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APPLICATION NOTE
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RF Pulse Transmission Technology

Introduction to the "microSP" Transmitter

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Abstract

Data transmission on ISM (Industrial Scientific Medical) or SRD (Short Range Devices) bands using RF pulse modulation and in particular the "Pulse Position Modulation" (PPM) has many advantages compared to more traditional modulations (OOK-ASK-FSK) : the main advantage is the reduced average consumption given by the low duty-cycle intrinsic of PPM. Therefore the pulse modulation turns out to be a winning choice for the creation of sensors or wireless alarms for the emerging "IoT" sector.
The "microSP" technology allows the creation of one-way transmitters, in particular on the sub-GHz frequencies (where the propagation problems are less critical) with a consumption in Joule/bit (the energy per bit) intrinsically much lower than that of other types of data transmission "Standards" such as Bluetooth or even BLE (Low Energy Bluetooth). Making cheap wireless sensors with an average consumption of a few µA, the possibility of using very small, low-cost batteries and with an operation life-span without maintenance of over twenty years are among the possibilities and the numerous advantages offered by the "microSP" Technology.

The IEEE 802.11 and 802.14 standards (WiFi and Bluetooth) are designed for "Information Technology" ("IT") applications and operate on frequency bands over the GHz. In almost all "IoT" applications, which are normally quite simple and require short data messages, they are not very efficient and have problems with propagation and coexistence with other "IT" applications.

The "microSP" Short Pulse Technology

The "microSP" technology is a special and sophisticated form of pulse-modulated transmission in which the data message is encoded in the spatial time position of the RF pulses. The peak RF power of the pulses is high (10-100 mW), but the "average" pulse frame energy is low and the resulting spectrum is spreaded in a broadband emission with a very low RF "Power Density" . A high peak power guarantees a robust RF signal while the low Tx duty cycle, resulting from the 2µs pulse time compared to the average time between the pulses in the message frame, keeps the Tx current in the order of 1mA : this is the typical current during the message transmission time. In most cases, in a WSN (Wireless Sensor Network) made by one-way transmitters, a message has a length between 6 and 10 ms and can be transmitted every 5 to 120 seconds ("heartbeat" time). This again leads to a system duty cycle of less than 1/1000 and therefore, also taking into account the MCU current, the Tx mean contribution to the total battery current is easily maintained at less than 1µA.

The "microSP" Transmitter .

In short, the "microSP" is therefore a form of RF pulse position modulation (PPM) : so far nothing particularly innovative. The problem is that of being able to generate microseconds pulses employing a simple and inexpensive RF circuit, easily reproducible in mass production, but nevertheless able to guarantee a few tens of nanoseconds precision of the pulse rising and falling edges. And all in a temperature range that can go from -40 °C to +125 °C .
A proprietary very simple RF oscillator circuit (patent WO2009019121A) , a single RF transistor plus a SAW resonator, allows the generation of the time accurate pulses. Another RF power transistor amplifies the pulse to the required peak power. In Fig.1 a typical Gaussian shaped 2µs RF pulse at a "microSP" transmitter output.
The peak power is 25mW (+14dBm) and the Gaussian shape of the pulse is necessary to reduce the side lobes of the emitted spectrum, to comply with the EN and FCC regulations and to maintain the emission bandwidth to the minimum as required by the receiver selectivity.

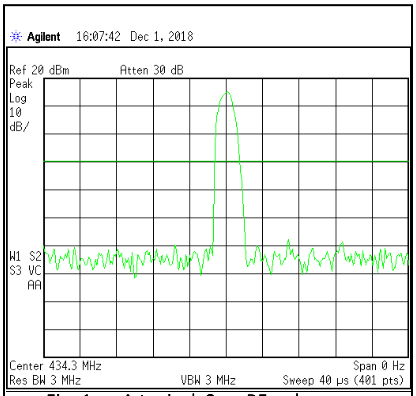


Fig. 1 – A typical 2 µs RF pulse

Fig.2 shows the block diagram of a typical "microSP" transmitter. The task of generating the pulses, of forming the "frame" constituting the message and of controlling the transmission times is assigned to the IC1 microcontroller. The µC activates the oscillator stage via "mod-2" and after a short period generates the "mod-1" pulse that modulates the power amplifier stage. To obtain a Gaussian shaped pulse, it is employed a simple RC filter.

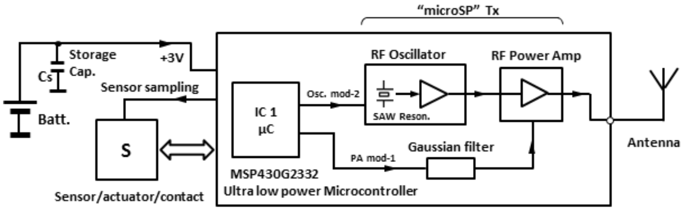


Fig. 2 – The "microSP Transmitter .

The "microSP" transmitter was originally developed to solve the problem of creating a TPMS (Tire Pressure Monitoring System) device that can be housed inside the body of a tire valve. The limit that cannot be overcome is the size of the lithium battery (CR1225 - 48mAh) and above all its inability to supply the current required by a transmission system that uses conventional modulation modes and this especially at temperatures of -40°C as required by the "Automotive" standard.
The PM9712 TPMS valve with an autonomy of more than 7 years is an example of the possibilities offered by the "microSP" technology.

The TPMS Valve PM9712

The "microSP" technology uses a PPM modulation in which pulse pairs are transmitted whose distance varies between about 50 and 90 µs in 16 different time positions. The sixteen different times represent a "nibble" of the data message. The distance between two successive "nibbles" is fixed and equal to about 400 µs and two nibbles obviously make up a Byte (Fig.3).
In most wireless sensor or alarm applications the message will consist of 8 to 16 Bytes with a total transmission time of about 6 to 12 ms. The low average consumption of the transmitter is ensured by the fact that the oscillator stage, thanks to the circuit described above, enters oscillation in nanoseconds and is completely inactive between adjacent impulses that make up the "Frame" and the same for the power amplifier (PA) stage.

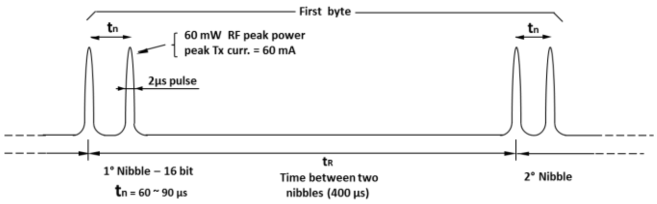


Fig. 3 – The RF pulse "Frame" : four pulses represent one Byte .

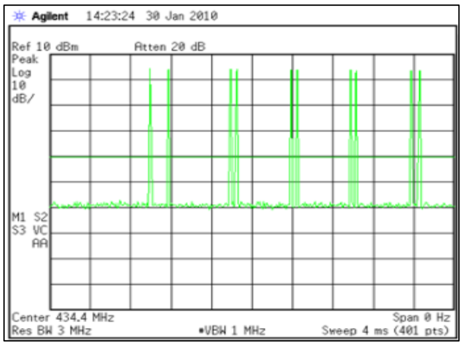


Fig. 4 - The first part of a message frame .

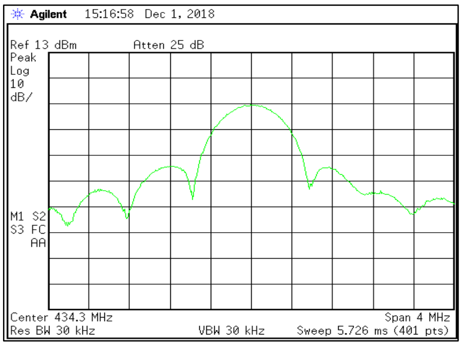


Fig. 5 - The "microSP" Tx Emission Spectrum

An in-depth discussion of the "Ultra Low Power" techniques applied to the "microSP" wireless sensors is reported in detail in the application note AN-907. Here, only a brief and approximate calculation of the current absorbed from the battery during the transmission period.
In a typical application, like the measurement of a single physical quantity, the message can be 64 bits long (sixteen nibbles) and the transmitted frame will therefore be composed of 32 pulses to which other two preamble pulses must be added. The 2µs pulses are therefore 34 and the pulse current required to obtain an RF peak power in the order of +16 dBm (40 mW) is about 80mA. The total time of a message of this type is 6,3ms and among the various nibbles the current of the microcontroller is 230 µA.
The total time of the pulses is therefore 34 x 2 = 68 µs over a total transmission time of 6,3ms. The duty cycle is 68/6300 = 0.0108 and therefore the average current is 80 mA x 0,01 = 800 µA. By adding the 230µA current of the µC, the total current is 1023 µA. This current represents the average consumption of the Tx alone for the 6,3ms of the transmission time. The final average current will obviously also depend on other parts and functions of the device: sensors, contacts, alarms, etc. In any case the contribution of the Tx part is very small. For example, if the device is programmed to transmit the life state (heartbeat) every 10 seconds, the additional duty-cycle to be applied in the calculation is 6,3ms/10s = 0.00063 and therefore the final contribution of the transmission to the total device current is 1023 x 0,00063 = 0,64µA . For a heartbeat time of 30" the Tx contribution to the total current is only 210nA .

At this point one might think, given the very small consumption of the "microSP" transmitter, that it is possible or convenient to transmit every few seconds or even every second. This is absolutely to be avoided, except in the case of very low radiated power (ERP << 1mW) and only when strictly necessary. The International Standards governing the SRD and ISM bands recommend or even prohibit transmission methods that represent a limit for other user of the same "Unlicensed" bands. As an example, FCC admits polling or supervision transmission, but limits the total transmission time to 2 seconds per hour for each transmitter.

It is not just a problem of Normatives, it is also important not to create interference in the networks of others, but also in yours!

And this in particular on "Unlicensed" frequencies and if you plan to install billions of "IoT" sensors ....

"microSP" Technology "IoT" Sensor

"Low Energy Design" of a wireless Sensor

The "microSP" transmitter can be used alone, for Tag or Beacon, or it can be used in wireless sensors or wireless alarms. In fig. 6 the block diagram of a "Reed contact" wireless sensor. This simple application is very suitable for explaining the "Low Energy" design criteria followed in establishing the "reed" sensor sampling time, the sensor status transmission time and the "Heartbeat" time. And then make a first assessment of the total current that will be required by the battery.

In a network of unidirectional wireless sensors, the transmitter must always issue a "Heartbeat" message at regular intervals that includes data and other information on the status of the device (eg the battery voltage). This is what FCC (part 15) calls the message "Polling" or "Supervision". The "Heartbeat" is used by WSN ("Wireless Sensor Network") to monitor the correct operation of all devices, detect malfunctions or reductions in RF signal level, etc.

The "Heartbeat" typically has transmission times of minutes; the sensor sampling (in this case the control of the open/closed status of the reed contact) must instead be performed every few seconds and the µC can be programmed to transmit immediately if a state variation occurs.

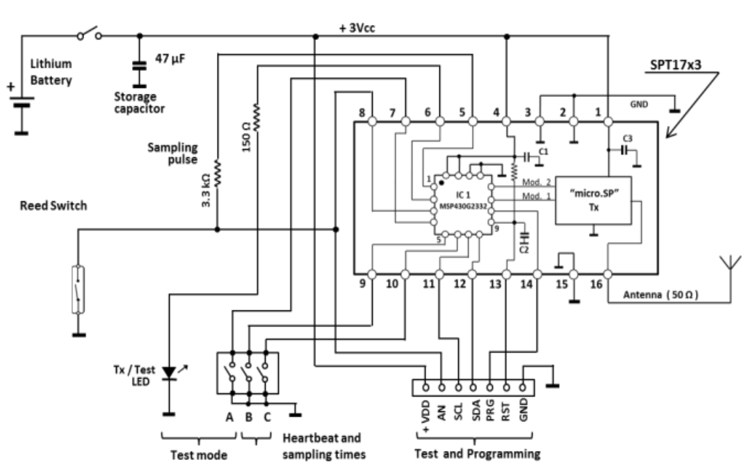


Fig. 6 - A "microSP" Reed Contact Sensor

- We can assume half a minute time for the "Heartbeat": the Tx current for 30'' heartbeat time was calculated above and is 210nA .
- In this example, a time of 1 second for the contact status may be considered. The sampling is performed by the microcontroller applying a 3V - 100µs pulse every second to the 3,3kΩ resistor (Sampling pulse – fig.6) and measuring the resulting tension on the reed contact. The duty cycle is 100µs/1s = 0,0001 and the current is around 1mA comprising the resistor current and the microcontroller current (this is the worst case of a permanently closed contact). The contribution of the "reed contact" sampling to the total current is only 1mA x 0,0001 = 10nA .
- Now we add the microcontroller current in sleep mode with only the watchdog timer active for all the time: about 500 nA with the MSP430 microcontroller :

500nA (µC) + 210nA (Tx) + 10nA (Reed) = 720nA

In short: a wireless sensor like the one shown in Fig.6, made with "microSP" Technology, will have a current consumption of 0.72 µA and, powered by a CR2032 battery (210 mA / h), will have a theoretical duration over 29 years and even considering the self-discharge of the battery, the expected lifespan will be > 25 years.

The Lithium Battery

Beacons and wireless sensors or alarms designed with the "microSP" Technology can be powered by small and inexpensive Lithium button cells. The very low average current consumption makes it possible to design devices with a service life of over twenty years without maintenance. In many cases, the cost of the battery holder and even of the "on" switch can be avoided.

Fig.7 - A wireless sensor powered by a CR2450 battery

Lithium batteries have a very low self-discharge (less than 1% per year) and are perfect especially if they have to deliver a few microamps in the absence of high current peaks. In the "microSP" Transmitter (Fig. 2) the high but very short current peaks of the RF pulses are absorbed and delivered by the CS "storage" capacitor. In the wireless sensor example of Fig.6 the storage capacitor is a 47µF 6,3V (0805) and the stored energy in this small capacitor is sufficient for the transmission of three messages even with the battery disconnected. In fig.7 a "microSP" wireless sensor to measure vibrations (in real time) with onboard a magnetometer and a temperature/humidity sensor and powered by a CR2450 battery : expected life span > 20 years .

The characteristic of the "microSP" Technology of being able to generate RF pulses with a peak power up to +20dBm (100 mW) with an average battery current of only some microamps has two other important advantages:

(1) The first advantage is related to the low capacity of CR and BR batteries to deliver currents in the order of 10/100 mA and this especially at low or very low temperature (-20/-40 °C). This problem practically does not exist with "microSP".

(2) The second advantage, which is closely related to the first, is evident from the diagram in Fig.8. The mA / h capacity of a lithium battery decreases dramatically if required to deliver milliampere currents and/or the temperatures are very high or very low.

For a CR2450 battery like the one used on the Fig.7 wireless sensor, the nominal capacity of 580 mA/h is reduced by 30% at a temperature of -20 °C and a current of 3 mA (Load = 1 kΩ).
This problem simply does not exist with a "microSP" transmitter which, with an average current consumption of 3µA, is equivalent to a load of 1MΩ.

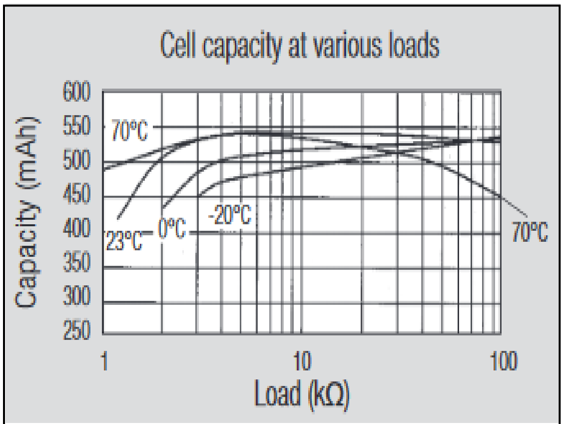


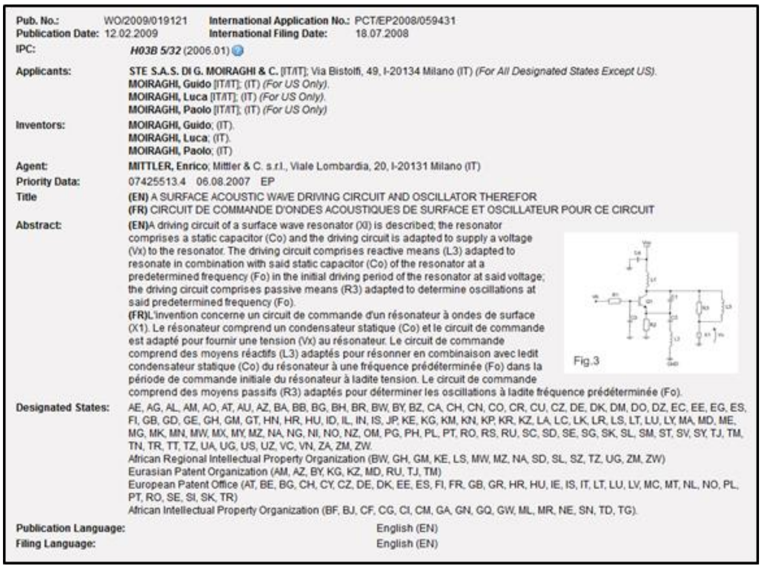
Fig. 8 - The mA/h capacity of a CR2450 battery
(Renata batteries CR2450N)

CR (Manganese Dioxide) and BR (Poly-carbon Monofluoride) batteries can both be used to power "microSP" transmitters. Here differences on the greater capacity of CRs to deliver higher currents are not relevant . BRs can be preferred in "Automotive" applications where a temperature up to + 125 °C can be requested.

Appendix

The Patent WO2009019121

PPM modulation of an RF carrier is certainly not an original idea. What it is not easy to do is to design an RF circuit simple and inexpensive, but at the same time capable of generating 2 µs RF pulses with precise 100ns rise and fall time, easily reproducible and reliable even in extreme voltage and temperature conditions (-40 +125°C in automotive applications).
This is the object of the STE patent “A Surface Acustic Wave Driving Circuit and Oscillator Therefor” The "microSP" oscillator circuit employes only one transistor and one SAW resonator plus few components: it is similar to a Colpitts circuit , but uses a “SAW” resonator in an unconventional way to stabilize the oscillator on the channel frequency. The operation and the theory of this circuit are explained in the patent: in practice it does not need tens of microseconds to start the oscillation (as normally happens with the traditional SAW stabilized oscillators) but it enters oscillation at full power in a few tens of nanoseconds.



Pub. No.: WO/2009/019121 **International Application No.:** PCT/EP2008/059431
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Priority Data: 07425513.4 06.08.2007 EP
Title **(EN)** A SURFACE ACOUSTIC WAVE DRIVING CIRCUIT AND OSCILLATOR THEREFOR
(FR) CIRCUIT DE COMMANDE D'ONDES ACOUSTIQUES DE SURFACE ET OSCILLATEUR POUR CE CIRCUIT
Abstract: **(EN)**A driving circuit of a surface wave resonator (XI) is described; the resonator comprises a static capacitor (Co) and the driving circuit is adapted to supply a voltage (Vx) to the resonator. The driving circuit comprises reactive means (L3) adapted to resonate in combination with said static capacitor (Co) of the resonator at a predetermined frequency (Fo) in the initial driving period of the resonator at said voltage; the driving circuit comprises passive means (R3) adapted to determine oscillations at said predetermined frequency (Fo).
(FR)L'invention concerne un circuit de commande d'un résonateur à ondes de surface (X1). Le résonateur comprend un condensateur statique (Co) et le circuit de commande est adapté pour fournir une tension (Vx) au résonateur. Le circuit de commande comprend des moyens réactifs (L3) adaptés pour résonner en combinaison avec ledit condensateur statique (Co) du résonateur à une fréquence prédéterminée (Fo) dans la période de commande initiale du résonateur à ladite tension. Le circuit de commande comprend des moyens passifs (R3) adaptés pour déterminer les oscillations à ladite fréquence prédéterminée (Fo).
Fig.3
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