Transponder Basics

Definitions

AMB AMB is a company from the Netherlands that makes active transponders. The AMB transponders have been used at xc world cups and Olympics since 2002. AMB transponders are expensive, but they are the gold standard for xc timing.

RFID radio frequency identification. Sometimes AMB folks want to split hairs and say that their transponders are not truly RFID devices. No big deal unless you want to get really technical.

Transponder electronic gizmo that automatically transmits a signal upon reception of a designated incoming signal.

Chips a very general term for electronic gizmos.

Throughout the rest of this document, I will use the terms chips and transponders interchangeably.

Active vs Passive Chips

There are two fundamentally different types of chip, passive and active. Active chips have a battery, which powers the chip. Typically, the system has an antenna loop which “activates” the chip. The chip then transmits its ID code, and this is picked up by a receiver. Because active chips have a battery, the chips tend to be very expensive compared to passive chips. Active chips are more accurate and are read more reliably than passive chips. In addition, active chips have a greater read range which also means a greater read height.

Passive transponders do not have a battery. As a result, the antenna has to be able to couple enough energy into the chip so that the chip can successfully transmit its ID code to a receiver. Because there is a need to transmit energy (as well as information), passive chips have issues with the orientation of the chip, and passive chips have issues with the read range. Finally, passive chips have a problem with collisions, that is, missing chips when two or more chips are in the antenna at the same time. Because they are so cheap, passive chips are used in many, many commercial applications such as inventory control. The cost will continue to come down, until they cost about nickel. At that cost, the chips can be considered disposable, and can even be manufactured in a paper bib.

Accuracy vs Resolution

Please note that accuracy and resolution are **NOT** the same thing. Resolution is merely the number of digits to the right of the decimals point that is reported by the timing system. It is very, very easy to have any timing system report a lot of digits to the right of the decimal point, but resolution alone does not necessarily mean anything.

I think of accuracy as the difference between the time that the timing system reports and the time that the good Lord above would have recorded. Here is a example showing the difference between accuracy and resolution. Suppose that each athlete only wears only one chip on one of his ankles. If the athlete throws the "wrong" foot forward, the transponder would report the time that the trailing leg crosses the finish with a very high resolution (say a resolution of 0.001 seconds). But the good Lord above would have properly recorded the time when the lead toe crossed the finish line. So there would be an error between the chip time and the good Lord's finish time. In this example, the error could be as big as 0.4 seconds.

For another example, if a volunteer pushes a plunger (ie push button), it would be very simple to report the time to the nearest microsecond (0.0000001 seconds), but a human being is only capable of timing an xc racer with an accuracy of about 0.1 seconds.

Repeatability

Repeatability is another important concept when evaluating transponder performance. Suppose that a company's chips were **ALWAYS** detected exactly 1 meter in front of the finish line. No big deal, just locate the antenna a meter past the finish, and this problem totally disappears.

Generally, repeatable errors apply to the entire field, and do not affect the fairness of the competition.

Time Error

Transponders transmit their ID codes when the transponder is detected near the finish. There is often variance due to the shape of the electromagnetic fields, due to interference, due the battery strength in active chips, and due to other causes.

As the transponder approaches the finish line, lets call the distance between the location of the transponder when the transponder is detected and the true finish line the Position Error.

The time error is then given by the following equation:

Time Error = Position Error / Racer Velocity

If the skier velocity is 5 meters per second, and if the Position Error is 0.5 meters, then the Time Error is 0,1 seconds. This is a relatively small time error. But at the start, the skier velocity is essentially zero, so a relatively small Position Error can generate a very large time error. This is why using a start wand is so important in an interval start race.

Transponder Bottom Line Questions

Here is a list of bottom line questions to ask of chip manufacturers and vendors and timing contractors. Some of this information is rather easy to acquire. It is easy to find the chip cost and the reader cost. It is much harder to get honest answers regarding accuracy and reliability. Appendix A shows a comparison of some of the more common transponder timing systems.

Antenna Width For the finish, FIS rules stipulate 4 lanes each 3 meters wide for a total of a 12 meters wide finish line. Dag has an transponder system whose maximum antenna width is only 10 meters. Is this good enough for xc racing? If you ask anyone in North America who is the best expert on xc stadium layout, those in the know will unanimously say “John Estle”. So I climbed to the top of the mountain, to ask John whether it would be OK to only have only 3 lanes at the finish in order to accommodate certain transponder systems. John said **NO!** Of course, I agreed with him!

Read Reliability Sometimes a chip fails to read. One vender of passive chips told me that his chips are read 98-99 percent of the time. He insisted that they are as good as anyone else. Obviously we all want 100% read reliability, but that is a very difficult goal to reach. The truth is hard to come by. AMB claims that their chips can be read with 100% reliability. This is an exaggeration. I know that one chip (out of 400) failed to reliably read at the 2007 Junior Nationals at Soldier Hollow (we had fantastic volunteers, so this did not cause a problem).

Read Height Read height is the maximum height above ground that the chip can be read. This is very important when evaluating a transponder system for other sports, such as bicycling. A system with a high read height permits placing the chip on the waist or chest (ie in pocket on the bib).

Antenna Form Factor Some systems use large mats, some use wire loops, and some systems use portals (ie doors). The snow surface must be totally smooth for the width of the finish line. If a portal is used, it must be at least 12 meters wide. Wire loops buried in the snow are probably the simplest.

Buried mats are quite a pain to deal with! In the worst case, a hole is dug across the finish line the night before the race, the mats are placed in the hole and covered with plywood, then snow is spread on top, and the groomer is forbidden to groom the finish line because the mats are too fragile.

Overhead antennas are used with some transponder systems. They would also be quite a pain for a 12 meter wide finish line.

Number of Readers Required Some antenna systems require several different antennas to span a 12 meter xc finish line. Sometimes this requires several readers. This can get quite expensive!

Reader Cost Readers in a transponder system cost between $ 4,000 and $ 13,000. One of the big benefits of chips is the ability to acquire intermediate times without volunteers. If the reader is horribly expensive, then it may be too expensive to acquire intermediate times, half defeating the purpose of the transponders in the first place.

Chip Cost When timing the Olympics, the transponder cost is no big deal, because the fields are small, and there is a nearly infinite supply of money. For domestic races, however, the chip cost is a big factor. At the present time, the AMB system is the gold standard in transponder technology, but the AMB chips cost about $85 each. So if you wanted to put two chips on each racer at the junior nationals (400 kids), the chips alone would cost $ 68,000.

Timing Accuracy Active chips are more accurate than passive chips. AMB claims that their chips are more accurate than 0.1 seconds.

Chip Configuration - shoe tag or ankle bracelet or bib or chest or waist etc

Overall System Reliability Clearly it is important for the transponder system to work reliably in the cold and in the rain. Reliability is important, but it is very hard to quantify. Every vender reports that his system is very reliable.

Power Source It's preferable if the transponder system can run from a 12 volt battery. This is particularly important for remote timing points

Transponder Issues

One Chip or Two

For the Olympics and World Cups, the athletes have a transponder on each ankle. This gives more accurate times if either the left or right foot is thrown forward at the finish. Due to the expense of the transponders, many domestic timing contractors use only one transponder.

Is it proper to tell the athlete to put a single chip on the leg that the athlete intends to throw forward? If the athletes were able to do this, this approach would give more accurate times and more accurate finish order. But this would mean that the timer guy is fundamentally changing the sport to suit the timing equipment. Again, I journeyed to the top of the mountain to ask John Estle. He felt that requiring the athlete to choose ahead of time which foot to throw forward is fundamentally a wrong-headed idea. Of course, I agreed with him!

Using Chips for Timing an Interval Start Race

It is the feeling of this transponder study group that it should be OK to use **ACTIVE** transponders for finish times in an interval start race if there is a chip on each ankle. A start wand should always be used for start times.

Using Chips for a Mass Start Race

It is the feeling of this transponder study group that video should be used for adjudicating close finishes in a mass start race. Transponders can be very helpful in getting approximate finish order, but at this point, chips are not as accurate as good video. For important races, a photo finish camera (ie Finish Lynx) camera should be used. For regional races, good digital video cameras are sufficient.

Suppose that one athlete's chip is on the front of his ankle, and another athlete's chip is on the back of his ankle. Clearly this would generate about a 4 inch uncertainty. A good video can resolve finishes that are as close as 1 inch (2.5 centimeters). For several reasons, transponders cannot resolve finishes that close.

An experienced volunteer crew is surprisingly good at writing down the correct finish order. Experienced volunteers can easily pick out the winner if two racers are separated by at least 0.5 meters at the finish. Volunteers become overwhelmed, however, when hordes of racers are pouring across the finish line. In these cases, transponders and video are extremely helpful.

The table below shows that xc skiers approach the finish at a velocity of 4 to 10 meters per second. The table shows that in 0.2 seconds, the athletes cover a distance of 0.8 to 2.0 meters.

Pace (min/km)	Velocity (meters/second)	Distance in 0.2 sec (meters)	Notes
4:00	4.17	0.83	
3:00	5.56	1.11	
2:47	6.00	1.20	Nordic Combined Average
2:30	6.67	1.33	
1:40	10.00	2.00	Sprint

Most xc racers throw their lead leg forward at the finish line. The lead boot crosses the finish line sooner, but the racer slows down, and sometimes falls. Often the trailing leg does not cross the finish for about 0.4 seconds after the first toe crosses the finish line.

Case #1: Chip on Each Ankle: The table above shows that in 0.2 seconds, xc racers will cover between 0.8 meters and 2 meters. This gap is big enough for an active transponder system to consistently get the proper finish order. Finishes when there is less than 0.2 seconds between athletes should be flagged for video review. In some cases, the volunteers can confidently write down the bib order, eliminating the need for video review.

Case #2: Chip on One Ankle Experience has shown that when a skier throws one leg forward, there can easily be 0.4 seconds between the time that the first leg crosses the finish and the time that the trailing leg crosses the finish. As mentioned above, this is a much bigger time difference that one might calculate from the finish velocities shown above, because often the skiers momentum is killed as he throws his lead foot forward (because he stopped skiing). Therefore if the athletes are wearing a chip on only one ankle, then all finishes that are closer than 0.6 seconds (ie 0.2 seconds + 0.4 seconds) should be flagged for video review. In many of these cases, the volunteers can confidently write down the bib order, eliminating the need for video review.

Case #3: Chip on the Body When the athlete wears a chip on the waist or on the chest, this case is about half way between case #1 and case #2 above. So it is recommended that all finishes should be reviewed when there is less than 0.4 seconds between athletes.

Track races have traditionally used the chest to determine the order of finish. Ironically, the governing body for track and field is discussing the merits of putting a chip on both shoes, in order to accommodate the Champion chip system. This is because Champion has a poor read height capability, prohibiting placing a chip on the chest (ie with the bib).

Using Chip Times in a Mass Start Race

Many folks ask whether chips times can be used in a mass start race. After all, exact times are not particularly important in a mass start race. Order of finish alone determines finish rank.

As mentioned above, video should be used for adjudicating close finishes. In all three cases described above, it is OK to use the chips times, except in cases when the video review indicates a different finish order than the chips indicated. In these cases, the times need to be adjusted based on the video to reflect the proper finish order. Ties should show the same time.

Case Study

Suppose that you are a TD for a JOQ, and the night before a race, you find out that the timing contractor will be using chips for racer identification and timing in an interval start race. Suppose that he only has one chip per athlete. He has no start wand and no photo beam for the finish. What should the you do? I know that this has happened.

Appendix A Transponder Comparison

Manufacturer/Vendor	AMB	Winning Time	Champion	Winning Time	Dag (ski)	Dag (bib)
Active vs Passive	Active	Active	Passive	Passive	Passive	Passive
Reader Cost	$4,000	?				
Chip Cost	$85	?				
Finish Line Width	12 meters	12 meters				
Read Height		6 feet				
Reliability of Chip Reading	100%					
Antenna Form Factor	Wire Loop	Wire Loop				
Antenna Dimensions						
Number of Antennas for 12 Meter Finish Line	1					
Number of Readers for 12 Meter Finish Line						
Ease of Antenna Installation	very good					
Size and Weight						
Issues						
Contact Person			Mike Burns/Jay Michaelson			
Email						
Phone			734 665 7052			