# New Marking and Monitoring Technologies for the Passive Integrated Transponder

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[1] This report was funded by the Bonneville Power Administration (BPA), U.S. Department of Energy, as part of BPA's program to protect, mitigate, and enhance fish and wildlife affected by the development and operation of hydroelectric facilities on the Columbia River and its tributaries. The views in this report are the author's and do not necessarily represent the views of BPA.

# Abstract

We designed and tested a transceiver system for monitoring passive integrated transponder (PIT) tags to be utilized in the spillway of dams in the Columbia River Basin. This work was funded by the Bonneville Power Administration (BPA). Previous efforts by NOAA Fisheries and BPA have led to the design, construction, and testing of a new PIT-tag detection system that can be utilized in areas with very high water velocities.

In order to finalize transceiver development for the new spillway systems, we contracted with engineers to make several modifications to the existing FS3001 prototype transceiver. Tasks which were conducted and evaluated during 2015 included:

- Update the exciter module and firmware of the existing prototype FS3001 transceiver
- Incorporate phase-measurement circuitry in the transceiver that also provides improved temperature tolerance and overall stability
- Update the transceiver to accept input voltages up to 48V DC
- Select a dual output power supply that can be used with the FS3001 transceiver
- Investigate alternative configurations for the antenna control cable, and identify a cable that is optimal for use in variable locations

Since completion of the new multiplexing transceiver in 2013, instream monitoring applications for the PIT tag have entered a more mature phase of development. Recent developments include new power systems and the finalization of data-collection methods. The new transceiver has also enabled new antenna designs; however, there have been problems with the first round of new antenna installations. For example, antennas that had yielded high performance in the laboratory encountered problems once installed in the field.

Staff of NOAA Fisheries has been collaborating with Biomark and other agencies to solve these and other problems related to instream monitoring applications. Our instream monitoring system on the John Day River (site code JD1) provided invaluable data and installation guidelines for PIT antennas collocated with the new IS1001 transceivers. The John Day monitoring site has also been used to evaluate various basin-wide upgrades to the PIT-tag information infrastructure. Agencies throughout the fisheries community rely on the vital data generated by these evaluations.

# Contents

# Introduction

This project is intended to expand fish-tracking technologies that will provide a means to conduct the research and monitoring activities prescribed in biological opinions and supplemental opinions (NMFS 2000, 2004, 2008, 2014) for operation of the Federal Columbia River Power System (FCRPS). Expansion of fish-tracking technology is needed for Action Agencies[2] to accomplish the reasonable and prudent alternatives (RPAs) identified in the biological opinions.

The goal of this project is to address these monitoring needs by developing new interrogation systems that will collect data on tagged juvenile and adult salmonids passing high-velocity areas, including through the spillways of Columbia River Basin dams. An important component of this goal is to develop interrogation systems that will work for juveniles that pass via surface collection routes, such as removable or temporary spillway weirs (RSWs and TSWs). Also important is the ability of interrogation systems to work in high-velocity streams and rivers, where fish at various life stages are released after implantation with a passive integrated transponder (PIT) tag.

Fish-tracking technologies for the PIT tag have proven critical to assessing the effectiveness of management actions and strategies to recover stocks listed under the U.S. Endangered Species Act (ESA). For example, data from PIT-tagged fish are used to evaluate transportation and other juvenile fish passage strategies. Nearly 2 million fish are implanted with PIT tags annually. Therefore, monitoring systems that will work with this resource in large streams or rivers are essential. These systems will provide data for determining the effectiveness of stock recovery and restoration programs supported by the Action Agencies. These data can also help to delineate the different types of interaction between hatchery and wild stocks in the field.

At present, spillways or surface-passage structures are the preferred route of passage for juvenile fish at FCRPS dams. This preference is based on high estimated rates of passage efficiency and survival through these routes (Axel et al. 2010; Hockersmith et al. 2010). However, tagged fish passing via spillway routes are not detected because monitoring systems for these routes are not yet available. In 2006, NOAA Fisheries started a project to investigate development spillway monitoring systems for PIT-tagged fish. In May 2008, NOAA Fisheries contracted with Destron Fearing to help develop this system (Anderson and Downing 2009).

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[2] Action Agencies include the Bonneville Power Administration, U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service, and U.S. Army Corps of Engineers.

Initial tests of a prototype spillway transceiver were conducted in 2011 at NOAA Fisheries Pasco Research Station. These tests showed that further improvements to the transceiver would be needed if the ability to detected PIT-tagged fish during spillway passage was to be achieved. A new monitoring system was developed for the spillway at Ice Harbor Dam, but the U.S. Army Corps of Engineers (USACE) was unable to obtain funding for its installation.

In late 2011, NOAA Fisheries and the Action Agencies agreed on a plan to install a new interrogation system at Lower Granite Dam. However, progress on the design of a specialized spillway or ogee transceiver was slowed when Destron Fearing Corp.[3] was acquired by Allflex USA, Inc. After the acquisition, Biomark was appointed to lead Destron engineering staff in the development effort; however, the transition delayed work on the ogee transceiver until September 2012.

Thus, work on this project has been interrupted by technical and financial challenges, as well as by organizational shifts. However, a prototype ogee transceiver was tested at the Biomark facility in Eagan, Minnesota in 2013. These tests produced lower read ranges than desired. The prototype transceiver also failed during a fish test at the corner-collector system at Bonneville Dam.

Biomark continued work to improve the transceiver, and tests in 2014 showed better performance in fish tests at the corner-collector system at Bonneville Dam. Biomark finalized the transceiver in 2015, and a final fish test will be conducted in 2016 to evaluate the finished product. During 2016 we will also issue a contract to design and develop a final antenna configuration. The first antenna configuration from this work would be incorporated into construction at Lower Granite Dam for winter 2017.

Instream applications are the fastest growing segment among PIT-tag monitoring technologies for fish. Instream applications are critical for monitoring restoration efforts, identifying areas of high relative mortality, learning about fish behavior (e.g., straying), and determining interactions between hatchery and wild stocks in the field. Researchers from NOAA Fisheries Fish Ecology Division have been at the forefront in developing and adapting technologies for in-stream applications (Downing et al. 2001, 2008; Anderson and Downing 2009). We have designed antennas and adapted power systems to enable PIT-tag systems to work in remote stream locations (Achord et al. 2012).

For instream applications, power systems are a common source of internal electromagnetic interference (EMI), and can produce EMI severe enough to prevent tag reading entirely. To solve the problem, NOAA Fisheries staff has conducted extensive

[3] Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

testing of power system components (Downing et al. 2008). Based on results from this testing, we designed a reliable power system that switches between two sets of 12-V batteries to quietly power transceivers and data-collection devices for instream monitoring systems (Downing et al. 2008).

The need for a transceiver to operate larger, multiple antennas had been identified even before the first instream PIT tag monitoring system was installed in 2002 (Achord et al. 2012). Thus, a new multiplexing transceiver and master controller for instream applications has been long anticipated by biologists and managers from NOAA Fisheries, the U.S. Geological Survey, U.S Fish & Wildlife Service, Oregon and Washington Departments of Fish & Wildlife, and Idaho Department of Fish & Game.

In early 2013, Biomark introduced the IS1001 transceiver for instream applications (where IS indicates in stream). Unfortunately, problems were encountered by NOAA Fisheries and others using IS1001 field installations. Among these problems, the most serious was significantly reduced read range for long cables or cables immersed in water—both unavoidable configurations in instream applications.

Biomark made some modifications to the IS1001 transceiver in 2014. In the meantime, we worked with them to methodically determine the optimal methods for field installation of the new equipment. This work continued in FY15, and evaluations indicate that the new transceiver should enable researchers and agencies to monitor fish in large streams or even rivers. Such work is essential to determine the effectiveness of all types of stock restoration and recovery programs supported by BPA.

# Spillway Detection System Development

## Methods

Following testing in June 2014, FS3001 transceivers were returned to the Biomark facility in Eagan, Minnesota. Testing and implementation of hardware and firmware were performed at the Biomark facility prior to testing at the NOAA Fisheries research station in Pasco, Washington. Three new FS3001 transceivers were assembled: serial number 05, 06, and 07, and the hardware and firmware of FS3001 transceivers 03 and 04 were updated to match the new configuration.

### Requirements for Cable Selection

The following properties were identified as requirements for cable selection:

- Low capacitance
- High voltage rating
- External shield
- Adequate separation between conductor and outer shield
- Readily available
- Relatively inexpensive

Experimental low-loss cables were tested by placing them in a flexible metal conduit, which was then submerged in water. This test reflected the ultimate configuration of cables deployed in the field.

### Requirements for a New Power Supply

The FS3001 reader requires a power supply that can operate at a higher load and at a higher electrical current than those tested previously. Power supply requirements included an output capability of up to 50 V DC and the ability to operate with a load of up to 10 A of electrical current.

### Shielding to Isolate Test Conditions

During the time required by the contractor to complete the design and construction of dual-output power supply modules, NOAA Fisheries built experimental antenna shielding. Draft drawings for the shields were provided by the U.S. Army Corps of Engineers (USACE). This opportunity allowed us to test power supplies and antenna separation distances in a shielded environment. Shields were fabricated from 0.25-inch aluminum plate by NOAA Fisheries welders and fabricators, and existing prototype antennas were placed in the shields for testing.

## Read Range Profiles

Read-range measurements were performed with Destron-Fearing FS3001 transceivers. These transceivers were powered using batteries with 37.6-V DC input, an exciter voltage of 35-V DC, and an antenna current of 29 A. One 100-ft length of cable was used for all read-range measurements (AIR802, Aurora, IL). For each test, tags were positioned at specific horizontal and vertical axis coordinates, and the height at which they were detected was varied. Detection data were recorded at intervals of ~1 second.

Four complete, custom built dual-output power-supply modules and five FS3001 transceiver systems were delivered to NOAA Fisheries Pasco Research Station on 3 December 2015. Our first test after delivery was to determine transceiver performance with the new power-supply modules as compared to the baseline power supply for instream monitoring systems, which consists of two sets of 12-V batteries.

For static read-range tests, one antenna comprised of two sub-antennas was placed into the aluminum-shield housing (Figure 1). The antenna was connected to an FS3001 ogee transceiver (SN 6) using two lengths of RM-400 coaxial cable. This exciter cable was housed within a 2-inch flexible steel conduit. The unit was operated at 24.1-V DC, and readings for EMI, tuned phase, antenna current, and capacitance were recorded. After tuning the unit and recording measurements, static read ranges were measured and recorded for a 12-mm SST-1 tag.

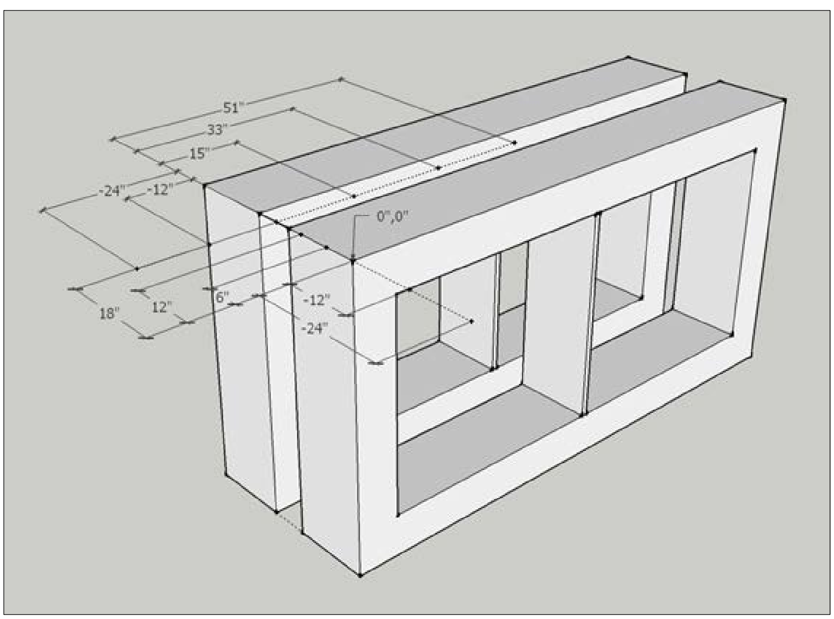


Figure 1. Drawing shows prototype antenna consisting of two sub-antennas. Locations used for static read-range measurements are indicated.

# Results

## Cable Evaluation

Two brands of coaxial cable were delivered for testing in Pasco: the AIR802 and the Cicoil (Valencia, CA). We initially tested four transceiver/antenna configurations using 8 lengths of 50-ft cable. To emulate actual field deployments, we tested configurations using 2 lengths of 150-ft coaxial cable housed in a flexible metal conduit.

Read-range measurements for these evaluations were conducted using two test tags: the Biomark TX1411 SST-1 (SST-1) standard telegram tag, and the Biomark Fastag or half-telegram tag. The first test performed was a comparison of read range using 50-ft lengths of both cable brands (Cicoil and AIR802). For this test, we used a single antenna with two sub-antennas separated by 7.5 inches.

For both cable tests, we used the existing baseline power supply for instream applications (two 12-V DC batteries wired in series to produce 24 V). During initial testing, antenna current was 24.7 A for the Circoil cable and 22.4 A for the AIR802 cable. Minimal internal EMI was approximately 200 mV during the Cicoil test and 120 mV during the AIR802 test. Read range was higher for tests using the AIR802 cable than for those using the Cicoil cable (Table 1); thus, all subsequent tests were conducted with the AIR802 cable.

Table 1. Read range measurements using two 50-ft lengths of Cicoil vs. AIR802 cable.

| | Read range (inches) | |
|---|---|---|
| Cable | SST-1 PIT tag | Fastag PIT tag |
| Cicoil | <40 | 42 |
| AIR802 | 48 | 51 |

## Static Read Range Tests for New Power Supply Modules

Static read range for the 12-mm SST-1 PIT tag was measured at 36 locations within in the electromagnetic field of the antenna using two 12-V DC batteries wired in series to produce 24 V (i.e., the baseline power supply for instream applications; Table 2a). These ranges were used to determine a read volume for the entire antenna assembly (Figure 2a).

Table 2. Static read ranges (inches) for a 12-mm SST-1 PIT tag at 36 locations shown in Figure 1 using (a) baseline power, or two 12-V batteries connected in series to produce 24.1V DC vs. (b) dual-output power supply modules. Distances were measured using a right-handed 3-dimensional coordinate system with planes oriented horizontally front-to-back (X), horizontally right-to-left (Y), and vertically (Z). For each test, tag position was varied on the vertical plane only (Y-axis).

**a**

| Ant. 1 | X | Z | Y | | X | Z | Y | | X | Z | Y | | X | Z | Y | | X | Z | Y | | X | Z | Y |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SN6 | 51 | 18 | 40.0 | | 33 | 18 | 41.0 | | 15 | 18 | 37.0 | | 0 | 18 | 30.5 | | -12 | 18 | 23.0 | | -24 | 18 | 4.0 |
| 22.5A | | 12 | 42.0 | | | 12 | 40.5 | | | 12 | 35.5 | | | 12 | 28.0 | | | 12 | 21.0 | | | 12 | 5.0 |
| 300mV noise | | 6 | 39.0 | | | 6 | 36.5 | | | 6 | 32.0 | | | 6 | 27.0 | | | 6 | 16.5 | | | 6 | 0.0 |
| 500mV spikes | | 0 | 32.0 | | | 0 | 31.0 | | | 0 | 25.0 | | | 0 | 19.5 | | | 0 | 13.0 | | | 0 | 0.0 |
| Caps 61 | | -12 | 6.5 | | | -12 | 6.0 | | | -12 | 4.5 | | | -12 | 0.0 | | | -12 | 0.0 | | | -12 | 0.0 |
| Exciter 24.1 | | -24 | 10.5 | | | -24 | 9.5 | | | -24 | 5.0 | | | -24 | 0.0 | | | -24 | 0.0 | | | -24 | 0.0 |
| Tuned phase 584 | | | | | | | | | | | | | | | | | | | | | | | |

**b**

| Ant. 1 | X | Z | Y | | X | Z | Y | | X | Z | Y | | X | Z | Y | | X | Z | Y | | X | Z | Y |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SN6 | 51 | 18 | 44.0 | | 33 | 18 | 43.0 | | 15 | 18 | 38.0 | | 0 | 18 | 32.0 | | -12 | 18 | 24.0 | | -24 | 18 | 9.0 |
| 22.5A | | 12 | 43.0 | | | 12 | 41.0 | | | 12 | 38.0 | | | 12 | 31.0 | | | 12 | 24.0 | | | 12 | 4.0 |
| 150-180mV noise | | 6 | 41.0 | | | 6 | 40.0 | | | 6 | 37.0 | | | 6 | 28.5 | | | 6 | 21.0 | | | 6 | 0.0 |
| 500mV spikes | | 0 | 35.0 | | | 0 | 33.0 | | | 0 | 29.0 | | | 0 | 20.5 | | | 0 | 6.0 | | | 0 | 0.0 |
| Caps 61 | | -12 | 7.0 | | | -12 | 6.0 | | | -12 | 5.0 | | | -12 | 0.0 | | | -12 | 0.0 | | | -12 | 0.0 |
| Exciter 24.1 | | -24 | 11.0 | | | -24 | 10.5 | | | -24 | 7.0 | | | -24 | 0.0 | | | -24 | 0.0 | | | -24 | 0.0 |
| Tuned phase 584 | | | | | | | | | | | | | | | | | | | | | | | |

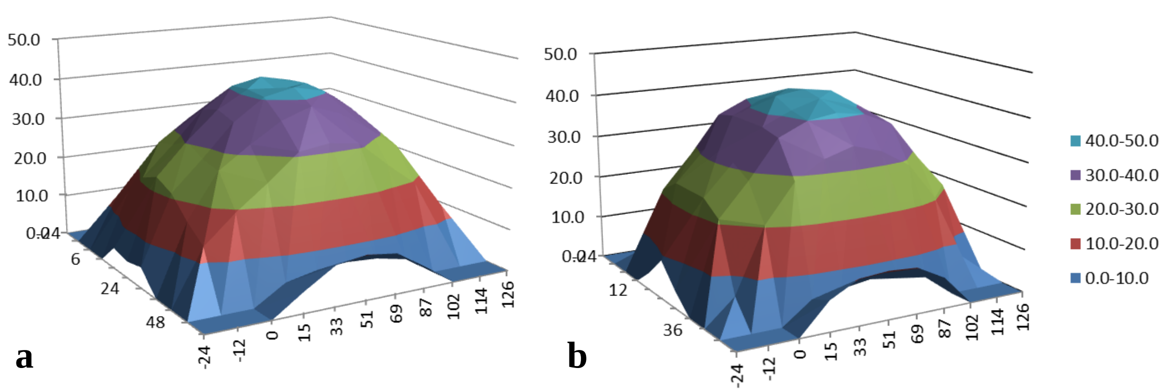


Figure 2. Read volume (inches) across the entire antenna field using (a) two 12-V batteries wired in series to produce 24.1-V DC vs. (b) a dual-output power supply module.

The second test was conducted using the same transceiver (SN 6) with identical antenna and exciter cable configurations. During this test, the power supply was changed from batteries to the custom built dual-output power supply module. All measurements were recorded, and the read field was modeled using the same 12-mm SST-1 PIT tag (Table 2b and Figure 2b). This test helped to determine whether the power supply module would perform as well as batteries, which produce no electromagnetic interference. Other than the power supply, all operating parameters in the second test were identical to those in the first (i.e. input voltage, antenna current, capacitors and tuned phase) so that test variables were restricted to the input power source.

## Preliminary Tests of Ogee Antenna Configuration

For first test of this series, three antennas were placed into aluminum shields and positioned end-to-end with shields separated by a 48-inch gap (Figure 4). All three antennas were controlled by synchronized FS3001 transceivers, connected using 50-ft exciter cables, and powered from the same branch circuit. Read ranges were recorded at the centerline of each antenna. During this test, several grounding schemes were tested and the results of each were recorded.

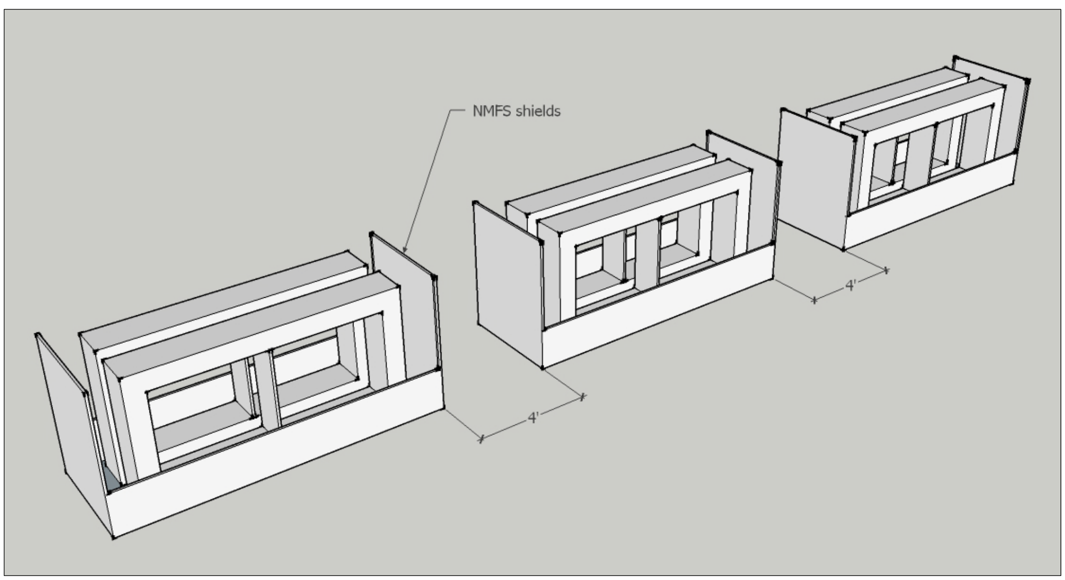


Figure 4. Antennas in aluminum shields positioned end-to-end with antenna shields separated by 48-inches. All three antennas were driven by synchronized FS3001 systems on 50-ft exciter cables and powered from the same branch circuit. Read ranges were recorded at the centerline of each antenna.

For the second test of this series, we attempted to establish a minimum separation distance between adjacent antennas in order to decrease gaps in read range for antennas deployed across a spillway. Antennas were moved close together, so that the gap between each shield was only 4 inches. This test was aborted because the transceivers would not stabilize with antennas at this proximity. No read range results were taken.

We then conducted a series of tests to determine minimum spacing between antennas placed in upstream and downstream rows along the spillway. Three shielded antennas were used, with two placed in the "upstream" row and one centered on the downstream "row" (Figure 5). Adjacent antennas in the upstream row were separated by a gap of 48 inches. The downstream antenna was positioned 10 ft from the upstream antenna row (Figure 5). Read range measurements were taken with a 12-mm SST-1 tag, and results were recorded (Table 4).

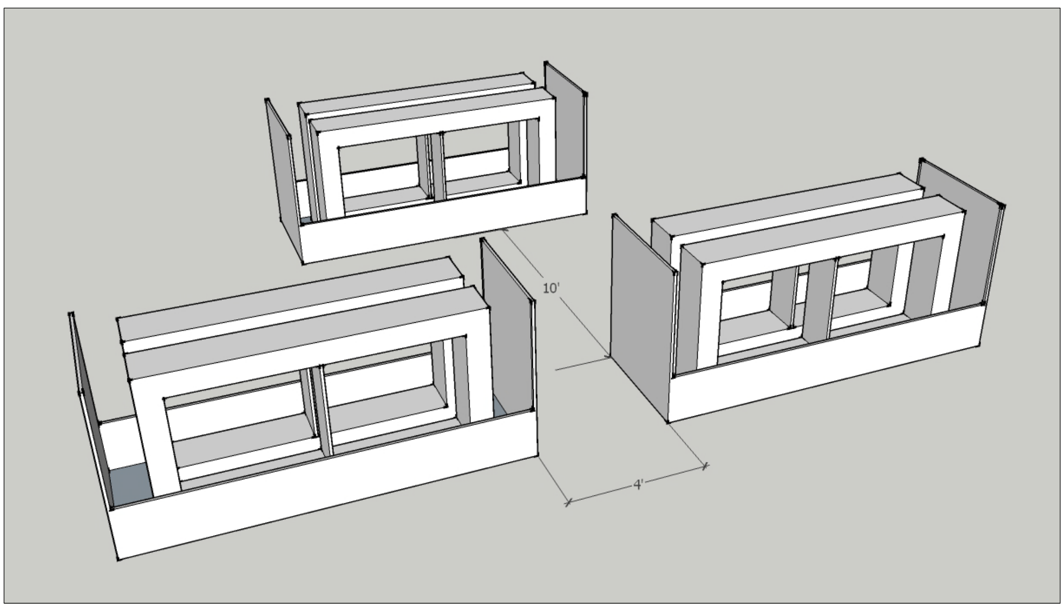


Figure 5. Test configuration for determining separation between two rows of antennas.

Two key observations were noted during this test.  First, the antenna field between two adjacent antennas appeared to merge, adding a read field in the gap between them.  Second, the upstream antennas appeared to induce a field in the downstream antenna:  while the downstream antenna was tuned at a current of 21 A, the exciter was set to only 12-V DC.  This suggests that the majority of current on the downstream antenna was coupled from the two upstream antennas.  We inferred from this outcome that a spacing of 10 ft between upstream and downstream antenna arrays is not ideal.

We repeated this test after extending the space between upstream and downstream antennas to 15 ft.  Transceivers were tuned, and peak read range and operating parameters were recorded (Table 5).  Coupling between the upstream and downstream antennas fields still occurred, but was diminished from the previous test, indicating that 15-ft spacing could be appropriate in a field installation.  Read ranges were recorded across the centerline of all antennas.  These read ranges were used to model the full read field across both the upstream and downstream antenna arrays (Figure 6).

Table 4. Individual antenna static read ranges (inches) for a 12-mm SST-1 PIT tag during synchronization testing of the configuration shown in Figure 5 using the dual-output power supply with a 10-ft (a) vs. 15-ft (b) separation between antenna rows.

**a**

Staggered antennas, with two antennas upstream and one antenna downstream. Upstream antennas had 48" separation between shields.
Downstream antenna was located 10' dowstream and centered between antennas. Antenna one is upstream near.

| Ant. 1 | X | Z | Y | | X | Z | Y | | X | Z | Y | | X | Z | Y | | X | Z | Y | | X | Z | Y |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SN3 | 51 | 18 | 45 | | 33 | 18 | 44 | | 15 | 18 | 39 | | 0 | 18 | 34 | | -12 | 18 | 25.5 | | -24 | 18 | 0 |
| 20.4A | | | | | | | | | | | | | | | | | | | | | | | |
| 30-40mV noise | | | | | | | | | | | | | | | | | | | | | | | |
| 100 mV spikes | | | | | | | | | | | | | | | | | | | | | | | |
| Caps 61 | | | | | | | | | | | | | | | | | | | | | | | |
| Exciter 20.5 | | | | | | | | | | | | | | | | | | | | | | | |
| SST-1 tag | | | | | | | | | | | | | | | | | | | | | | | |

**Test: 7**

Staggered antennas, with two antennas upstream and one antenna downstream. Upstream antennas had 48" separation between shields.
Downstream antenna was located 10' dowstream and centered between antennas. Antenna two is upstream far.

| Ant. 2 | X | Z | Y | | X | Z | Y | | X | Z | Y | | X | Z | Y | | X | Z | Y | | X | Z | Y |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SN5 | 51 | 18 | 46.5 | | 33 | 18 | 45 | | 15 | 18 | 43 | | 0 | 18 | 36 | | -12 | 18 | 28 | | -24 | 18 | 19 |
| 21A | | | | | | | | | | | | | | | | | | | | | | | |
| 50-60 mV noise | | | | | | | | | | | | | | | | | | | | | | | |
| 110 mV spikes | | | | | | | | | | | | | | | | | | | | | | | |
| Caps 82 | | | | | | | | | | | | | | | | | | | | | | | |
| Exciter 17 | | | | | | | | | | | | | | | | | | | | | | | |
| SST-1 tag | | | | | | | | | | | | | | | | | | | | | | | |

This additional read range results from the two fields merging.

**Test: 7**

Staggered antennas, with two antennas upstream and one antenna downstream. Upstream antennas had 48" separation between shields.
Downstream antenna was located 10' dowstream and centered between antennas. Three is downstream.

| | X | Z | Y | | X | Z | Y | | X | Z | Y | | X | Z | Y | | X | Z | Y | | X | Z | Y |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SN7 | 51 | 18 | 40 | | 33 | 18 | 38.5 | | 15 | 18 | 35 | | 0 | 18 | 27 | | -12 | 18 | 15 | | -24 | 18 | 0 |
| 21A | | | | | | | | | | | | | | | | | | | | | | | |
| 60-70 mV noise | | | | | | | | | | | | | | | | | | | | | | | |
| 120 mV spikes | | | | | | | | | | | | | | | | | | | | | | | |
| Caps 5 | | | | | | | | | | | | | | | | | | | | | | | |
| Exciter 12.0V | | | | | | | | | | | | | | | | | | | | | | | |
| SST-1 tag | | | | | | | | | | | | | | | | | | | | | | | |

**b**

Staggered antennas, with two antennas upstream and one antenna downstream. Upstream antennas had 48" separation between shields.
Downstream antenna was located 15' dowstream and centered between antennas. Antenna one is upstream near.

| Ant. 1 | X | Z | Y | | X | Z | Y | | X | Z | Y | | X | Z | Y | | X | Z | Y | | X | Z | Y |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SN3 | 51 | 18 | 45 | | 33 | 18 | 44 | | 15 | 18 | 40 | | 0 | 18 | 29 | | -12 | 18 | 20 | | -24 | 18 | 0 |
| 20.4A | | | | | | | | | | | | | | | | | | | | | | | |
| 50 mV noise | | | | | | | | | | | | | | | | | | | | | | | |
| No spikes | | | | | | | | | | | | | | | | | | | | | | | |
| Caps 66 | | | | | | | | | | | | | | | | | | | | | | | |
| Exciter 23.5 | | | | | | | | | | | | | | | | | | | | | | | |
| SST-1 tag | | | | | | | | | | | | | | | | | | | | | | | |

**Test: 9**

Staggered antennas, with two antennas upstream and one antenna downstream. Upstream antennas had 48" separation between shields.
Downstream antenna was located 15' dowstream and centered between antennas. Antenna two is upstream far.

| Ant. 2 | X | Z | Y | | X | Z | Y | | X | Z | Y | | X | Z | Y | | X | Z | Y | | X | Z | Y |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SN5 | 51 | 18 | 42 | | 33 | 18 | 42 | | 15 | 18 | 38 | | 0 | 18 | 33.5 | | -12 | 18 | 22.5 | | -24 | 18 | 8 |
| 19.2A | | | | | | | | | | | | | | | | | | | | | | | |
| 70 mV noise | | | | | | | | | | | | | | | | | | | | | | | |
| No spikes | | | | | | | | | | | | | | | | | | | | | | | |
| Caps 97 | | | | | | | | | | | | | | | | | | | | | | | |
| Exciter 16.5 | | | | | | | | | | | | | | | | | | | | | | | |
| SST-1 tag | | | | | | | | | | | | | | | | | | | | | | | |

**Test: 9**

Staggered antennas, with two antennas upstream and one antenna downstream. Upstream antennas had 48" separation between shields.
Downstream antenna was located 15' dowstream and centered between antennas. Antenna three is downstream centered.

| Ant. 3 | X | Z | Y | | X | Z | Y | | X | Z | Y | | X | Z | Y | | X | Z | Y | | X | Z | Y |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SN7 | 51 | 18 | 42 | | 33 | 18 | 40.5 | | 15 | 18 | 37 | | 0 | 18 | 31 | | -12 | 18 | 20 | | -24 | 18 | 0 |
| 20.6A | | | | | | | | | | | | | | | | | | | | | | | |
| 70 mV noise | | | | | | | | | | | | | | | | | | | | | | | |
| No spikes | | | | | | | | | | | | | | | | | | | | | | | |
| Caps 83 | | | | | | | | | | | | | | | | | | | | | | | |
| Exciter 15.2 | | | | | | | | | | | | | | | | | | | | | | | |
| SST-1 tag | | | | | | | | | | | | | | | | | | | | | | | |

# Performance of Instream Monitoring Systems

## Methods

Since 2007 NOAA Fisheries has operated an instream monitoring system at McDonald Ferry on the John Day River (PTAGIS site code JD1). We used this site, located near Arlington, Oregon, to evaluate new instream monitoring equipment for the detection of passive integrated transponder (PIT) tags. The FS1001-M (MUX) system at this site had been upgraded to the FS1001-MTS multiplexing transceiver system prior to these evaluations, in August 2013.

At the time of this upgrade, researchers noted that the system would work well only with a single antenna attached. They reported that when additional antennas were connected, electrical current dropped on 11 of the 12 multiplexing transceiver system (MTS) readers, and internal EMI fluctuated. After extensive troubleshooting by NOAA Fisheries staff and Biomark, a problem was discovered that appeared to result from proximity of the CAN bus to adjacent antennas.

To address the problem, CAN bus cables for all antennas were routed downstream and anchored in locations outside the electromagnetic field of the antennas. This information was shared with both Biomark and other users who had experienced similar problems with MTS installations. During a site visit in October 2013, all antennas were tuned, and information was recorded on internal EMI, electrical current, and read range.

In May 2014, all communications with FS1001-MTS transceivers was lost at the John Day experimental instream monitoring system. Investigation revealed that debris had severed the two CAN bus cables connecting the instream antenna arrays to the MTS transceiver enclosure.

We replaced the multiplexing transceiver system with a QuBE-IS1001 controller/data logger from Quantitative Sampling Technologies (QST). This product uses a "star" network or topology with a 3-wire cable. The 3-wire cable enables communication between instream detection system components without the use of a CAN bus cable. This approach will offer redundancy and should prevent any further catastrophic failures of arrays.

## Results and Discussion

In September 2014 the multiplexing transceiver system (MTS) was removed from the John Day site (site code JD1), and a QuBE data logger/controller was installed (Quantitative Sampling Technologies, Inc.). The entire CAN bus cable was removed and replaced by standard SO[4] four-wire cable, with each enclosure powered by a single run of SO cable. The site was then re-tuned, and read ranges were taken for comparison (Figure 6). We monitored the site for performance during 2015.

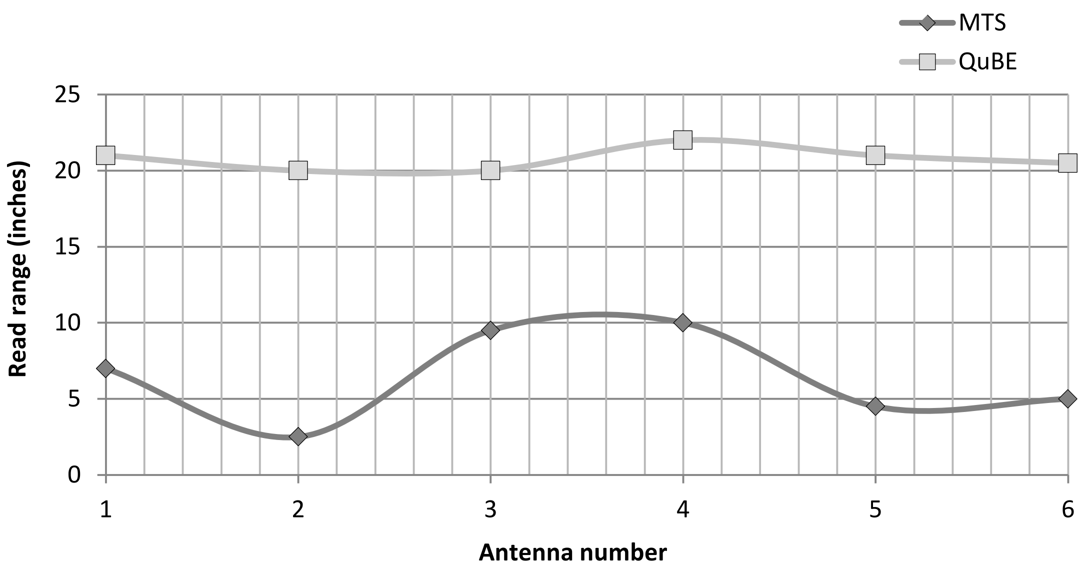


Figure 6. Static read range comparison between instream monitoring systems using the multiplexing transceiver system (MTS) vs. the QuBE-IS1001 controller/data logger at John Day Dam (JD1). Tests were conducted using a standard SST-1 PIT tag.

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[4] SO is a designation assigned by the National Electric Code, with S indicating heavy duty or service-grade cable and O indicating cable with an oil-resistant outer jacket.

# Conclusions

## Cable Selection

Results from tests comparing coaxial cables indicated that the AIR802 cable performed much better than the cable tested in 2014. All subsequent tests utilized this cable, including tests repeated from 2014. Repeat tests with the AIR802 cable achieved more consistent results.

## Power Supply

The Biomark dual-output power supply module performed better than batteries in all tests. Results from testing with the new power supply indicated that a shared ground between the power supply and central processing unit (CPU) is likely to decrease system-generated EMI. This was indicated by the observed drop in noise from 300-500 to 150-180 mV. Results indicated that power supply modules and transceivers can operate on the same branch circuit, as appropriate for field installation.

This test was also used to compare previous test data, which had been conducted with three transceivers powered by independent battery banks, to a system operating completely on AC power. Results showed that improvements in the synchronization circuits, combined with improved shielding methods, produced an increase in overall read ranges between synchronized antennas.

## Preliminary Configuration of the Ogee Antenna

In order to maintain ~20 A of current to the downstream antennas, voltage of the input power supply to the downstream antenna and transceivers had to be significantly reduced. This observed result indicated that the upstream antennas were coupling to and energizing the downstream antenna. Although the antennas will operate with an upstream-downstream separation of 10 ft, this orientation may be less than optimal and will likely reduce the operating life of transceivers. Further testing indicated that the appropriate minimum separation is about 15 ft. This observation will be revisited as we evaluate new antenna design concepts.

## Performance Upgrade for Instream Monitoring Systems

Performance issues related to proximity of the CAN bus to adjacent antennas appears limited to the pipe antennas. However, these antennas are used by many agencies throughout the basin (Biomark reports they have not experienced the issue in “sturdy” antenna installations).

To address this issue, the existing MTS system was removed from the experimental instream monitoring site on the John Day River (JD1) in September 2014. A QuBE data logger/controller was installed in place of the MTS, and the entire CAN bus cable was removed and replaced by standard SO four-conductor-wire cable. Each enclosure was powered by a single run of this cable. This approach will offer redundancy and should prevent any further catastrophic failures of arrays. Biomark has been working on a "star topology" upgrade for the MTS system, and it is the intention of NOAA Fisheries to use the JD1 site as a testbed for this upgrade.

# Adaptive Management and Lessons Learned

At present, resource managers use spillways and other surface-bypass systems (e.g., the corner collector or spillway weirs) as the primary route of passage for migrating juvenile salmonids at hydroelectric facilities. Because of its high estimated rates of passage efficiency and survival, this passage route is preferred by fisheries biologists from federal, state, and tribal agencies that direct river operations throughout the Columbia River Basin.

However, as a result of this practice, significantly less data has been collected from annual PIT-tagging of juvenile migrant salmon. Detection data from these fish are lost because spillway passage routes are not monitored at present. Four specific consequences of this data loss were identified by Faulkner et al. (2015).

1) Reduced certainty in survival estimates, for which standard errors become larger and confidence intervals wider
2) Greater negative correlation between survival estimates in consecutive reaches. That is, an increased chance that estimates will be biased high in one reach and low in the next, or vice versa
3) Insufficient data to estimate survival at all in some cases
4) Reduced certainty in estimates of travel time and smolt-to-adult return ratios

This project develops technologies that help monitor listed fish stocks at critical life stages and locations. Data from monitoring of PIT-tagged fish is essential in informing critical management decisions for ESA-listed salmonid stocks, developing appropriate restoration plans, and monitoring and assessing restoration plans after they have been implemented.

To avoid continuing losses of PIT-tag detection data, we need to develop fish-tracking systems that will interrogate tagged fish in spillways and other high-velocity flow areas that now lack detection systems. This project continues to develop interrogation system components (tags, antennas, receivers, etc.) that will enable us to monitor PIT-tagged fish as they migrate through these pathways.

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