AQUATIC PIT TAG INTERROGATION SYSTEM CONSTRUCTION & STANDARD OPERATING PROCEDURE

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Introduction:

Since the 1980s, passive integrated transponder (PIT) tags have been used to support the collection of various biological and population demographic data in a variety of animal models (Gibbons and Andrews 2004). For example, this technology has been used extensively in the Pacific Northwest for monitoring the behavior and survival of juvenile and adult salmonids in the Columbia River Basin (Zabel et al. 2005). Over 15 million salmon and trout have been PIT tagged in the Columbia River Basin since 1987 (Pacific States Marine Fisheries Commission 2005). Though 12-mm PIT tags are most commonly used, to maximize detection distance and to minimize tag burden of fish many researchers employ a variety of tag sizes ranging from 8-mm to 23-mm PIT tags (Roussel et al. 2000; Zydlewski et al. 2001; Hill et al. 2006). The distance at which a PIT tag can be detected is particularly important in applications where fish are not recaptured but are remotely detected via a fixed or mobile antenna. Since data collected from PIT tag detections is often used to determine stock identity (Jenkins and Smith 1990; Achord et al. 1996), movements (Ombredane et al. 1998; Zydlewski et al. 2001), migration rates and routes (Achord et al. 1996; Kennedy et al. 2007), abundance (Achord et al. 1996), growth (Peterson et al. 1994), mortality (Kennedy et al. 2007), and stocking success (Wills 2006), it is important that the PIT tag systems are designed and constructed to maximize read ranges, thus ensuring that biologists have the highest quality data possible.

PIT tag systems are, at the most simple level, comprised of a transceiver and antenna (i.e. series of wire loops). The transceiver facilitates how much electrical power delivery to the wire loops that in turn energize the PIT tag with a magnetic field. The energized PIT tag then transmits a unique identification code back to the antenna for decoding by the transceiver. Wire loops are commonly housed in an airtight frame of polyvinyl chloride (PVC) pipe that is necessary in aquatic environments to detect half and full duplex PIT tags for commonly used transceivers (e.g. Destron Fearing® and Allflex®). More complex PIT tag systems may also include a memory storage devices for PIT tag codes, software that organizes data and coordinates uploading of data to a central database, as well as various means (e.g. solar panels, thermoelectric generators, hydropower, wind turbines, etc.) to power the transceiver and any additional ancillary equipment. Herein we describe only the most basic elements of antenna design, construction and transceiver operation. Further we limit our discussion to systems driven by two models of transceivers, the Destron-Fearing® (model # FS1001M) and the Allflex® (model # RM310) since they are commonly employed by biologists in the Pacific Northwest.

Objective:

To provide procedures for the construction and installation of antennas that detect and decode PIT tags for the identification of individual aquatic organisms.

PIT TAG SYSTEM CONSIDERATIONS

Transceiver Comparison:

Herein we discuss two models of transceivers, the Destron-Fearing® (model # FS1001M) and the Allflex® (model # RM310) have both commonly employed by biologist. The transceiver performs two functions in a PIT station. It transmits power to an antenna and it receives information from a PIT tag inside a fish (via the antenna). Project goals and site-specific conditions commonly determine what transceiver will be the best option. Transceiver features are as follow:

Table 1. Specifications of two commonly used transceivers used to power passive integrated transponder antennas in aquatic systems.

Specifications	Destron Fearing® (FS1001M)	Allflex® (RM310)
Decodes Full Duplex (FDX) Tag	YES	YES
Decodes Half Duplex (HDX) Tag	NO	YES
Antenna Channels	6	1
Transceiver to Transceiver Synchronization	NO	YES
Date/Time Stamp	YES	NO
Internal Memory	YES (5,350 Tags)	YES (1 Tag)
Internal Memory Battery	YES (CR2032)	NO
Auto Tuning	YES	NO
Antenna Capacitor Required	YES	NO
External Power Needed	Yes (18 to 30 VDC, 3A)	Yes (6 to 12 VDC, 2A)
Computer Serial Port (RS232)	YES (57,600 baud, N, 8, 1)	YES (300-57,600 baud, N, 8, 1)
Computer Serial Port (RS422/RS485)	NO	YES (300-57,600 baud, N, 8, 1)
Relative Cost	HIGH	LOW

- Full Duplex (FDX; ISO 11784/11785) tags are the most commonly used for monitoring salmonids in the Columbia River Basin (CRB). FDX tags meet standards developed by the Pacific States Marine Fisheries Commission's (PSMFC) PIT Tag Information System (PTAGIS) program that integrates PIT tag data collected from all registered sites. PIT tag codes detected *in situ* at registered sites are archived and data can be queried to meet individual project goals. FDX tags are available in smaller sizes (e.g. 7 mm) compared to HDX tags (e.g. 12 mm) as a result the lower tag burden may be an important consideration to meet project goals.

- Half Duplex (HDX; ISO 11784/11785) tags are employed in the CRB less frequently; however, project costs and objectives may make this a more suitable option than FDX tags. In the CRB, HDX tags have been used for marking lamprey since they will not interfere with reading FDX tags if the lamprey affixes itself near or to an antenna.

- The Destron-Fearing® (model # FS1001M) transceiver can drive up to six antennas in a user specified sequence. Allflex® (model # RM310) transceiver will only drive a single antenna. Multiple antennas each need an individual RM310 to function. The Allflex® (model # RM310) transceiver reads FDX and HDX PIT tag codes alternating between FDX (while the transmitter is on) and HDX (when the transmitter is off) an important consideration if different PIT tag types are used.

- Any number of Allflex® (model # RM310) transceivers can be synchronized so that their antennas all read simultaneously and do not interfere with each other. Antennas attached to different Destron-Fearing® (model # FS1001M) transceivers can only be synchronized using a terminal script (e.g. with a computer that controls the transceivers so that they read alternately). Without synchronization, the transceivers they must be at least 300 ft from each other to avoid interference. The read rate for each of two or more antennas attached to Allflex® (model # RM310) transceivers will be higher than the read rate for the equivalent number of antennas attached to a Destron-Fearing® (model # FS1001M) transceiver. However, unless the project expects to have very large number of fish passing antennas simultaneously (e.g. intensive culture facility) the read rate of either transceiver will likely be adequate for most applications.

- The Destron-Fearing® (model # FS1001M) transceiver records up to 5,350 PIT tag codes and the date and time when a PIT tag is decoded. Conversely, the Allflex® (model RM310) transceiver does not have that capability. Instead, it only stores the last PIT tag transmitted, so a computer or data logger must be used to record PIT tag codes.

- The Destron-Fearing® (model # FS1001M) transceiver automatically adjusts its tuning capacitance to maintain near optimal performance when conditions such as water depth change. Conversely, the Allflex® (model RM310) transceiver does not have that capability and must be manually tuned.

- The Destron-Fearing® (model # FS1001M) transceiver requires high voltage capacitor(s) in the antenna, so that the antenna is tuned to resonance slightly below 134.2 kHz when its cable is attached. The antenna for the Allflex® (model RM310) transceiver is a simple wire coil of 220µH to 280µH which is tuned to resonance by selecting jumper combinations on the motherboard. A jumper is a short length of conductor used to close a break in or bypass part of an electrical circuit.

- The Destron-Fearing® (model # FS1001M) transceiver can be powered from the grid using a linear or switching AC to 24VDC power supply If a switching supply is used it should have a switching frequency of at least 300kHz. Battery power can be provided by two 12 V batteries in series. The Allflex® (model RM310) transceiver can be powered from the grid using a linear AC to 12VDC power supply or a switching power supply operating at 300 kHz or higher. Isolated battery power from batteries is preferable; however, to prevent conducted noise to the reader through its power input. A single 6 volt battery is an easy power source to isolate to power the reader. A DC-DC converter that puts out 6 or 12 volts operating at 300kHz or higher can be used to provide power to an Allflex (model RM310) transceiver from a 24 or 12 volt battery source (note that a 12 V battery cannot be used to power the Allflex® (model RM310) transceiver directly, since it may reach up to 14.5 V when fully charged).

- The Destron-Fearing® (model # FS1001M) transceiver communicates via an RS232 serial port at 57,600 baud, no parity, 8 data bits, and 1 stop bit. The Allflex® (model RM310) transceiver has an RS422/RS485 serial port that can be configured at any baud rate from 300 to 57,600. RS422/RS485 serial port is preferred over RS232 if high data rates must be communicated over long distances (4000 feet or more, versus 45 feet for RS232). The Allflex® (model RM310) transceiver can also be configured as a node on an RS422/RS485 network, so that one RS422/RS485 serial port on a computer or network controller can be used to communicate with and control a large number of Allflex® (model RM310) transceivers.

- The cost of a Destron-Fearing® (model # FS1001M; Drive N = 6 antennas) transceiver is significantly greater than an Allflex® (model RM310; Drive N = 1 antenna) transceiver.

Antenna Orientation and Design:

Pass-over/Flat panel.-Pass-over antennas are installed flat against the substrate, allowing the majority of water to pass-over the antenna (Figure 1).

Advantages:

- The advantage to this method is that little of the antenna array's surface area is exposed to damage from debris or high water velocities.
- Antennas can be attached in areas where there are no manmade or natural structures to easily affix the antenna to in an upright position.
- Antennas can be attached against the substrate by strapping them to rebar, fence posts, or cables (e.g. duckbill anchors) driven into the substrate, or to anchor bolts attached to bedrock or large rocks.

Disadvantages:

- The disadvantage of this configuration is that the most extensive detection area of the antenna, the area within the antenna loop, is not exposed to the water column, which reduces PIT tag detection efficiency. In short, only 10 to 24 inches, depending on the antenna, of the water column above the substrate will detect PIT tags. An antenna (≤ 10 feet in length) will typically read 12mm Destron Fearing® FDX "Supertags" up to 12 to 18 inches. Pass-over antennas are therefore limited to relatively shallow (≤ 24 inches) and narrow watercourses (≤ 60 feet wetted area for six antennas placed end to end).
- Affixing antennas to substrate can be labor intensive and dependent upon site-specific characteristics. For example, hard bedrock or loose fine soils may preclude antenna attachment.
- Each pass-over antenna should not exceed a coil geometry of 10 feet by 2 feet to ensure a maximum read range, unless the water is very shallow.

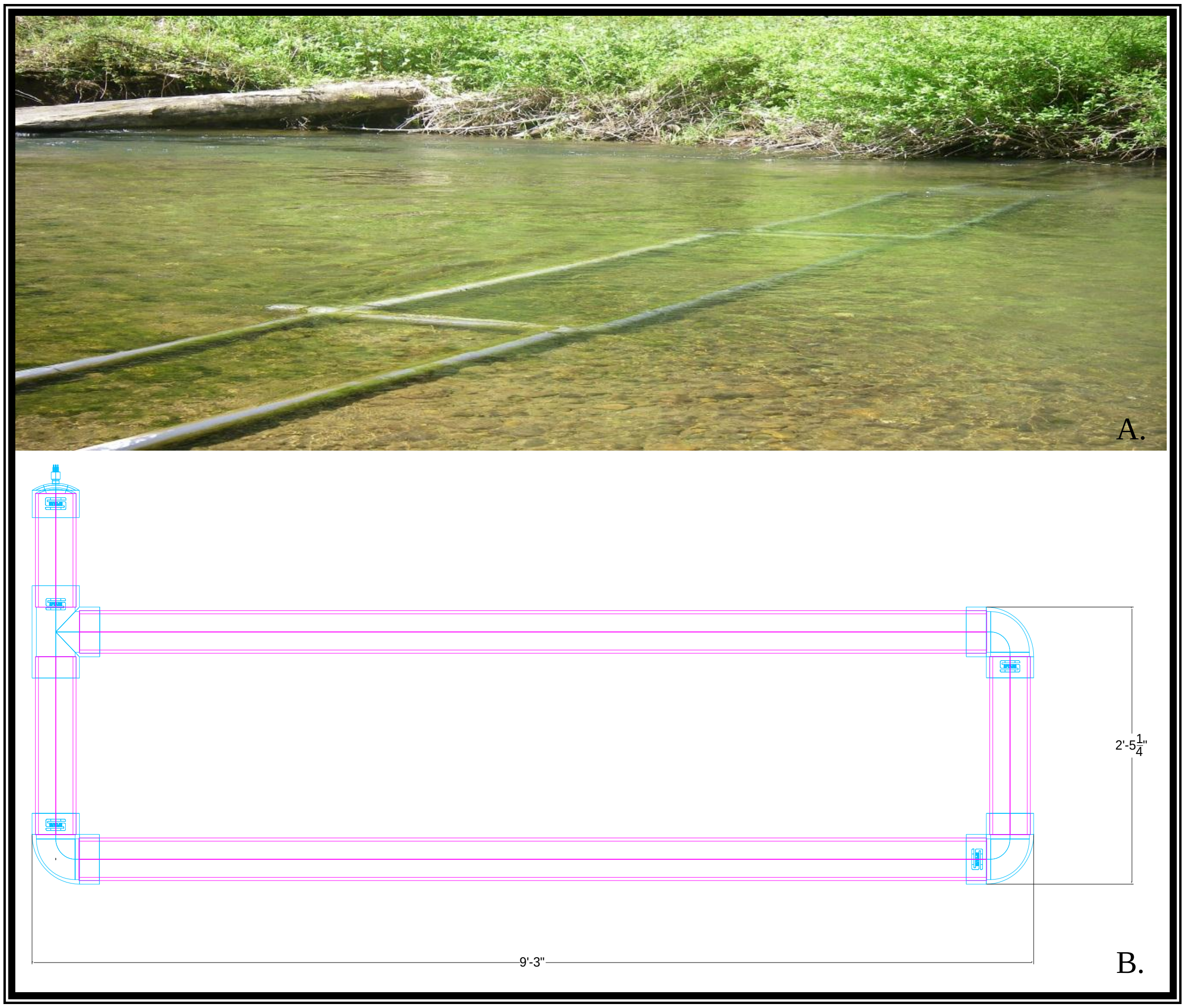

Figure 1: Pass-over Antenna constructed and designed to be positioned flat on the substrate. A) Four pass-over antennas end to end within Abernathy Creek, WA. B) Line drawing of a pass-over antenna including outside dimensions.

Pass-through.-Pass-through antennas are installed in an upright position allowing water to flow through the middle of the antenna (Figure 2).

Advantages:

- More of the water column is covered by the antenna field as compared to a pass-over antenna. As a result, detection efficiencies may be higher due to more PIT tag detections.
- Antennas commonly use existing man-made structures for attachment.
- The bottom of an antenna can be the only point of attachment. Since the antenna is buoyant, it can pivot up and down with rising and falling water levels.
- Antenna dimensions can be relatively tall so debris in high gradient environments can pass-through the antennas. A 10 foot by 3 foot pass-through antenna will typically read 12mm Destron Fearing® FDX "Supertags" at a distance of 18" to 24" inches.

Disadvantages:

- Pass-through antennas built larger than 10 feet by 3 feet will commonly result in lower performance within the center of the antenna. Antennas with height greater than 4 feet may result in "holes", located in the center of the antenna, where PIT tags cannot be read.
- It can be difficult to support pass-through arrays consisting of multiple antennas without manmade structures.
- Vertical members of the antenna and the supporting posts can be vulnerable to damage by the downstream movement of large debris, the pressure of debris accumulation, or large volumes of fast moving water common to high gradient streams.

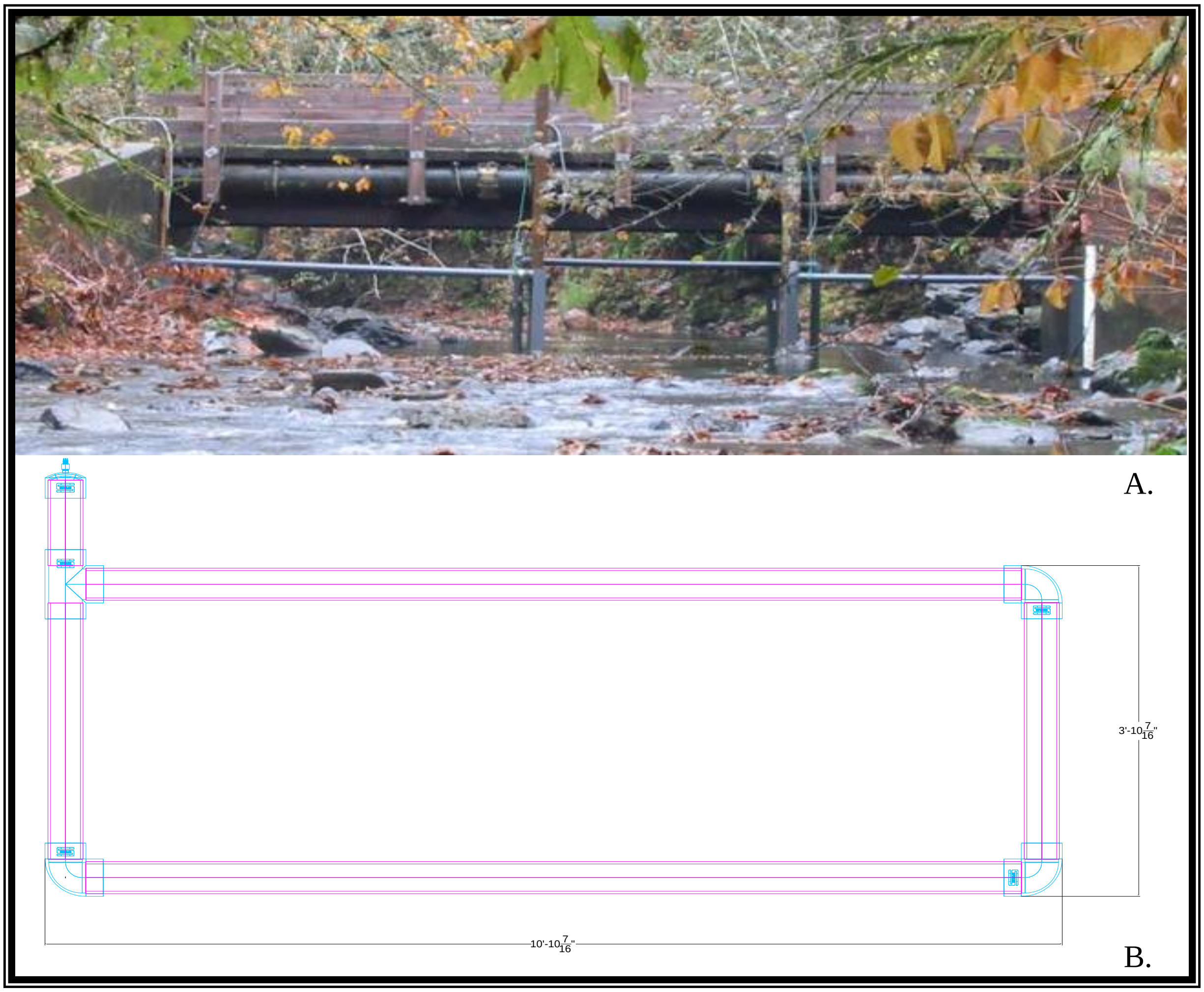

Figure 2: Pass-through antennas constructed and designed to be positioned upright. A) Three pass-through antennas end to end within Abernathy Creek, WA. B) Line drawing of a pass-through antenna including outside dimensions.

Double-loop.-A double-loop antenna can be installed either in an upright position allowing water to flow through the middle of the antenna or in a flat position against the substrate, allowing the majority of water to pass-over the antenna (Figure 3).

<u>Advantages:</u>

- Double-loop antennas provide higher PIT tag read efficiencies for small PIT tags (e.g. Destron Fearing® FDX 9 mm).
- Double-loop antennas can be relatively large without “holes”.
- Although a double-loop antenna does not increase read range for pass-over antennas, pass-over antennas with a double-loop design will often read relatively well in high noise environments.

<u>Disadvantages:</u>

- Double-loop antenna poses a middle pipe most commonly oriented perpendicular to the stream flow that may collect debris.
- A double-loop antenna is more expensive and difficult to construct than single-loop antennas.

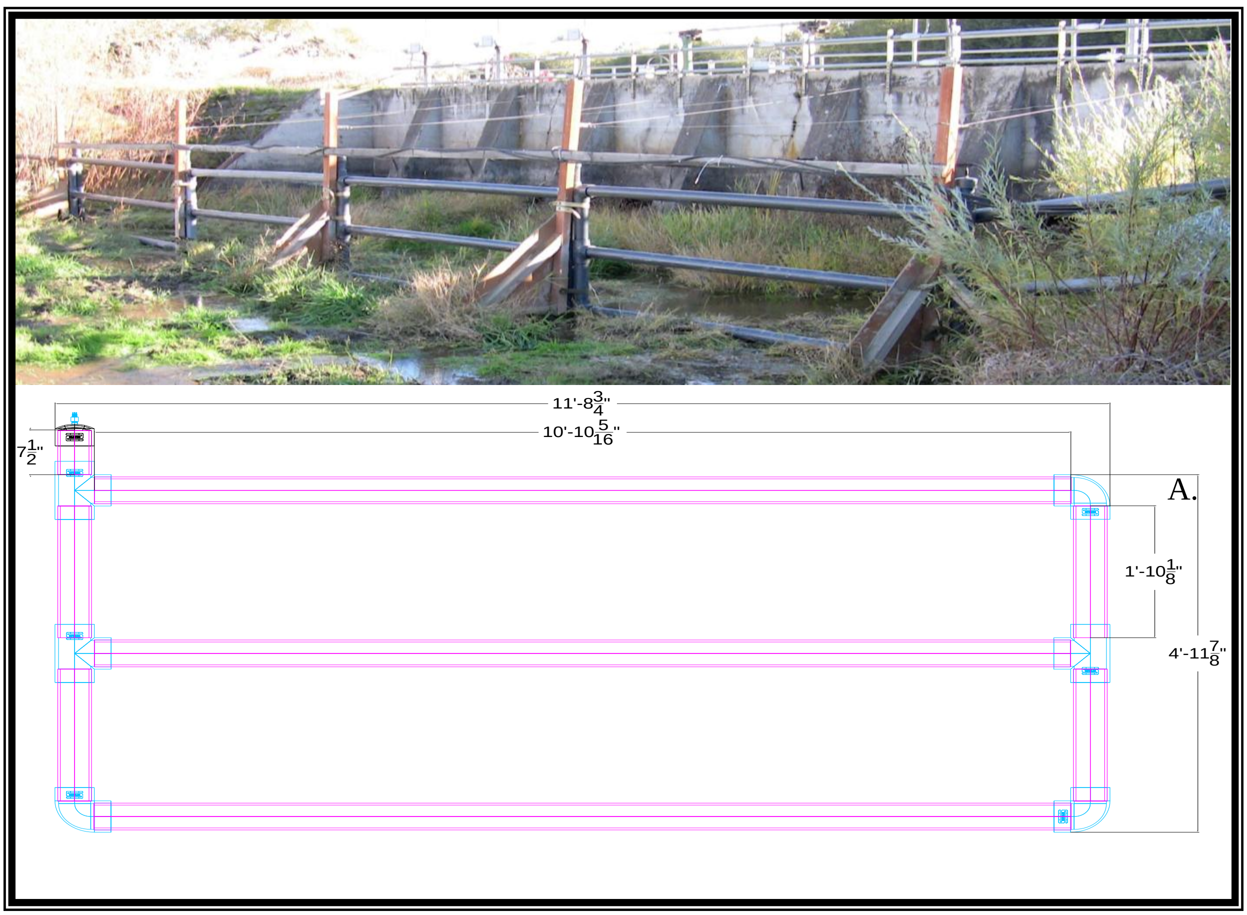

Figure 3: Double-loop antennas constructed and designed to be positioned upright. A) Six double-loop antennas positioned end to end within Umatilla River OR. B) Line drawing of a double-loop antenna including outside dimensions.

B.

Antenna Dimensions:
In general, the larger an antenna, the more likely it will have gaps in its detection area. Often antenna size is limited to 15ft x 5ft or smaller. Pass-through antennas may need to be tall enough to read the entire water column and pass debris. As a result, the width of the watercourse and availability of suitable structure for antenna attachment will dictate the size of the antenna.

Number of Antennas:
The width of wetted area interrogated dictates the number of antennas needed. Migratory direction is also a common consideration. At least two antennas in series (i.e. a fish must pass one antenna to reach the next) are required if migratory direction is to be determined. Antennas positioned in series are also critical for determining detection efficiency statistics. As general "rule of thumb", an antenna spanning the entire waterway in a low noise environment has a PIT tag detection efficiencies of 70%, two such antennas in series often detect about 91% of tagged fish, and three antennas often detect about 97% of fish.

PIT Tag System Construction

Tools and Materials for Antenna Construction:

Tools

- Laptop or portable computer with a serial port and data acquisition software (e.g. Minimon available at www.ptagis.org)
- Transceiver
- DB9M to DB9F serial cable (when using Destron-Fearing® (model # FS1001M) transceiver)
- Table saw with:
    - Fence
    - Pusher
    - 1/8” blade and appropriate table insert
    - 5/16” dado blade and appropriate table insert
    - Feather board is highly desirable
- Rubber mallet
- Wire stripper
- Wire cutter
- Soldering iron
- Heat gun
- Scissors
- Box cutter
- LCR meter
- Digital voltmeter
- Optional: Vector Network Analyzer (VNA) (when using Destron-Fearing® (model # FS1001M) transceiver)
- Drill press or electric drill and a 3/8" bit
- 7/16-20 National fine (NF) tap and tap handle
- 12" compound miter Saw
- Tape measure
- PVC pipe cap with tire valve
- Air compressor with tire inflation fitting
- Tire pressure gauge accurate to ±0.5 psi at 3 psi.
- Small brush, disposable solder flux brush
- Vacuum pump (or shopvac) with tire inflation fitting
- 3/4” open end wrench
- 11/16” open end wrench

Consumables:

- Solder (Sn63)
- 3-conductor multistrand 14 gauge or 16 gauge jacketed cord
- PVC primer
- PVC glue
- Aquarium grade silicone adhesive

- Vinyl electrical tape
- Vector electronics prototyping perfboard
- 1:1 to 1:2 liquid dish soap to water mixture
- 3/32" heat shrink tubing
- 3/8" 3:1 ratio adhesive lined heat shrink tubing
- 3/4" 3:1 ratio adhesive lined heat shrink tubing

Supplies:

- PVC pipe
- PVC elbows
- PVC Tee(s)
- Schedule 40 PVC cap
- 2000 V low effective series resistance (ESA) capacitors (when using Destron-Fearing® (model # FS1001M) transceiver)
- CAT 6 ethernet cable
- 1" thick polystyrene foam sheet
- BH3MP male bulkhead connector
- 7/16-20 nut
- 12 gauge, 2 conductor with braid shield antenna cable
- IL3FS female in-line connector
- TYCO/AMP 206322-9 cable gland
- TYCO/AMP 202236-2 contact
- TYCO/AMP 211768-1 circular connector, male, 9-pin
- 3-conductor 14-gauge or 16-gauge multi-strand outdoor rated electrical cord

Choosing the Pipe:

There are four types of pipe commonly used:

- 4" schedule 80 is used where high, fast water events and high debris loads are expected, for very large antennas, or where maximum mechanical strength is required (Pipe length = outside antenna dimension – 10-1/2").
- 3" schedule 80 is used for medium sized antennas that require moderate mechanical strength (Pipe length = outside antenna dimension – 8-3/8").
- 3" schedule 40 is used for large antennas that will be structurally supported and will not experience mechanical loads, or medium sized antennas that do not experience mechanical loads (Pipe length = outside antenna dimension – 7-3/4")
- 2" schedule 40 is used for small antennas, portable antennas, or well supported antennas that don't experience mechanical loads (Pipe length = outside antenna dimension – 5-3/8")

How to Estimate the Number of Wire Loops:

Antennas work optimally with an inductance range of 220µH to 280µH, regardless of the transceiver type. Bigger antennas require fewer loops to reach that inductance range than smaller antennas. The number of loops must be established prior to cutting grooves in the foam

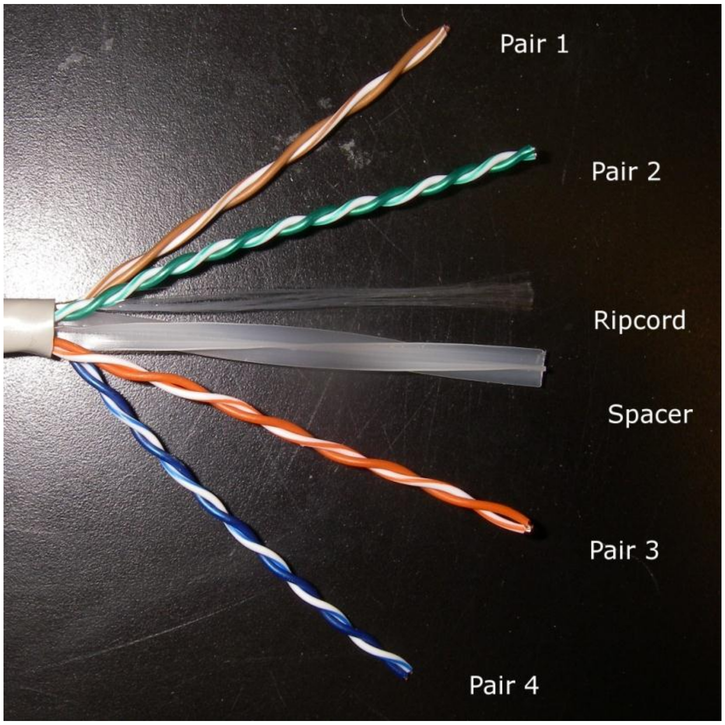

Figure 4. Anatomy of CAT6 Ethernet Cable

for CAT 6 network cables. Each CAT 6 network cable contains four pairs of different colored wires (Figure 4), so each cable can make four loops. Appendix A provides examples for the number of loops required for common antenna sizes and styles. The number of loops for a custom antenna size can be determined by stringing a loop of wire supported by a non-metallic structure. Space the wire as though it was at the centerline of the pipes, nails can be used to hold the wires in place. Measure the inductance of the loop with an LCR meter. When measuring inductance, set the LCR meter to test at 1 kHz using "series" mode (designated SER on some meters) so that it will properly measure series inductance. If you use a pair of wires in a length of CAT 6 cable for your "one-turn" measurement, multiply the measured inductance by about 1.25 to compensate for the fact that the capacitance to the other pairs makes it look to the LCR meter as though the inductance is lower than it is.

The amount the inductance increases with each added loop relative to the inductance of a single loop is proportionate to the number of loops. In other words, the inductance of two loops is proportional to three (1+2) times the inductance of a single loop, the inductance of three loops is proportional to six (1+2+3) times the inductance of a single loop, and so forth. Multiply the inductance you measured for a single loop by the loops factor (1, 3, 6, 10, 15, 21, 28, 36, etc.) to find the number of loops which will give an inductance closest to 250µH.

Table 2: Example Calculations for a 12'6-1/8" x 2' Antenna

Measured inductance of one loop = 11.0 µH Corrected inductance or one loop = 1.25x11.0µH = 13.8 µH			
# Turns	Loops Factor	Estimated Inductance	Measured Inductance
1	1	13.8 µH	11.0 µH
2	3	41.3 µH	41.5 µH
3	6	82.5 µH	90.4 µH
4	10	137.5 µH	159.8 µH
5	15	206.3 µH	213.4 µH
6	21	288.8 µH	286.6 µH
7	28	385.0 µH	378.1 µH
8	36	495.0 µH	489.1 µH

- In Table 2 above, the measured inductance of a single 12’6-1/8” x 2’ loop of a wire pair from CAT6 Ethernet cable was measured at 11.0 µH.
- The measured inductance was corrected for capacitance effects by multiplying it by 1.25.
- The estimated inductance was calculated for 1 to 8 turns by multiplying the corrected inductance value for a single loop by the Loops Factors for 1 to 8 turns.
- Six was chosen as the “best” number of turns based on the estimated inductance, since the estimated value of 288.8 µH for six turns was closest to 250 µH.

Divide the number of loops (6 in the example above) by 4 and round up if there is a remainder to calculate the number of loops of CAT 6 cable required (there are four pairs of wires in each cable). If you are building a double-loop antenna, you will need twice that number of grooves in the foam for the middle pipe.

- In the example above, 6/4 = 1-1/2 which rounds up to 2, so two loops of 4-pair CAT 6 network cable are required to provide the 6 turns needed for the antenna.
- Measure the inductance of one less than and one more than the calculated number of loops to verify the choice of the number of turns. In the example in Table 2, the turns were connected one at a time and the resulting inductance was measured and recorded (Measured Inductance in the table above) for every turn, confirming that six turns was the best choice.

Most 3’ to 14’ antennas use 1, 2, or 3 loops of CAT 6 network cable.

Cutting the Foam:

Strips of polystyrene foam are used to space apart the 1/4” diameter CAT 6 network cables inside the PVC. The spacing is critical for minimizing the interwinding capacitance and capacitive losses and for maximizing the antenna current. Specific dimensions of foam strips for common antenna sizes and styles are given within the subsequent diagrams (Figure 5 to Figure 9). One inch and 0.6 inch (nominal 1/2”) thick pink Foamular® polystyrene foam insulation can be purchased at local hardware stores in 4’ x 8’ sheets. The foam sheets can be easily cut and grooved on a table saw into many different shapes and configurations to suit the needs of a variety of different antenna sizes and pipe dimensions. A table saw fence and pusher are necessary for safety and accuracy in this process. A featherboard is useful to improve accuracy of cutting slots in the strips of foam. Prior to cutting, remove any plastic protective film attached to the foam. The plastic film can clog up the saw blade. The foam should be cut on a table saw so the foam strips can easily slide through the pipe. Use a standard 1/8” blade and insert to rip the foam sheets into 8’ long strips of the desired width (the foam should fit snugly within the PVC pipe). Use a dado blade adjusted for a 5/16” wide cut and approximately 5/16” deep cut to make the grooves shown in the diagram on half of strips. The groove spacing for large antennas should be approximately 3/4”. One inch thick foam with two 5/16” cut grooves works well for antennas constructed out of 3” or 4” PVC pipe. Half inch (0.6” thick) foam with three grooves works well for antennas constructed out of 2” PVC pipe. Thinner foam is needed for small antennas and when narrower PVC pipe is used.

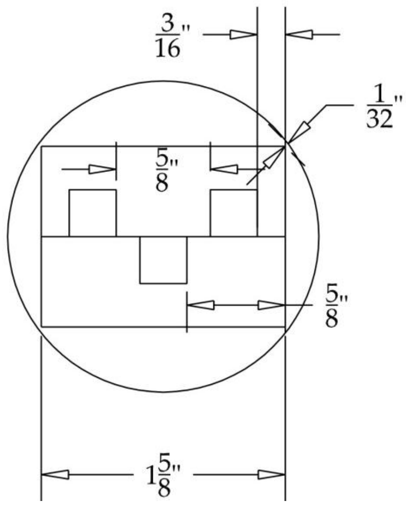

Figure 5. 2" Schedule 40 PVC (represented by the circle) with two strips of 0.6" thick polystyrene foam insulation with grooves for three CAT 6 network cables.

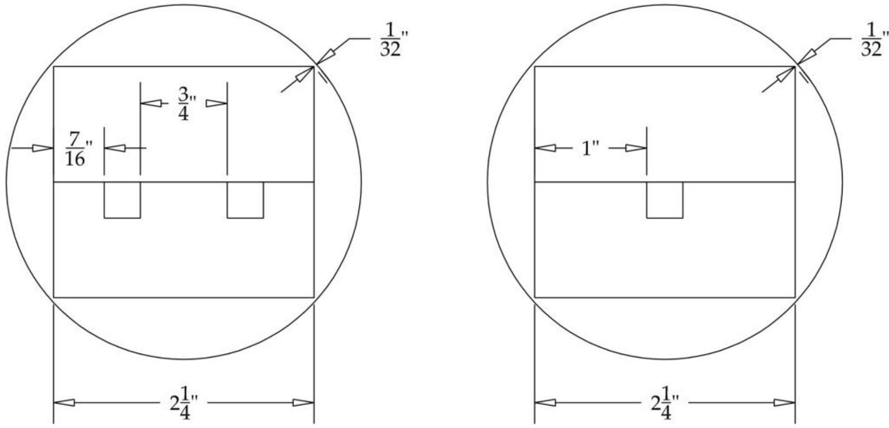

Figure 6. 3" Schedule 40 PVC (represented by the circle) with two strips of 1" thick polystyrene foam insulation with grooves for one or two CAT 6 network cables.

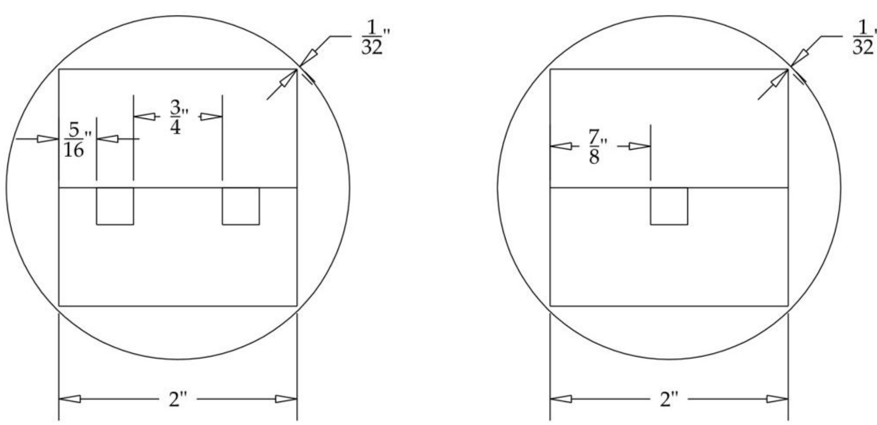

Figure 7. 3" Schedule 80 PVC (represented by the circle) with two strips of 1" polystyrene foam insulation with grooves for one or two CAT 6 network cables

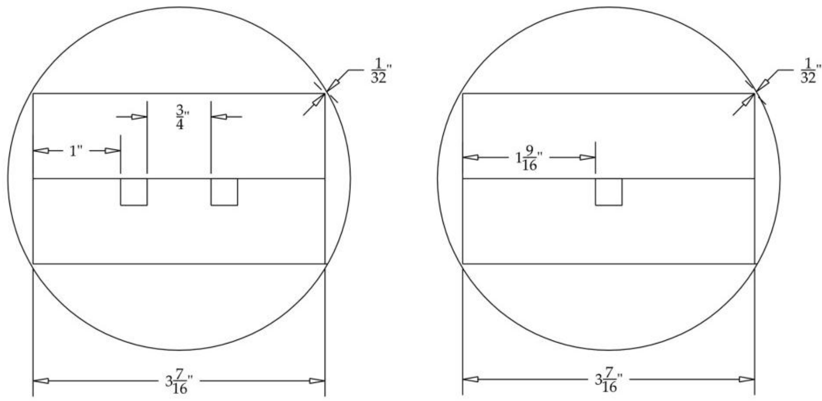

Figure 8. 4" Schedule 40 PVC (represented by the circle) with two strips of 1" thick polystyrene foam insulation with grooves for one or two CAT 6 network cables.

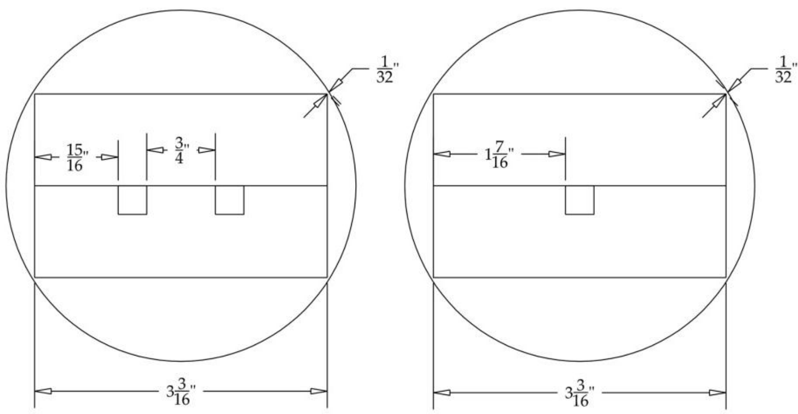

Figure 9. 4" Schedule 80 PVC (represented by the circle) with two strips of 1" thick polystyrene foam insulation with grooves for one or two CAT 6 network cables.

Assembling the Antenna:

1. Cut the foam strips to length so that they match the length of the pipe (Figure 10A). It is easy to cut the foam strips to length by scoring them with a box cutting knife and then breaking the strips at the scored point. If the pipe is longer than 8 feet, alternate short and long sections top and bottom of the stack so that only one side of the stack is "broken" at any position along its length (Figure 10B).

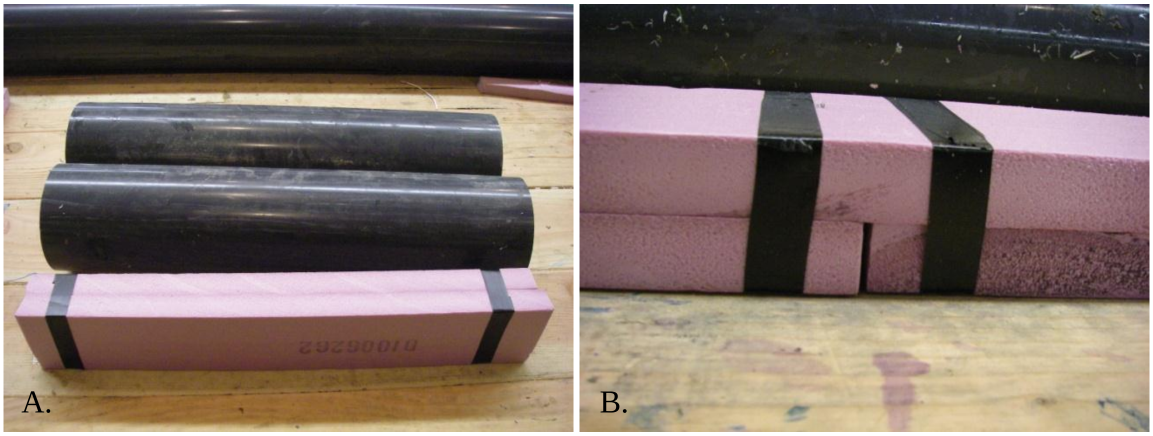

Figure 10. A. Polystyrene foam insulation cut to match the length of PVC pipe. B. When the length of PVC pipe is greater than the length of foam it should be spliced together.

2. Wrap vinyl electrical tape at approximately 2’ intervals (and both sides of any “break”) along the stack to tape it together.
3. Insert the stack of foam into the pipe lengths. If the foam is loose in the pipe, you can use scraps of foam as filler at the ends to hold each stack of foam tighter in the pipe. Lay out the antenna components as they will be assembled. Make sure that the orientation of the grooves in the foam are similar in all the PVC pipes. For example, with the antenna components laid out on the floor, all the foam stacks should have the grooved piece on the bottom with the slots side by side and horizontal (Figure 11).

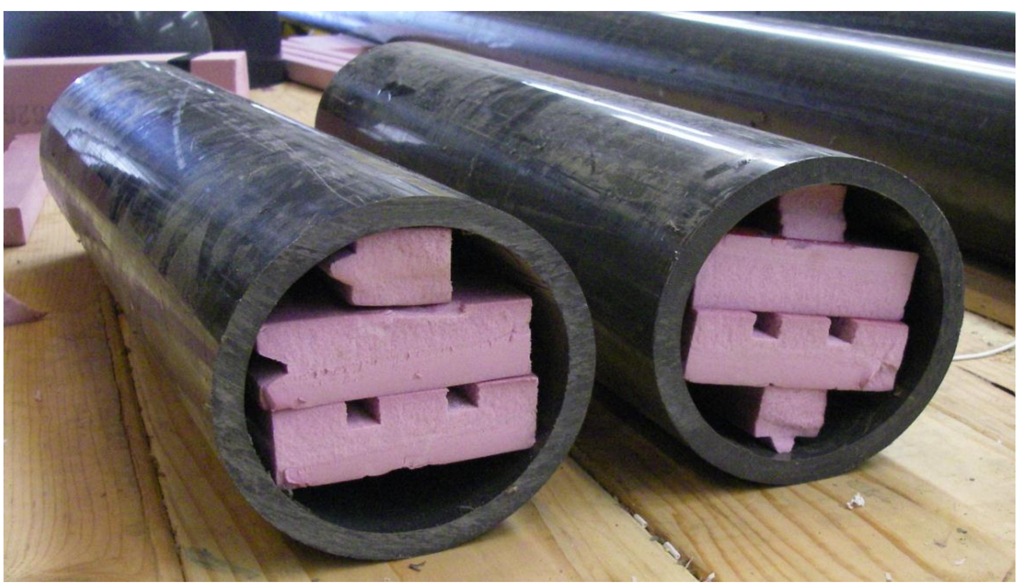

Figure 11. Polystyrene foam insulation should be oriented within a PVC pipes similarly, where all the grooves are match-up so that the CAT 6 network cable(s) can be easily fed through during assembly.

4. Label the terminal ends of the CAT 6 network cable sequentially (numbers 1 and 2 represent the ends of the first cable and 3 and 4 represent the ends of the second cable; Figure 12).

Figure 12. The terminal ends of each CAT 6 network cable should be uniquely marked prior to being fed through the Polystyrene foam.

For example, the terminal ends of an antenna that uses only one CAT 6 network cable should be labeled one and two. If additional CAT 6 network cables are needed for a particular antenna they should be labeled three and four. Feed end #1 of the first CAT 6 network cable into the slot nearest the inside of the antenna in the first length of pipe, end #3 of the second CAT 6 network cable into the next slot so the odd and even ends of the cables go in the same direction. Push the cables through the polystyrene foam stack until it exits the first pipe (Figure 13).

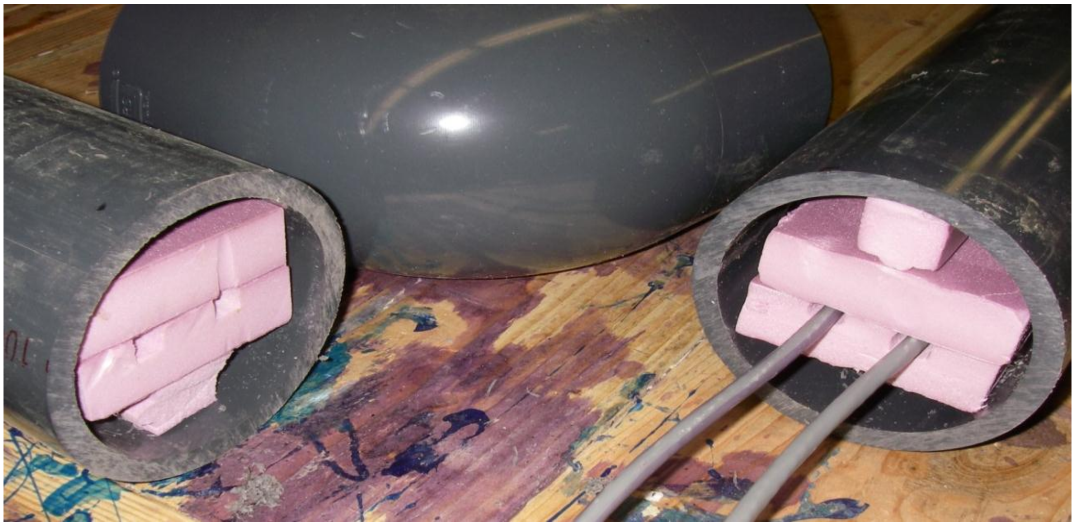

Figure 13: Two CAT 6 network cables positioned within the polystyrene foam.

5. Pull the odd numbered ends of the CAT 6 network cables through the elbow joint without twisting or crossing the cables. Again feed end #1 into the inside groove of the next straight section of pipe, and end #3 into the outside groove, so the CAT 6 network cables maintain a consistent orientation and do not get twisted in the antenna (Figure 14). The CAT 6 network cables should be pulled tight so that when the PVC is glued together there is not a large amount of slack in the cables. Once the CAT 6 network cables have been feed through the three elbows and the lengths of pipe they will be fed through a PVC “T” fitting. Pull the CAT 6 network cables out the other end of the “T” fitting so that at least 6” of cable protrudes (Figure 15). Re-label ends of the CAT 6 network cables so that when the excess cable is cut off they remain marked..

Figure 14: CAT 6 network cables must have a consistent orientation so they do not get twisted in the antenna.

6. A double loop antenna will follow the same procedure; however, the CAT 6 network wire will be fed through making a figure eight within the PVC (see Appendix A).

Wiring the Antenna to Create Wire Loops:

7. Using a pair of scissors, remove about 2.5” to 3” of the outer jacket from each end of the Cat 6 network cable cables protruding from the “T” PVC fitting, being careful not to damage the insulation on the individual wires. Cut back the spacer between the wires. There are now four pairs of wires exposed from each end of the cables.

Figure 15: CAT 6 network cables protruding from "T" PVC fitting with insulation jackets stripped and spacer trimmed.

8. Strip about 3/8" of insulation off the end of both wires in each pair, and twist the stripped ends of both wires of each pair together. Apply solder to the twisted wire ends (Figure 16).

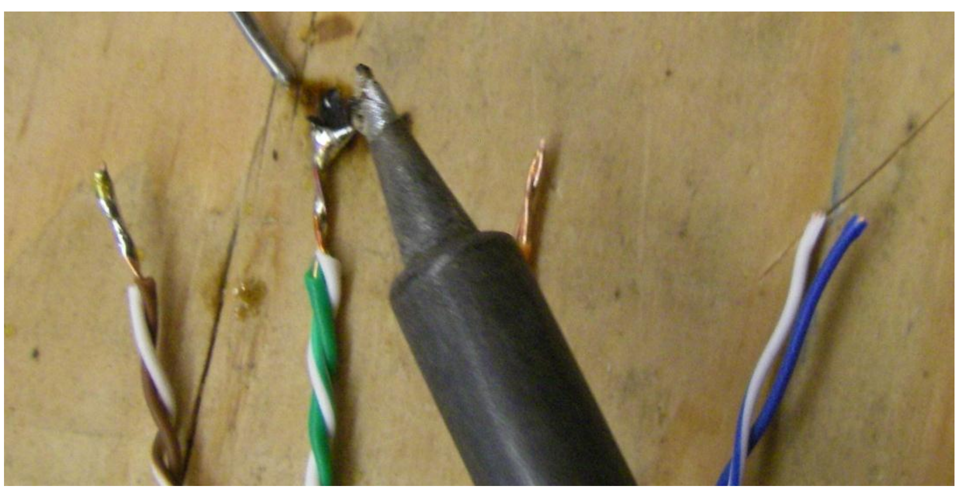

Figure 16: Solder each of the four pairs of wires from the CAT 6 network cables.

9. There are four color-coded pairs of wires in each Cat 6 cable. A typical color-coding includes pairs of brown, green, orange and blue. Each pair includes a wire white wire with a stripe of the same color as the colored wire in the pair. Brown/White (Pair 1), Green/White (Pair 2), Orange/White (Pair 3), and Blue/White (Pair 4). Measure and record the inductance between End 1/Pair1and End 2/Pair 1. The wires in each pair are joined at the ends (Figure 17).

10. Wire pairs from inside the cable make the wire loops in the antenna. First, slip a 1" length of 3/32" heat shrink tubing over the End 2/Pair 1 (Figure 18). Hold the end of End 2/Pair 1 alongside End1/Pair 2 and solder them together by touching both pairs with a soldering iron with a drop of solder on its tip. Measure and record the inductance between1/Pair1and End 2/Pair 2. Continue to connect and insulate the connections in the wires in the following sequence until the desired inductance (between 220µH and 310µH) is reached.

    - End 1/Pair 1 (Connection 1 to the capacitor pack)
    - End 2/Pair 1 (the end of loop 1) to End 1/Pair 2
    - End 2/Pair 2 (the end of loop 2) to End 1/Pair 3
    - End 2/Pair 3 (the end of loop 3) to End 1/Pair 4
    - End 2/Pair 4 (the end of loop 4) to End 3/Pair 1
    - End 4/Pair 1 (the end of loop 5) to End 3/Pair 2
    - End 4/Pair 2 (the end of loop 6) to End 3/Pair 3
    - End 4/Pair 3 (the end of loop 7) to End 3/Pair 4
    - End 4/Pair 4 (the end of loop 8) to End 5/Pair 1
    - End 6/Pair 1 (the end of loop 9) to End 5/Pair 2
    - End 6/Pair 2 (the end of loop 10) to End 5/Pair 3
    - End 6/Pair 3 (the end of loop 11) to End 5/Pair 4
    - End 6/Pair 4 (the end of loop 12) … and so forth

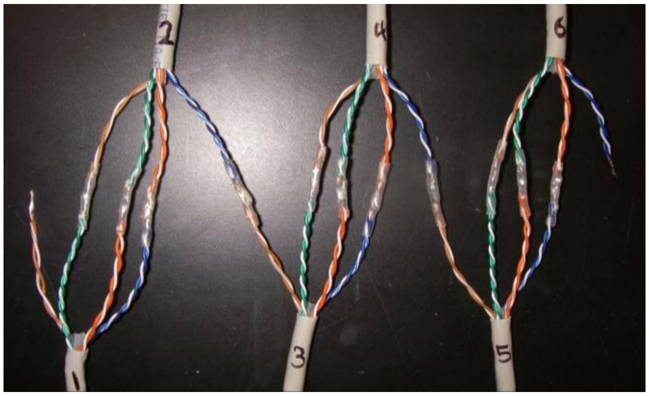

Figure 17: Example showing the CAT 6 network cable and 12 loops connected.

- Add or remove loops until you obtain an inductance close to 250 µH.

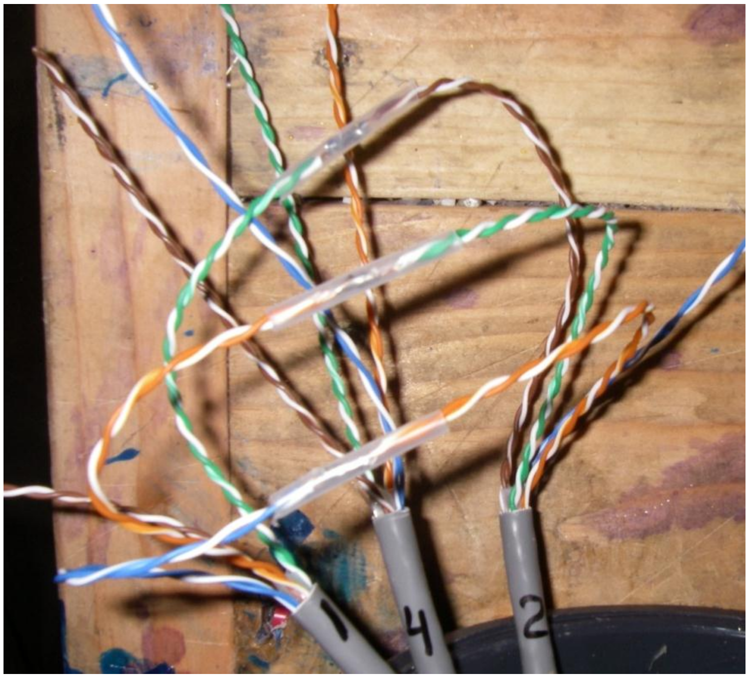

Figure 18: Wire pairs from inside the CAT 6 cable that make the wire loops in the antenna. Solder joints are covered with a 1" length of 3/32" heat shrink tubing.

11. There are two ends of wire available once all the other wire loops have been soldered together. These ends are used for the connection with capacitors when the antenna is used with the Destron Fearing® (model FS1001M) or connected directly with the Allflex® (model RM310) transceiver.

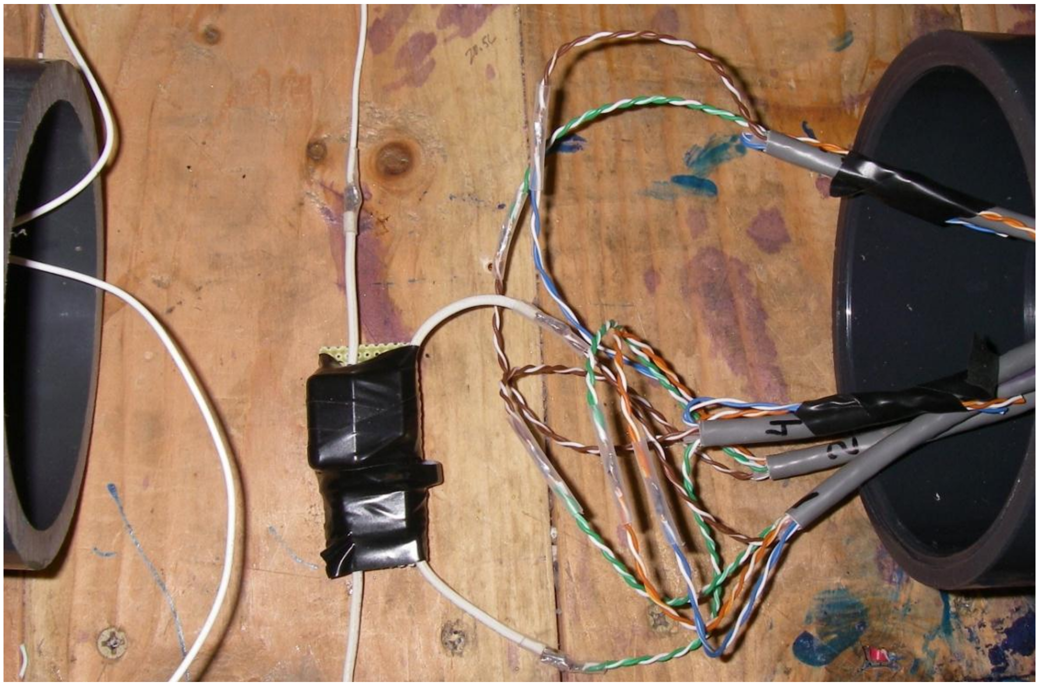

Figure 19: Antenna wired and capacitor pack connected to the remaining two ends of the wire coil constructed using CAT 6 network cables.

Tuning an Antenna with a Destron Fearing® (model FS1001M) Transceiver:

The Destron Fearing® (model FS1001M) transceiver requires series capacitance in the antenna for proper operation. It works best using capacitors in series on each end of the coil. The coil is the series of connected loops in the antenna. The capacitors in the antenna will tune the antenna circuit to resonate at approximately 135kHz which is slightly above its operating frequency of 134.2 kHz. Connecting the antenna to a cable adds capacitance which lowers the frequency so that it is within the operating range. The longer the cable, the more the resonant frequency is lowered. Although the transceiver “tunes” itself to the antenna and cable by adding capacitance in series with the antenna that raises the resonant frequency, it is imperative to adjust capacitors at the antenna to ensure the greatest performance.

1. First, calculate the capacitance needed(see Appendix A) . If there’s not a suitable example, use the following equation to calculate the approximate target capacitance:

   Capacitance $\approx \frac{104-0.2*L}{0.02*L-0.4}$ where L = the measured inductance of your antenna coil.

2. Temporally assemble capacitor packs by soldering capacitor leads together in a configuration based on the diagrams from the sample antennas (Appendix A), or from the different capacitance values (Appendix B). The values of capacitors in parallel are

additive. The value of capacitors in series is calculated, $C = \frac{C_1 * C_2}{C_1 + C_2}$. Measure your assembled capacitors to make sure they are within 5% of the target value.

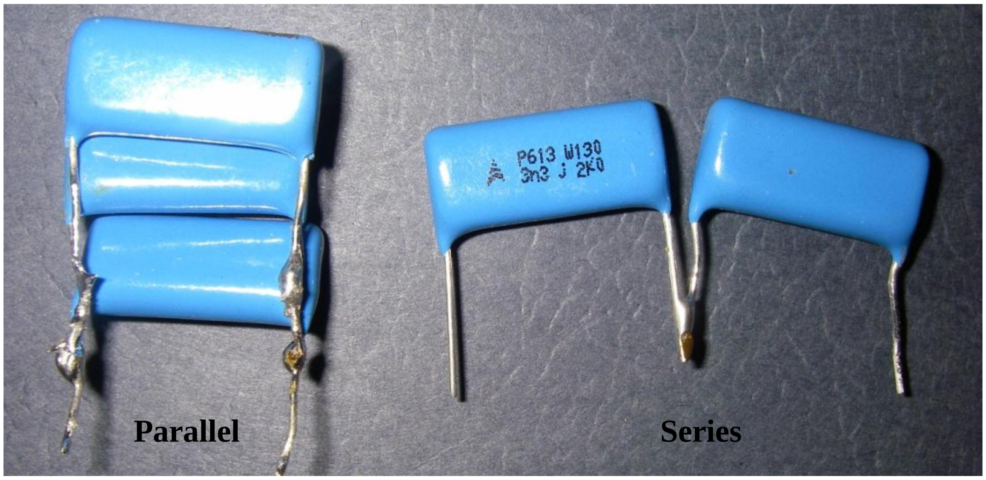

Figure 20: Capacitors arranged and soldered either in a parallel or series configuration.

3. Test the antenna capacitor configuration (pack) by connecting it to the transceiver. Solder two wire leads to the capacitors. Connect one capacitor lead to the wire labeled “1” on the male bulkhead connector and the other capacitor lead to the wire labeled “2” on the male bulkhead connector. Plug the male bulkhead connector into an antenna cable of the type and length you will use with the antenna (see Antenna Cable Construction section). Plug the antenna cable into the transceiver, turn on it and verify that the transceiver recognizes that the antenna is present.

4. Since the tuning of the antenna will change depending on the environment surrounding the antenna (water level, proximity to iron etc), it is important to make sure that the antenna will remain within the range in which the transceiver’s auto tuning function can compensate for environmental changes. Perform a “Max Current Tune” (see Transceiver Manual). Note the hexadecimal value of the tuning capacitor that the transceiver selects for the antenna. Hexadecimal numbers count from low to high in the following sequence: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F, and each digit to the left has a 16 times greater value than the one to its right. If that value is below 0x3FF (the next lower value is 0x3FE and the next higher value is 0x400), you should decrease the value of one of the capacitors in the antenna. If that value is above 0xE00 (the next lower value is 0xDFF and the next higher value is 0xE01), you should increase the value of one of your capacitors.

5. Note: The values in the Series/Parallel Capacitor table are nominal, and, due to manufacturing tolerances, the value of the capacitor pack you construct will almost

certainly differ from the target value in the table. The difference from the target value may even exceed the differences between "steps" in the Series/Parallel Capacitor table. Measure the value of the capacitor assembly you built to check it (see Appendix B to determine how to increase or decrease the capacitance). Reconfigure your capacitor configurations to increase or decrease its value as necessary. It may be best to measure and "cherry pick" (choose a capacitor near the nominal value or the high or low end of the tolerance range) the most critical capacitors since tolerance variation will have the most effect there. For parallel capacitors, the capacitor with the largest value is most critical. For series capacitors, the capacitor with the smallest value is most critical. To make a small change, it is usually best to add or subtract capacitance where it affects the total value the least.

Capacitor Pack Assembly:

Once the capacitor pack is within the transceiver's tunable range, it can be assembled. Cut a piece of perfboard big enough to hold a 10nF capacitor and the tuned capacitor pack determined earlier. Leave enough additional space for a 1/8" hole drilled in each corner. This is typically a board about 1.5" x 2.5" (***Figure 21*** below).

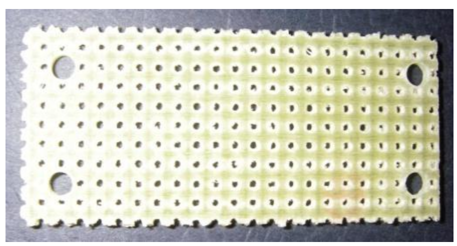

Figure 21: Perfboard used to mount capacitor packs within a PIT tag antenna driven by a Destron Fearing® (model FS1001M) transceiver.

Remove the solder on one of the temporary capacitor assemblies. Mount the capacitors on the perfboard by pushing the leads through the small holes in the board. Solder the connections between the capacitor leads. Do not twist the leads together since this makes disassembling or changing the capacitor configuration much more difficult in the future. Cut two pieces of multistrand wire (e.g. 14 or 16AWG) 8" long. Strip each end of the wires and tin them with solder. Tinning means applying a light coat of solder to materials before soldering components together. Thread the wire through the holes drilled at the far corners of the board and solder one to each lead of the capacitor assembly (Figure 22A). Trim the ends of all leads to keep the capacitor pack from shorting out or exhibiting 'corona discharge', both of which can create noise in the circuit.

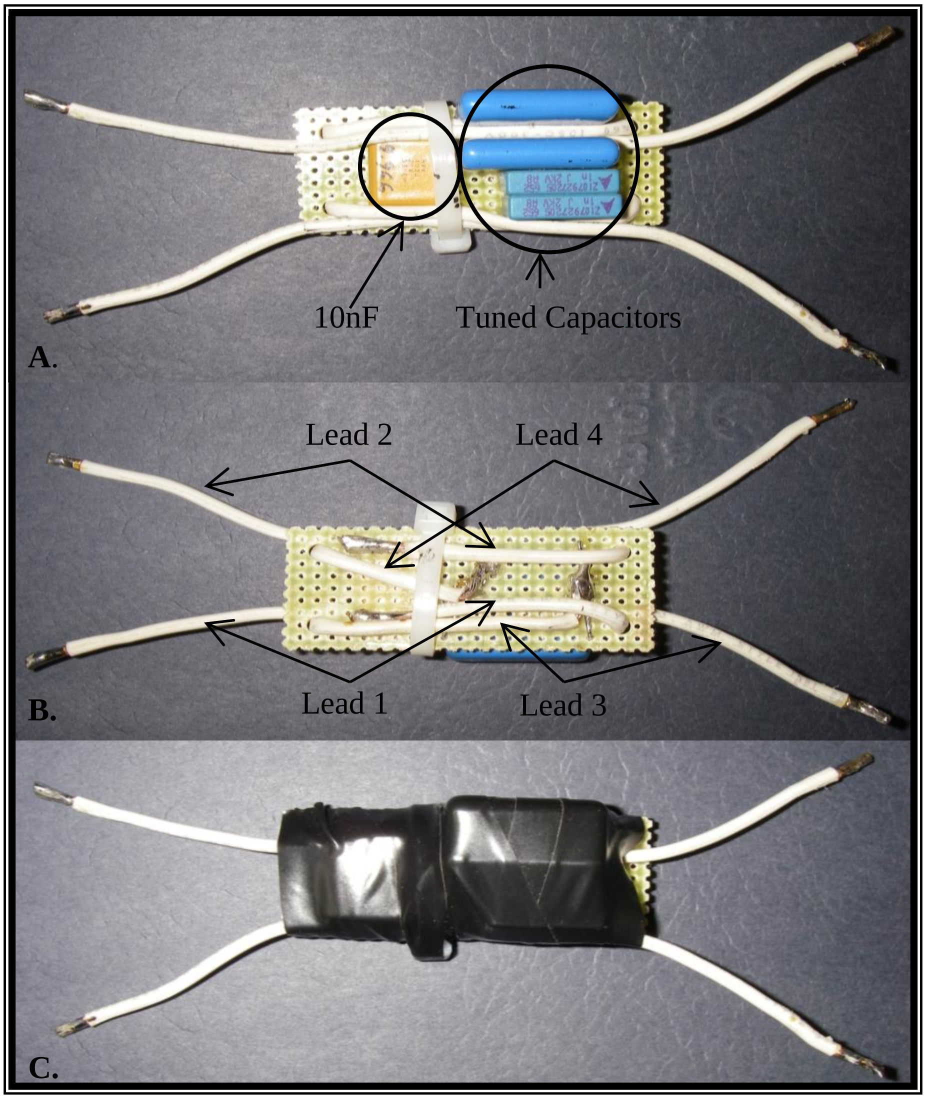

Figure 22: Assembled capacitor pack, A. Top view B. Bottom view, C. Protective electrical tape.

1. Wrap the entire assembly in electrical tape to prevent movement of the capacitors and to help prevent corona discharge (Figure 22C). Label the leads to the 10nF capacitor 1 and 2, and the leads to the tuned capacitor 3 and 4.

Creating a Water Tight Seal for a Single-Loop Antenna:

2. The antennas should be glued on a flat surface so that all the joints will be inline. Glue the joints of a single loop antenna starting at the furthest elbow from the PVC "T" fitting first, the next furthest elbow second, the closest elbow third, and the PVC "T" fitting glued last. At each elbow glue the joint attached to the longest pipe section first followed by the joint glued to the shorter pipe section. PVC joints should be glued in sequence (Figure 23). To glue each joint, coat the entire inside of the fitting and the first 2" of the

end of the pipe section with PVC primer, then with a liberal amount of PVC glue. Quickly push the fitting back onto the pipe and seat it completely with a rubber hammer. If the joint tends to creep apart, it may be necessary to hold the joint together for a minute until the glue begins to set. Make sure that all unglued joints are fully seated in the fittings to ensure proper antenna alignment. Wait five minutes before gluing the next joint to allow the glue to set. The glue can dry very quickly, so avoid attempting to glue two joints at once. The joint will leak water if the glue begins to dry before the joint is seated and the antenna will not work.

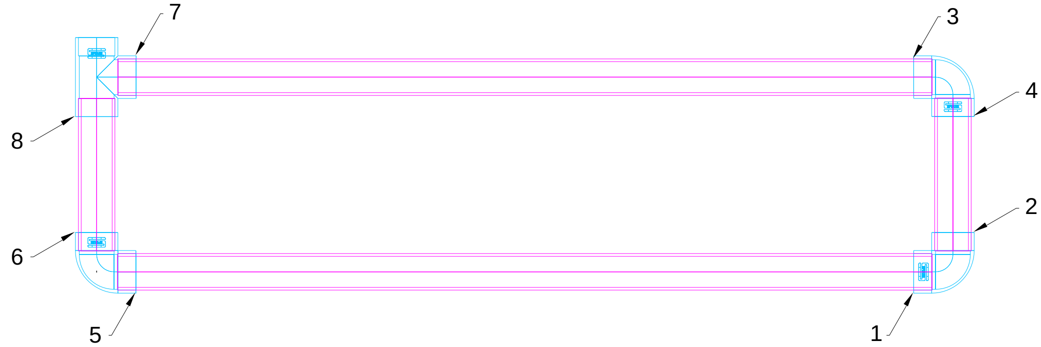

Figure 23: Single-loop joint gluing sequence.

Glue a Double-Loop Antenna:

3. The gluing sequence in Figure 23 below is typical for a single loop antenna. Although a two-loop antenna is more difficult to glue properly it can be done efficiently following a specific joint sequence (Figure 24). Generally, gluing begins at the farthest elbow of the farthest loop and works back to the “T” fitting. At each corner glue the joint to the longest pipe section into the fitting first followed by the joint to the shorter pipe section into the fitting second. To glue each joint coat the entire inside of the fitting and the first 2” of the end of the pipe with PVC primer, then with a liberal amount of PVC glue. Quickly push the fitting back onto the pipe and seat it completely with a rubber hammer. If the joint tends to creep apart, it may be necessary to hold the joint together for a minute until the glue begins to set. Make sure that all unglued joints are fully seated in the fittings to ensure proper antenna alignment. Wait five minutes before gluing the next joint to allow the glue to set. The glue can dry very quickly, so avoid attempting to glue two joints at once. The joint will leak if the glue begins to dry before the joint is seated.

Figure 24: Sequence to glue joints for a double-loop antenna

Leak Check the Antenna:

Seat the test cap (see Appendix E for test cap assembly) on the PVC collar a rubber hammer. Pressurize the antenna to 3 psi (more than 5 psi could force the cap off unexpectedly). Paint the glued joints with a solution of 1 part dish soap to 2 parts water. Check for any bubbles that develop as a result of air leaks (Figure 25).

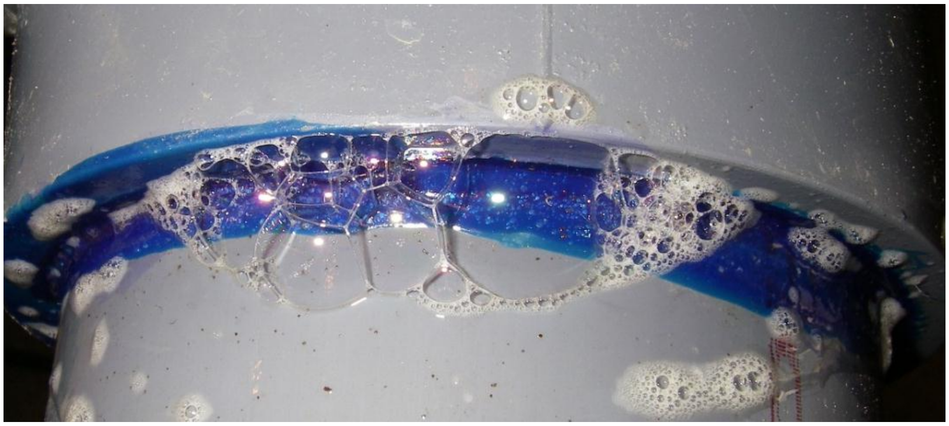

Figure 25: An antenna displaying bubbles formed at a PVC glue joint due to an air leak.

Mark any leak(s) detected, and rinse the joint with water then with alcohol. Once the joint is dry, connect a tire inflation fitting to a vacuum (such as a vacuum pump or even a vacuum cleaner) to create a negative pressure at the leak. Apply cleaner/softener and let it dry. Liberally apply PVC glue to the area of the leak(s) so that it is sucked into the space. Let the glue dry, then leak test the affected area again.

Vent the air from the antenna by holding open the valve in the valve stem using the tip on the top of the valve cap (to prevent the test cap from popping off with force when it is removed). Remove the test cap by driving it off by tapping it sharply on alternate sides with a rubber hammer or block of wood.

Assembling the Cap and Male Bulkhead Connector:

1. Drill a 3/8” hole centered in the end of the pipe cap (Figure 26).
2. File a flat 3/4” to 1” diameter around the hole.
3. Thread the hole with a 7/16-20 tap.

Figure 26: PVC cap drilled and tapped to accommodate the male bulkhead connector.

4. Place an O-ring (included with the connector) over the wires of a waterproof antenna connector and seat it in the groove at the base of the waterproof antenna connector.

5. Apply a bead of aquarium grade silicon adhesive to the threads and around the base of the waterproof antenna connector. This will hold the O-ring in place and help seal the connector. Feed the wires from the waterproof antenna connector through the hole in the cap and screw the connector into the hole (Figure 27). Tighten it with a 3/4" open-end wrench.

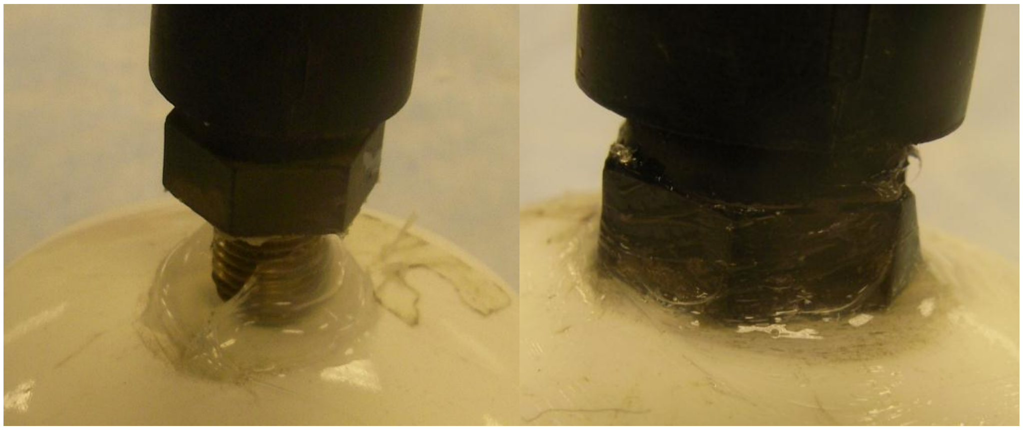

Figure 27: Silicone adhesive and male bulkhead connector attached to a PVC cap.

6. Apply a bead of silicon adhesive around the threads of the waterproof antenna connector on the inside of the pipe cap (Figure 28).

Figure 28: Silicone adhesive around inside of the PVC cap and male bulkhead connector.

7. Slip a 7/16"-20 nut (included with the connector) over the wires and screw it onto the threaded end of the connector on the inside of the pipe cap, and tighten it with a 11/16" open end wrench to form a snug connection between the nut, waterproof antenna connector, and the cap (Figure 29).

Figure 29: Inner connection between the nut, waterproof antenna connector, and the PVC cap.

8. Glue the PVC neck (7" piece of PVC pipe) of the antenna into the PVC cap with PVC primer and glue as described earlier (Figure 30).

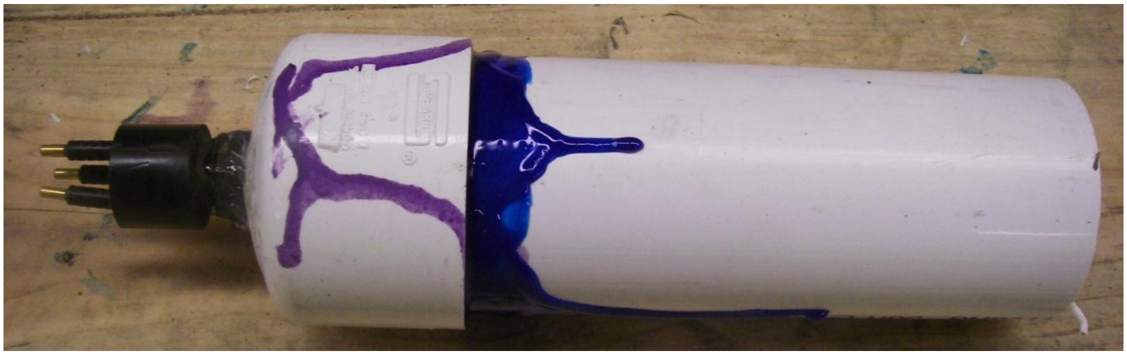

Figure 30: PVC cap and waterproof antenna connector glued to the PVC neck.

Mounting the Cap to the Antenna:

1. Solder Lead 1 of the capacitor pack to lead 1 of the antenna and solder Lead 2 of the capacitor pack to lead 1 from the cap assembly.
2. Solder Lead 3 of the capacitor pack to lead 2 of the antenna and solder Lead 4 of the capacitor pack to lead 2 from the cap assembly.
3. Apply a bead of silicone adhesive around the inside lip of the "T" fitting of the antenna, and another bead of silicone adhesive around the outside lip of the PVC neck (Figure 31).

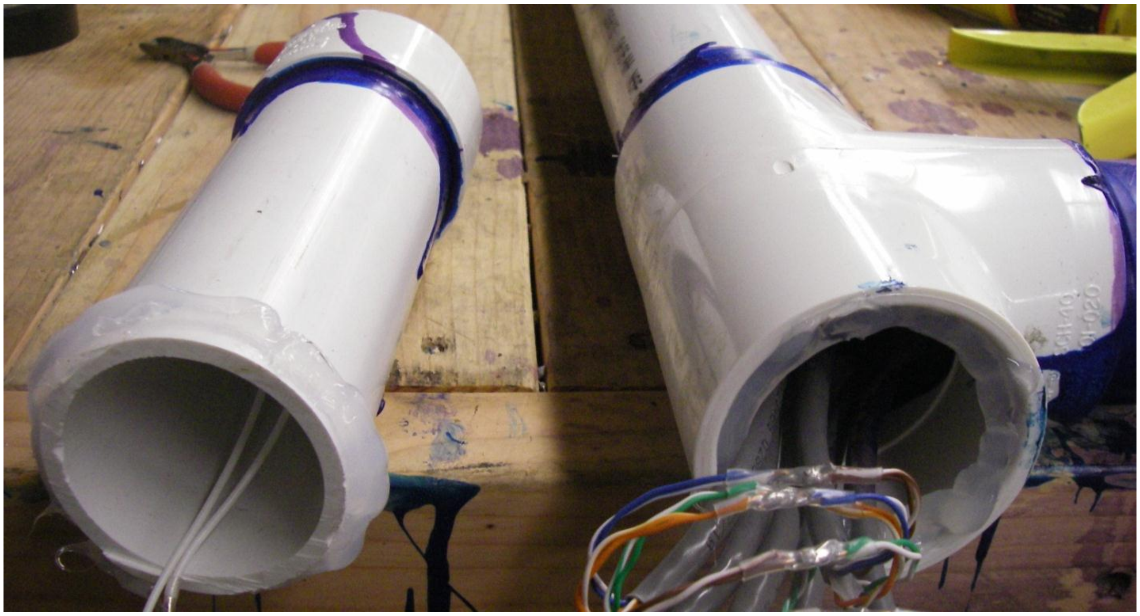

Figure 31: Silicone adhesive around the outside of the PVC neck and inside the "T" fitting of the antenna.

1. Insert the neck of the cap assembly into the tee fitting of the antenna such that the silicon adhesive on each part bonds to itself. Twist the cap assembly down into the tee, and seat it completely with a rubber mallet (Figure 32). Allow the silicone adhesive to set for 24 hours.

Figure 32: Cap, neck, waterproof antenna connector seated with silicon adhesive in the "T" fitting of the antenna.

Building an Antenna Cable for a Destron Fearing (model FS1001M) Transceiver:

Assembling the Pigtail for the Transceiver End of the Cable

1. Insert 3 pins (e.g. item TYCO/AMP 202236-2) into positions 1, 6, and 7 on the back (i.e. threaded) end of a circular male connector (e.g. item TYCO/AMP 211768-1 male, 9-pin). Make sure the connector pins snap into position so they do not pull out.
2. Tin the back ends of the connector pins (e.g. item TYCO/AMP 202236-2) contacts with solder.
3. Cut a piece of outdoor rated extension cord 10” long.
4. Find the end of the 10” cord where the sequence of wire colors is black-white-green clockwise looking at the end of the wire. Strip 3/4” of the outer jacket being careful not to cut the insulation of the wires. Strip 1/4” of insulation from the end of each of the wires, and tin the stripped ends of the wires with solder.
5. Cut three 3/8” long pieces of 3/8” diameter 3:1 heat shrink tubing.
6. For each wire of the 10” cord:
    a. Slip one of the pieces of heat shrink tubing over it.
    b. Solder it to the appropriate contact of the connector: White to contact 1, green to contact 6, and black to contact 7. Hold the tinned end of the wire against the tinned contact of the connector, and touch the tip of the soldering iron with a drop of melted solder on it to the wire only until the solder melts on both the wire and the back of the contact.
7. Slide the pieces of heat shrink tubing down over the back ends of the contacts, and shrink them using the heat gun.
8. Slip the cable clamp (e.g. item TYCO/AMP 206322-9) over the end of the 10” cord and screw it onto the back (threaded) end of the circular connector (e.g. item TYCO/AMP 211768-1 male, 9-pin).
9. Select the clamping bar appropriate to the diameter of the 10” cord and attach it tightly enough that it cannot be moved or twisted.
10. Strip 2-1/2” of the outer jacket from the free end of the 10” cord from the connector.
11. Trim 3/4” off the black wire and 1-1/2” off the white wire.
12. Strip 1/4” of insulation off the end of each wire and tin the stripped ends with solder.

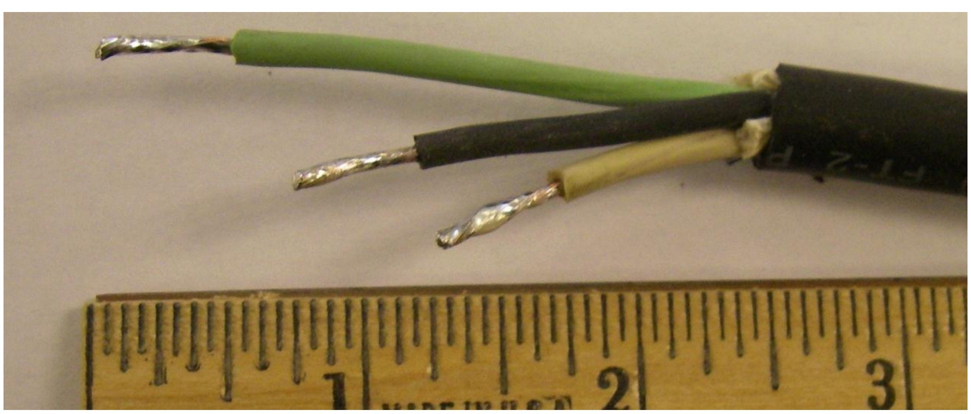

Figure 33: Trimmed, stripped and tinned green, black, and white wires coming from the female bulkhead connector.

Attaching the Waterproof Female Cable Connector to the Cable

13. The Female Cable Connector has its own pigtail already attached. Strip 2-1/2” of the outer jacket from this pigtail (item IL3FS). Trim 3/4” off the black wire and 1-1/2” off the white wire. Strip 1/4” of insulation off the end of each wire and tin the stripped ends with solder (Figure 31).
14. Cut a length of antenna cable to the desired length.
15. Strip 2-1/2” of the outer and inner jacket from each end of the antenna cable leaving the shielding on the cable and the insulation on the individual wires intact.
16. Unbraid the shield on one end and twist it together to one side so that the sequence of the conductors is black-red-shield clockwise looking at the end of the cable.
17. The shield conductor is the outer braided wire in the antenna cable. Unravel the braid and twist it into a wire that can be cut to a length 1-1/2” shorter than the red wire. Tin the shield conductor.
18. Trim 3/4” off the black wire.
19. Strip 1/4” of insulation off the ends of the red and black wires, and tin the stripped ends with solder.
20. Cut a 6” and an 8” piece of ¾” heat shrink tubing. Slip the 8” piece over the end of the antenna cable that you prepared, followed by the 6” piece.
21. Cut a 3/4” piece of 3/8” heat shrink tubing and slip it over the green wire of the 10” cord from the circular male connector. Hold the tinned end of the green wire of the 10” cord against the tinned end of the shield wire on the antenna cable, and touch the tip of the soldering iron with a drop of melted solder on it to both wires only until the solder melts and flows on both wires (Figure 34A).

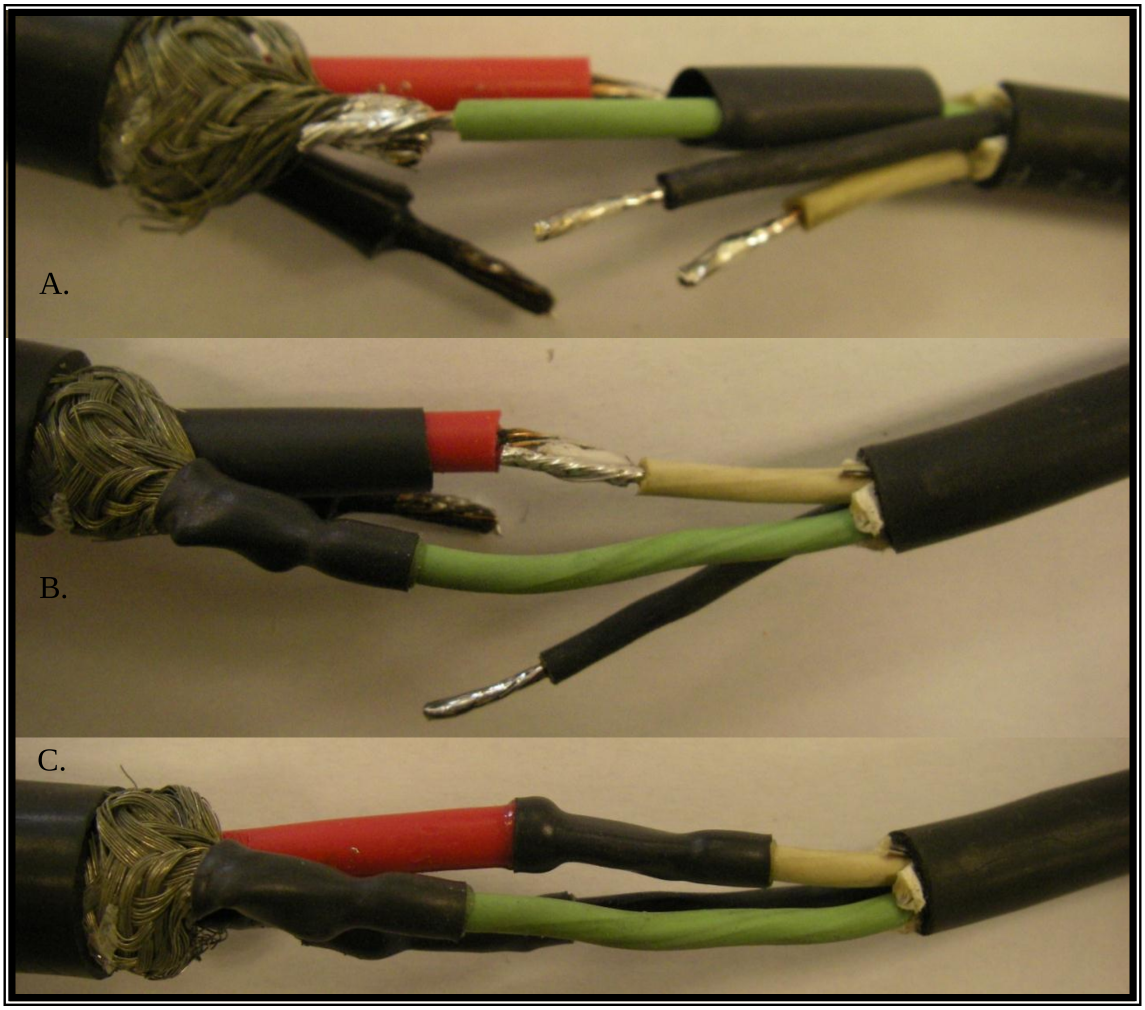

Figure 34: A. The antenna cable's braided shield prepared and soldered to the green wire coming from the female antenna connector. B. White wire of the antenna cable soldered to the white wire of the female antenna connector. C. Heat shrink tubing is in place after soldering is complete.

22. Cut a 3/4" piece of 3/8" heat shrink tubing and slip it over the red wire of the antenna cable. Hold the tinned end of the white wire of the 10" cord against the tinned end of the red wire on the antenna cable, and touch the tip of the soldering iron with a drop of melted solder on it to both wires only until the solder melts and flows on both wires (Figure 34B).
23. Cut a 3/4" piece of 3/8" heat shrink tubing and slip it over the black wire of the antenna cable. Solder the black wire of the 10" cord to the black wire on the antenna cable. Slide the pieces of 3/8" heat shrink tubing to cover the solder joints, and shrink them using the heat gun (Figure 34C).
24. Slide the 6" piece of 3/4" heat shrink tubing so that it overlaps the antenna cable and the wire to the connector equally, and shrink it using the heat gun starting at one end and moving to the other. Slide the 8" piece of 3/4" heat shrink tubing so that it is centered

over the 6” piece, and shrink it using the heat gun starting at one end and moving to the other.

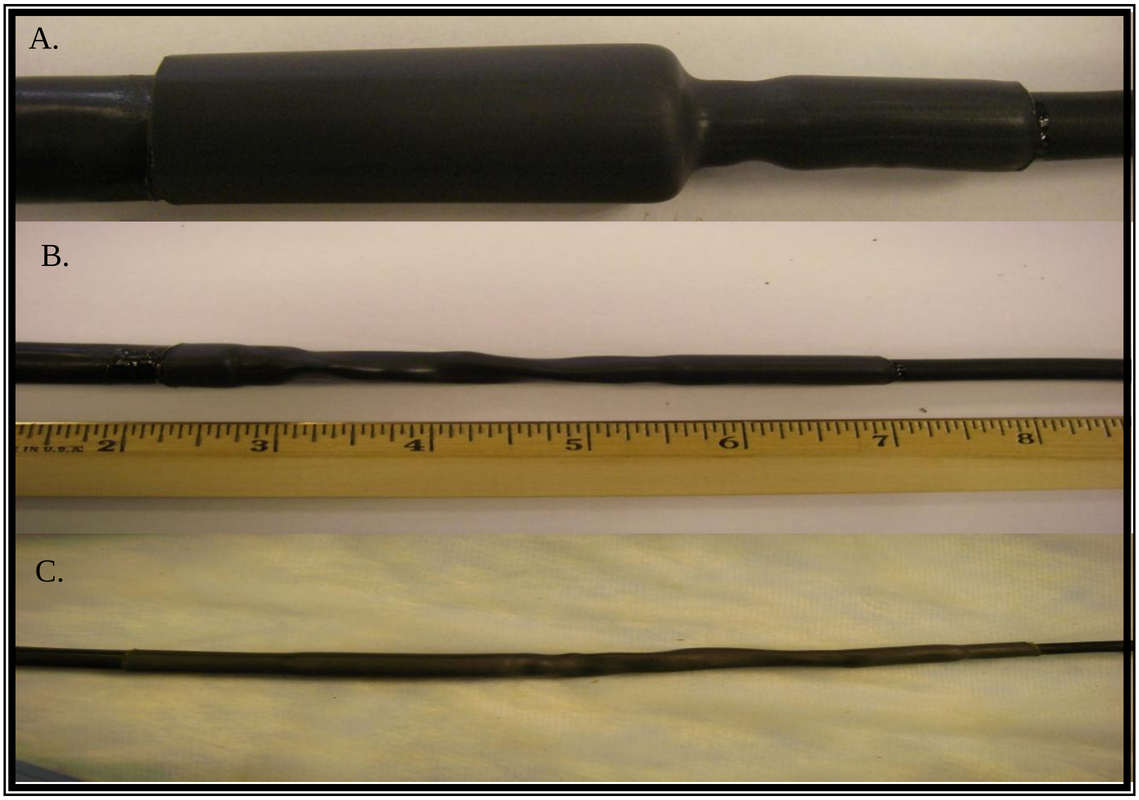

Figure 35: A. Heatshrink the tubing from one end to prevent trapping air bubbles. B. First layer of tubing shrunk. C. Both layers of tubing shrunk.

25. Unbraid the shield on the other end of the antenna cable and twist it together to one side of the cable so that the sequence of the conductors is red- black-shield clockwise looking at the end of the cable.

Attach the Pigtail to the Transceiver End of the Cable

26. Follow steps 17 through 24 to attach the wires from the pigtail connected to the circular connector (e.g. item TYCO/AMP 211768-1 male, 9-pin) to the antenna cable.

Destron Fearing® (model FS1001M) Transceiver Tuning:

1. Ensure the antennas are connected and the transceiver is powered on, and grounded.
2. Start a terminal connection to the transceiver
    a. The tuning for the transceiver is performed in a terminal emulator running on a computer connected via a serial cable. If a computer is already setup running Minimon (available free from Pacific States Marine Fisheries Commission) and connected to the serial port it is easy to open a “MiniTerm” terminal window from within Minimon. You can use other terminal emulators if you wish instead.

Communication with the transceiver is fixed at 57,600 baud and the common communication configuration of 8 databits, no-parity, and 1 stopbit (8-N-1).

b. If you are already running Minimon, stop interrogation if it is running and choose the transceiver to tune from the Device Status window. Right click on it to bring up the dropdown menu and select Terminal (Figure 36).

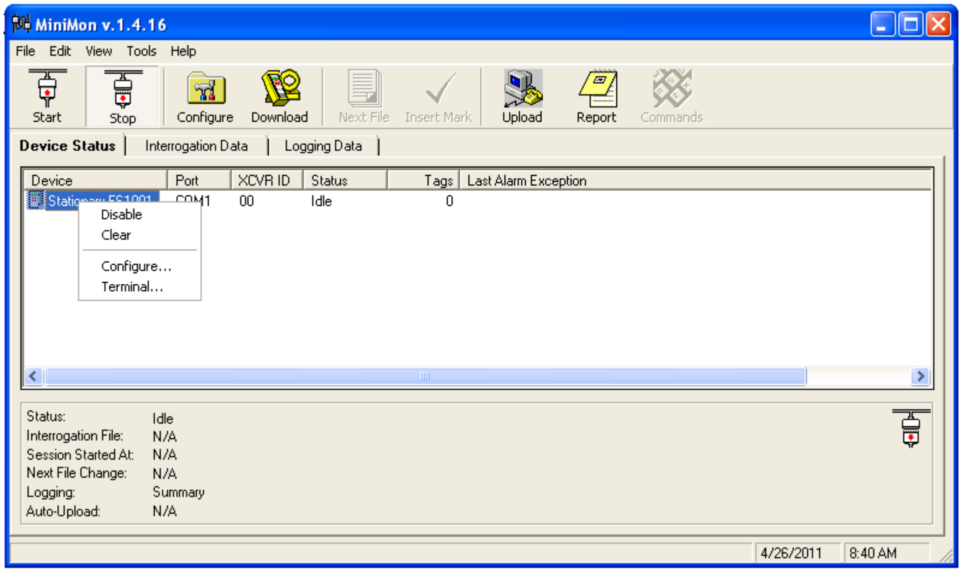

Figure 36: Opening a MiniTerm session from within Minimon

2. In the terminal type "MT" to enter the manual tuning menu. Select the antenna you are tuning using the +/- key on the keyboard (Figure 37).

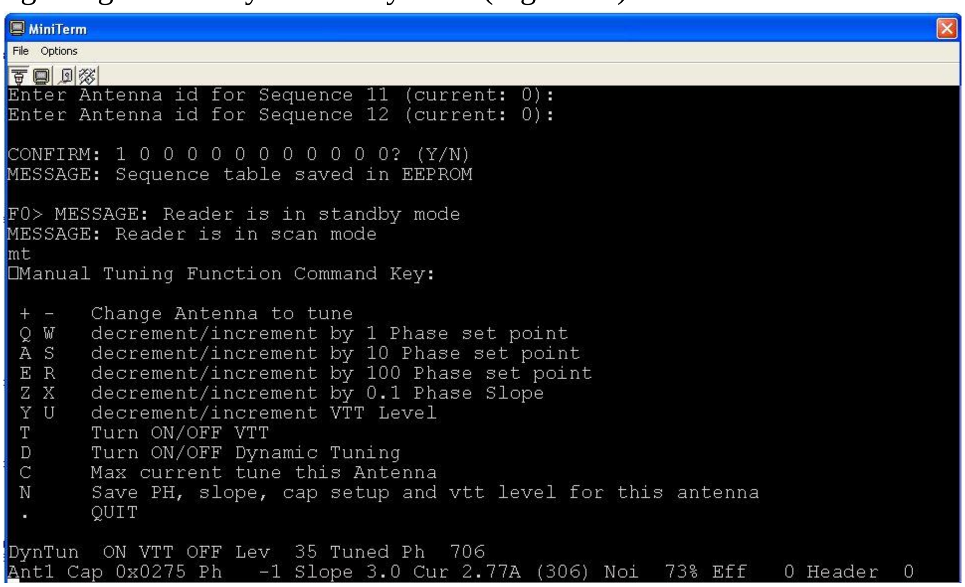

Figure 37: Selecting an antenna for tuning

3. There are two tuning procedures. A coarse tune (max current tune) and a fine tune.

4. To perform the max current tune, type "C".
5. If dynamic tuning is off, type "D" to enable dynamic tuning. Enabling dynamic tuning is important so that the multiplexor will automatically choose new capacitor values as the phase target is changed.
6. Check phase slope and make sure it is set to 5 (default).
7. Type "T" to enable the Virtual Test Tag (VTT) for this antenna.
    a. The VTT has possible values from 0-99. At 0 the strongest virtual test tag signal is generated and at 99 the weakest virtual test tag signal is generated. A successful read will always be indicated by the read light on the transceiver. This will blink even with unique mode enabled and the reader buzzer disabled. If the VTT level is set high you may need to reduce it to detect reads from the VTT.
    b. Set the VTT to the highest level where it can still be read consistently. This can be accomplished bv using the "Y" or "U" keys on the keyboard to vary the intensity of the VTT.
8. Adjust the phase target in 10 point increments using the "A" and "S" keys. If the read rate improves, increase the level of the VTT using "U" and then adjust the phase target again and repeat this process until you get the VTT to the highest level where it will still read. At this point the antenna is tuned.
    a. Under low noise conditions you should be able to get the VTT to a level of around 70.
    b. Once the antenna is tuned with the VTT to the highest level where it consistently will read, adjust the VTT to 0 so that the VTT will generate consistent diagnostic reads in the log files when it is fired at periodic intervals. Save the antenna setting by using "N".
    c. Exit manual tuning using "." At this point the terminal should show the command prompt at the bottom of the screen as shown in Figure 38.

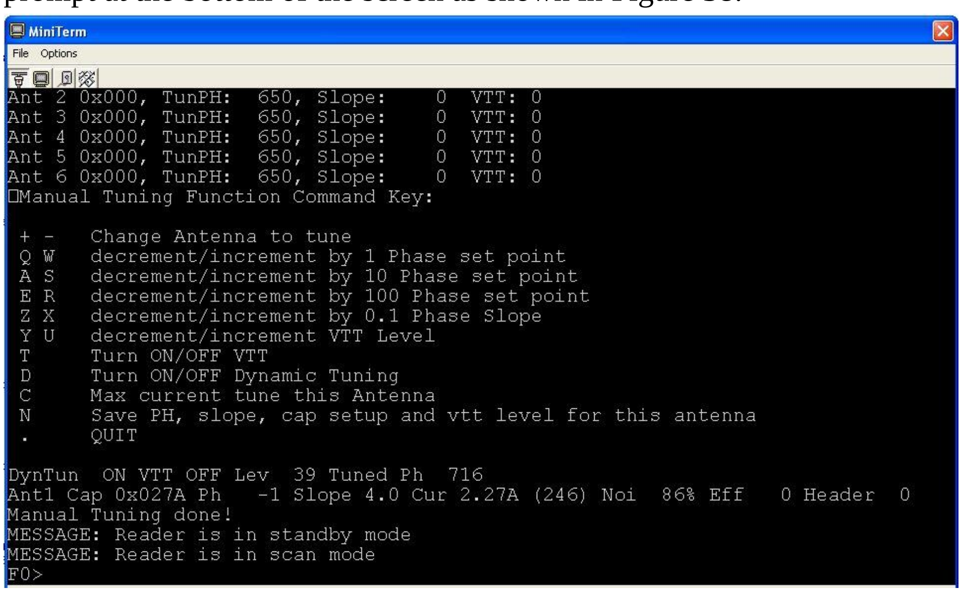

Figure 38: Exit manual tuning in a terminal

9. Use the +/- keys to select a different antenna for tuning and repeat the tuning process for that antenna (steps 4-10).
   If you are using an attached computer running Minimon to log data, make sure you start interrogation in Minimon before leaving the site.

Determining Background Noise with a Destron Fearing® (model FS1001M) Transceiver:

1. An oscilloscope with a 10:1 or higher voltage probe can be used to measure the voltage at the comparator circuit of the transceiver. Test point, TP21 is designed for this purpose.
2. You can find this test point by opening the door to the transceiver and looking in the bottom third of the transceiver. There is a daughterboard for the VTT positioned underneath the F-232, fiber to serial converter module. On the daughterboard you will find a horizontally rectangular stainless steel panel covering several test points and tuning knobs. It is possible that this panel has already been removed, if not, remove it by prying with a small straight bladed screwdriver carefully around the edges.

Figure 39: Test Point 21 (TP21) can be seen just below the potentiometer that is used to adjust the high pass filter.

3. Underneath the panel, you will find that all the components are labeled with such small text as to be almost unreadable. A tiny potentiometer with a flat blade knob on it is located middle of the right third of this enclosed space. Underneath is TP21 with a tiny

ring where a positive probe can be attached. The negative clip of the probe can be grounded to the stainless steel enclosure.

4. With the transceiver running and the probe connected, look at the RMS voltage value. Values greater than 0.1V indicate significant ambient noise. If there are sudden spikes in the plot on the scope, check to see if the transceiver is tuning in too narrow of a range for the phase slope as excessive seeking to match the tuned phase introduces noise as the relays open and close between the onboard dynamic tuning capacitors. Measuring the RMS background noise at TP21 can be a useful reference to know how much noise was present when tag performance measurements were taken for an antenna. You can also observe the tag modulation on the scope at this point when a tag is placed over the antenna.
5. Since this measure will change quickly, it can be more useful for isolating sources of noise than using the noise/signal measure on the transceiver which may also be scaled and not tell the absolute noise even on average.

Note on high pass filter:
The potentiometer near TP21 allows adjustment of the high pass filter of the FS1001M and can be used to tune it to work with unusual tags sizes. It is possible that after adjusting this to optimize a particular tag performance, the performance of other tags, even larger tags may decline, so be careful.

Testing the Antenna:

It is a good idea to make sure that the antenna performs adequately before it is transported and install it *in situ*. PIT tag transceivers are highly sensitive to the electrical and magnetic noise that may be present at many sites. To test an antenna, situate it in an environment where the noise is as low as practical. Ideally this would either be miles from any electrical equipment, or inside of a specially shielded room, neither of which is typically practical. A shop with metal siding, after hours, with all the electrical and electronic equipment and associated power supplies unplugged and turned off. Fluorescent lights in particular should be turned off. Support the antenna on wooden sawhorses or a wooden bench (the presence of rebar in a concrete floor will affect the tuning and performance of your antenna).

1. Power the transceiver from batteries, if available, or a linear (as opposed to switching) AC to DC power supply.
2. The laptop computer should not be plugged in to its power supply.
3. Turn off all lights and other electrical or electronic equipment except incandescent lights.
4. The antenna should be placed away from metal objects. Take keys and metal objects out of your pockets and place them away from the antenna.
5. Plug in the antenna, turn on the reader and tune it, and test with the type of tag you expect to read in the field in the orientations (Figure 40).

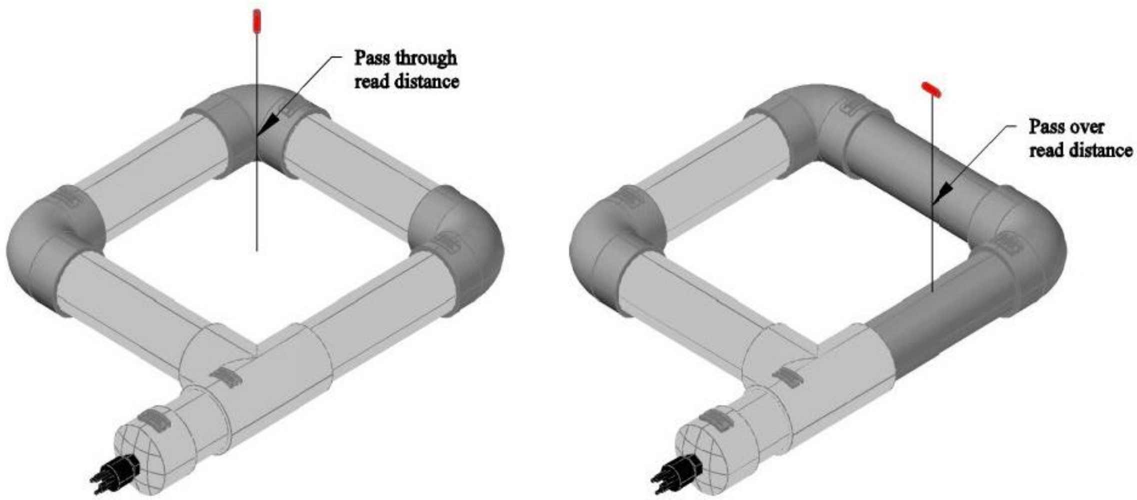

Figure 40: Tag (denoted in red either horizontal or vertical to the test antenna) orientation for antenna testing

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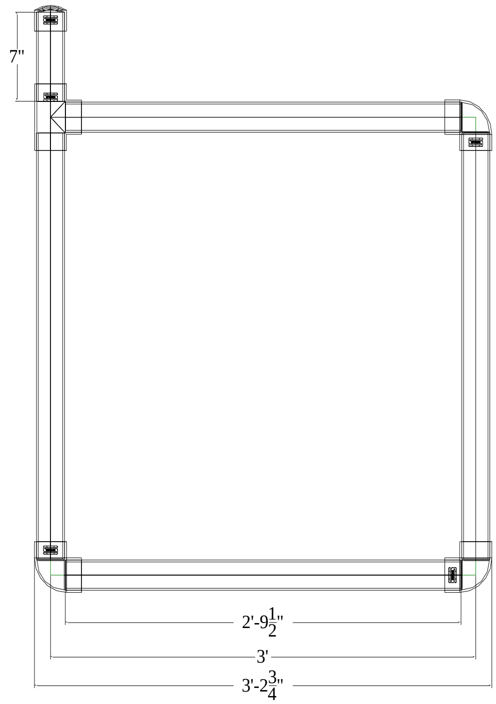
Appendix A

Example Configurations and Specifications for Commonly Used PIT Tag Antenna(s)

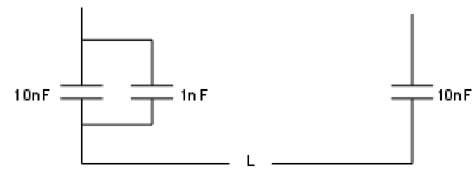
Antenna general specifications and read ranges for standard passive integrated transponder tags.

PAGE	**LOOP(S)**	**COIL LENGTH**	**COIL WIDTH**	**DF 12mm SST1 Pass Thru Read Range**	**DF 12mm SST1 Pass-over Read Range**
47	Single	3’	3’	31”	17”
48	Double	7’ 7-3/4”	3’ 7-3/4”	15”	13”
50	Single	10’	2’	22”	14”
51	Single	13’ 6”	2’	16”	11”

Example 1: 3’x3’ Antenna: Suitable for a raceway, portable test antenna, or at the end of a culvert.



Capacitor configuration of the antenna:

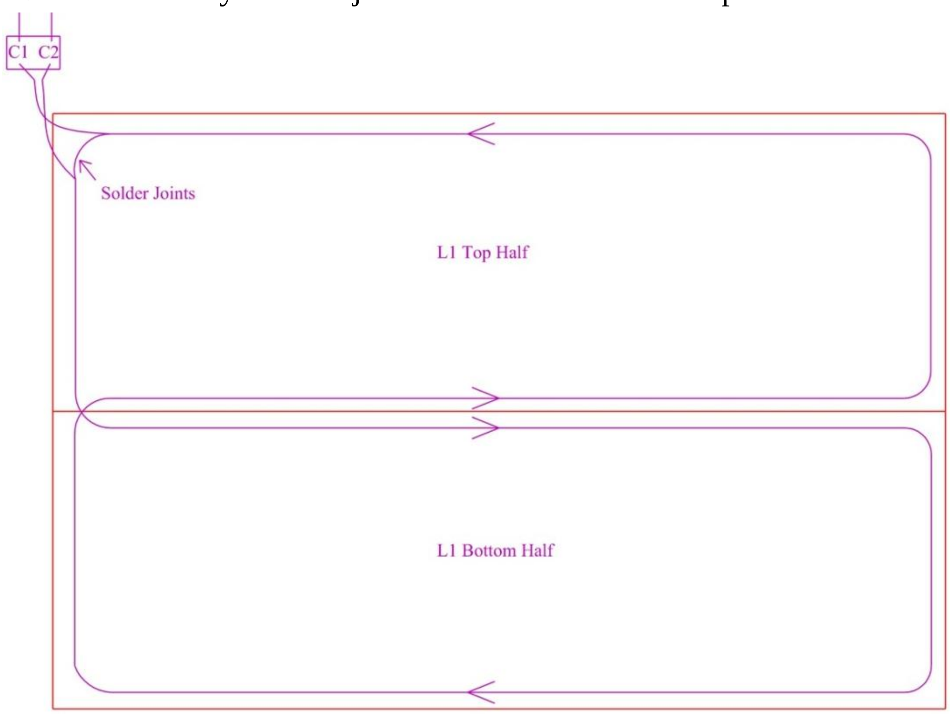


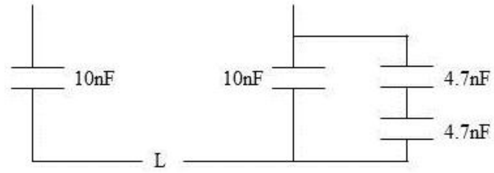
EXPECTED PERFORMANCE (with FS1001M and low noise, 0% to 4%)			
Number of Loops:	9		
Inductance	268 µH		
Capacitors	C_1 = 10 nF		C_2 = 11 nF
Tag Type	DF 12mm SST1	DF 9mm TX149011B	DM 23mm
Pass-through	31”	19”	42
Pass-over	17”	9.5”	25

MATERIALS			
Pipe Choice	2” Sch 40	3” Sch 40	3” Sch 80
Pipe (Qty) Length	(4) 2’ 9-1/2”	(4) 2’ 7-1/8”	(4) 2’ 6-1/2”
Pipe (Qty) Length	(1) 7”	(1) 7”	(1) 7”
Elbow (Qty) Size	(3) 2” Sch 40	(3) 3” Sch 40	(3) 3” Sch 80
Tee (Qty) Size	(1) 2” Sch 40	(1) 3” Sch 40	(1) 3” Sch 80
Cap (Qty) Size	(1) 2” Sch 40	(1) 3” Sch 40	
CAT 6 Cable (Qty) Length	(2) 20’		
2-Slot 8’ Foam Strips (Qty) Thickness, Width	(2) ½”, 1-5/8”	(2) 1”, 2-1/4”	(2) 1”, 2”
1-Slot 8’ Foam Strips (Qty) Thickness, Width	(2) ½”, 1-5/8”	(2) 1”, 2-1/4”	(2) 1”, 2”
Capacitors (Qty) Value, (Qty) Value, etc.	(2) 10 nF, (1) 1000 pF		
Waterproof Antenna Connector (Qty)	(1)		

Example 2: 8ft x 4ft Antenna: Typically used for pass-through with low flow conditions.

The wire layout below shows how the wires are run through the pipes in a two loop figure 8 configuration. There are only 3 solder joints used to make the 4 loops of the inductor.

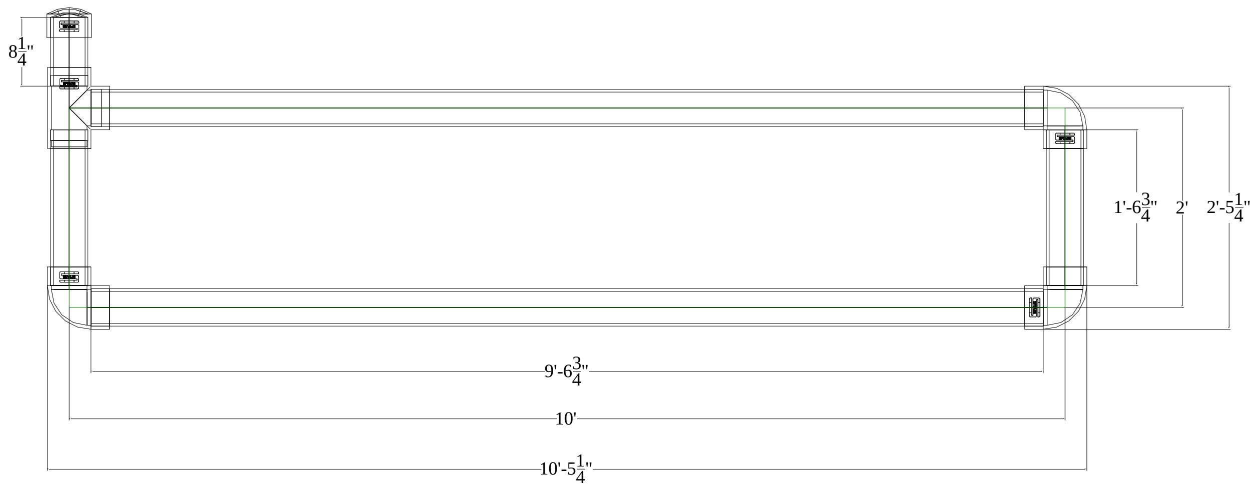


Capacitor configuration of the antenna: 

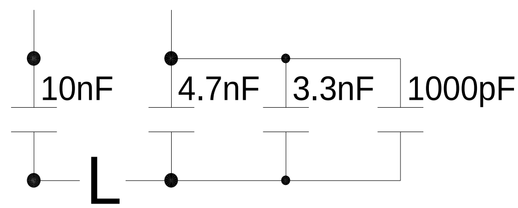
EXPECTED PERFORMANCE (with FS1001M and low noise 0% to 4%)			
Number of Loops:	4		
Inductance	242.5 µH		
Capacitors	C_1 = 10 nF	C_2 = 12.4 nF	
Tag Type	DF 12mm SST1	DF 9mm TX149011B	DM 23mm
Pass-through	15”	6”	20”
Pass-over	13”	5”	19””

MATERIALS			
Pipe Choice	3” Sch 40	3” Sch 80	4” Sch 80
Pipe (Qty) Length	(4) 1’ 6-1/4”	(4) 1’ 5-5/8”	(4) 1’ 3-1/2”
Pipe (Qty) Length	(3) 7’ 2-7/8”	(3) 7’ 3-1/2”	(3) 7’ 5-5/8”
Pipe (Qty) Length	(1) 7-1/2”	(1) 7-1/2”	(1) 7-1/2”
Elbow (Qty) Size	(3) 3” Sch 40	(3) 3” Sch 80	(3) 4” Sch 80
Tee (Qty) Size	(3) 3” Sch 40	(3) 3” Sch 80	(3) 4” Sch 80
Cap (Qty) Size	(1) 3” Sch 40		(1) 4” Sch 40
CAT 6 Cable (Qty) Length	(1) 40’		
2-Slot 8’ Foam Strips (Qty) Thickness, Width	(1) 1”, 2-1/4”	(1) 1”, 2”	(1) 1”, 3-3/16”
1-Slot 8’ Foam Strips (Qty) Thickness, Width	(3) 1”, 2-1/4”	(3) 1”, 2”	(3) 1”, 3-3/16”
0-Slot 8’ Foam Strips (Qty) Thickness, Width	(4) 1”, 2-1/4”	(4) 1”, 2”	(4) 1”, 3-3/16”
Capacitors (Qty) Value, (Qty) Value, etc.	(2) 10 nF, (2) 4.7nF		
Waterproof Antenna Connector (Qty)	(1)		

Example 3: 10ft x 2ft Antenna: Typically used as a pass-over antenna. 4” schedule 80 shown.



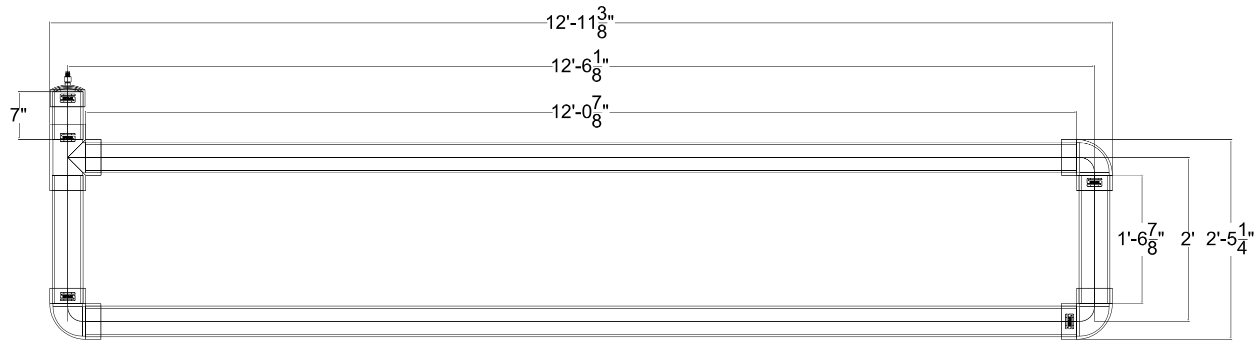
Capacitor configuration of the antenna:



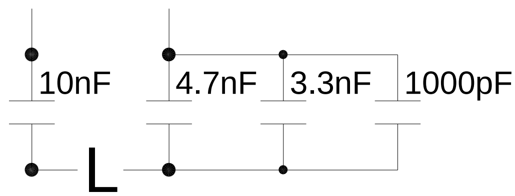
EXPECTED PERFORMANCE (with FS1001M and low noise 0% to 4%)			
Number of Loops:	7		
Inductance	295 µH		
Capacitors	C_1 = 10 nF	C_2 = 9.0 nF	
Tag Type	DF 12mm SST1	DF 9mm TX149011B	DM 23mm
Pass-through	22”	13”	32”
Pass-over	14””	8”	23””

MATERIALS			
Pipe Choice	3” Sch 40	3” Sch 80	4” Sch 80
Pipe (Qty) Length	(2) 1’ 9-1/2”	(2) 1’ 8-7/8”	(2) 1’ 6-3/4”
Pipe (Qty) Length	(2) 9’ 9-1/2”	(2) 9’ 8-7/8”	(2) 9’ 6-3/4”
Pipe (Qty) Length	(1) 8-1/4”	(1) 8-1/4”	(1) 8-1/4”
Elbow (Qty) Size	(3) 3” Sch 40	(3) 3” Sch 80	(3) 4” Sch 80
Tee (Qty) Size	(1) 3” Sch 40	(1) 3” Sch 80	(1) 4” Sch 80
Cap (Qty) Size	(1) 3” Sch 40		(1) 4” Sch 40
CAT 6 Cable (Qty) Length	(2) 25’		
2-Slot 8’ Foam Strips (Qty) Thickness, Width	(3) 1”, 2-1/4”	(3) 1”, 2”	(3) 1”, 3-3/16”
0-Slot 8’ Foam Strips (Qty) Thickness, Width	(3) 1”, 2-1/4”	(3) 1”, 2”	(3) 1”, 3-3/16”
Capacitors (Qty) Value, (Qty) Value, etc.	(1) 10 nF, (1) 4.7 nF, (1) 3.3 nF, (1) 1000 pF		
Waterproof Antenna Connector (Qty)	(1)		

Example 4. 12ft 6in x 2ft Antenna: Typically used as a pass-over antenna. 4" schedule 80 shown.



Capacitor configuration of the antenna:



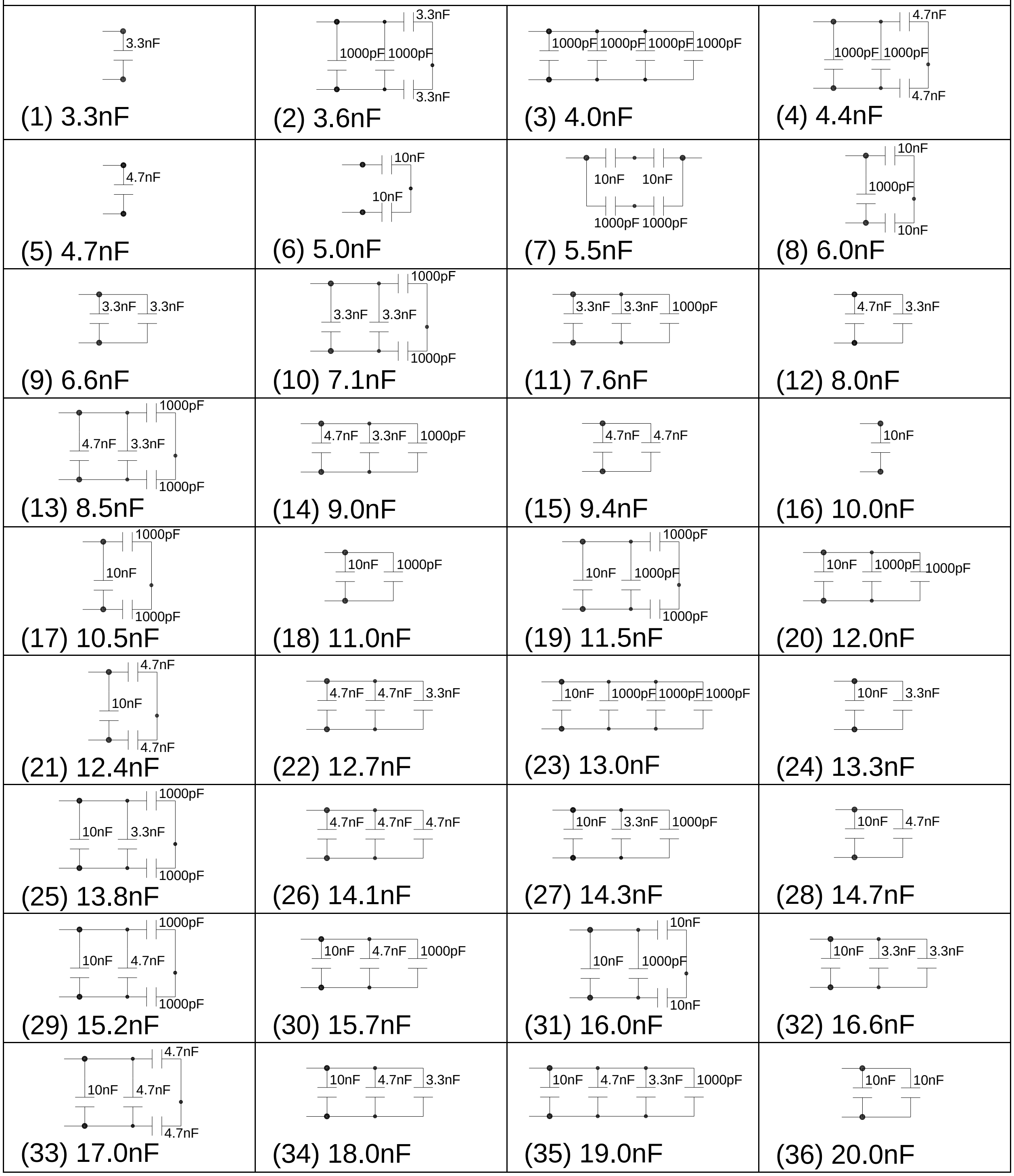
EXPECTED PERFORMANCE (with FS1001M and low noise 0% to 4%)			
Number of Loops:	6		
Inductance	287 µH		
Capacitors	C_1 = 10 nF	C_2 = 9.0 nF	
Tag Type	DF 12mm SST1	DF 9mm TX149011B	DM 23mm
Pass-through	16"	6.5"	26"
Pass-over	11"	3.5"	16"

MATERIALS			
Pipe Choice	3" Sch 40	3" Sch 80	4" Sch 80
Pipe (Qty) Length	(2) 1' 9-1/2"	(2) 1' 8-7/8"	(2) 1' 6-3/4"
Pipe (Qty) Length	(2) 12' 3-5/8"	(2) 12' 3"	(2) 12' 0-7/8"
Pipe (Qty) Length	(1) 7"	(1) 7"	(1) 7"
Elbow (Qty) Size	(3) 3" Sch 40	(3) 3" Sch 80	(3) 4" Sch 80
Tee (Qty) Size	(1) 3" Sch 40	(1) 3" Sch 80	(1) 4" Sch 80
Cap (Qty) Size	(1) 3" Sch 40		(1) 4" Sch 40
CAT 6 Cable (Qty) Length	(2) 31'		
2-Slot 8' Foam Strips (Qty) Thickness, Width	(4) 1", 2-1/4"	(4) 1", 2"	(4) 1", 3-3/16"
0-Slot 8' Foam Strips (Qty) Thickness, Width	(4) 1", 2-1/4"	(4) 1", 2"	(4) 1", 3-3/16"
Capacitors (Qty) Value, (Qty) Value, etc.	(1) 10nF, (1) 4.7nF, (1) 3.3nF, (1) 1000pF		
Waterproof Antenna Connector (Qty)	(1)		

Appendix B

Series and Parallel Capacitor Combinations for Passive Integrated Transponder Systems

SERIES/PARALLEL CAPACITOR COMBINATIONS



Appendix C

Antenna and Cable Materials and Sources Including Manufacturer and Vendor

ANTENNA COMPONENTS & SOURCES			
Item	Part#/Description	Manufacturer	Vendor
Solder	Sn63/Pb37 rosin activated flux core wire solder	MG Chemicals	Allied Electronics (GSA Advantage)
PVC Primer	30757 Purple Primer, 16 oz. can	Oatey	Plumbing supply, e.g. Cutright, Ferguson's
PVC Glue	31857 Rain-R-Shine Blue 16 oz. can	Oatey	Plumbing supply, e.g. Cutright, Ferguson's
Silicone Adhesive	NUFLEX 333	NUCO	www.jjshort.com www.hitechglazing.com
Electrical Tape	¾" wide, vinyl		Building supply, e.g. Lowes, Home Depot
Liquid Dish Soap			Grocery store, e.g. Safeway, Fred Meyer
3/32" Heat Shrink	FP-301 2:1 shrink	3M	Mouser
3/8" Heat Shrink	PHS-024-4025-BLK 3:1 shrink adhesive lined	SPC Technology	Newark Electronics (GSA Advantage)
3/4" Heat Shrink	PHS-048-4005-BLK 3:1 shrink adhesive lined	SPC Technology	Newark Electronics (GSA Advantage)
PVC Pipe			Plumbing supply, e.g. Ferguson, Cutright
PVC Elbows			Plumbing supply, e.g. Ferguson, Cutright
PVC Tees			Plumbing supply, e.g. Ferguson, Cutright
PVC Cap	Schedule 40		Plumbing supply, e.g. Ferguson, Cutright
Perfboard	8.5"x 17" FR4 Epoxy Glass	Vectorbord Part# 169P84WE	Newark 34F1228 Digi-Key V1011-ND
Capacitors, 10 nF	0.01µF, 2000V, ±5% polypropylene	Vishay BFC237540103	Newark 26M6544
	0.01µF, 2000V, ±5% COG	Novacap 3530N103M202LE	Novacap
Capacitors, 4.7 nF	0.0047µF, 2000V, ±5% polypropylene	Vishay BFC238560472	Newark 53M6834
	0.0047µF, 2000V, ±5% COG	Novacap 3530N472K202LER	Novacap
Capacitors, 3.3 nF	0.0033µF, 2000V, ±5% polypropylene	EPCOS B32652A2332J	Newark 30C6190
	0.0033µF, 2000V, ±5% polypropylene	Vishay BFC238580332	Newark 53M6839

Capacitors, 1000 pF	1000pF, 2000V, ±5% polypropylene	EPCOS B32652A2102J	Newark 30C6172
	1000pF, 2000V, ±5% polypropylene	Vishay BFC238560102	Newark 53M6828
Ethernet Cable	CAT61000GY, 23 ga. 4-pair CAT 6		www.cablesandkits.com
Polystyrene Foam	Foamular 1” thick (½” thick for 2” PVC)	Owens Corning	Building supply, e.g. Lowes, Home Depot
Bulkhead Connector (Waterproof Antenna Connector)	BH3MP, nut & O-ring incl.	MECCO, INC	MECCO, INC
	BH3M, nut & O-ring incl.	SubConn Inc.	SubConn Inc.
	BH-3-MP, nut & O-ring incl.	Teledyne Impulse	Teledyne Impulse
ANTENNA CABLE COMPONENTS & SOURCES			
In-line Connector (Waterproof Cable Connector)	IL3FS	MECCO, INC	MECCO, INC
	IL3F	SubConn Inc.	SubConn Inc
	IL-3-FS	Teledyne Impulse	Teledyne Impulse
Antenna Cable	X-00138897-001, 12/2 PE braid shield PVC	Custom Cable	Custom Cable
	AWC21247PE639-OUV, 12/2 braid shield	Allied Wire Corp.	Allied Wire Corp.
Cable Gland (Backshell & Clamp)	206322-9 Cable Gland	Tyco/Amp	Newark #78K6814 Allied Elect. #374-1280
Contacts (Pins)	202236-2 Contact	Tyco/Amp	Newark #33B6814 Digi-Key #A1629-ND
Circular Connector (Mates to FS1001M)	211768-1 Circular Connector	Tyco/Amp	Allied Elect. #512-8873 Newark #92F4844
Outdoor rated extension cord	Sacrifice an outdoor rated extension cord		Hardware store, e.g. Lowes, Home Depot

Appendix D

Test Cap Materials and Building Protocol for Leak Checking Antenna(s)

Tools:

- Drill press or electric drill and a 5/8" bit
- Tape measure
- 12" Compound Miter Saw
- 9/16” open end wrench
- Rubber mallet

Materials:

- Schedule 40 PVC cap of a diameter to match that of the antenna(s) to be leak tested.
- TR575 1-1/8 Truck & Bus Clamp-in Tubeless Tire Valve
- 6” length of PVC pipe of a diameter to match that of the antenna(s) to be leak tested.
- Aquarium grade Silicone Adhesive

Construction:

1. File a flat area on the top center of the pipe cap at least 1” in diameter.
2. Mark the center of the pipe cap and drill a 5/8” diameter hole.
3.

Figure 41, Filed flat ara on PVC cap used to ensure that the tire valve has a proper seal, and drilled pipe cap

4. Insert the tire valve in the hole from the inside of the pipe cap, place the clamping washer and nut over the threaded end of the tire valve where is sticks out of the pipe cap, and tighten the nut with a 9/16” wrench.
5. Cut a 6” piece of PVC pipe of a diameter to match that of the antenna(s) to be leak tested.
6. Place a bead of silicone adhesive around the inside lip of the pipe cap, and a bead of silicone adhesive around the outside lip of the end of the piece of pipe.
7. Place the cap on the piece of pipe, adhesive to adhesive, twist the cap down onto the pipe, and seat it completely with a rubber hammer.
8. Wipe the bead of silicone adhesive with a paper towel or tissue to form a smooth fillet at the joint between the pipe and the cap.
9. Allow the silicone adhesive to set for 24 hours.

10.

Figure 42: Completed Test Cap to leak check antennas.

Appendix E

Establishing Data Archive in Pacific States Marine Fisheries Commissions PIT tag Information System

Defining a New Interrogation Site in PIT tag Information System (PTAGIS):

Once an array of PIT antennas is configured and working at a new site, it is useful to get the data stored in the PTAGIS database that is accessible on the internet. PTAGIS makes it easier to manage the data collected from sites by storing the PIT tag detection information and providing tools for querying the database to assist in analyzing PIT tag data. By copying interrogation data from a site into PTAGIS, researchers in the CRB can have easy access to it. As the number of sites in the CRB contributing to the database increases, the resolution of data about the movement of salmonids increases. This benefits all users of the database since salmonids tagged and released near a particular site which are detected at other interrogation sites at some point during their life history will register in the database with these additional detections.

To facilitate new sites being registered in PTAGIS, the instructions for registering a new site are copied here with minor adaptations. For the most recent information about registering a site in PTAGIS see the following website:
http://php.ptagis.org/wiki/index.php/Required_information_for_defining_an_interrogation_site

Responsibilities of Data Contributors:

If a site will be an active contributor to PTAGIS, there are certain responsibilities of the data contributors.

Data contributors need to provide metadata about operational and site conditions at the interrogation site that may affect likelihood of detecting PIT tags. It is the responsibility of the Data Steward to provide this information in the form of event log updates. The following types of events require an event log to be submitted:

- Annual initiation and termination of site operations
- Any time the transceiver stops reporting (or recording) data from one or more antennas
- Any time an individual antenna is shut down or blown out
- Any environmental conditions that have a severe impact on an antenna's likelihood of detecting PIT tags

Required Information to Register a Site:

1. Unique 3-character site code. (e.g. “CIC” is Cottonwood Island Channel)
2. A short site name (up to 30 characters).
3. A long site name (up to 80 characters).
4. A site description (up to 1000 characters) that describes the location, layout and setup of the site.
5. Name of the stream or location (eg. dam or hatchery) on which the interrogation site will be located, and the corresponding PTAGIS tag/release site code.
   - If the site is on a stream or river segment, provide the distance in kilometers from the mouth of the stream to the location of the site.
6. The latitude and longitude of the interrogation site, reported in decimal degrees precise to six decimal places.
7. A Google Earth kmz, Google Maps link (maps.google.com), or similar map confirming the lat/long position.

8. The transceiver and antenna information for the interrogation site.
    - Transceiver type and firmware version
    - Transceiver ID (i.e. two digit hexadecimal)
    - Antenna type (i.e. flat plate, pass-through, hybrid, etc)
    - Antenna IDs
    - Timer Tag Code (i.e. 3E7.0000001DA0)
    - Photo or diagram of the antenna configuration, with each antenna identified by ID
9. The (expected) first date of operation.
10. Contact information for the site Data Steward, Technical Point of Contact and any other interested parties:
    - email address
    - phone number
    - mailing/physical address

Submit Required Information to the PIT Tag Steering Committee (PTSC):

- Contact your PIT Tag Steering Committee representative to request a new interrogation site.
- Include required information in a memo or document attached to the email.
- PTSC representative will forward the request to PTAGIS via email.
- ptagis_support@ptagis.org
- Subject: New Interrogation Site

Follow-up:

- PTAGIS may contact the proposed site Data Steward if any additional information or clarifications are required.
- When the interrogation site is defined and configured in the PTAGIS database, PTAGIS will submit an event log and notify you via email.