New Generation of non-invasive Sensors for Road Surface Condition

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Abstract

Reliable, easy to operate and cost effective monitoring stations on the roadside are the most important data source for road and weather condition information. In hazardous Weather situations this data sources enable information systems to gain reliable information and warnings for maintenance operators and car drivers.
A new sensor generation was developed by LUFFT GmbH, Fellbach, which belong to the smart and modular UMB Technology, introduced at the lakeside conference in 2008. Besides in-pavement surface condition sensors, which are the standard used for many years, the development of a new generation of so called "non-invasive" Sensor is in its end phase.

This "non-invasive" Sensors are able to identify the type of road condition, to detect the ice, snow and water layer thickness as well as the friction coefficient. Also the road temperature is reported. Non-invasive Sensors can be installed easily besides road without road groundwork.

The paper describes the principles of the spectral analysis method and gives first results of a numerous field applications.

Introduction

Road Weather information systems became more and more indispensable and important for supporting winter maintenance decisions. Winter maintenance decision support makes the highest demands on quality and range of measurements, information and forecasts (see also [5]). This highly sophisticated data should also be used for traveller and traffic information. Road weather information systems are part of the road infrastructure and helps improving the safety on roads for winter maintenance decision support as well as enhancing the information for the car drivers.

Modular remote stations with Universal bus Technology

Road Weather and environmental remote stations should be well arranged and arbitrarily extendable. Up to date remote stations should also be designed for low power consumption – which allows – under certain conditions - solar or/and fuel cell power supply assembly. Each top hat rail plugged Module should be able to control one Sensor or a complex sensor device. A mobile Phone network communication can be established by adding a GPRS Module. National or international line communication protocols, such as TLS or NTCIP can be supported by adding an embedded PC Module (resp. a small top hat rail mounted IPC). More about UMB Technology can be obtained from [1]

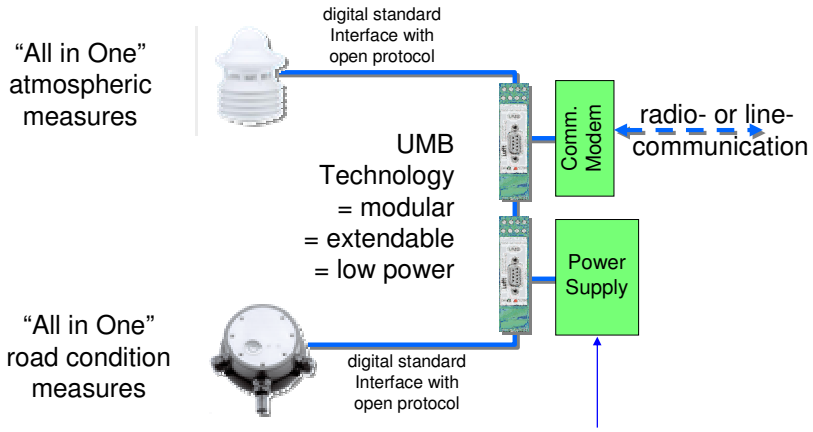

Fig. 1 A complete road weather station built up with a few elements.

There was been developed intelligent devices, both for road pavement condition detection and for atmospheric road side weather situation. Complete road weather remote station can now be composed of two sensor devices only – the minimum amount possible.

INTELLIGENT SENSOR DEVICES

Reliable and precise data directly from the road pavement are an essential requirement for maintenance decision support. In order to make it affordable increasing the density the acquisition network on the road, easy to install, compact, intelligent and maintenance friendly devices are necessary.

Combined sensor device for road pavement condition

An intelligent sensor device to be installed into the pavement has proven its reliability in hundreds of installations. One of the mechanical advantage is the possibility of easily removing the electronic transducer inlet in order to exchange it into a calibrated new device. Repair or recalibration can be done in a laboratory environment. Therefore the live time cost of an installation can be significantly reduced.

The road surface detector [2] comprises “all in one” the following measures:

- Road surface Temperature
- Up to 2 Subsurface Temperature probes (e.g. for a depth of 30 cm)
- Water film depth measurement by means of a microwave radar transducer
- Freeze Point Temperature from the chemical concentration of the solution by their conductivity measured with gold electrodes and under consideration of the water film thickness and the temperature
- road surface condition (dry, ice, wet, slush) measured by the dielectric characteristics of the cover.

Microwave radar transducer for water film depth

Accurate measurement of water film height is achieved by a microwave radar transducer built in the pavement sensor device. The characteristic and calibration curve of the radar transducer shows fig. 2. The water film height is reported with a resolution of 0.01 mm. The maximum range is typically 3.00 mm. Due to the used method the measurement of the waterfilm is not be influenced from the concentration of deicing chemicals.

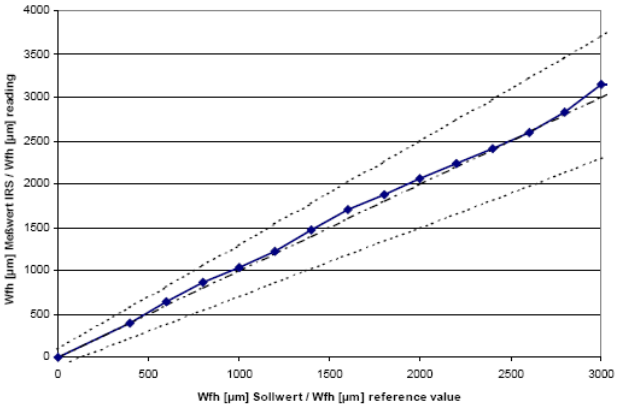

Fig. 2 Measurement characteristic of the microwave radar transducer in the passive road sensor

Active measurement method for freeze temperature detection

The new developed Sensor device [3] measures the freeze point temperature by means of cooling and heating up a small sensitive area on top of the sensor surface. This active measurement method enables the sensor to measure the actual freeze temperature of the liquid solution on the pavement surface. This sensor can also be installed in combination with the passive sensor, described above, to enable a comprehensive knowledge about the condition on the surface. Other than the passive measurement of freeze temperature via conductivity, the active method is totally independent of the used de-icing chemical.

Fig. 3 The new developed intelligent active freeze temperature road sensor

Non-Invasive Road surface condition detection

In comparison with built in road surface sensor, a non invasive measurement provides accurate surface condition parameters with less installation and maintenance costs. The Table 1 shows a comparison with state of the art in pavement sensors and their suitability for certain applications. In this context IR resp. IR-sensitive cameras should be also considered.

Applications:	IR Camera	in-pavement all-in-one sensor including passive Freeze Temperature Measurement	in-pavement sensor active Freeze Temperture measurement	in-pavement combination: passive and active sensor	Non-invasive IR spectrum sensor
Winter maintenance on roads	***	****	***	****	***
winter maintenance on roads with forcast and early warning	***	****	***	****	**
Winter maintenance on Airports	**	***	***	****	--
Winter maintenance on Airports with forcast and early warning	**	***	***	****	--
Automated Traffic control systems	**	****	**	***	****
Traffic information purposes	***	***	**	**	****
explanation:	****	best suitable			
	***	good applicable			
	**	applicable			
	--	not suitable			

Table 1 comparison of in-pavement and non-invasive sensor solutions and their suitability for different applications.

For non invasive measurements an optical spectrometer method is used. Water, snow and ice have different spectrum adsorption characteristics. The development and field testing of a new and innovative Sensor is currently in progress. The sensor uses three different wavelength, which can be extended up to 8 spectrum lines.

There are two principle ways to detect the adsorption at different wavelength.

1. emission of small band resp. coherent light at different wavelength and receive the scattered light by a broadband detector (see also [7]).
2. emission of broadband light with suitable spectrum and receive the scattered light by a small band detector or resp. application of different filters (see also [6]).

In the current development – alternatively to other products on the market, the second method is used. From this solution a better long time reliability can be expected. Since coherent light emitting diodes are known for their aging process.

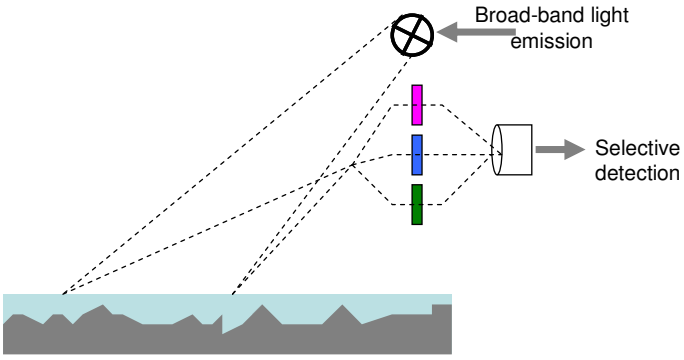

Fig. 4 principle of the spectrum adsorption detection of the non-invasive sensor.

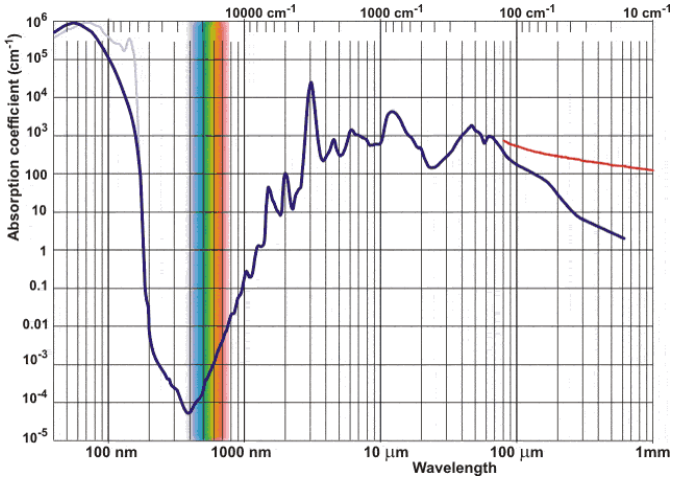

Fig. 5 – adsorption spectrum of waterfilm

As an example fig. 5 shows the adsorption spectrum of a waterfilm layer on the road pavement. By means of the analysis of the reflected light emission in different spectrum lines the sensor provides layer depth up to 3 mm from waterfilm, snow and ice. Also the tire friction is reported, due to the measured surface condition. The area where the layer thickness is measured depends on the distance the sensor is mounted from the pavement surface. But typically is much larger than the measurement area of in pavement sensors. This leads to more reliable measures in terms of the actual pavement condition parameter. The non-invasive measurement can not detect the freeze temperature of the deicing

chemical solution. For winter maintenance purposes, the non invasive sensor had to be combined with an in-pavement sensor with active freeze point detection.

Fig. 6 – prototype of LUFFT non-invasive surface sensor NIRS

The result of the actual status of the development shows fig. 6. The Prototype NIRS-UMB is currently under field testing. The Sensor also includes measurement of road surface temperature by means of an Infrared measurement method.

The field test currently running include also comparison of the increase and decrease of layers on surface due to precipitation and evaporation with the measurement of accurate Pluviometers.

Conclusions

The immense progress in road environmental sensor devices and in forecasting of weather situations is not only useful for maintenance but also for information to vehicle drivers.

The now available new technologies made it affordable to gain the density of the detection networks on the roads.

The tire friction due to the surface condition which can be reported from this device can be an essential input directly for traffic flow models using tire friction as key parameter for safe velocity estimation.

Future research will have their focus on automatically consideration of weather and road surface condition in traffic situation forecast in order to control the traffic and also for logistic application in the transportation industry.

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