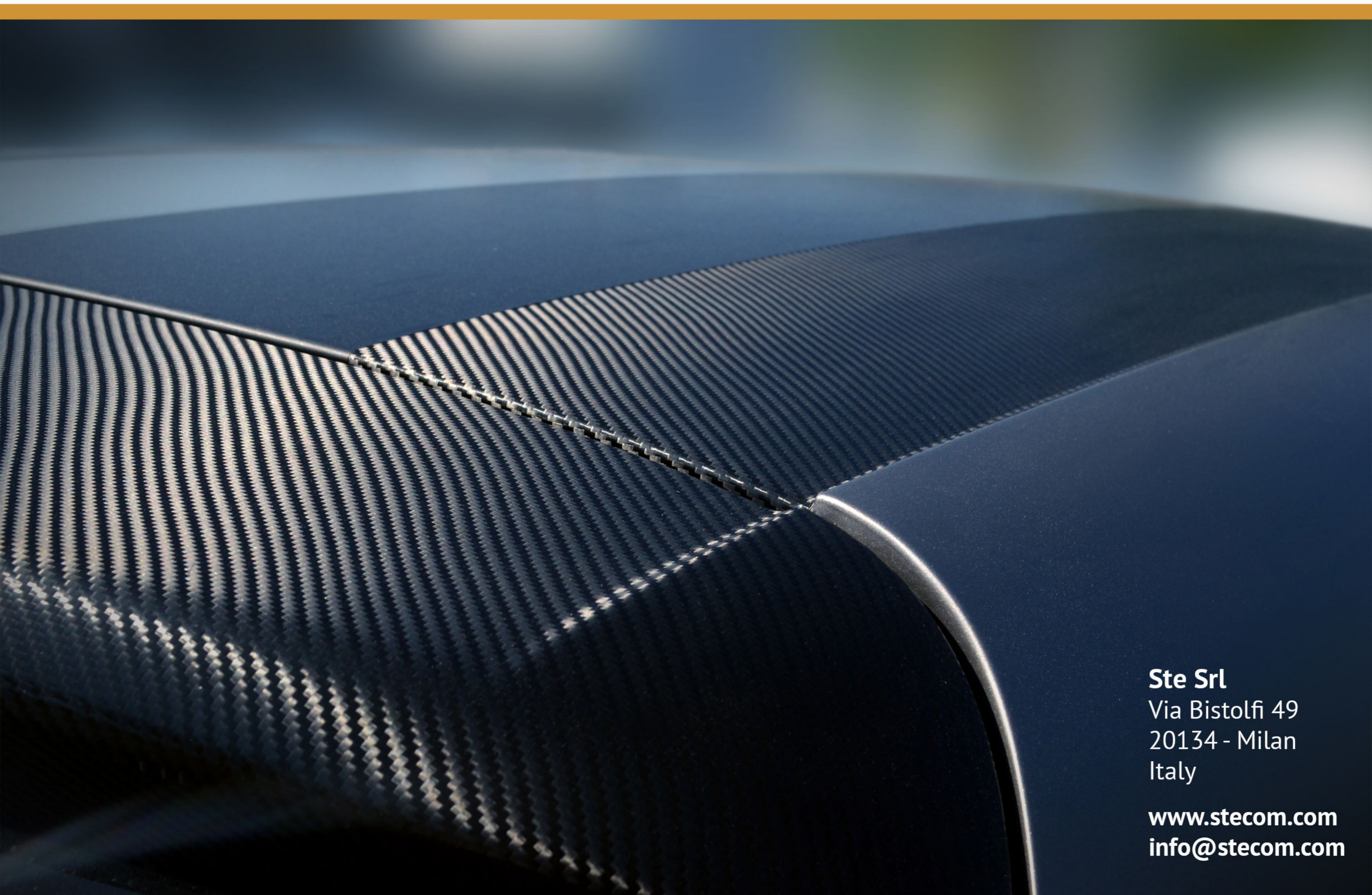
casehistory



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TIRE PRESSURE MONITORING SYSTEM

"CONNECTING INNOVATION FOR INTELLIGENT WIRELESS"

Ste TireTech
Department
2014

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2014

Energy efficency and mechanical robustness will be the foundation of future intelligent tyre system development

Intelligent tyre systems (ITS) are based upon the accurate estimation of important dynamic variables. Measuring these parameters directly from tyres offers the potential to greatly improve tyre performance as well as tyre conditions in terms of maintenance. This will ultimately have a big impact on safety and fuel efficiency, both of which are issues in need of some worldwide harmonisation. The design of a reliable ITS is highly challenging due to the very limited available energy and tight specification requirements in terms of data rate, size, weight, robustness and reliability. Developing a platform that conforms to a process for integrating electronics into a tyre carcass requires expertise in multiple disciplines. RF energy efficiency and management are key areas of research. Placing a sensor system to compute the forces in a tyre and transmit this information to drivers is even more challenging than in the past due to the increased specification requirements and the more stringent economical targets.

ITS requirements

The most important requirements for intelligent tyre components are a lifetime that should be at least equal to that of the tyre, together with an extremely miniaturised tyre unit form factor to guarantee the highest grade of robustness in extreme conditions.

The ability to meet the widest temperature range from -40° up to higher than 100°C is also vital.

Among all of the technologies that permeate ITS, the most challenging is the system's energy efficiency and the migration from batterypowered applications to 'battery-free autonomous and ubiquitous energyefficient' wireless sensors. That these sensors would potentially be attached to the carcass or integrated into the carcass is now mandatory. Mechanical stress and the temperature of usage strongly limits the use of battery cells in ITS. The standard automotive-grade 20-24mm diameter lithium ion cells usually used in TPMS today not only determine the real form factor of the tyre unit but limit technological progress in terms of integration. This effectively imposes the migration to powering through alternative sources: energy scavengers or micro electromechanical systems (MEMS) that convert mechanical forces into electrical energy via inductive or capacitive coupling, for instance.Battery-free autonomous and ubiquitous energy-efficient wireless sensors have to be designed in a way that makes them extremely efficient in energy consumption and through specific protocols of the communication and hardware reduces the energy absorption from the source. As the available power is low or relatively limited, the overall system's energy efficiency becomes relevant, and strategies of communication – between the tyre unit and the associated receiver need to be built well enough to achieve a durable and robust RF link.

On the other hand, it is also true that the quantity of energy that energy harvesters (as in lithium battery cells) can create is proportional to their physical dimensions. The MEMS that are beginning to reach the commercial market tend to be too large in form factor to be used in ITS applications, and are thus unable to supply energy exceeding some tens of µW in real conditions. The relatively high power consumption of a standard wireless sensor architecture – usually based on a PLL (phase lock loop) radio transmitting unit – strongly limits their use in tyres. A few hundred µW are currently insufficient to regularly trigger wireless data transmission from carcass to human machine interface (HMI) during normal usage. The PLL data transmitter components have an inherently high energy consumption that imposes a consequential increase of the mechanical dimensions of the scavenger. This corresponds to a reduced grade of miniaturisation with negative influences on a system's robustness and its ability to survive in harsh environments and, naturally, to higher costs of manufacture.

As of today, to meet ITS targets and specifications requirements, it's necessary to overturn the approach to RF and data transmission and move to more advanced applications. The recent diffusion of new semiconductors in favour of 'ready-to-use', 'plug-andplay' transmitting devices applied to short-range communication – despite having positively contributed to the large spread of wireless in the mass market – has also contributed to reduce skills and know-how in the case of RF research. Indeed, there are very few R&D centres of excellence dedicated to research in RF.

"A more efficient PPM scheme seems to be the future step in ITS"

The next generation

››STE Engineering's research and tests show that the success of the ITS depends on the reduction of the average energy consumption. It must be of at least two orders less than existing approaches: this requires a system's energy consumption to move from a scale that ranges in terms of milliampere down to scale that is measured in nanoAmpere. And a more efficient PPM scheme seems to be the future step in ITS. The next decade of technological progress in the field of integration of electronics into tyres will witness a generational change in the way to approach system level design, with a natural replacement of traditional OOK, ASK or FSK modulation scheme in favour of a more reliable and energy efficient PPM modulation. This will guarantee efficiency not only in energy consumption and form factor integration, but also in facilitating the migration from standard battery cells to more efficient, reliable and compact energy harvesters.

Flair for design

STE Engineering, an R&D and manufacturing company based in northern Italy and devoted to RF, has been cooperating with one of the world's largest tyre manufacturers. An innovative method of data transmission and radio-wave propagation in-carcass was recently demonstrated, which will lead to more energy-efficient and smaller form factor ITS devices. The approach relates to the adoption of a new type of PPM (pulse position modulation) scheme that has shown great promise in terms of trespassing the tyre structure without being negatively affected by the carbon and metal wires that make the tyre structure a kind of Faraday cage.
When moving the sensor from standard packaging attached to tyre stems to sensors attached to the inner liner or sidewalls of tyres, the mechanical form factor becomes a key feature. Also, the use of alternative generators – such as piezoelectric, electrostatic or an electromagnetic energy harvester – is only possible when a system's overall mean energy consumption is extremely low. A more intricate energy strategy would impose larger dimensions on certain critical components, such as energy management and super-capacitors. Generally, the higher the energy consumption the more complex the hardware becomes. And the ability to save the energy produced by the energy harvester is critical not only for the system's operation but also for when it's not able to scavenge and consequently store energy in capacitors. Enough energy must be stored to operate the ITS when the vehicle is stationary.

Modulation techniques

In most (if not all) of today's TPMS, the commonly adopted modulation techniques involve amplitude-shift keying (ASK), frequency-shift keying (FSK) or phase-shift keying (PSK).
According to recent experiments conducted by STE Engineering, in the case of radiowave propagation in a tyre's carcass, its new type of PPM modulation – in combination with a few µs (microseconds) width-energy pulses – has shown an extremely lower current consumption together with higher robustness and redundancy compared to standard systems.
PPM information is conveyed via the position of pulse in the time domain with respect to a specific location so that this modulation has been revealed to be more robust to channel noise than most other traditional methods of modulation used. Also, the energy consumption achieved by STE – proven to be lower than 500 nanoamperes of mean current absorbed from the energy source – was revealed to be in the range of energy-harvesting technology design recommendations, with positive influence on the system's form factor and also in line with tyre fabrication specification requirements.
The obtained transmission peak power of around 100mW was the best compromise between energy consumption and output power, which is the trade-off for an optimal RF link margin budget, in doing so allowing the use of the smallest power sources and guaranteeing full functionalities.
The research has enabled STE Engineering to create a simple hardware component mounted on top of a flex substrate, including an innovative data-transmission unit with an oscillator circuit based on a SAW (surface acoustic wave) resonator. This is capable of generating very short pulses of energy and is operated through a standard MSP430 microcontroller device. Electrically connected to an energy management unit and a small capacitor, it stores the energy produced by the smallest energy source. Such an approach brings relevant benefits in terms of hardware simplification, tyre integration and systems autonomy. It is compatible with ITS requirements, functions even at the lowest temperatures (below -40°) and guarantees operations even when energy is below budget.

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