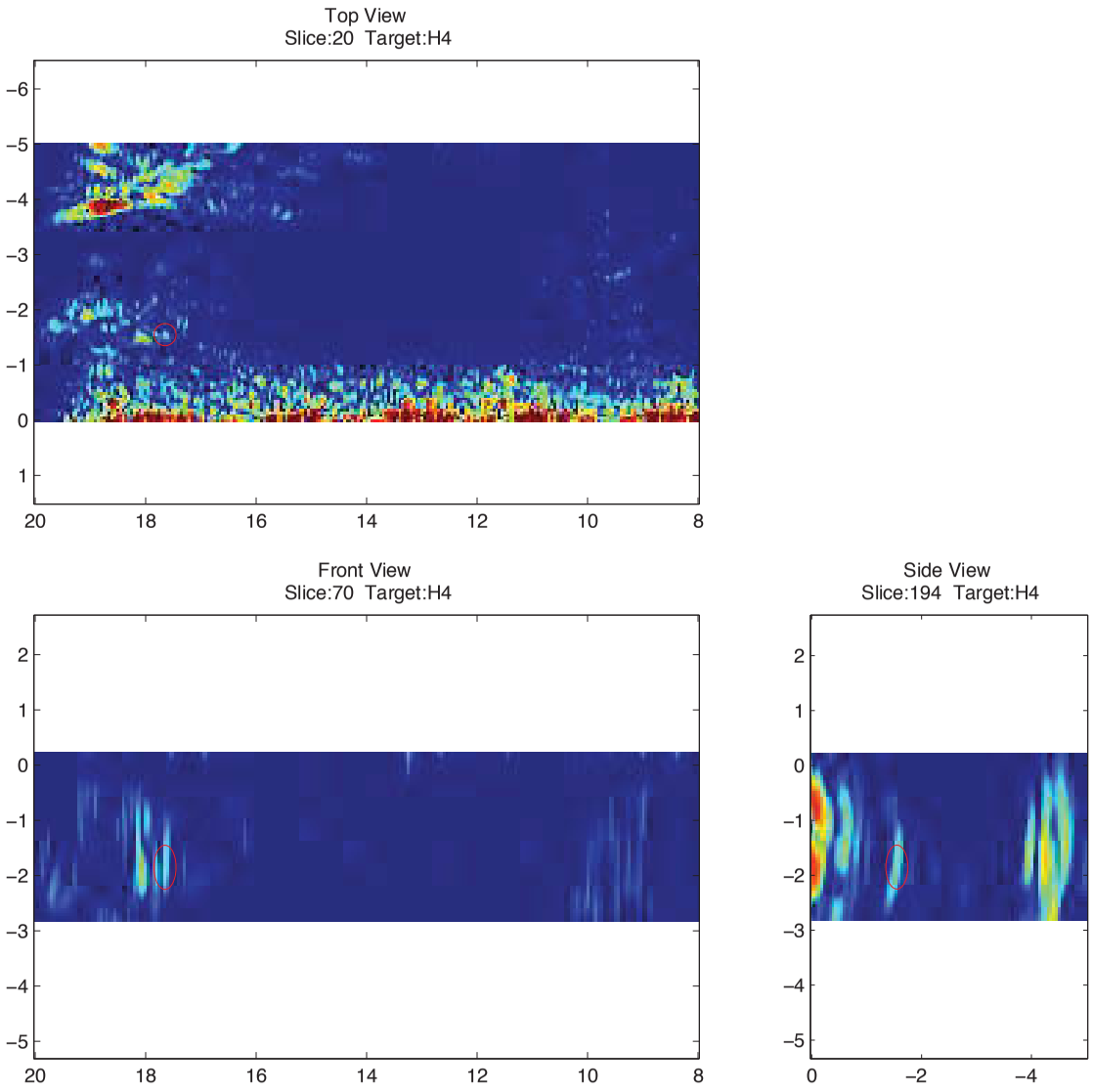


Figure 8: Detection: Target H4, ts_front_s3_01.

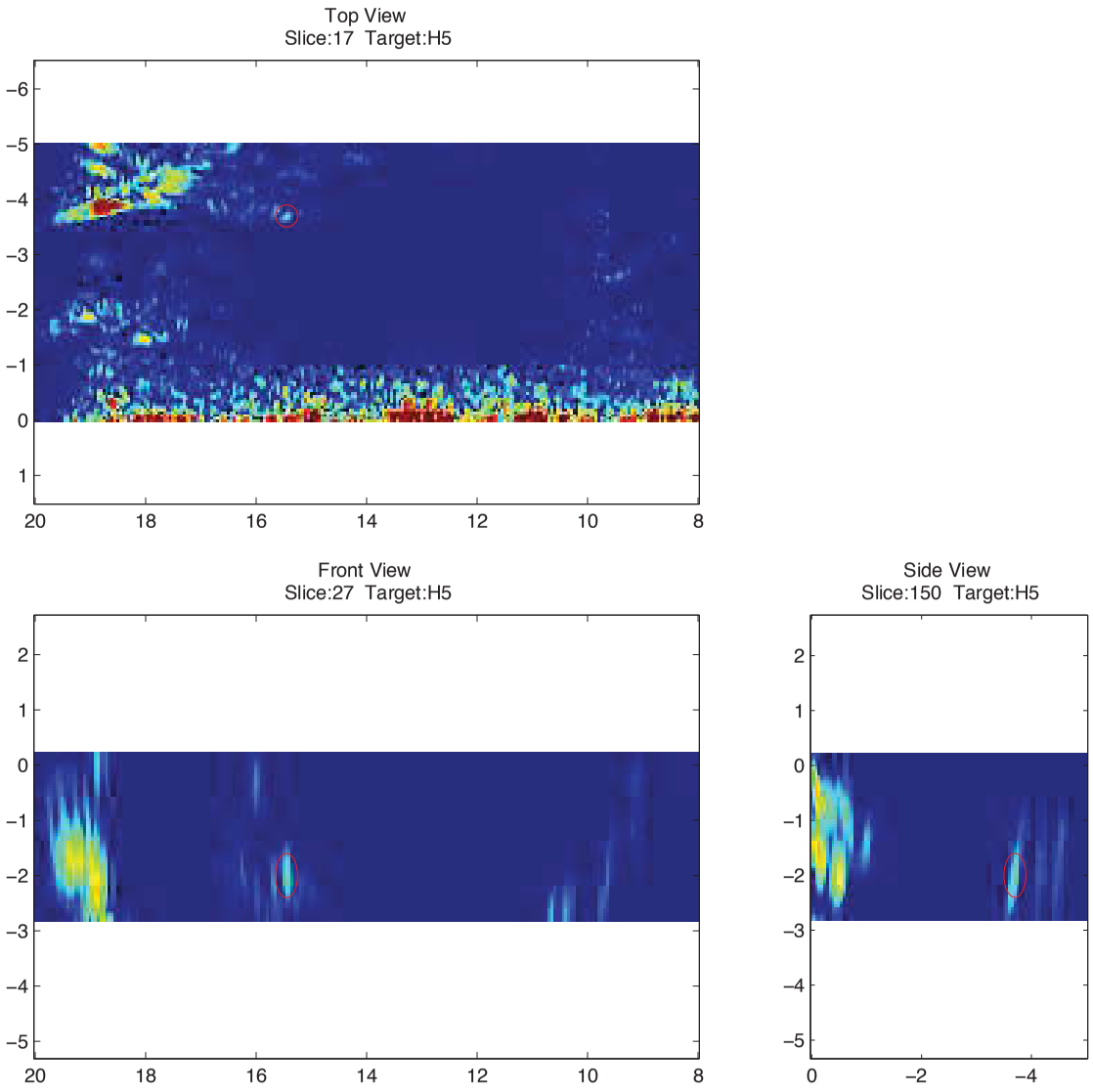


Figure 9: Detection: Target H5, ts_front_s3_01.

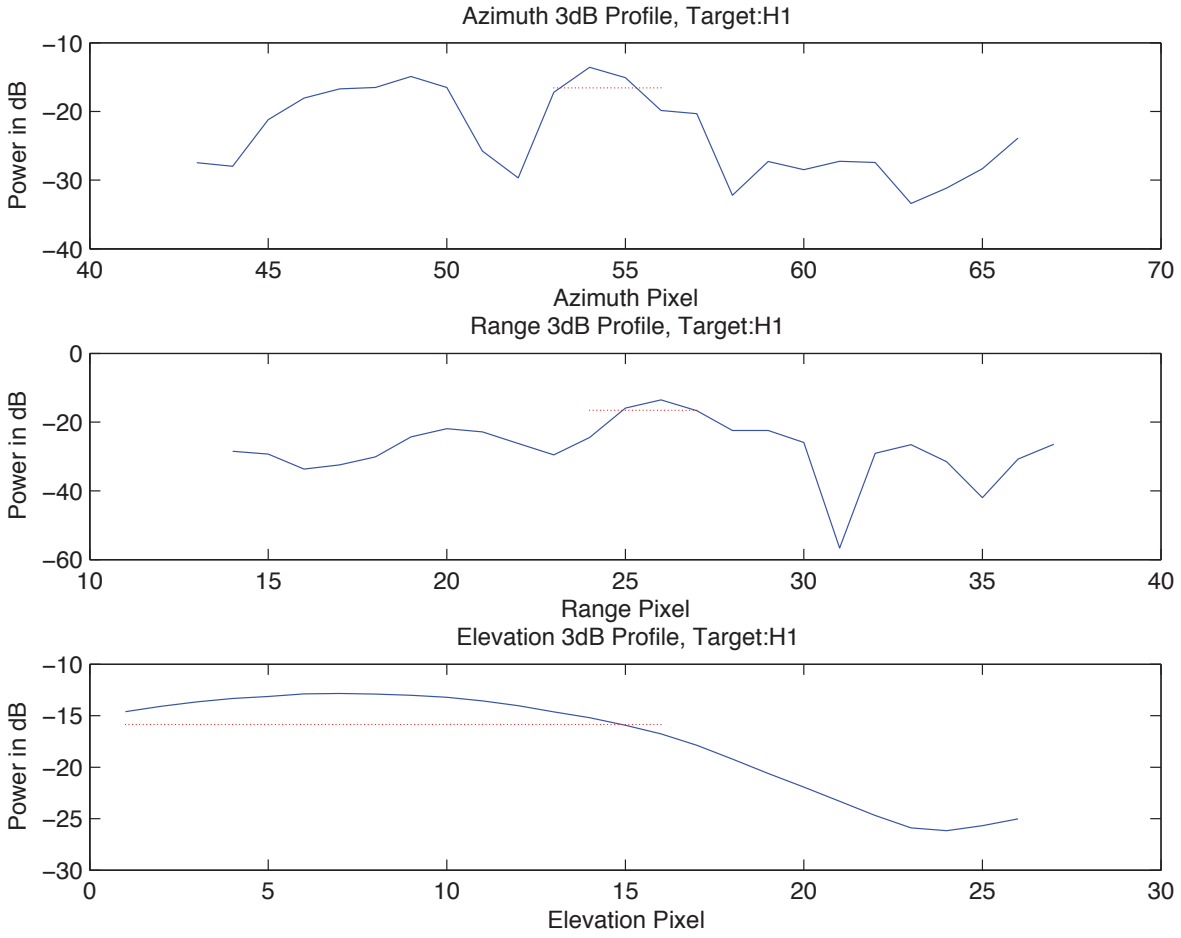


Figure 10: Target H1 3dB Profile, ts_front_s3_01.

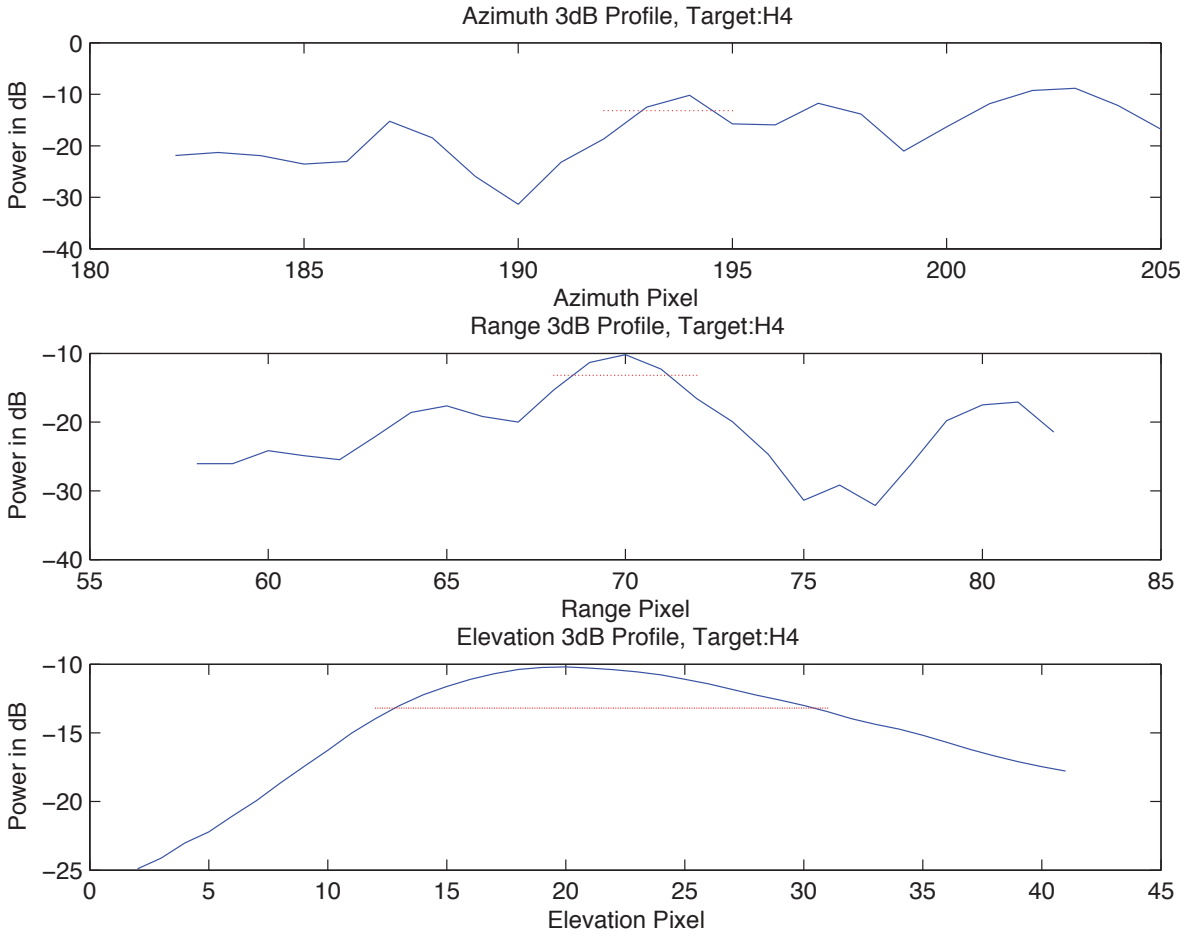


Figure 11: Target H4 3dB Profile, ts_front_s3_01.

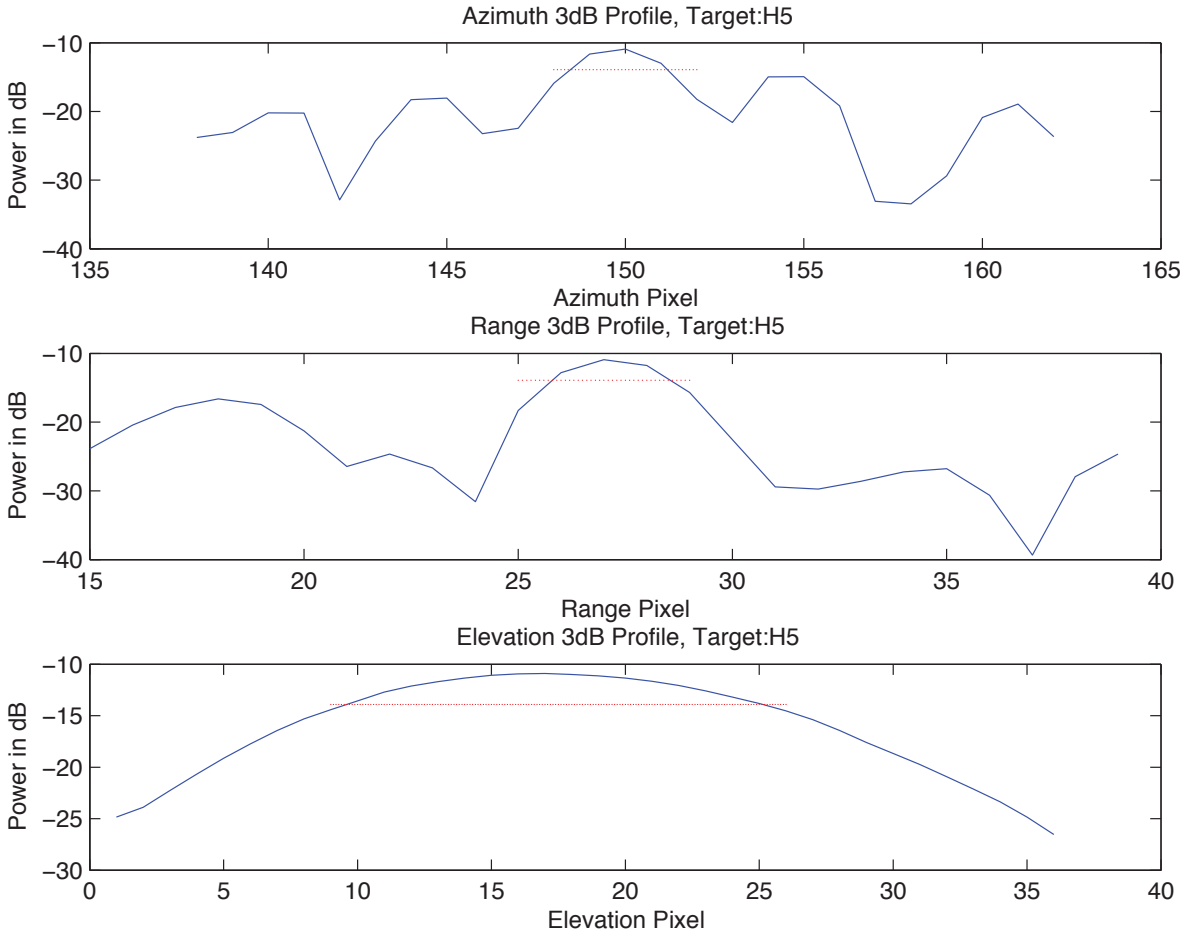


Figure 12: Target H5 3dB Profile, ts_front_s3_01.

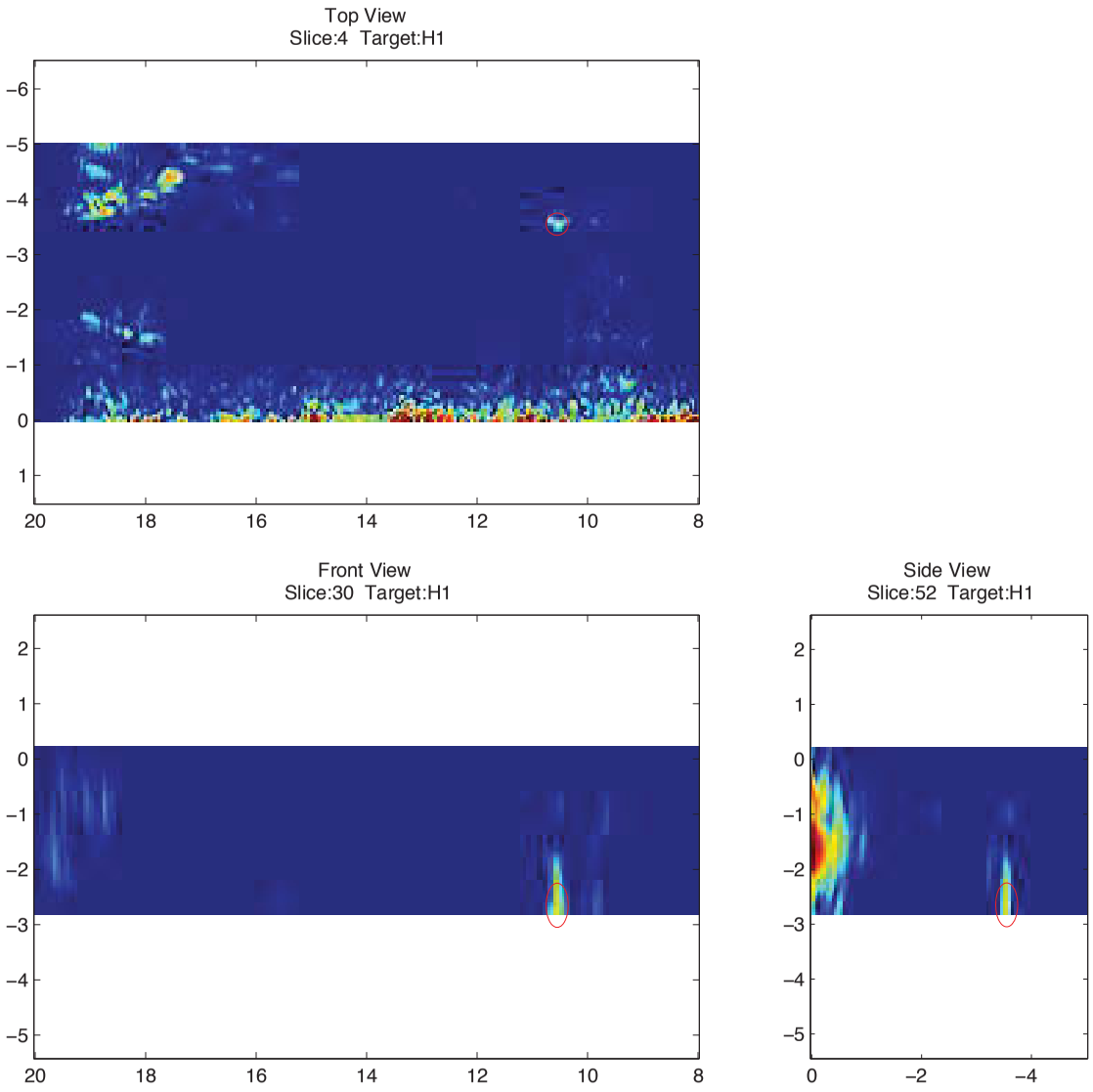


Figure 13: Detection: Target H1, ts_front_s4_01.

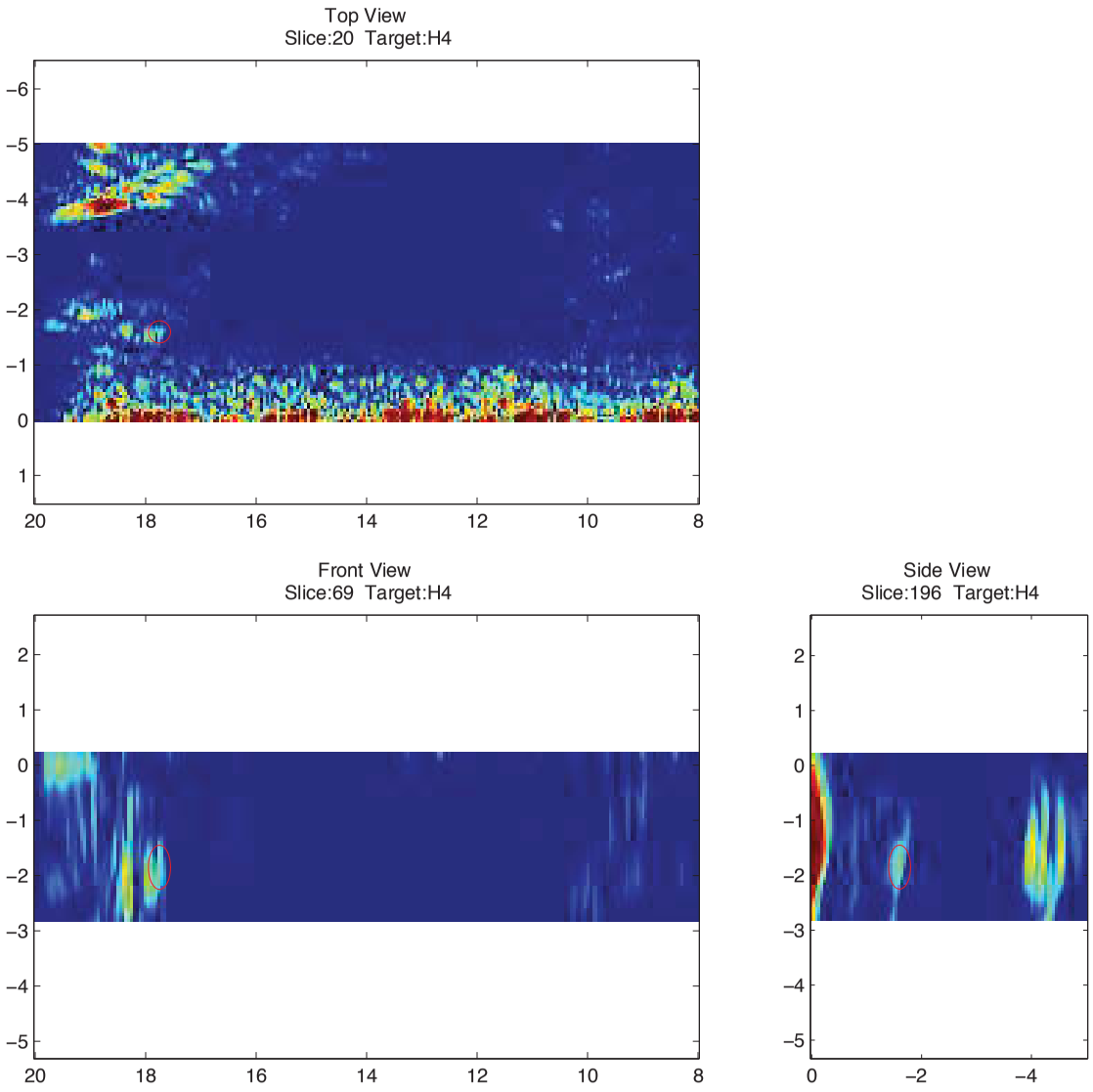


Figure 14: Detection: Target H4, ts_front_s4_01.

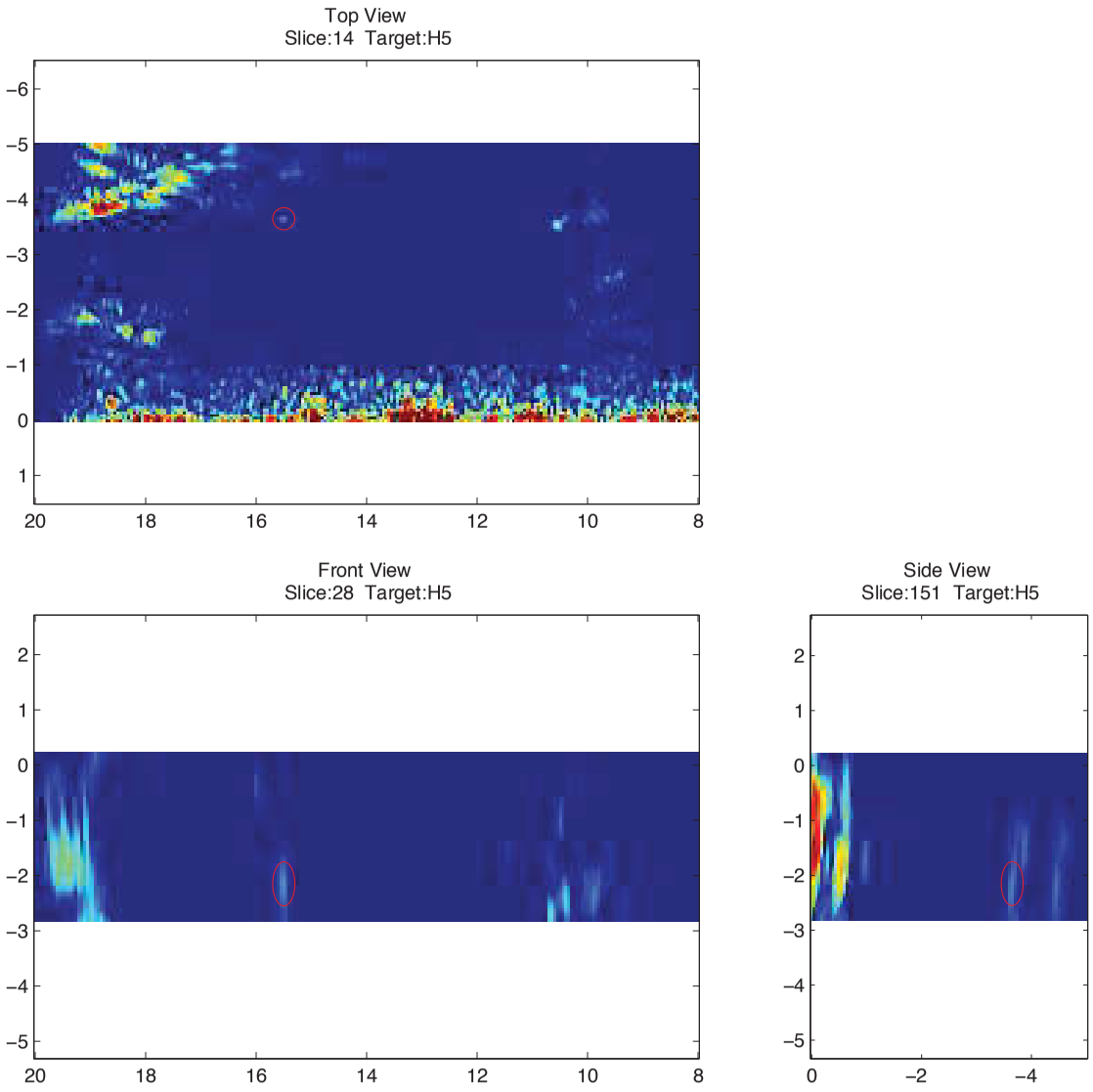


Figure 15: Detection: Target H5, ts_front_s4_01.

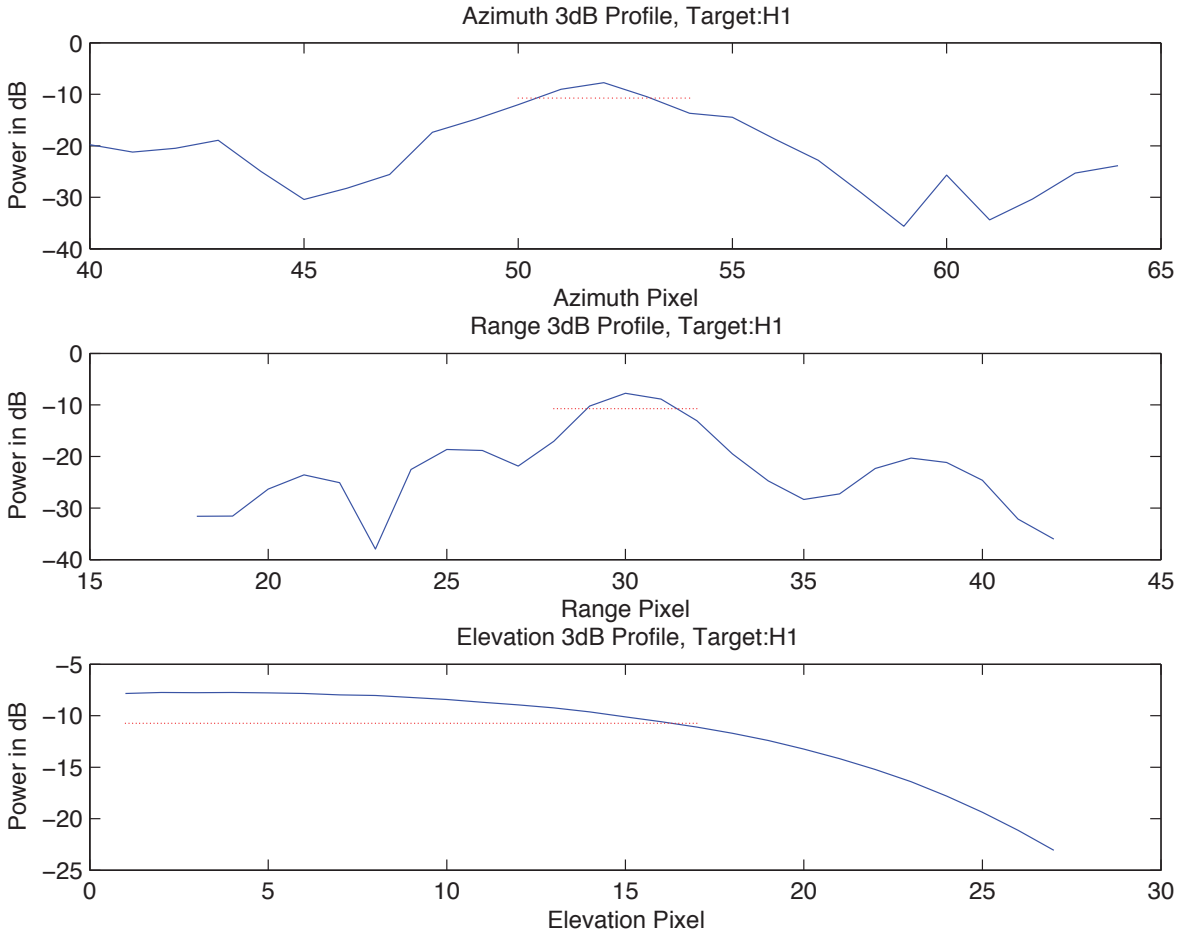


Figure 16: Target H1 3dB Profile, ts_front_s4_01.

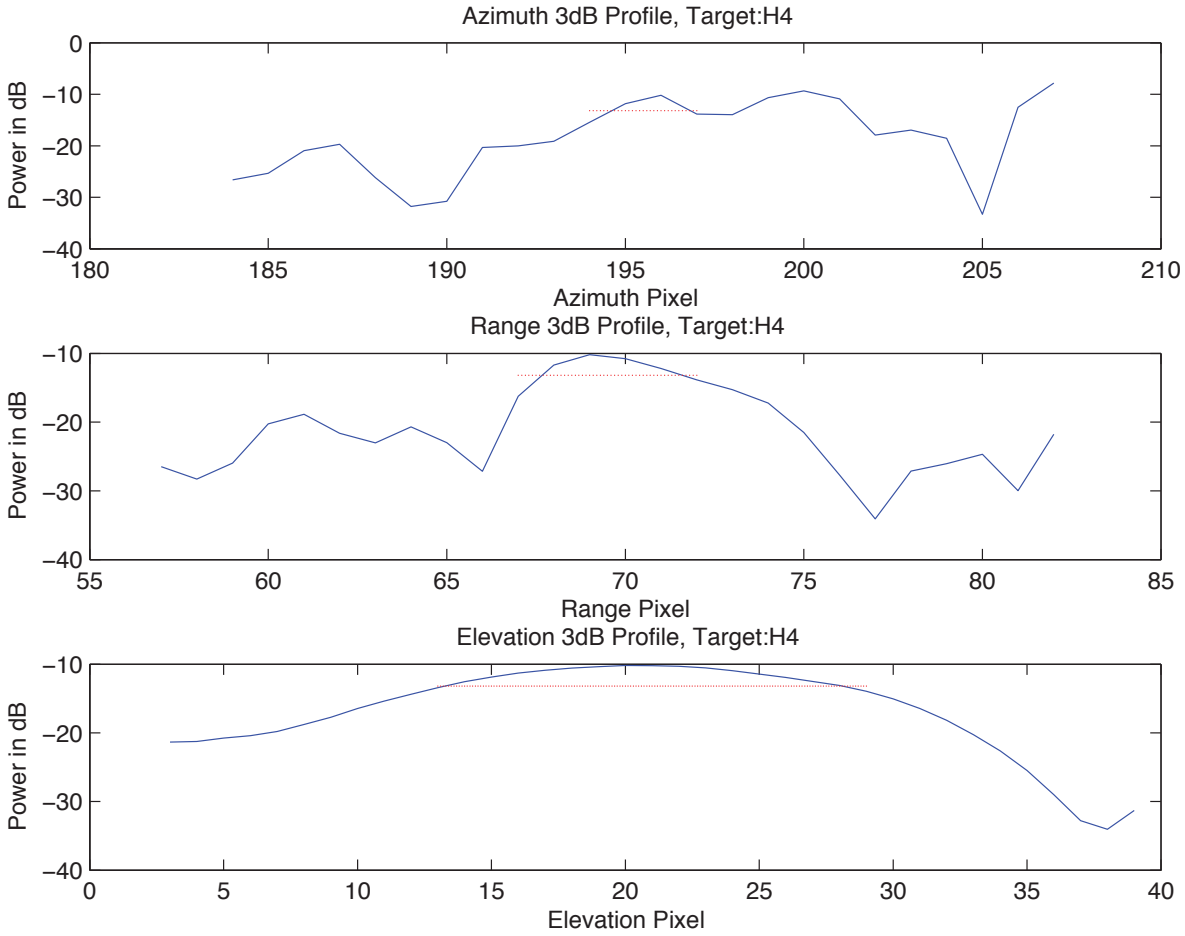


Figure 17: Target H4 3dB Profile, ts_front_s4_01.

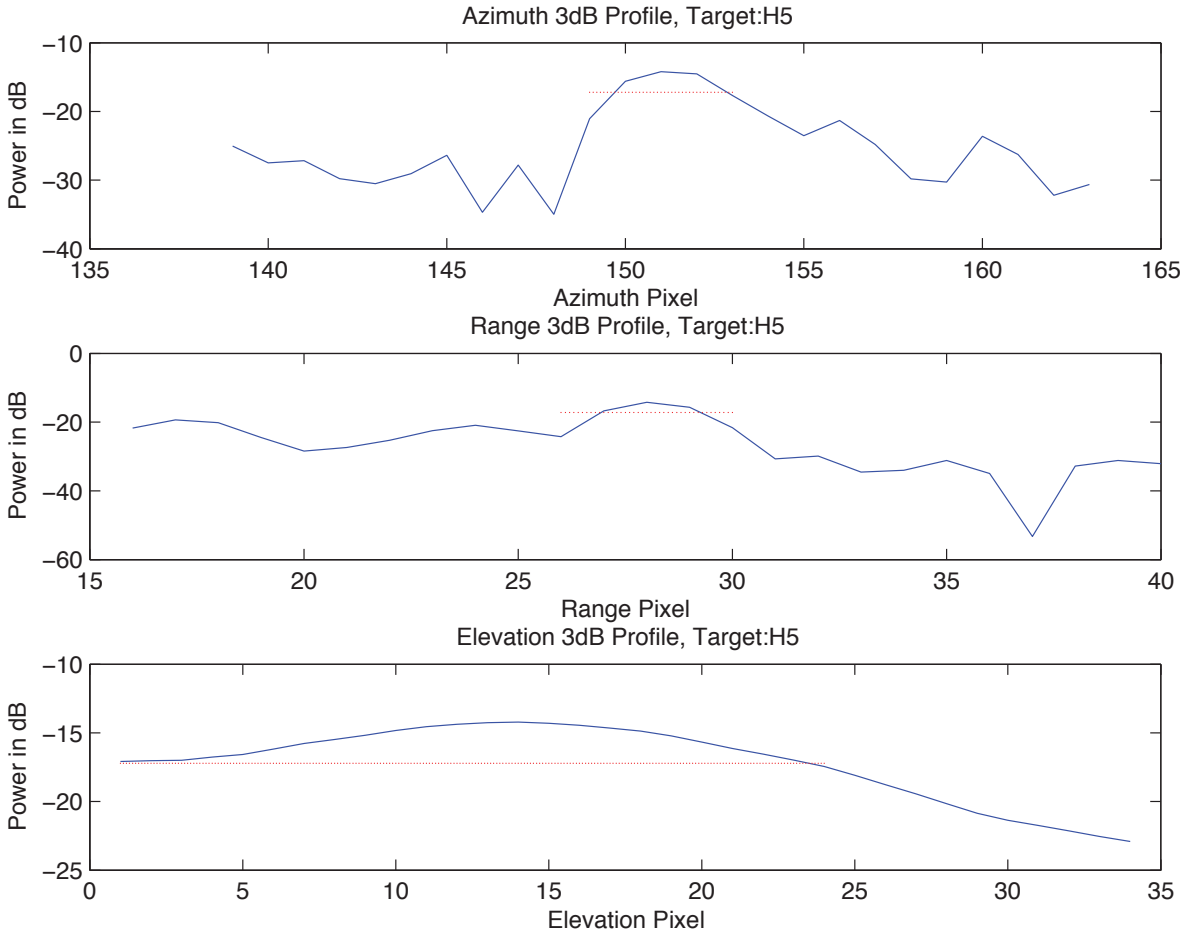


Figure 18: Target H5 3dB Profile, ts_front_s4_01.

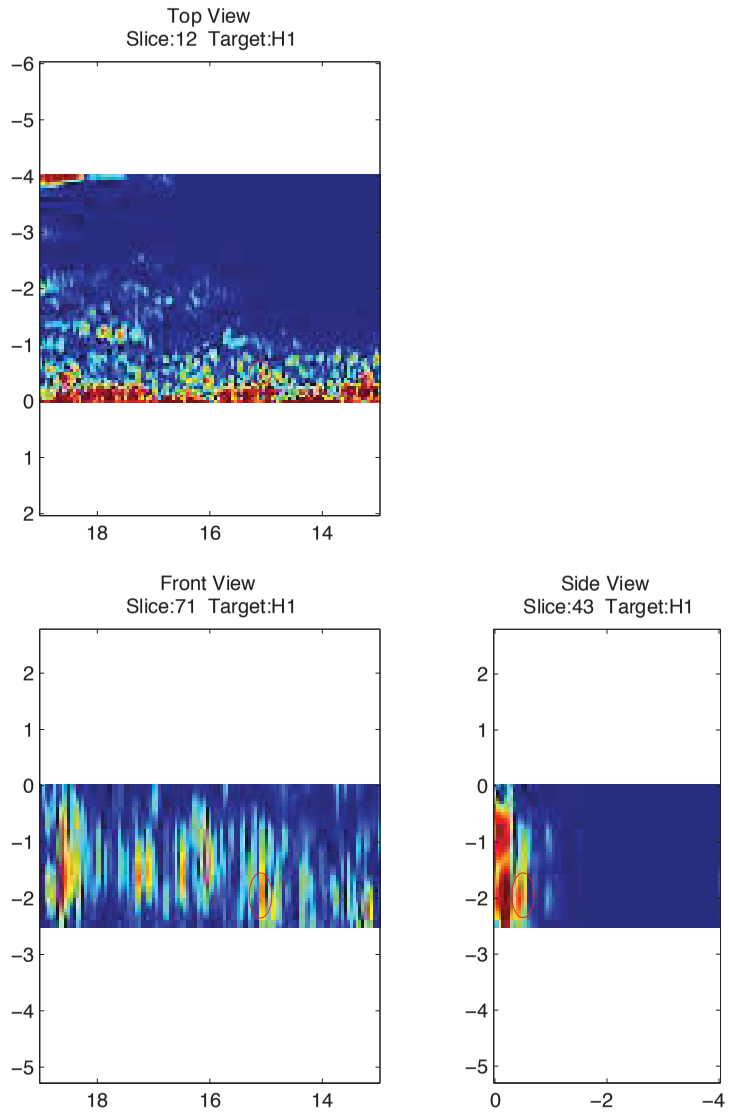


Figure 19: Detection: Target H1, ts_front_s5_02.

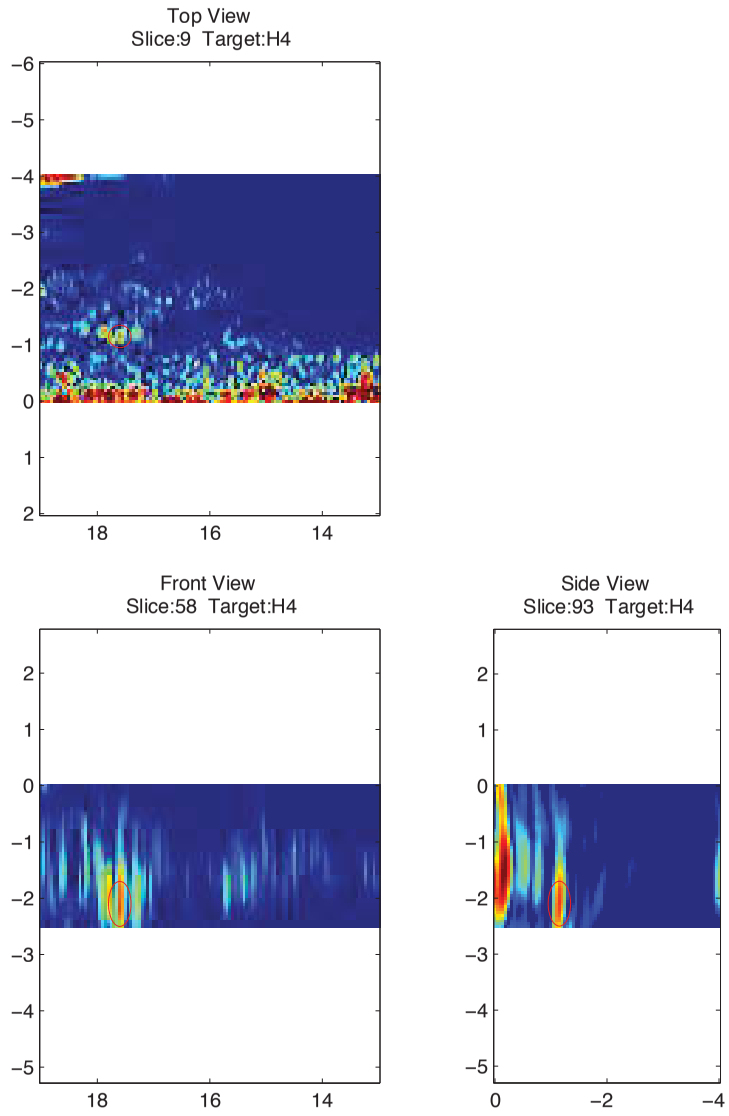


Figure 20: Detection: Target H4, ts_front_s5_02.

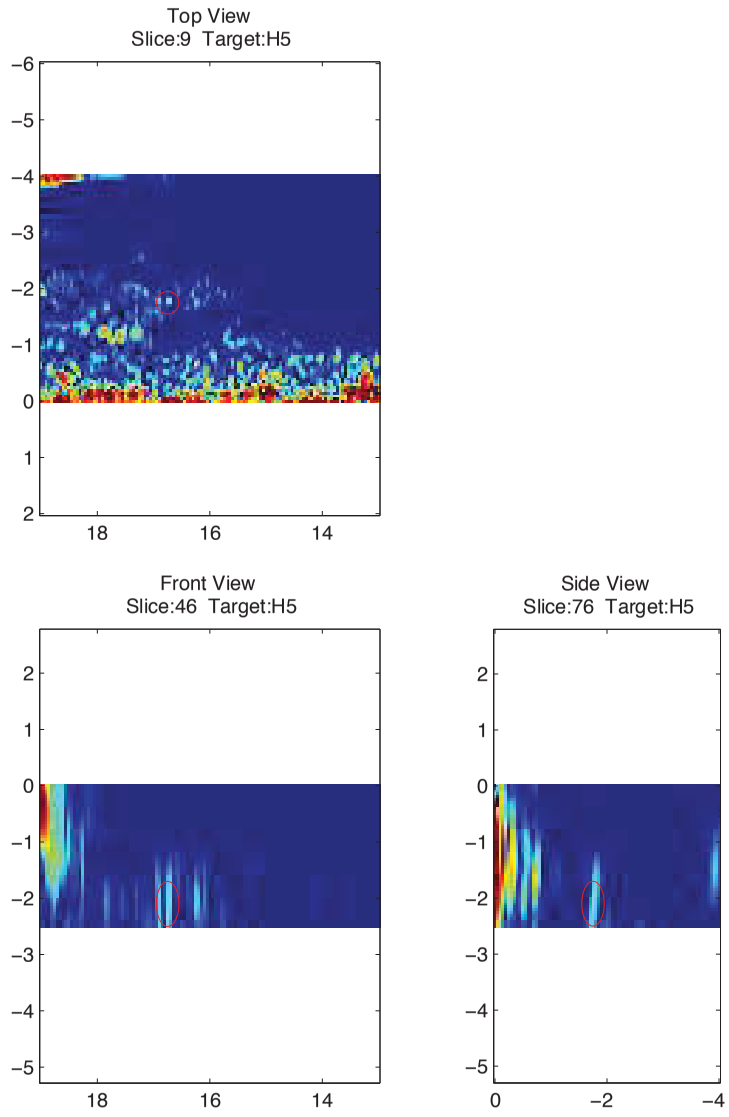


Figure 21: Detection: Target H5, ts_front_s5_02.

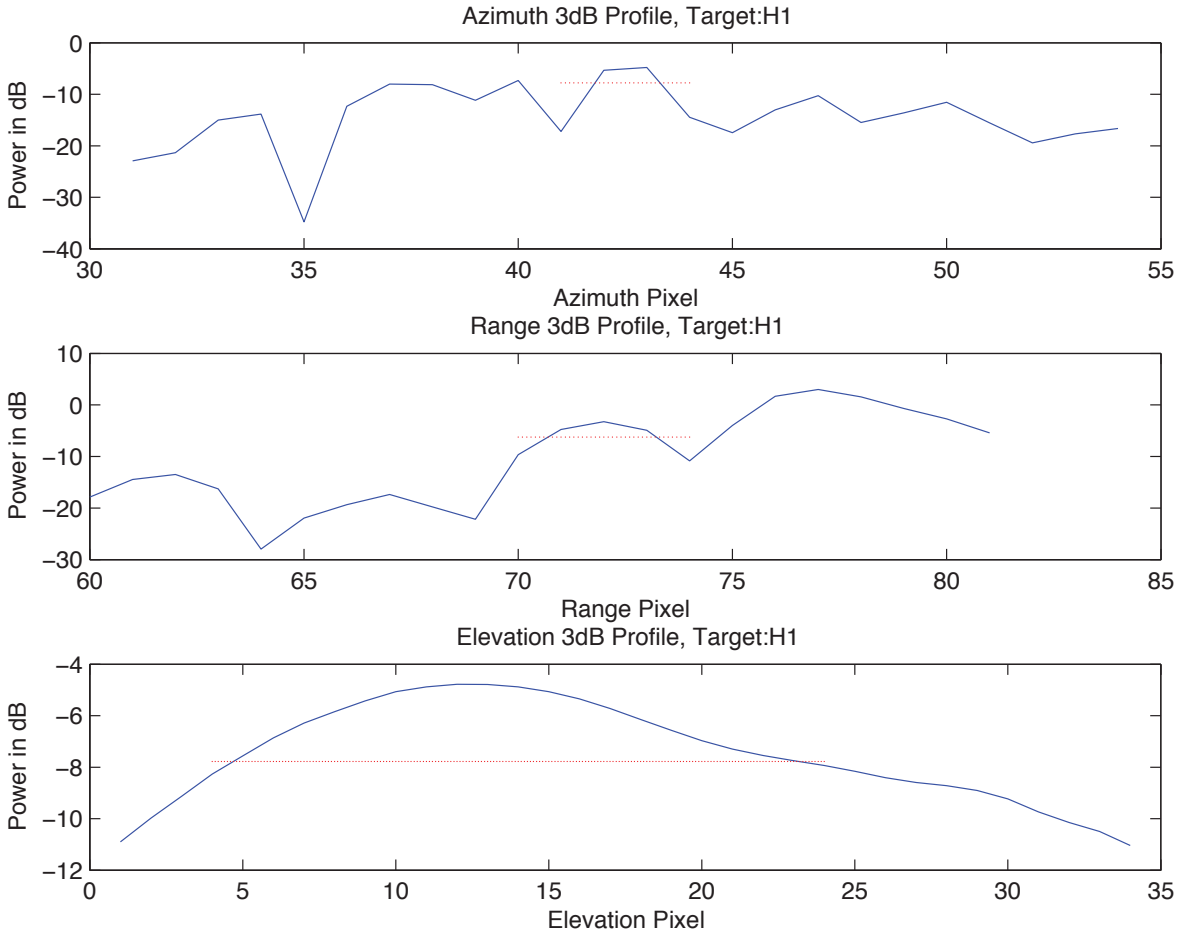


Figure 22: Target H1 3dB Profile, ts_front_s5_02.

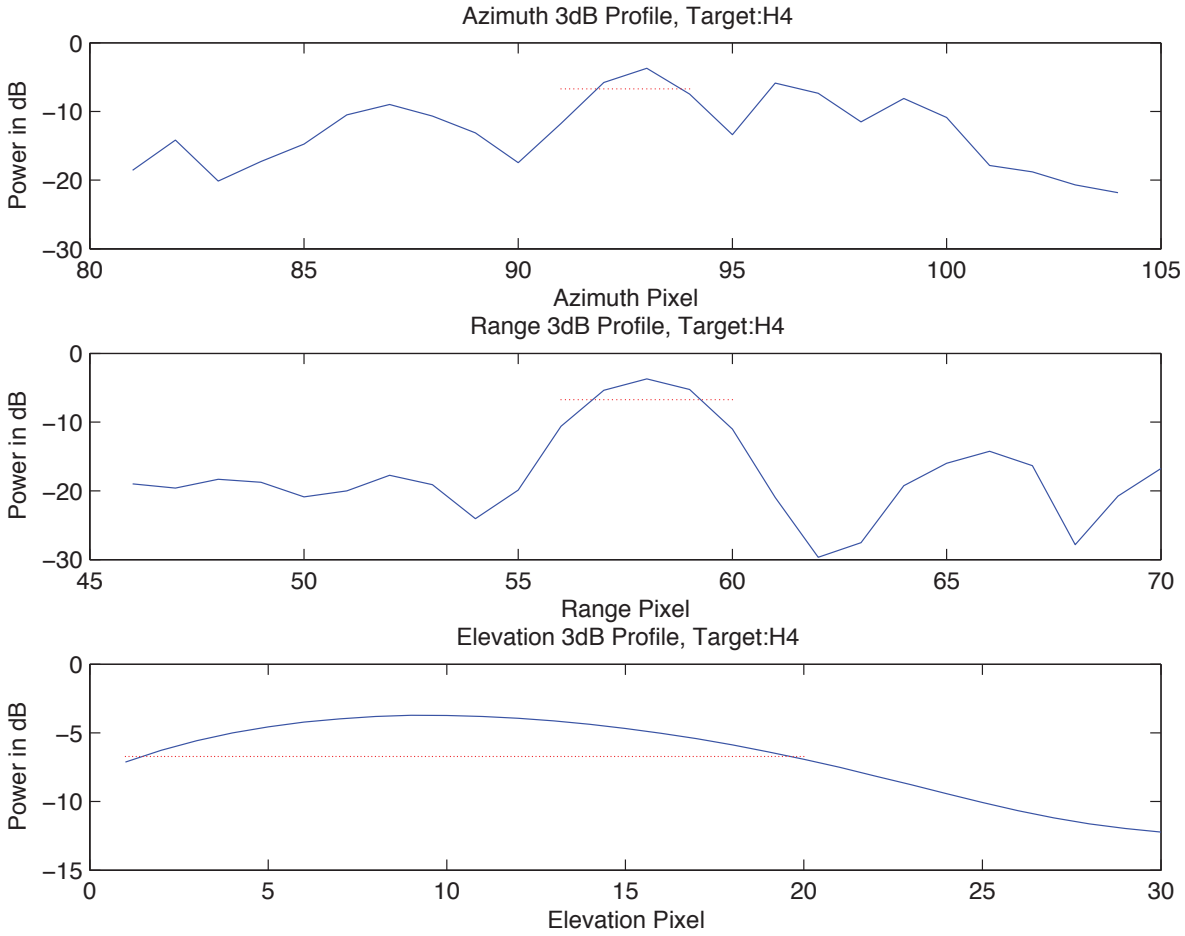


Figure 23: Target H4 3dB Profile, ts_front_s5_02.

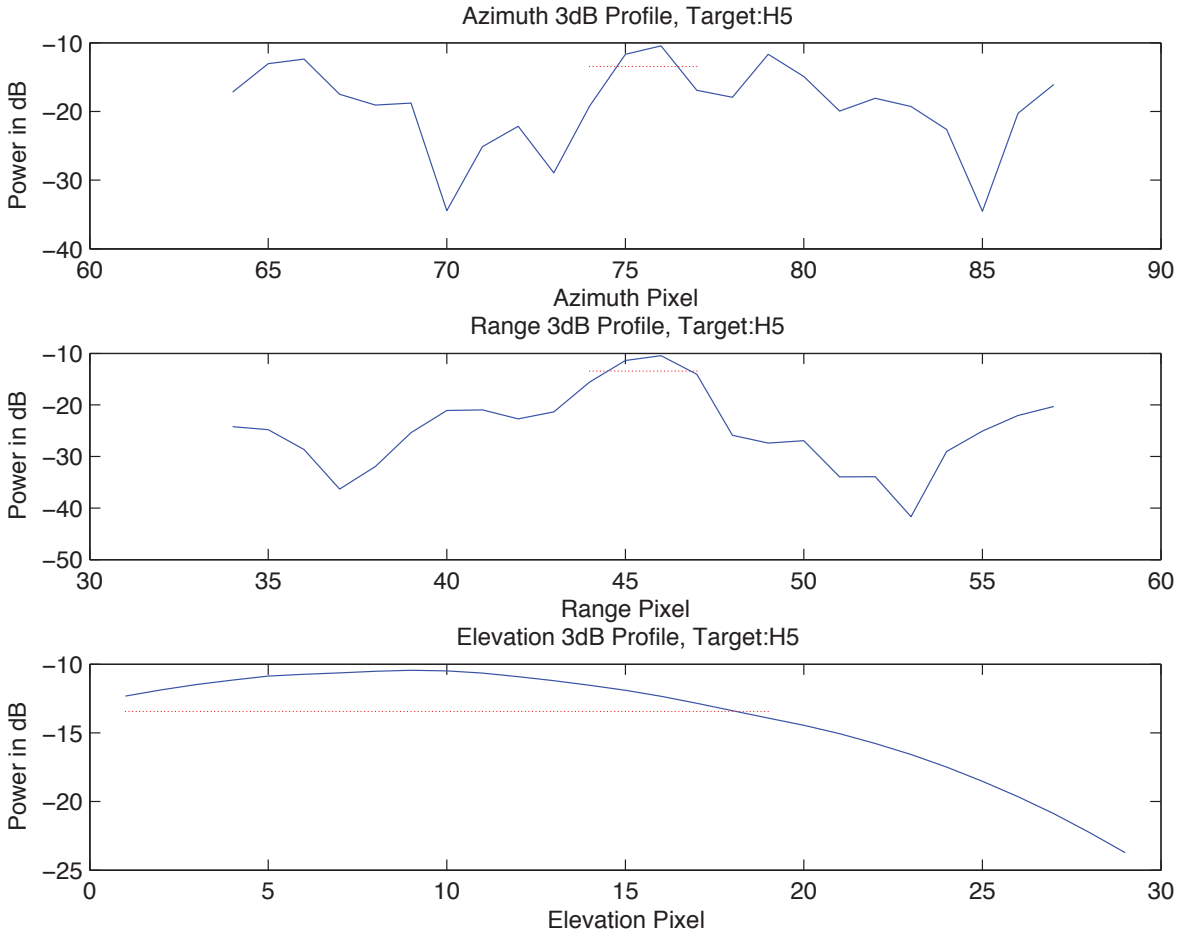


Figure 24: Target H5 3dB Profile, ts_front_s5_02.

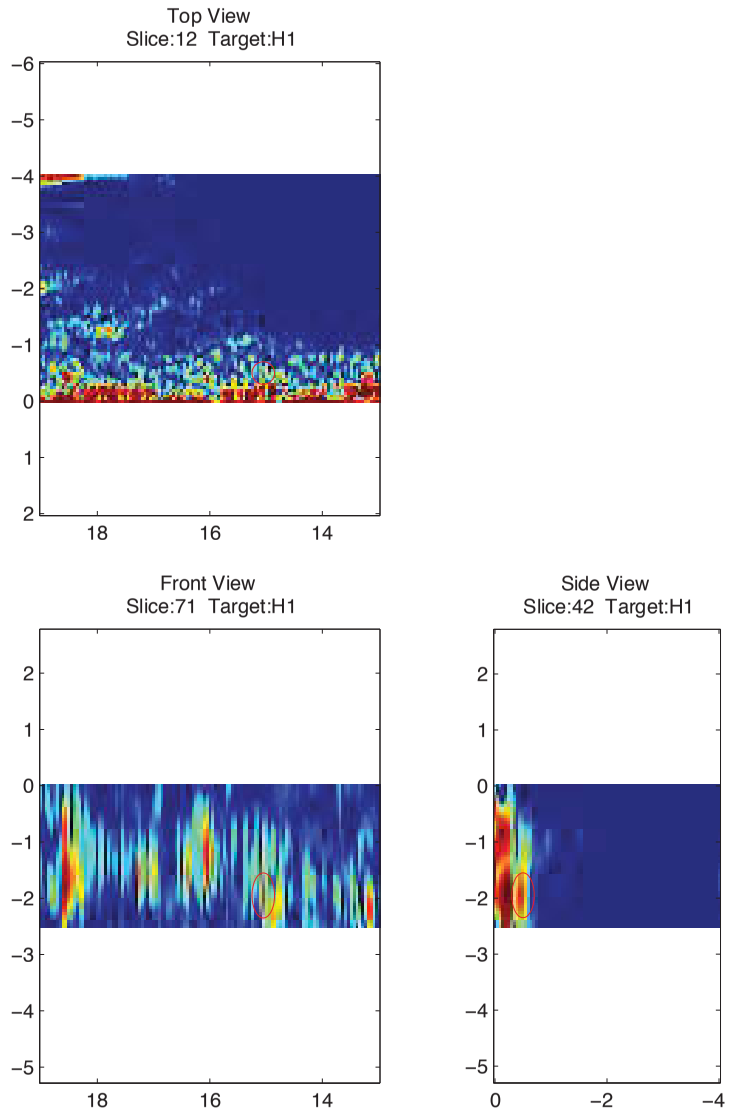


Figure 25: Detection: Target H1, ts_front_s6_03.

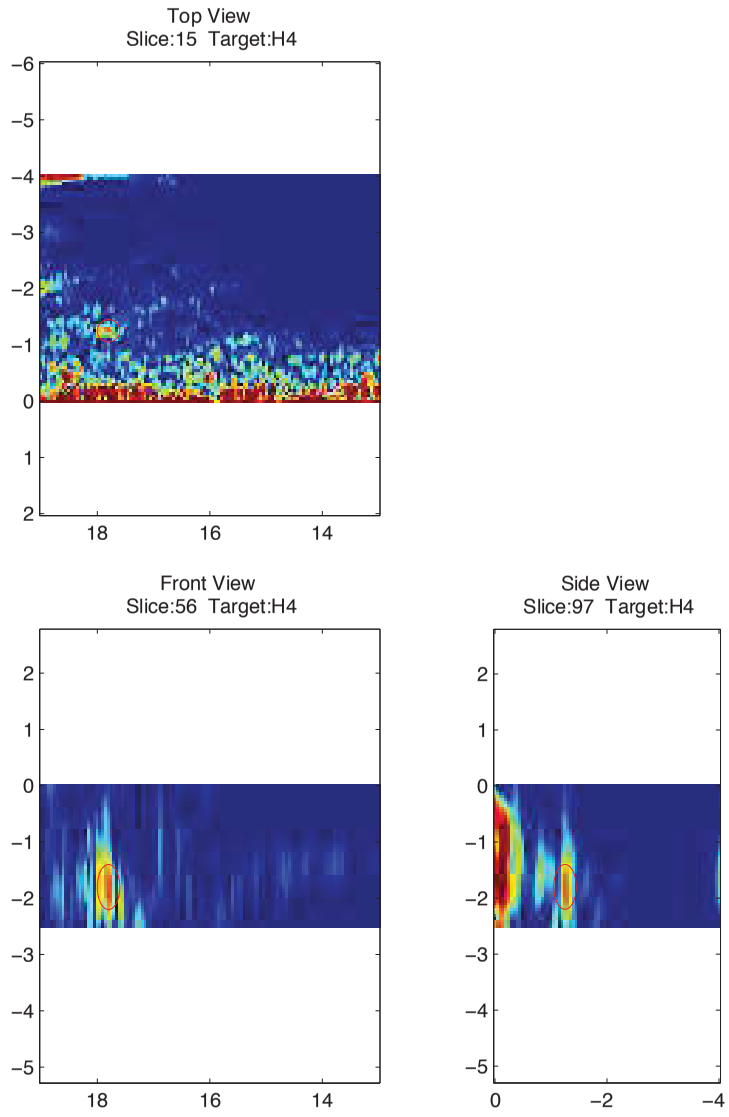


Figure 26: Detection: Target H4, ts_front_s6_03.

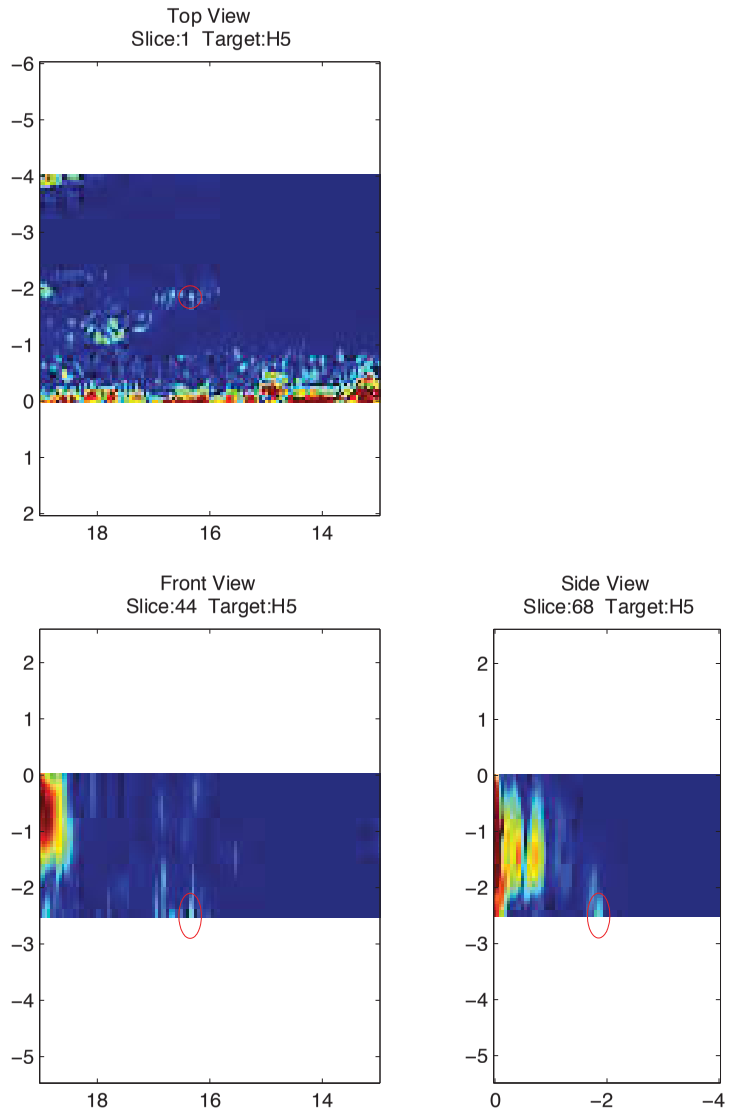


Figure 27: Detection: Target H5, ts_front_s6_03.

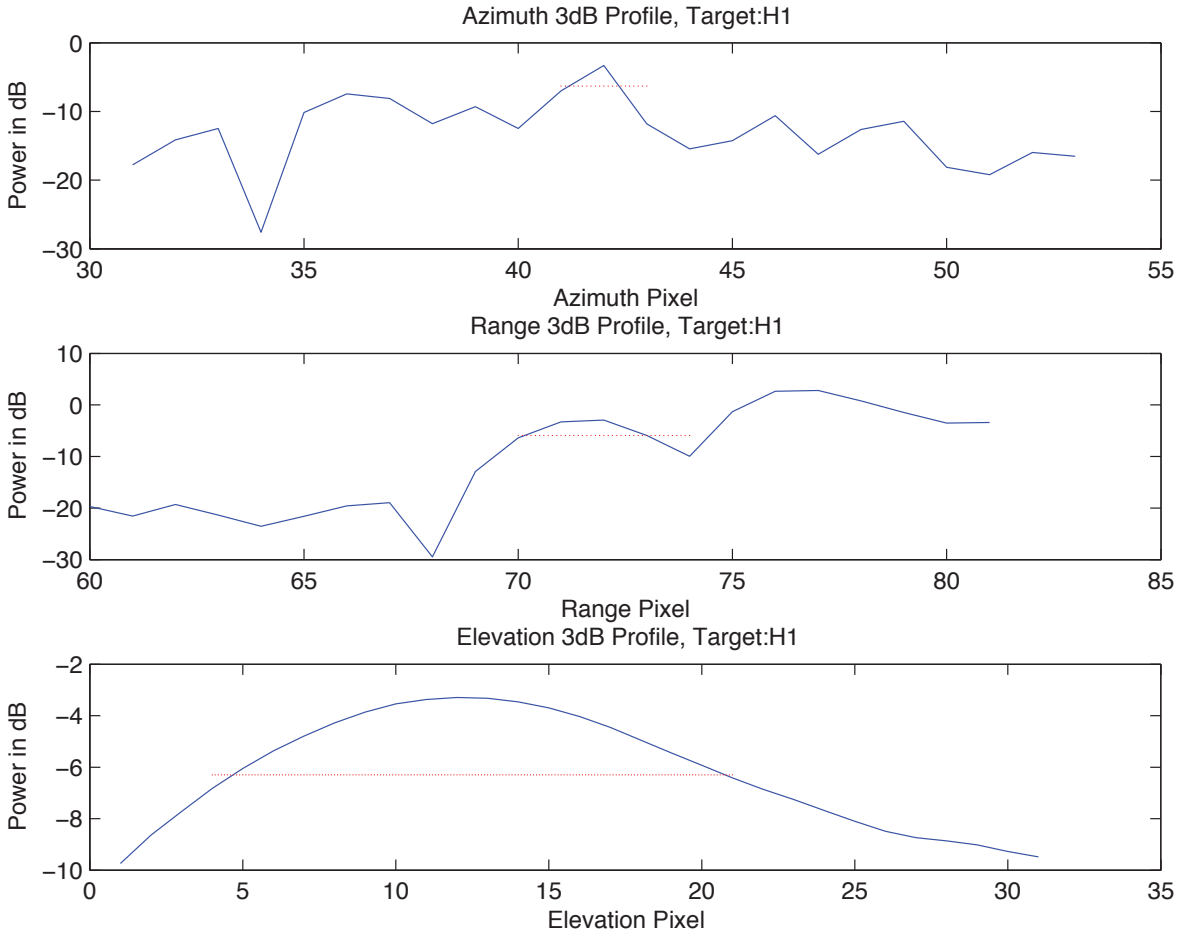


Figure 28: Target H1 3dB Profile, ts_front_s6_03.

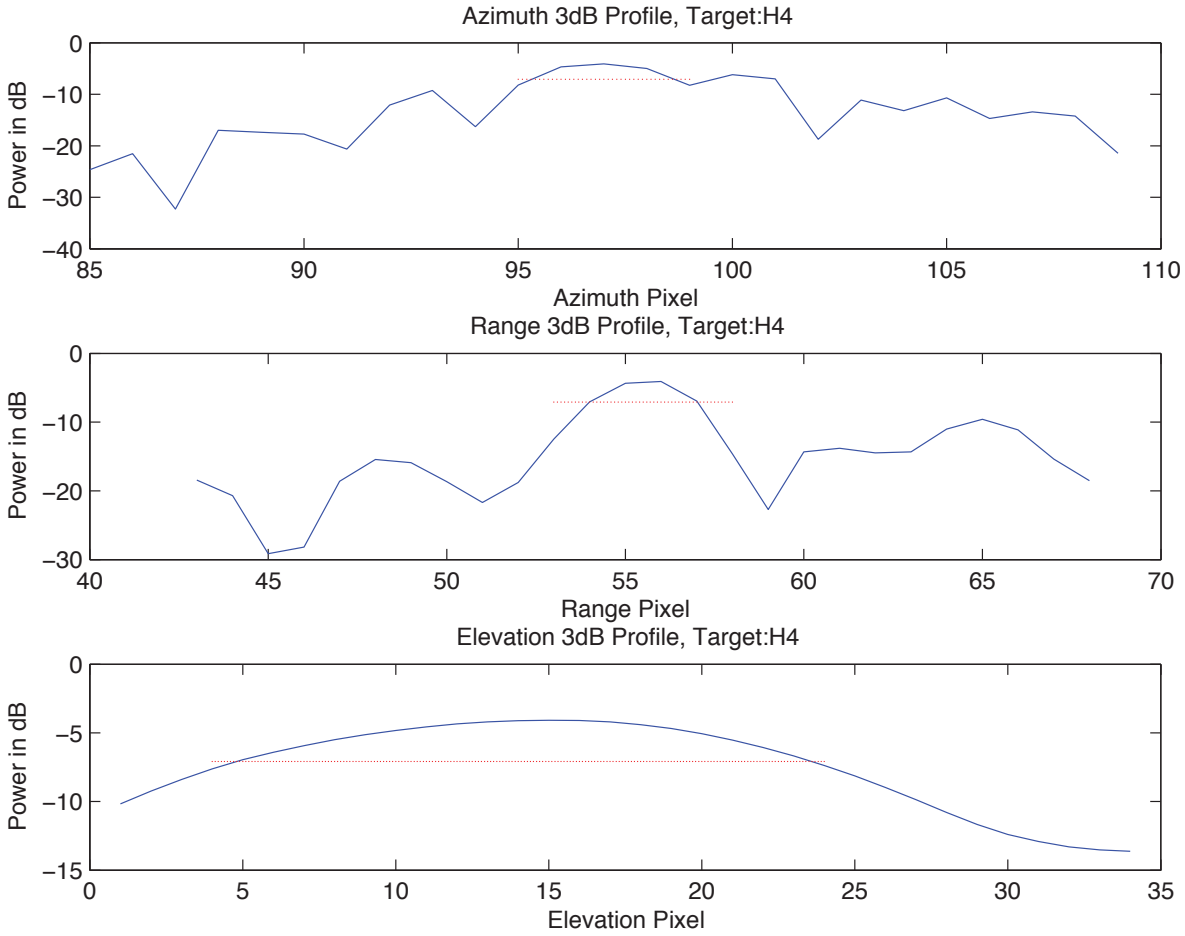


Figure 29: Target H4 3dB Profile, ts_front_s6_03.

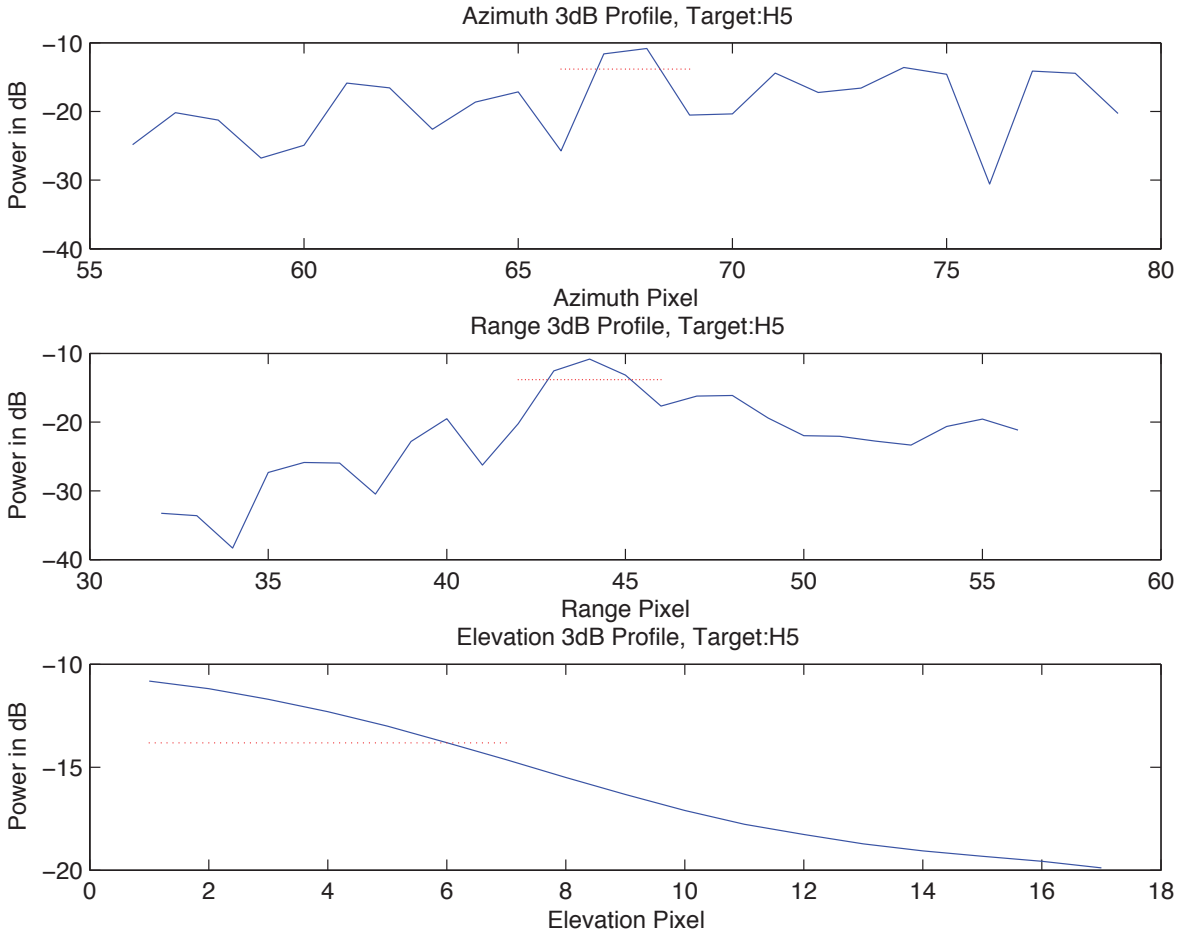


Figure 30: Target H5 3dB Profile, ts_front_s6_03.

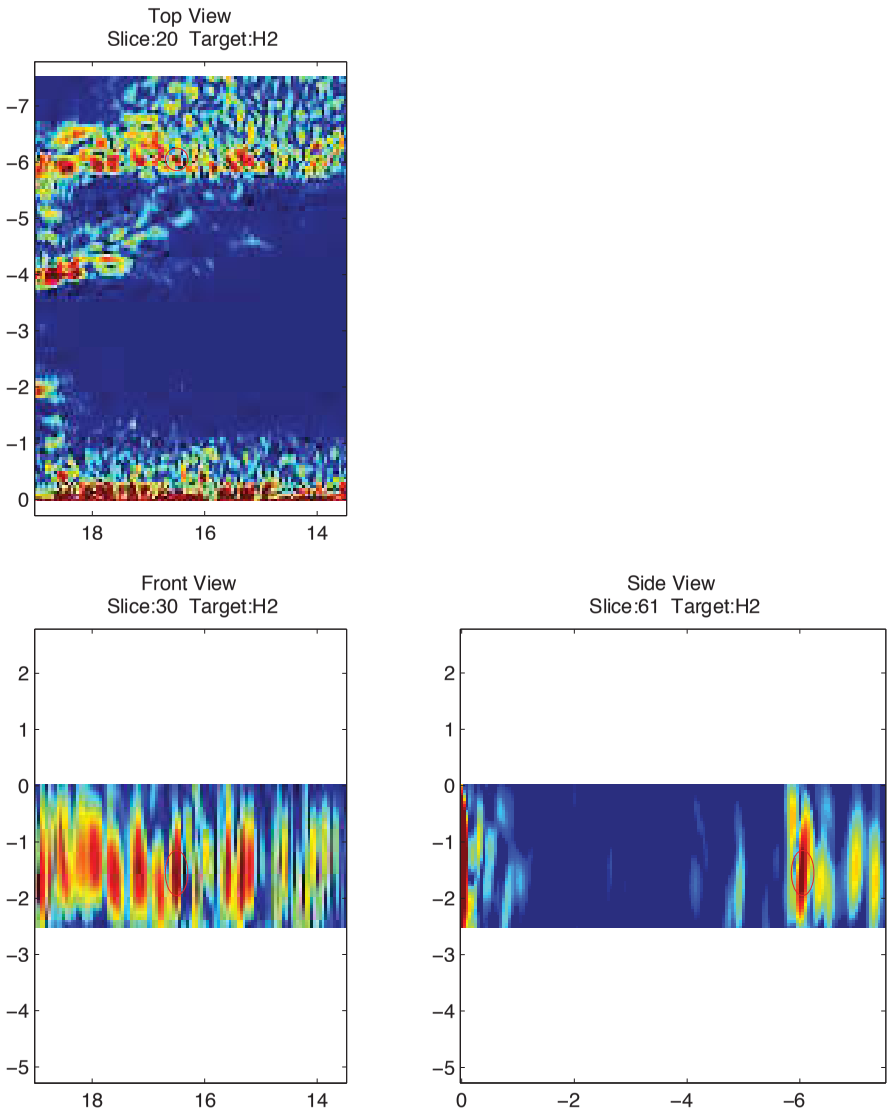


Figure 31: Detection: Target H2, ts_front_s7_01.

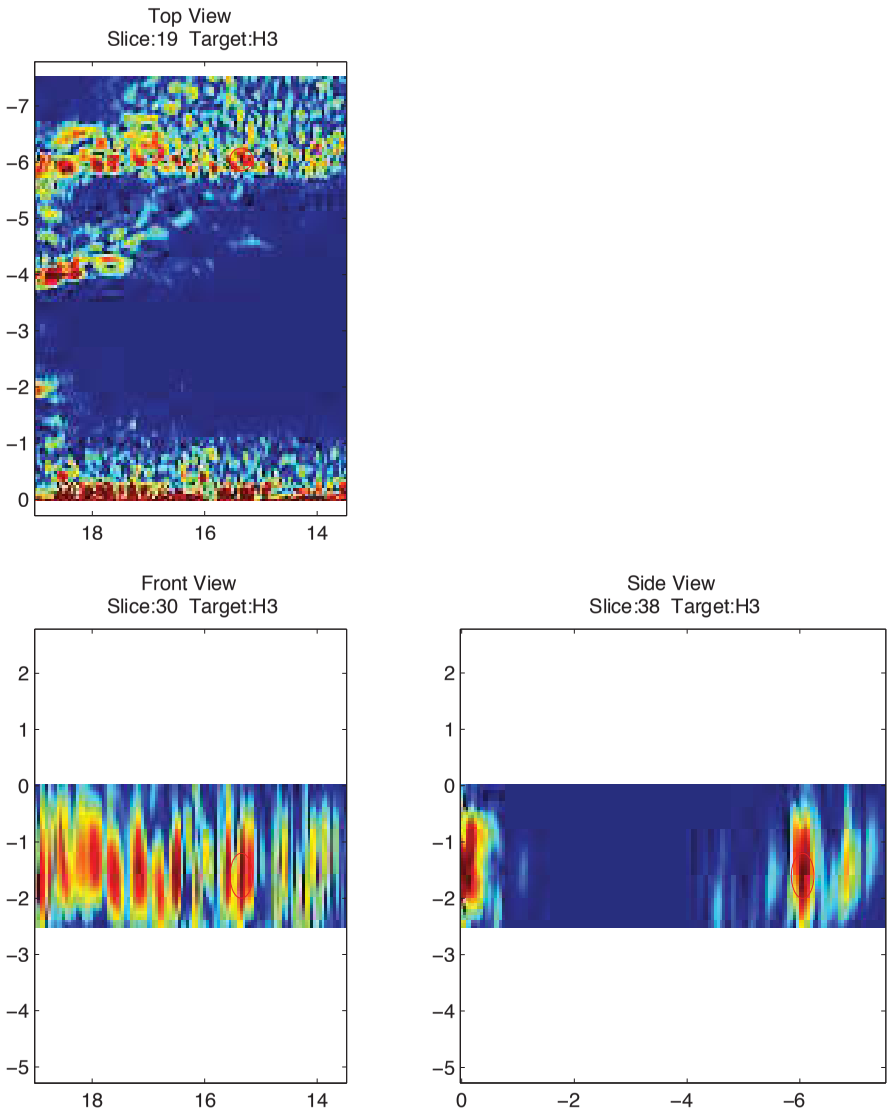


Figure 32: Detection: Target H3, ts_front_s7_01.

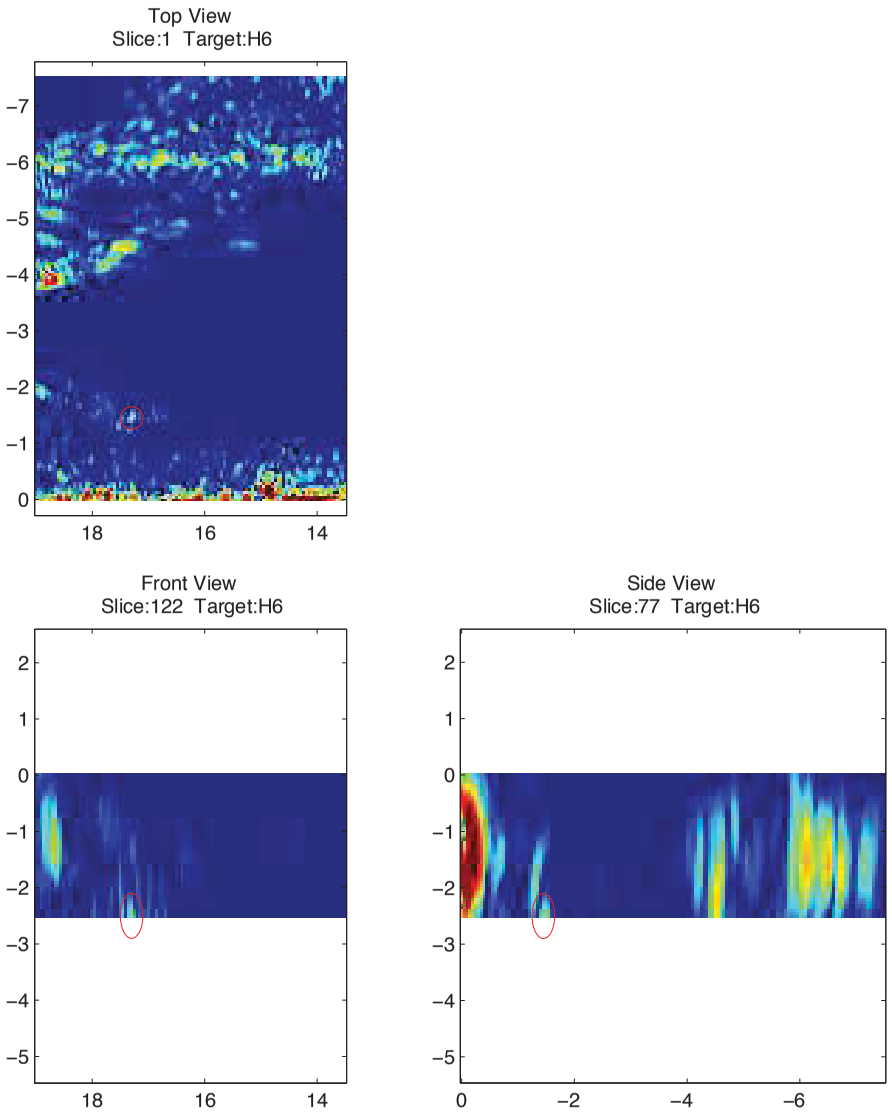


Figure 33: Detection: Target H6, ts_front_s7_01.

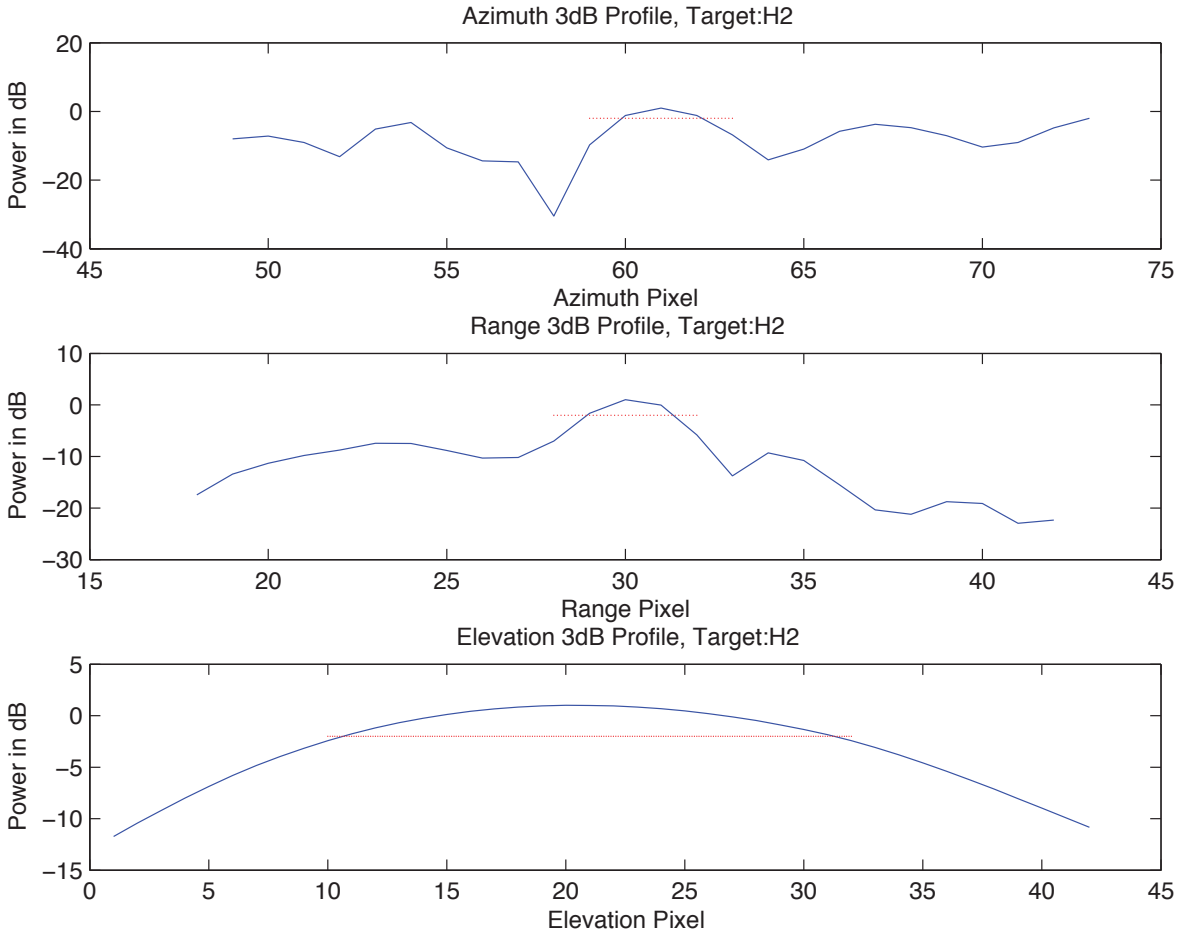


Figure 34: Target H2 3dB Profile, ts_front_s7_01.

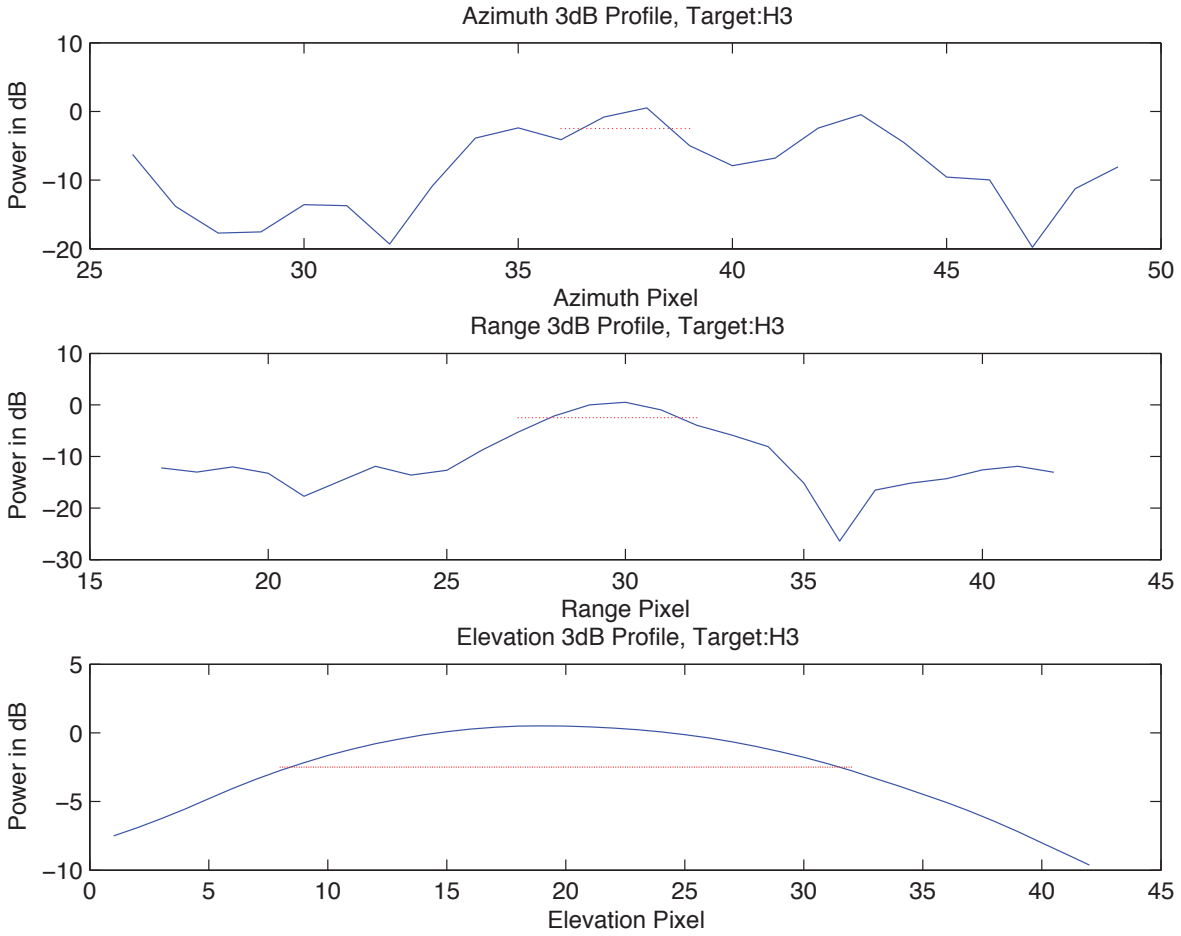


Figure 35: Target H3 3dB Profile, ts_front_s7_01.

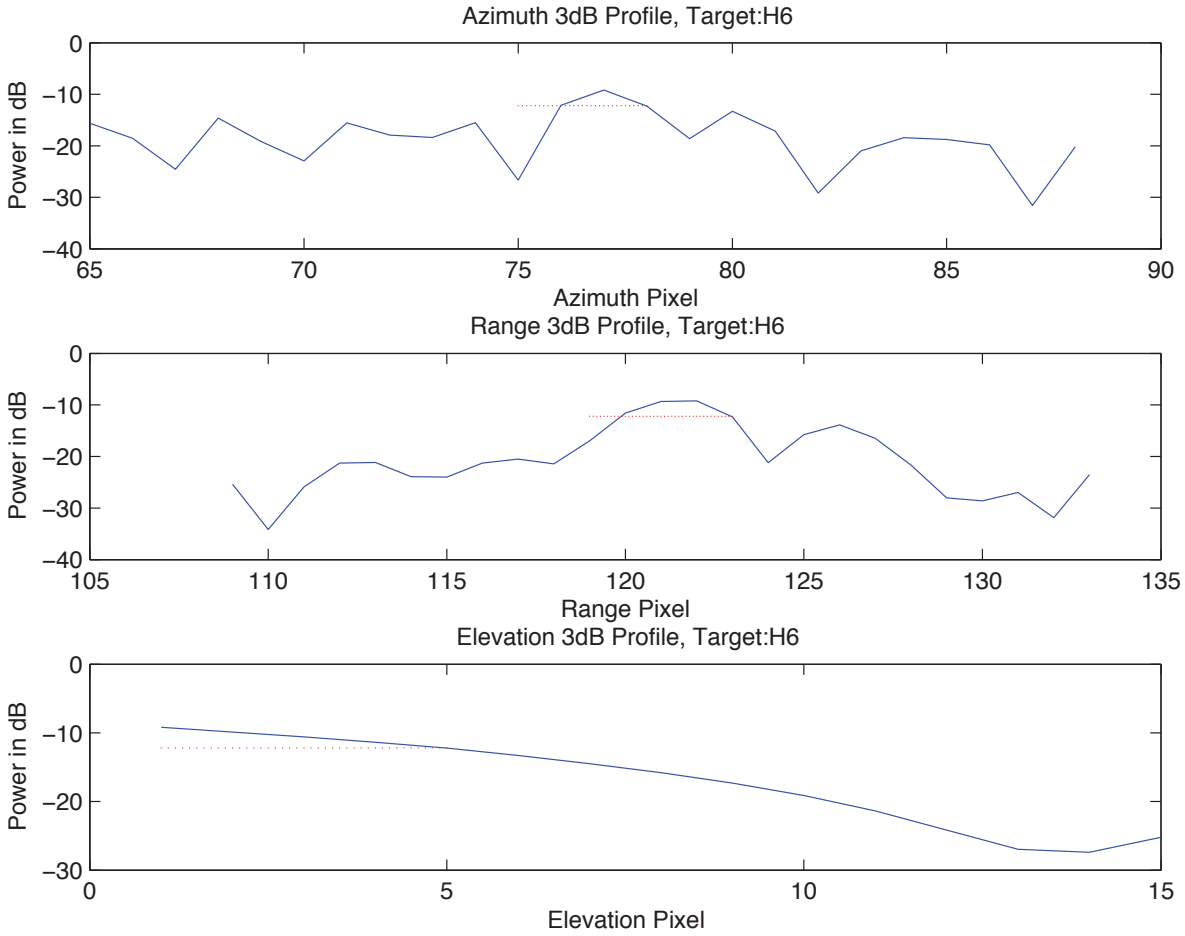


Figure 36: Target H6 3dB Profile, ts_front_s7_01.

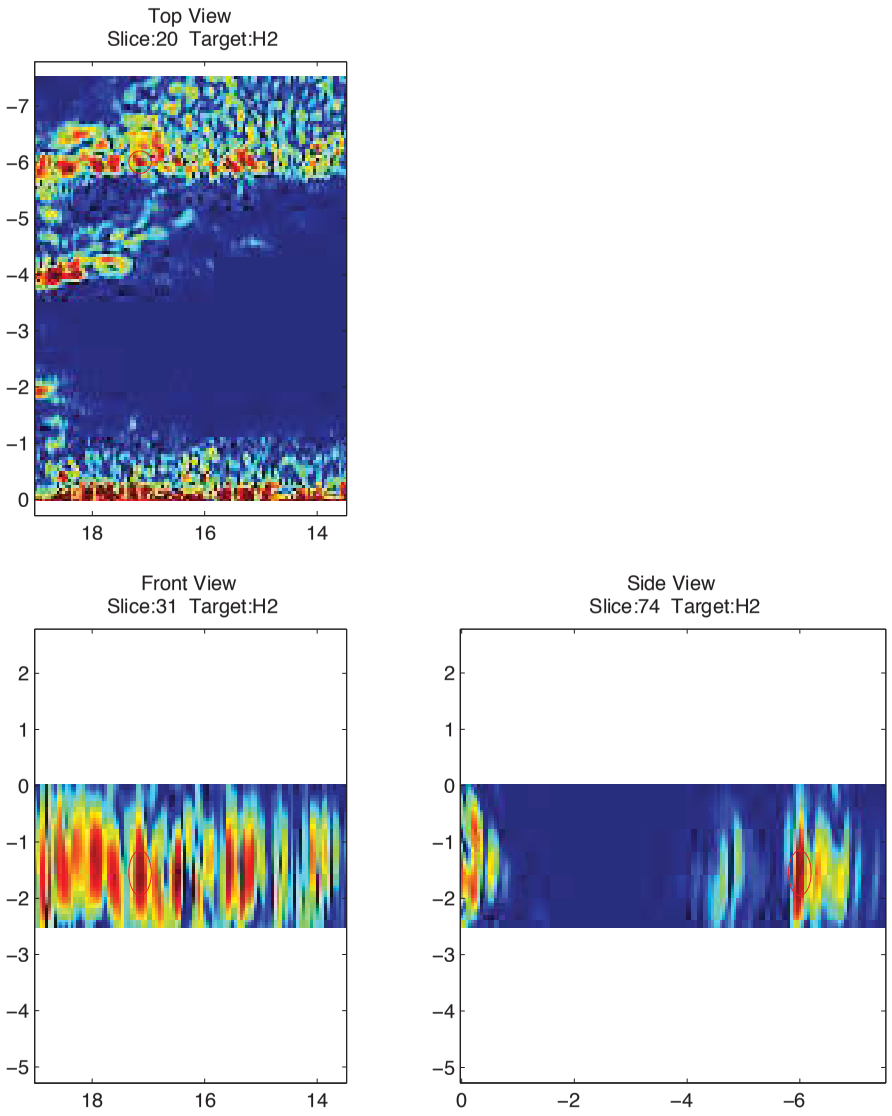


Figure 37: Detection: Target H2, ts_front_s7_02.

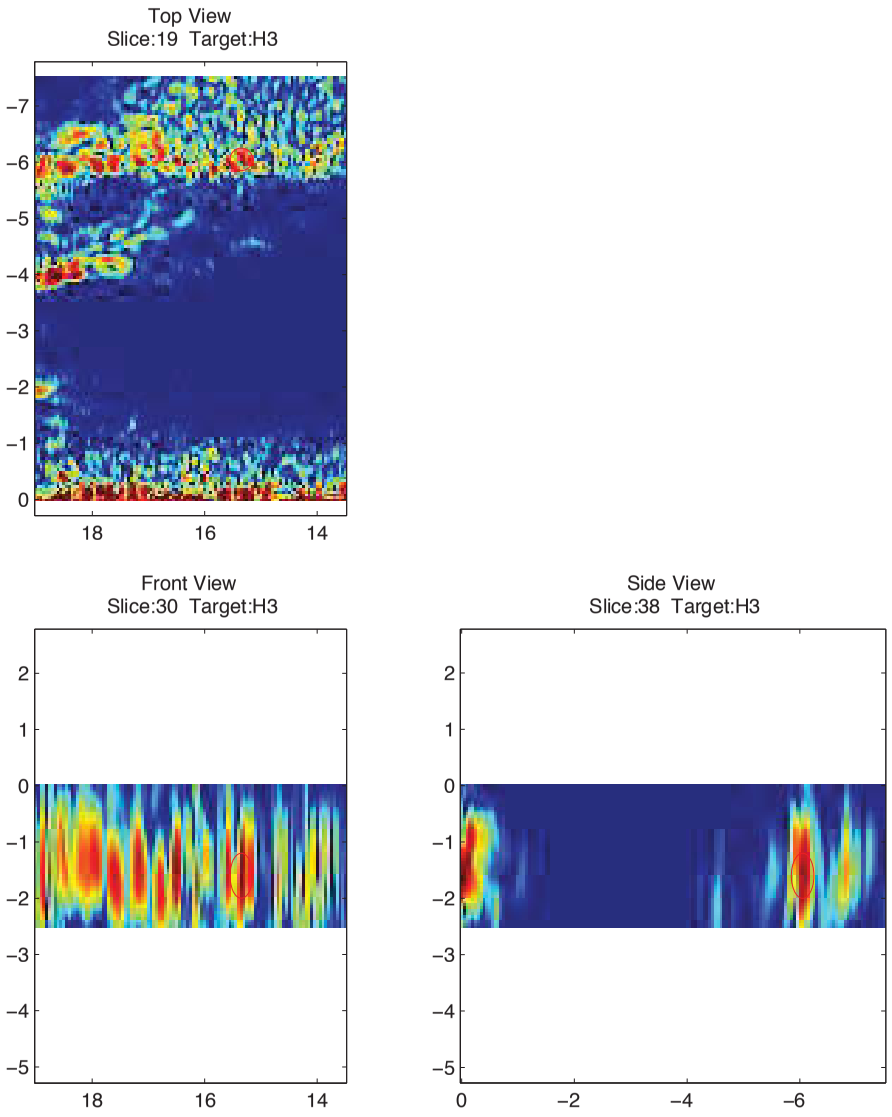


Figure 38: Detection: Target H5, ts_front_s7_02.

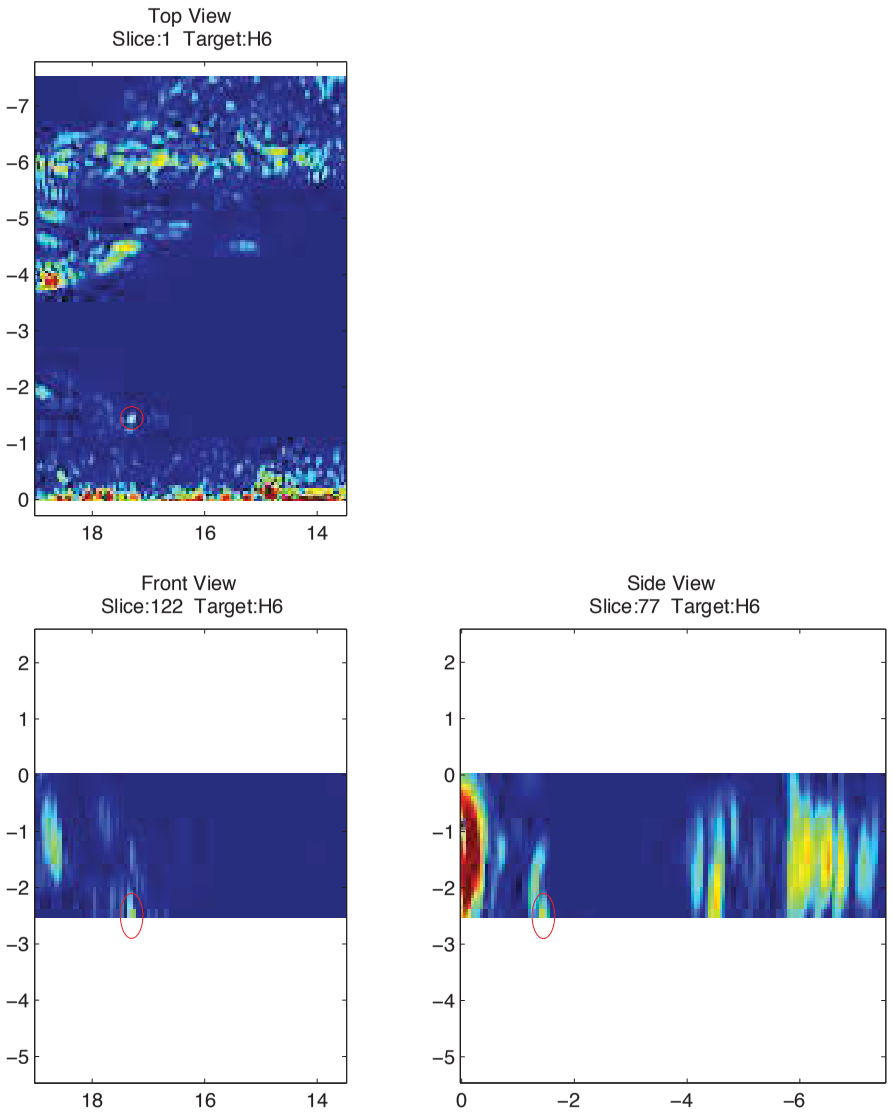


Figure 39: Detection: Target H6, ts_front_s7_02.

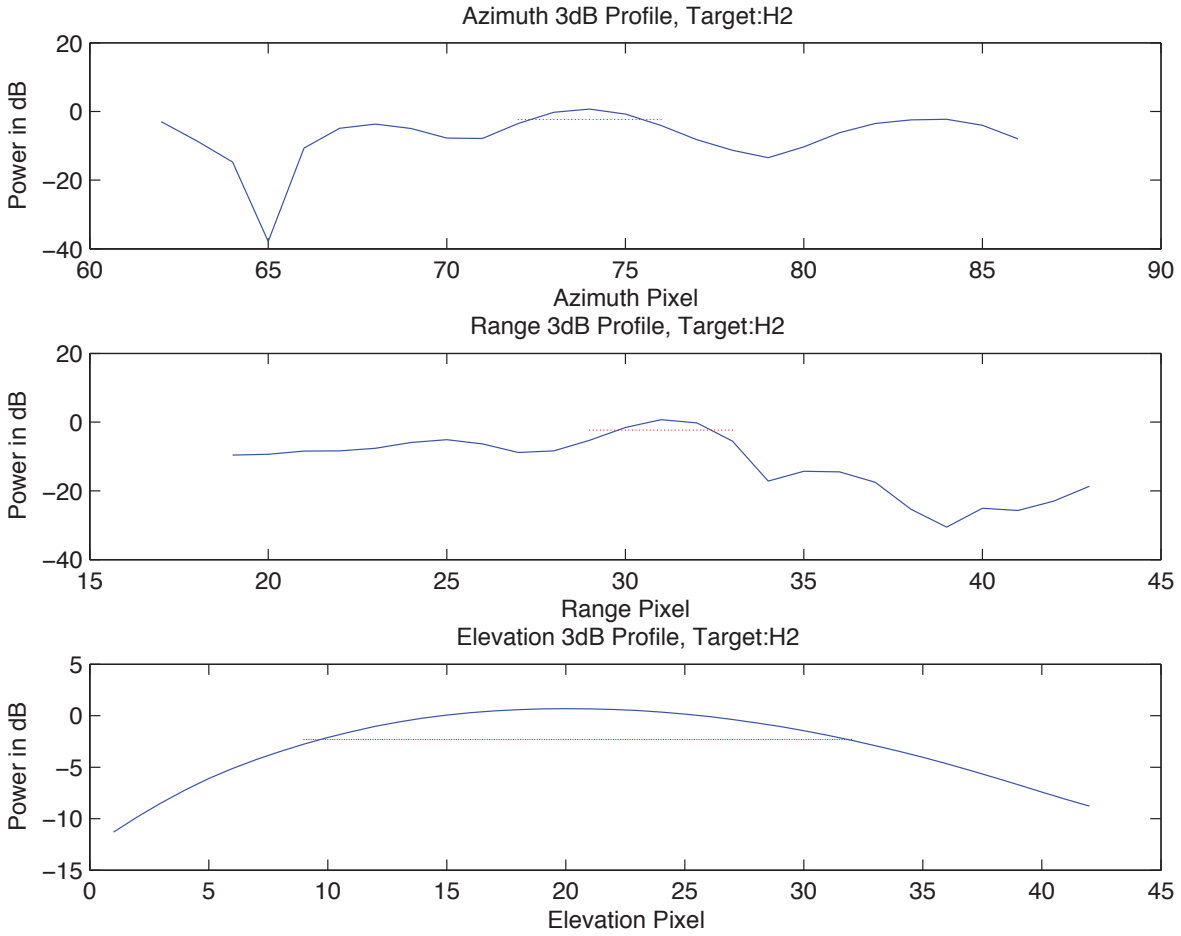


Figure 40: Target H2 3dB Profile, ts_front_s7_02.

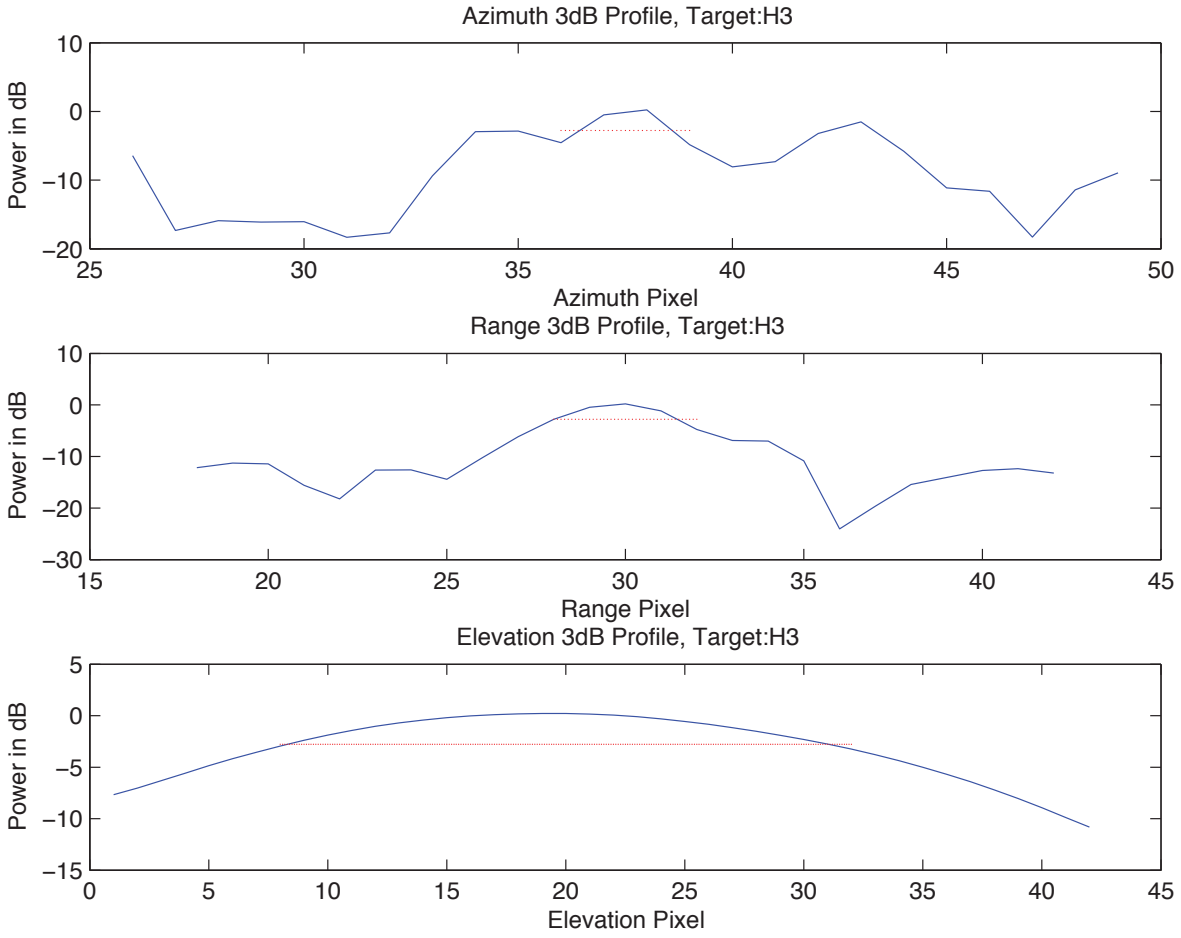


Figure 41: Target H3 3dB Profile, ts_front_s7_02.

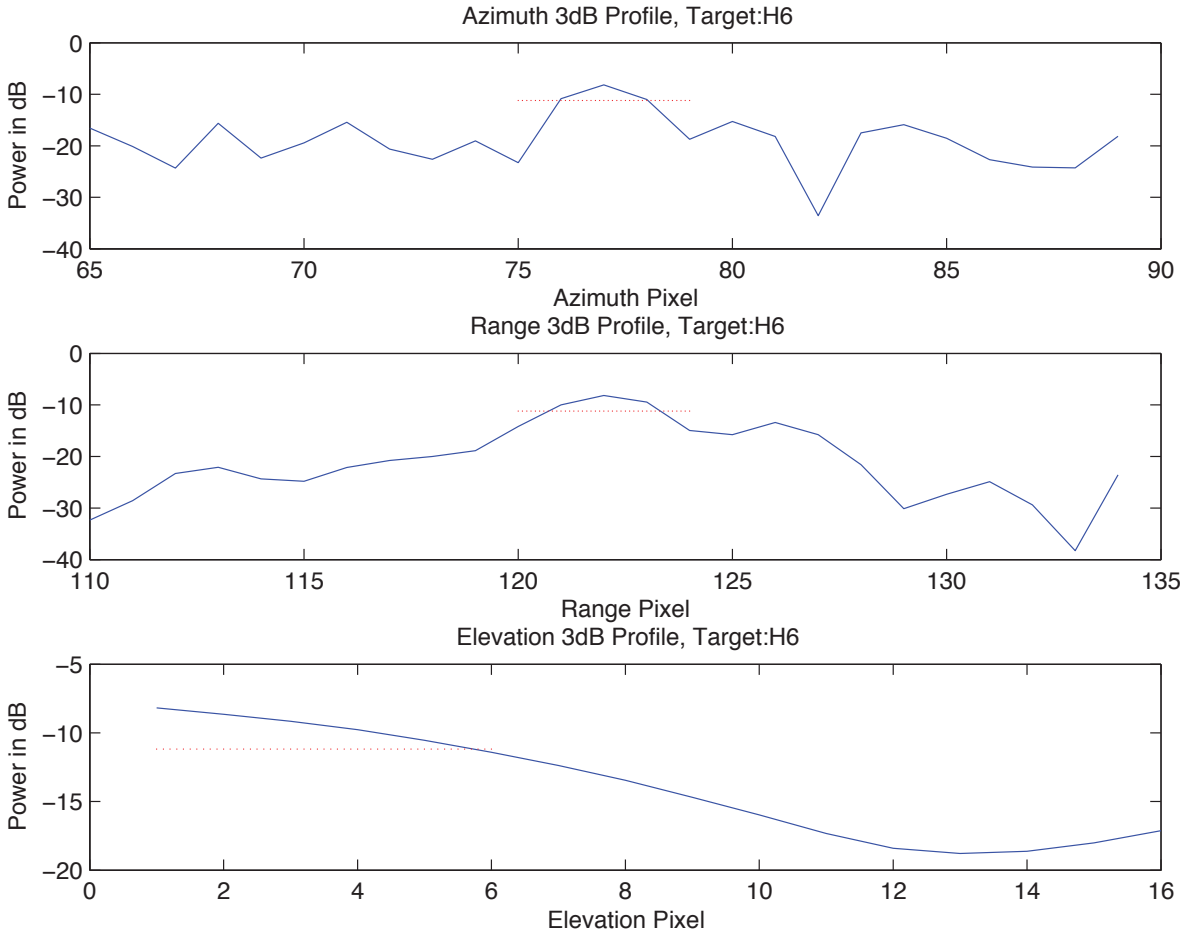


Figure 42: Target H6 3dB Profile, ts_front_s7_02.

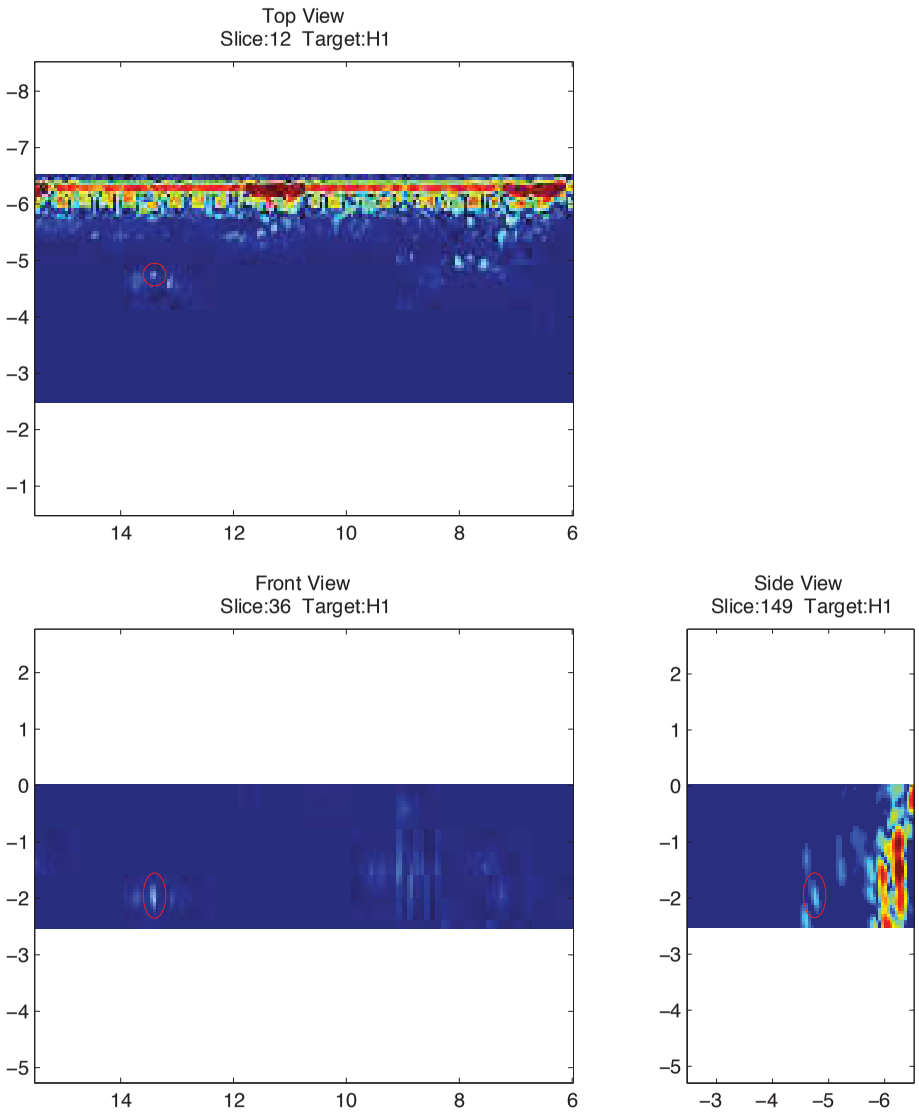


Figure 43: Detection: Target H1, ts_back_s8_04.

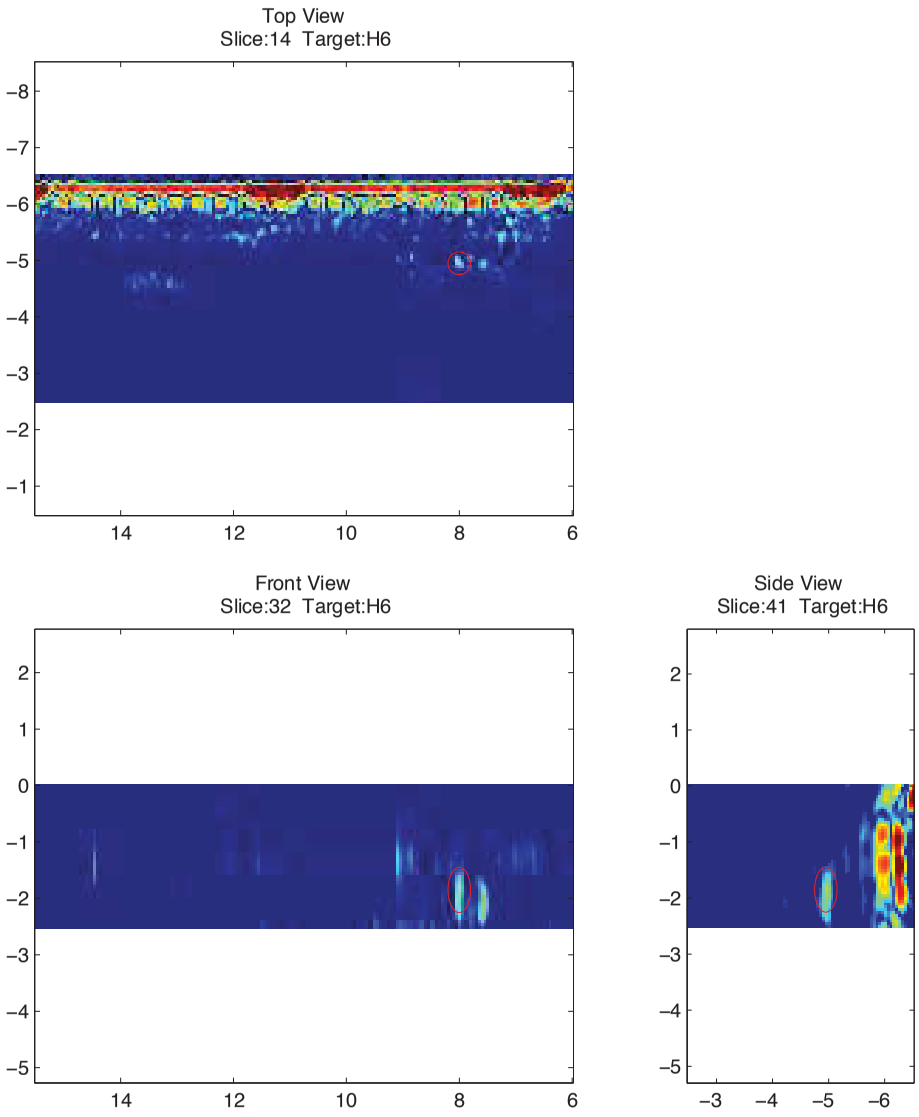


Figure 44: Detection: Target H6, ts_back_s8_04.

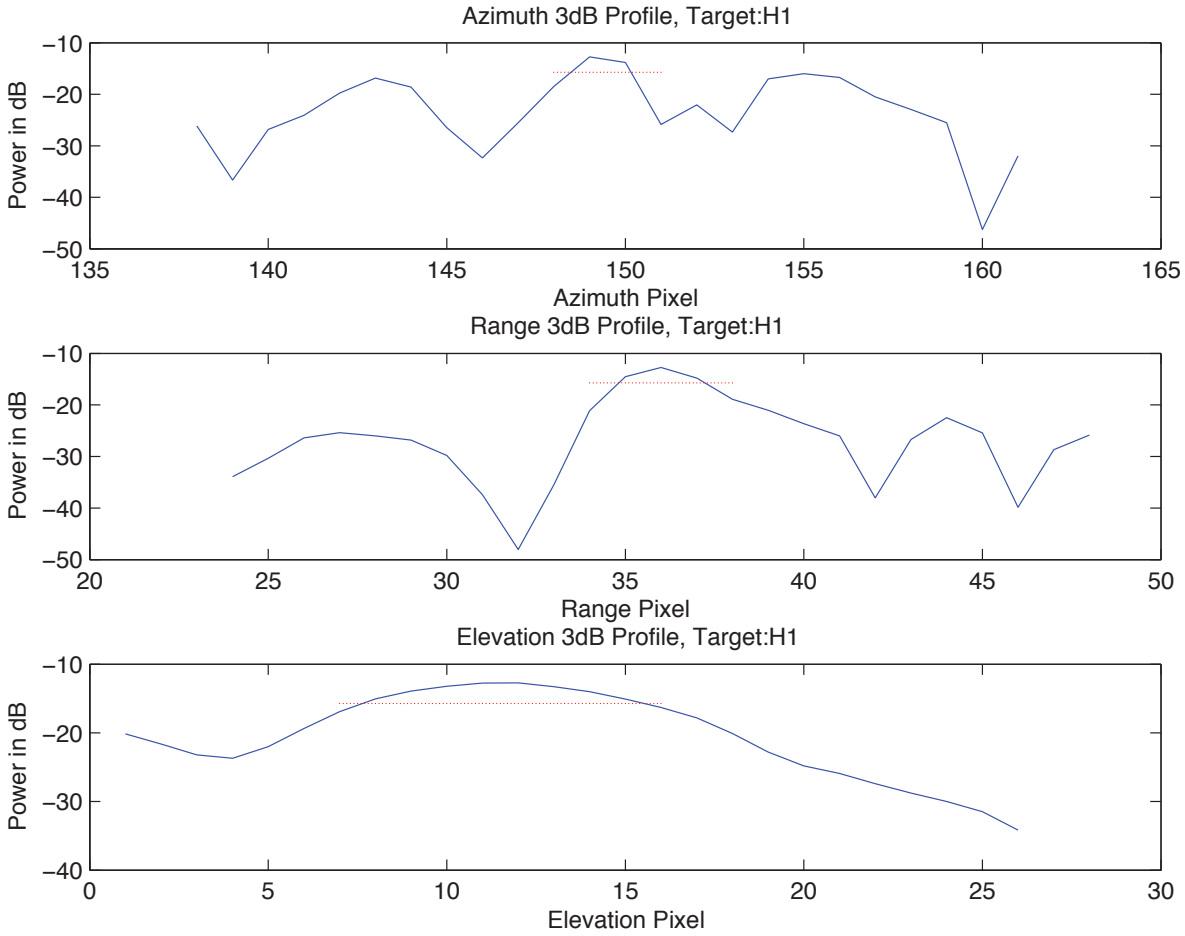


Figure 45: Target H1 3dB Profile, ts_front_s8_04.

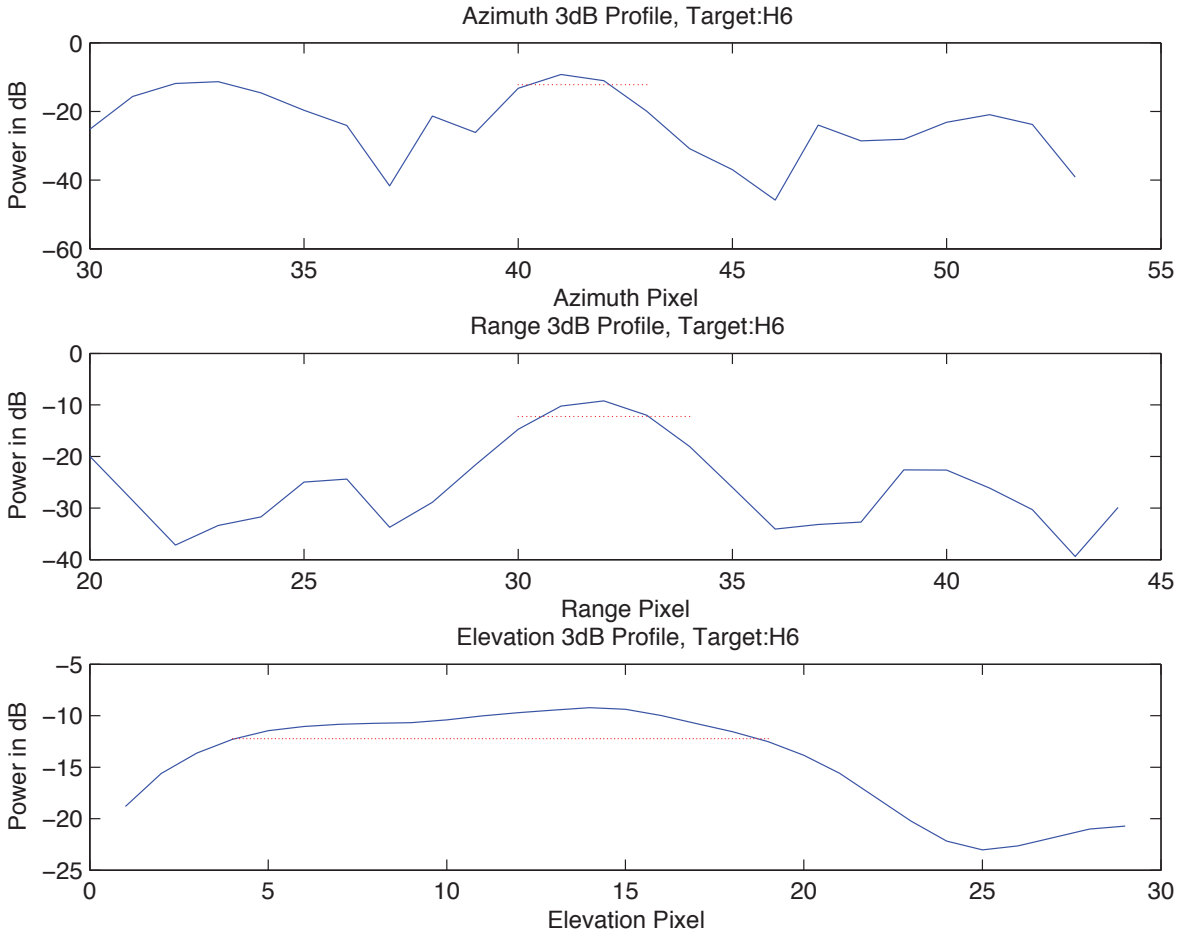


Figure 46: Target H6 3dB Profile, ts_front_s8_04.

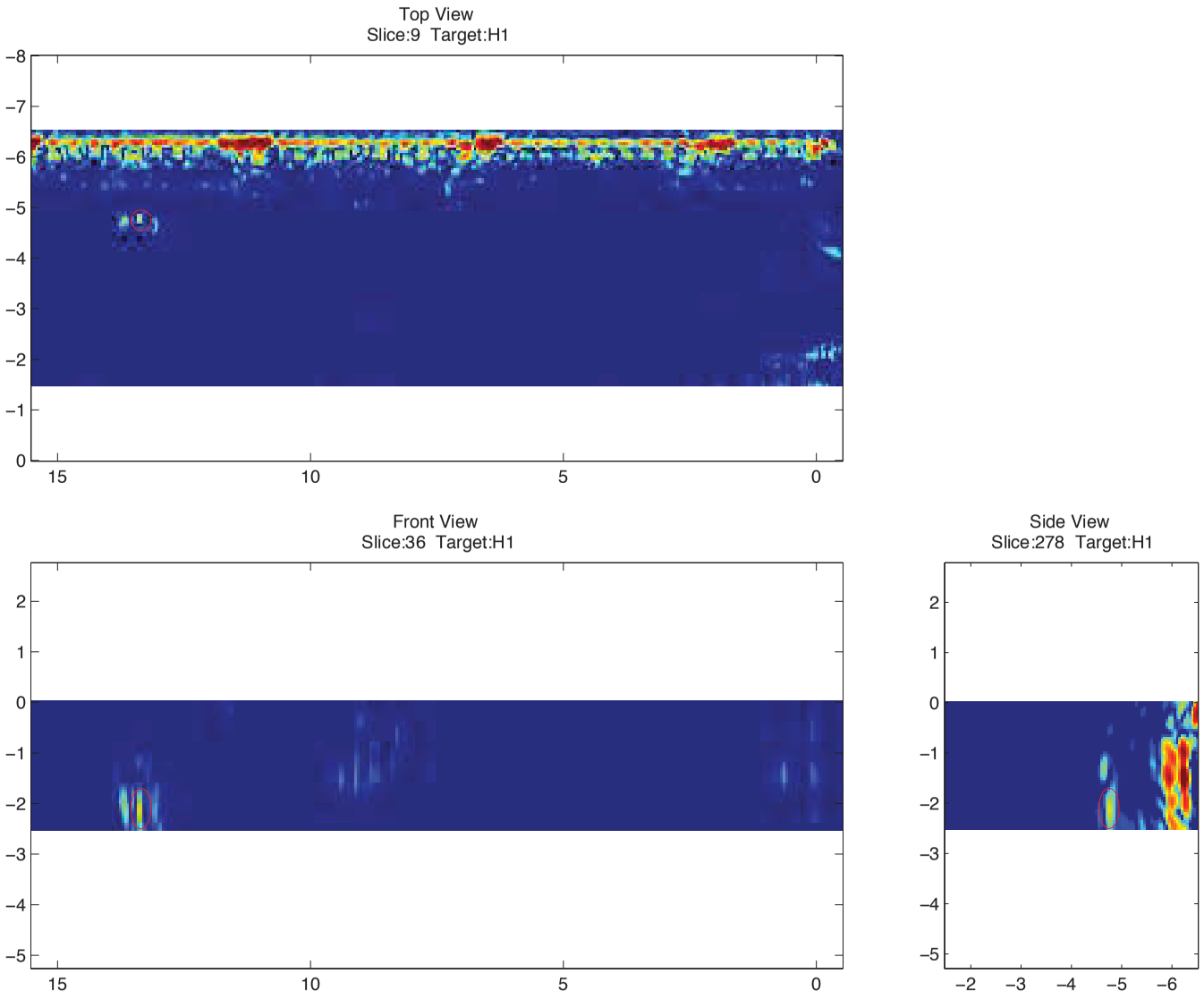


Figure 47: Detection: Target H1, ts_back_s10_01.

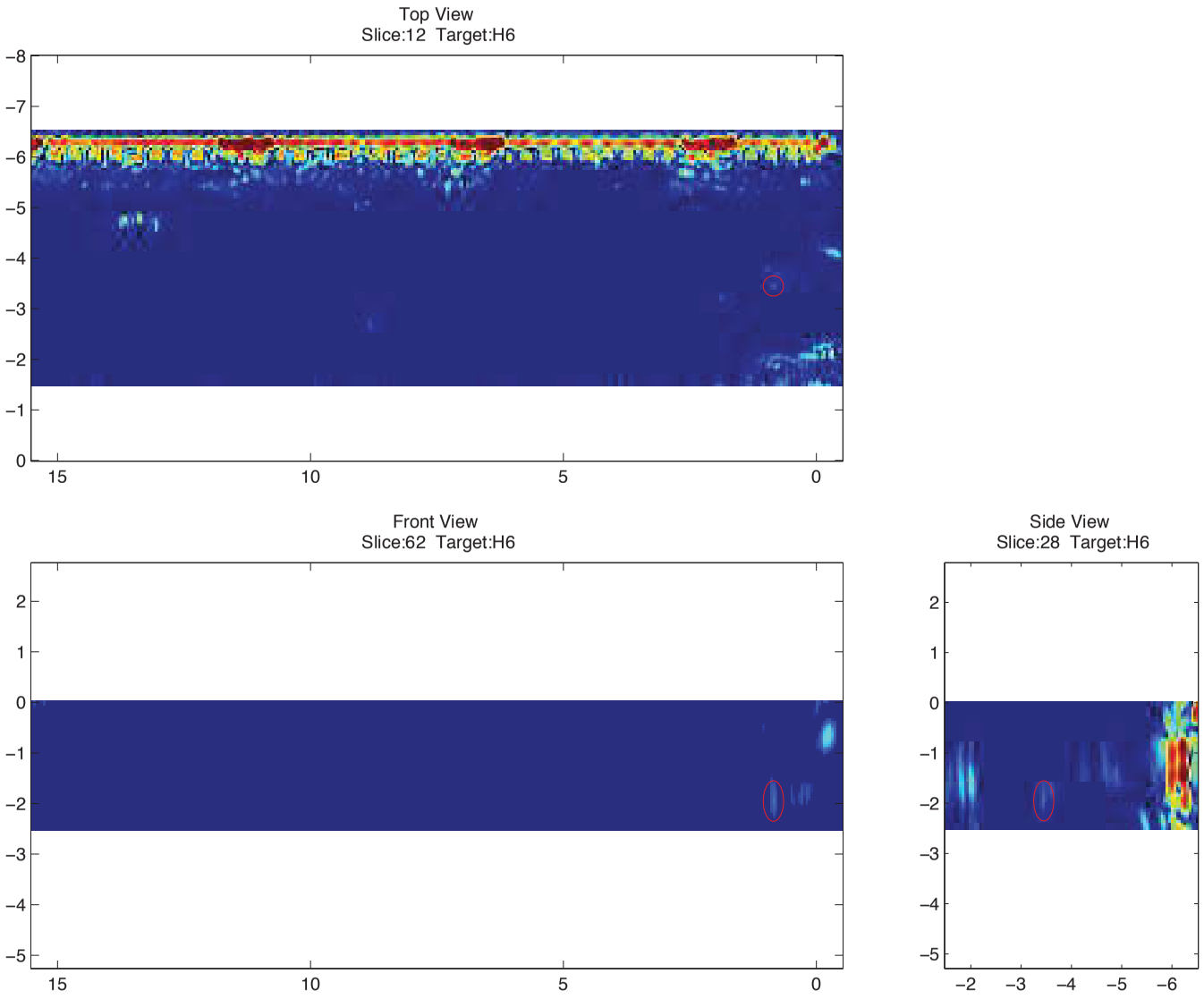


Figure 48: Detection: Target H6, ts_back_s10_01.

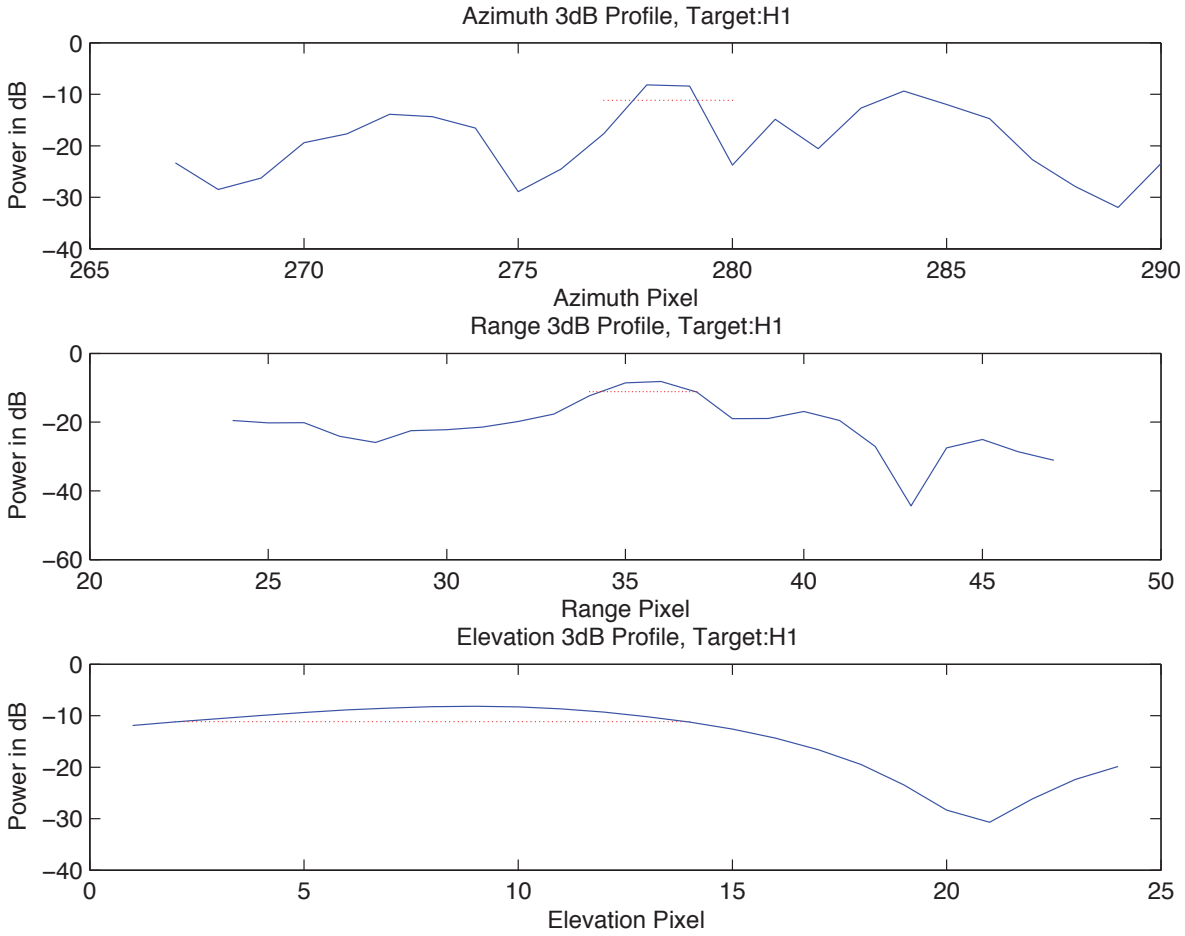


Figure 49: Target H1 3dB Profile, ts_front_s10_01.

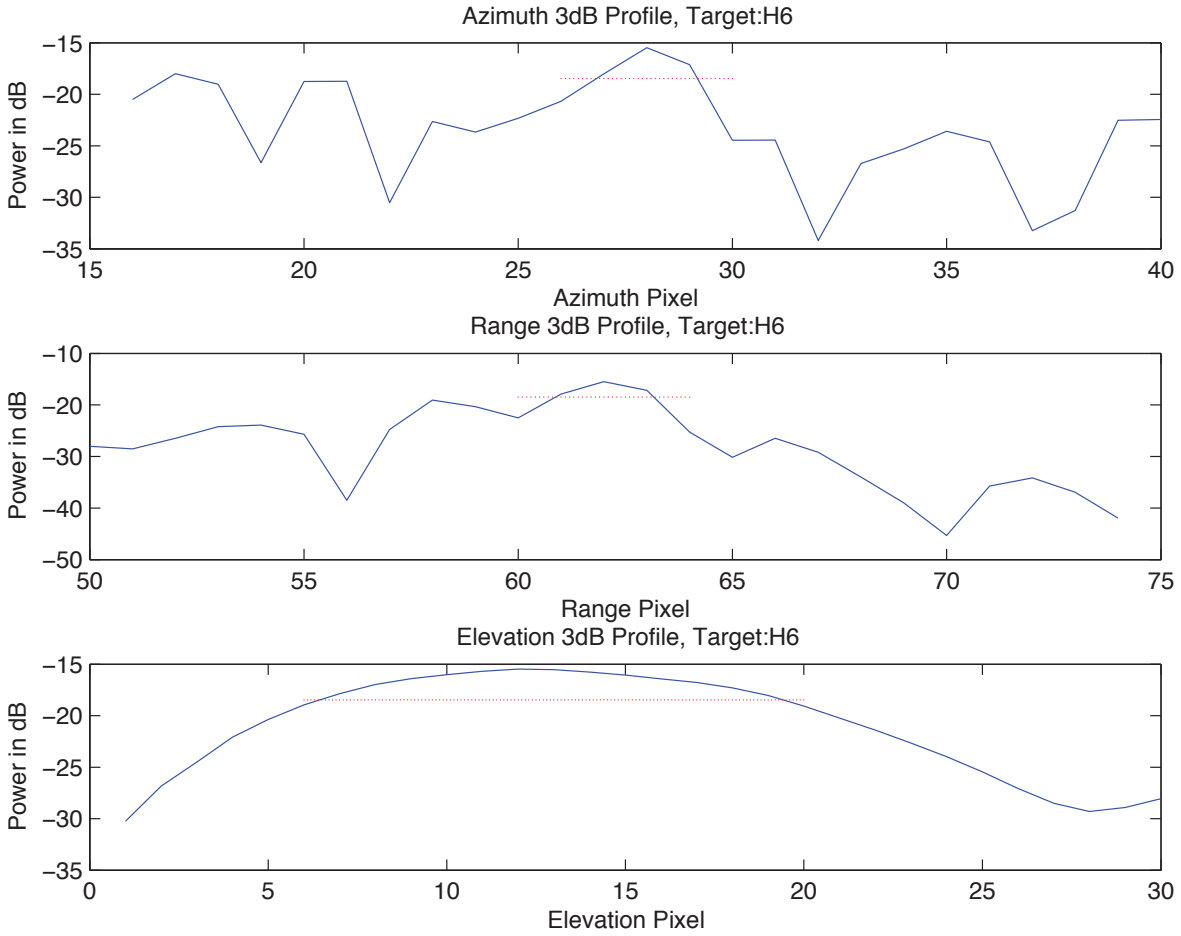


Figure 50: Target H6 3dB Profile, ts_front_s10_01.

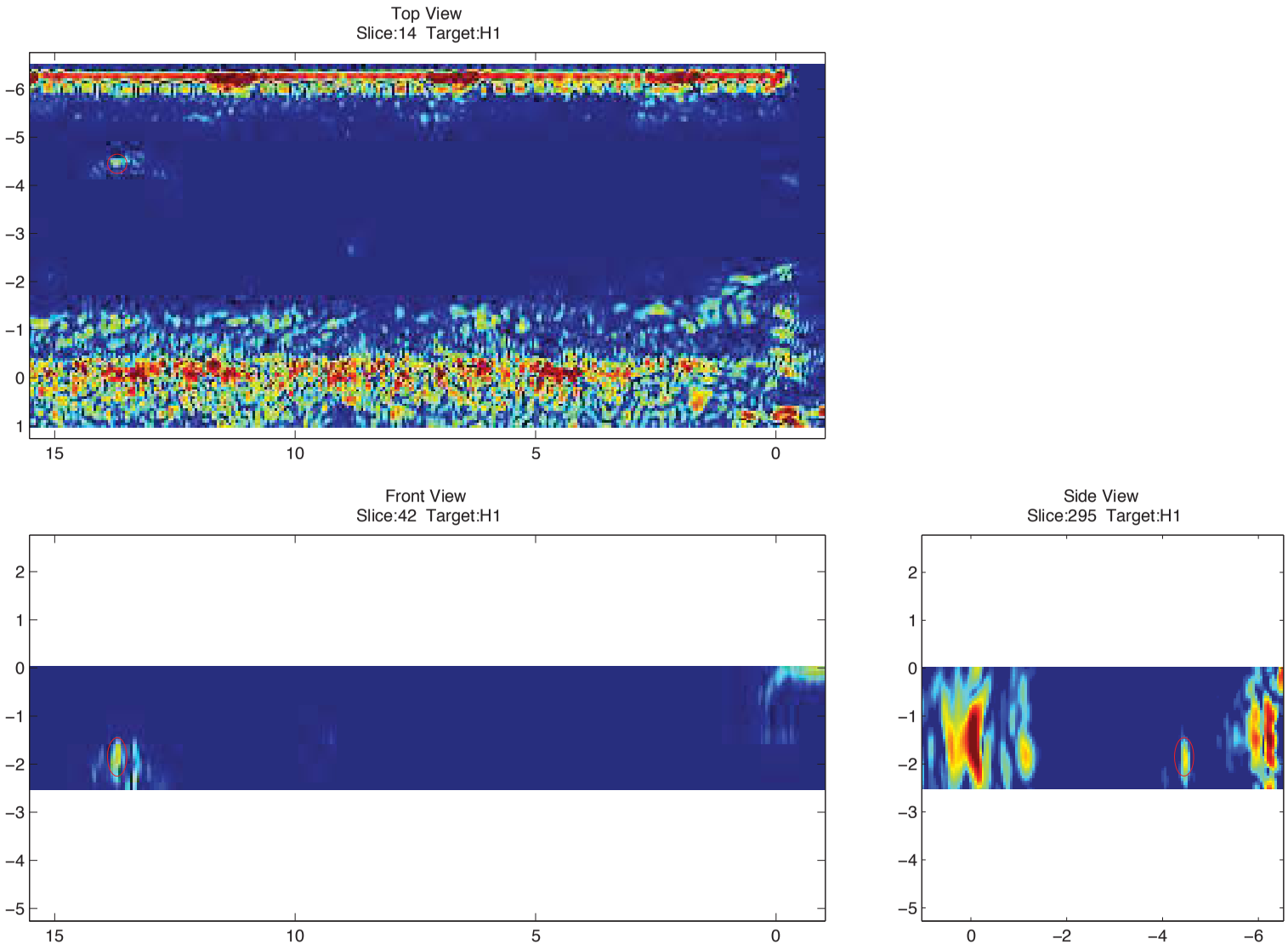


Figure 51: Detection: Target H1, ts_back_s11_01.

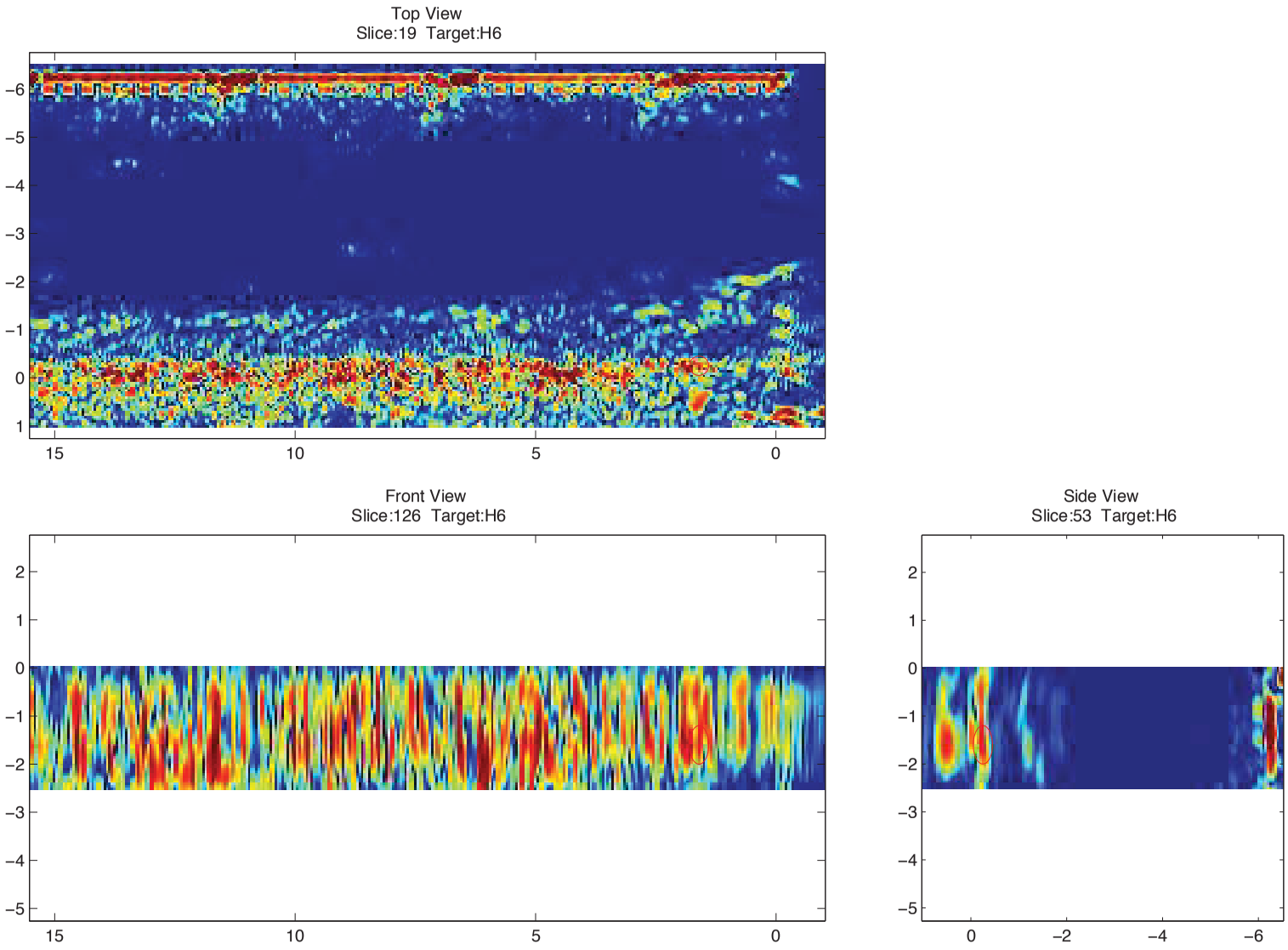


Figure 52: Detection: Target H6, ts_back_s11_01.

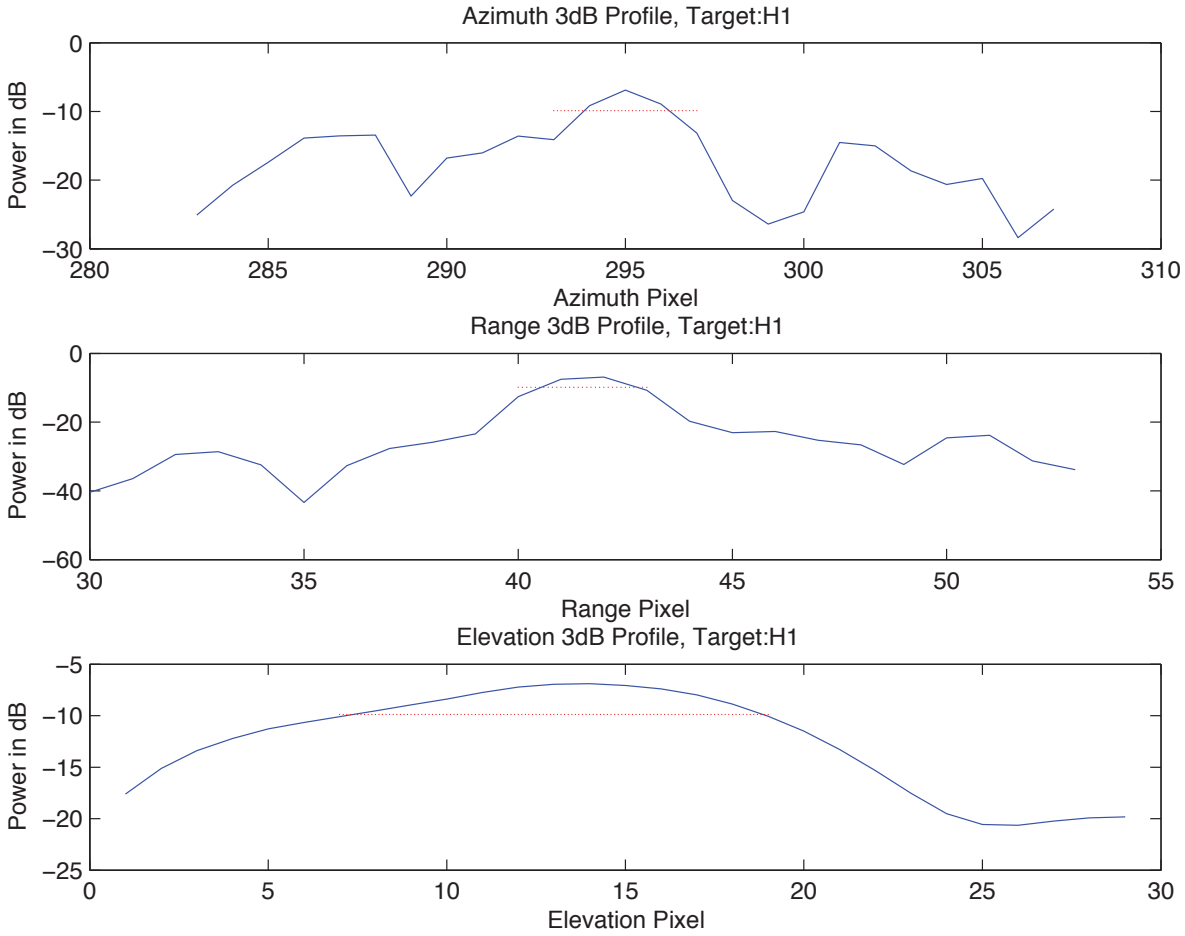


Figure 53: Target H1 3dB Profile, ts_front_s11_01.

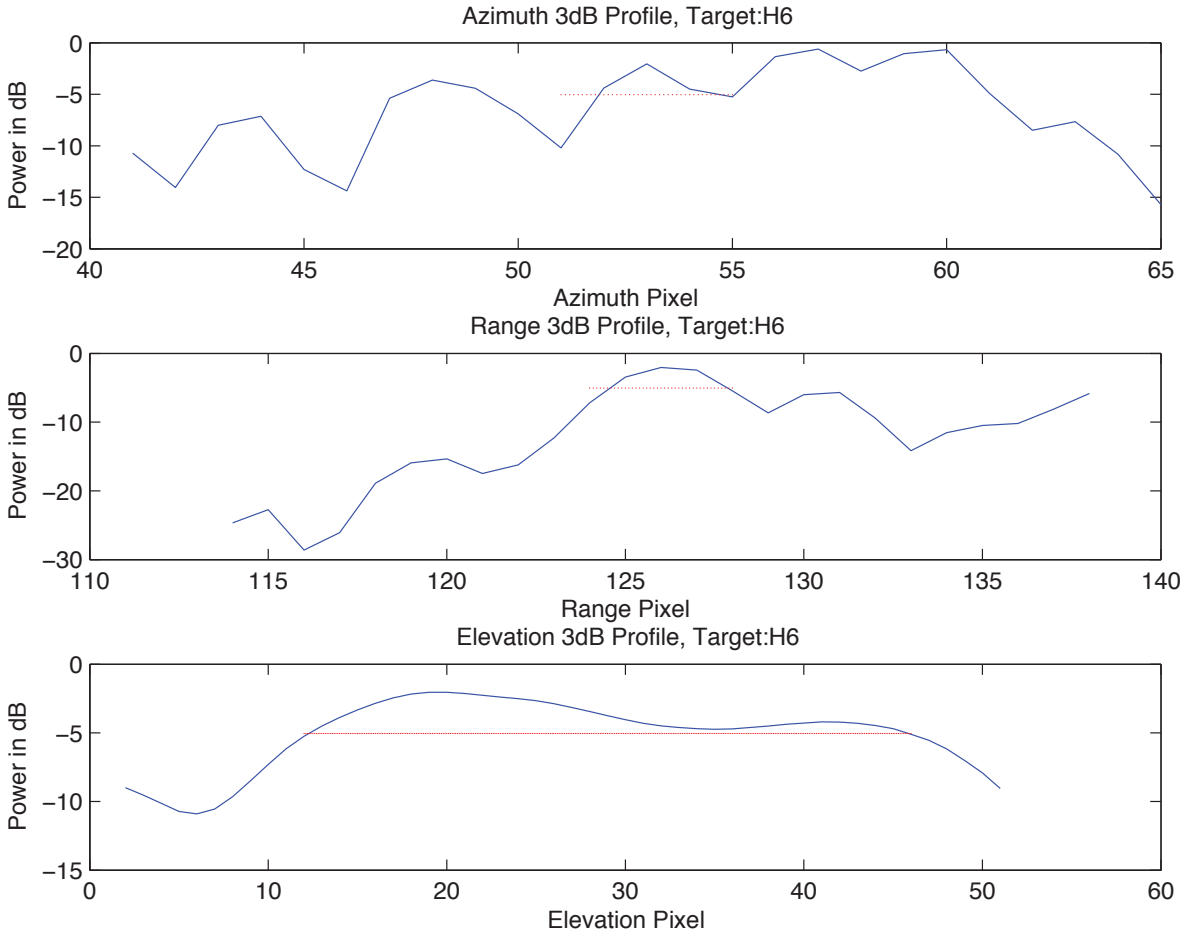


Figure 54: Target H6 3dB Profile, ts_front_s11_01.

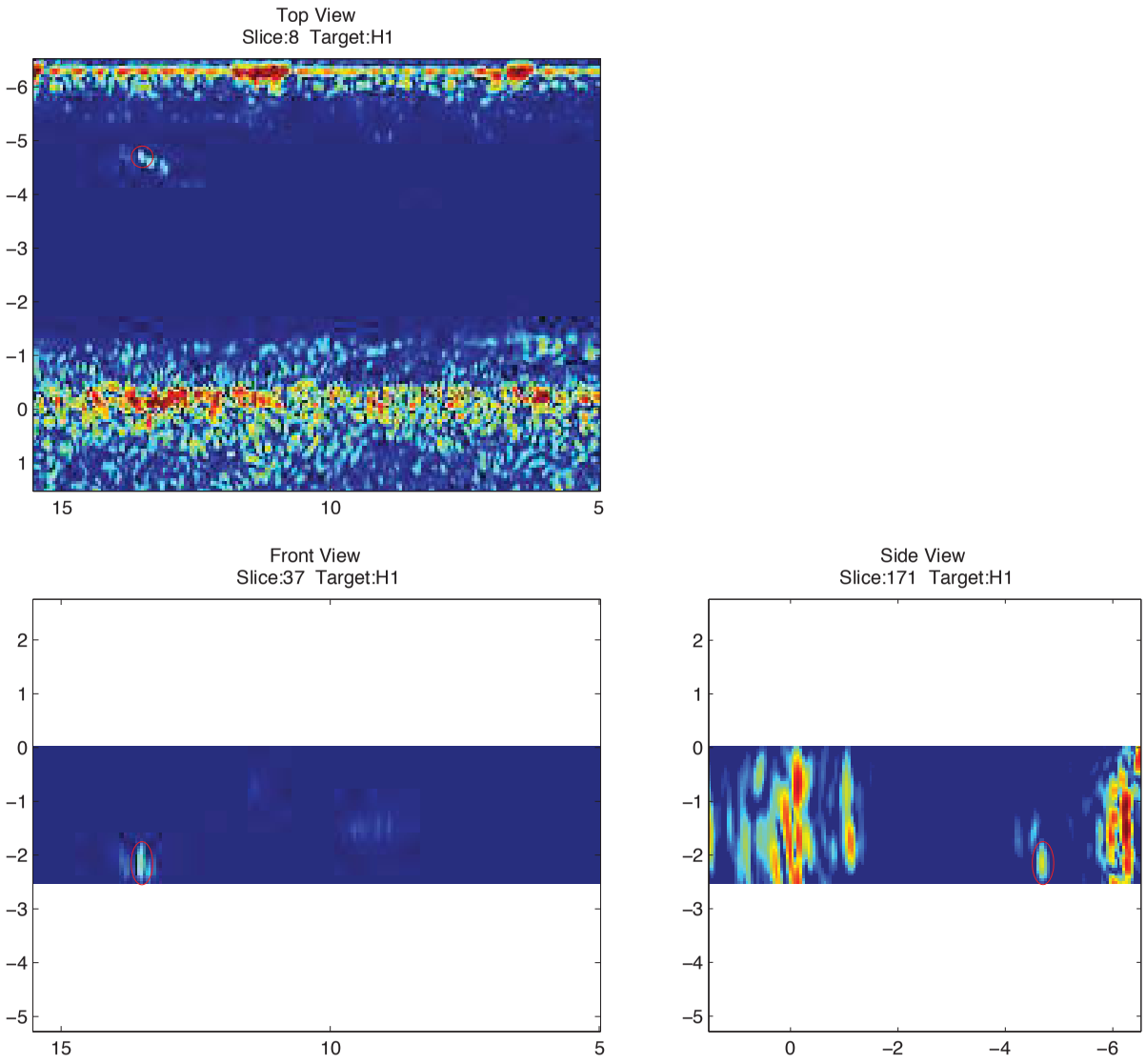


Figure 55: Detection: Target H1, ts_back_s12_01.

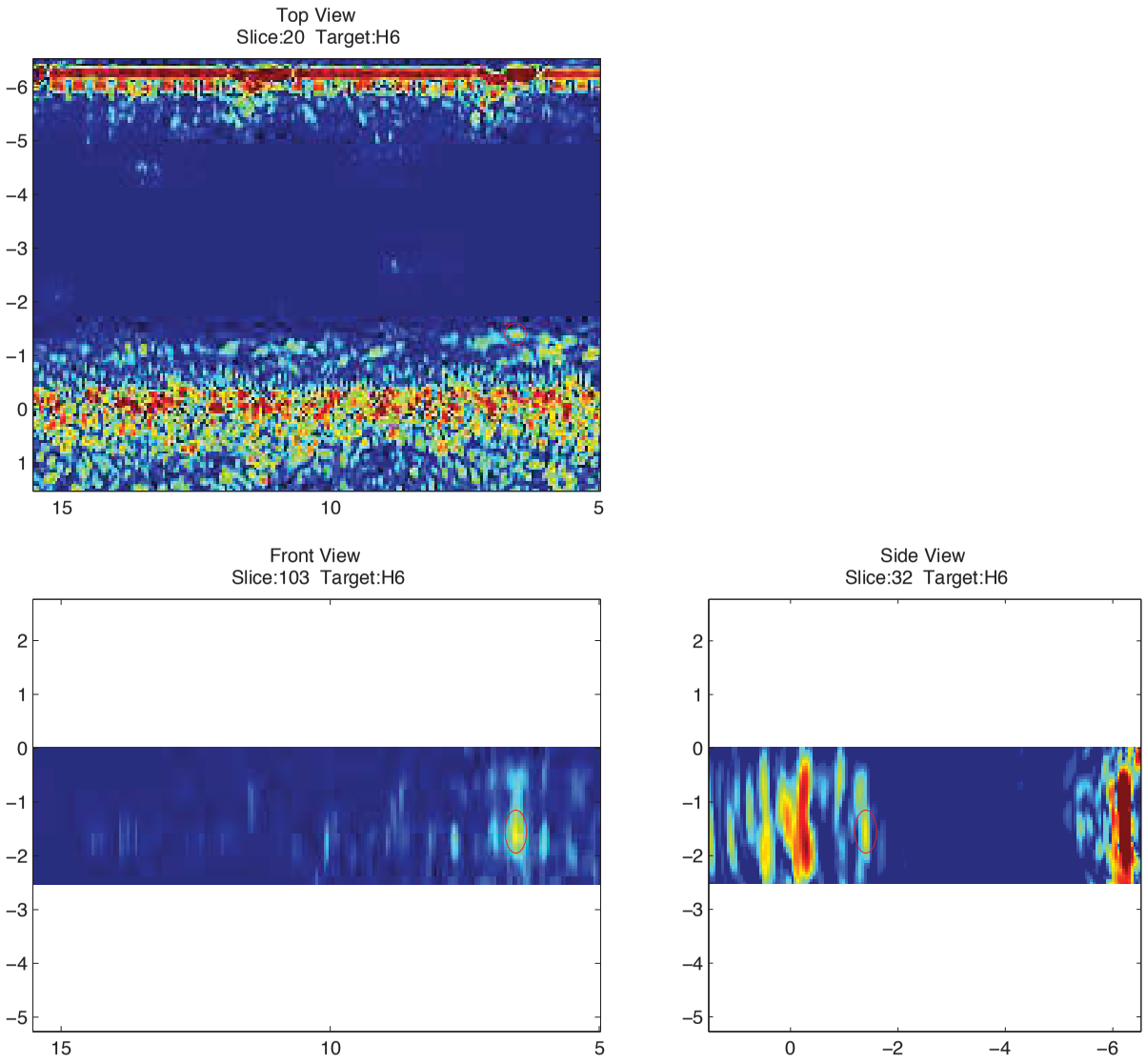


Figure 56: Detection: Target H6, ts_back_s12_01.

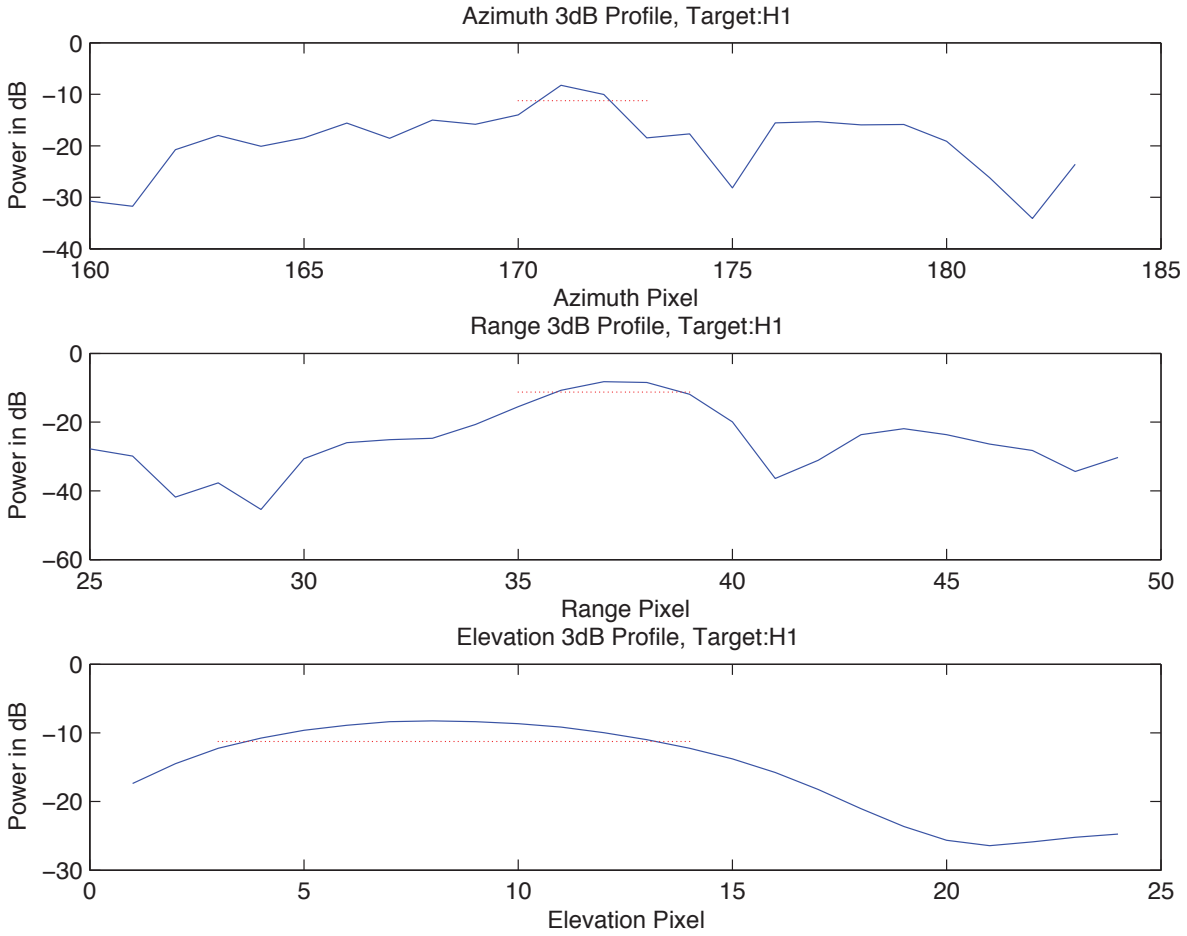


Figure 57: Target H1 3dB Profile, ts_front_s12_01.

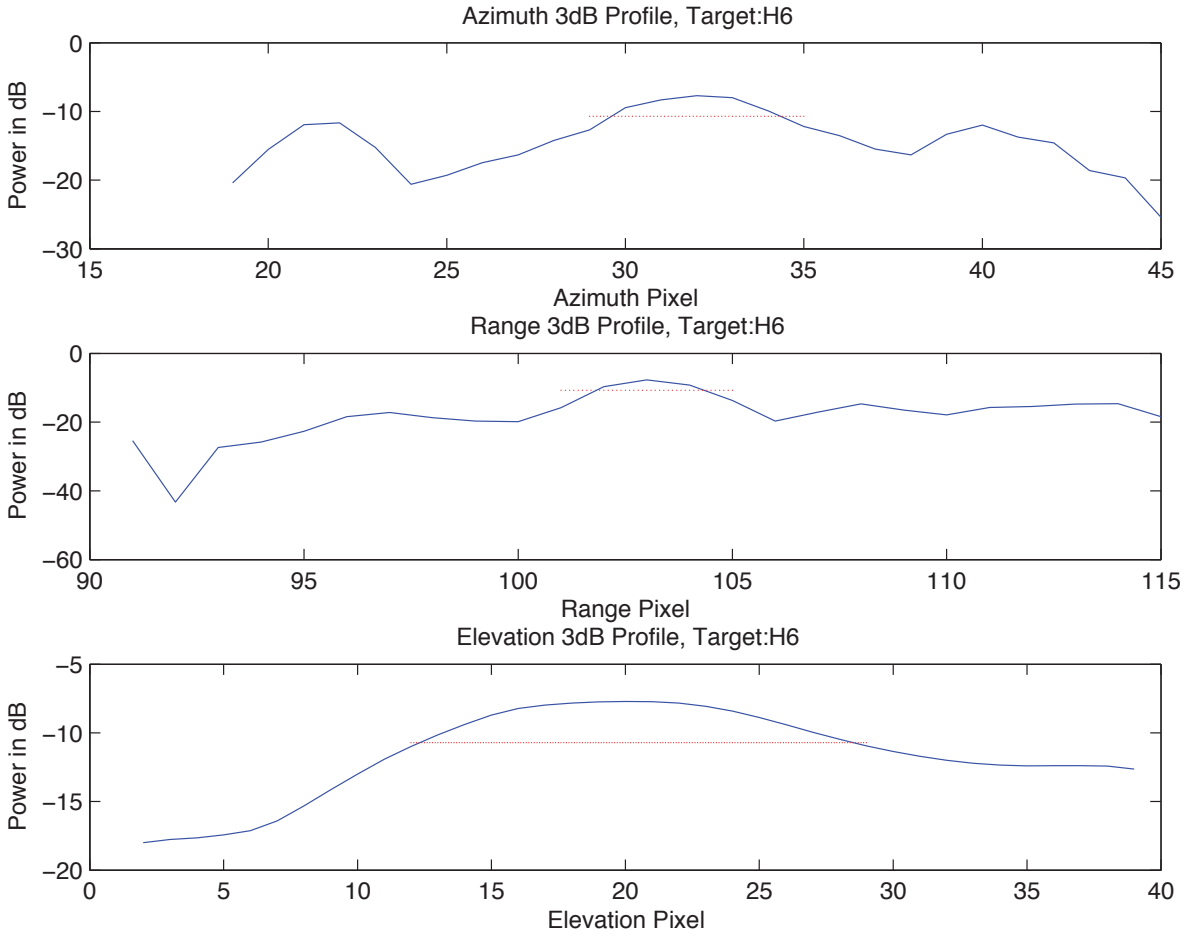


Figure 58: Target H6 3dB Profile, ts_front_s12_01.

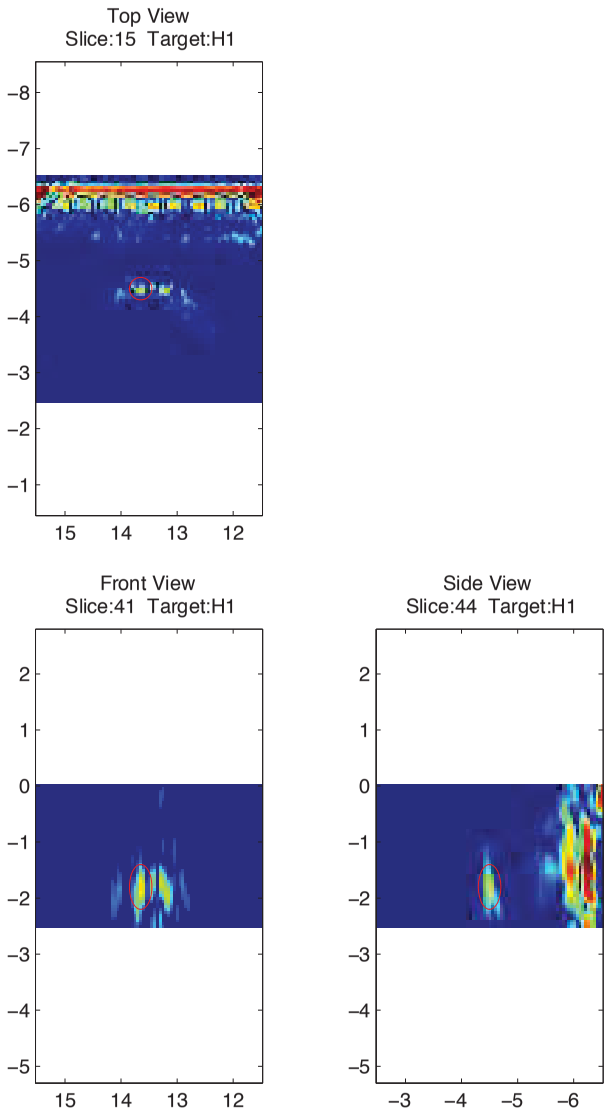


Figure 59: Detection: Target H1, ts_back_s14_01.

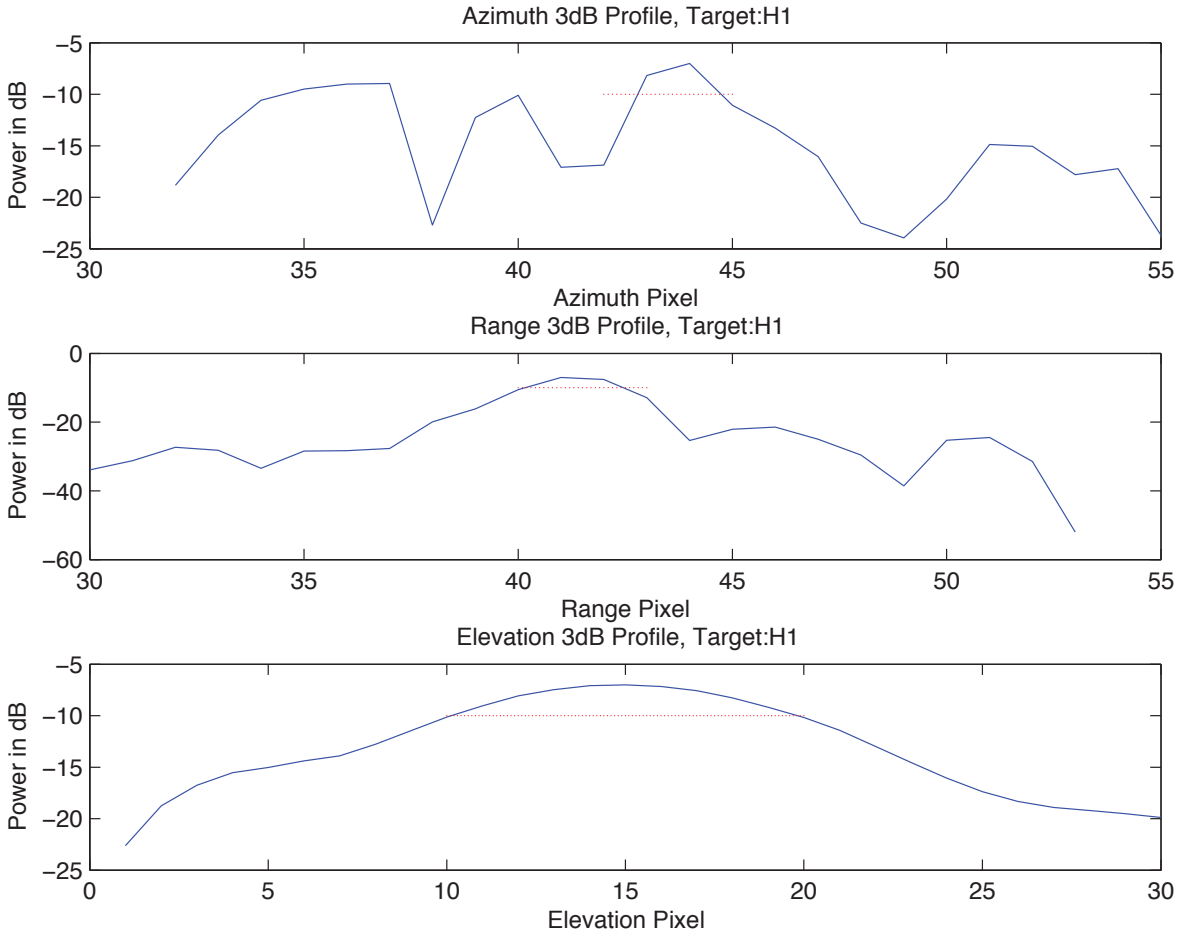


Figure 60: Target H1 3dB Profile, ts_front_s14_01.

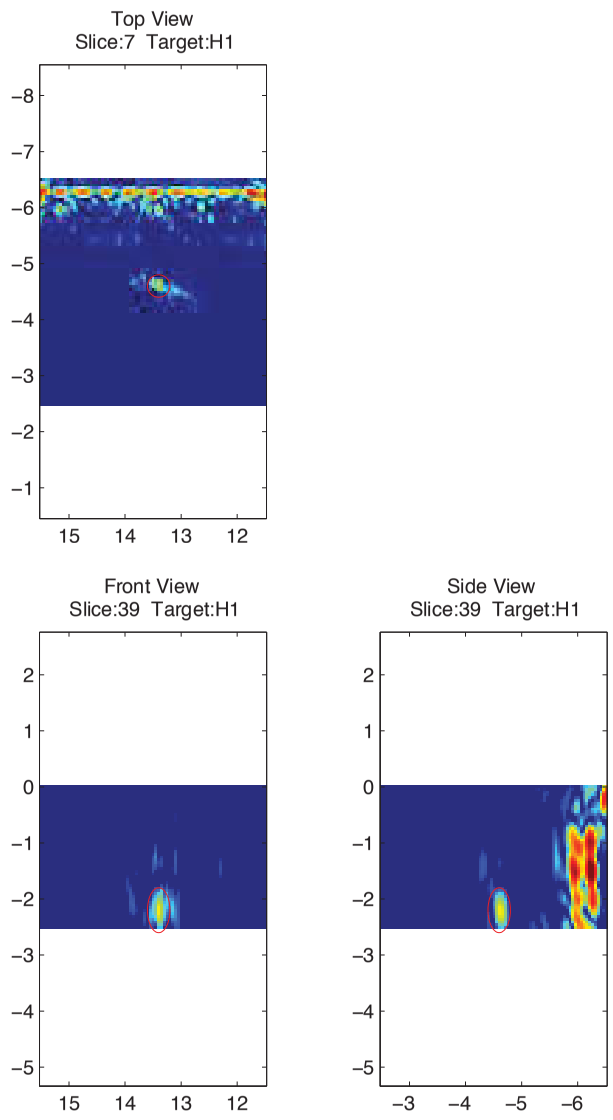


Figure 61: Detection: Target H1, ts_back_s15_01.

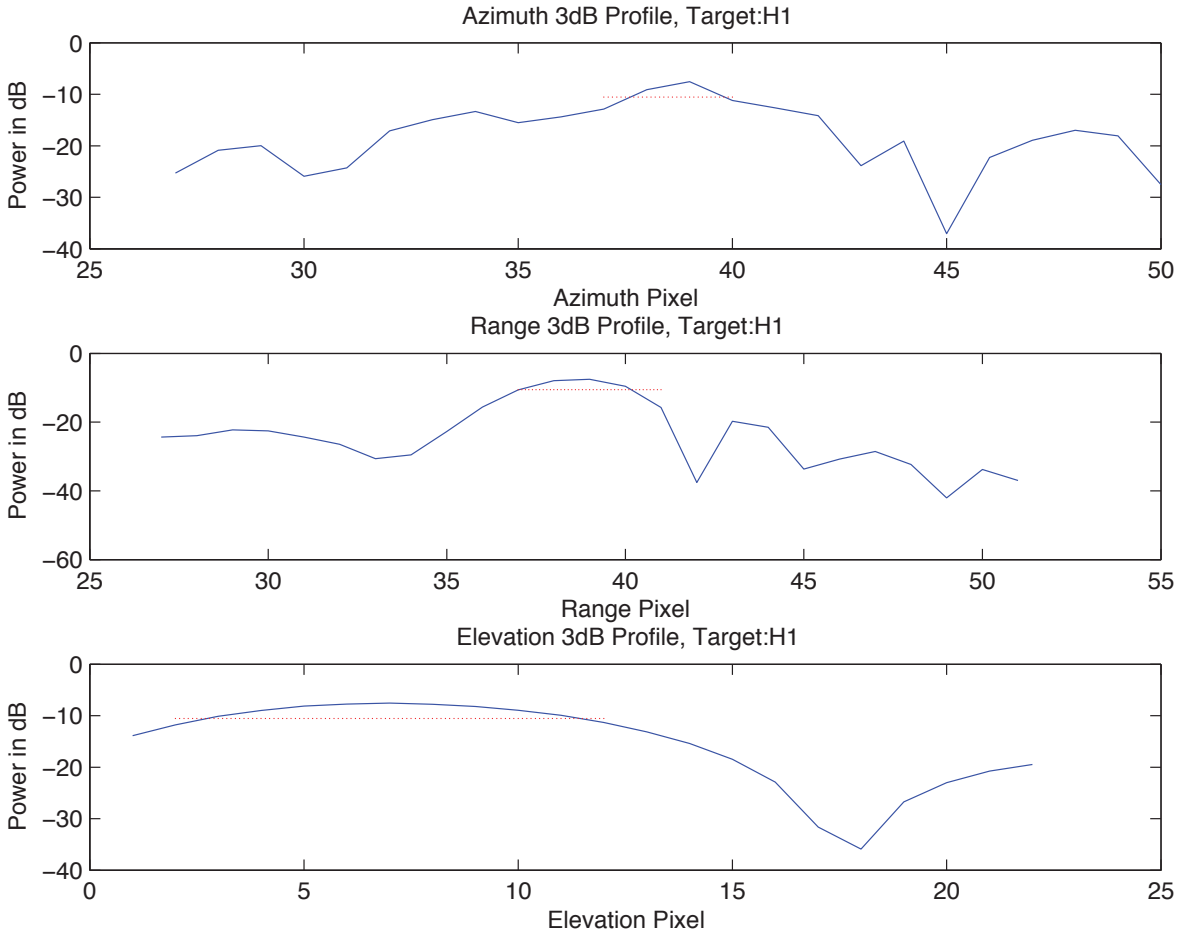


Figure 62: Target H1 3dB Profile, ts_front_s15_01.

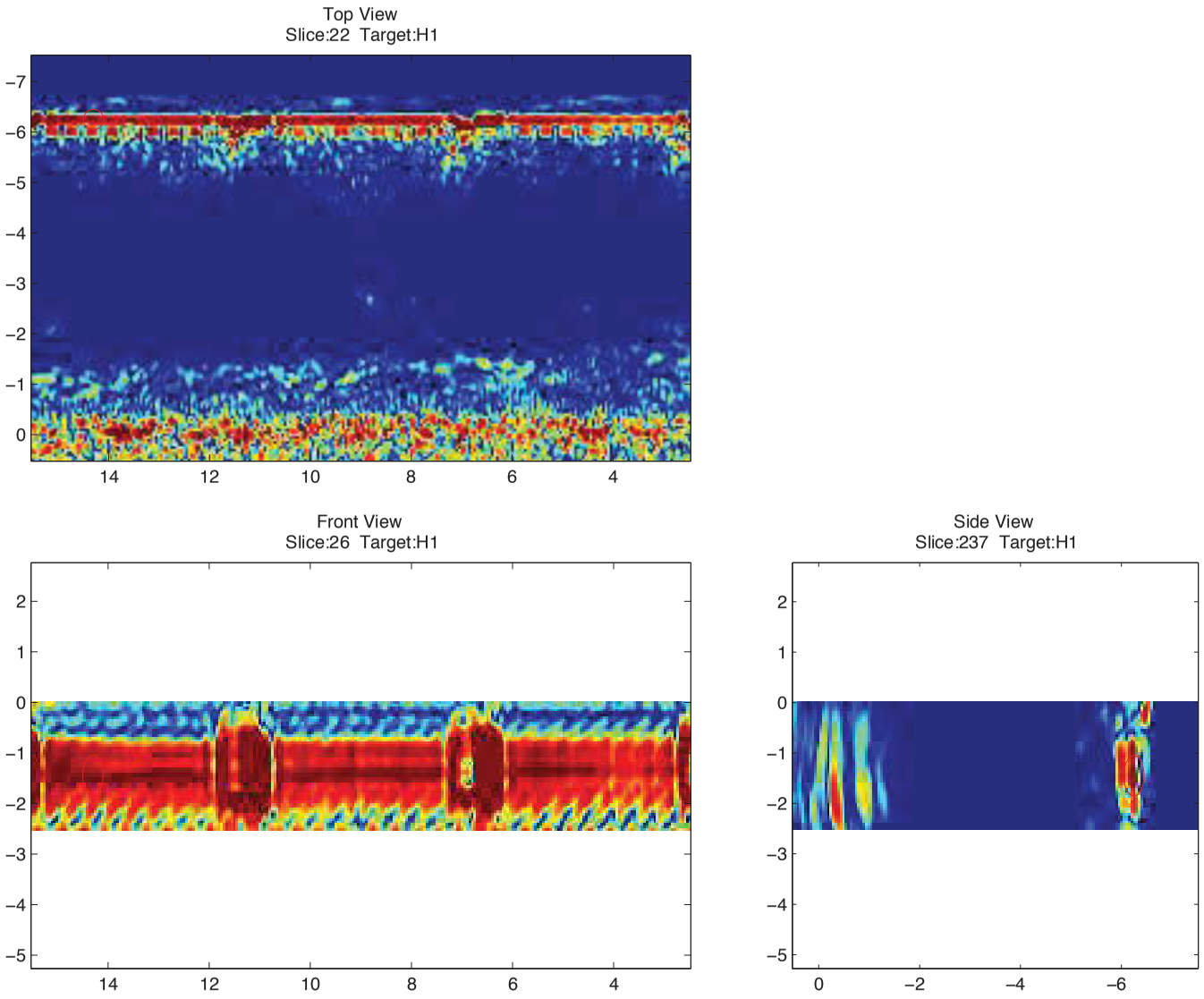


Figure 63: Detection: Target H1, ts_back_s13_01.

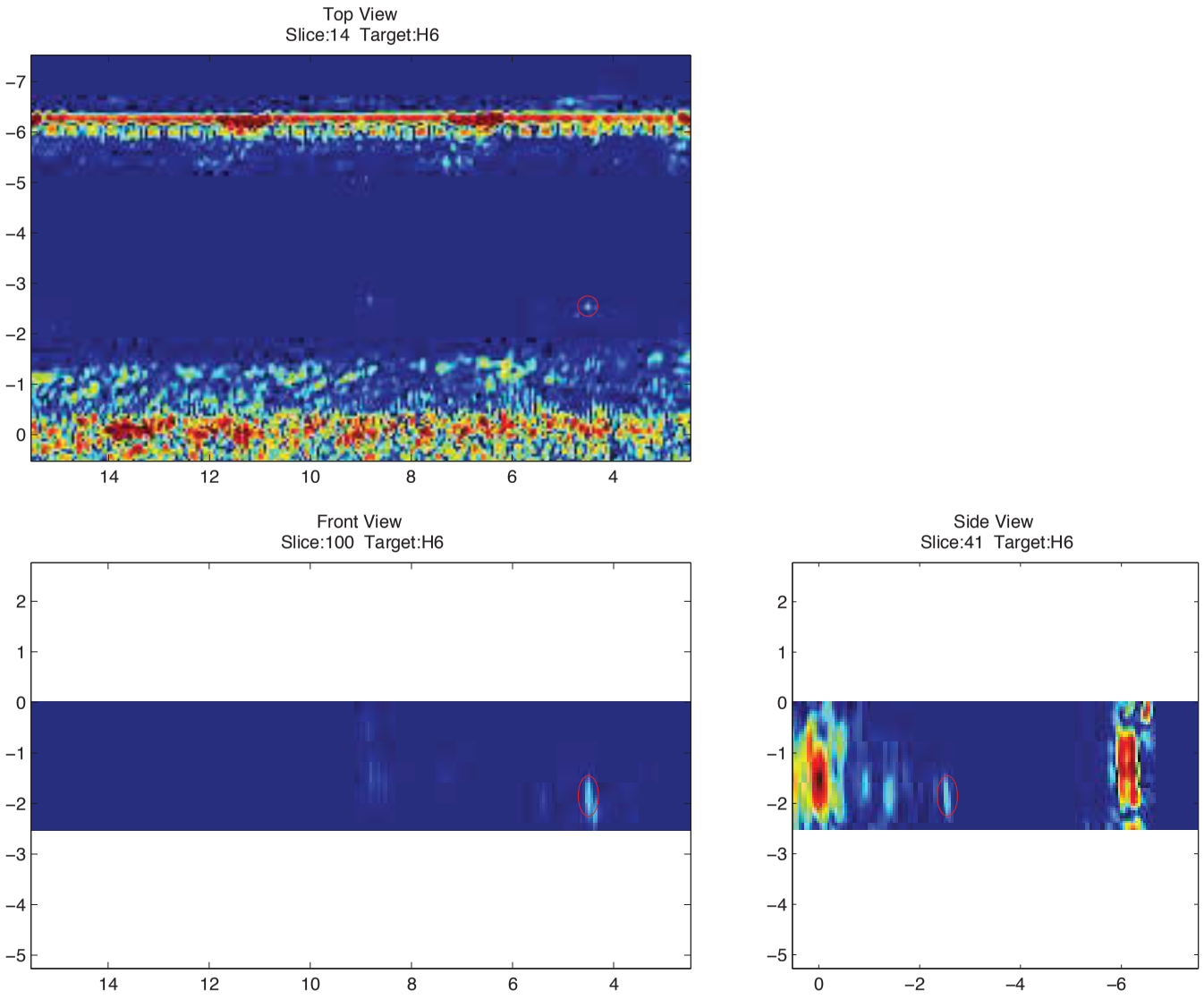


Figure 64: Detection: Target H6, ts_back_s13_01.

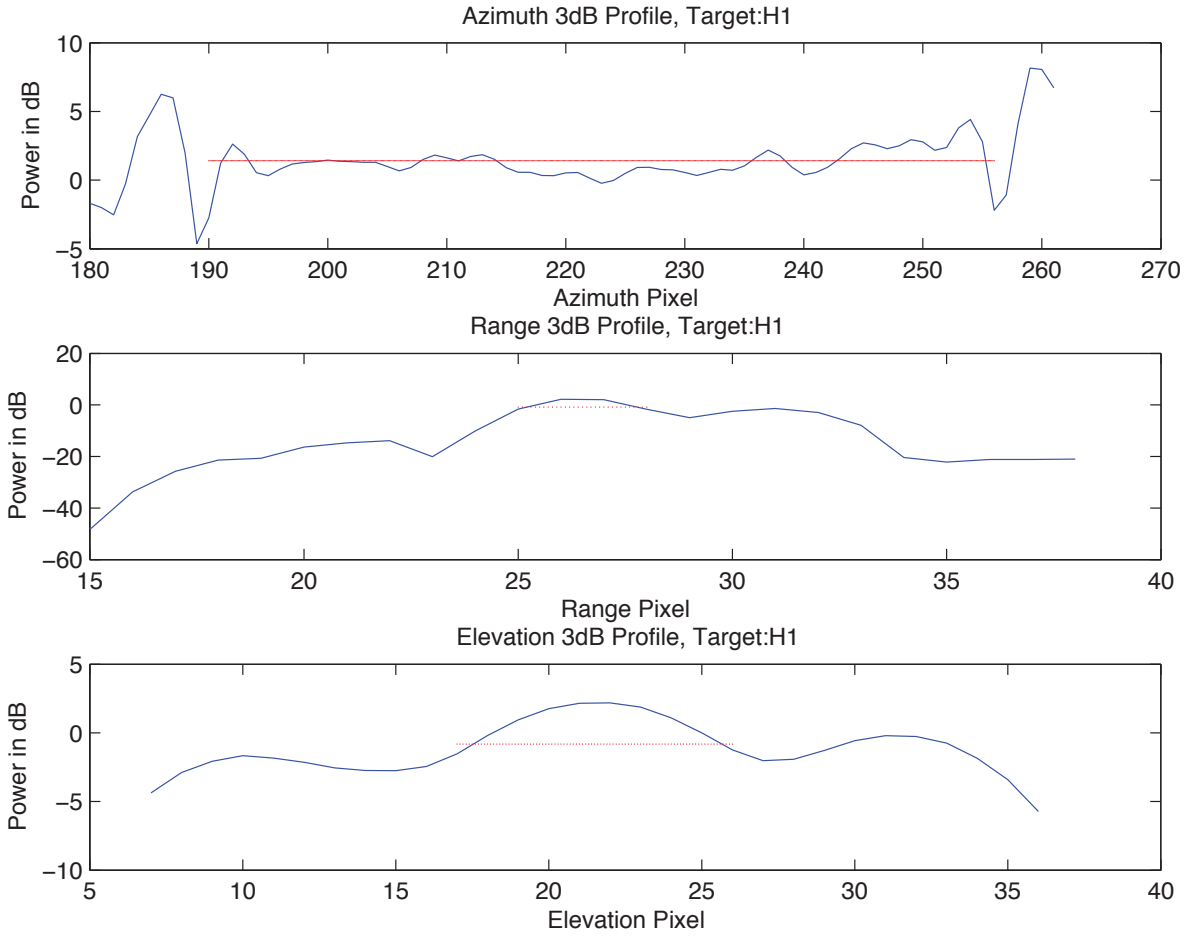


Figure 65: Target H1 3dB Profile, ts_front_s13_01.

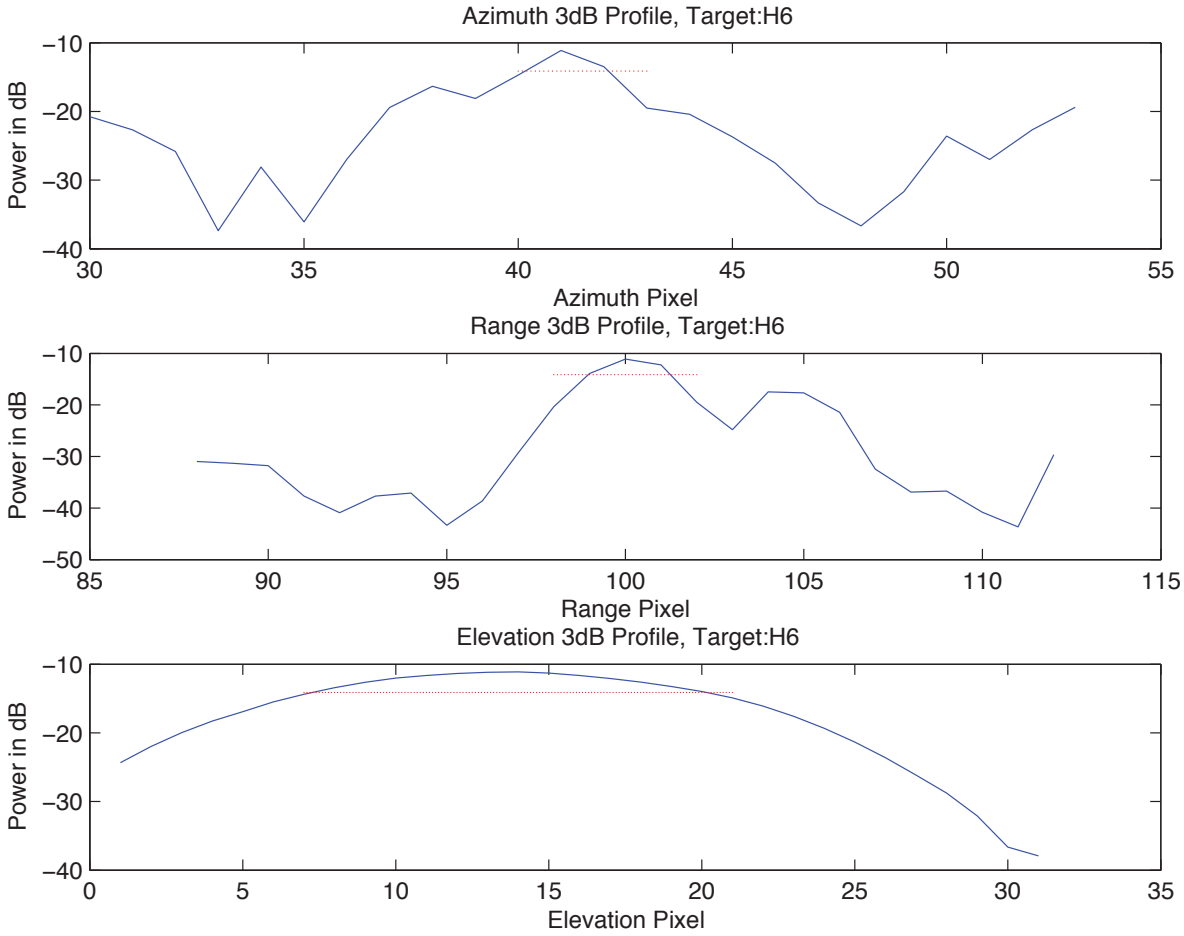


Figure 66: Target H6 3dB Profile, ts_front_s13_01.

3.2 Statistical Analysis on Human Targets

For all the targets that were detected using the maximum pixel intensity method, the maximum intensity, azimuth, range and elevation 3dB width and location offsets (azimuth, range and elevation) from the ground truth positions were found and reported in Table 2. The first column of the table is simply the ground truth location for each target.

3.2.1 Maximum Intensity

Figure 67 shows the value of the maximum intensity for each of the human targets extracted in the previous section.

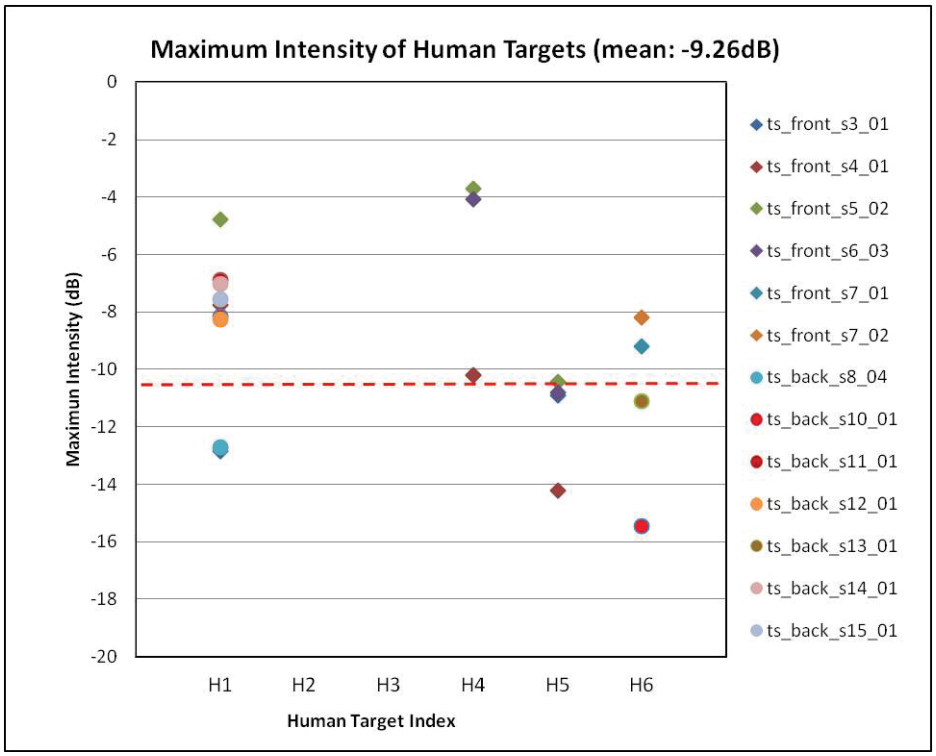


Figure 67: Maximum Intensity of All Human Targets.

3.2.2 Dimension in Azimuth, Range and Elevation Directions

The following figures shows the 3dB width dimension in each of the range, azimuth and elevation direction for all humans extracted from the Troop Shelter data.

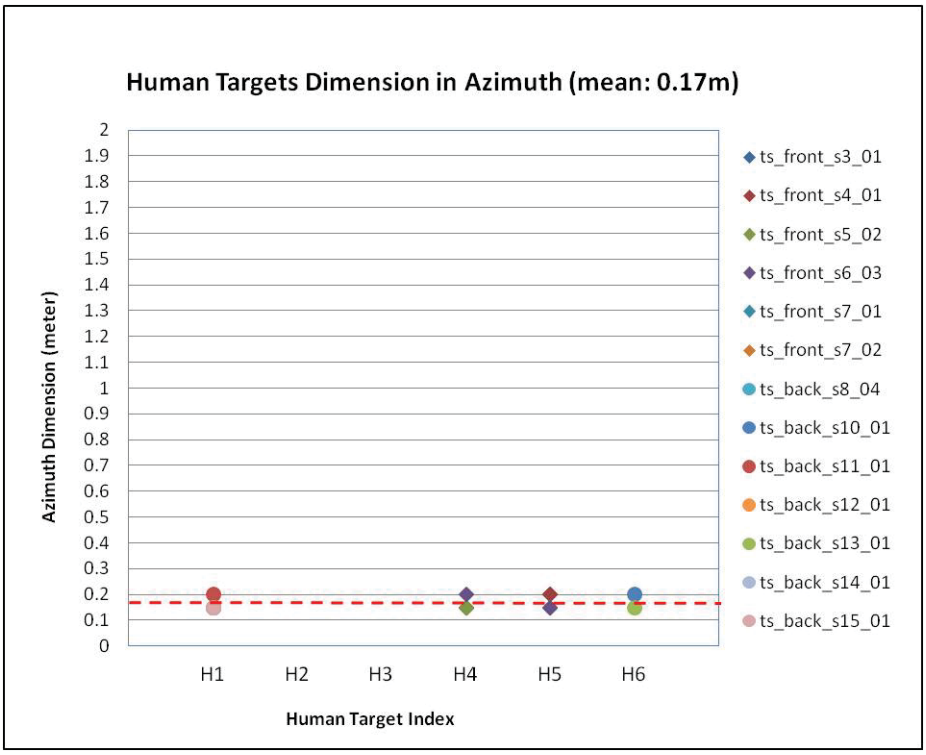


Figure 68: Human Target Dimension in Azimuth.

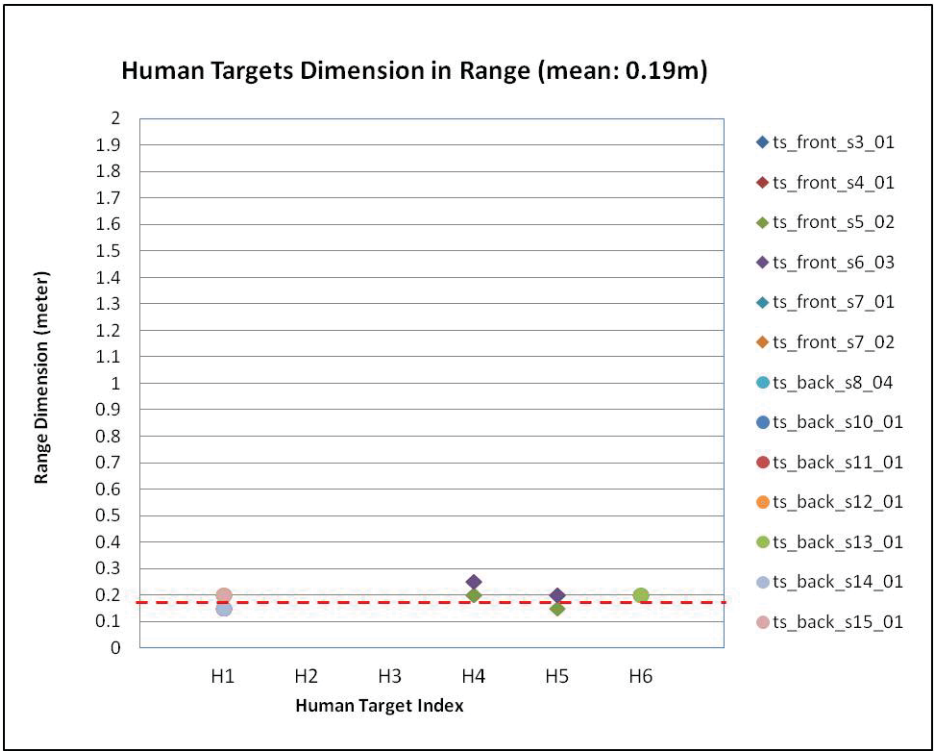


Figure 69: Human Target Dimension in Range.

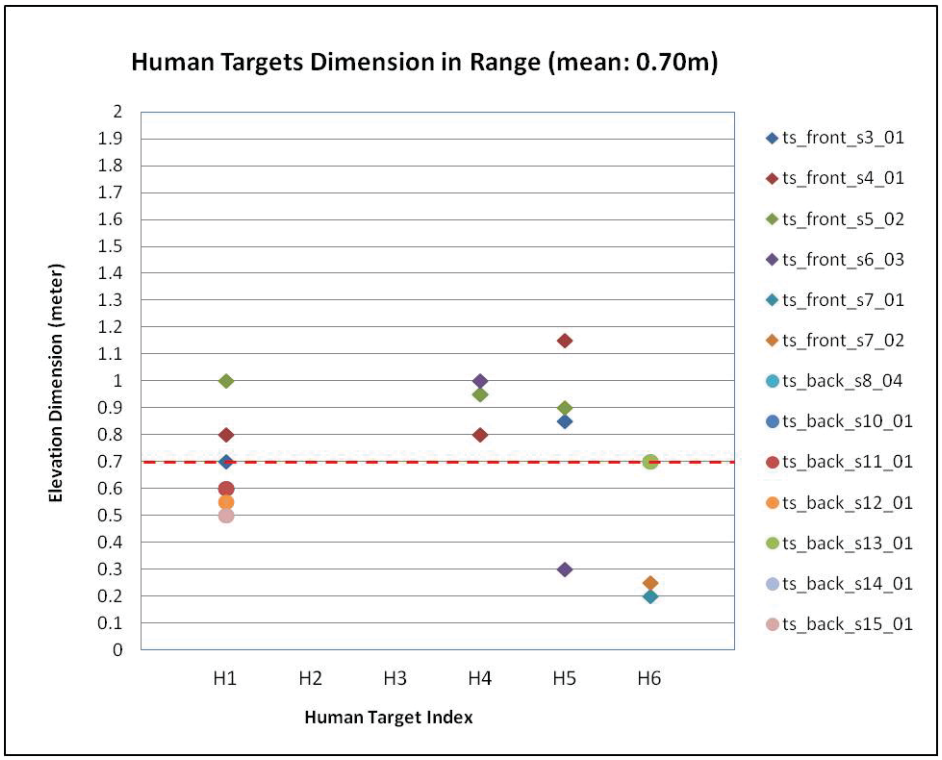


Figure 70: Human Target Dimension in Elevation.

3.2.3 Location Offset in Azimuth, Range and Elevation Directions

This section shows the location offset for each target versus the ground truth position. It is noted that the offsets in elevation demonstrate consistent bias to one direction (to the ground), i.e., the detected location of each target was always below its ground measurements.

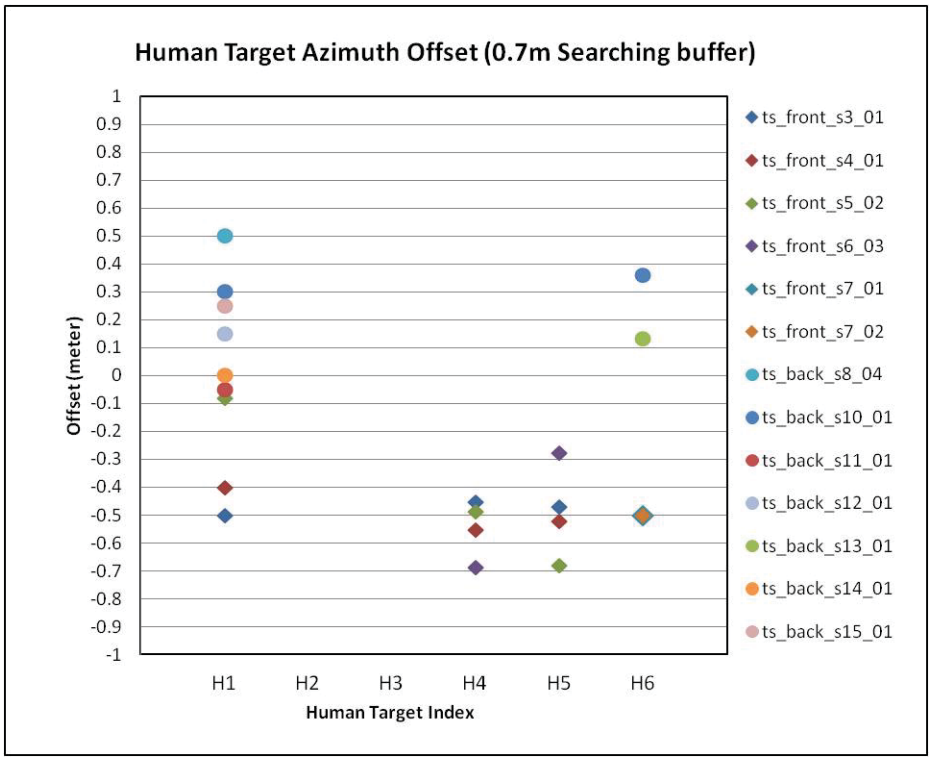


Figure 71: Human Target Azimuth Location Offset.

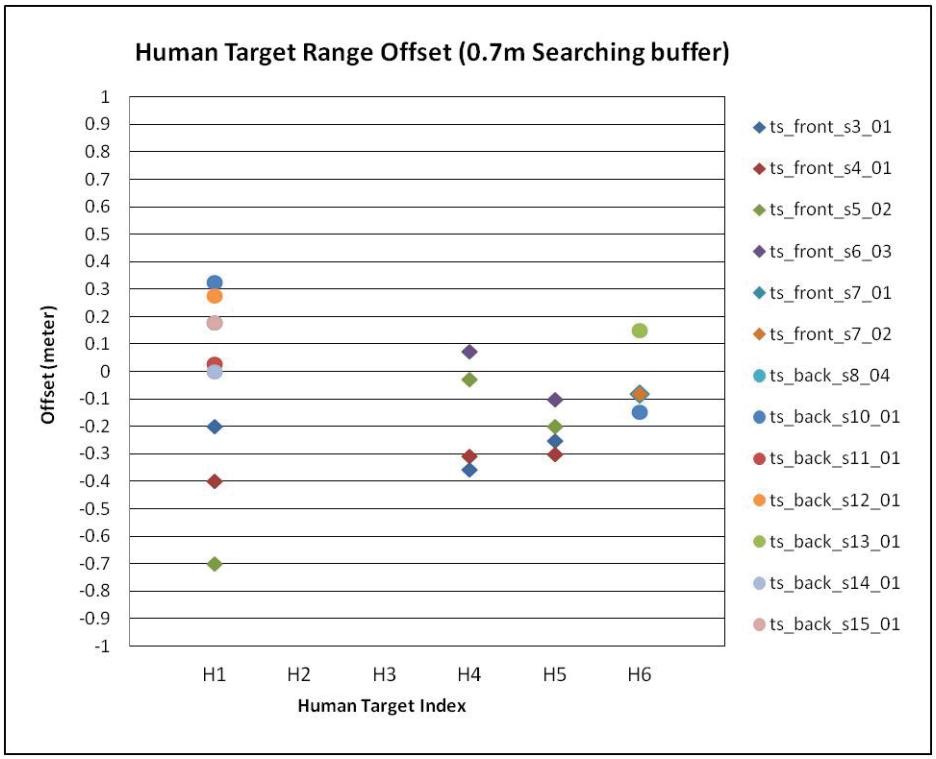


Figure 72: Human Target Range Location Offset.

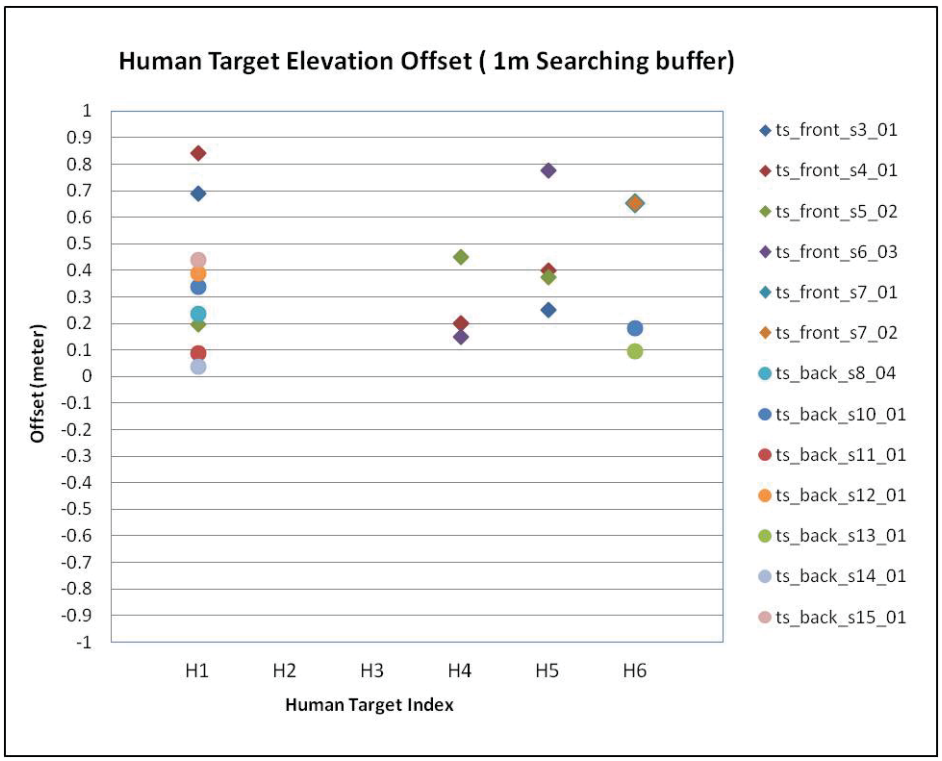


Figure 73: Human Target Elevation Location Offset.

Table 2: Human Target Parameters.

Targets	Ground Location (A,R,E_hip),m	Detected Location (A,R,E_hip),m	Max Intensity dB	3dB Extent (A,R,E_hip),m	Offset (A,R,E_hip),m
ts_front_s3_01					
H1	(10.15,-3.95,-1.81)	(10.65,-3.75,-2.5)	-12.85	(10.6 ∼10.75,-3.8∼-3.65,-2.8∼-2.1)	(-0.5,-0.2,0.69)
H4	(17.199,-1.908,-1.65)	(17.65,-1.55,-1.85)	-10.19	(17.55 ∼17.7,-1.65∼-1.45,-2.25∼-1.3)	(-0.451,-0.358,0.2)
H5	(14.979,-3.95,-1.751)	(15.45,-3.7,-2)	-10.91	(15.35 ∼15.55,-3.8∼-3.6,-2.4∼-1.55)	(-0.471,-0.25,0.249)
ts_front_s4_01					
H1	(10.15,-3.95,-1.81)	(10.55,-3.55,-2.65)	-7.74	(10.45 ∼10.65,-3.65∼-3.45,-2.8∼-2)	(-0.4,-0.4,0.84)
H4	(17.199,-1.908,-1.65)	(17.75,-1.6,-1.85)	-10.20	(17.655 ∼17.8,-1.7∼-1.45,-2.2∼-1.4)	(-0.551,-0.308,0.2)
H5	(14.979,-3.95,-1.751)	(15.5,-3.65,-2.15)	-14.21	(15.4 ∼15.6,-3.75∼-3.55,-2.8∼-1.65)	(-0.521,-0.3,0.399)
ts_front_s5_02					
H1	(15.02,-1.2,-1.754)	(15.1,-0.5,-1.95)	-4.78	(15 ∼15.15,-0.55∼-0.35,-2.35∼-1.35)	(-0.08,-0.7,0.196)
H4	(17.114,-1.178,-1.65)	(17.6,-1.15,-2.1)	-3.72	(17.5 ∼17.65,-1.25∼-1.05,-2.5∼-1.55)	(-0.486,-0.028,0.45)
H5	(16.072,-1.95,-1.726)	(16.75,-1.75,-2.1)	-10.44	(16.65 ∼16.8,-1.85∼-1.7,-2.5∼-1.6)	(-0.678,-0.2,0.374)
ts_front_s6_03					
H1	(15.02,-1.2,-1.754)	(15.05,-0.5,-1.95)	-3.3	(15 ∼15.1,-0.55∼-0.35,-2.35∼-1.5)	(-0.03,-0.7,0.196)
H4	(17.114,-1.178,-1.65)	(17.8,-1.25,-1.8)	-4.01	(17.7 ∼17.9,-1.4∼-1.15,-2.35∼-1.35)	(-0.686,0.072,0.15)
H5	(16.072,-1.95,-1.726)	(16.35,-1.85,-2.5)	-10.82	(16.25 ∼16.4,-1.95∼-1.75,-2.5∼-2.2)	(-0.278,-0.1,0.774)
ts_front_s7_01					
H2	(16.68,5.745,-1.836)	(16.5,-6.05,-1.55)	1.0	(16.4 ∼16.6,-6.15∼-5.95,-2.05∼-0.95)	(0.18,0.305,-0.286)
H3	(15.122,-5.502,-1.948)	(15.35,-6.05,-1.6)	0.51	(15.25 ∼15.4,-6.2∼-5.95,-2.15∼-0.95)	(-0.228,0.548,-0.348)
H6	(16.8,-1.53,-1.846)	(17.3,-1.45,-2.5)	-9.20	(17.2 ∼17.35,-1.6∼-1.4,-2.5∼-2.3)	(-0.5,-0.08,0.654)
ts_front_s7_02					
H2	(16.68,-5.745,-1.836)	(17.15,-6,-1.55)	-8.19	(17.05 ∼17.25,-6.1∼-5.9,-2.1∼-0.95)	(-0.47,0.255,-0.286)
H3	(15.122,-5.502,-1.948)	(15.35,-6.05,-1.6)	0.68	(15.25 ∼15.4,-6.15∼-5.95,-2.15∼-0.95)	(-0.228,0.548,-0.348)
H6	(16.8,-1.53,-1.846)	(17.3,-1.45,-2.5)	0.22	(17.2 ∼17.4,-1.55∼-1.35,-2.5∼-2.25)	(-0.5,-0.08,0.654)
ts_back_s8_04					
H1	(13.651,-4.423,-1.763)	(13.15,-4.6,-2)	-12.73	(13.05 ∼13.2,-4.7∼-4.5,-2.3∼-1.7)	(0.501,0.177,0.237)
H6	(8,-4.795,-1.797)	(7.3,-5.4,-1.45)	-7.11	(7.15 ∼7.35,-5.5∼-5.25,-1.8∼-1.1)	(0.7,0.605,-0.347)
ts_back_s10_01					
H1	(13.651,-4.423,-1.763)	(13.35,-4.75,-2.1)	-8.16	(13.3 ∼13.45,-4.85∼-4.7,-2.45∼-1.85)	(0.301,0.327,0.337)
H6	(1.212,-3.596,-1.769)	(0.75,-3.45,-1.95)	-15.4	(0.75 ∼0.95,-3.55∼-3.35,-2.25∼-1.55)	(0.362,-0.146,0.181)
ts_back_s11_01					
H1	(13.651,-4.423,-1.763)	(13.7,-4.45,-1.85)	-6.89	(13.6 ∼13.8,-4.55∼-4.4,-2.2∼-1.6)	(-0.049,0.027,0.087)

Continued on next page

Table 2 – continued from previous page

Targets	Ground Location (A,R,E_hip),m	Detected Location (A,R,E_hip),m	Max Intensity dB	3dB Extent (A,R,E_hip),m	Offset (A,R,E_hip),m
H6	(1.012,-0.791,-1.782)	(1.6,-0.25,-1.6)	-2.04	(1.5 ∼1.7,-0.35∼-0.15,-1.95∼-0.25)	(-0.588,-0.541,-0.182)
ts_back_s12_01					
H1	(13.651,-4.423,-1.763)	(13.5,-4.7,-2.15)	-8.26	(13.45 ∼13.6,-4.8∼-4.6,-2.4∼-1.85)	(0.151,0.277,0.387)
H6	(6.911,-1.506,-1.803)	(6.55,-1.4,-1.55)	-7.71	(6.4 ∼6.7,-1.5∼-1.3,-1.95∼-1.1)	(0.361,-0.106,-0.253)
ts_back_s14_01					
H1	(13.651 -4.423 -1.763)	(13.65,-4.5,-1.8)	-7.01	(13.35 ∼13.7,-4.55∼-4.4,-2.05∼-1.55)	(0.001,0.077,0.037)
ts_back_s15_01					
H1	(13.651 -4.423 -1.763)	(13.4,-4.6,-2.2)	-7.56	(13.3 ∼13.45,-4.7∼-4.5,-2.45∼-1.95)	(0.251,0.177,0.437)
ts_back_s13_01					
H1	(13.651,5.594,2.142)	(14.3,-6.25,-1.45)	2.18	(11.95 ∼15.25,-6.3∼-6.15,-1.7∼-1.25)	(-0.649,0.656,-0.692)
H6	(4.632,2.398,1.756)	(4.5,-2.55,-1.85)	-11.16	(4.45 ∼4.6,-2.65∼-2.45,-2.2∼-1.5)	(0.132,0.152,0.094)

3.3 Some observations on Human Target Detection Results

Figure 74 displays the detected and enlarged images of Target H1 in six different acquisitions. The ground locations of H1 in the six acquisitions are the same. However, the postures of H1 in each image are varied. In the first two images ts_back_s11_01 and ts_back_s14_01, H1 was holding an AK47-v1 riffle vertically; in the next two images ts_back_s12_01 and ts_back_s15_01, H1 was holding AK47-v1 at an angle; H1 was standing alone toward the back of the building ts_back_s8_04; and H1 was standing alone sideways in ts_back_s10_01.

A cross-cut display of each of these acquisitions shows that the return signature for H1 is different in each of these scenarios. In the first group, the target was holding an AK47-v1 riffle vertically and the three views of the target in the two images look similar showing a somewhat horizontal pattern analogous with some type of object held across the body. The target signatures also look similar in the second group, showing a slanted pattern analogous to holding an object at an angle. Finally, when H1 is standing alone, the image intensity is decreased and no such horizontal or slanted patterns are visible.

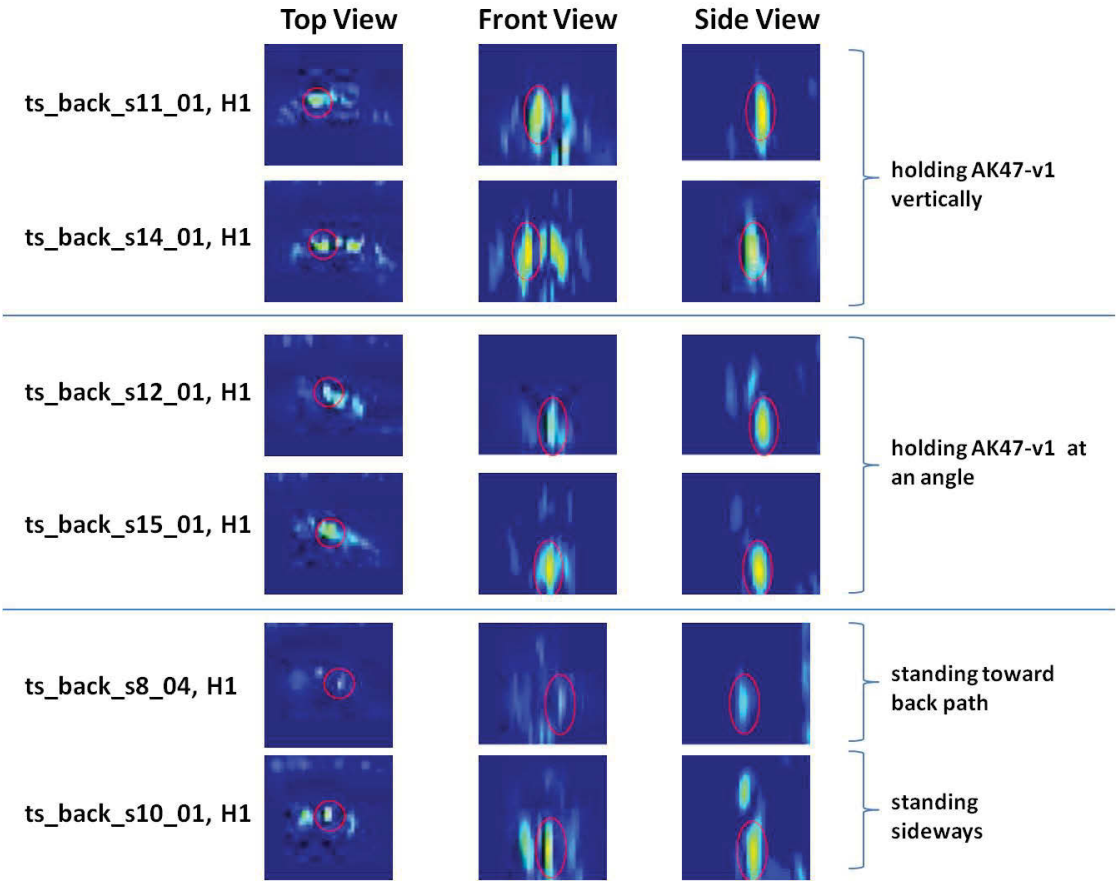


Figure 74: Target H1 in different acquisitions with different setting.

Due to the poor detection of targets near the wall, an experiment was conducted by comparing the difference between the target detection using the original and a filtered version of

the SAR images. An obvious fact about the through the wall data is that the walls have the strongest return. To remove the returned signal from the wall, a high pass filter was found to be an useful tool. In this experiment, a high pass filter was applied to the frequency response of the SAR image. First, the MATLAB function remez.m is used to generate a 1-D filter by giving the frequency band edges F=[f1 f2 f3 f4] and the desired amplitude response A=[a1 a2 a3 a4] of each band. The frequency band edges are the normalized value between 0 to 1. 1 corresponds to the Nyquist frequency or half the sampling frequency of the signal. The desired amplitude response is also between 0 to 1 which specifies the desired amplitude of the frequency response of the resultant filter. The parameters used in this experiment is F=[0 0.01 0.05 1] and A=[0 0 1 1]. Then the MATLAB function ftrans2.m is used to produce a 2-D filter corresponding to the 1-D filter. The filtered image was generated by apply the 2-D filter to the 2-D SAR frequency image generated using fft2.m. Figure 75 displays the original and the filtered images using the 2-D filter, the detected locations of the three targets are marked by the red circles. The same scaling level (in dB) was applied to all the displays in this section. Comparing the original and filtered images the clutter signal from the wall was reduced.

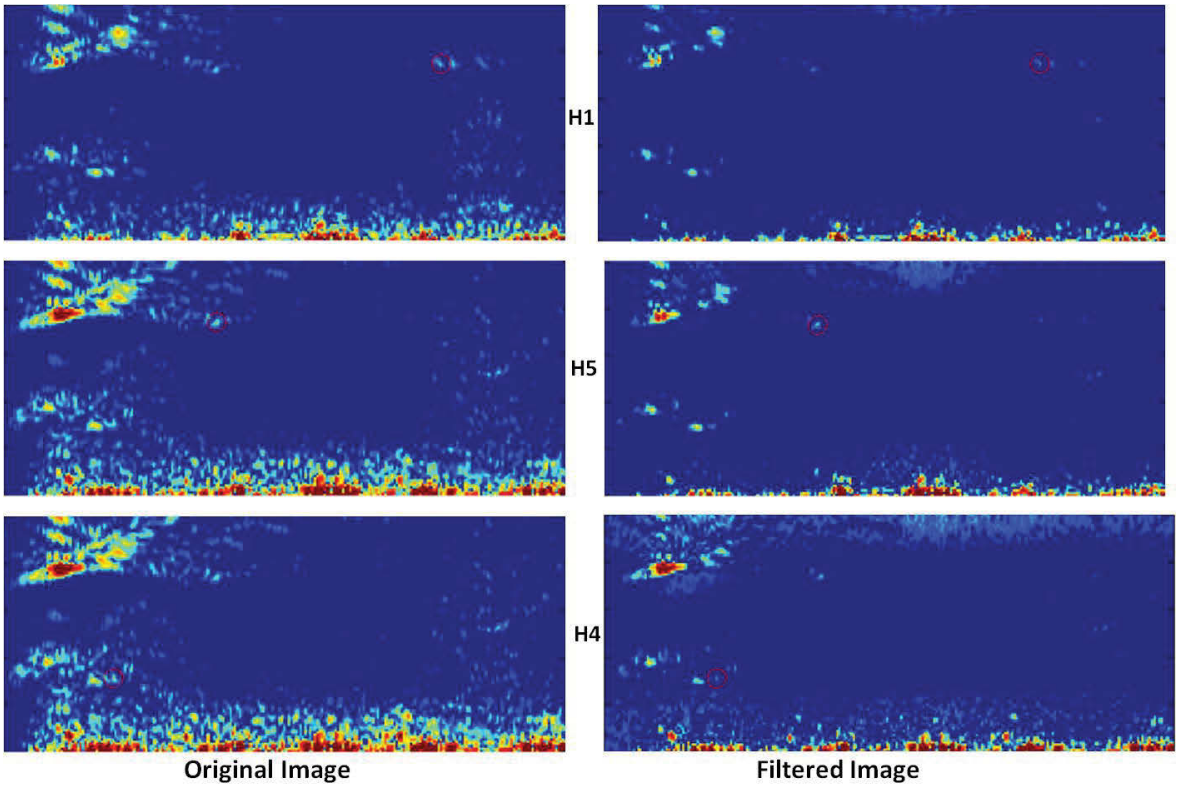


Figure 75: Human target detection using original and filtered image, ts_front_s3_01.

Figure 76 shows another pair of detection results between the original and filtered images. Target H1 was located very close to the wall and is recognized as a difficult target. In this case, the target in the filtered image could be more easily recognized.

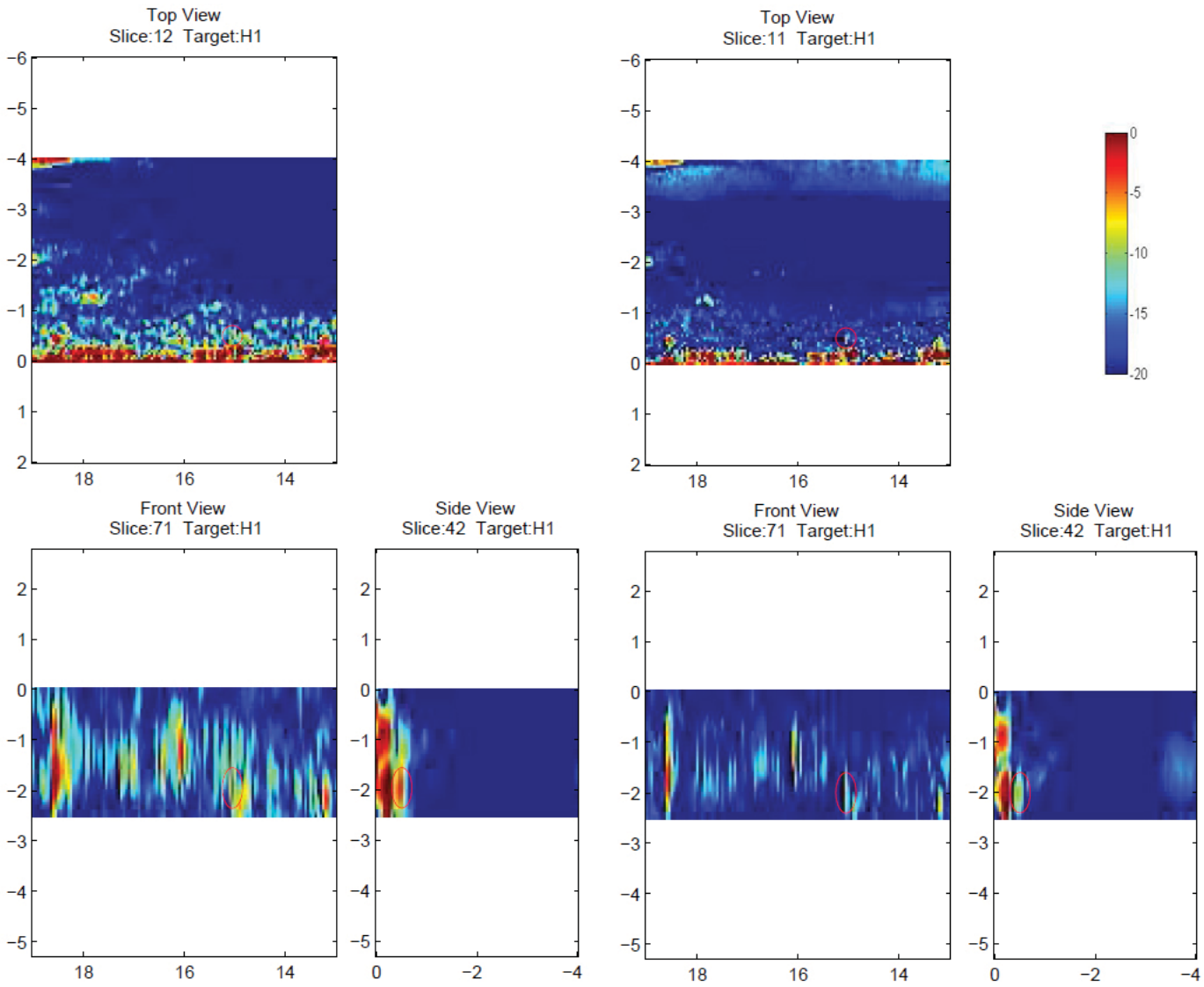


Figure 76: Detection: Target H1, ts_back_s6_01, left: orginal image, right: filtered image

3.4 Detection Result Summary

This section examined the possibility and results of trying to detect human targets in high resolution through the wall data. One of the main results is that the detection is highly dependent on the location of the target with respect to the wall. This is due to the high backscatter from the wall, which hides the expected high return from the human target. In this case, the signal reflected back from the targets is weaker than the signal returned from the wall, the detection algorithm based on the target and background intensities will not work.

Simple image filtering techiques were used to show the potential of reducing the signal returned from the wall and thus help any intensity-based detection algorithm.

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