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The “microSP” Receiver

Receive and decode pulse-modulated messages

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Abstract

The advantages offered in the design of “IoT” Wireless Sensor Networks by the "microSP" impulse transmission technology would be clearly useless if not supported by an appropriate receiver. The "microSP" Receiver is described herein both in the RF circuit part (patent WO2012150565A3) and in the part dedicated to the detection and recovery of the pulses. It is also briefly described the "Software" programmed in the microcontroller which is entrusted with the task of decoding the messages. An in-depth description of how the receiver works can help in "IoT" Gateways design: this especially because there is a growing problem of coexistence with other wireless systems and a continuous increase in broadband and impulse noise. And this in particular on the "Unlicensed" bands.

The “microSP” Receiver

The "microSP" receiver adopts a direct amplification circuit (Fig.1) and uses an RF Log Amplifier/Detector (IC1). In the RF front-end, three low-noise RF transistors and a SAW filter ensure sensitivity and selectivity. The L-C bandpass filters (BPF in fig.1) help to attenuate out-of-band interfering signals, in particular by the crowded 2.4 GHz band. The demodulated signal, in our case the pulses that compose the PPM message, are present at the output of IC1 and are sent to a fast peak detector (IC2). On C1 the averaged level of the PPM frame is the measure of the received signal strength ("RSSI"). A fraction of this signal and the pulses from IC1 ("Rx out") are sent to the "Adaptive Slicer" (IC3) which reconstructs the pulses ("Pulse"). The process of decoding the received signal depends on the SW programmed in the microcontroller IC4.

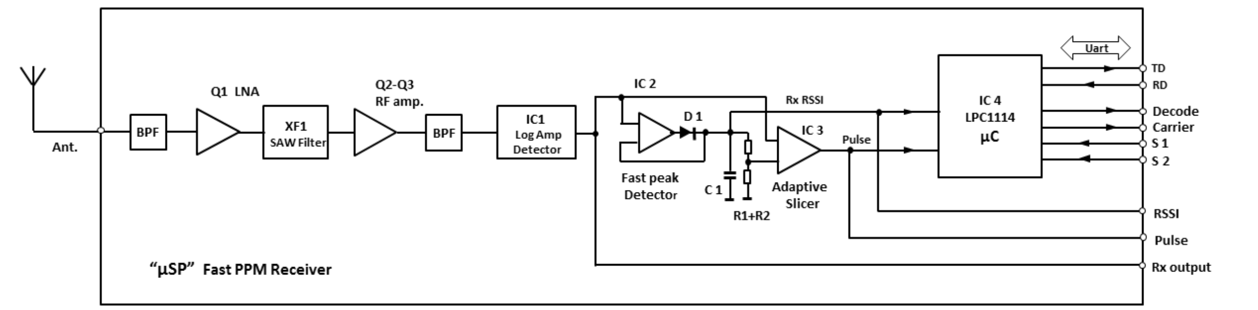

Fig. 1 - The “microSP” Receiver functional diagram

The standard “D2” Software programmed in the "microSP" receivers, for example in the Rx modules SPR27S3-D2 and the SPR97S3-D2, includes important functions and options useful for speeding up the design of an "IoT" Gateway and to facilitate installation and the maintenance of a Wireless Sensor Network (WSN). And generically to facilitate understanding and realization of "Access Points" of generic wireless networks of sensors, actuators and alarms.

- Two outputs, "Decode" and "Car" (RF Carrier or Noise), are provided to indicate locally the decoding of a valid message and to continuously monitor the presence of interfering signals.
- Two inputs, S1 and S2, inputs are designed to be able to choose various data presentation options at the Td output of the UART.
- Measurements of the intensity of the received signal and the level of broadband noise present immediately before decoding are added to the data message issued by the UART.

Receiver operation analysis "Rx out" , "RSSI" and "Pulse"

"Rx Out", "RSSI" and "Pulse" are the three main signals that can be observed and monitored at the receiver output. In Fig. 2 the first trace is "Rx out" and this waveform represents the RF pulses as they appear at the "Log Detector" (IC1) output. A single pulse can be monitored with a 2µs/div horizontal scale, for example to assess any distortions introduced by radio wave propagation anomalies. The following waveforms are "RSSI", the IC2 peak detector output, and "Pulse", the pulse frame as reconstructed to a logic level by the "Adaptive Slicer" (IC3). "RSSI" is the averaged peak level of the received RF pulses and this is the voltage sent to the µC AD converter together with the "Pulse" frame.

The microcontroller continuously monitors the presence of RF signals at the receiver input. The "RSSI" level can represent the arrival of a valid "microSP" message, but can also be the consequence of noise or interference from other wireless or non-wireless electronic devices.

The µC (IC4) has two outputs designed to monitor the reception and the decoding status: the "Car" and "Decode" outputs.

(1) "Car" is activated whenever an RF carrier is detected that exceeds a certain threshold above the background noise. As can be seen from the waveforms in Fig.3, "Car" is also activated by valid messages, but its main function is to warn of interference.

(2) "Decode" is activated when a message is recognized as valid and acquired.

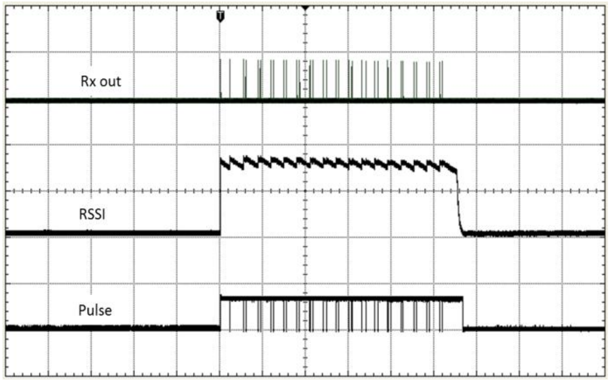

Fig. 2 - "Rx out" , "RSSI" and "Pulse" waveforms .
(Horizontal scale 1ms/div)

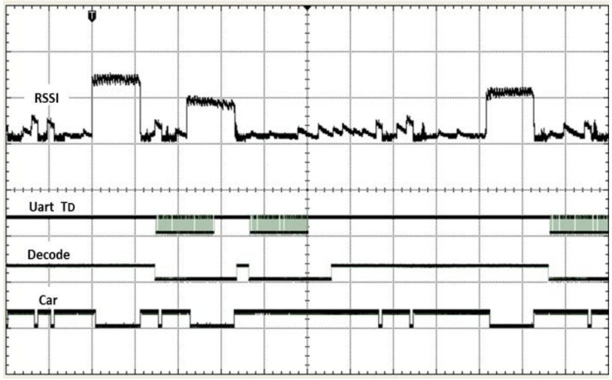

Fig. 3 - Waveforms in a real case with Noise and Interference
(Horizontal scale 5ms/div - RSSI Vertical 500mV/div).

The decoding process

The RSSI signal level is continuously monitored by the microcontroller and when a rising edge is detected with characteristics compatible with a 2 µs RF pulse, the decoding process is started. The "Pulse" output is analyzed in real time and interference and disturbance pulses are immediately discarded. When a valid message is recognized, it is decoded and sent to the UART ("UART TD" in Fig.3).

In order for the µC to successfully decode "microSP" data messages, both the accurate digital analysis of the pulse frame and the correct operation of the Peak Detector/Adaptive Slicer system are of fundamental importance. The decay time constant of the peak detector output and the threshold level of the Adaptive Slicer must be calculated with precision to adapt to the conditions of the variability of the received signal and the presence of noise and interference. In particular, the average of the RSSI level measure must be calculated to be compatible and also to adapt to messages with variable intensity as may occur in the presence of anomalies in the propagation of radio waves. The decay time of the peak detector together with an accurate drawing of the adaptive data slicer allows the receiver to have a co-channel rejection of about 15 dB: practically for correct decoding, the useful signal must be only 15/20dB above an interfering signal.

When a message is decoded, the "Tail eliminator" function is activated (Fig.3 – RSSI waveform) to allow the decoding of an immediately subsequent message, even if of much lower intensity.

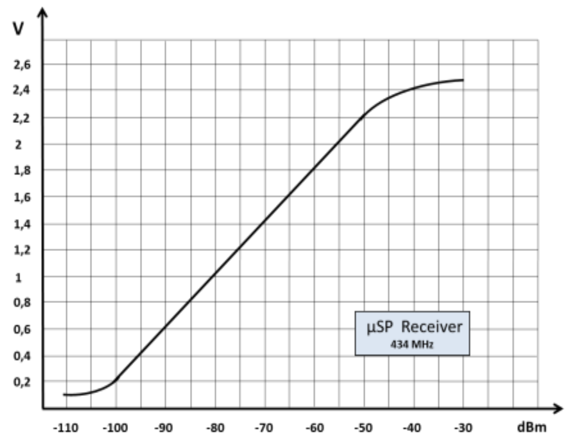

Fig. 4 - Relative Signal Strenght Indicator (RSSI)

Noise and interference

Fig.2 shows the ideal case of receiving a strong signal in the absence of disturbances: practically a laboratory measurement. The case of the real world is very different. In Fig.3 the first waveform is the RSSI signal and shows the reception of three "microSP" messages from remote wireless sensors and the receiver is obviously equipped with an antenna. Frames of various amplitudes received from the sensors are recognizable, but there are also various disturbances, noise peaks and interferences.

The waveforms of fig.2 and fig.3 and the RSSI diagram of fig.4 are typical of the series of receiver modules SPR27x3-D2 (SPR47xx and SPR97xx) programmed with the software "D2", and refer to them in the following discussion concerning the behavior of a reception system in a noisy environment. The SPR27S3x receiver is a typical example of a generic "microSP" receiver, suitable for "IoT" access points or gateways or repeaters, or simply as "point-to-point receiver" of data or alarms from remote wireless devices.

Decode "microSP" messages in a noisy World

In the real world and in the specific case of wireless sensor networks (WSN) located in homes, factories, offices, etc. It is necessary to face a situation of continuous increasing interference from electronic devices in general and in particular from other wireless devices. Interference can be RF signals on the same radio channel used by our system (co-channel interference), but they can also be RF emissions on other nearby frequencies, harmonics or spurious emissions. Under the generic name of "Noise" we can then consider a whole series of EMI disturbances caused not by other wireless devices, but by fast digital or power switching regulator, etc.

The SPR27S3 "microSP" Receiver module

SPR27S3-D2 - RF Performance Data	
Operating Frequency	434.4 MHz
Selectivity	500KHz
Sensitivity	-102dBm (Pulse modulation) -108dBm (AM modulation)
Modulation	PPM / ASK / OOK
Supply Voltage	3.3V DC ±5%
Current consumption	16 mA
RF Input Impedance	50 Ω
Data rate	150 cps – 1 Mcps
Operating Temp.	-40 + 85 °C
Size	36 x 21 x 3,5 mm

Many interesting considerations can be made by looking at the waveforms of fig.3 :

(1) Fig.3 shows a real situation of an SPR27S3-D2 receiver equipped with an antenna and located in an environment where there are a large number of PCs, Bluetooth and WiFi networks plus any kind of high speed electronic devices.

(2) "RSSI" is the reference waveform to which the other three waveforms are related: the UART "T_D" , the "Decode" and "Car" signals. The RSSI waveform shows the reception of three "microSP" message frames, the second of which is received at a level of about -95dBm (refer to the diagram in Fig.4).

(3) From this simple waveform check it is clear that problems can be caused by other wireless systems. Always bear in mind that the "microSP" system operates on "Unlicensed" frequency bands: other users have the right to transmit data (hopefully respecting the limits of Power and Occupied Bandwidth and also a reasonable time control of transmission (duty cycle).

(4) Note the presence of broadband RF background noise (approximately 100 mV, -95dBm at antenna input) and the presence of interference and transient peaks. Note also that, despite this peak level of the transient impulses, the second message (the weakest one) is also successfully received and decoded. About 10dB of difference between the noise and the signal are enough for correct decoding. Nevertheless it is clear that the noise has an influence on the frame averaged level.

(5) Note how at each transient pulse received the microcontroller activates the "Car" output while the "Decode" output is activated only upon receipt of a valid recognized message. It can also be seen that the decoding is immediately followed by a reset of the RSSI signal: this process (Tail eliminator – above described) allows the maximum sensitivity of the receiver to be restored as quickly as possible. Two successive messages, very close to each other, also if the second message has much lower amplitude, are managed by the microcontroller, decoded and sent to the UART output.

“IoT” Gateway and the “microSP” Receiver

This detailed description of the operation of the receiver is provided here as an aid in the design of “Access points” and “Gateways”, in particular for the "IoT" sector. If there are "billions" of wireless devices operating on unlicensed frequencies and if there is a further increase in the various wireless technologies in the "IT" (Information Technology) sector, it would be good to adopt appropriate "EMI" and "EMC" countermeasures. It is in fact useless to have a good reception system, good antennas and a high RF sensitivity if, together with the useful signal, disturbances and interferences are received by other electronic and wireless systems. Both during the design and during the installation of the wireless network it is of great importance to be able to evaluate the integrity of the signals coming from the wireless sensors so as to be able to introduce countermeasures: (1) in the design phase, for example with further filtering of the RF signal at the Rx input and (2) during installation, for example by changing the position of the gateway or antennas.

When the "Noise" is created by the Gateway itself

It should also be noted that the noise sources can be internal to the reception system itself: high speed digital logics, quartz oscillators, etc. A switching power regulator on the same board where the receiver is located or, worse still, on the "Ground" portion of the antenna can cancel the best "IoT" Gateway design.

Message collisions

Along with the rapid development of Web of Things, the great challenge we face is how to avoid information conflict and collision in the process of acquisition and treatment of massive information. Along with the rapid development of the Internet of Things, the big challenge we face is how to avoid conflicts of information and collisions in the process of acquiring and processing large amounts of data. This problem of data processing exists not only at the level of the wireless network (RF Level), but also after the reception and decoding of the messages, i.e. in the subsequent networks until the data is processed.
At RF level it is clear that collisions can occur especially taking into account that the "microSP" technology is made up of one-way transmitters. A first precaution, if you want to enjoy the advantages of the "microSP" technology, fundamentally of the advantage of having cheap wireless sensors with a maintenance duration of 15/25 years, consists in evaluating very well the times of transmission of the state in life (Heartbeat) and eventually exploit the possibility of transmission only to a significant change of the measures or of the alarm level thresholds.

Appendix

The Receiver Patent

Abstract

There is described a receiver (1) of at least one radiofrequency modulated signal deriving from an antenna (101) external to the receiver; the receiver comprises a first stage (103) for the low noise amplification of the radiofrequency modulated signal and a demodulation stage (106) of the above-mentioned signal. The receiver comprises a SAW filter (104) adapted to act as a pass band filter about a predetermined frequency for the signal deriving from the first stage, a logarithmic amplifier (105) adapted to amplify the signal deriving from the SAW filter, a peak detector (402) of the output signal of the logarithmic amplifier, means (203) adapted to control the gain of the first stage (103) for the amplification of the radiofrequency modulated signal as a function of the output signal (Vopeak) of the peak detector.

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WO Application

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