# *Infrared Based Roadbed Monitoring*

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System Innovations is a high technology company, which is a leader in developing electronic counter measures. They [make] remote sensors and surveillance codes [?]. The company has a strong science and engineering staff and has the electronic RS computer laboratories needed to develop the advancements.

Hopefully this won't be too boring and maybe a little bit of fun. We are a [great] company. We do a lot of technology development and so today I promise not to sell you anything but just talk about technology.

We do a lot of technology development work. We have a subsidiary with System Innovations and we are hear telling you all kinds of things but today I'm going to just talk about some technology. The key thing is, interrupt me if you have any questions. I'll give you some time at the end but if I'm saying something that's not clear, feel free to ask.

I'm going to talk about doing Roadbed monitoring to find out what's going on with the Roadbed and doing it in a way that is a lot less painful for the customer and for the user. What I'm going to be talking about, principally, is some infrared technology that we are developing to be able to accomplish this.

What we are going to put into the marketplace at some point down in the future but don't have it right now, is the ability to tell you, "Hey, is there water on the road? Is there any de-icing, anti-icing material on the road? What are the temperatures on the road? Do we have ice on the road?" We are using a variety of optical techniques to be able to do that and we've done a lot of work in this area that I'll give you some insight into.

Obviously, what we want to be able to do is alert the public. If you have an icy stretch of road, particularly, say an icy bridge, we want to be able to trigger warning signs that say, "Bridge, caution, the bridge ahead is icy." For those systems that are just starting to become a reality, particularly bridge systems with de-icing and anti-icing material on them in which the systems now spray materials, we want to be able to do an accurate trigger for those and you obviously don't want to turn those on if you don't have problems. This is because de-icing material, first of all, is not inexpensive but also on an application like a bridge, the icing puts just kind of a limiting quantity [?].

When you have already been out and you have done de-icing/anti-icing applications, you have to ask if you have enough material out there for the conditions. We need to continually assess that. The materials are expensive, you don't want to over use them and you don't want to put down more than you absolutely have to. This can have a significant impact on a budget.

So why do we want to do this with a non-contact? Non-contact means we are going to put a sensor up over the road. It is not going to be in the road. It is going to look down on the road for the obvious reason that if you have sensors on the road, and we have, with our system right now, you have problems; you have to put them in the road. If you are going to resurface the road, you have to pull all that out, and then put it back in. There are cases where snowplow activity alone will cause damage to the sensory, or catch the sensors and damage them.

Right now if you have a sensor in the road, you are looking at the conditions right where that sensor is, you are really not seeing the whole road. You are seeing what conditions are at the sensor [location]. As we all know, you can have a situation where you may have a dual lane highway and one lane, the most used lane, is relatively clear.  You may have a situation where the other lane, commonly the high-speed lane is not clear. And if you happen to have your sensor in the clear area, you're going to report that, "Hey, things are swell.  Life's fine."  If you happen to have it in the high-speed lane, you might think, of course, things are not swell when, in fact, at least one lane is.

We are obviously going to take advantage of new technology but another advantage of the techniques that I'm going to talk about is that they can be mobile. You can put this technology on a snowplow and determine what the road conditions were.

We are going to start out with a full-mounted, looking-down-the-road application.  In the long term, we are going to put some systems on vehicles and we will be able to tell you pretty much what the road's conditions are.  We will put out an equivalent friction and we're going to be able to tell you what the road friction is in the vehicle.  It has some applications beyond just winter driving.  It has some applications in the automobile control systems, knowing what friction is.  Solid vehicles today, as you know, have a really outstanding vehicle control computer systems in which they look at the various accelerations on the vehicle, know and actually brake the appropriate wheel and slow the vehicle down on time so you don't lose control.  An interesting ingredient that would help those systems would be road friction – what kind of friction conditions you have.

We started [studying] this back in 1999.  I'm a physicist, so if you talk chemistry to me, I am only semi-knowledgeable.  We hired a company called Sensar that is very strong in chemistry and they have been doing a lot of the chemistry applications for us.  I'm going to talk about a couple of instruments here, a scanorometer and a spectrometer and what we are doing [with them].

We have been taking some measurements with spectrometer and I'll show you the basic principles for that.  The spectrometer's purpose is to determine whether we have a wet or a dry road.  We have an infrared transmitter and an infrared detector on a dry surface and I'm going to equate this to something that we can all relate to.  On a dry surface you get a lot of backscatter.  What we can all relate to is we're driving around and our headlights really work well, reasonably well, and we're happy with them. As soon as you get any rain at all everything goes black.  Typically when you have water on the road - and you're driving, you can see very little from your headlights.  The reason is, your lights are forward scattered, not back scattered.  So, all of the energy in your headlights is being forward scattered and you are not able to see the road any more to the degree that you might have.  We have done numerous experiments where we can give very large detectability even just for wet tape but there's no water.

This is high arc.  This is just moist and the only thing you could tell was there was a color change in phases.  This is particularly kind of crazy.

You can detect extremely small amounts [of water].  We actually can detect in millimeters the depth of the water with the instruments that we are using.  That is very useful because, right off the bat, we know whether we've got moisture on the surface and, what we are really reading is the degree of the friction of the surface.

Here are some experimental values; meaning that there are significant decreases in the backscatter when we introduce any amount of water, even very small amounts of water to the surface.  We have a lot more data than that but that's just sort of our user picture.

I'm now going to talk about using a spectrograph spectrometer to get further information about the road.  On a very basic level, if I have a broadband energy source and what we're using is the mid IR range.

What I just showed you before was the scanorometer. Here IR, depending upon your definition, is somewhere around one micron and out to – some people cut it different ways of two me's, 2.5 microns. Our IR spectrum is basically about two to eight microns. This is weighed on itself. Here IR is just next to the visible range. The mid IR is a range in which the wavelengths do get longer but what we're able to do is if you have [something], in the mid IR, a broadband source, and you put it through material, depending upon what the material is, it will absorb. This would be all of the energy coming through as you put something out here, depending, very definitely on what the material is, it will absorb energy and where it absorbs the energy I'll tell you what types of material it is. So this is very simplistic but you can determine what is out there, specifically in determining headwater. You can actually determine whether water is going in as liquid form or if it's in ice form because it shifts the wavelength. It will absorb at a different wavelength. I will get into a little bit of that.

There are other materials that will show up-sodium chloride, and typical salts that are used for de-icing. They will absorb and they absorb at different wavelengths. What happens when you put a very broadband infrared energy source and then you put a layer of water, the water will absorb a typical amount of energy in the spectrum here. In just sort of a very operable sense, is the hydrogen and the oxygen molecules that are all bound by internal forces. They are actually flexible. That is what makes the water very interesting is that when these hydrogen and oxygens bond, they actually flex. That is why we find water as a gas, we find it as a liquid, and we find it as a solid. The amount of oscillations in the bonds determines what state it's in. Interestingly enough, you can tell when water goes from, let's say, in this case, water to ice because the flexing of these molecules actually achieve [?]. Therefore, they resonate at a different frequency. The molecule itself resonates at a different frequency and that tells you what is happening. You can see in the spectrum for water and that turns into ice and shifts the frequency and the spectrum remains looking very much like there is a shift in frequencies. This is really nice, because now we know we have ice and no longer have to guess about it.

Another interesting point is that, when I introduce a de-icing material, I think of salt or something, I throw it on the road and I introduce that now and [?]. One of the things I do is I affect these bonds. The water itself now starts resonating at different frequencies depending upon what is there. So if I have salt, sodium chloride, these actually resonated in a new frequency. I can tell, by looking at the mid IR, what chemicals are present. I can also tell how much there is in terms of concentration.

What happens with the systems that are out right now, the systems that we classically use and are used by others, uses sensors that they will tell you that you have ice as opposed to water. Right now they are relying upon capacitants and they are working against ionic compounds. What that means is these are false [?] but they conduct electricity. Many of them do, particularly anti-icing materials that prevent the ice from ever forming are various forms of acetates. These are not ionic materials, they are not conducting materials. So, the current sensors actually do not work against these, and yet these are becoming more prevalent.

If you take something like propylene glycol; airports, when they spray down airplanes, they are spraying it down with propylene glycol. You do need to detect this so the same thing applies on airports and one of the principle reasons is that, as you have seen on some of the video, there is a lot of it on an airplane. There is a lot of runoff. And so the principle interest there is how much of that material is there and where is it going and how does it run off?

Just to show you some answers to this, it will be a little bit difficult for you to see here. But, in black, is water. This is just this region highlighted. The sort of purple color is a sodium chloride solution in this case. What actually happens is there is a shift here in frequency and it doesn't look very perceptible there but it's very identifiable in the shift in terms of process.

Similarly here is a potassium acid base and, in this case, the water is actually purple, it was black in the other case, but it is along the same principle. The black is actually the potassium acetate. You can see there is a perceptible shift in what we see in the infrared spectrometer. We can detect that this is potassium acetate because, as you know, this did not look like the other example and, therefore, we know what the material is as well as what concentrations are there. This is a glycol as a [?].

What we are doing with all of this, and I know I'm throwing a lot of technical terms at you, but what we are doing with all this is putting together a system. It is not really difficult through the IR system to be able to have the ability to tell you what is going on in the road and what the conditions are. [You can also determine] what kind of concentration of material you have to be able to give that the right amount of de-icing.

[This is not very difficult]. What part is [difficult] is the cost and the basic counseling and basic physics behind it. As I have tried to share here, it is fairly straightforward. What we have done is we have prototyped some things. We are working with some of the things on a cooperative basis, to do some testing. We hope at some point that we will have this out on the market as a viable system and want to keep readings [simple] for us to keep the price down. To do that, we are probably going to greatly simplify the spectrometer - the scaleometer is really not much of a problem – but we've got to do some simplifying on the spectrometer. [This will take some] work.

What I have described to you is a bunch of work that we have been doing for the Department of Transportation. We hope that, basically, we can get a lot better information about the roadbed and not have something in the roadbed and the net result will be hopefully a much wider application to road monitoring so that you have a much wider application. If you want variable message signs and with specific roadbed data so that you know what the conditions ahead are on the road so you can have very factual information during a time when …

Attendee Question: Inaudible

We can swap out chemicals. You can detect hazardous materials. No, that has not been a problem. I would tell you that most of this work that I'm talking about right now came out of a chemical warfare and biological warfare. And there's quite a bit of history on toxic materials and their absorption, and you have wavelengths. We have concentrated on what I thought were more responsible [uses], but, technically, I haven't thought about it….

Attendee Question: Inaudible

… Right. Well, two comments back. One is, for the voter public, at least you can get us up on variable message signs. I think the good news is, we now are getting a larger population, particularly rural areas have variable metric signs so a really nice thing now is, we get the information to the public as we better understand it. The other one I'm interested in, is that you can mount this on a vehicle and, therefore, you can determine what the roadside condition is and you can determine that before you get to it. You can look ahead and you can take it into account what the conditions are ahead. We think that that will directly feed right back to the consumer.

Attendee Question: Inaudible

For time purposes I will not go into the temperature setting but it's part of this, yes. One of the values of what we are doing is actually mapping temperature over a large region so we can cover all the length of the road, not just one spot. Yes, we can map the change in temperature and the variability across the roadway…