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High-Density Polyethylene Pipe: A New Material for Pass-By Passive Integrated Transponder Antennas

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MANAGEMENT BRIEF

High-Density Polyethylene Pipe: A New Material for Pass-By Passive Integrated Transponder Antennas

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Abstract
Pass-by passive integrated transponder (PIT) antennas are widely used to study the movements of fish in streams. At many sites, stream conditions make it difficult to maintain antennas and obtain a continuous record of movement. We constructed pass-by PIT antennas by using high-density polyethylene (HDPE) and found them to be robust to high flows and winter ice flows. Costs for HDPE antennas were similar to those of traditional polyvinyl chloride (PVC) antennas, although construction was somewhat more complicated. At sites where PVC antennas are frequently damaged, HDPE is a durable and economical alternative for PIT antenna construction.

Pass-by passive integrated transponder (PIT) antennas have been used in stream environments to detect fish movements (e.g., Armstrong et al. 1996; Nunnallee et al. 1998; Greenberg et al. 2001). In contrast to the typical pass-through PIT antenna design, pass-by PIT antennas lie on the bottom of the stream channel and decode tags as a fish swims above. Using this configuration, antennas are less prone to damage during storms. Recent advances in PIT technology have increased the read range of PIT antennas and have made pass-by antennas more effective than ever before (e.g., Model 1411SST tag; Digital Angel, South St. Paul, Minnesota).

As part of an ongoing investigation into the life history of sea-run brook trout *Salvelinus fontinalis*, we constructed PIT antenna arrays at the mouth of Cove Brook, a tidal tributary to the Penobscot River, Maine. The mouth of Cove Brook presents a challenging location to install and maintain stationary PIT antennas. The stream is characterized by regular high-flow events and substantial bedload transport and is dominated by coarse, irregular substrate. Additionally, large amounts of ice form in the brook and are routinely flushed out of the system during winter months. These site characteristics make it difficult to maintain operational PIT antennas constructed of polyvinyl chloride (PVC) pipe, which becomes very brittle at cold temperatures and breaks easily when impacted. Because brook trout are known to transition between freshwater and saltwater at any time of year, it was important to develop an antenna that could remain deployed through the winter months.

MATERIALS AND CONSTRUCTION

We constructed our antennas with nine turns of 10 American wire gauge (AWG)-equivalent Litz wire (5 × 5 × 44/40) by using methods similar to those described by Bond et al. (2007). The unusual construction and geometry of Litz wire maximize reader efficiency and minimize harmful interference from ambient radio noise. Laboratory testing indicated that we could build a 600- × 45-cm pass-by antenna that would read tags in low-noise environments. However, our field site is noisy and we chose to build antennas that were somewhat smaller (250 × 45 cm) so as to reduce the interference from ambient noise. Additionally, we used twin 10-AWG coaxial cables (9913F7; Belden, Inc., Richmond, Indiana) with a custom waterproof coating to shield the antenna cables from environmental interference.

We used a Model FS1001M reader (Destron Fearing, South St. Paul, Minnesota) to power our antennas. The FS1001M reads full-duplex PIT tags, thus allowing small fish (≥65 mm fork length) to be studied. Additionally, the FS1001M allows

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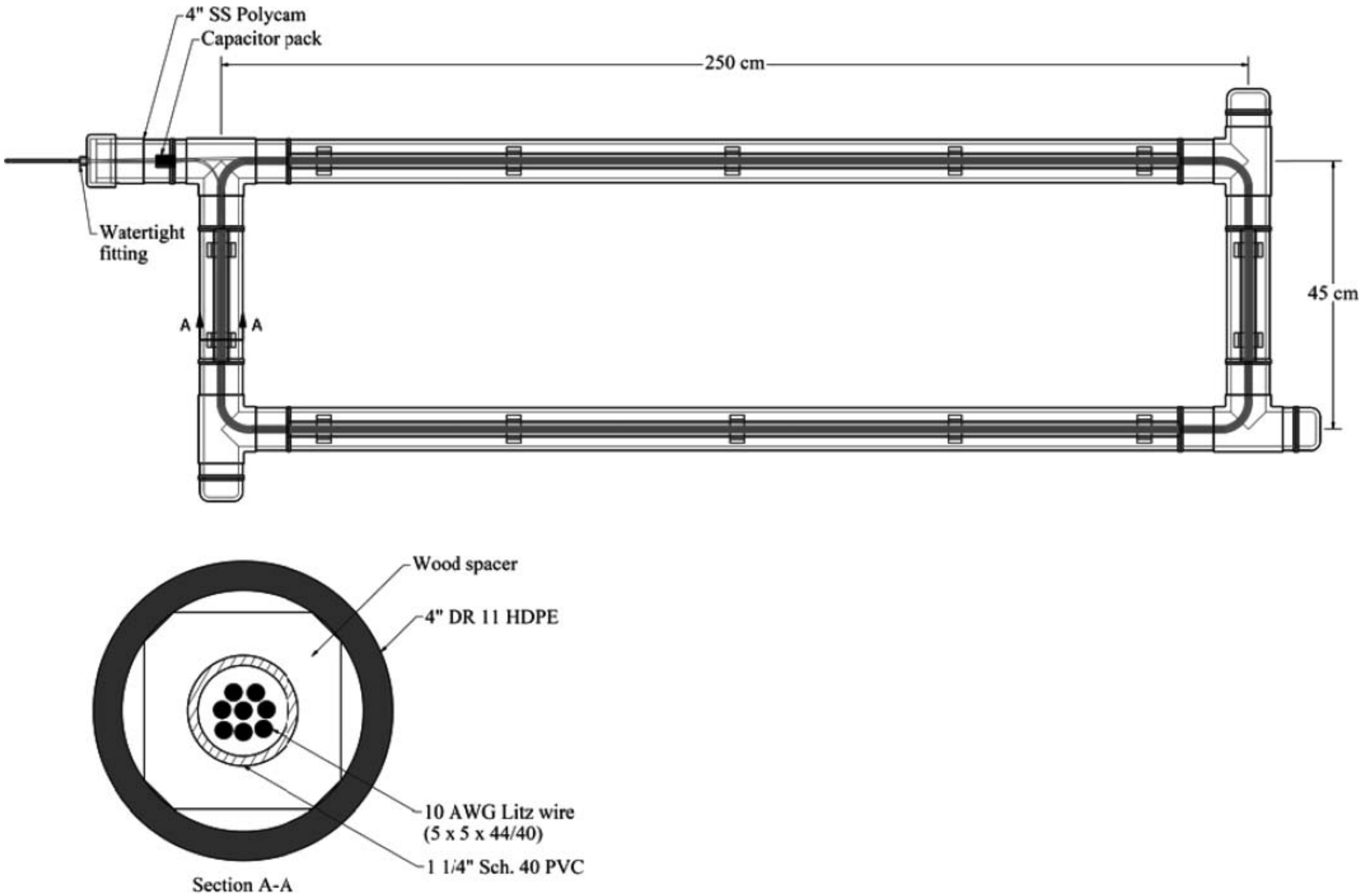

FIGURE 1. Schematic configuration of a pass-by passive integrated transponder (PIT) antenna made of 4-in, standard dimension ratio (SDR)-11 high-density polyethylene (HDPE), as tested at the mouth of Cove Brook, Maine (SS = stainless steel; AWG = American wire gauge; 1 1/4′ Sch. 40 PVC = 1.25-in schedule-40 polyvinyl chloride). Section A-A corresponds to the A-A in the top view.

automatic tuning to adjust for changing water conditions and can multiplex up to six antennas to permit operation in close proximity. Antennas were installed in a completely balanced 3 × 2 configuration (using the nomenclature of Connolly et al. 2008) that covered the width of the stream channel.

We considered a suite of candidate materials for antenna housings, including PVC, fiberglass, and high-density polyethylene (HDPE). Schedule-80 PVC pipe is commonly used for instream PIT antennas but becomes extremely brittle at cold temperatures. High-density polyethylene is very strong and has excellent cold-weather performance. This material has been used in other PIT tag antennas in sheet and molded formats, but to our knowledge HDPE in pipe format has never been used for this purpose. Pipe constructed of HDPE is priced similarly to schedule-80 PVC pipe, is available in a range of sizes, and could be easily adapted to existing PVC antenna designs. To highlight the durability of HDPE pipe, a sample of HDPE pipe at a temperature of −10°C was subjected to a blow from a sledgehammer. The sample received only superficial damage. In contrast, a similar test with schedule-80 PVC pipe fragmented the pipe into many pieces. Fiberglass may also be well suited to antenna construction; although fiberglass has been used at other locations, this material was cost-prohibitive for the size of our stream and budget.

We selected 4-in, standard dimension ratio (SDR)-11 HDPE pipe for use in PIT antenna construction. Because HDPE must be bonded with heat and pressure in a specialized tool, we needed to modify the design of our previous antennas to facilitate construction (Figure 1, 2). First, we built a rectangular antenna frame with openings on each corner. Next, we wired the antenna by using PVC pipe to hold the wires at the center of the pipe. Once wiring was complete, we sealed three of the corners with HDPE end caps. The fourth corner was sealed by use of a stainless-steel Poly-cam (Poly-cam, Inc., Anoka, Minnesota) and threaded endcap. We used waterproof fittings (Sealcon USA, Centennial, Colorado) to pass a waterproof antenna cable through the endcap, and we reinforced the fittings with copious quantities of 5200 Marine Adhesive Sealant (3M Marine, St. Paul, Minnesota).

We anchored the antennas in place by using three techniques. First, each antenna housing was filled with silica sand to make it negatively buoyant. Silica sand is nonferrous and does not

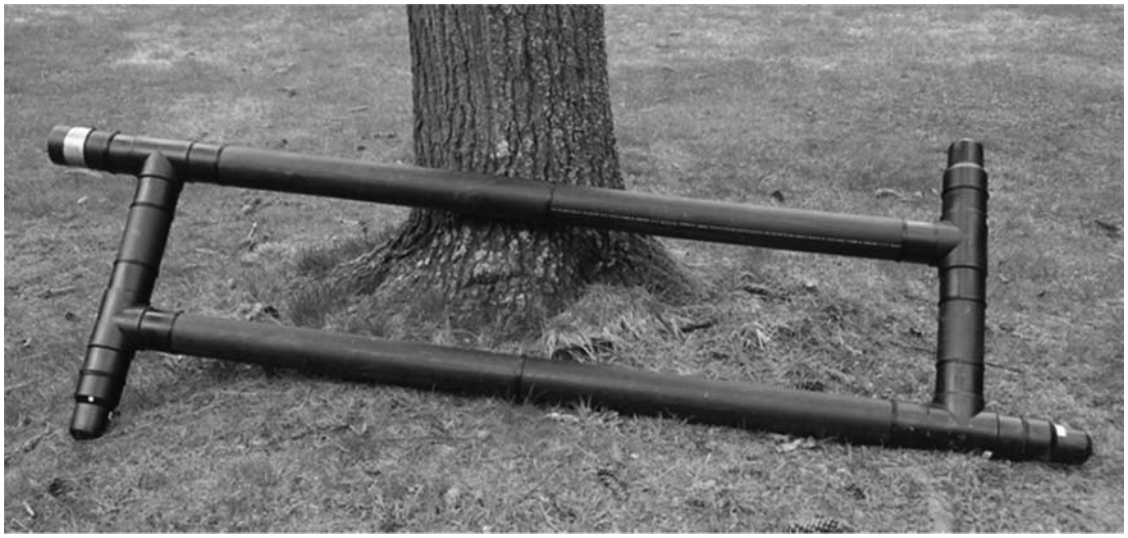

FIGURE 2. Photograph of a finished pass-by passive integrated transponder antenna constructed of high-density polyethylene.

interfere with the operation of the antenna. Second, we placed a few large boulders (>100 kg) on top of each antenna to minimize its tendency to shift under high-flow conditions. Finally, we anchored the antenna into the stream channel by using several Duckbill earth anchors (Foresight Products LLC, Commerce City, Colorado) and rope. At sites with bedrock or large boulders, wedge anchor bolts offer an additional means by which to secure the antennas.

FIELD RESULTS

In situ, our pass-by antennas were able to detect 134.2-kHz tags (Digital Angel Model TX1411SST) up to 90 cm above the antenna coil in environments with low levels of ambient radio noise. Under typical environmental conditions, tags could generally be read at least 35 cm above the antenna. Consequently, at this site, these antennas should be able to detect any fish that passes over during normal flow conditions. These read ranges are nearly identical to those we have attained with similar antennas constructed by using PVC.

The HDPE antennas are more durable than PVC antennas. Although PVC antennas were routinely damaged at our study site, our HDPE antennas have been operational since April 2010 and have withstood numerous high-flow events without being damaged. The major limitations of HDPE are that construction requires specialized fusion equipment and that construction is more complicated than the solvent-welded fitting construction used with PVC. The fusion process creates one continuous piece of plastic and eliminates the joint weakness that is associated with PVC antennas. Although HDPE fusion requires specialized tools, the process itself is simple and can easily be learned by a fisheries biologist.

The overall cost of construction for an HDPE antenna (~US$500) was comparable to the cost of construction with schedule-80 PVC but resulted in a much more durable antenna. High-density polyethylene antennas take somewhat longer to build than comparable PVC antennas (11 h/antenna versus 7 h/antenna) because each pipe fusion requires several minutes of heating and cooling. However, the added durability of HDPE may save time in the long run and may improve data continuity at sites where PVC antennas are routinely damaged.

Antennas constructed of HDPE appear to be well suited to dynamic stream environments in cold climates. Although our antennas were deployed in a pass-by configuration, the performance characteristics of HDPE also make it highly suitable for pass-through applications. Our approach to pass-by antenna construction has facilitated the use of PIT technology at challenging sites where stream conditions and financial limitations were previously prohibitive.

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