



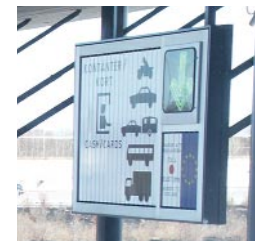
Electronic Tolling Turns Ugly: Solving the Failed-Transponder Problem

By Wally Kreutzen and Mike Leahy

Oh no! More failed transponders. Send out another 25,000 replacement units next quarter!

Sound familiar? If you're a toll operator in today's electronic tolling environment, it's a refrain with which you can likely empathize, if you haven't already exclaimed it yourself. It's certainly true in California, despite the state's comparatively rookie status in electronic toll collection.

While road and bridge tolling has been around for centuries—with many decades of toll experience in the eastern United States—California, the land of freeways, is a relative newcomer to direct payment for highway use. Fortunately for the state, we've had the opportunity to learn electronic tolling from those who've been in the business a long time, including E-ZPass, the Pennsylvania Turnpike, and the Florida toll roads. California also enjoyed the advantage of implementing tolled roads in an era of expanding technological capabilities. As a result, the state's modern toll roads are efficient, state-of-the-art facilities able to serve the public for years to come.



California Title 21

When the first electronic toll roads were proposed for California in the early 1990s, electronic toll collection was in its infancy. In 1990, the California Senate was, with Bill 1523, directing the California Department of Transportation (Caltrans) to “develop and adopt functional specifications and standards for an automatic vehicle identification (AVI) system.” Two years later, the final draft of the “Compatibility Specification for Automatic Vehicle Identification (AVI) Equipment” was submitted to the state’s office of administrative law. The final legal specification became known as Title 21 of the California Administrative Code and defined the frequency, operational characteristics, and message formats for the AVI system in great detail.

OK, so now we had an agreed-upon technical specification, but no transponders.

At a concept level, the Title 21 specification for electronic toll collection (ETC) specifies the use of a reader or antenna at the tolling location and a transponder (transmission responder), commonly known as a tag, in each vehicle. The design of the transponder tends to drive the design of the ETC system because the quantity of the tags (one per vehicle) and their location inside vehicles (the windshield area) are limited. The tag has to be relatively simple to contain manufacturing and purchasing costs plus be reliable to be effective.

In the opinions of some toll industry experts, the Title 21 transponder specification went too far. Rather than just set out performance goals for the technology, it mandated many absolute requirements by utilizing a fixed data content (identification number) that can be read but not altered.

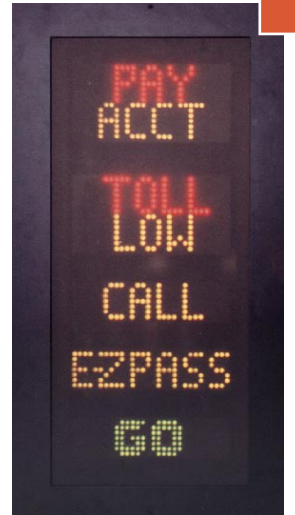
In the opinions of some toll industry experts, the Title 21 transponder specification went too far. Rather than just set out performance goals for the technology, it mandated many absolute requirements by utilizing a fixed data content (identification number) that can be read but not altered. This “read-only” characteristic simplifies the transpon-

der design but dictates that extensive communication and “back-room” computer systems be implemented to track user account information and ensure proper assignment of toll transactions to the appropriate toll account.

At the time the Title 21 standard was being finalized, a design decision was made to select a modulated backscatter device to transmit the unit identification number for tolling purposes. For those really into the technical details, modulated backscatter transponders detect the radio frequency energy from the reader and modulate it (impose the identification code) in the signal. The resulting modulated signal is then backscattered (reflected back) to the reader. The reader detects the difference between the transmitted signal and the digitally modulated backscattered signal and reads the difference as the code programmed into the transponder.

After a couple of false starts, manufacturers developed a workable Title 21 transponder. A few tweaks and adjustments to the reader system to minimize errors, and high-speed electronic toll collection was a reality in California. There were a few hiccups at first, including the metallized windshields used in some cars, which blocked the radio frequency energy, or the obscuring cab configurations of some large trucks, preventing the transponders from working. The transponder manufacturers developed externally mounted transponders to address these issues. Now, a transponder issued by one California toll system can be read reliably on any other toll road or bridge in the state with the toll correctly charged to the proper customer account.

It was now possible to travel many miles and pass through multiple open-road toll-payment points without stopping or even slowing down. Life was good! New sections of road were opened, new customers flocked to sign up, and everything was wonderful. The reliability of the electronic toll system approached 100 percent.



Problems with Battery Life

Before long, many hundreds of thousands of transponders were issued to customers. Then, after five years of near perfect operation, the honeymoon was over. System reliability began to degrade. Large numbers of transponders were no longer being properly read, and the apparent toll-violation rate was steadily increasing. What had been a manageable number of toll photo-enforcement images doubled and then doubled again, for no apparent reason. What was going on?

What was going on was that the transponder batteries were simply wearing out. It turns out that the average transponder battery life is about five years. The five-year-old batteries failed, and the transponders stopped working. After a short time, it became obvious that about 20 percent of the transponder population would fail each year. We hadn't planned for this problem, but we had no choice: we had to deal with it immediately, or electronic tolling would be doomed.

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In the excitement over the success of transponders allowing AVI and high-speed tolling, everyone forgot or underestimated the long-term consequences of battery-powered transponders. Manufacturers started scrambling to satisfy their now less-than-thrilled customers. Solar power was tried as a battery supplement, but besides being fragile, the technology produced too little increase in battery life to justify the increase in cost. The question was obvious—what to do?

Transponder Recall Programs

The operational cost of dealing with aging and failing transponders is enormous. Further, the failures are not fully predictable or easy to identify or rectify. Nevertheless, to maintain ETC system integrity and good customer service, toll agencies have to initiate pro-

grams to recall large numbers of failed or failing transponders. Doing so is far from convenient, as the problematic transponders are scattered all over your customer account base. A failing transponder must be identified (in open-road tolling systems, it's very likely the transponder holder is unaware the transponder has failed), the customer contacted, a replacement unit sent out, the failed unit returned, and all database account records accurately updated to reflect the change in transponder assignments.

The cost of the transponder recall process is much greater than the cost of issuing new transponders to account holders: it entails about twice as much work and cost to replace a failed transponder as to issue a new one. The associated labor and distribution costs add to the cost of the replacement units. The only thing worse for your bottom line than replacing a failed transponder is not replacing a failed transponder. And not replacing a failed transponder can result in bad customer service. If bad units are not replaced, customers with imperfect transponders risk getting toll-violation notices, causing customer dissatisfaction and a greater customer-service workload for you.

Imagine having to spend 20 percent of your annual transponder budget with no benefit other than to maintain original system accuracy, recalling the transponders that fail each year. Until you replace these failed transponders, tolls that were formerly collected by automated means appear to the system as toll violations and the missed tolls can be collected only via the photo-based violation-enforcement system. You have no choice. Failed transponders must be identified and replaced. If they are not, toll revenues will be lost.



Battery-Free Transponders

Clearly, battery-powered transponders are a mixed blessing to the electronic tolling industry. Toll authorities reap the benefits of cost-efficient toll collection because each high-speed open-road toll lane can replace seven or eight manual cash toll lanes. Open-road electronic tolling is fast, efficient, and convenient. It is currently

absolutely the best way to collect tolls, and it provides the toll-road customer with the fastest and easiest means of using the toll facility. But the truth is that battery-powered transponders are not a long-term solution, and in calculating their life-cycle costs, the actual costs of electronic toll collection are generally understated by a significant amount. The question then becomes: What next-generation device will support even more-advanced ETC at a lower collection cost? One answer that seems to have merit is battery-free transponders.

For some time now, two U.S. manufacturers of California Title 21 transponders, SIRIT Inc. and TransCore, have been extolling the virtues of battery-free transponder technology. While no significant demonstration of this technology

has yet occurred in an existing ETC facility, the concept has been known for a while. At this point in the development of battery-free transponders, it is clear that the standards for these devices will need to be modified if the transponders are ever to get off the drawing board.

Who cares that battery-free transponders can't be read by any current ETC toll lane equipment? So what that the current prototype battery-free transponders lack a beeper or an acknowledgment light that is required at some toll authorities? Why worry that the design for battery-free transponders doesn't meet the current transponder

regulations in California? And so what that there's no national R&D program to fund this product development? Let the free-market-economy process work its magic. In time, the market will demand a better product and current or future transponder manufacturers will succeed by meeting that need.

What are we to do while the evolution of superior transponder designs takes place? Must we put up with 20-percent annual transponder failure rates? Must we incur added expenses for recalling aging and failed transponders? Are we the unwitting dupes of the inscrutable transponder manufacturers in a bad case of planned obsolescence? This industry needs a superhero, or at least a super solution, to help it out.

Competition, Please!

For the past two years, SIRIT and TransCore have begun to experiment with battery-free units. Now, both manufacturers have battery-free transponders deployed in very limited field evaluation tests at the Transportation Corridor Agencies. The good news is the transponders being evaluated operate in the same 915 MHz frequency band as the Title 21 transponders. The bad news is that neither of the two designs is compatible with the California Title 21 specification nor with each other. Given that, are these devices "ready for prime time"?

A purely passive transponder (no battery) needs to draw enough power from the overhead antenna to operate the electronics in the transponder and then backscatter or bounce the modulated signal back to the antenna. The Title 21 specification, however, limits the power that can be transmitted from the antenna. The technology for detecting the backscattered signal combined with the power limit imposed by Title 21 dictated use of a powered transponder to increase the backscattered power to a level sufficient to be read reliably.

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As alluded to earlier, Title 21 standards went too far in nailing down a limited technology and are too restrictive in our free-market economy. We need a more-open standard for these devices. The current state of transponder technology has lived past its prime and is endangering both itself and the entire ETC industry. We are operating in a Pentium IV environment with a 286 computer.

Both SIRIT and TransCore have recognized the need to get around the Title 21 design requirements to achieve interoperable compatibility and have constructed “dual-mode” transponder readers. In concept, these transponder readers rapidly alternate between the current Title 21 mode and a mode that supports their own particular battery-free transponders. In this fashion, the dual-mode transponder readers can read Title 21 transponders and their own battery-free transponders virtually simultaneously, but not the battery-free transponder produced by the competition. The problem is the data format of the battery-free transponder is not Title 21-compliant.

To address this issue, the manufacturers are proposing to convert the data to Title 21 format in the reader so that the toll back-room system can’t tell the difference between Title 21 and battery-free transponders. This data-decoding process would allow Title 21 transponders and battery-free transponders to be on the toll road at the same time and would make them essentially interchangeable. Granted, for this to work, you would need to have one or more of the proprietary readers matched to the battery-free transponder design in use locally.

The dual-mode reader approach is a good one in that it doesn’t require the immediate and total replacement of all the transponders in the state. On the down side, these battery-free transponders will require that all of the readers in the state be replaced with the same type of dual-mode readers in order to retain interoperability.

Neither SIRIT nor TransCore is designing its battery-free transponder to support the competition’s battery-free device. What a surprise. This could be a last-man-standing duel. Who will be left at the end of the day? This lack of an open architecture for a new-generation transponder is not good for the California tolling community. One supplier will succeed, but one will likely fail. What do you suppose will happen to transponder pricing in the event the competition is eliminated? From an operations and public-policy standpoint, this does not portend a positive future. The facts appear to be that the two varieties of battery-free transponders being developed don’t comply with California Title 21 specifications or, undoubtedly, with any other existing transponder standard. Further, there is no standard or specification for battery-free transponders. This issue is a concern, but is one we believe can be managed.

At this point, the situation is similar to the VHS-versus-Beta format battle in the early days of video recorders. Either we let the market decide which is best, possibly leaving us with only one transponder supplier, or we establish new standards. In either case, and assuming a positive outcome, the end beneficiary will be the entire tolling industry and the traveling public.

Pending Federal Standards for DSRC

In the meantime, what is going on with the development of federal standards for DSRC (dedicated short-range communications)? The concept is that the federal government will establish communications standards for future intelligent transportation systems capabilities that will also support, among many other features, electronic tolling. Those involved in this process have estimated that the establishment of such standards and the equipment to support them are probably still about 10 years away. Given that the average life of a vehicle in this country is 7 to 10 years, it seems the DSRC is about 17 to 20 years away, at best, for an effective deployment.

As toll operators, we simply cannot wait that long to replace our battery-powered transponders. Even if we do, the infrastructure implications of shifting to a totally new tolling system are daunting. Will the Feds be prepared to fund that transition as part of mandating this future technology? It is probably safe to assume that such a funding source is unlikely in the transportation budget for years to come.

Today, we have the East Coast transponder standards and the West Coast transponder standards. If an incrementally better transponder design evolves, those standards will need to change to allow the design to succeed. Ultimately, we believe the future of transponder design will become an economic question, not a local question, about which standard is better. Will any responsible toll agency sit back and ignore an emerging technology that can help reduce the operating costs associated with purchasing and replacing transponders in a significant and rapid manner? At the same time, the U.S. electronic tolling industry must demand open designs that allow for and, in fact, promote competi-

tion. Change is inevitable for future ETC projects that use transponders. The faster we move to the next-generation system, the better off we'll be.

Where Do We Go from Here?

Recently, all California toll operators began meeting to discuss issues of common interest, including battery-free transponders. Perhaps this group will band together to seek legislative modifications that will benefit toll authorities and the motoring public with lower-cost nonbattery transponders. We'd like to suggest that IBTTA members seriously discuss challenging not only existing suppliers but also potential new vendors to develop an acceptable and comparable new technology. In so doing, we need to consider partnering with the industry, including funding a portion of R&D costs, to help the next generation become a reality.

Wally Kreutzen is chief executive officer and Mike Leahy chief toll operations officer of Irvine, Calif. Wally can be reached at kreutzen@sjhtca.com. Mike can be reached at leahy@sjhtca.com.

