COMPREHENSIVE PIT TAG EVALUATION PROCEDURE

Outline of tests that shall be conducted to determine if candidate tags can be acceptably detected by the PIT-Tag systems installed throughout the Columbia River Basin

Revision 4
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And

PIT Tag Steering Committee

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Introduction

The fisheries community in the Columbia River Basin, through research funded primarily by Bonneville Power Administration (BPA) and the US Army Corps of Engineers (USACE), tags around 2 million salmonids each year with FDX-B PIT (passive integrated transponder) tags. Most of these fish are tagged with one of two standard size PIT tags. One is 12.34 mm in length by 2.04 mm in diameter, the other is 9.05 mm in length by 2.04 mm in diameter. BPA contracts NOAA (National Oceanic and Atmospheric Administration) Fisheries and PSMFC (Pacific States Marine Fisheries Commission) to evaluate the potential impact of adopting alternative technologies, such as new tag models or transceivers, before the technology is adopted or installed. This testing is critical because once integrated, these new technologies can have a significant impact on how well the current interrogation systems detect tagged juvenile and adult salmonids for timing of migration and survival estimation.

NOAA Fisheries and PSMFC work together to evaluate the potential impact of adopting alternative technologies because the agencies have different responsibilities. PSMFC's responsibility is related to operations and maintenance of detection sites for real-time data provided to the Basin, and NOAA Fisheries' responsibility is to ensure that a technology is appropriate for fisheries applications and that the new technologies perform as advertised through evaluation. This partnership ensures that a tag or technology is ready to move from research and development into operations before it is adopted or installed.

Over the years, BPA has periodically requested that PSMFC and NOAA Fisheries evaluate different models of standard FDX-B PIT tags to determine if they will perform acceptably in the network of interrogation systems installed throughout the Columbia River Basin (see the PTAGIS Website at www.ptagis.org/ for a description of the sites and associated detection systems).

The evaluation process consists of a series of laboratory tests that are conducted to determine if candidate tags could be acceptably detected by the network of PIT-tag systems. NOAA Fisheries published a document in 2005 that described a series of tests that were to be conducted for evaluating new PIT tags (Downing, 2005). PSMFC and NOAA Fisheries have modified those tests by utilizing a large 17' by 17' antenna representative of the corner-collector detection system in use at Bonneville Dam (½-scale BCC model antenna). The data collected by the corner-collector detection system provides key data for the survival models used for evaluating ESA-listed salmonid stocks. Given its importance for detection, we have determined that the ½-scale model provides the most realistic evaluation tool for tag testing purposes.

In this document, we list the minimum values determined for passing each test for the candidate tag model to continue being tested. During the evaluation process, points will be given for each test based on the results. Furthermore, the performance of any tag model that is evaluated will be compared to the current tag, which as of this writing is the model APT12 manufactured by Biomark.

All the steps listed and described below will need to be completed successfully for a tag to be considered for purchase. BPA will be responsible for negotiating contracts with the selected manufacturer(s). The USACE issues contracts separately from BPA.

Testing will be conducted in response to a request from BPA to evaluate available production tags. Manufacturers can request that their tags be evaluated through the PIT Tag

Steering Committee or through BPA. If BPA or the PIT Tag Steering Committee requests it, then PSMFC and NOAA Fisheries will also evaluate specialty tags that are outside the standard size range. There are fewer steps to be completed for specialty tags because the focus of the testing is to inform the fisheries community of their general level of performance and to ensure that the tags do not negatively impact the data collection of fish tagged with the standard size tags. On the last page, we list the tests we recommend running for the specialty tags based on their length.

Steps Involved in the Evaluation Standard Size PIT Tags

There are multiple steps involved in the evaluation of a new standard sized tag model. Each test must be passed before the evaluation proceeds to the next step.

Step 1) Tag model must satisfy determined length, diameter, and weight limits

Step 2) Tag model must pass hit-rate tests with the ½ scale corner-collector antenna

Step 3) Tag model must pass the following laboratory tests
- Test A. Electrical parameter testing performed with Automated PIT Tag Testing System (APTTS)
- Test B. Read range tests under different noise levels
- Test C. Maximum read speed tests under different noise levels
- Test D. Drop test
- Test E. Pressure test

With the above tests in step 2, the appropriate transceiver shall be used for that size antenna. In other words, the B2CC transceiver shall be used in the corner-collector tests. Prior to the BCC testing, the FS1001J was used for the 12” pipe antenna that represents most antennas found at the existing bypass facilities for juvenile salmons, and the FS2020 for the orifice antenna or 4’ by 4’ antenna.

Under the description for each test, we indicate the minimum result that must be reached for the candidate tag to continue testing. Meeting the minimum does not mean that the tag will be recommended for use by the fisheries community; it needs to perform as well as or better than the current tag. If a tag model does not meet that minimum requirement for any test; we will stop testing it and will <u>not</u> recommend the tag for widespread use in the Columbia River Basin.

Step 1 Tests (length, diameter, and weight)

1) Measure the individual length and diameters (in millimeters) of 30 randomly selected tags to the second decimal point. The tags shall be individually measured using a micrometer that measures accurately to 0.001 mm (e.g., Starrett Model 721) or with the APTTS. Record the individual values and determine the average value and the standard deviation. Tags must pass freely through the bore of a standard 12-gauge veterinary hypodermic needle.

    - *Testing shall stop at this point if the candidate tag does not have an average length of ≤ 12.7 mm (or 9.3 mm for the shorter standard tag) and an average diameter of ≤ 2.14 mm.*

    - *The fisheries community prefers tags with lengths <12.5 mm; therefore, during the RFP evaluation, higher scores shall be given to tags with average lengths <12.5 mm.*

    - *The tag must fit into the bore of a standard 12-gauge or smaller needle, or the testing shall stop here.*

2) Measure the individual weight (in grams) of 30 randomly selected tags to the third decimal point. The tags will be individually weighed on an electronic analytical balance that weighs accurately to 0.0001 g (e.g., Mettler AE100). Record the individual values and determine the average value and the standard deviation.

    - *Testing shall stop at this point if the candidate tag does not have an average weight of ≤ 0.115 g when measured in air.*

    - *The fisheries community prefers tags with weights <0.105 g; therefore, during the RFP evaluation, higher scores shall be given to tags at or below this weight.*

Step 2 Test (hit-rate tests in the ½-scale corner collector detection system)

In 2006, BPA contracted Digital Angel Corporation (aka Destron Fearing), PSMFC, and NOAA to install a PIT-tag detection system that Digital Angel designed to fit into the exit flume for the corner collector at Bonneville Dam (Figure 1). The corner collector PIT tag system is unique in many ways: 1) it has the largest (17'x17') RFID full-duplex pass-through antenna for fisheries applications, 2) it has only one antenna instead of multiple antennas, and 3) it has a specialized transceiver (FS3001) designed specifically for this application.

Figure 1. PIT tag antenna being lowered into place at the corner collector flume at Bonneville Dam, 2006.

Since the data collected by the corner collector detection system at Bonneville Dam are key to the survival models used for evaluating ESA-listed salmonid stocks, NOAA Fisheries has decided that PIT tags must be detected well in that system to be acceptable. If a tag cannot perform well in the corner-collector detection system, then there is no reason to spend the time determining how well it performs in the other detection systems for juvenile and adult salmonids.

Tag tests are conducted in the ½-scale model of the BCC antenna in PSMFC's large RF room in order to replicate detection conditions at BCC. For these tests, the evaluators shall connect a lab power supply to reduce the amperage accordingly. In addition, the B2CC Ogee transceiver shall be put into diagnostic mode, where the number of times a tag is read out of 100 opportunities is reported. The output of this diagnostic mode is called the hit rate. During the testing, the transceiver shall be periodically taken out of the diagnostic mode so that noise measurements can be recorded.

Using an apparatus made of non-ferrous material, tags shall be placed into the field in two positions that are measured from the inside of the antenna housing (Figure 2). They are the center point (4.25', 4.25'; horizontal, vertical measurements) and near one of the corners (1', 1'). The tags shall be centered in the Z-axis of the antenna. The tags shall be attached to the test apparatus using plastic blocks and Velcro.

As a control, the currently approved BPA tag shall be tested each time the test is conducted. Ten PIT tags from each tag type shall be chosen randomly for the test. All the tags shall be tested in the corner location first, and then the apparatus shall be moved to the center location. At each location, each tag shall be tested in 0° orientations relative to the Z axis, which is the optimal orientation for the antenna. The tag types shall be alternately tested (i.e., TypeA-1, TypeB-1, TypeA-2…). The order for the 20 tags (or more if two or more tag types are tested simultaneously) shall be kept constant for all four sets of tests. For each of the four tests, 10 hit rates shall be recorded for each tag. An average hit rate shall then be determined for each candidate tag type in each location and each orientation.

Figure 2. Photo of the ½-scale model of the BCC antenna. Note the RF shielded room, aluminum shield and pneumatic shuttle for passing the PIT tag through the antenna automatically.

If a candidate tag type averages a hit rate of 98% in the corner position for either orientation, then it shall be tested in the center position.

- *Testing stops here if the average hit rate for the corner location is ≤ 98% for 0°-oriented tags.*
- *Testing stops here if the average hit rate for the center location is ≤ 98% for 0°-oriented tags or ≤ 90% for 45°-oriented tags.*

Step 3 Tests (laboratory tests)

Test A. Electrical parameter testing performed with APTTS

The Automated PIT Tag Testing System (APTTS – Figure 4) energizes the tag with a range of frequencies from 94.2 kHz to 174.2 kHz (40 kHz above and below the nominal 134.2 kHz of the PIT tag). The signal returned from the PIT tag is then analyzed for amplitude to determine the frequency with the highest amplitude. An antenna system was developed that could eliminate the bias imposed by reading the tag micro-chip end of the tag first, rather than antenna end first which allows for consistent automation of testing. A minimum of 200 PIT tags will be tested. The fixed voltage that shall be used in the amplitude and resonant frequency tests will be determined for each specific tag model. It shall be determined with 10 tags. Then, the entire group of 200 tags shall be tested in one automated batch.

Once the APTTS is set up, results for the following electrical parameters shall be collected:

- Amplitude returned from the PIT tag when it is energized with a 134.2-kHz constant amplitude wave form. Amplitude is a simple measurement of raw signal returned from the tag while it is activated. *Higher numbers are better*.
- Resonant frequency, measured to the nearest 25 Hz resolution. Resonant frequency should ideally be the ISO standard 134.2kHz. Testing methodology affects the measurement/result, so *these data are more relevant for showing consistency from tag to tag within the test group.*
- Turn-on voltage, measured to the nearest 10 mV. Turn-On voltage is an indication of how much energy is needed to activate a tag. *Lower numbers are better.*
- Bandwidth at -3dB (kHz). Each model of PIT tag has a characteristic bandwidth. A PIT tag's bandwidth is the range of frequencies, from above to below the resonant frequency, where the tag is most effective. *Typically, a narrow BW is better.*
- Q. "Q" is another common method for characterizing frequency response. The Q is derived from the bandwidth, determined by this formula: Freq@Peak / (Freq@+3dB – Freq@-3dB) *Typically, a higher Q is better (if the transceiver is tuned close to 134.2kHz).*
- Modulation percentage. Modulation percentage is a measure of how strong the tag sends its data to the transceiver. *Higher percentages are better.*

Testing shall stop here if:

- *98% of the tags do not have resonant frequency values of 132-136.5 kHz*
- *98% of the tags do not have turn-on voltages values ≤ 700 mV*
- *98% of the tags do not have bandwidth values < 9 kHz*

- *98% of the tags do not have modulation values > 75%*

Figure 3. Photo of the Automated PIT Tag Testing System (APTTS).

Test B. Read ranges under different noise levels

PSMFC will use the Kennewick Automated Read Range Tester (KARRT) for this test. The KARRT will automatically move the tags into the ½-scale model of the BCC antenna in PSMFC's large RF room. This will eliminate human error, record the data automatically and provide efficiency to the process. "Read ranges under different noise levels" will be tested using one of two tests, KARRT or the manual method which was used in the BPA RFO evaluation in 2011.

<u>KARRT Test</u>

Randomly choose 30 PIT tags from the group of tags. The same tags shall be used in both parts of Test B. Data shall be collected on the tags in the 0° orientation relative to the Z axis of the antenna. The tags shall only be tested with the tags going into the center of the antennas. The test shall be
conducted in the ½-scale model of the BCC antenna in PSMFC's large RF room.

The KARRT automatically moves individual tags into the field in small increments. Each PIT tag to be tested shall be placed on the carriage and moved straight into the center of the field, at approximately 2"/second until the transceiver registers a read. That specific distance, the PIT tag from the center of the antenna, shall be recorded to the nearest ¼". The tag shall then be pushed farther into the field 0.25” at a time, pausing for 3.053 seconds (the minimum time it takes to read a tag 100 times). The next distance measurement shall be recorded when the tag is read 300 times in 9.159 seconds.

The noise for the tests shall be created using a function generator outside of the RF room that is connected to a noise antenna inside the RF room. The noise antenna shall be driven with a 132.2 kHz sine wave. The amplitude shall be varied to provide controlled noise.

If the tag does not reach the 1 or 100% read count, then the read-range distance shall be recorded as N/A.

Run these read range tests with the ½-scale model of the BCC antenna with 0 and 10% added noise.

- *Testing shall stop at this point if the median read range for 100% hit rate for the 0°-oriented tags is < XX” with no added noise (XX will be determined from the currently approved BPA tag).*

Manual Test (if BCC model is not available)

Randomly choose 30 PIT tags from the group of tags. The same tags shall be used in both parts of Test B. Data shall be collected on the tags in the 0° orientation relative to the Z axis of the antenna. The tags shall only be tested with a belt in the center of the antennas. The test shall be conducted in a RF-screen room.

Similar to the Step 1 test, the transceivers shall be set into the diagnostic mode where the number of times a tag is read out of 100 opportunities is reported. The output of the diagnostic mode is known as the hit rate.

Each PIT tag to be tested shall be placed on the belt and moved by hand straight into the center of the field, pausing 4 seconds at each ¼” increment for the transceiver to register a hit rate. The first read range (i.e., the distance of the PIT tag from the center of the antenna) shall be recorded when the display reads a hit. The distance shall be recorded to the nearest ¼”. The tag shall then be pushed farther into the field, and the next distance measurement shall be recorded when the display reads a hit rate of 100%.

The noise for the tests shall be created using a function generator outside of the RF room that is connected to a noise antenna inside the RF room. The noise antenna shall be driven with a 132.2 kHz sine wave. The amplitude shall be varied to provide controlled noise.

If the tag does not reach the 1 or 100% hit rates, then the read-range distance shall be recorded as equaling zero.

Run these read range tests with the 4’ by 4’ antenna with 0 and 10% added noise.

- *Testing shall stop at this point if the median read range for 10% hit rate for the 0°-oriented tags is < 21” with no added noise.*

Test C.Maximum read speed

The evaluators shall conduct this test using the ½-scale model of the BCC antenna in PSMFC's large RF room with the pneumatic shuttle. The tags will be passed through the antenna at approximately 80'/second (the actual velocity will be recorded for each repetition). The number of times the tag is read will be recorded for each pass.

Determine the number of reads for each tag type.

- *Testing shall stop at this point if the candidate tags cannot be detected at the 50% level compared to the currently approved BPA tag.*

Test D. Drop test

To simulate what could happen in the field when fish are being tagged, 10 tags shall be rolled (lightly nudged) from a height of 42" onto a concrete floor. Each tag shall be dropped three times. For verification, tags shall be read before and after dropping with a reader. We shall also record whether the glass breaks on any of the tags. If the glass breaks, photos shall be taken to record how each glass breaks.

- *Testing shall stop here if more than 2 tags stop reading or if more than 40% (4) of the tags break their glass (this includes cracks).*

Test E. Pressure test

The evaluators shall randomly choose 30 PIT tags and confirm that they all read with a transceiver. They shall then put the tags into the pressure chamber with water that is approximately 4.5-10° C.

For the test, increase the pressure by 50-100 psi/sec until the chamber reaches 2,000 psi. Hold the pressure for 90 seconds. Then bring the pressure down using a similar rate (50-100 psi/sec). Repeat this back up and down five times (holding it each time for 90 seconds). After these six cycles, examine the tags for breakage (take photos of any breakage) and test if they read.

- *Testing shall stop here if 10% or more of the tags stop reading or break during any of the tests.*

Steps Involved in the Evaluation of Specialty Tags

There are multiple steps involved in the evaluation of a new specialty tag model. Since these tags may be of different lengths, the evaluators shall modify the tests listed above accordingly. Except for the tests in Step 2 below, there would be no pass/fail criteria for these tags; the testing is just to provide information. Although the evaluators might choose to conduct a more robust set of tests to learn more about the tags, these are the minimum set of tests to be conducted on any specialty tag model whose use is expected to result in the detection of at least 5,000 tagged animals annually.

Step 1) We will measure the length, diameter, and weight as described in Step 2 above.

Step 2) The following tests are run for tags <10 mm in length

Test A. Electronic parameter testing performed with APTTS

Test B. Read ranges (10% hit rate) on the 4' by 4' antenna with no noise added

Test C. If the tags cannot be read in the center of the 4' by 4' antenna, then the read ranges recorded shall be the distance measured from the side of the antenna (out from the middle of one of the sides). The tags shall still be in the 0° orientation relative to the Z axis.

OR

Step 3) The following tests are run for tags >15 mm in length

Test A. Electronic parameter testing performed with APTTS

Test B. Read ranges (10% hit rate) on the 4' by 4' antenna with no noise added

For all of these tests, the appropriate transceiver will be used for that size antenna.

References

Sandra L. Downing, Alan Brower and Don Warf. Process for Evaluating Candidate Pit Tags In 2011. Outline of tests that shall be conducted to determine if candidate tags can be acceptably detected by the PIT-Tag systems installed throughout the Columbia River Basin.

Downing, S. 2005. Procedures for evaluating candidate PIT tags: Description of tests that shall be conducted to determine if the candidate tags can be successfully adapted to the PIT tag systems installed throughout the Columbia River Basin. Technical Report prepared for Bonneville Power Administration and PIT Tag Steering Committee.

Revision History

Rev 0 – October 2016 - Initial release – Axel, Brooks, Brower, Warf

Rev 1 – March 2017 – Redefined "standard tags" to include 9mm types – Brower

Rev 2 – April 2023 – Clarify KAART testing, remove live fish test, clarify and streamline testing - Brower

Rev 3 – June 2026 – Clarify testing procedures and remove belt testing from protocols – Axel

Rev 4 – August 2026 – Added Appendix A and B to provide information related to the APTTS system and how it operates to conduct PIT tag evaluation procedures – Axel

Appendix A

Automated PIT Tag Test System

21 January 2010

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PTAGIS Field Operations

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1. History

The PIT Tag Information System (better known as PTAGIS) has been tracking anadromous salmonids since the late 1980’s. This has been accomplished using passive integrated transponders (PIT Tags) and a system of equipment interrogating those tags at 400 kHz. Between 1986 and 1999, essentially all PIT tag research and monitoring projects in the Columbia River basin (CRB) marked salmon and steelhead using 400 kHz full duplex (FDX) tags manufactured by Destron Fearing Corp. These tags were approximately 11.5 mm long and 2.1 mm in diameter.

In the late summer and fall of 2000, researchers in the CRB transitioned from the use of 400 kHz PIT tags and detection equipment to equipment compatible with 134.2 kHz FDX-B tags conforming to the International Standards Organization standards ISO 11784 and 11785. Again, Destron Fearing (later Digital Angel) has been the primary manufacturer of the 134.2 kHz ISO FDX-B tags used in the CRB. Almost all of these tags are 12.5 mm long and 2.1 mm in diameter.

At times Digital Angel has made changes to the design of the PIT Tags supplied to researchers. These design changes were made to improve the PIT Tag with respect to performance, cost efficiency, etc.

An approximate summary of Digital Angel PIT Tags is shown in the following table:

Common Name	Digital Angel Part Number	Approx Dates of Use
BE PIT Tag	TX1400BE	1997-2002 (Out of Production)
ST PIT Tag	TX1400ST	2001-2005 (Out of Production)
SGL PIT Tag	TX1400SGL	2005 (Out of Production)
SST PIT Tag	TX1411SST	2006 - Current Production

Occasionally the design changes come unannounced. Sometimes the changes have deleterious effects. In 1996, a change was made to the 400 kHz PIT Tag that caused an approximate 20% reduction in read range. The signal received from the PIT Tag was weaker than previous PIT Tags. Data loss from this occurrence is a possibility. PTAGIS personnel spent many hours trying to determine what happened to the readers, but the problem turned out to be degraded PIT Tag performance. To their credit, Destron Fearing quickly re-designed the PIT Tag and increased the sensitivity of the transceivers (through a firmware change) to restore performance.

Around 2000, due to a raw material supplier oversight, some of the ferrite antennas broke when subjected to impact. 20% of these PIT Tags broke in shipping. Due to this occurrence, Digital Angel recalled all of the PIT Tags in question. This included 80,000 PIT Tags already distributed to researchers by PTAGIS.

In 2005 Digital Angel released an interim tag, the TX1400SGL, prior to the completion of the present SST PIT Tags. These tags were needed for early testing of the Corner Collector System. Desiring a process to qualify these PIT Tags prior to distribution in the CRB, PTAGIS created the PIT Tag Electrical Test Fixture (PETF). The PETF is a system used to measure various electrical properties of PIT Tags. Tests performed using the PETF, along with practical application testing at the PTAGIS Kennewick office, showed a variability in the performance of the TX1400SGL PIT Tags. Subsequently, Digital Angel also saw the variability with their equipment. PTAGIS returned their stock of TX1400SGL PIT Tags to Digital Angel, who retested the PIT Tags, removed the outliers, and sent the consistent performers back to PTAGIS.

Although very labor intensive for PTAGIS staff, the additional testing proved beneficial. These occurrences illustrate the need to be able to test PIT Tags in an efficient manner prior to deployment in the CRB.

They also facilitated the creation of the Automated PIT Tag Test System (APTTS). In late 2005 and early 2006, the PTAGIS project contracted with Wintegra, Inc. (PSMFC Contract No. 06-51) for the development of the APTTS. The machine was delivered, installed, and became operational on June 23, 2007.

The APTTS will be used to qualify new PIT Tag models from potential new manufacturers for use in the Columbia River Basin.

2. Testing Capabilities

The APTTS has the ability to make many electrical and physical measurements to each PIT Tag. The measurements can be automated to obtain data from small samples of PIT Tags, large (thousands) samples of PIT Tags, or they can be performed individually.

The ability of the test equipment to accurately measure a physical quantity changes with a number of factors. Time in service, temperature, humidity and environmental exposure can affect measurement accuracy. Calibration quantifies this change in measurement accuracy and, when required, adjusts the device's measurement capability to decrease error.

The electronic test equipment in the APTTS is calibrated to National Institute of Standards and Technology (NIST) traceable equipment. PTAGIS has the APTTS test equipment re-calibrated as per the manufacturer’s suggested two-year schedule.

During APTTS power up, a self-check is performed and the results are printed on each report. If an error occurs during a test run, the test run will be halted immediately. The data from the tags that have already been completed will be saved to a report. The error will be displayed in the “Error Status” indicator on the Main Screen.

2.1 *SIZE*

A camera takes a picture of the PIT Tag under test; the software analyzes the picture and reports the size of the PIT Tag to the nearest 0.01mm.

2.2 *WEIGHT*

Prior to testing, the entire sample is weighed on a computerized scale. After testing, the software divides the weight by the number of units tested and reports this weight to the nearest 0.001g.

2.3 *FREQUENCY RESPONSE*

Frequency response is quantified in amplitude vs. frequency for a given PIT Tag.

2.3.1 Resonant Frequency

The PIT Tag under test is aligned in the antenna. It is then energized with a swept radio frequency of the operator's choice. Typically, the range of frequencies is from 94.2 kHz to 174.2 kHz (40 kHz above and below the nominal 134.2 kHz of the PIT Tag). The frequency steps during the sweep are also adjustable, typically 100 Hz for a detailed sweep and 1 kHz for a quick sweep.

The signal returned from the PIT Tag is then analyzed for amplitude. The frequency at which the highest amplitude is measured is the resonant frequency of that PIT Tag.

2.3.2 Band Width

During the amplitude analysis, the amplitudes at all frequencies are logged to create a "curve." The bandwidth at the -3dB points on that curve (an RF standard) are included in the report.

2.3.3 "Q-Factor"

"Q-Factor" (quality factor) is a function of how narrow the bandwidth is. It's the resonant frequency divided by the bandwidth. A narrow bandwidth translates to better noise rejection performance. "Q" is an indicator of how the PIT Tag will react to off-frequency signals vs. on-frequency signals. A higher "Q" leads to better performance in our application. The "Q" of the of the PIT Tag is included in the report.

2.4 *MINIMUM "TURN ON VOLTAGE"*

A test can be run to quantify a particular PIT Tag's ability to transmit information. The PIT Tag under test is aligned in the antenna. It is then energized with a single radio frequency of the operator's choice at a very low amplitude. The voltage driving the antenna increases until the PIT Tag successfully sends its data. The voltage at that point is the "turn on" voltage for that PIT Tag and is included in the report.

2.5 *RF MODULATION*

RF modulation is a measure, quantified in a percentage, of the intensity with which the PIT Tag signal is transmitted by the PIT Tag once it is fully activated. Higher modulation percentages are better. During the minimum turn on voltage test, the RF modulation is measured and included in the report.

2.6 *ABILITY TO DECODE A PIT TAG*

The APTTS is able to read the code of the PIT Tag under test. This code is presented in its usual hexadecimal format (i.e. 3D9.257C663DDD) in the report. The APTTS also has the ability to graphically show the signal received from the PIT Tag. This allows the operator to analyze the individual “ones” and “zeros” as read during the interrogation.

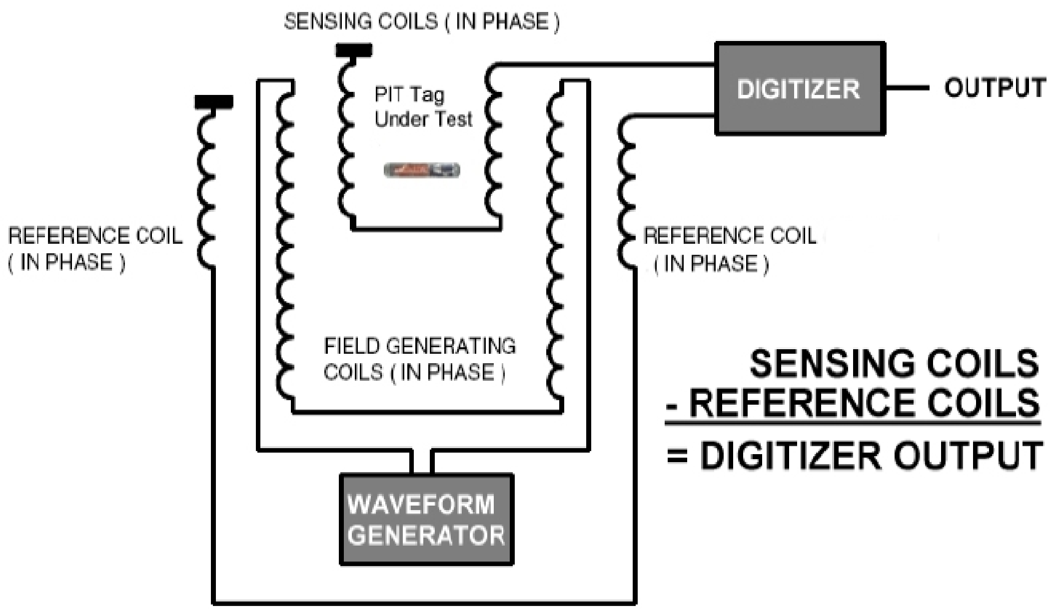
2.7 *SIMULATE MANUFACTURER’S QUALITY ASSURANCE*

Digital Angel qualifies PIT Tags using a fixed frequency/fixed amplitude test. The response from The PIT Tag under test must respond with amplitude higher than a preset threshold. The APTTS can simulate this test.

Appendix B

Summarizing the Automated PIT Tag Test System

The Automated PIT Tag Test System was designed and built by a third party and most of the specifications were proprietary. The antenna windings are coated with black conformal coating, and we were not provided with the specifications for that.

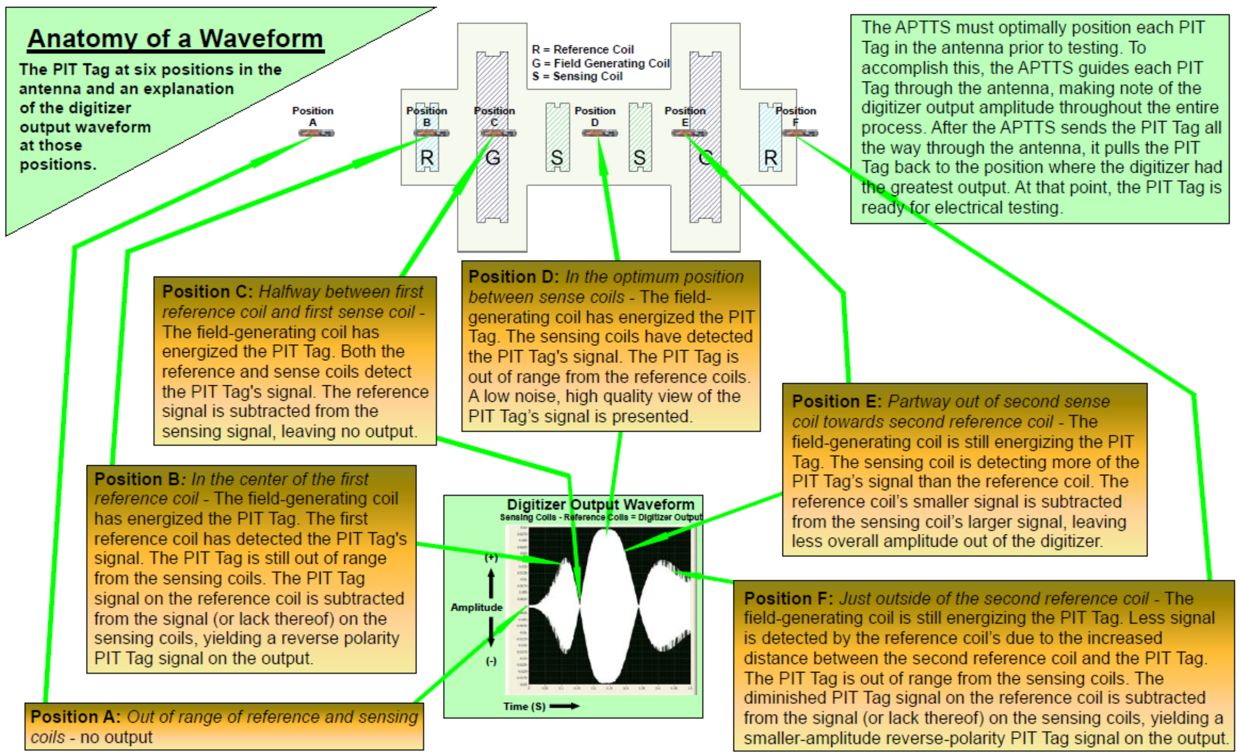


The antenna assembly consists of three pairs of coils: the field generating coils, the reference coils, and the sensing coils. The field generating coils are outputs from the APTTS. They are driven by the waveform generator in the National Instruments PXI rack. These coils energize the PIT Tag under test and cause it to transmit its data.

The reference coils and sensing coils are inputs to the APTTS. They are identical and are placed symmetrically about the field generating coils. The reference and sensing coils detect essentially the same signals. The signals detected by the sense and reference coils are each digitized in the National Instruments PXI rack. In software, the signals detected by the reference coils are subtracted from the signals detected by the sensing coils. This signal is a function of what the sensing coils detect, minus what the reference coils detect. All things being equal, this cancels the signal presented to these coils by the field generating coils, as well as any other RF signals (local radio stations, random RF noise, etc.).

The PIT Tag under test is then placed in the antenna such that it is only near the sensing coils. The PIT Tag is energized by the field generating coils and is transmitting its data. The reference coils are not close enough to detect the PIT Tag's signal. The resultant waveform is only the data being transmitted by the PIT Tag.

There is a laser alignment tool built into the APTTS which is used to ensure the proper alignment of the antenna, glass v-block, and the vibratory bowl tag shuttle. This process is necessary upon the initial setup of the system prior to testing. The automated system can then run an individual tag incrementally into the antenna and locate the optimal spot for electrical testing, which is based on the maximum amplitude for that specific tag. Not all tags are created equal, but we expect to have tags with tight tolerances for use in the Basin.



Q and Bandwidth Testing

The PIT Tag's resonant (or center) frequency is the frequency at which the signal from the PIT Tag is the most powerful. Nominally, this frequency is 134.2KHz.

Half-Power or -3dB Points: The half-power point of a signal is reached when the output power has dropped to half of its peak level. For our PIT Tag testing, this occurs when the voltage measured by the APTTS has dropped 3dB below the voltage measured at the peak. The PIT Tag signal has two half-power points, one below the peak frequency and one above.

This formula determines the half power point: **Voltage Peak/ 1.414 = -3dB**

Bandwidth is defined as the range of frequencies between the upper and lower half power points. Each model of PIT Tag has a characteristic bandwidth. The transceivers also have a characteristic bandwidth. Compare the "juvenile" FS1001 with the "Hi-Q" BCC transceiver.

Another common method for characterizing frequency response is referred to as the Q-Factor, or "Q." The Q is derived from the bandwidth, determined by this formula:

Resonant Frequency/ Bandwidth (at the half power point)

Higher Q's have a narrower bandwidth which can be beneficial in noisy environments.

The National Instruments PXI cards are sent back for calibration every three years and before any RFO testing is to begin. We also use a set of tags with known test characteristics to confirm that readings are correct on a periodic basis. In addition, we send our calipers and scale out for calibration at the same time to the Energy Northwest Standards Laboratory to make sure that everything is in complete compliance for measurements.