In-River Accessory Equipment For Fixed-Location Hydroacoustic Systems

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by

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ABSTRACT

Enzenhofer, H. and G. Cronkite. 1998. In-river accessory equipment for fixed-location hydroacoustic systems. Can. Tech. Rep. Fish. Aquat. Sci. 2250: 24 p.

This report describes the design, construction and use of the in-river equipment that aids the operation of a fixed-location hydroacoustic system located near the confluence of Qualark Creek with the Fraser River near Yale, British Columbia, Canada. The equipment can be easily deployed by one person and is designed to withstand the forces created by strong current flow. This equipment is essential to the operation of the hydroacoustic system to maintain accurate and defensible enumeration of migrating salmon. Fish migrating in rivers with higher current flow tend to be shore and bottom oriented and require a shore based system aimed close to the river bottom and perpendicular to the flow. Specialised equipment must be used to move fish away from the shore so they can be counted. The operator must be able to aim the transducer precisely to ensure that the beam is close to the river bottom and covers the volume where fish passage occurs. The beam aim must be repeatable after moving the equipment. Since the detection characteristics vary between transducers, the ability to detect a target should be determined for each transducer in the environment where it is used.

RÉSUMÉ

Enzenhofer, H. and G. Cronkite. 1998. In-river accessory equipment for fixed-location hydroacoustic systems. Can. Tech. Rep. Fish. Aquat. Sci. 2250: 24 p.

Ce rapport décrit la conception, la construction et l'utilisation de l'équipement placé en rivière qui aide à exploiter un système hydroacoustique fixe situé près du confluent du ruisseau Qualark et du Fraser, près de Yale, en Colombie-Britannique (Canada). Cet équipement peut facilement être déployé par une personne seule et est conçu pour résister aux forces engendrées par l'intensité du courant. Cet équipement est essentiel au fonctionnement du système hydroacoustique pour établir un dénombrement précis et défendable des saumons migrateurs. Les poissons migrant dans les cours d'eau à débit élevé ont tendance à nager près de la rive et du fond; il faut donc disposer d'un système installé sur la rive, ciblé à proximité du fond du cours d'eau et perpendiculairement à l'écoulement. On doit utiliser du matériel spécialisé pour éloigner les poissons de la rive afin de pouvoir les compter. L'utilisateur doit pouvoir orienter le transducteur avec précision pour que le faisceau soit proche du fond et couvre le volume dans lequel passent les poissons. L'orientation du faisceau doit être répétable après déplacement de l'équipement. Étant donné que les caractéristiques de détection varient d'un transducteur à l'autre, la capacité de détecter une cible devrait être établie pour chaque transducteur dans l'environnement où il sera utilisé.

INTRODUCTION

Fixed-location hydroacoustic systems are used in the riverine environment to estimate fish population sizes (Gaudet 1990; Burwen et al. 1995; Daum and Osborne 1995). When these hydroacoustic systems use split-beam technology coupled with an automated target tracking algorithm, the resulting measure of fish swim speed, acoustic size, and direction of travel can provide reliable and timely estimates of fish passage (Ehrenberg and Torkelson 1996).

Often hydroacoustic systems must be used in rivers with high flow rates or fluctuating water levels which can make equipment deployment difficult. Fish migrating in rivers with higher current flow tend to be shore and bottom oriented and require a shore based acoustic transducer aimed close to the river bottom and perpendicular to the flow to detect their passage. In order to monitor fish passage in these conditions, several operational considerations must be addressed. First, the fish must be moved away from the shore and transducer so they will pass through the ensonified region beyond the near field of the acoustic beam. Second, the operator must be able to aim the transducer precisely to ensure that the beam is close to the river bottom and covers the volume where fish passage occurs. Third, the beam aim configuration must also be repeatable during equipment moves. Finally, the selection of an appropriate transducer should ensure that the area being ensonified is appropriate for the population being studied. If fish passage occurs near the river bottom, a narrow elliptical transducer is more effective than a wide beam circular transducer (Enzenhofer et al. 1998). Since the detection characteristics vary between transducers, the ability to detect a target should be determined for each transducer in the environment where it is used.

This report describes the design, construction and use of in-river equipment that aids the operation of a fixed location hydroacoustic system. The equipment is designed to withstand the forces created by high current flow and can be easily deployed by one person. The equipment consists of: an automated fish deflection weir, an adjustable reference target frame, and a transducer-to-weir bracket. Use of the equipment provides the ability to maintain a repeatable and precise aim of the acoustic beam.

We describe the ideal substrate conditions for deploying fixed location hydroacoustic systems as well as some modifications to the river bed which can potentially make a poor site favourable. An example of a beam map procedure for a 200kHz circular 8° transducer using a target of similar acoustic properties as an adult salmon is described in detail. All equipment design and beam geometry experimentation was performed at the Qualark Creek hydroacoustic facility in the Fraser River near Yale, British Columbia, Canada.

EQUIPMENT DESCRIPTION

A three dimensional view of the complete in-river accessory equipment shown in Fig. 1 includes a free standing track mounted fish deflection weir, an adjustable reference target frame, and an adjustable transducer-to-weir bracket. The equipment can be operated by one person and allows complete reconfiguration, including re-aiming the acoustic transducer, within

20 minutes. The equipment had to be strong enough to withstand heavy current flows which existed at our hydroacoustic facility at Qualark Creek.

A track mounted deflection weir immediately downstream from the transducer forces fish offshore to pass through the beam where the probability of tracking is greater. A reference target frame, with an attached acoustic target, operated in the far field of the acoustic beam can be used to aim the transducer and perform *in situ* beam geometry experiments. An adjustable transducer-to-weir bracket which is attached to the deflection weir and holds the transducer assemblage is able to maintain a repeatable beam configuration during equipment moves.

RIVER BANK AND BOTTOM PROFILE

When considering a site for the deployment of hydroacoustic gear and installation of the in-river equipment, several criteria need to be considered: 1) The river reach should be straight rather than meandering. A meandering reach tends to exhibit back-eddies and pools which collect debris and in which fish may mill. 2) Ideally, the river bank profile should be planar rather than shelved and maintain the same degree of slope for the entire range to be acoustically monitored during the fish migration period. A shelved bank profile creates zones that are inaccessible to the acoustic beam (Fig. 2). A planar surface provides a flat bed to mount the tracks for the fish deflection weir system. 3) The substrate should be moderate in size and free of any large boulders, which can interfere with the path of the acoustic beam and can create turbulent flow.

Often a potentially poor site can be made favourable through modifications to the river bank during low water periods. Although initial construction and development of a hydroacoustic site may seem onerous, the added improvement in acoustic detection of fish is worth the effort. Bank modifications could be as simple as removal of large boulders either by hand, machine or by blasting. They can also be on a large scale in which the original bottom is stripped from the region where echosounding occurs. The new bottom is flattened, partially filled with 5 cm crushed rock, and sandbags are laid down to form a smooth planar ramp. First, the addition of a sandbag ramp will simplify the installation of the deflection weir track system and ensure that the tracks run true. If undulations were present in the track, movement of the weir carriages could be impeded. Second, the acoustic beam can be aimed close to the river bottom for the entire range of interest. The presence of sandbags allows the beam to be aimed closer to the river bottom than if the original substrate were present, since they are less reflective for sound than rock. Finally, the ramp will ensure that the lower support member of the reference target frame rests entirely on the river bottom when in use. If a portion of the lower support member was sitting on a rock then the resulting beam aim will be higher than anticipated. This could result in fish passing underneath the beam and escaping detection.

AUTOMATED FISH DEFLECTION WEIR AND TRACK SYSTEM

The fish deflection weir is a free-standing structure supported by a brace system connected to a double track that runs perpendicular to the river flow (Fig.3). The weir connects to the track at 4 positions, each made up of a carriage assembly that allows the weir to move freely up and down the track (Fig. 4). A catwalk with handrails runs along the top of the weir providing foot access along its length. The 6 m long aluminium weir panel is trapezoidal to conform to the river bank and prevents fish from migrating under or through it. The main frame consists of aluminium angle with pipe welded on 5.4 cm centres vertically spaced along the length of the panel. Diagonal bracing of steel pipe join the top of the weir to the downstream carriages and steel pipe is used for the bracing and handrails. A complete description of the construction and a materials list is available in Enzenhofer and Olsen (1996). The double track which connects the weir to the substrate consists of sections that interlock and are anchored to the river bottom with track pegs made of steel reinforcing bar. Each track section is constructed of two lengths of square tubing welded on a diagonal corner to a flat bar. Along the length of the track, the flat bar is welded to a bearing plate. Each bearing plate is bolted to a steel channel track tie that maintains the spacing between tracks.

WINCH MOUNT PLATFORM

The fish deflection weir is the support structure for the adjustable reference target frame and the transducer-to-weir bracket. Once they are attached to the weir, all three will move in unison. We position the weir along the tracks by a galvanised cable attached to the bank side of the weir and to a 3600 kg capacity electric winch (Warn model 8000x). The winch is positioned in the centre of the tracks and bolted to a steel plate (Fig. 5). The plate is welded to two lengths of steel tubing, spaced 43 cm apart, to form a winch mount platform. The winch mount platform bolts to the top of two lengths of steel channel each of which fit inside the uppermost track section (Fig. 6). Also mounted to the plate are a 12-Volt DC battery and winch roller assembly.

ADJUSTABLE REFERENCE TARGET FRAME

The reference target frame is an aluminium frame mounted to the upstream side and at the deep end of the fish deflection weir. The frame allows vertical and horizontal movement of an attached acoustic target in the far field of an acoustic beam. The transducer beam axis is aligned perpendicular to the shoreline and towards the frame centre. The frame body is open at the upstream end and consists of three support members (Fig. 7).

The design meets several operational requirements. First, it allows the frame body and target to be at the same range from the transducer. This eliminates the possibility of acoustic noise being created by water flow around an upstream vertical support member which would interfere with the return signal. Second, we can tilt the entire frame body from a bottom pivot point attached to a support structure. This feature allows us to test for the presence of transducer side lobe activity which can impact the detection efficiency of a transducer. Third, the frame is easy to re-deploy when fluctuating river levels necessitate frequent repositioning of equipment. Finally, the cables that control the position of the target are accessible from one location near the support structure. This ensures that the target can be positioned at any time by a person located on the support structure. The position of the target can also be read from this location using tape measures mounted to the frame's top support member.

FRAME CONSTRUCTION

The reference target frame is an aluminium frame featuring three support members constructed of schedule 80 round tubing (Fig. 7). The upright member is assembled from two sections joined by a splice tube. The frame was split in this fashion to provide a smaller package for transporting. A 2.4 mm stainless steel cable with a turnbuckle connects the end of the upper support member to the top plate of the vertical support member. Adjusting the turnbuckle removes flex when the frame is in position. Gusset plates were added to the top and bottom of the vertical support member for added rigidity. The lower support member extends out on the mounting side to provide room for the lower gusset plate and to bolt on the pivot hinge slider. The pivot hinge slider, lined with polyethylene, is connected to the supporting structure by sliding onto a T-bar slider column constructed of 2 welded pieces of aluminium angle. A tilt adjustment bracket welded to the vertical support member of the frame bolts to a removable bracket (Fig. 7, part A) which fits over top of the T-bar to lock the frame into position. These brackets are constructed from aluminium angle with evenly spaced bolt aligning holes spaced on 10 cm centres. The spacing of these holes provides 10° of tilt to the frame body (5° towards or away from the transducer). The option to tilt the frame was added, as sometimes a vertical support member can cause acoustic interference by acting as a secondary target. By tilting the vertical member relative to the transducer axis, we found that we can remove this interference completely.

Movement of an acoustic target is accomplished by external and internal slider tubes which travel in unison along the upper and lower support members (Fig. 8). The external slider tube is lined with PVC bushing sleeves and has cable attachment brackets welded to each end. The lower support member is slotted on the top and bottom to allow the internal slider tube to travel inside. Any sand carried by the river flow, which would otherwise accumulate and impede the slide mechanism, will flush through these slots. We used an internal slider tube to provide a low profile to the bottom support member when aiming the acoustic beam. An external slider tube could not be used on the frame bottom as it would support the entire frame weight making any horizontal movement of the target difficult.

FRAME CABLING

All possible target positions within the frame can be made by adjusting the stainless steel cables shown in Fig. 8. To move the target horizontally we insert a pull rod into the external slider tube and push or pull the tube into the desired position (Fig. 1). A single cable joins the external slider tube on the top support member to the internal slider tube on the lower support member. Thus, both top and bottom slider tubes move in unison, maintaining a rectangular configuration. Pulleys constructed of polyethylene rod with a groove cut in the centre to fit the cable were placed on the main frame body. A double pulley housed in one bracket is required on either end of the vertical support member.

We position the target vertically by adjusting a second cable which runs over pulleys mounted on both ends of the slider tubes. This cable has a loop at each end, hand-swaged to attach a 1.5 m bridle containing the acoustic target. We use stainless steel fishing line for the bridle with snap swivels to connect to the vertical cable. The smaller line is used to minimise interference with the acoustic beam; it should be as acoustically transparent as possible. A constant tension bracket (Fig. 7) mounted to the external slider tube keeps the vertical cable tight and reduces movement of the target.

TRANSDUCER-TO-WEIR BRACKET

The transducer-to-weir bracket is an aluminium bracket mounted to the upstream side and shoreline end of the fish deflection weir. The bracket has two components; a main horizontal section and a transducer assemblage. It is designed to house the dual axis rotator and transducer and provides the ability to maintain an established beam configuration when moving equipment during fluctuating river levels. It features three stabilising jacks which support the bracket on the river bottom and eliminates excessive vibration caused by current flow. It is also equipped with a levelling bubble easily adjusted with the stabiliser jacks to maintain horizontal beam alignment to the river bottom.

BRACKET CONSTRUCTION

The bracket consists of a main horizontal section constructed of aluminium tubing welded to the centre of a mounting plate (Fig. 9). The mounting plate is bolted to the vertical pipe members of the deflection weir and secured with a backing plate. Two stabilising struts welded to the bottom of the horizontal member are bolted to the weir with a mounting plate and backing plate. Bolted to the upstream end of the horizontal member is a camper jack with a stainless steel pipe extension. A swivel foot pad is bolted to the jack extension. This pad self-adjusts to conform to the bottom slope.

The transducer assemblage locks to, and travels along the main horizontal member by a collar that has a locking nut and carpenter's level. The collar is constructed of aluminium plate welded together and lined with polyethylene. Centred and welded to both the underside of the collar and to a base plate is an aluminium pipe. The base plate is cut from aluminium. A stanchion tube is welded 90° to the base plate and holds the dual axis rotator and transducer assembly. On either side of the collar are two jacks, each having stainless steel pipe extensions added. Each pipe extension passes through a corresponding hole in the base plate and has a swivel foot pad attached. These pads are aluminium plate designed to have a low profile and be flush with the bottom of the base plate when the jacks are in their uppermost position. A removable lock, connecting the top of the transducer assemblage stanchion tube to the collar, removes flex in the base plate once the weight of the transducer and rotator is added.

We placed the main horizontal section of the transducer assemblage 2.1 m from the shore end of the weir and just above the water surface. This was ideal for the bank slope of 22° which exists at the Qualark Creek site. Exact placement at other sites would depend on the water depth and slope. If shallower depths were encountered the transducer assemblage depth could be reduced.

DEPLOYMENT OF THE IN -RIVER EQUIPMENT

Once the equipment is installed on the site, the operation of each component is simple and can be done by one person. A second person is needed to operate the hydroacoustic system during beam aiming.

Initially the reference target frame is in its resting position which has the top support member lying on the hand rail and the lower support member attached to the top of the T-Bar which holds it to the weir. The transducer-to-weir bracket will have the stabilising feet in their uppermost position to allow movement of the weir. We position the weir with the winch to the point where the catwalk is just above the water surface. The three stabiliser feet on the transducer-to-weir bracket are then lowered to the point of contact with the substrate. The horizontal level is adjusted by observing the carpenter's level mounted to the top of the collar of the transducer assemblage. The distance that the transducer and rotator assemblage is placed along the horizontal channel of the bracket will have previously been set and does not require further adjustment. This distance is set such that the transducer beam axis is parallel to the deflection weir and is far enough upstream so that the end of the weir is not detected by the acoustic system. Beam coverage must also be such that fish coming around the end of the weir are detected. For example, we set the 4 x 10° elliptical transducer on the transducer bracket at a distance of 1.37 m upstream from the weir. This distance allows us to move an acoustic target attached to the reference target frame throughout the entire cross section of the beam at the weir end and not receive any interference from the weir itself.

With the deflection weir and transducer-to-weir bracket in place the reference target frame is set to rest on the river bottom by lowering the pivot hinge slider down the deflection weir T-bar. The removable bracket is then mounted to lock the frame into position. We use a boat secured to the catwalk and top support member of the frame as a platform to operate the cable adjustments and measure target frame positions. At this stage the transducer beam can either be aimed for detecting fish passage or beam geometry experiments can be performed. If the transducer is to be aligned for fish detection the beam axis would be set to the point where the target is in the bottom most position (See Standardisation of the beam aim below). The target frame is then raised out of the water to its resting position. Subsequent repositioning of the fish deflection weir does not require the use of the target frame as long as the mounting of the transducer to the rotator assembly is not changed.

APPLICATIONS

The in-river equipment allows us to accomplish acoustic measurements that are generally difficult to perform in the riverine environment. We can routinely perform procedures such as: 1) standardisation of the beam aim; 2) routine system calibrations; 3) test the detection characteristics of a transducer and echosounder combination. Use of the adjustable reference target frame is crucial to performing these procedures and is outlined in detail in Enzenhofer and Olsen, 1997. In order to perform these routine procedures, the acoustic system should have real-time software which displays vertical and horizontal target position on a PC monitor.

STANDARDISATION OF THE BEAM AIM

An acoustic target having the same signal strength as an adult salmon is attached to the vertical cable of the frame. We use a hollow plastic sphere [1](12.7 cm diameter, used in the food industry to provide surface insulation for open vats of liquids) to yield an average target strength of -31dB. The target frame is set to its working position and the target is approximately positioned vertically to mid-water. Next, the transducer is aimed via a remotely operated rotator until the target is located within the acoustic beam, as indicated by signal strength monitored from the oscilloscope. The target's vertical-horizontal position (XY) is then displayed by software on a PC monitor. The rotator is used to align the acoustic beam until the target appears on the beam axis. The target is then lowered to the bottom of the frame, below the beam of the transducer. The transducer is then aimed down until the target echo is breaking threshold on the oscilloscope. With the transducer in this position the target echo should disappear if the target is raised vertically out of the beam. This establishes the bottom-most position for the aim and ensures that errant bottom signals are not detected. Finally, the target is raised vertically to the beam axis as seen on the XY graph screen display. The target to frame position and rotator tilt angle is recorded. The geometry can then be verified to see if the beam is in fact aimed where we think it is. As long as the transducer position on the transducer-to-weir bracket is not physically changed, the beam configuration will remain constant during equipment moves. Periodic checks of this established bottom position can be made by re-deploying the frame and placing the beam axis on the previously recorded target to frame beam axis position.

TESTING THE DETECTION CHARACTERISTICS OF A TRANSDUCER AND ECHO SOUNDER COMBINATION

Knowledge of the detection efficiency of the hydroacoustic system is important to the accuracy of the acoustic estimates. Transducer selection should be determined by performing controlled *in situ* experiments which measure the system's ability to detect fish above the background noise present in the river. These measurements can reveal problems such as

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[1] United States Plastics Corporation (spheres float on surface of liquid in open tanks and thereby greatly reduce the exposed liquid surface area).

transducer malfunction, peculiarities in the function of the digital echo processor or system software and errors in calibration data.

We use the split-beam system's three-dimensional target positioning ability to produce a beam map that defines the probability of detection for a target based on its position within the beam cross section (Mulligan and Kieser 1996). To do this we attach either a freshly killed fish or the plastic sphere to the target frame. The target is placed on the beam axis in a manner similar to the standardisation of the beam aim. We then move the target over a set of grid points which cover the entire beam cross-section. Data is recorded at each position for a known period of time.

ACOUSTIC EQUIPMENT

We developed the in-river equipment to assist the operation of an HTI Model 240 Digital Split-beam Hydroacoustic System (Hydroacoustic Technology, Inc. 1993a, 1993b). The acoustic system includes three-dimensional target tracking software, a 200 kHz Model 240 digital echo sounder (DES), a monitor and keyboard, an oscilloscope, a chart recorder, a digital-audio tape recorder, a PC equipped with a digital echo processor (DEP), a dot-matrix printer, and a rotator controller (Fig. 10). The receiver contained in the split-beam echo sounder provides simultaneous 20 log(R) and 40 log(R) time-varied-gain output, so echo-integration and individual target tracking can be accomplished concurrently. The digital echo processor in the PC processes signals received from the split-beam echo sounder. The PC also runs real-time integration and target-tracking software and stores the output from these programs on a hard drive. The dot-matrix printer is the output device for a digital chart recorder in the split-beam echo sounder and is used to record echograms. The keyboard and monitor connect to the echo sounder and are used to control echo sounder and chart recorder settings. The digital audio tape recorder records raw echo sounder output on tape. Tapes can later be reprocessed through the echo sounder, using modified system parameters if desired. The oscilloscope displays the return signal voltage vs. time and aids in aiming the acoustic beam and monitoring the system. The rotator controller remotely actuates a rotator to which the split-beam transducer is attached. This allows vertical and horizontal aiming of the acoustic beam.

Data from the single-target echoes were processed by the DEP and written to a computer file. This file was further processed by a real-time tracking algorithm to indicate those echoes that grouped into reasonable trajectories for migrating fish. The transducer transmits simultaneously on all four quadrants, but receives the return signals from the four quadrants independently. Signals from the four quadrants are then amplified and combined by the DES to form four, half-beam components: up, down, left, and right. The shift in the phase between these four components is used by the DEP to calculate the vertical and horizontal off-axis angles for an echo. Thus, three-dimensional position data is measured for an echo. Knowing the position and associated time for each echo permits the estimation of direction of travel, target speed, and target strength.

BEAM MAP EXAMPLE

A beam map was made with a 200kHz Model 240 digital echo sounder with an 8° circular transducer using a 12.7cm plastic sphere attached to the target frame. The echo sounder was operated at 25dB transmit power and -18dB total receiver gain. The transmitted pulse width used was 0.2ms at a pulse repetition rate of 10 pings per second. We used a maximum of 0.3ms and a minimum of 0.1ms pulse width acceptance criteria for the echo signal. The acoustic signal was amplified with 40LogR time-varied-gain. A minimum echo amplitude threshold of 200mv (corresponding to a target strength of -40.5dB) was used to eliminate background noise created within the river. These settings are the same as those used for enumerating salmon at the Qualark Creek site.

Figure 11 shows the result of a 54 position beam map which was recorded at 8 minutes per position, at a range of 3.7m from the transducer. The solid dot represents the actual target to frame position measured with the reference target frame. The end point of the solid line corresponding to each position denotes the mean acoustic position of detected echoes determined by the hydroacoustic system.

To obtain this beam map the target is first located on the acoustic axis as in standardisation of the beam aim and a recording session is made and denoted as the first position (POS 1). Once the position is completed the target is moved vertically on the frame and the distance moved from the vertical axis is recorded. This procedure is done above and below the beam axis towards the edge of the beam, until the target falls below the minimum amplitude threshold set for the target tracking program. After a vertical run of the acoustic beam is completed the target is returned to the beam axis position and then moved right or left along the horizontal beam axis. Another vertical run of the beam is then made. This procedure is done until the entire cross section of the beam is covered (Appendix 1).

The probability of detection shown in Fig. 12 is the ratio of the number of target echoes detected divided by the total number of pings transmitted, for each position. The dotted line in the figure denotes the nominal -3dB beam edge of the transducer and illustrates how well defined this beam edge is.

Similar beam map sessions can be done using a freshly killed fish in place of the hollow plastic sphere. The fish is tethered to a harness that is attached to the vertical cable of the reference target frame and the rest of the procedure is the same as described for the plastic sphere.

DISCUSSION

We believe that the equipment and methods presented in this report can be applied to most riverine acoustic enumeration facilities. We also believe that for accurate and defensible acoustic enumeration of migrating fish stocks, these techniques are important, if not essential. Several years of research and development have gone into the Qualark Creek site and we have been able to show that our estimates of salmon passage have greatly improved due to the changes we have made. We anticipate that in presenting our developments we can save others time in starting new riverine acoustic facilities.

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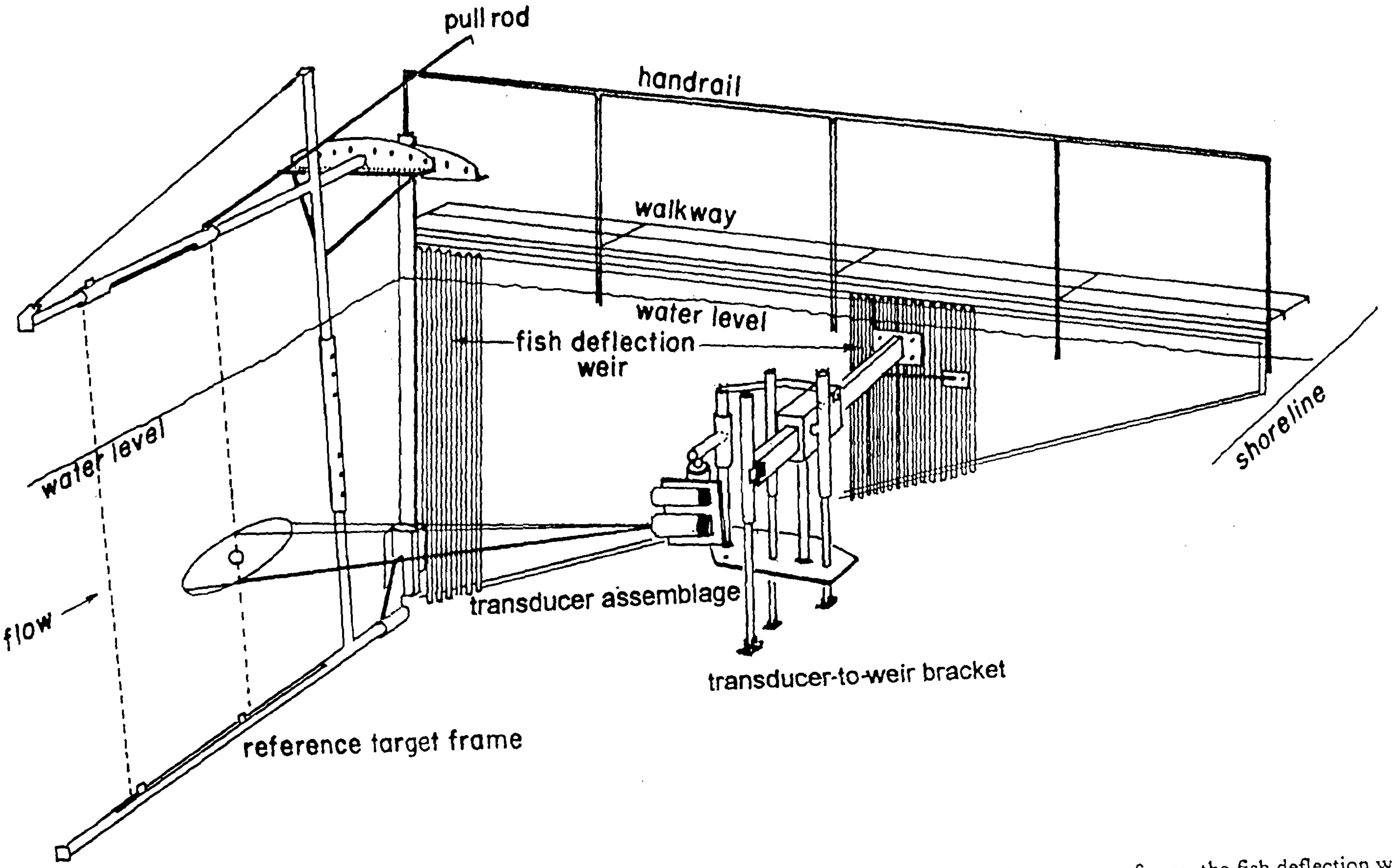

Fig. 1. Three dimensional view of the in-river accessory equipment which includes the reference targe frame, the fish deflection weir and the transducer-to-weir bracket.

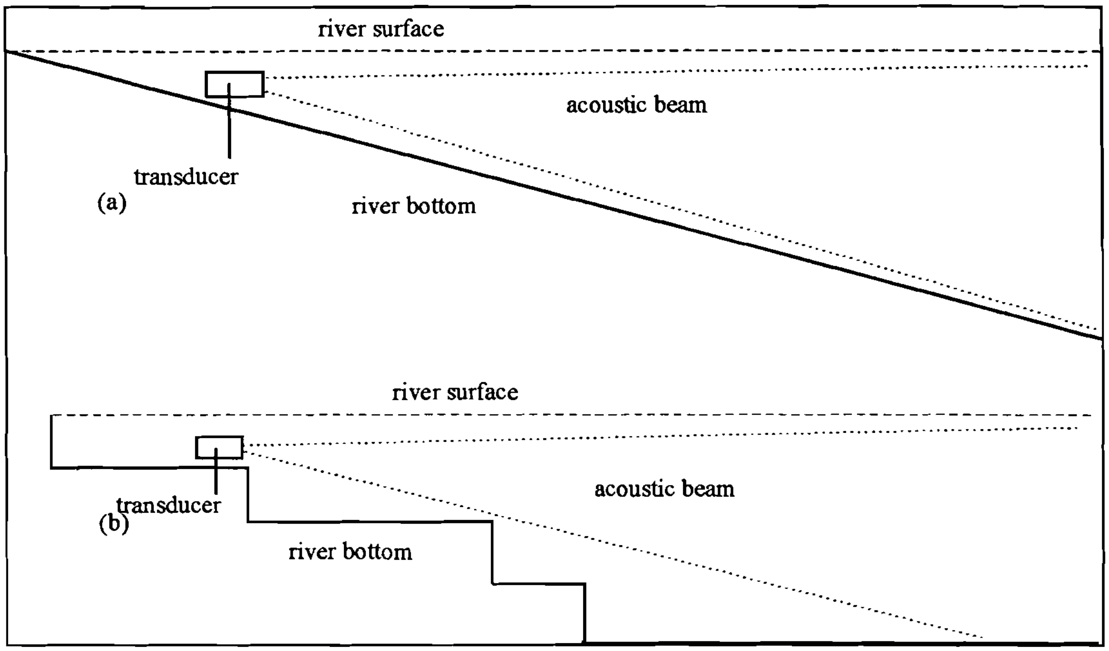

Fig. 2. Comparison of the deployment of an acoustic beam on a planar (a) and shelved (b) river bottom. The shelved bottom or the presence of large boulders results in areas which are inaccessible to the acoustic beam.

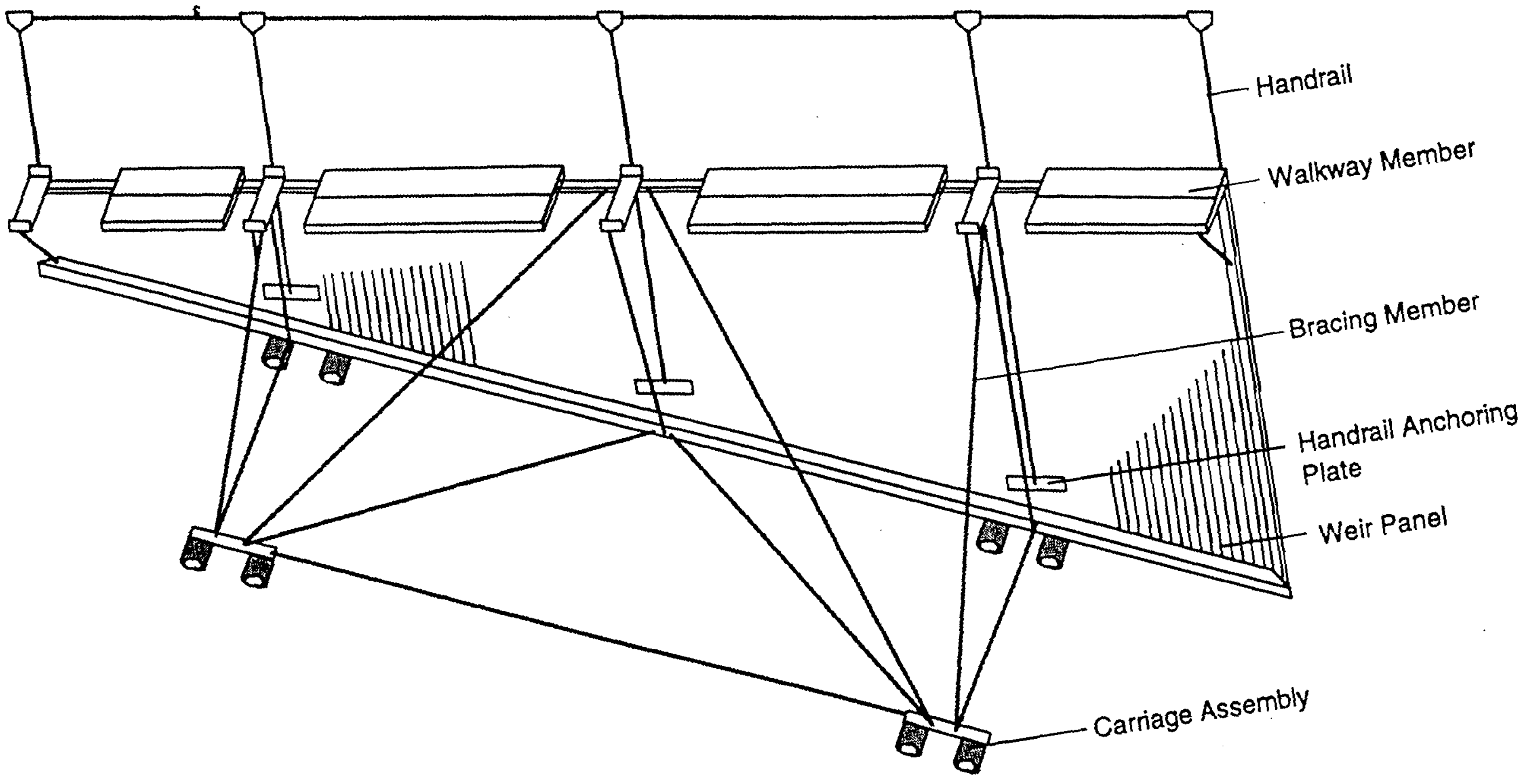

Fig. 3. Schematic of diversion weir showing weir panel, bracing, carriage assembly and walkway with handrail.

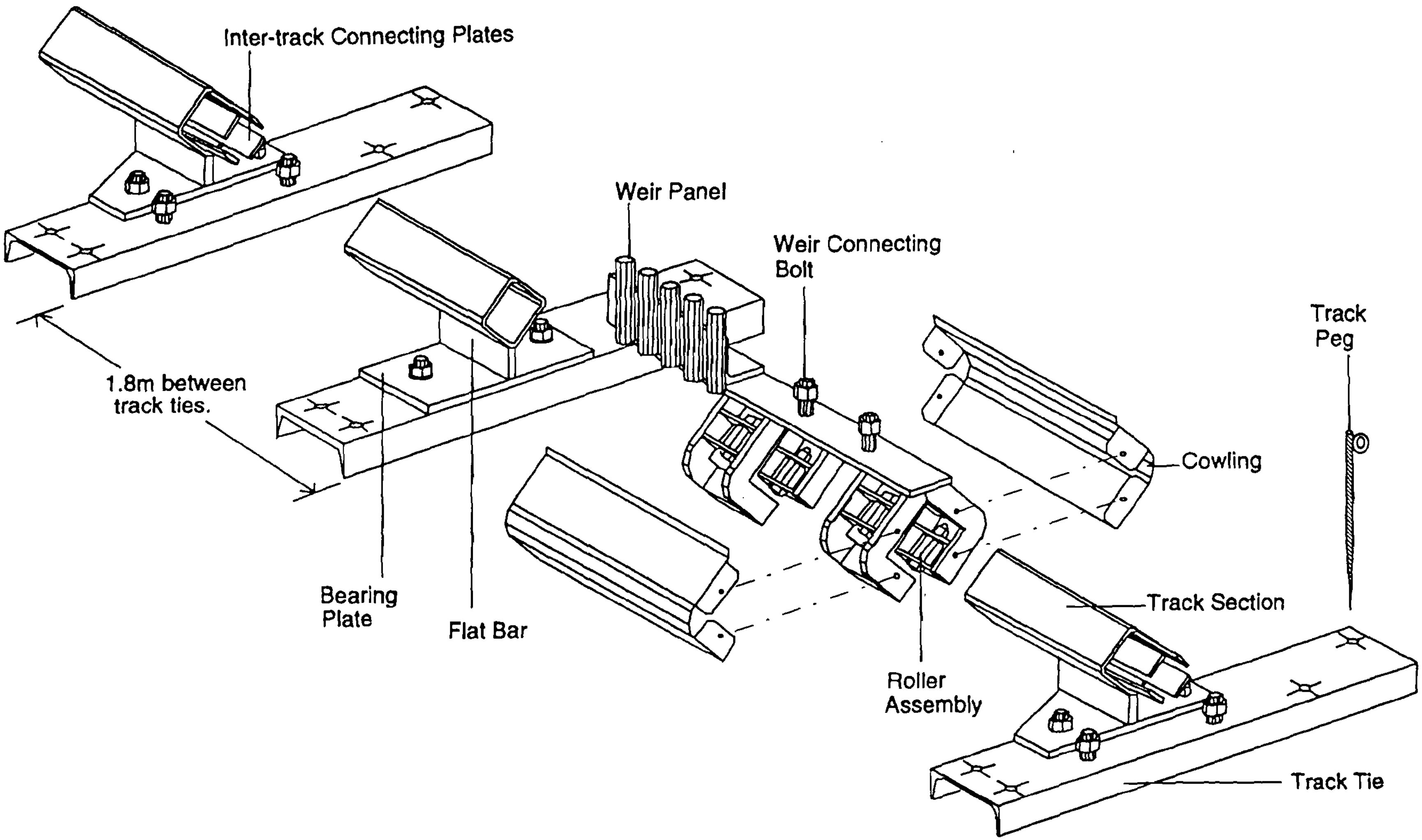

Fig. 4. Exploded diagram of carriage assembly and track section.

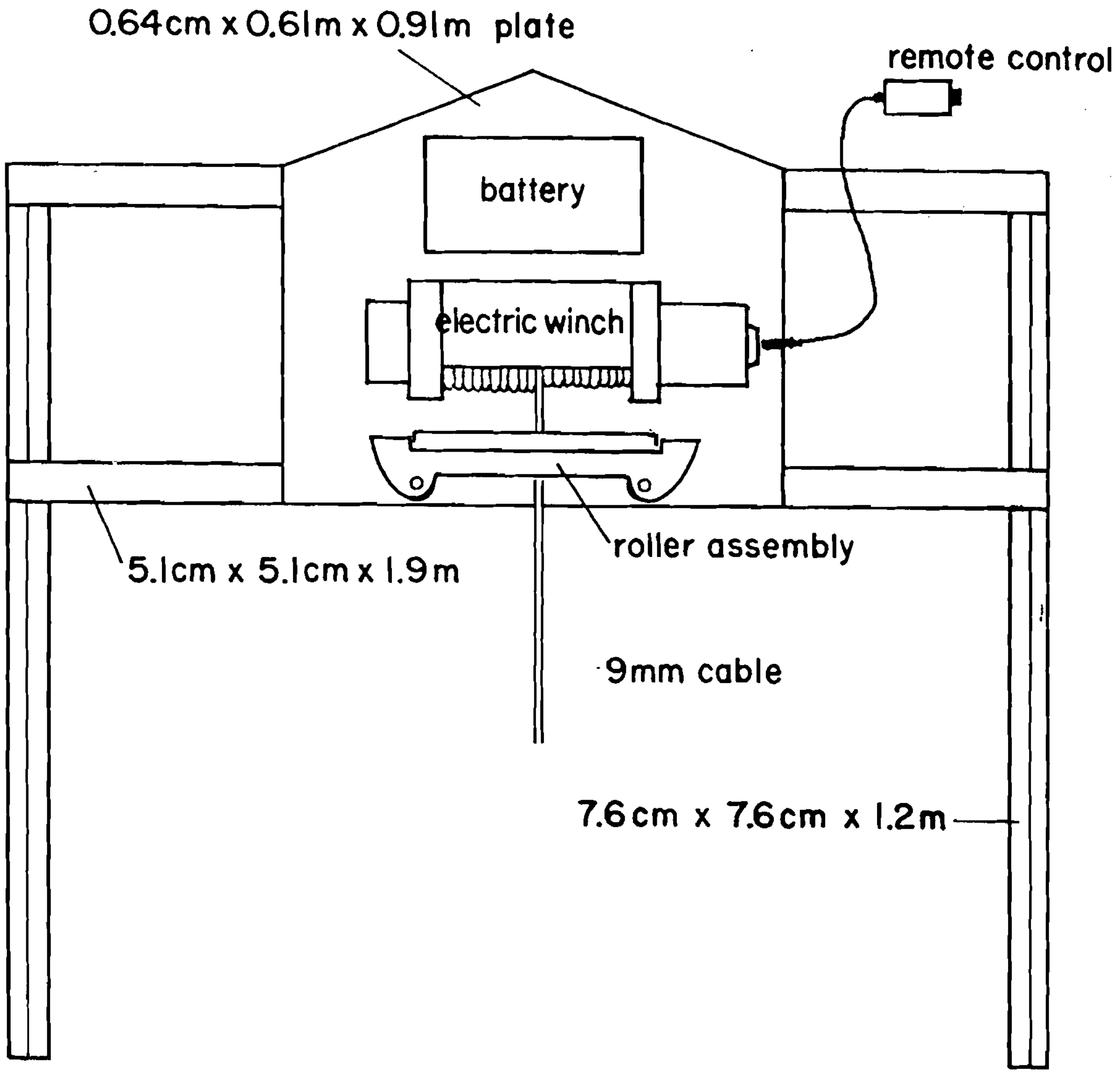

Fig. 5. Winch mount platform.

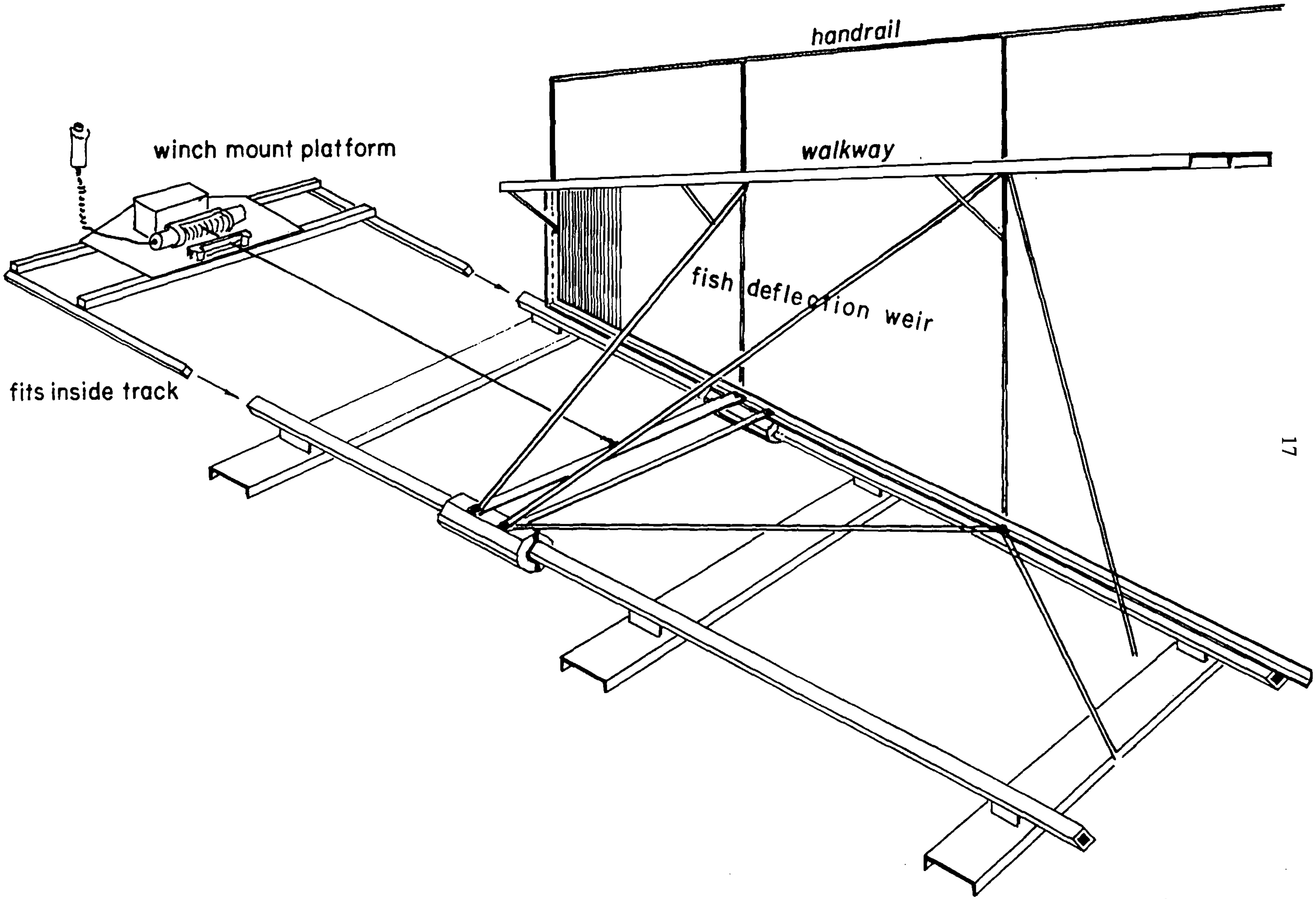

Fig. 6. Three-dimensional view showing the installation points of the winch mount platform to the fish deflection weir and track system.

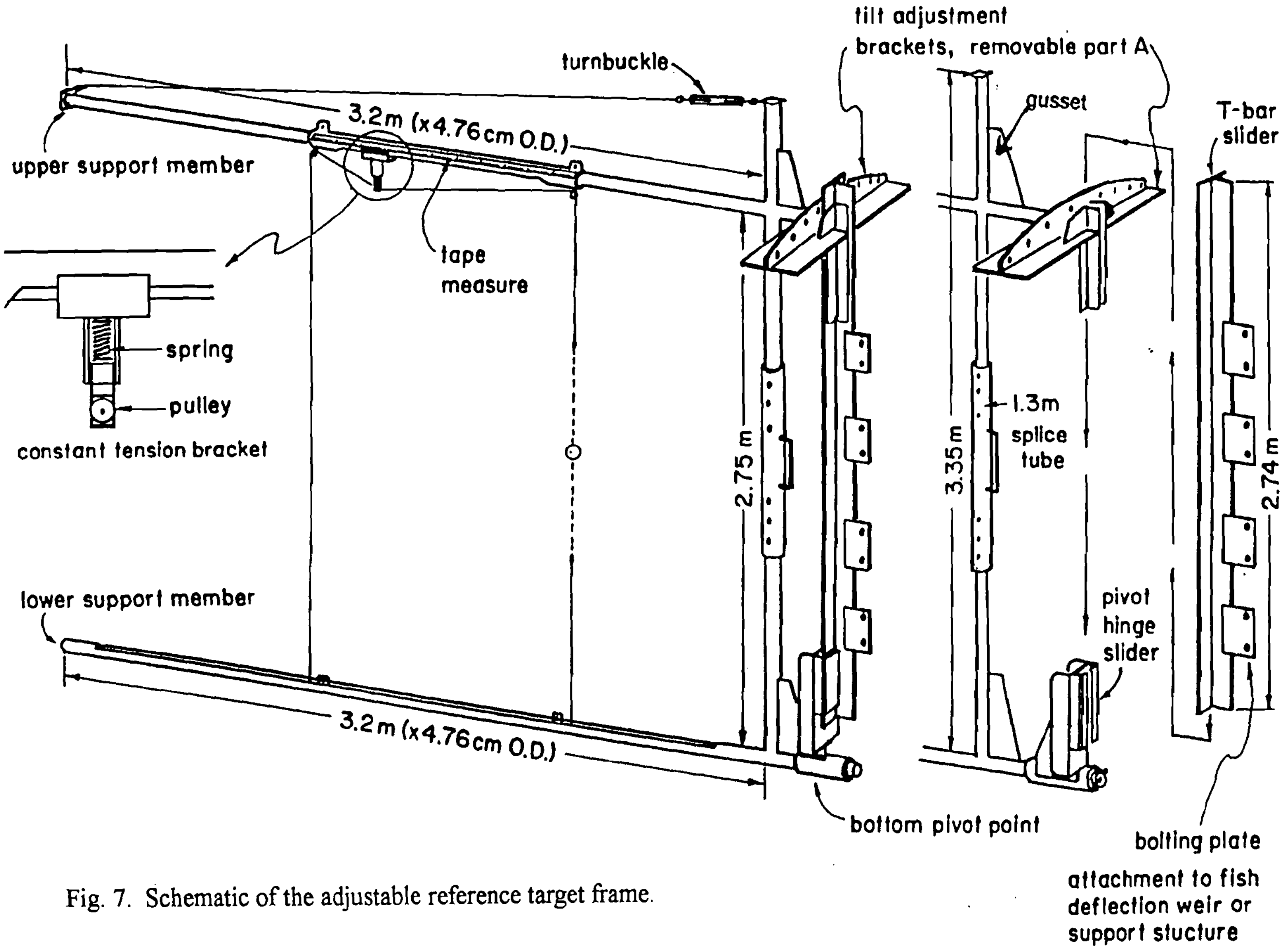

Fig. 7. Schematic of the adjustable reference target frame.

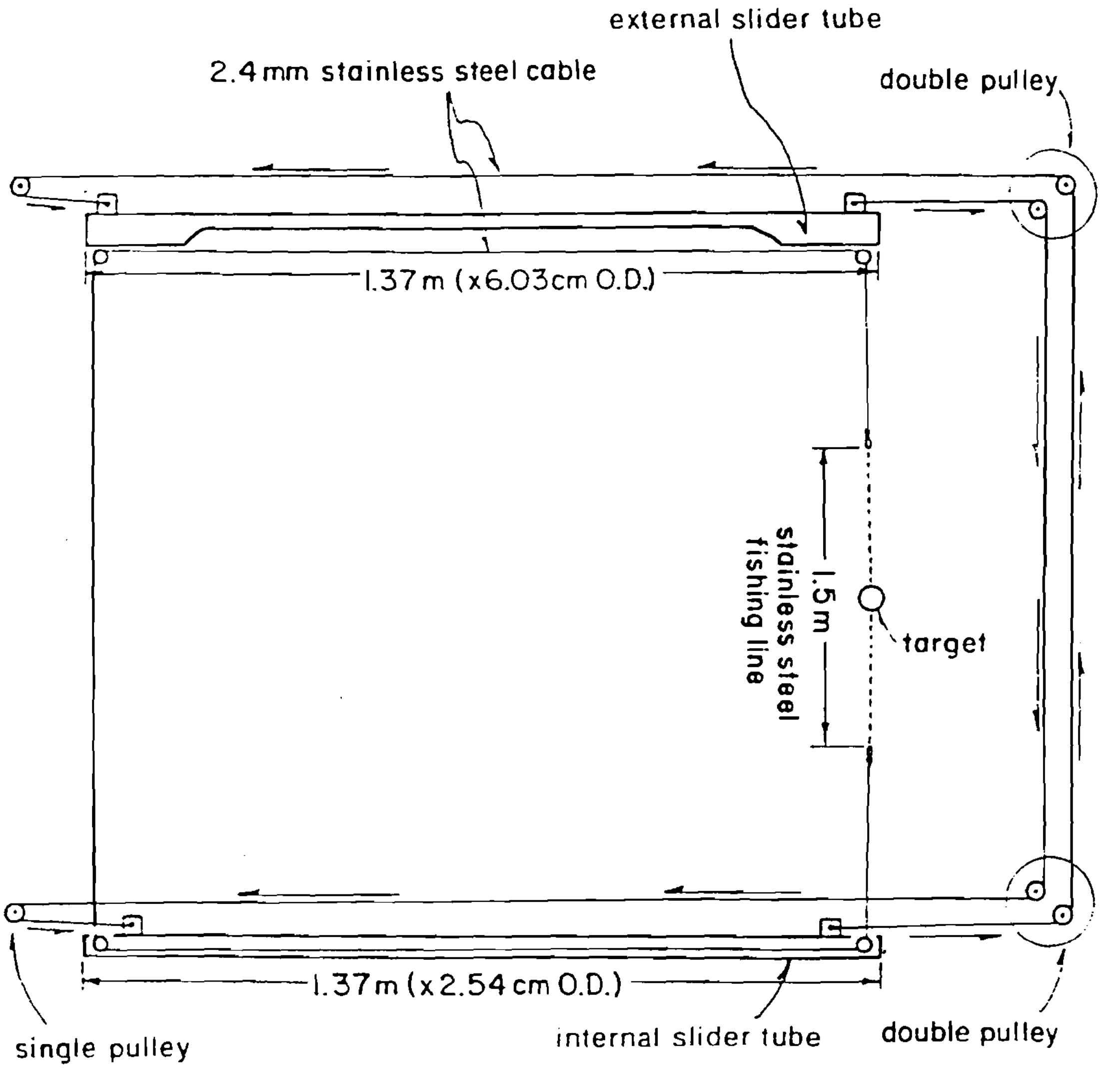

Fig. 8. Cable assembly of the adjustable reference target frame.

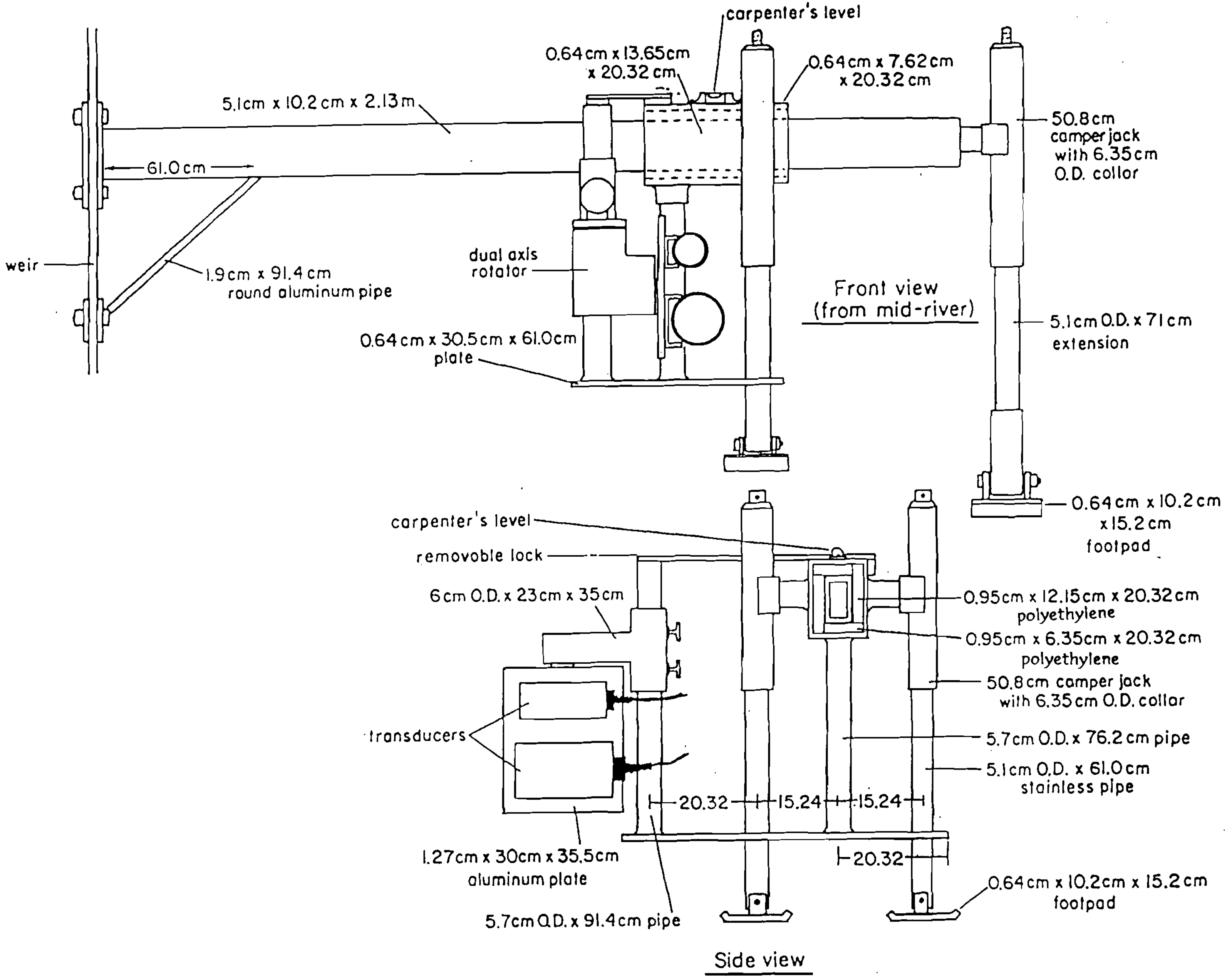

Fig. 9. Schematic of the transducer to weir bracket showing a front view of the main horizontal section and transducer assemblage. The side view shows the transducer assemblage alone.

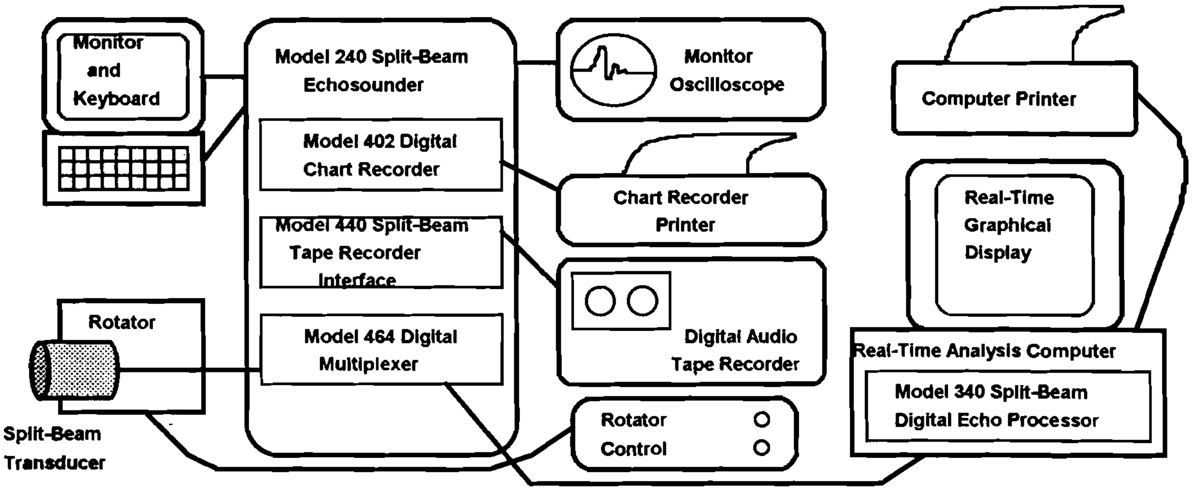

Fig. 10. Schematic diagram of the model 240 split-beam hydroacoustic system provided by Hydroacoustic Technologies Inc., Seattle, Washington (From HTI, 1993).

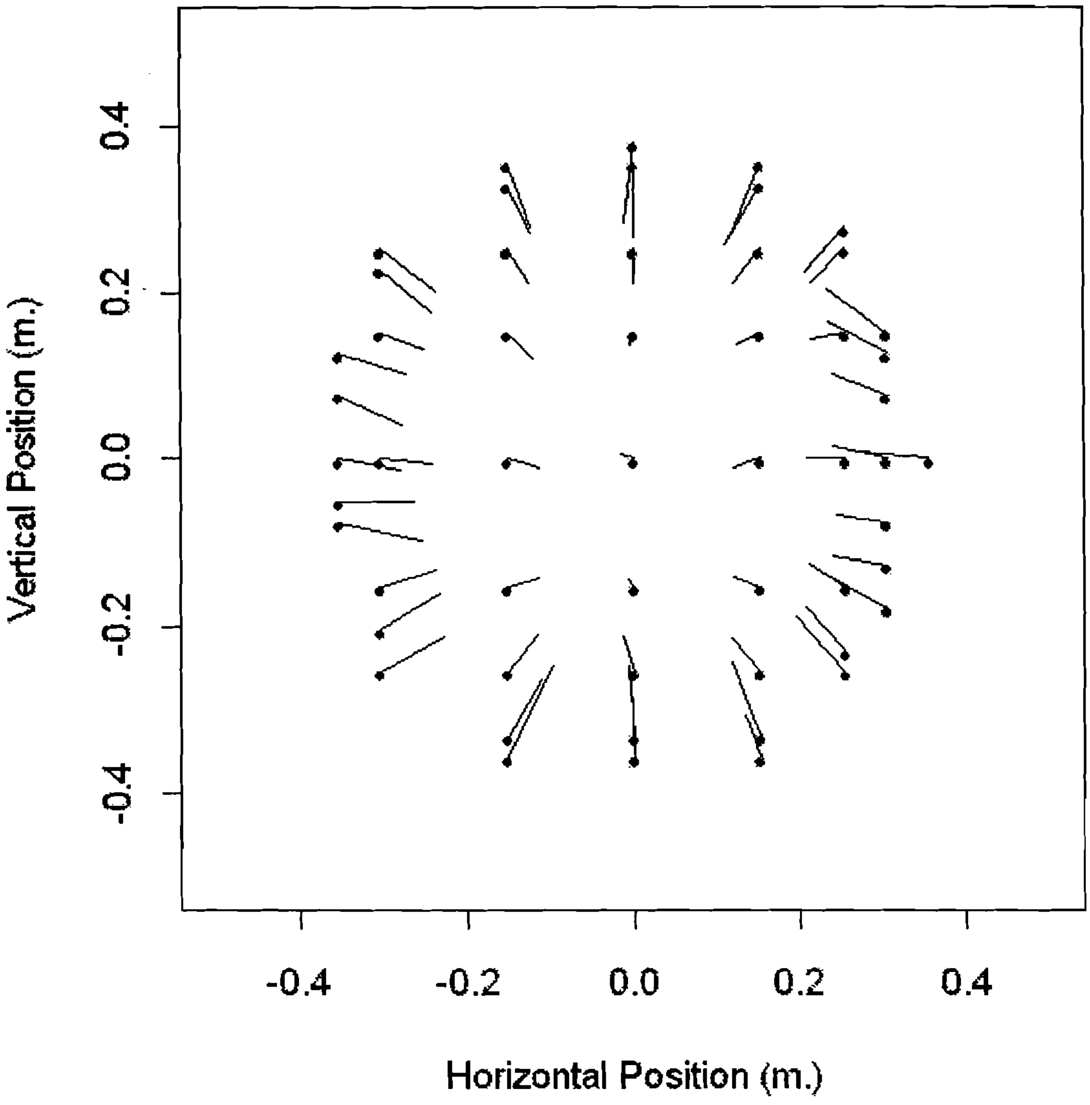

Fig. 11. Comparison of the split-beam acoustic position vs. the actual target frame position for an 8° circular transducer (200 kHz) using a 12.7 cm plastic sphere. The solid dot (•) represents the true position of the target. The end of the corresponding line (—) represents the acoustically determined position.

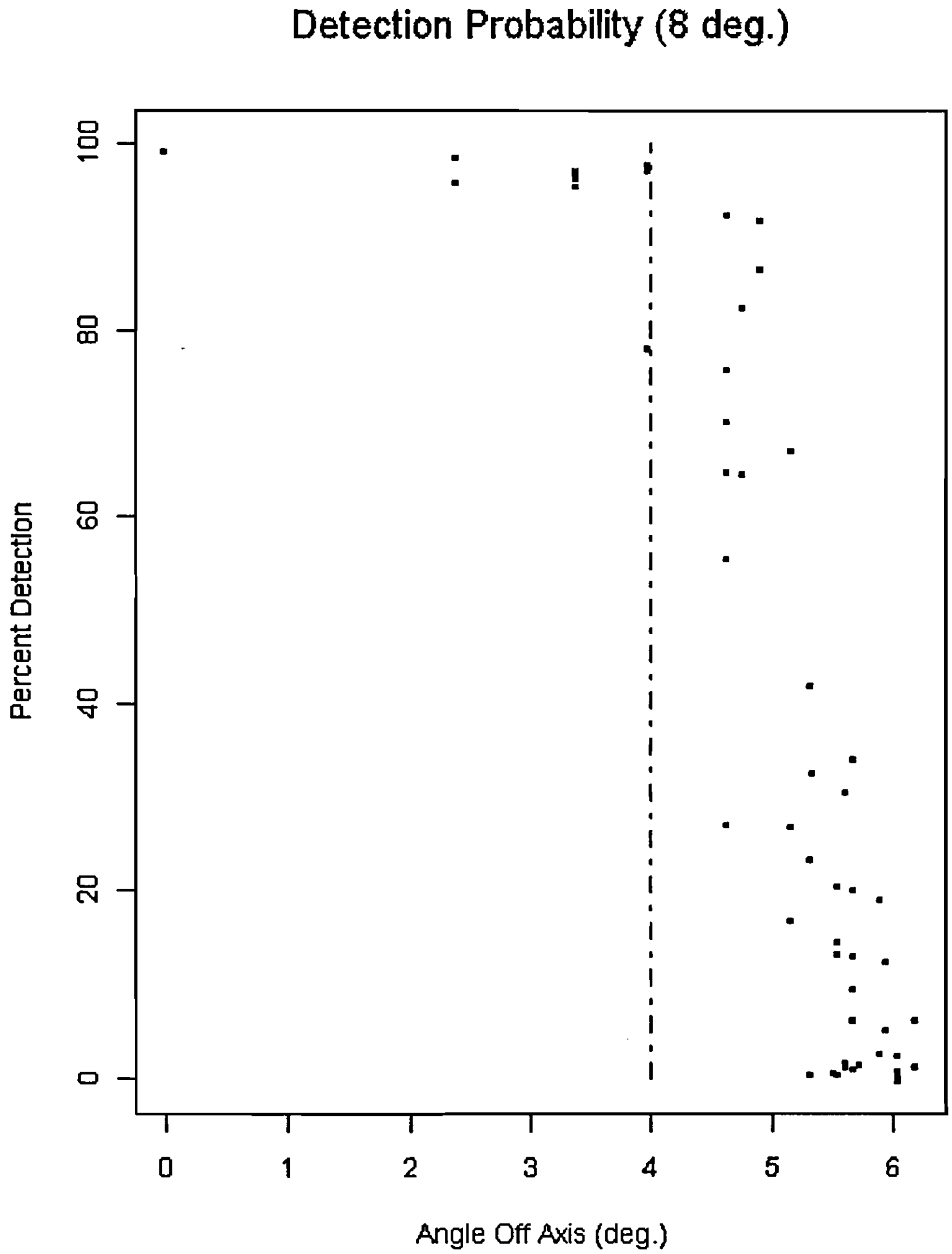

Fig. 12. Probability of target detection vs. off axis angle for an 8° split-beam 200kHz transducer. Target used was a 12.7 cm plastic sphere at 3.7 m range. The dashed line represents the nominal beam width at -3dB off axis.

Appendix 1. Vertical and horizontal target to frame position changes for a 200kHz circular 8° split-beam transducer using a 12.7cm plastic sphere target. Measurements referenced from beam axis position (Vertical = 0.0m, Horizontal = 0.0m)

Position	Horizontal (m)	Vertical (m)	Position	Horizontal (m)	Vertical (m)
1	0.0	0.0	28	.3556	.127
2	"	0.1524	29	"	.1524
3	"	.254	30	"	-.0762
4	"	.3556	31	"	-.127
5	"	.381	32	"	-.1778
6	"	-.1524	33	.4064	0.0
7	"	-.254	34	-.1524	0.0
8	"	-.3556	35	"	.1524
9	"	-.3302	36	"	.254
10	.1524	0.0	37	"	.3302
11	"	.1524	38	"	.3556
12	"	.254	39	"	-.1524
13	"	.3302	40	"	-.254
14	"	.3556	41	"	-.3302
15	"	-.1524	42	"	-.3556
16	"	-.254	43	-.3048	0.0
17	"	-.3302	44	"	.1524
18	"	-.3556	45	"	.254
19	.3048	0.0	46	"	.2286
20	"	.1524	47	"	-.1524
21	"	.254	48	"	-.254
22	"	.2794	49	"	-.2032
23	"	-.1524	50	-.3556	0.0
24	"	-.254	51	"	.0762
25	"	-.2286	52	"	.127
26	.3556	0.0	53	"	-.0508
27	"	.0762	54	"	-.0762