HYDRAULICS DIVISION
TECHNICAL NOTE

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DATE March 1984 **REPORT NO.** 84-09

TITLE: An Engineering Proposal for a Sonde to Measure Ice Jam Thicknesses

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REASON FOR REPORT: In discussion with Dr. S. Beltaos it was agreed that the challenge to measure ice thickness in a spring breakup jam was difficult to meet but important because ice thickness is a key parameter in dealing with ice jams both theoretically and practically.

FILE/STUDY NO:

1.0 INTRODUCTION

Ice jams in the spring breakup period are economically important because of their potential to do damage through flooding of private and public property. Recent studies have worked toward understanding the mechanics and formations of ice jams that are in equilibrium. (Beltaos, 1983, Shen et al., 1982). Some jams are not in equilibrium when they are surveyed because the techniques are slow and cumbersome (drilling holes in the ice) or costly (operating out of helicopters which have limited availability). Furthermore, some areas of a jam, such as the toe, are not well understood, because of their complex shapes.

Without knowing the actual thickness of the ice cover over the length of the jam it is difficult to estimate the hydraulic head losses through the jam. The rate of progress of the theory and models of jams will be hampered unless verifications with field data are made. If the theory is to be extended into other zones of jams like the head and the toe, or extended into describing the dynamics of jam formation and breakup, then some means of profiling the jam thickness must be developed.

This note describes a proposal to produce a device that travels under the ice jam with the river current and signals its depth to shore stations along the bank. The risk of loss is very high so the proposed device must be low cost and expendable.

Interest in this proposal has been shown by Dr. S. Beltaos, Hydraulics Res. Div., NWRI, Burlington, and Mr. T. Prowse, Surface Water Division, NHRI, Ottawa. Both would like to see what can be achieved by this technique.

2.0 TECHNICAL AND OPERATIONAL REQUIREMENTS FOR THE SYSTEM

Little is known about the ice thickness of spring breakup jams. This has hampered the development of more accurate models to predict the stage (height) that a jam would reach for a given discharge and a given zone in a river. Because jams are unpredictable occurrences and the observation of them is costly and time consuming, a portable, expendable profiling device could enhance the information gathered in each survey.

In some cases, jams are dynamited to break them up before they cause severe flooding. It would be helpful to know what the "structure" of the toe is like and whether the jam is unstable enough to break; otherwise, the operation could be futile, costly or dangerous. A profiling device could give some indication of the vertical structure which might be useful in making decisions about dynamiting.

A list of the operational requirements would be as follows:

1. The system must be reasonably simple to deploy and operate.
2. It must not be a hazard or nuisance to the operators or the adjacent land owners.
3. It must be practical in cost considerations.
4. It must produce data that is relevant and accurate enough for the needs at the time.
5. It must be useful for surveying jams over much of Canada.

It is obvious that the tracking subsystem must be as inexpensive as possible, at least until the principle and usefulness of the technique are evaluated.

3.0 DESIGN PROPOSAL

In considering the various methods for measuring ice thickness, a few possibilities were explored.

One method would use sonar techniques where a hydrophone would be lowered to the ice from a helicopter. The echo patterns would contain information about the ice thickness. Unfortunately, the reverberations from the ice and water pockets hamper the interpretaion of the echoes. The use of a helicopter is expensive and not readily available to ice jam field parties.

Radar reflections from ice surfaces are also under study in some areas and are considered successful for hard, dry ice cover (Watson 1982). If the ice is wet the performance drops considerably and is considered unuseable when dealing with broken ice and water situations.

Recently the laser has been developed to produce a bathimeter for relatively shallow water. With the techniques available to civilian ranging systems, it appears that this mode of detecting ice thickness will not be available for some years. The problem centres on detecting very fast light pulses of extremely low energies. Therefore, ice jam thickness measurements are not possible with laser bathimetry (Casey 1984).

The concept proposed here is to develop a specialized expendable profiling float which would be carried under the ice cover by the currents. The configuration of this float will be established by model tests and field experiments. The float will be buoyant enough to support its payload and keep itself on the underside of the ice. It will incorporate a drogue or shaped appendage such that should the float become trapped in an under surface pocket, a downward force will be generated to pull the float free.

An existing inexpensive fish tracking system will be applied to the float. It uses a small radio transmitter tag and a loop receiving antenna for location tracking. The radio tag would be fixed to the float, and would incorporate a pressure sensor so that the depth of the tag could be determined from the tag pulse repetition rate.

Fig. 1 depicts the profiler travelling under the ice cover. The pressure datum is the atmospheric pressure at the water surface at the head of the jam and at the free water surface in the jam itself. The pressure transducer, providing there are no extraneous influences, will measure the pressure of water from the free surfce to the transducer's sensing element. The possible extraneous influences will be discussed in the next section. Once the absolute pressure P2 from the transducer is known, and the atmospheric pressure, P1, is subtracted, the depth of water from the free surface to the transducer can be calculated with the density of water at 0°C, w. This result is corrected for the transducer's displacement, d and the specific gravity of ice, S_i. The formula is $t = \{[(P2 - P1)/w]-d\}/S_i$. This is the measurement, t, defined by Beltaos (1983).

The location of the radio tag is monitored with two or more radio direction finders which triangulate onto the tag from known locations on the river banks. From the locations of the tag over time, some information on the flow patterns under the ice may be gathered.

4.0 ESTIMATES FOR THE APPLICATION

The Bernoulli theorem (Giles 1962) describes three components of energy in the water that might influence the radio tag as it passes under the ice cover. One is the pressure head of the water that is contained in conduits, the second is the dynamic head that is caused by motion of the water under the ice cover and around the sensor, and the third is the static head that is caused by the weight of water above the tag.

With regard to the first component, the common assumption for a breakup jam is that the water is free to flow and reach equilibrium through the ice cover because the ice is unconsolidated. This assumption should be checked in the field because of the enormous pressures in a jam which could give zones of reconsolidation and low porosity. However, for the purposes of this proposal, the assumption will be continued, therefore pressures due to containment are considered negligible.

With regard to the second component, the range of mean speeds of the water under the ice jams studied by Beltaos was 0.39 to 0.88 m/s. The Reynolds numbers were around 10^6 which indicates fully turbulent water. From this the dynamic head was estimated to range between 7 to 39 mm which is insignificant compared to the ice thicknesses that are expected, such as 0.7 to 4.4 metres. Since the sonde travels with the water when it is operating correctly, the dynamic effects on the sensor should be negligible. This may not be so if the sonde becomes trapped but by then the tracking system will give an indication that questionable data are being received.

If the sonde is successful in staying on the underside of the ice, then the pressure it reports is directly related to the ice thickness when the atmospheric pressure is subtracted. The atmospheric pressure is measured at the time the sonde is deployed.

An estimate of the size of traps that the sonde might encounter can be obtained from Equation 7 of Beltaos. His Figure 4 shows that 84% of the amplitudes of the undulations and projections of the underside would not exceed 1.25 metres. Therefore, an appendage 2 metres below the float would still experience the flow forces below the ice and pull the float down free from the pockets.

For the river jams reported by Beltaos (1983), the drag forces developed by a disc with a diameter of one metre will range from 60 to 300 newtons when the disc is normal to the flow. Using neutral density materials such as plastic, a float having a 4.2 litre displacement can support the disc with a net upward force of 60 N. When the float is impeded, the disc will turn and develop forces to accelerate the float or, in extreme cases, pull the float out of a trap. If the sonde should encounter an obstruction, such as a hanging dam there is the chance that the disc may be carried downward too far with the streaming around the obstruction. The vertical acceleration due to buoyancy of the sonde is calculated to be 0.23 m/s^2. Therefore, from zero vertical speed the sonde would take 3 seconds to rise the first metre. There is also the risk that both the float and the disc may be trapped in a pocket or vent. Therefore, the cost of the sonde must be low and the radio must not interfere with other sondes being used in the area.

In the early stages of development the shore stations should be kept as simple and inexpensive as possible. The simplest radio locating system is a pair of direction finders set up in known locations. The triangulation from these will give a position estimate for the sonde. In addition, a third receiver is used with a chart recorder to record the telemetered depth readings versus time.

The technique is to set up a baseline that runs parallel to the river some distance back from the jam, so that good crossing angles are possible to keep the uncertainty down on the position fixing. Appendix I deals with the problem more thoroughly. At each end of the baseline is a radio direction finder. Two operators would be stationed at the "master station". One operates the direction finder and the other operates a plane table and the depth recorder. The other station would have one operator to operate the direction finder and signal the time for each measurement to be taken. Each time a measurement is taken a mark is put on the pressure recorder, the two bearings are fixed and plotted on the plane table along with the time. If the river has been surveyed aerially, then the plotting can be done on an air photograph; otherwise, a map or a special plane table survey of the site would have to be used.

The angular error expected for this technique is 3° (Admiralty, 1963; Sonnenberg, 1970). Some expectations are as poor as 5 to 10° (Eaton, 1975) but that seems extreme compared to the others. One adverse and unpredictable problem with radio triangulation is the radio reflections that can be received from obstacles like power wires and river banks. This is noticeable at 200 MHz but has not appeared to be a problem at 40 MHz (Sundet, 1984) except in a bedrock canyon in Alaska where fish tags were difficult to locate from an aircraft (possibly by absorption of the signal rather than reflection). In the developmental stages of this technique, the effects of reflection can be checked by visually tracking and radio tracking the tag as it is carried along the banks of representative rivers. If there is a problem, then at each deployment site a sonde will have to be transported along the bank while visual and radio tracking is done. From this, a set of corrections would be compiled for application to the bearings from the actual run.

One tracking system (Harrison, 1975) is specifically designed for tracking an oil spill. He anticipated an angular resolution of 0.06°. This system may well use a large array for an antenna. For the purposes of this proposal, the antenna is kept simple until the usefulness of accurate positioning is known.

There are other improvements that can be made to the tracking system such as analyzing the relative time of arrival amongst three stations having omnidirectional antennas. Each station pair produce a locus passing through the sonde's position. The method lends itself to automatic tracking processes.

The final accuracy of position readings will be set once the behaviour of the sonde under the ice is better known. For example, if the jam is quite non-uniform and the sonde accelerates in all three dimensions, the rate of acceleration may be an important consideration in which case, the positional accuracy must be much better than what is proposed here, ±50 metres.

The radio range for the tags is highly dependent upon water conductivity. The advertised ranges for Smith-Root radio tags is 1/4 to 1/2 a mile in water conductivity ranging between 50 and 250 μs/cm. This is confirmed by Sundet. That conductivity is about the range of many of Canada's rivers, except for the east coast and prairie rivers which will reduce the range signficantly. The range can be regained or extended if the life of the tag is reduced to a short period and the power diverted into producing a stronger radio signal. As well, the present transmitting antenna is limited to 18 cm. Lengthening the antenna by some ratio will increase the propagation considerably as shown by the equation (Westman, 1961)

$$G = \frac{\sin^2\left(\frac{\pi r H}{\lambda}\right)\sin\left(\frac{2\pi h}{\lambda}\right)}{\sin^2\left(\frac{2\pi r H}{\lambda}\right)\sin\left(\frac{\pi h}{\lambda}\right)} \quad \text{for } h < \frac{\lambda}{4}$$

where G is the relative gain in the electric field,
r is the new to old antenna length ratio,
λ is the radio wavelength, metres,
h is the old antenna length, metres.

Figure 2 is a plot of this function which shows that the radio range can be increased by 12 for an increase of the antenna from 18 cm to 180 cm. Because the tags are meant to last several months in fish tracking studies, the transmitter gives out the minimal energy per pulse. In the case of river ice studies a 24-hour life of the tag could allow the range to be increased another tenfold plus an increase in pulse repetition rate of three to five fold to minimize the direction finding problems with respect to aural discrimination of sound levels. Assuming an inverse relationship between radio range and conductivity and direct relationships between radio range and electric field intensity, it would seem feasible to operate ten metres down in water having conductivities of more than 500 μS/cm.

Additional triangulation stations may be added along the jam site to survey long jams completely. At least one more receiver and antenna would be required.

5.0 COST AND LOGISTICS CONSIDERATIONS

An unmodified fish tag from Smith-Root costs $200 U.S. (about $300 Canadian), see Appendix II. It is estimated that the modifications which include changing the antenna, the radio frequency power and adding the pressure-dependent modulation circuits will add another $150 Canadian to the price. It is estimated that about ten tags will be consumed per jam until the nature of jams is better understood. The first ten tags will be double the cost since they will be specials (Christianson, 1984).

The receiver and search equipment total about $7200 Canadian (3 receivers, 3 antennas, 3 battery packs) for two stations. In addition, a special audio, pulse-rate demodulation and recorder package will be produced to monitor the depths. This is estimated to be $4000 Canadian unless a ready-made package can be found in the meantime. It is assumed that transits and a plane table can be rented or borrowed.

A four or five man team is required to deploy and operate the sondes and equipment. This amounts to about $500 per day on site, not including salary and overhead costs.

The equipment is portable and not a problem with regard to bulk and mass. The equipment is moderately sophisticated to operate in that a baseline has to be surveyed in place and familiarity must be gained with operating a direction finder to its most accurate capabilities. Therefore, a good prefield training exercise must be carried out in open water conditions to minimize the setup times and maximize the number of fixes per actual run. At the same time, the accuracy expectations of the system can be verified with visual fixes using an extra two men on transits.

Preceding the exercise, effort will be spent in purchasing and preparing the equipment to ensure that it is fully operational.

As well, to minimize the chances of failure, before any items are purchased, a scale model of the sonde and the anticipated jam conditions must be constructed and tested in a laboratory flume. At this stage of planning it is estimated that the project will consume a person-year including the modellers and the field team. About $11,000 to $12,000 capital are required and about $10,000 operating costs are anticipated depending upon the location of the jam sites to be studied.

6.0 CONCLUSION

There seems to be no self-contained economical way to measure ice jam thickness from end to end except to send some device under the jam. The least costly device is an expendable sonde that measures pressure as it passes under the jam. The interfering pressures such as containment and hydrodynamic are assumed or estimated to be negligable compared to hydrostatic head that the sonde experiences as it passes under the ice.

Equipment already exists which has been used under ice to study the behaviour and migration of fish. With some modifications by the vendor this equipment can be adapted to the project.

An experienced team is required in the first tracking system because the tracking is to be done manually. If the information is useful for other applications, such as jam breaking, then more sophisticated equipment can be developed to ease the burden of the operators.

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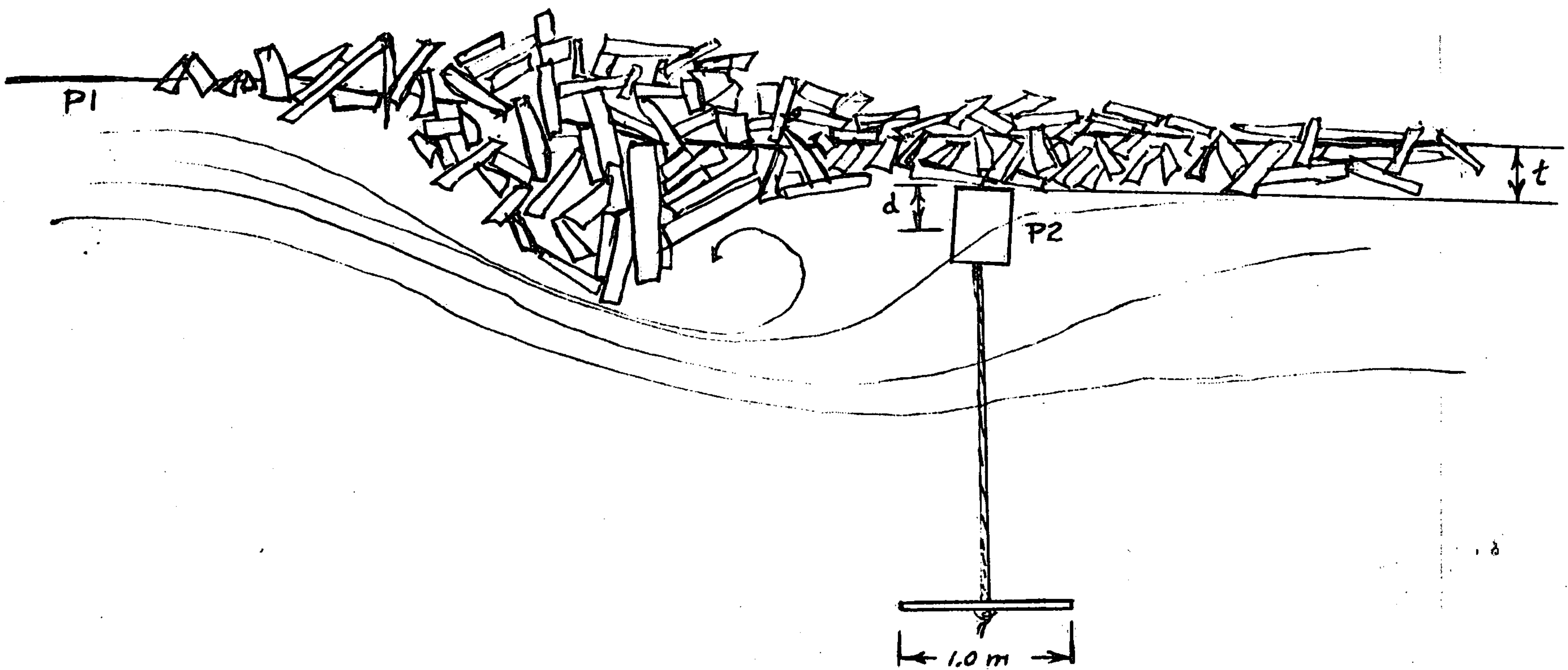
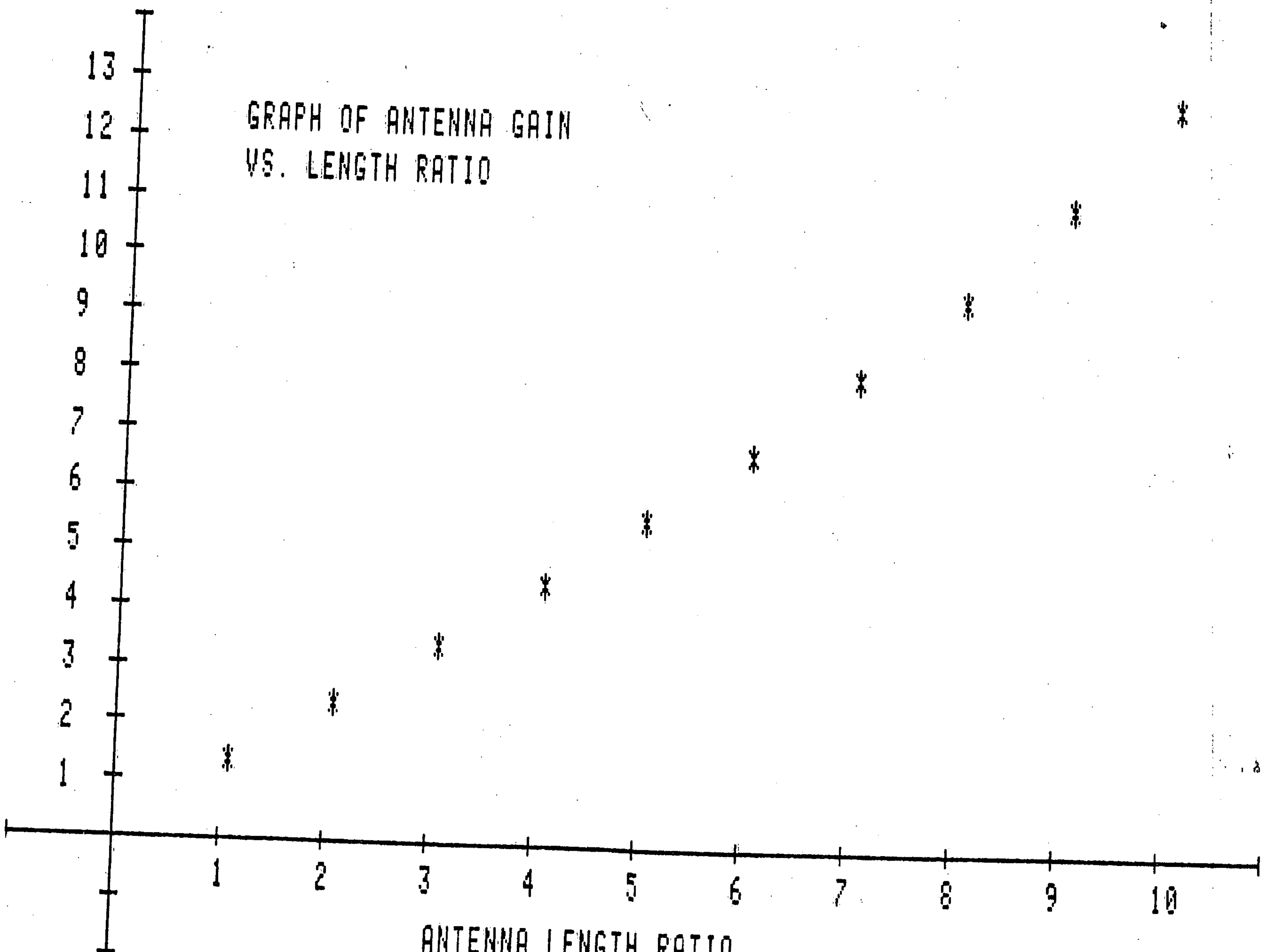
FIGURE 1. Sketch of Profiler Under River Ice Cover.



NOTE: Configuration of profiler to be established by flume model test and field experiments.


GRAPH OF ANTENNA GAIN
VS. LENGTH RATIO
13
12
11
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9
8
7
6
5
4
3
2
1
1
2
3
4
5
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7
8
9
10
ANTENNA LENGTH RATIO

FIGURE 2.

APPENDIX I

Radio Triangulation Accuracies

APPENDIX I

Given the problem of triangulating on a sonde with a pair of radio direction finders, having an error of $\pm\alpha$ degrees, what is the optimum setup for the baseline of length L and the offset of length y, to cover the maximum area of the river to within an accuracy radius of length r times y?

From Figure AI-1 a set of triangles can be trigonometrically analysed to give

$$x_7 = \frac{L \sin(\theta_2 - \alpha) \cos(\theta_1 + \alpha)}{\sin(180 - \theta_1 - \theta_2)}$$

$$x_8 = \frac{L \sin(\theta_1 - \alpha) \cos(\theta_2 + \alpha)}{\sin(180 - \theta_1 - \theta_2)}$$

$$y_3 = \frac{L \sin(\theta_1 - \alpha) \cos(\theta_2 + \alpha)}{\sin(180 - \theta_1 - \theta_2 + 2\alpha)}$$

$$y_5 = \frac{L \sin(\theta_1 - \alpha) \cos(\theta_2 + \alpha)}{\sin(180 - \theta_1 - \theta_2 - 2\alpha)}$$

where α is the angular error of the direction finder, i.e.,

$$\theta_5 - \theta_1;\ \theta_1 - \theta_3;\ \theta_6 - \theta_2;\ \theta_2 - \theta_4 = \alpha;$$

and

$$\theta_2 = \tan^{-1}\left(\frac{\tan\theta_1}{n\tan\theta_1 - 1}\right) \text{ for } (m \tan\theta - 1) > 0;$$

$$\theta_2 = 180 + \tan^{-1}\left(\frac{\tan\theta_1}{n\tan\theta_1 - 1}\right) \text{ for } (m \tan\theta - 1) < 0;$$

where n = L/y the baseline to offset lengths ratio.

When the values of y_3, y_5, x_7 and x_8 are known an error factor versus θ_1, y, ∝ and n may be plotted. To simplify the interpretation y_1 is set to unity. The angle ∝ is set to 3° according to the expected errors of radio triangulation. The resulting graph is seen in Figure AI-2. The numbers near the curves are the values of the baseline-to-offset distance ratio, m. The error factor in the ordinate is computed as:

$$r = \left[\left(\frac{L - x_7 - x_8}{2}\right)^2 + \left(\frac{y_5 - y_3}{2}\right)^2\right]$$

which can be interpreted as the error radius per unit offset from the baseline as a function of the baseline length and the lefthand bearing to the point of interest. The units for r are metres/metre offset. This is a representative radius for the area of uncertainty. It is not exact because the area is actually an irregular diamond as can be seen in Figure AI-1. A more exact treatment is possible by actually computing the area from the x and y coordinates of the points of the diamond but for the purpose of expediting this proposal, the full development was not done.

Figure AI-2 can be used in three ways to give an estimation of the triangulation errors that can be expected along the river's course. In one way the figure can be used to set up a practical baseline where access to the river banks are unlimited. In another way it may be used to set up a practical baseline length when the access is limited to a roadway running parallel to the river. Finally, it may be used to estimate the errors over the working zone given the baseline that was used. The three procedures are given below. With extra work they could be automated somewhat with microcomputer programming.

Method I Setup in an Unlimited Area.

1. Choose an error radius that appears acceptable, such as 50 metres.
2. Assume a working error factor that allows a reasonable range of lefthand bearings in Figure AI-2, such as 0.25.
3. Calculate the maximum offset of the baseline from the far bank (y_{max} = 50/0.25 = 200 m).
4. Calculate the baseline length to be three times the offset that is 600 m because a ratio of 3 gives a low error factor and a good range of bearings.
5. Set one turning point for the end of the baseline at the offset distance and fix this to some point on the map by reference to local features.
6. Set the second turning point relative to the first at approximately 600 metres and fix its location on the map by reference to local features. Measure its length, L.
7. Calculate the baseline-to-offset distance ratio, or $L/y_{max} \approx 3.2$ say.

8. Turn off the maximum bearing from the baseline that can be used without exceeding the error factor (0.25). In the example this is 108° in Figure AI-2. Do this for the other turning point in mirror image.
9. Measure the offset to the near bank which is y_{min} (say 100 m).
10. Calculate the error factor to keep the error radius to 50 metres ($E = 50/y_{min} = 0.5$).
11. Calculate the baseline-to-offset ratio (6.4).
12. Find and turn off the maximum bearings as before.

The area between where the rays strike their respective banks will have positional errors no greater than a circle of 50 metres radius. In this example, the working length along the river is not less than 700 metres.

Method II Setup where the Area is Limited

In the case where only a road may be used that parallels the river, the following method is used to obtain a reasonable working zone. In this case, say the offset from the far bank is 300 m.

1. Compute the error factor to hold the radius of the error circle to an acceptable level, say 50 metres. Therefore $E = 50/y_{max} = 0.166$.
2. Since the only curve in Figure AI-2 that falls below 0.166 is the one with a baseline-to-offset ratio of 1.6, choose this to compute the baseline length (300 x 1.6 = 480 metres).
3. Establish the two turning points on the map using references to local features.
4. Find the maximum bearing to stay within the error factor of 0.166 (90° in this example) and turn it off at each end of the baseline.
5. Measure the offset of the baseline from the near bank (say y_{min} = 150 m).

6. Calculate the error factor (E = 50/150 = 0.33).
7. Calculate the baseline-to-offset ratio (380/150 = 2.53).
8. Find the maximum angles (120°) as before and turn it off at each end of the baseline.

In this example the minimum working length along the river is 475 metres.

Method III Calculating Error Circles over Working Length

Once the baseline is established and the tracking completed, it is useful to calculate the radii of the error circles over the length of the river that radio fixes were made. A more direct method would be to draw the error rays with a protractor to define the diamond of uncertainty; however, this method is given for completeness.

1. Measure the offset to the first position on the track by scaling off the map perpendicularly from a projection of the baseline (say 250 m).
2. Calculate the baseline-to-offset ratio (say 480/250 ≈ 1.5).
3. Measure the maximum bearing from the baseline (say 120°).
4. From Figure AI-2 find the error factor that corresponds to an angle of 120° and a ratio of 1.5 (about 0.22 by interpolation).
5. Calulate the error radius by multiplying offset by the factor (radius = 55 m).
6. Repeat as often as necessary to define a set of circles to represent the expected errors along the track.

In this example the error circle shrinks to a 37.5 metre radius at a bearing of 50° from the baseline.

These methods are useful in setting up the baseline to suit the topography near the jam and to determine what errors of the triangulation can be expected along the track.

The information on the speeds of the sonde is limited by the ability to fix the sonde's position from time to time. Over a stretch of 500 metres of an ice jam it appears possible to estimate the mean speed to within ±10%. For shorter tracks the speed error is proportional to the ratio of the radius of the error circle divided by the length of the portion of the track. Tracks as short as 75 to 100 metres could be used to estimate the location of high speed zones versus low speed zones, if an error of ±50% is acceptable.

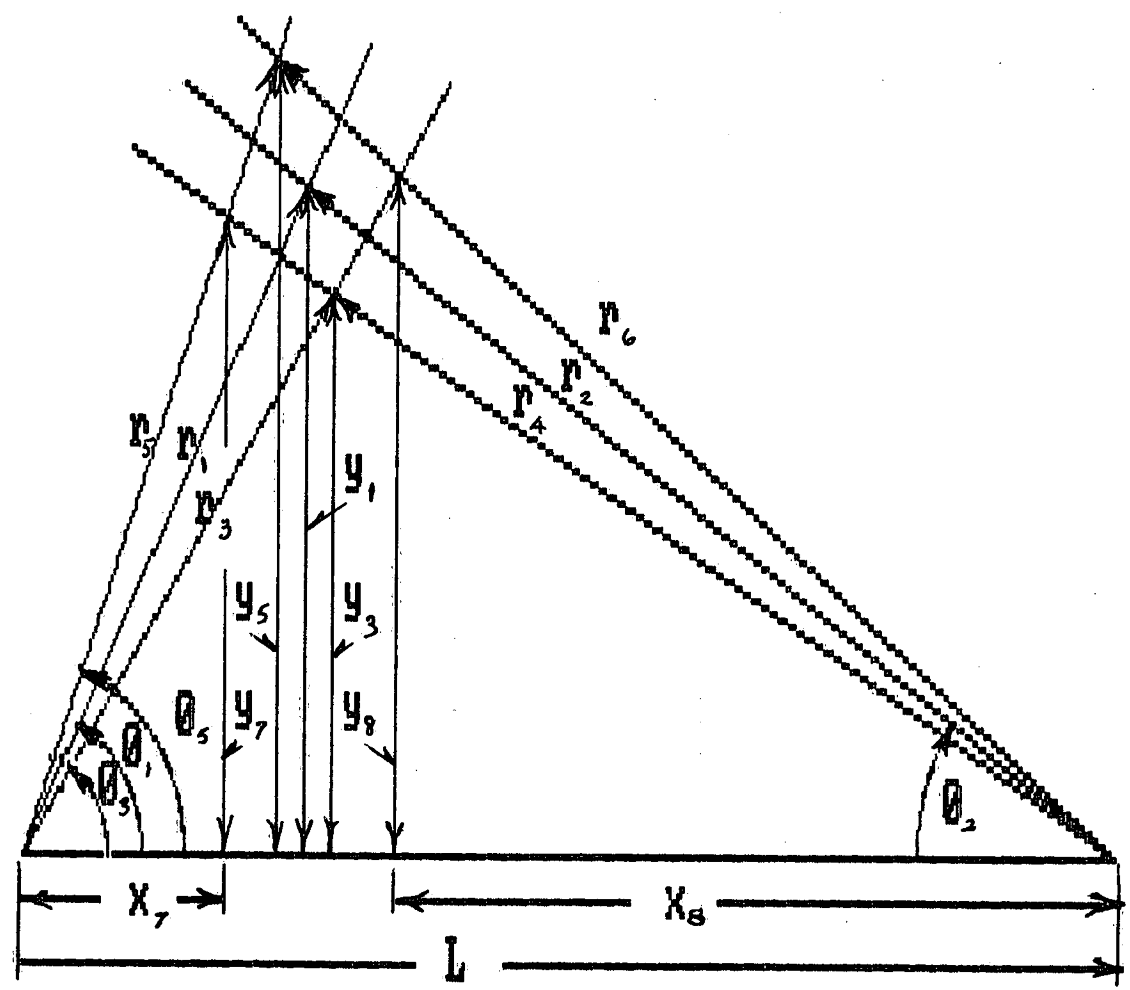


FIGURE A1 **RADIO TRIANGULATION DIAGRAM**

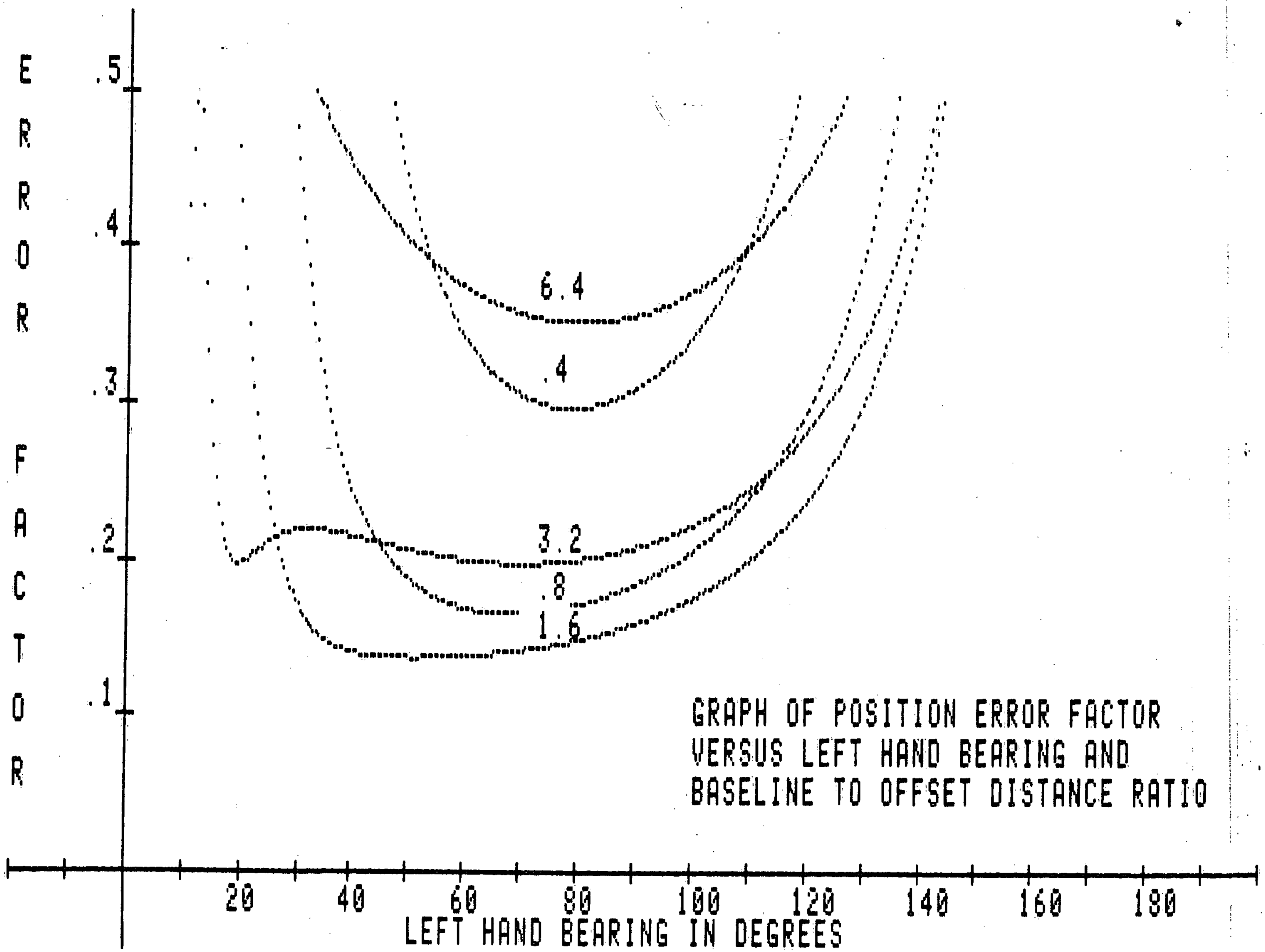

ERROR FACTOR
.5
.4
.3
.2
.1
6.4
.4
3.2
.8
1.6
20
40
60
80
100
120
140
160
180
LEFT HAND BEARING IN DEGREES
GRAPH OF POSITION ERROR FACTOR
VERSUS LEFT HAND BEARING AND
BASELINE TO OFFSET DISTANCE RATIO

FIGURE A1-2

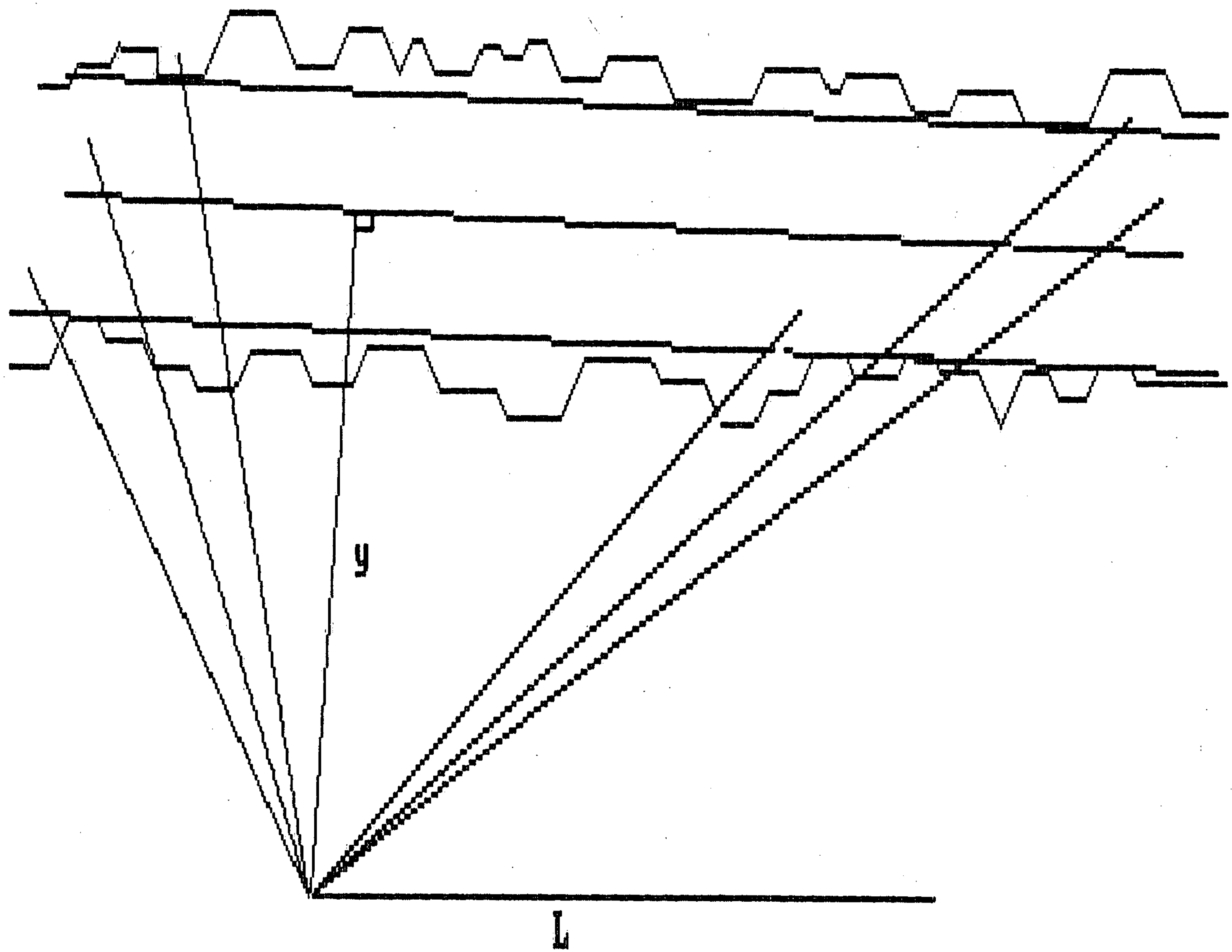


FIGURE A1-3 DIAGRAM OF BASELINE AND WORKING ANGLES

APPENDIX II

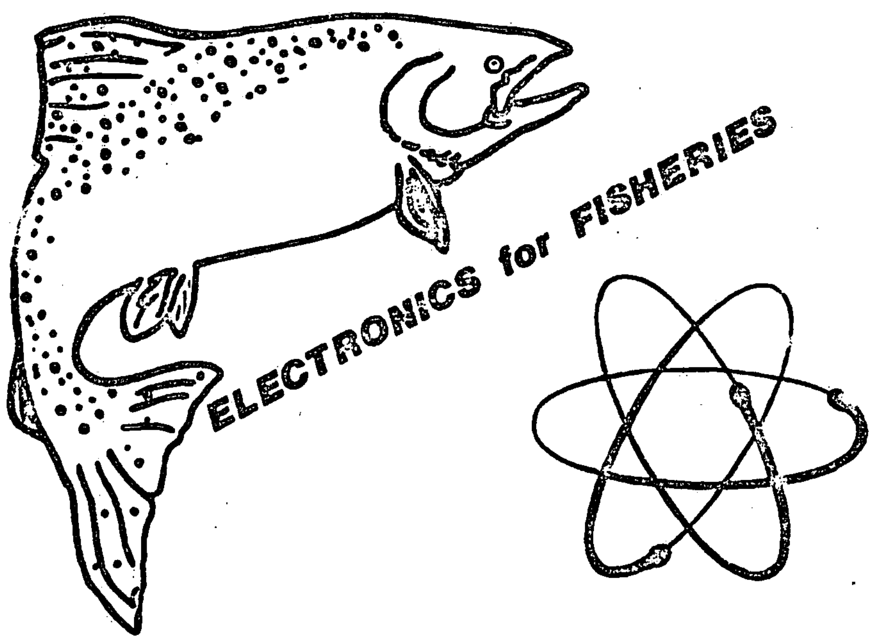
Radio Fish Tag Brochure

SMITH-ROOT INCORPORATED

14014 N.E. SALMON CREEK AVENUE • VANCOUVER, WASHINGTON 98665 • 1-206-573-0202

RADIO TRACKING EQUIPMENT

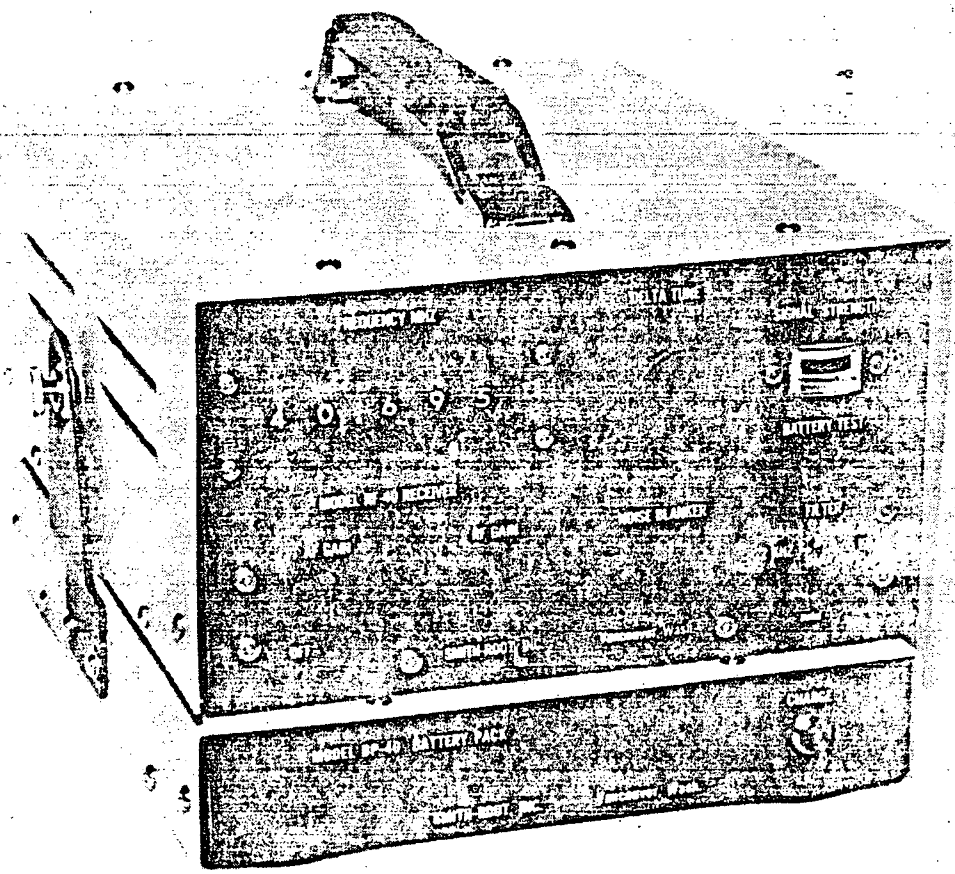
FOR FISHERIES AND WILDLIFE RESEARCH



THE LEADER IN ELECTRONIC EQUIPMENT

SMITH-ROOT, INCORPORATED

14014 N.E. Salmon Creek Avenue, Vancouver, Washington 98665 — 206-573-0202



SMITH-ROOT RF-40 RADIOTELEMETRY ANIMAL TRACKING RECEIVER WITH "SYNTHESIZED DIGITAL FREQUENCY CONTROL"

The Smith-Root RF-40 is a state-of-the-art tracking receiver with digitally synthesized frequency control. Its exceptionally high sensitivity, crystal filter, and the ability to receive 1000 discrete channels make the RF-40 the finest receiver available.

Each 1 MHz SUB-BAND has 1000 channels in 1 KHz increments. A delta-tune control of plus or minus 500 Hz provides continuous frequency coverage.

RF-40 SPECIFICATIONS:

Frequency coverage standard..........................40.000 to 40.999 MHZ *
Frequency resolution.........................continuous 1 KHz steps with
+/- 0.5 KHz delta-tune
Frequency accuracy.......................within 100 Hz, 0 to 40 degrees C
Frequency readout...............................3 digit direct readout
Sensitivity...........................-143 DBM with 500 Hz bandwidth
Dynamic range...80 db
RF gain control...80 db
Antenna imput impedance..............................50 ohm unbalance
Selectivity............................2.1 or 0.5 KHz switch selectable
Image rejection...................................greater than 60 db
Spurious and harmonic superssion......................greater than 60 db
Spurious emissions..........................Better than FCC requirements
Audio output....................................1.5 watts at 1000 Hz
Audio output.................................Internal 8 ohm speaker with
phone jack for earphones
Power requirements....................external 12 volt DC, negative ground
Dimensions...............................8" wide x 4" high x 10" deep
20.4 cm wide x 10.2 cm high x 25.4 cm deep
Weight.....................................6 1/2 pounds, 2.4 kilograms

* Other frequencies available to 200 MHz

Specifications subject to change without notice

The. RF-40 employs 4 tuned circuits in the RF section and the I-F amplifier incorporates two six-pole crystal lattice filters which almost completely eliminate receiver image and supurious response problems. The first crystal filter has a 2.1 KHz bandwidth for general coverage. The second filter has a 0.5 KH bandwidth for close channel spacing and is especially useful in noisy areas. The I-F filters are front panel switch selectable.

Receiver intermodulation and cross modulation performance are enhanced through the use of dual-gate MOSFET's in all critial RF amplifier and mixer stages. Strong signal handling capability is expanded by the RF gain control which is capable of reducing signal levels in excess of 80 db. This RF gain control, combined with dual-gate MOSFET'S in all stages ahead of the crystal filter, allow the Smith-Root RF-40 to deliver the maximum dynamic range while maintaining the lowest noise figure attainable in a tracking receiver today.

Optional converters are available to cover frequencies up to 200 MHz. Frequency selection is provided by front panel lever-wheel switches which provided direct digital read-out of the selected frequency. The frequency control is provided by a state-of-the-art frequency synthesizer, which gives crystal frequency, accuracy, and stability to any frequency selected.

The RF-40 operates from a 12 volt DC source, negative ground. The power input is polarity protected to prevent damage to the receiver circuitry in the event of reverse polarity connection. An optional battery-pack with a built-in charger is available. The battery-pack charger operates from 120 volts, 60 Hz, AC. Battery life with the optional battery-pack is greater than 24 hours.

The audio amplifier frequency response is shaped for maximum intelligibilty of the received signal.

The front panel meter displays relative signal strength and also serves as the battery condition indicator when the battery test push-button is depressed.

The RF-40 has an extremely effective digital noise blanker which is front panel adjustable. The noise blanker allows full sensitivity settings under the most adverse noise conditions, such as high voltage power line, troublesome generator, and ignition noise that most receivers are unable to contend with.

LA-40 DIRECTIONAL LOOP ANTENNA

The Model LA-40 antenna is a compact directional loop antenna designed for taking radio bearings of fish or animal tag transmitters. Its compact size, coupled with its rugged construction, make the LA-40 an ideal field tracking antenna. When used with the Smith-Root RF-40 Tracking Receiver, the range is about 1/2 mile for a transmitter 10 feet under water with a conductivity of 100 micromhos. In air, the range would be about 1 mile on level terrain.

The construction is of laminated fiberglass, bonded to protect the printed circuit antenna elements. Printed circuit electrostatic shielding is provided to help eliminate unwanted interference and provide deeper null patterns for accurate bearings. Connections to the antenna and the tuning capacitor are housed in molded weatherproof junction boxes.

The tuning provided can be adjusted over the range of 30 to 50 MHz. This matches the tuning range of the RF-40 receiver for frequency compatibility.

SPECIFICATIONS:

Tuning Range	30-50 MHz
Forward Sensitivity	-0.4 DB (Ref. Dipole)
Null Sensitivity	-20. DB Min.
Pattern Symmetry	plus or minus 5%
Matching Impedence	50 Ohms Nominal
Construction	Fiberglass Laminate
Weight	3 Pounds
Loop Dimensions	13 1/2" X 14 1/2"
Handle Dimensions	3/4" Dia. - 26" Long (with Handgrip)

Specifications subject to change without notice.

P-40 RADIO FISH TRACKING TRANSMITTER

The P-40 RF fish transmitter is used to track the movements of aquatic animals and fish. It is suitable for internal or external attachment.

The P-40 emits RF signals in the frequency range of 40.600 to 40.690 MHz. Within this frequency band, 10 channels are usually employed with 10 KHz spacing between channels. Other frequencies between 30 and 50 MHz can also be supplied upon customer request. The frequency band between 30 and 50 MHz is a good selection for fish tagging as it offers a good compromise between "high frequency" attenuation through water and "low frequency" large transmitter size limitations.

Maximum range of reception depends greatly upon the water medium. For example, water which exhibits a conductivity of about 10 to 50 micromhos will usually give a range of 1/2 to 1 mile with a 3 element beam antenna into a RF-40 receiver. In the range of 50 to 250 micromhos, a distance of 1/4 to 1/2 mile can be expected. These figures are based on a transmitter at a depth of 10 feet.

The pulsed output signal, which allows individual transmitters to be identified, has a pulse rate or "code" of from 0.5 to 4 pulses per second. Normally, a random scattering of codes will be sent to allow use of more than one transmitter on the same channel at the same time.

The transmitters are normally placed in the fish's stomach with a 7" antenna wire attached to the roof of the fish's mouth. With some species of fish, external placement may be required due to size or inability to contend with stomach tag placement. Transmitters are also available without external antennas, although some loss of range may be expected.

The transmitters, with fresh batteries installed, are sealed, pressure tested at the factory and are ready for use when received. The transmitters are activated by removing a biasing magnet from outside the transmitter. Mercury or lithium batteries are used which provide the greatest amount of energy per unit volume and weight of any battery type available. The batteries will maintain about 90% life for up to 1 year if stored within a temperature range of from 0 degrees to 10 degrees C.

TRANSMITTER SPECIFICATIONS

P-40 - 350M-9V

Battery Type..9V - Mercury 350 MAH
Useful life..............................45 days typical @ 2% duty cycles
Range (10 - 50 micromhos water)......................1.2 to 1.6 KM typical
Range (50 - 250 micromhos water)....................0.5 to 1.2 KM typical
Body Types available (see diagram)............................Type A body
Weight..45.2 Grams
Weight in Water...18.4 Grams
Low Temperature Operation.........................70% output @ 0 degrees C

P-40 - 150M-6V

Battery Type..6V - Mercury 150 MAH
Useful Life..............................70 days typical @ 1% duty cycle
Body Types available (see diagram)......................Type C & D Bodies
Weight (C Type body)...15 Grams
Weight in Water (C Type body).....................................4 Grams
Weight (D Type body)...13 Grams
Weight in Water (D Type body).....................................6 Grams
Low Temperature Operation.........................70% output @ 0 degrees C

P-40 - 1000L-6V

Battery Type..6V - Lithium 1000 MAH
Useful Life..............................180 days typical @ 2% duty cycles
Body Types available (see diagram)............................Type A body
Weight..37 Grams
Weight in Water...10 Grams
Low Temperature Operation.........................95% output @ 0 degrees C.

P-40 - 500L-3V

Battery Type..3V - Lithium 500 MAH
Useful Life..............................150 days typical @ 1.5% duty cycle
Body Types available (see diagram)............................Type C Body
Weight..13 Grams
Weight in Water...2.6 Grams
Low Temperature Operation.........................95% output @ 0 degrees C.

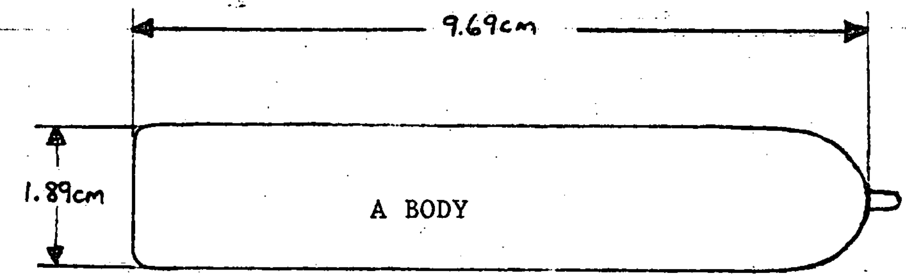
P-40 - 500L-6V

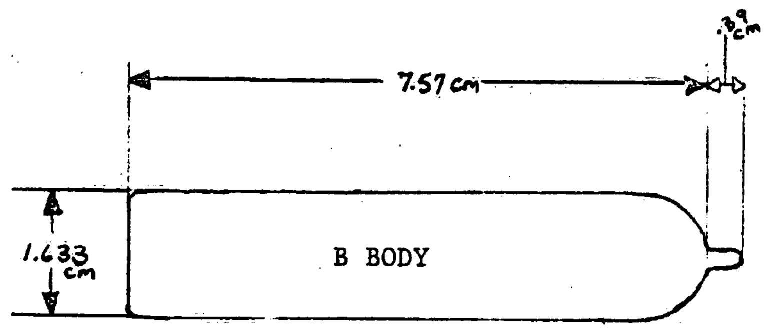
Battery Type..6V - Lithium 500 MAH
Useful Life..............................90 days typical @ 2% duty cycle
Body Type available (see diagram)............................Type B Body
Weight..21.5 Grams
Weight in Water...5.2 Grams
Low Temperature Operation.........................95% output @ 0 degrees C.

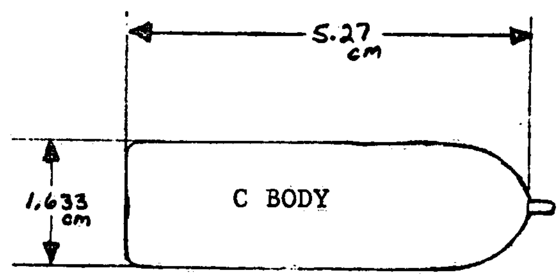
NOTE: Transmitters are pressure tested at 44 lbs/sq. in. - equivalent to submersion in 100ft. of water.

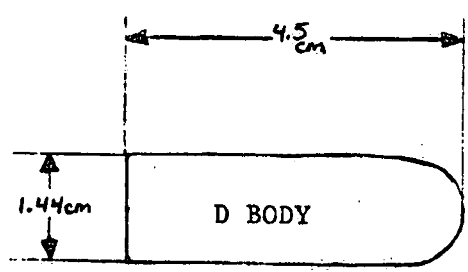
Specifications subject to change without notice.

BODY SPECIFICATIONS









Special Order -
Prices on Request

RF TRACKING EQUIPMENT PRICE LIST

RF-40 Synthesized Tracking Receiver..........................$1,860.00
SR-40 Search Receiver, 10 Channel.............................1,975.00
BP-40 Rechargeable Battery Pack.................................181.00
OM-40 Omni-Directional Whip Antenna..............................67.00
LA-40 Direction Finding Loop Antenna............................180.00
AD-40 Adcock Directional Array..................................402.00
YA-40 3 Element Yagi Antenna....................................260.00

FDL-10ER 10 Channel Field Data Logger including:...............5,000.00
SR-40-10C Receiver
Battery
1 Roll of Paper

FDL-10ER 10 Channel Field Data Logger less SR-40-10C...........3,000.00
SR-40-10C SR-40 modified to work with FDL-10ER.................2,475.00

FDL-15ER 15 Channel Field Data Logger including:...............6,000.00
SR-40-15C Receiver
Battery
1 Roll of Paper

FDL-15ER 15 Channel Field Data Logger less SR-40-15C...........3,500.00
SR-40-15C SR-40 modified to work with FDL-15ER.................2,975.00

Battery for FDL-10ER or FDL-15ER, 28 AH sealed Rechargeable.......99.00
External Battery for FDL-10ER or FDL-15ER........................75.00
(40 AH with marine case)
Paper for FDL-10ER or FDL-15ER...................................12.00

P-40 - 350M-9V TRANSMITTER (Mercury batteries - 45 day life)
P-40 - 150M-6V TRANSMITTER (Mercury batteries - 70 day life)

Quantity	
1 - 24	181.00 each
25 - 49	164.00 each
50 - 99	153.00 each
100 - 249	147.00 each

P-40 - 500L-6V & 3V TRANSMITTERS (Lithium Batteries - 90 & 150 day life)

1 - 24	186.00 each
25 - 49	167.00 each
50 - 99	154.00 each
100 - 249	152.00 each

P-40 - 1000L TRANSMITTER (Lithium Batteries - 180 day life)

1 - 24	193.00 each
25 - 49	174.00 each
50 - 99	165.00 each
100 - 249	160.00 each

Prices FOB Vancouver, WA USA
Prices are subject to change without notice

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