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ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

Research, Development, and Field Testing of a New Fish Tracking System

AF 4.2.2

June 1978

Sponsored jointly by

Alberta ENVIRONMENT

Environment Canada Environnement Canada

15th Floor, Oxbridge Place
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ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

RESEARCH REPORTS

These research reports describe the results of investigations funded under the Alberta Oil Sands Environmental Research Program, which was established by agreement between the Governments of Alberta and Canada in February 1975 (amended September 1977). This 10-year program is designed to direct and co-ordinate research projects concerned with the environmental effects of development of the Athabasca Oil Sands in Alberta.

A list of research reports published to date is included at the end of this report.

Enquiries pertaining to the Canada-Alberta Agreement or other reports in the series should be directed to:

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Research, Development, and Field
Testing of a New Fish Tracking System
Project AF 4.2.2

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The Hon. D.J. Russell
Minister of the Environment
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Edmonton, Alberta

and

The Hon. L. Marchand
Minister of State for the Environment
Fisheries and Environment Canada
Ottawa, Ontario

Sirs:

Enclosed is the report "Research, Development, and Field Testing of a New Fish Tracking System".

This report was prepared for the Alberta Oil Sands Environmental Research Program through its Aquatic Fauna Technical Research Committee (now part of the Water System), under the Canada-Alberta Agreement of February 1975 (amended September 1977).

Respectfully,

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RESEARCH, DEVELOPMENT, AND FIELD TESTING OF A NEW FISH TRACKING SYSTEM

DESCRIPTIVE SUMMARY

ABSTRACT

Design techniques are presented for a very high frequency telemetry system capable of transmitting short radio frequency pulse signals from the body of a fish to an aircraft flying over a river. The system design has considered the water chemistry and river turbulence of the Athabasca River in the Alberta Oil Sands Environmental Research Program study area and five species of fish indigenous to that region. Surgical implant procedures are described and preliminary results are presented.

BACKGROUND

The project was undertaken during 1976-77 to design radio tags for implantation in walleye, goldeye, and northern pike; to observe reactions of the fish to the tags; to test interrogation of radio tags carried by goldeye in the North Saskatchewan River from an aircraft; and to generally test the feasibility of using radio tags under the field conditions prevelant in the AOSERP study area. The fish utilization of the large river-lake systems in the AOSERP study area for migration prompted this research and development feasibility study.

ASSESSMENT

This study has been terminated as complete. The report has been reviewed by different members of the Program Management staff of AOSERP and it is recommended that it be placed in selected Canadian libraries to fulfil obligations to make the information public. The content of the report does not necessarily reflect the views of Alberta Environment or Fisheries and Environment Canada. The mention of trade names for commercial products does not constitute an endorsement or recommendation for use. The Alberta Oil Sands Environmental

Research Program accepts the report "Research, Development, and Field Testing of a New Fish Tracking System" and thanks the researchers for their contributions.

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RESEARCH, DEVELOPMENT, AND FIELD TESTING OF A NEW FISH TRACKING SYSTEM

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ALBERTA OIL SANDS ENVIRONMENTAL
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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Design techniques are presented for a very high frequency telemetry system capable of transmitting short radio frequency pulse signals from the body of a fish to an aircraft flying over a river. The system design has considered the water chemistry and river turbulence of the Athabasca River in the Alberta Oil Sands Environmental Research Program study area and five specie of fish indigenous to that region. Surgical implant procedures are described and preliminary field test results are presented.

ACKNOWLEDGEMENTS

This project was jointly funded by the Fisheries Research Section, Fish and Wildlife Division, Alberta Department Recreation, Parks and Wildlife; the Alberta Oil Sands Environmental Research Program; and the Histopathology Section, Veterinary Services, Alberta Department of Agriculture.

D. Ferster assisted in the field work by monitoring movements of radio tagged fish in Buck Lake and by collecting and transporting live fish to the laboratory for implantation experiments. D. Clish maintained the live specimens in the laboratory and documented experimental procedures. G. Gish assisted with the assembly of electronic devices. Dr. G.R. Johnson developed the surgical implantation technique. Equipment used to capture and maintain live fish, office and laboratory space, and aircraft time was supplied by the Alberta Fish and Wildlife Division.

1. INTRODUCTION

In September 1975, authorization to proceed on Aquatic Fanua AOSERP Project 4.2.1 "Development of Apparatus and Methods to Monitor Migration of Fish" was received from the Alberta Oil Sands Environmental Research Program. The system design phases, in sequence, are: general analysis, transmitter design, transmitter circuit, surgical implant procedure development, and preliminary field testing. The initial study covered a period of seven months and was subsequently funded from 1 April 1976 to September 1976 and from October 1976 to 31 March 1977. The frame of reference for this work is based on the following assumptions:

1. An adequate study of the annual migration patterns of sport and commercial species of fish of the northern Athabasca River basin is necessary to determine the requirements of these fish within this system to permit perpetuation of these species. It is initially assumed that fish depend, to some degree, on the entire river, its tributaries, and contiguous lakes for spawning sites, nursery areas, foraging and overwintering locations, and migration routes.
2. Early knowledge of important or critical sites is essential since oil sands development activities are already in progress on the surface mineable area.
3. It is hypothesized that it is technically feasible, within a reasonable period of time, to develop a telemetry system to delineate the critical geographic locations for sport and commercial species of fish in this river system sooner, more completely, and at a lower cost than currently practised conventional methods of fish tagging and recovery. In view of the lack of road access, low population density, climatic conditions, and the expansive area of the Athabasca River drainage system, conventional tag recoveries would be infrequent and low. Conventional tags on captured fish only provide a two point reference system: the location of release

and the location of capture. The movements of the marked fish between the two known dates and reference points are unknown. Knowledge of critical geographical locations under ice cover for six months of the year, one half the life span of the species, would be difficult to acquire through conventional tagging because of the intensive effort required to capture tagged fish under ice cover in river systems as expansive as the Athabasca.

2. RESULTS

2.1 GENERAL ANALYSIS

Specific design objectives were established that were considered essential if results of this effort were to be competitive or superior to other methods. To be of significant value, a fish tracking system for the Athabasca River must locate radio tagged fish in any part of the river system at any time of the year. Initial consideration was given to battery operated ultrasonic transmitters, commercially available and in reasonably wide use. This technique was abandoned, however, because such devices require intensive effort to maintain signal contact and do not operate as well in shallow or turbulent water or in areas with subsurface vegetation. Ice conditions throughout the winter months would restrict the use of ultrasonic devices at a time of primary interest since fish are migrating to spawn either at freeze-up or before spring break-up in the main river.

Consideration was then given to approaches using electromagnetic (radio) propagation. The first technique, involving interrogation of a passive transponder (Baldwin et al. 1973), had many attractive features for long term studies of large numbers of fish that could be individually identified. While the limited feasibility of this system has been demonstrated, it is not commercially available and would require considerable developmental time before it could be applied to the Athabasca River study. The final approach using small, battery operated, implanted transmitters was adopted providing that the system could meet the following criteria:

1. Provide signals from fish with sufficient strength to be detected during an aircraft overflight,
2. Provide locating signals for a full year or more,
3. Be physically small enough to be implanted in or attached to fish without causing a significant increase in mortality or significant modification of behavior patterns, and

4. Provide signals which can differentiate or identify the following five species of fish: northern pike, *Esox lucius* Linnaeus; lake whitefish, *Coregonus clupeaformis* (Mitchill); mountain whitefish, *Prosopium williamsoni* (Girard); goldeye, *Hiodon alosoides* (Rafinesque); and walleye, *Stizostedion vitreum* (Mitchill).

2.2 TRANSMITTER DESIGN

Very High Frequencey (VHF) radio transmitters designed to operate in a lossy medium were first described by Smith and Baldwin (1961) and Baldwin (1963) and inserted in the stomach of freshwater fish (Baldwin 1965). Lonsdale and Baxter (1968) provided a description of a system for tracking trout in streams. Of related importance was an investigation by Waite (1962) of errors in height indication from pulsed radar altimeters in aircraft operative over thick ice and snow. More recently, Casadei et al. (1972) described the radiated VHF power which might be expected from inside the body of large animals, technically a problem analogous to that of telemetry from fish in fresh water.

Radio waves originating in a fish in the Athabasca River must pass through the fish, water, ice, snow, and air, and signal attenuation is caused by the conductivity of the surrounding medium, free space losses, and losses suffered as energy is reflected at the various transmissible medium boundaries. The major losses are frequently dependent. A layer of snow may cover the ice but its effect is minor compared to other media.

For the calculations which follow, the fish are thought to overwinter in depths up to 10 m of water. The maximum ice thickness on the Athabasca is assumed to be 1 m and a representative water conductivity in the delta mouth of the river is taken as 250 mmho/cm or 2.5 milli siemens per metre.

The attenuation due to absorption in a medium is expressed by the loss tangent, δ and following Waite (1962) may be calculated as:

$$S_{LA} = 8.686 \left(\frac{2\pi}{\lambda}\right) \frac{\varepsilon}{2} \{(\sqrt{1 + \tan^2\delta} - 1)\}^{\frac{1}{2}}$$

where S_{LA} is loss in db/m and λ is free space wave length in metres. The "free space" loss (Westman 1968) is given by:

$$S_L = -27.5 + 20 \log f + 20 \log D$$

where S_L is the loss in db, f is frequency in MHz, D is distance in metres.

We will assume that an aircraft is used to carry a receiver to detect radiated signals from fish transmitters at an elevation of 150 m above the river and at a velocity of 120 km/h. Values assumed for calculations are presented in Table 1.

Losses occur due to reflections at the interface between two media. Assuming vertical incidence, the reflection coefficient, R_c, is given by:

$$R_c = \frac{\sqrt{\varepsilon 2} - \sqrt{\varepsilon 1}}{\sqrt{\varepsilon 2} + \sqrt{\varepsilon 1}}$$

The loss suffered by the incident wave penetrating the new medium is given by:

$$S_{LP} = -10 \log (1 - |R_c|^2)$$

For the values given these penetration losses are:

Water-ice	2.42 db
Ice-snow	0.18
Ice-air	0.42
Snow-air	0.05

It is interesting to note that layer of snow on the ice actually improves the signal transfer over that with bare ice. For calculations, the condition in winter with bare ice gives a penetration loss of 2.84 db. In the summer the water-air boundary is

Table 1. Values assumed for calculations of signal attenuation.

Medium	Conductivity in mho/meters	Dielectric const (relative)	Loss Tangent Tan δ	Temperature (^{o}C)
Water	2.5×10^{-3}	86.5 to 87	.007 to .03[a]	+1.5
Ice	1×10^{-4}	3.5	.001	-12
Air	0	1.0	0	N/A
Snow	1×10^{-5}	1.56	.0003	N/A

[a]Varies with temperature and frequency. Interpolated values used from Von. Hippel (1954:301).

mismatched even more than with ice and the loss increases to 4.6 db.

The path loss calculation for a number of frequencies which might be considered is summarized in Table 2. These calculations are based on vertical incidence, i.e., the receiver in the aircraft is assumed to be directly over the transmitter in the fish. The signal strength is attenuated as we depart from vertical incidence so that very little signal is available horizontally in air when the transmitter is at a depth of 10 m. Snell's law for refraction is difficult to apply in a practical case because the water surface is rarely flat. Field tests suggest that the signal is reduced considerably at angles of about $\pm 30^{\circ}$ from the vertical at 150 MHz.

Certain other considerations are involved in selecting a frequency of operation. A crystal controlled transmitter is required for sufficient stability to stay within the receiver pass band. Third harmonic crystals to about 60 MHz are available with good output and low cost. Above 60 MHz, fifth or seventh crystal harmonic modes are required and these are more difficult to employ in simple circuits. While 50 MHz offers the least path attenuation, directional antennas suitable for aircraft mounting are either inconveniently large or inefficient at this frequency. At 150 MHz a three-element yagi antenna with 10 db gain can be attached under the wing of a light aircraft and pointed downward. The boom length is 1 m. For these reasons the design effort has been concentrated at 150 MHz.

The transmitter power source is a critical component. It must operate efficiently at $0^{\circ}C$ and ideally must have the highest energy density possible on both a weight and volume basis. The lithium primary battery (Mennie 1976) commercially available since 1973 offers the following features: nominal working voltage of 2.8V, energy density 2 to 4 times higher than conventional batteries (silver oxide, alkaline, mercury), storage life at least 5 years, perhaps 10, and the ability to function from $-54^{\circ}C$ to $+71^{\circ}C$.

Table 2. Summary of path loss by frequency in db.

MEDIUM	DISTANCE (Metres)	FREQUENCY (MHz)							
		50	100	150	200	250	300	350	400
Absorption Losses:									
Water	10	2.99	5.94	10.18	16.97	42.42	81.21	118.46	168.71
Ice	1	0.08	0.14	0.15	0.17	0.04	0.05	0.07	0.08
Free Space	161	50.58	56.60	60.13	62.62	64.56	66.15	67.49	68.65
Total Absorption Losses		53.65	62.68	70.46	79.76	107.02	147.41	186.02	237.44
Boundary Reflection Losses		2.84	2.84	2.84	2.84	2.84	2.84	2.84	2.84
Total Path Loss in Winter		56	66	73	83	110	150	189	240
Total Path Loss in Summer		58	67	75	84	112	152	141	242

The "AA" cell (Tadiran) weighs 16.5 g in a volume of 7.31 cc and has a rated capacity (at 5 ma) of 2.0 ampere hours. The model 1/2 AA is approximately half the length, volume, weight, and capacity.

Some lithium cells generate gas as they are used. Lithium cells manufactured by Power Conversion Inc. emit sulphur dioxide at rates of up to 0.4 mg per day with a vapor pressure of 2 atmospheres. Lithium batteries of this type should be avoided in these applications.

The model AA cell, derated for $0^{\circ}C$ operation and assuming an average voltage of 3.4 V with an end of life voltage of 2.4 should provide an average current of 46 μa during 60 months of operation. The use of this energy on a low duty cycle basis will provide the dc power for a pulsed cw type signal. The objective is to convert the power available to a radiated signal at the correct frequency with the greatest efficiency in a package small enough to fit in the peritoneal cavity of a 25 cm fish. Concurrent experimental work on surgical implantation techniques has established a maximum transmitter diameter of 1.7 cm and 8 or 9 cm as an approximate length.

The immediate environment of the transmitter is a high dielectric medium. One suitable type of small antenna is a magnetic dipole. One of the simplest transmitter circuits investigated to date is shown schematically (Figure 1).

A third harmonic vibrational resonance is induced in a series resonant mode in the crystal at a level which produces a rich third harmonic at 150 MHz. Consider the magnetic dipole to be represented by an impendance Z such that:

$$Z = J\omega l + Rv + Rs$$

where L is the dipole inductance, Rv the loss resistance and Rs the radiation resistance. The far field radiation for a small magnetic dipole is proportional to the dipole moment:

$$m_m = n\mu_o \overline{I} . \overline{F}$$

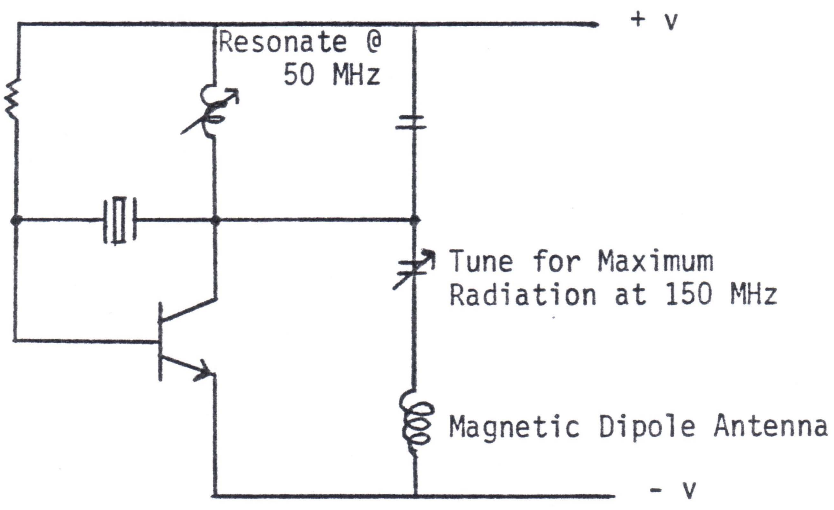

Figure 1. Transmitter schematic.

where: $\bar{I}$ is the peak value of the loop current,
$\bar{F}$ is the surface vector of the dipole loop area,
μ_o the permeability of free space, and
n the number of turns.

The radiated power is expressed by:

$$P_s = \frac{R_s i^2}{2}$$

The radiation resistance (Kraus 1950) can be expressed as:

$$R_s = \frac{Z_0}{6\pi C_o} \quad 4\ \omega^4 F^2 N^2$$

where Z_o is the wave impedance of free space,
C_o the velocity of light,
$\omega = 2\pi$ x frequency in Hz, and
F, the dipole area, such that $F = \bar{F}$.

In the circuit given the peak voltage across the inductance L will not exceed the supply voltage. The radiated power is thus limited by the peak voltage V (or the supply voltage). The radiated power can be written as:

$$P_s = \frac{V^2 R_s}{2\ Z^2}$$

For high Q magnetic dipoles, the following relationship holds:

$$R_s << \omega_L,\ R_v << \omega_L$$

Therefore the radiated power can be expressed as:

$$P_s = \frac{V^2 R_s}{2\omega^2 L^2}$$

According to Jahnke and Emde (1945), the inductance of a helical coil whose length and diameter are large compared to the conductor diameter is given by:

$$L = \frac{n^2 d\mu_o}{3} \qquad \frac{K(\alpha) + (\frac{d^2}{\ell^2} - 1)\ E(\alpha)}{\sin \alpha} - \frac{d^2}{\ell^2}$$

where d is the mean helix diameter, and

ℓ is the helix length: $\alpha = \tan^{-1} \frac{d}{\ell}$

K(m) and E(m) are the complete elliptical integrals of the first and second types.

μ_o is the permeability of free space, and

n, the number of turns.

In selecting dimensions, the helix diameter is restricted by the shape of the peritoneal cavity. For fish of 25 cm to 30 cm in length the diameter of the lithium cell, 1.68 cm, is about optimum. While the helix could be fitted around the cell it is probable that the metal case would cause considerable loss of radiated energy due to induced current flow in the metal container. Assuming the helical radiator is placed on the axis of the battery but not enclosing it the mean helical diameter is then approximately 1.60 cm.

Solving the above equation with d = 1.60 cm and letting ℓ be multiples of the diameter we can show that:

$$L = n^2 k \times 10^{-8} \text{ henries}$$

where k is given graphically in Figure 2 for various ℓ/d ratios.

Making the indicated substitution in the equation for radiated power gives:

$$P_s = \frac{V^2 Z o \omega^2 F^2}{12\pi C^4 n^2 k^2}$$

And evaluating constants gives:

$$P_s = 7 \times 10^{-4} \frac{V^2}{nk}$$

If the number of turns n are reduced beyond a certain limit the magnetic dipole ceases to have its field aligned with the helical axis and the equation used for L is no longer valid. The greatest amount of power can be radiated from a long helix with a high peak voltage.

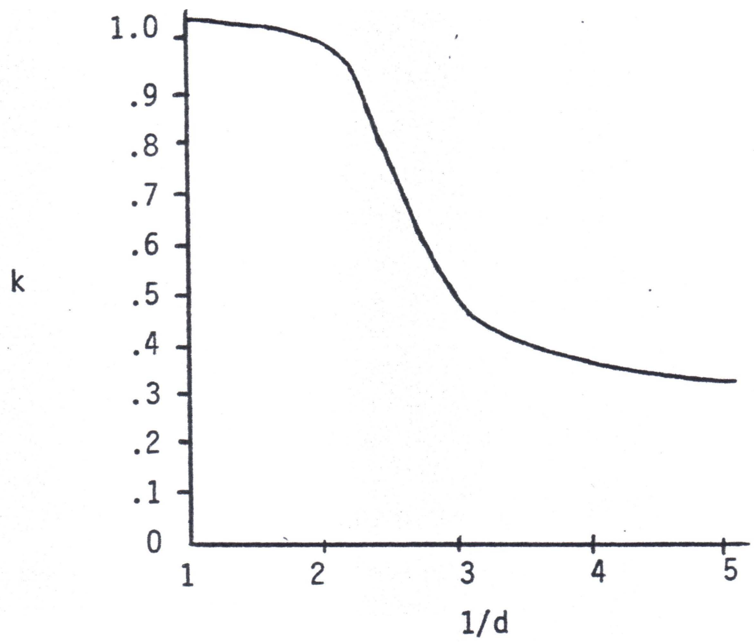

Figure 2. Inductance proportionality factor k.

For example, in a 5 turn helix whose length (8 cm) is 5 times the diameter the radiated power at 2.7 volts is 2.5 mw or + 4 dbm. With a single transistor acting as VHF oscillator, frequency multiplier and power output stage the typical peak to peak voltage at 150 MHz is approximately 200 mv. If the helical radiator were 4 cm long with 3 turns the power radiated is calculated to be 6.3 μ watts or -33 dbm.

Small transmitters and helical resonators of the type described have been "breadboarded" and tested under line of site conditions with a commercial receiver whose sensitivity is estimated to be 140 dbm. Ranges in excess of 2.5 km are obtained with easy recognition of 10 ms cw pulses. Under conditions specified for the AOSERP study area the telemetry system performance prediction is:

transmitter power	-22 dbm
path loss	-73 db
signal margin	-20 db
antenna gain	+ 10 db
receiver gain	+140 dbm
Excess signal strength	35 db

These calculations are intended to be conservative and are applicable to small transmitters under test conditions. When they are immersed in water the high dielectric medium not only affects the tuned elements but drastically modifies the antenna performance. Antenna dimensions are effectively reduced by $(\varepsilon_r)^{\frac{1}{2}}$. A half wave length in air at 150 MHz is 1 m. In water at 1.5°C it is 10.75 cm. For a single turn loop of the dimensions considered above, the radiation resistance in water is calculated to be about 10 ohms. The problem is further complicated however, by imbedding the transmitter in a mixture of glass microspheres (dielectric constant 1.2) and epoxy (dielectric constant 4.4) to preclude moisture absorption and to adjust the bouyancy of the transmitter.

Duty cycle control circuits have been described by Baldwin (1971) using simple complementary transistor astable multivibrators which operate at low currents and voltages. Recent advances in the availability of complementary metal oxide field effect semiconductor integrated circuits, particularly for the digital watch market, made it possible to consider precise timing of low duty cycles. The current consumption of wrist watch clock timers is given (RCA 1975) as low as 0.95 μa with timing accuracies better than one minute per year. The component cost of a crystal controlled duty cycle circuit using these techniques might be five dollars each in modest quantities. The major advantage of knowing the pulse period with precision would be to allow for automatic fish counting during an overflight even though a number of signals from instrumented fish were received at the same time.

The transmitted pulse length should be short to conserve power but the receiver is close to the aircraft engine and ignition noise levels may be high. An 8 to 10 msec pulse length has been selected to make the signal easily distinguishable from impulse noise interference. A pulse interval of one pulse per second allows the aircraft to move 33 m during pulse intervals. If the antenna beam width is 30° at least two and possibly three signal pulses will be received over each transmitter during flight at 150 m above the water. Since there is expected to be considerable excess signal strength flights at higher elevations will survey more area in shorter aircraft operating time.

Breadboard transmitters using these criteria have been fabricated. Average current drain is typically 30 μa. Since 46 μa are available with the model AA lithium cell for 5 years of operation the use of the ½ AA is being planned for field tests. This cell is half the length of the common "penlight" battery or 2.5 cm.

2.3 TRANSMITTER CIRCUIT

A number of circuit variations have been fabricated and tested. Field testing was conducted with the circuit configuration presented in Figure 3. Transmitters were placed in glass test tubes selected to accept the battery diameter and imbedded in epoxy with glass microspheres. The round ends of two test tubes, cut to appropriate dimensions, were used so that the unit provided a smooth glass surface for insertion in fish.

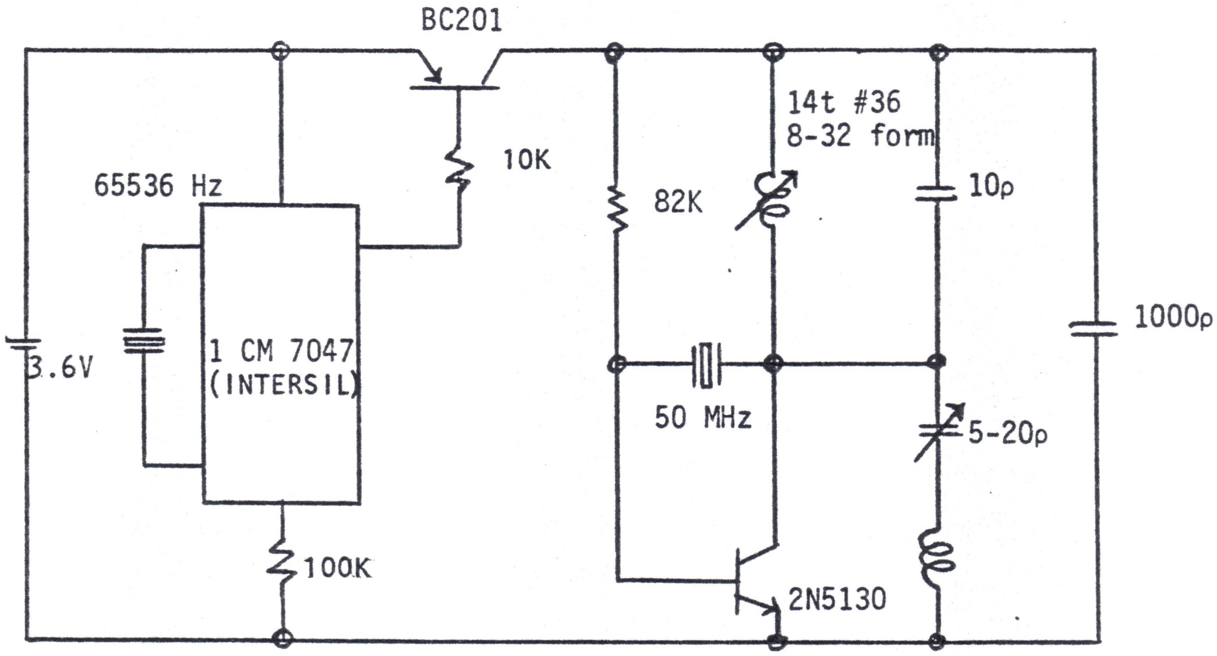

Figure 3. Transmitter circuit employed in preliminary field testing.

The duty cycle control circuit was found to operate with a current drain of about 2 μa. The duty cycle is 1 to 120 but the average current depends on tuning and antenna loading. Typical values are between 30 and 50 μa. Battery life predictions for various lithium cells commercially available fall between 1.5 and 5 years. Several transmitters were retained for life testing.

2.4 SURGICAL PROCEDURES

Surgical implantation of transmitters was developed and supervised by Gerald R. Johnson, D.V.M. Alberta Department of Agriculture. Approximately 40 experimental implantations were made in four species: goldeye, walleye, whitefish, and pike. In each experimental implant, a pathological analysis was performed. Tissue samples were retained to illustrate healing of the incision relative to water temperature. Goldeye were implanted with transmitter capsules and retained for up to 120 days in the laboratory. Field surgical procedures for implantation of radio tags in fish have been documented (Bidgood 1978).

The protocol for laboratory, surgical implantation that developed follows. Fish longer than 25 cm were anesthetized in a solution of 1:80,000 of ethyl m-amino benzoate sulfonate (Kent Laboratories, "Finquel", Ayerst Laboratories or MS-222, Sandoz). Anesthesia occurred typically in 2 to 4 minutes. The fish were placed ventral side up in a trough lined with polyurethane sponge that was pre-soaked in holding tank water to reduce thermal shock. Contact with the fish with bare hands was avoided as much as possible to reduce heat shock. Surgical instruments were autoclaved and the transmitter cleaned thoroughly, soaked in dilute clorhexidine gluconate (Hibitane, Ayerst Laboratories) and rinsed with sterile saline solution prior to insertion. Scales along the mid-ventral line were removed and an incision 3 to 4 cm long was made anterior to the pelvic girdle. The cylindrical transmitter was inserted in the posterior direction into the peritoneal cavity adjacent to the swim bladder. Five or six sutures were made continuously and tied at both ends of the incision.

Vetafil 00, a synthetic gut (Superamid, Serag-Wiessner) was found to be satisfactory for this purpose. Surgery typically took 3.5 minutes. After completion of the implant the fish were rinsed in clean water and returned to the holding tank. Recovery occurred in about 10 minutes. Adhesion of the incision occurred within 24 hours and tissue healing appeared to initiate in 2 days. No post-operative treatment was provided.

Preliminary investigation was made to test the effect of transmitter bouyancy and size on the fish. Transmitter capsules which tended to float were not accommodated by the fish. Transmitters in capsules with an excess weight in water of up to 10 grams were accepted by the fish without noticeable difficulty. The maximum capsule length and diameter was determined by the shape and size of the peritoneal cavity of each species. Capsules 1.6 cm diameter and 7.5 cm in length were acceptable to mature fish of the four species tested.

It is our opinion that transmitter implantation should be avoided in mature and ripe fish. Females, especially, when compacted with eggs in the peritoneal cavity have little available space for the capsule. When the eggs develop after the transmitter implant, the peritoneal organs are not disturbed, the membrane enclosing the egg mass remains intact, and the ovaries form around the implanted capsule.

2.5 PRELIMINARY FIELD TESTING

Transmitter tests were conducted using a commercial bio-telemetry receiver (AVM Model LA12). This instrument has a broad pass band for interfering signals in the vehicular communications band and is not considered suitable for work near population areas. Much of the preliminary testing was done by using small boats rather than aircraft since limited aircraft rental funds were available. During July 1976, tests were conducted at Buck Lake in central Alberta (Lat. 53°N, Long. 114°45'W), where walleye, whitefish, and pike were implanted with radio tags. Fish were tracked by boat and horizontal ranges up to 100 m were observed.

On 19 July 1976, three goldeye, captured in the North Saskatchewan River on 15 July and transported to the laboratory, were implanted with radio transmitters and retained in holding tanks in the laboratory until 20 September. At this time the fish were released at the Devon Bridge in the North Saskatchewan River. A Cessna 182 aircraft equipped with an antenna mount was used for periodic overflights. Signals from the three fish were available at a height of 609 m above the river and the location, within about 50 m, of each fish could be determined with a lower flight pass. The fish remained in the release area from 1030 hours to shortly after dusk. The next day they were located by aircraft approximately 72.4 km downstream and on the following day one fish was relocated 268.7 km downstream.

The migration patterns of goldeye are poorly understood but this species makes extensive movements within river systems. A goldeye tagged with a conventional tag in the North Saskatchewan River in Edmonton has been recaptured by an angler in the Saskatchewan River west of The Pas, Manitoba. The use of long-lived, surgically implantable radio tags will assist in obtaining a better understanding of the life history of these and other lotic species of fish indigenous to Canada.

3. SUMMARY

System design has been completed and tested in the laboratory. Surgical implant procedures have been investigated and developed. Acceptance of the radio tag capsule by four species of fish has been examined. Preliminary field tests with radio tag implanted fish were undertaken.

4. CONCLUSIONS

Radio transmitters were designed as superior to ultrasonic transmitters to monitor seasonal migration patterns of fish in the Athabasca River system. Radio transmitters at a frequency of 150 MHz will permit interrogation of radio tagged fish by aircraft fitted with a three element yagi antenna pointed downward when mounted under the wing of a light aircraft. A sealed, lithium primary battery was the chosen power source of a transmitter with an 8 to 10 millisecond pulse length and a pulse interval of one pulse per second. Field surgical procedures reduced stresses imposed on laboratory held experimental fish. Preliminary field tests indicated interrogation of radio tagged fish with a light aircraft was feasible.

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6. AOSERP RESEARCH REPORTS

1.		AOSERP First Annual Report, 1975
2.	AF 4.1.1	Walleye and Goldeye Fisheries Investigations in the Peace-Athabasca Delta
3.	HE 1.1.1	Structure of a Traditional Baseline Data System
4.	VE 2.2	A Preliminary Vegetation Survey of the Alberta Oil Sands Environmental Research Program Area
5.	HY 3.1	The Evaluation of Wastewaters from an Oil Sand Extraction Plant
6.		Housing for the North--The Stackwall System
7.	AF 3.1.1	A Synopsis of the Physical and Biological Limnology and Fisheries Programs within the Alberta Oil Sands Area
8.	AF 1.2.1	The Impact of Saline Waters Upon Freshwater Biota (A Literature Review and Bibliography)
9.	ME 3.3	Preliminary Investigation into the Magnitude of Fog Occurrence and Associated Problems in the Oil Sands Area
10.	HE 2.1	Development of a Research Design Related to Archaeological Studies in the Athabasca Oil Sands Area
11.	AF 2.2.1	Life Cycles of Some Common Aquatic Insects of the Athabasca River, Alberta
12.	ME 1.7	Very High Resolution Meteorological Satellite Study of Oil Sands Weather, a Feasibility Study
13.	ME 2.3.1	Plume Dispersion Measurements from an Oil Sands Extraction Plant
14.	HE 2.4	Athabasca Oil Sands Historical Research Design (3 volumes) (in review)
15.	ME 3.4	Climatology of Low Level Air Trajectories in the Alberta Oil Sands Area
16.	ME 1.6	The Feasibility of a Weather Radar near Fort McMurray, Alberta
17.	AF 2.1.1	A Survey of Baseline Levels of Contaminants in Aquatic Biota of the AOSERP Study Area
18.	HY 1.1	Alberta Oil Sands Region Stream Gauging Data
19.	ME 4.1	Calculations of Annual Averaged Sulphur Dioxide Concentrations at Ground Level in the AOSERP Study Area
20.	HY 3.1.1	Evaluation of Organic Constituents (in review)
21.		AOSERP Second Annual Report, 1976-77
22.	HE 2.3	Maximization of Technical Training and Involvement of Area Manpower (in review)
23.	AF 1.1.2	Acute Lethality of Mine Depressurization Water on Trout Perch and Rainbow Trout (in review)
24.	ME 4.2.1	Review of Dispersion Models and Possible Applications in the Alberta Oil Sands Area (in review)
25.	ME 3.5.1	Review of Pollutant Transformation Processes Relevant to the Alberta Oil Sands Area

26. AF 4.5.1 Interim Report on an Intensive Study of the Fish Fauna of the Muskeg River Watershed of Northeastern Alberta
27. ME 1.5.1 Meteorology and Air Quality Winter Field Study in the AOSERP Study Area, March 1976 (in review)
28. VE 2.1 Interim Report on a Soils Inventory in the Athabasca Oil Sands Area
29. ME 2.2 An Inventory System for Atmospheric Emissions in the AOSERP Study Area
30. ME 2.1 Ambient Air Quality in the AOSERP Study Area, 1977
31. VE 2.3 Ecological Habitat Mapping of the AOSERP Study Area: Phase I

These reports are not available upon request. For further information about availability and location of depositories, please contact:

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