An Adjustable Reference Target Frame For Fixed Location Hydroacoustic Systems

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AN ADJUSTABLE REFERENCE TARGET FRAME FOR FIXED LOCATION HYDROACOUSTIC SYSTEMS

by

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ABSTRACT

Enzenhofer, H. and N. Olsen. 1997. An adjustable reference target frame for fixed-location riverine hydroacoustic systems. Can. Manuscr. Rep. Fish. Aquat. Sci. 2419: 16 p.

The riverine environment presents unique difficulties for operating fixed-location hydroacoustic enumeration sites. In rivers with moderate to fast flows fish migration tends to be bank and bottom oriented. Bank-mounted transducers must be aligned precisely along the river bottom in order to maximize the acoustic coverage of the migrating fish. High currents and turbulent flow make calibrations and experiments using acoustic targets difficult to perform. To address these problems we constructed an adjustable reference target frame for use with a split-beam hydroacoustic system. The target frame holds targets stationary within the acoustic beam and allows vertical and horizontal positioning of the target, making calibrations and experiments possible. The diversion weir and target frame also have application to single and dual beam hydroacoustic systems.

RÈSUMÈ

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Le milieu fluvial présente des difficultés particulières pour l'exploitation de sites fixes de dénombrement hydroacoustique. Ainsi, dans les cours d'eau à écoulement moyen à rapide, comme les poissons ont tendance à suivre le lit et les berges, les transducteurs installés sur les berges doivent être très bien alignés avec le lit fluvial afin de maximiser la couverture acoustique. L'étalonnage de cibles acoustiques et les expériences réalisées au moyen de celles-ci sont plus difficiles à réaliser en présence de forts courants et d'un écoulement turbulent. Pour tenter de résoudre ce problème, les auteurs ont construit un cadre de cible de référence réglable pour un système hydroacoustique à faisceau divisé. Le cadre de cible permet de maintenir les cibles en place dans le faisceau acoustique et de les positionner à l'horizontale ou à la verticale; on peut alors effectuer l'étalonnage et des expériences. Le déversoir de dérivation et le cadre de cible peuvent être utilisés aussi bien avec un système hydroacoustique à faisceau unique qu'avec un système à faisceau divisé.

INTRODUCTION

Fixed-location hydroacoustic systems are used extensively to monitor and enumerate fish populations in the riverine environment (Burwen et al. 1995; Daum and Osborne 1995). In rivers with moderate to high flow rates, fish migrating upstream tend to be bank and bottom oriented because flow rates are lower in these regions and are easier for fish to navigate. As a consequence, the hydroacoustic system must be configured such that the acoustic beam is aimed precisely along the river bottom, maximizing acoustic coverage in the area that the fish are migrating. To facilitate this, it's necessary to implement a system that provides accurate information about the alignment of the acoustic beam with respect to the river bottom. Also, since river levels are susceptible to significant daily fluctuations which require that the transducer be repositioned, the system employed for acoustic beam aiming must ensure a repeatable configuration that can be implemented daily in a relatively short time. The repeatability of acoustic beam aiming is crucial in order to track changes in fish distributions over time.

Knowledge of the detection efficiency of the hydroacoustic system is important to the accuracy of the density estimate. Since transducers vary in beam width and detection characteristics their selection should ensure that the area being ensonified is appropriate for the population being studied. The selection of an appropriate transducer will depend on (1) the sounders ability to detect a target above the background noise created by the river flow, and (2) the detection efficiency of the acoustic beam operating in close proximity to a structure. These can be measured by *in situ* beam geometry measurements which can determine the detection characteristics of a sounder and transducer combination. A system which allows exact vertical and horizontal positioning of an acoustic target in the beam's path can be used to perform these experiments.

Periodic performance checks using calibration spheres test the overall transmit and receive components of the acoustic system indicating whether the system has remained stable (Mitson 1983). Often this is done by suspending a target from a fishing line into the acoustic beam. In rivers, keeping a target stationary in the beam is difficult at best due to the erratic movement of the target in the current. Some method of holding a target stationary in strong current is crucial for proper system calibration.

In order to address the problems of acoustic beam alignment and acoustic target measurements, we have constructed an adjustable target frame that allows an acoustic target to be positioned in two dimensions, vertically and horizontally. We use this target frame in conjunction with a diversion weir and a split-beam hydroacoustic system, to aim the acoustic beam along the river bottom in a repeatable configuration, to perform various *in situ* experiments, and to perform system calibrations. A split-beam acoustic system is ideal for such work since it allows us to determine exactly a target's position within the acoustic beam. Nevertheless, the target frame has potential application to single and dual-beam systems. We currently employ this system in the Fraser River near Hope, British Columbia, Canada.

DESCRIPTION

A three dimensional view of the of the adjustable reference target frame is shown in Fig. 1. For riverine application we mount the frame on the upstream side of the support structure. The transducer beam axis is aligned perpendicular to the shoreline and into the frame center. The frame allows vertical and horizontal movement of an attached acoustic target and is designed to operate in the far field of the acoustic beam. The main frame body is open at one end and consists of three support members .

The design meets several operational requirements. Firstly, 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 target's returned signal. Secondly, 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. An earlier reference target frame described by Enzenhofer and Olsen (1996) had a fixed lower support member which conformed to the river bank slope but did not allow for any vertical tilt. Thirdly, 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 repositioned at any time by a person located on the support structure. The position of the target can also be read from this location from tape measures mounted to the frame's top support member.

CONSTRUCTION

Frame

The reference target frame is an aluminum frame featuring three support members constructed of 4.76cm (O.D) Schedule 80 tubing. The upper and lower support members are 3.2m in length, welded 2.74m apart, to a 3.35m upright member. The upright member is assembled from two sections joined by a **splice tube** constructed from 6.03cm x 1.3m schedule 80 pipe. The frame was split in this fashion to provide a smaller package when transporting. A 2.4mm 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 working position. Gusset plates were added to the top and bottom of the vertical support member for added rigidity. The lower support member extends 28cm 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 6.4mm polyethylene is connected to the supporting structure by sliding onto a **T bar slider column** constructed of 2 welded pieces of 5.7cm x 5.7cm x 2.74m angle. Shown in Fig. 2, a **tilt adjustment bracket** (part B) is welded to the vertical support member of the frame. A **removable bracket** (part A) fits over top of the **T bar** to lock the frame into position. These brackets are constructed from 10cm x 10cm x 6.4mm aluminum angle with bolt aligning holes spaced on 10cm centers. This spacing provided 10 degrees of tilt to the frame body (5° towards or away from the transducer).

Movement of an acoustic target is accomplished by **external and internal slider tubes** 1.37m long which travel in unison along the upper and lower support members (Fig. 3). The external slider tube is 6.03cm (O.D) schedule 80 pipe 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 2.53cm x 1.37m 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.

Cabling

All possible target positions within the frame can be made by adjusting dedicated 2.4mm stainless steel cables (Fig. 3). 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. A single cable joins the external slider tube on the top support member to the internal slider tube on the lower support member. The cable runs through grooved pulleys mounted on the body of the frame, constructed of 2.54cm diameter x 3/8" polyethylene rod. This configuration ensures that both top and bottom slider tubes move in unison.

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 1.5m 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 minimize interference with the acoustic beam; it should be as acoustically transparent as possible. A **constant tension bracket** (Fig. 2) mounted to the external slider tube keeps the vertical cable tight and reduces sway in the target caused by river flow.

DEPLOYMENT

A typical configuration of transducer, support structure and frame used on the Fraser River is shown in Fig. 1. The target frame is positioned 3-5m from the transducer. Access to the support structure end is via a catwalk with handrail, mounted on the top of the diversion weir. When not in use the frame is pulled up out of the river and its top support member rests on the handrail while the lower support member remains attached to the top of the **T bar**. In this position we can easily attach the bridle and target assembly. To reset the frame to its working position we lower the pivot hinge slider down the support structure's **T bar** until the lower support member rests on the river bottom. The removable bracket is then mounted to lock the frame into position on the support structure. We use a boat secured to the catwalk and top support member of the frame as a platform to operate the cable adjustments and record target positions during experiments.

APPLICATIONS

We use the adjustable reference target frame in conjunction with an HTI Model 240 Split-Beam Hydroacoustic System to perform various *in situ* experiments and calibrations. The Model 240 Hydroacoustic System includes a split-beam transducer mounted to a remotely operated dual-axis rotator (ROS Model PT-25-348) fixed to an aluminum tripod. The system includes real-time software that allows us to plot the reference target's vertical-horizontal position on a video display terminal. We routinely perform procedures such as:

1) Standardization of the beam aim
2) Routine system calibrations
3) Determining the detection efficiency of a transducer
4) Selecting an appropriate transducer

Standardization of the beam aim

In some rivers fish passage occurs near shore and close to the bottom where current flow is lowest. This type of passage is evident at our site on the Fraser River at Yale, British Columbia. To effectively monitor these fish we force them around a 6m long deflection weir and through the far field of a fixed location split-beam acoustic beam. We aim the beam perpendicular to the river bank, parallel to the upstream side of the weir, and as close as possible to the river bottom. We developed a routine aiming procedure to maintain a consistent beam configuration over frequent equipment repositioning caused by fluctuating river levels. Firstly, a plastic sphere having approximately the same signal strength as an adult salmon is attached to the vertical cable of the frame. The target frame is deployed into the river and anchored to the diversion weir and the target is positioned vertically to approximately 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 an oscilloscope. Once the target is verified to be roughly within the acoustic beam, it's position is fine-tuned using software that displays the target's position in the X-Y plane. 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 detection range of the transducer, and the transducer is rotated down until the target just appears as a spike on the oscilloscope. With the transducer in this position no other point source target should be observed if the attached 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 being detected. Finally, the target is raised vertically until it again falls on the beam axis and the position of the target is recorded from the frame. Subsequent aims for this transducer can then be repeated by placing the beam axis to this measured target-to-frame position.

Routine system calibrations

We test the overall transmit and receive components of the hydroacoustic system by collecting *in situ* target strength data on a calibrated sphere attached to the target frame. For a 200kHz HTI Model 240 split-beam system a 38mm tungsten carbide sphere (-39.55 dB) is placed on the beam axis similar to the method discussed in standardization of the transducer aim. Returned echoes are collected for a 1-2 minute duration and the results compared to the theoretical target strength. Large differences between the two values would indicate that a problem may exist.

Determining detection efficiency of a transducer

We use the split-beam system's three dimensional target tracking ability (Ehrenberg, 1982) to determine the detection efficiency of a given transducer. The adjustable target frame allows a series of beam geometry tests which can define the probability of detection for a target based on its position within the beam cross section. To do this we attach a target with a similar acoustic target strength as the fish of interest to the frame at a 3-5m range from the transducer. We center the acoustic beam in the target frame and then position the target to the beam axis in the same manner as for transducer aiming. We then position the target over a set of pre-determined grid points which cover the entire beam cross-section. At each grid position the target is ensonified for a constant period of time and hence, for a known number of ensonifications. Movement of the target to each grid point is accomplished by means of the target frame only, no change is made to the transducer's position. This reduces the chance that the beam's acoustic characteristics might fluctuate during the experiment, due to interactions with other nearby structures in the environment. The number of times the target is detected compared to the number of times the target is ensonified gives a measure of the detection efficiency of the transducer at each grid point.

The detection efficiency for a particular transducer can also be determined with an actual fish attached to the frame. A freshly killed salmon tethered to a bridle and attached to the vertical cable of the frame is moved to pre-determined grid points to cover the entire beam cross-section. This type of experiment most closely maps the beam's characteristics when monitoring live fish passage.

Selecting an appropriate transducer

We can determine the optimum transducer to use for detecting fish migration based on the results of the detection efficiency beam mapping done *in situ*. For example, if fish passage occurs close to the river bottom then the selection of an elliptical transducer may be better suited than a circular transducer. Assuming that fish swim parallel to the river bottom then their trajectories through the acoustic beam run parallel to the horizontal beam axis. The horizontal cord-length through the acoustic beam is defined as the straight-line horizontal distance from one side of the beam to the other. This distance decreases more rapidly on the circular transducers than on elliptical ones, as distance from the horizontal axis increases (Fig. 4). Thus, fish swimming at the same speed remain in an elliptical beam longer than a circular one and the probability of detecting them increases correspondingly. Also, transducers which have a high probability of detection up to the -3dB level and then drop off rapidly after the -3dB level can be aimed closer to a boundary without encountering excessive interference.

Selection of a transducer also depends on the background noise level encountered while operating the acoustic system in the river or around structures. Detection of a target will only occur above the minimum amplitude threshold set within the acoustic system to compensate for the background noise levels. Wider beam transducers are subject to higher background noise levels and have poor detection efficiency which drops off slowly beyond the -3dB point. Thus, although a wide-beam transducer may be able to cover a large region of the water column, it's low detection efficiency may render it less useful than a narrower beam.

Deviations in the acoustic position of a target compared to the target's known position from the target frame can also reveal peculiarities in the transducer. For example, we encountered a situation where, when a target was moved vertically on the frame the recorded acoustic position moved diagonally. Since a target's position is determined from signals returned on four quadrants of the split-beam transducer, this indicated that one or more one quadrants was malfunctioning.

CONCLUSION

The adjustable reference target frame has been crucial to the continued success of our hydroacoustic salmon enumeration site on the Fraser River. Without such equipment we would have been unable to carry out key experiments that have formed the basis of our understanding of how a split-beam hydroacoustic system operates in riverine environments. We continually improve our ability to monitor fish migration as a result of the insights provided by these experiments.

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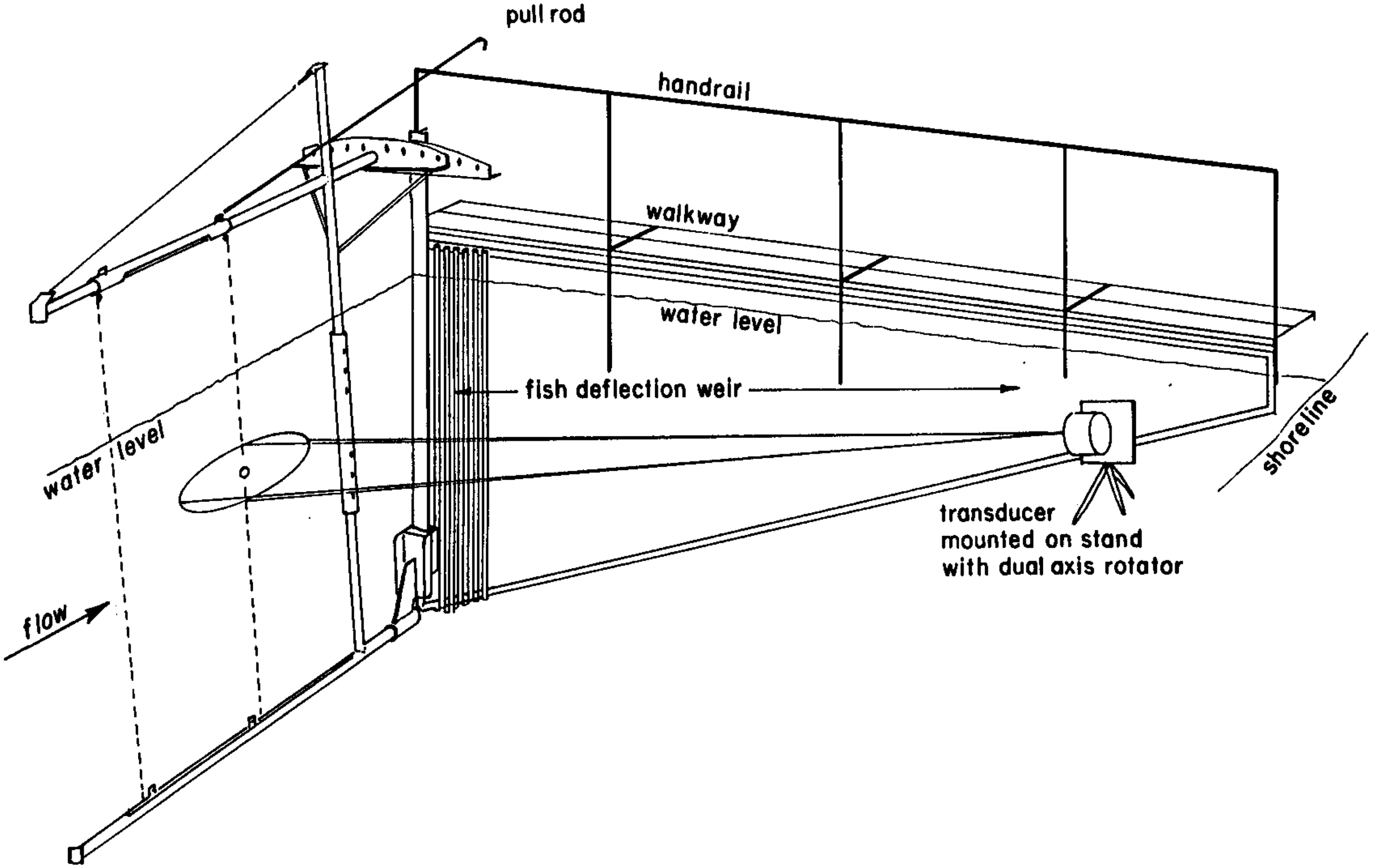

Figure 1. Three-dimensional schematic of adjustable reference target frame showing deployment with respect to fish deflection weir and transducer.

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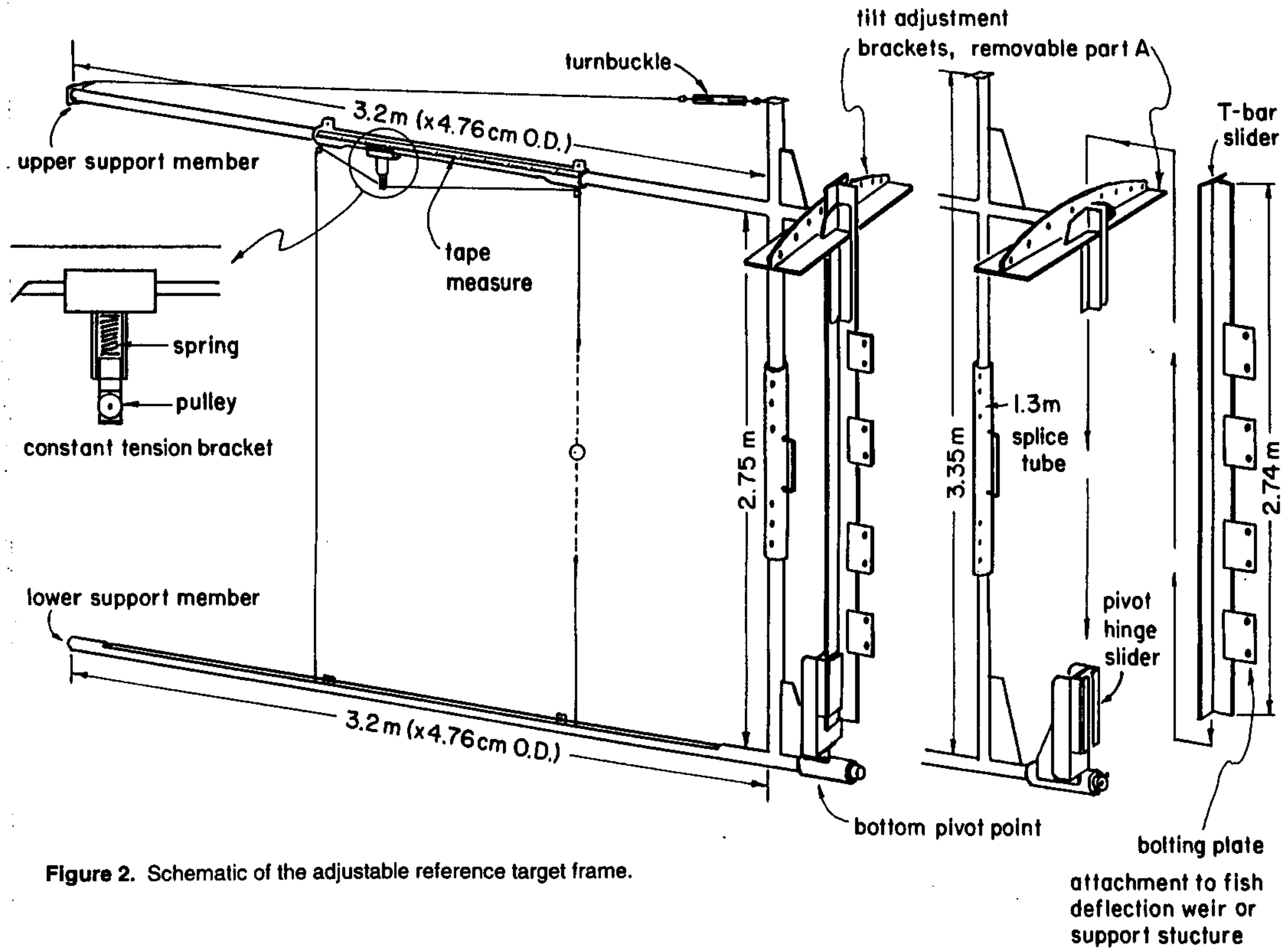

Figure 2. Schematic of the adjustable reference target frame.

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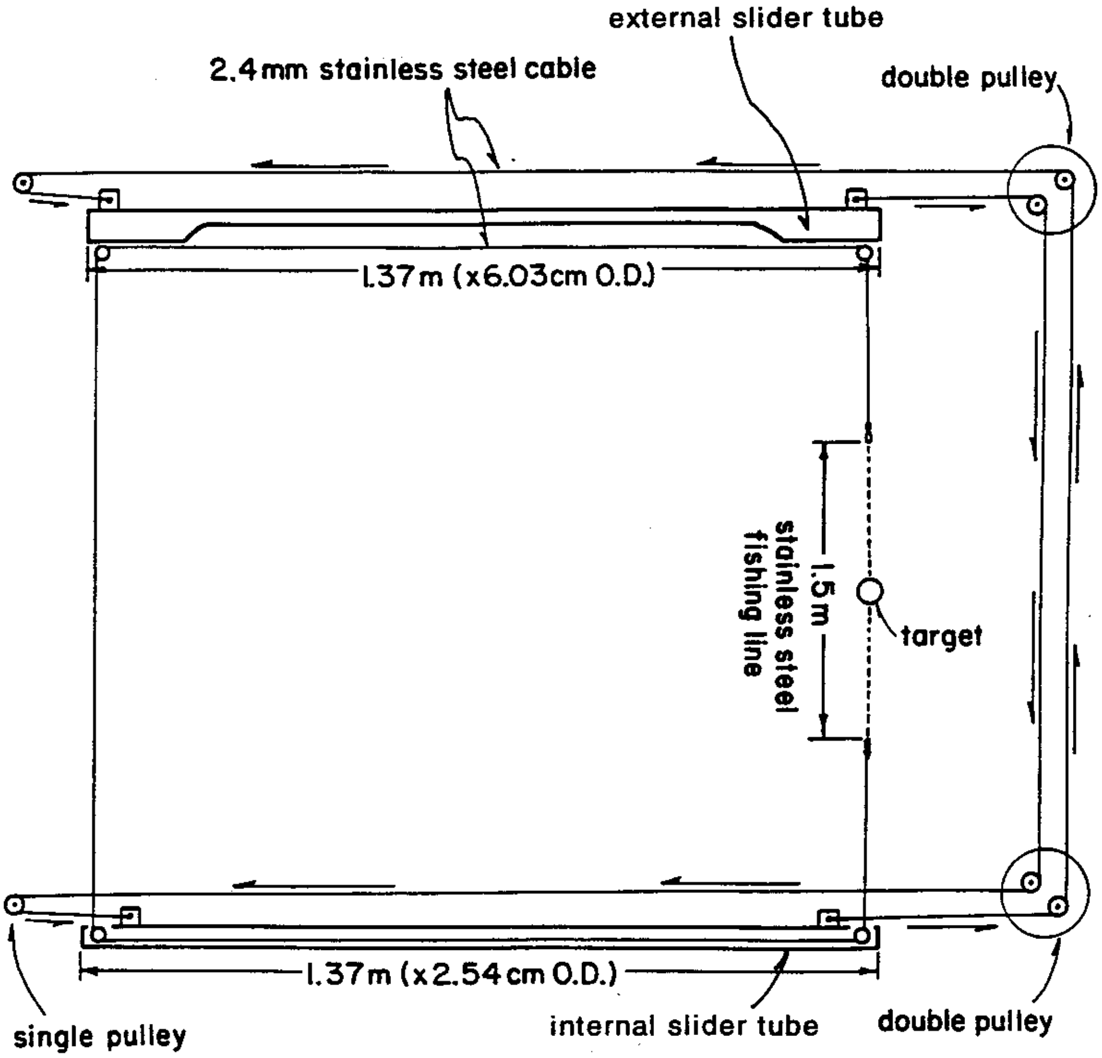

Figure 3. Cabling assembly of the adjustable reference target frame.

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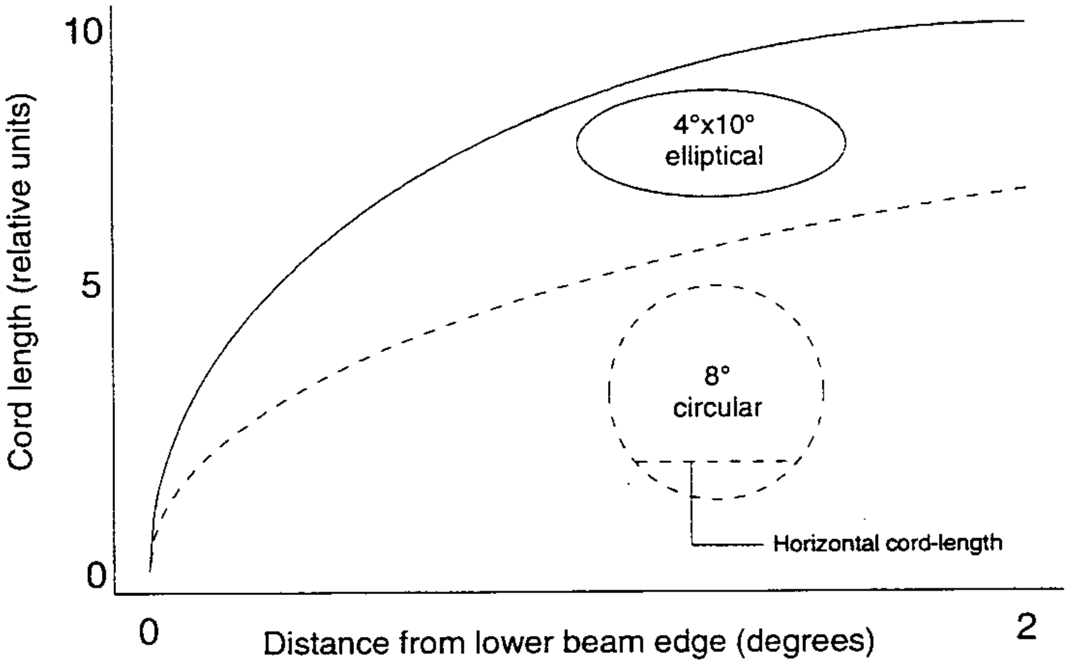

Figure 4: Comparison of horizontal cord-length between a 4°x10° and 8° acoustic beams. Cord-length for each beam is plotted from the beam edge, upwards 2 degrees on the vertical axis.