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(54) **RECEIVER OF RADIO FREQUENCY SIGNALS**

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H04B 1/16	(2006.01)
H03G 3/30	(2006.01)
B60C 23/04	(2006.01)
H04B 1/18	(2006.01)

(52) **U.S. Cl.**
CPC ***H04B 1/1027*** (2013.01); ***B60C 23/0435*** (2013.01); ***H03F 3/191*** (2013.01); ***H03G 3/3052*** (2013.01); ***H04B 1/16*** (2013.01); ***H04B 1/18*** (2013.01); *H03F 2200/435* (2013.01)

(58) **Field of Classification Search**
CPC H03F 2200/435; H04L 27/2647; H04L 1/20
USPC 455/234.1, 67.11, 226.1, 232.1, 245.1, 455/63.1, 278.1; 375/316, 345
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,175,883 A		12/1992	Ueno	
7,151,759 B1		12/2006	Ryan et al.	
8,121,221 B2 *		2/2012	Kuo et al.	375/316
8,428,194 B2 *		4/2013	Kuo et al.	375/316
8,559,379 B2 *		10/2013	Gainey et al.	370/329
2007/0207760 A1		9/2007	Kavadias et al.	
2015/0070058 A1 *		3/2015	Rada et al.	327/156
2015/0070093 A1 *		3/2015	Rada et al.	330/294

* cited by examiner

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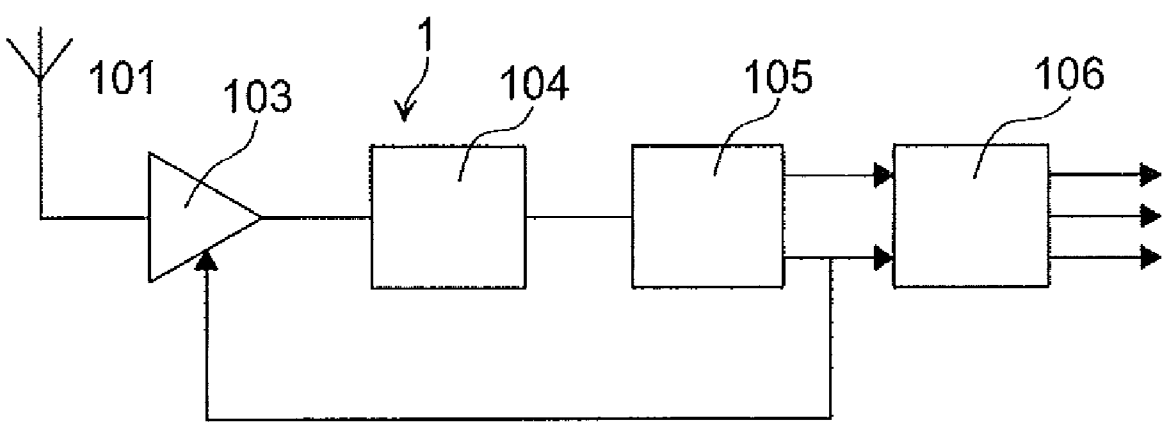
(57) **ABSTRACT**

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

8 Claims, 4 Drawing Sheets



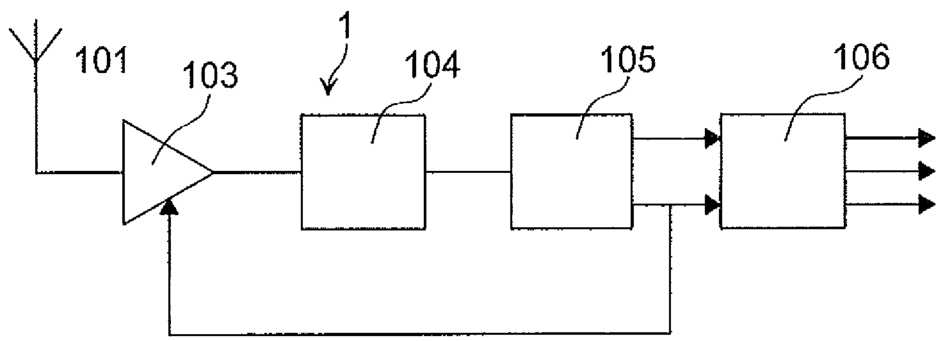


Fig.1

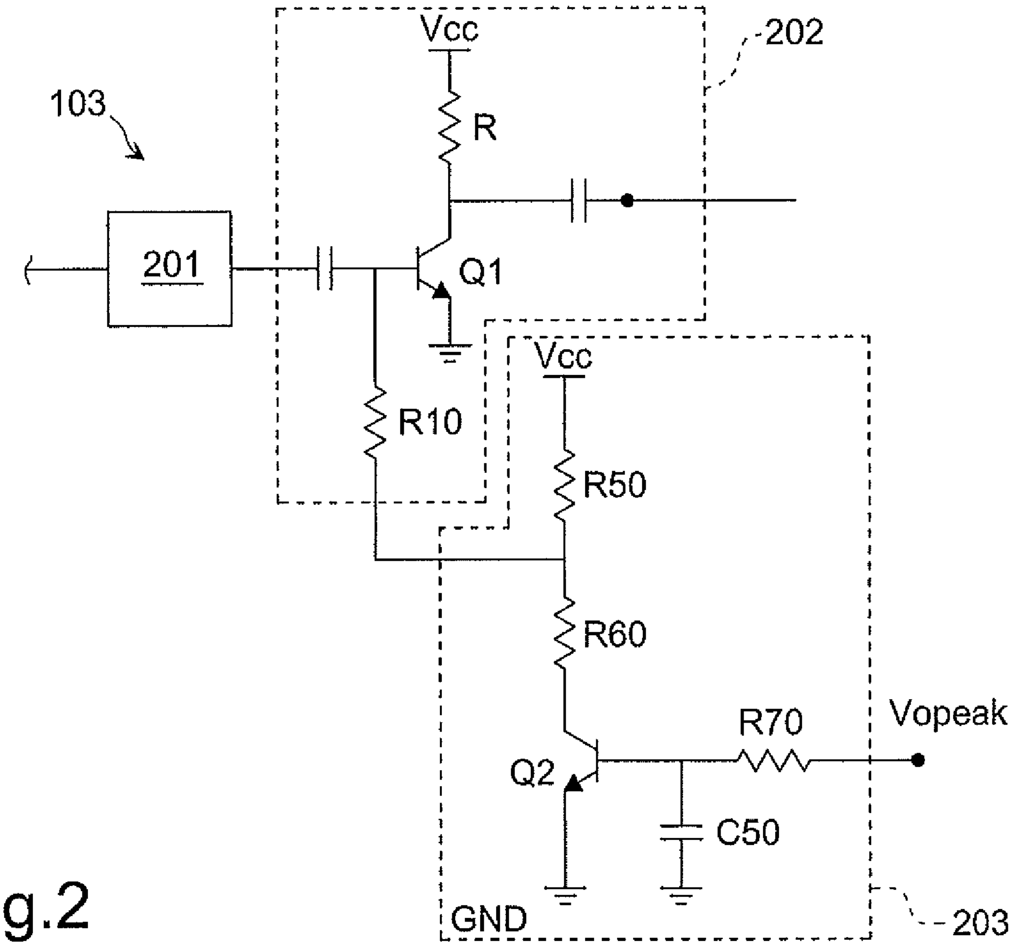


Fig.2

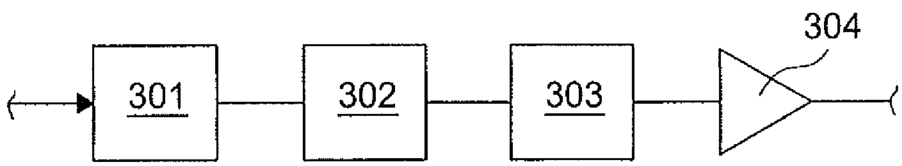
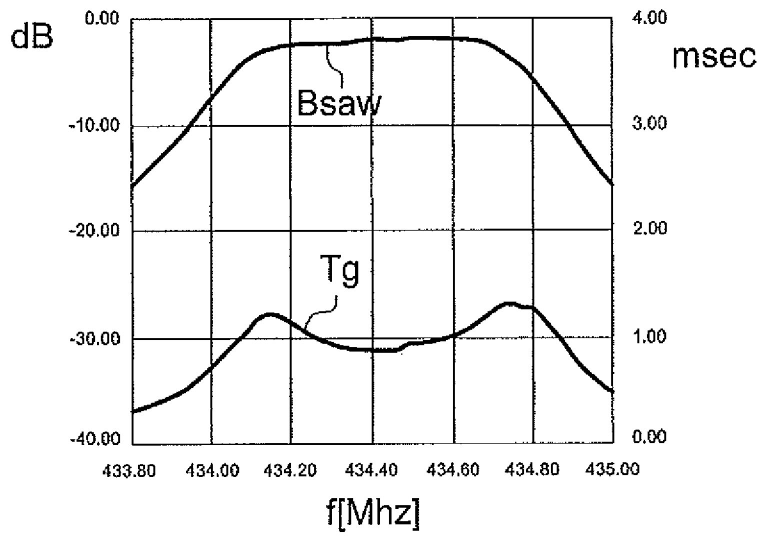
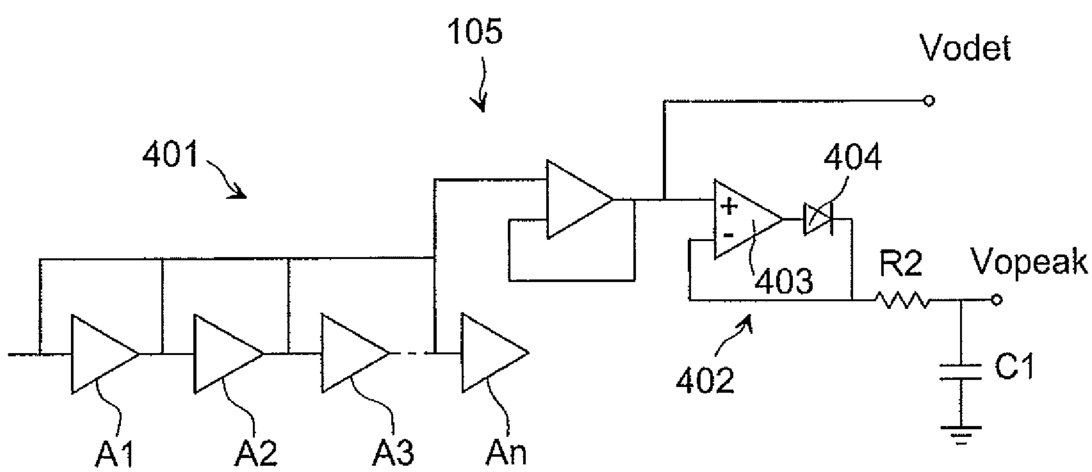


Fig.3



dB
msec
Bsaw
Tg
0.00
-10.00
-20.00
-30.00
-40.00
4.00
3.00
2.00
1.00
0.00
433.80
434.00
434.20
434.40
434.60
434.80
435.00
f[Mhz]

Fig.4



105
Vodet
401
404
+
-
403
R2
Vopeak
402
C1
A1
A2
A3
An

Fig.5

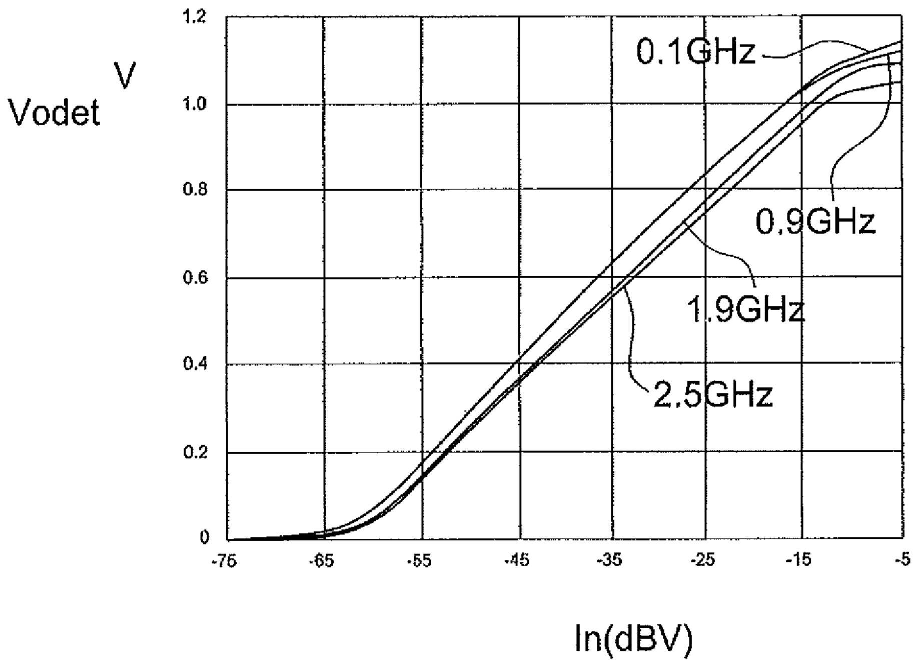

Vodet V
1.2
1.0
0.8
0.6
0.4
0.2
0
-75
-65
-55
-45
-35
-25
-15
-5
0.1GHz
0.9GHz
1.9GHz
2.5GHz
In(dBV)

Fig.6

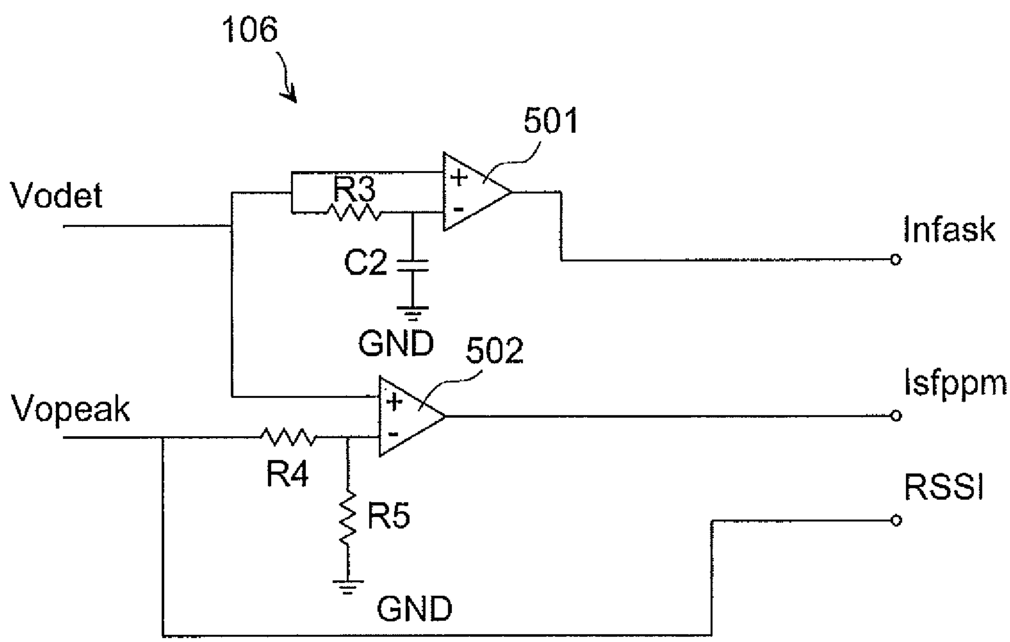

106
501
Vodet
R3
C2
GND
Infask
502
Vopeak
Isfppm
R4
R5
GND
RSSI

Fig.7

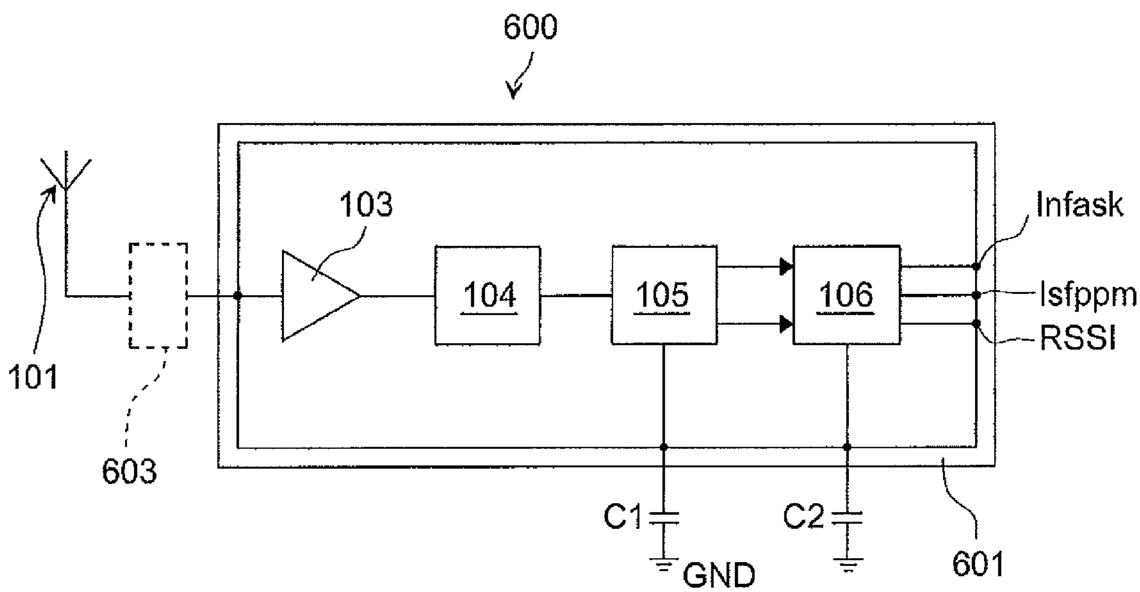

600
103
Infask
104
105
106
Isfppm
RSSI
101
603
C1
C2
GND
601

Fig.8

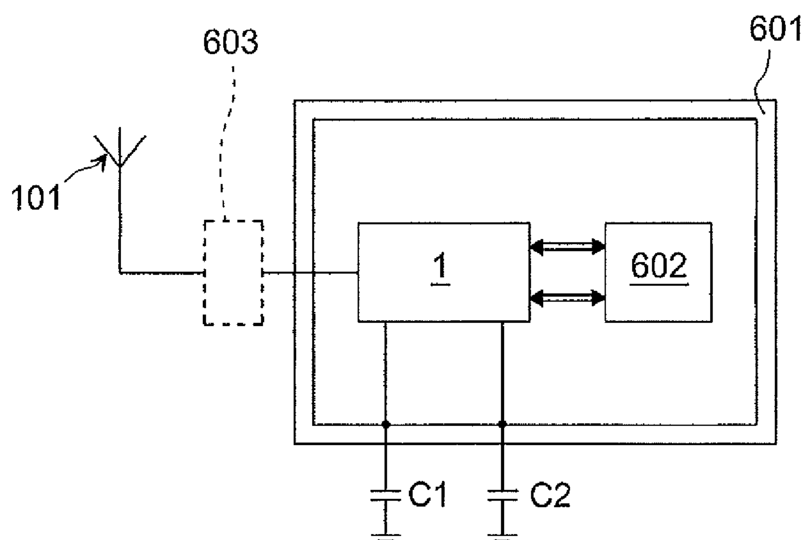

603
601
101
1
602
C1
C2

Fig.9

RECEIVER OF RADIO FREQUENCY SIGNALS

This is a national stage of PCT/IB12/052212 filed May 3, 2012 and published in English, which has a priority of Italian no. MI2011A000756 filed May 5, 2011, hereby incorporated by reference.

The present invention relates to a receiver of radiofrequency signals.

Most of the current receivers of radiofrequency signals use a complex circuit structure, typically of the superheterodyne type. Said receivers comprise a mixer, an oscillator for generating the heterodyne signal and a PLL circuit adapted to stabilize the receiver frequency.

In particular, in the case of devices for transmitting and receiving information related to some parts of the vehicle, such as for example the correct level of liquid in a tank, temperature and pressure in a tire, the battery status and so on, receivers are often integrated in the onboard computer or located in a more suitable position for receiving signals inside the vehicle and communicating with the onboard computer. The data received by the receiver are transmitted to the computer inside the motor vehicle for displaying simple information messages or alert conditions on a dedicated display.

However, current receivers are complex especially due to the presence of a phase detector adapted to compare two signals at different frequencies and to emit a signal with a phase proportional to the phase difference of the two signals at different frequencies.

In addition, said receivers absorb significant levels of current and actuate a consequent energy dissipation.

In view of the prior art, the object of the present invention is to provide a receiver of radiofrequency signals which is circuit-wise simpler than known ones and has a lower current absorption than known ones.

According to the present invention, said object is achieved by a receiver of at least one radiofrequency modulated signal deriving from an antenna external to the receiver, said receiver comprising a first stage for the low noise amplification of the radiofrequency modulated signal and a demodulation stage of the radiofrequency modulated signal, characterized by comprising a SAW filter adapted to act as a pass band filter about a predetermined frequency for the signal deriving from the first stage, a logarithmic amplifier adapted to amplify the signal deriving from the SAW filter, a peak detector of the output signal of the logarithmic amplifier, means adapted to control the gain of the first stage for the amplification of the radiofrequency signal as a function of the output signal of the peak detector, said output signal of the logarithmic amplifier and said output signal of the peak detector being in input to the demodulation stage.

Due to the present invention it is possible to provide a receiver of radiofrequency signals particularly suitable to be used in short-range data transmission and reception systems such as car door opening systems or tire pressure monitoring systems.

The receiver is particularly suitable for receiving signals with pulse position modulation (PPM) or with pulse width modulation (PWM).

The features and the advantages of the present invention will appear more clearly from the following detailed description of a practical embodiment thereof, made by way of a non-limiting example with reference to the annexed drawings, wherein:

FIG. **1** shows a block diagram of the receiver of radiofrequency signals according to the present invention;

FIG. **2** shows a circuit scheme of the low noise preamplifier stage of the receiver of FIG. **1**;

FIG. **3** shows a circuit scheme of the filtering stage of the receiver of FIG. **1**;

FIG. **4** shows a diagram of the frequency response of the filtering stage of FIG. **3**;

FIG. **5** shows a circuit scheme of the logarithmic amplifier of the receiver of FIG. **1**;

FIG. **6** shows a diagram of the output voltage as a function of the input signal level of the stage in FIG. **5**;

FIG. **7** shows a circuit scheme of the "ASK" and "PULSE" comparators used in the receiver of FIG. **1**;

FIG. **8** schematically shows a package with the receiver of FIG. **1** made in a substrate of ceramic material according to an embodiment of the present invention;

FIG. **9** schematically shows a package with the receiver of FIG. **1** and a microcontroller made in a substrate of ceramic material according to a variant of the embodiment of the invention.

With reference to FIG. **1**, there is shown a receiver **1** of radiofrequency signals according to the present invention. The receiver comprises a preamplifier stage **103** of a radiofrequency signal received by an antenna **101**, a filtering stage **104**, an amplification stage **105** and a signal demodulation stage **106**.

The signal deriving from antenna **101** is at the input to the low noise preamplifier stage **103** comprising, as better seen in FIG. **2**, a pass band filter **201** tuned to the reception frequency; the filter **201** also has the function of impedance adapter.

The output signal of filter **201** is transmitted to a circuit block **202** comprising a radiofrequency transistor Q1 controlled by the output signal to a circuit **203**; the output signal from transistor Q1 flows through a low value resistance R, preferably about 100 Ohm, such as to have a constant impedance at the input of the next stage. The transistor Q1 is preferably a common emitter bipolar transistor. The circuit block **202** represents a low noise amplifier stage the gain G of which is controlled by the circuit **203**.

The circuit **203** is controlled by signal Vopeak deriving from a peak detector **402** belonging to receiver **1**. Circuit **203** comprises a transistor Q2, preferably a common emitter bipolar transistor with the emitter terminal connected to ground GND. The base terminal of transistor Q2 is driven by signal Vopeak filtered by the low pass filter R**70***C**50**. The signal on the collector terminal of transistor Q2 drives the base terminal of transistor Q1 and varies the base bias current of the transistor Q1 for varying, in particular for decreasing, the gain G of transistor Q1 proportionally to the signal intensity on the antenna; therefore, circuit **203** forms an automatic gain control block. When the signal Vopeak increases, the transistor Q2 acts so as to reduce the gain G of the transistor Q1; the gain G of the bipolar transistor Q1 is inversely proportional to the amplitude of signal Vopeak.

The output signal of the stage **103** is at the input of a SAW filter **302** of the stage **104**, better shown in FIG. **3**, which must select the signals in a channel between 300 and 600 kHz, i.e. it must filter the signals in a pass band from 300 to 600 kHz and must ensure a constant group delay time Tg, where the group delay time indicates the variation of the passage time of a signal through the pass band Bsaw of the SAW filter. The impedance adapter circuits **301** and **303**, arranged at the input and at the output of the SAW filter **302**, are configured for obtaining a constant group delay time Tg on the whole pass band Bsaw of the SAW filter **302**. FIG. **4** shows the variation of the band and of the group delay time Tg as a function of the frequency for filter SAW of FIG. **3**. The output signal of filter SAW **302** is amplified by a fixed gain amplifier **304**.

The constancy of the group delay time Tg allows a correct amplification of the rising and falling edges of the radiofrequency modulated signal, such as for example when the modulated signal is a signal with pulse width modulation (PWM) or with pulse position modulation (PPM) where for example the radiofrequency pulses have rising and falling edges in the order of 100 nanoseconds.

The output signal of amplifier **304** is at the input of a logarithmic amplifier **401**, shown in FIG. **5**, belonging to stage **105** and adapted to amplify the input signal. The logarithmic amplifier **401** is a temperature-compensated amplifier and performs a high gain by the series of multiple amplification stages Ai . . . An. FIG. **6** shows a diagram of the waveform of the output voltage Vodet as a function of the input signal level In of the logarithmic amplifier **401** at different frequencies.

The output signal Vodet of the logarithmic amplifier is transmitted to a demodulation stage for demodulating the information. The same output signal Vodet of the logarithmic amplifier **401** is transmitted to a peak detector **402** adapted to detect the peaks of the output signals of the logarithmic amplifier **401**. Preferably, the peak detector **402** comprises an operational amplifier **403** having the output signal of the logarithmic amplifier **401** at the non-inverting input terminal, having the output connected with the anode of a diode **404** having the cathode connected with the inverting input terminal and with the terminal of a resistance R**2** having the other terminal connected with the terminal of a capacitor C**1** in turn connected to ground GND; the time constant related to capacitor C**1** has a small value, about one microsecond. The voltage Vopeak at the terminals of capacitor C**1** is the output of the peak detector. The output signal Vopeak is transmitted to a comparator adapted to carry out the signal demodulation and is used by the circuit **203** for controlling the radiofrequency transistor **202**. The resistance R**2** has a low value, preferably 22 Ohm, and serves for stabilizing the circuit operation compensating the signal propagation delays by means of the operational amplifier.

Finally, signals Vodet and Vopeak are transmitted to the demodulation stage **106** for digitally reconstructing the information contained in the received modulated signal, as better shown in FIG. **7**. The comparator **501** carries out a demodulation in case of signal modulated with amplitude modulation ASK (Amplitude shift Keying) or also an OOK (On-Off Keying) modulation; the comparator **501** receives the signal Vodet at the non-inverting input thereof, while at the inverting input thereof there is the average value of signal Vodet mediated by a circuit comprising a resistance R**3** connected with a capacitor C**2** in turn connected to ground GND and with the inverting input. The output signal of comparator **501** is the signal Infask. The output signal Vopeak is transmitted as the signal RSSI.

The comparator **502** carries out a demodulation in the case of signal modulated with pulse position modulation PPM or with pulse with modulation PWM; the comparator **504** receives the signal Vodet at the non-inverting input thereof, while at the inverting input thereof there is a reference signal derived by the resistive divider consisting of resistances R**4** and R**5** and the signal Vopeak is present across the series of the resistances R**4** and R**5**. The values of resistances R**4** and R**5** and of capacitor C**1** determine the decay time constant of the output voltage Vopeak; said time constant, generally of the order of few milliseconds, takes on a major importance if the signals received are affected by sudden amplitude variations, as in the signals used for transmitting the tire pressure. The output signal of comparator **502** is the signal Infppm. The signals Infask, Infppm and RSSI are the output signals of the demodulation stage **106** and of the receiver **1**.

In particular, the receiver according to the present invention is more suitable in data transmission reception systems arranged in vehicles, preferably motor vehicles. The transmitters may be located in various parts of the motor vehicle, for example next to the battery or in the tires for transmitting data on the tire temperature or the tire pressure.

The receiver is adapted to receive said data and transfer them to a central computer for displaying alarms or messages on a display.

Preferably, in the case of transmission of tire pressure data with pulse position modulation, the signal transmitted starts after a given period of time by the triggering of the oscillations with the generation of a first pulse that represents the beginning of the message and has a width W typically of 3 microseconds. Other subsequent pulses are then generated, the temporal positions thereof, i.e. the periods of time between one pulse and the next one, represent the content of the information to be transmitted.

The receiver according to the invention is particularly suitable for receiving data modulated according to a pulse position modulation.

According to the invention it is possible to make a package **600**, also called package LTCC, wherein receiver **1** shown in FIGS. **1-6** is made in a substrate of ceramic material **601** using the LTCC (Low Temperature Cofired Ceramic) technology, as shown in FIG. **8**. The receiver is integrally manufactured in the ceramic substrate except for capacitors C**1** of the peak detector **402** and C**2** of demodulator **106**; said capacitors are accessible from the outside for adapting the time constants of the peak detector and of the demodulator to the different requirements of the receiver.

FIG. **9** shows a package according to a variant of the embodiment of the present invention; the package comprises a microcontroller **602** coupled to the receiver **1** wherein the microcontroller **602** is adapted to manage the PPM modulated signals received.

The invention claimed is:

1. A receiver of at least one radiofrequency modulated signal deriving from an antenna external to the receiver, said receiver comprising a first stage for the low noise amplification of the radiofrequency modulated signal and a demodulation stage of the radiofrequency modulated signal, characterized by comprising a SAW filter adapted to act as a pass band filter about a predetermined frequency for the signal deriving from the first stage, a logarithmic amplifier adapted to amplify the signal deriving from the SAW filter, a peak detector of the output signal of the logarithmic amplifier, means to control the gain of the first stage for the adapted amplification of the radiofrequency modulated signal as a function of the output signal (Vopeak) of the peak detector, said output signal (Vodet) of the logarithmic amplifier and said output signal (Vopeak) of the peak detector being in input to the demodulation stage.

2. The receiver according to claim **1**, wherein said means are adapted to reduce the gain of the first stage of the amplification of the radiofrequency modulated signal in correspondence of a value increase of the output signal of the peak detector, said means being adapted to increase the gain of the first stage of amplification of the radiofrequency modulated signal in correspondence of a value reduction of the output signal of the peak detector.

3. A The receiver according to claim **1**, wherein said means comprise a first common emitter bipolar transistor the base terminal of which is controlled by the output signal (Vopeak) of the peak detector, said first amplification stage comprising a second common emitter bipolar transistor, the current flowing through the base terminal of said second bipolar transistor depending on the current flowing through the collector terminal of the first bipolar transistor.

4. The receiver according to claim **1**, wherein said peak detector comprises at least one capacitor the value of which determines the decay constant of the output signal of the peak detector.

5. The receiver according to claim **4**, wherein said peak detector comprises a operational amplifier having the output signal of the logarithmic amplifier at the non-inverting input terminal, the output terminal connected with the anode of a diode having the cathode connected with the inverting input terminal of the operational amplifier and with one terminal of a resistance having the other terminal connected with one terminal of said capacitor having the other terminal connected to a reference voltage.

6. The receiver according to claim **1**, wherein said demodulator comprises means adapted to average the output signal of the logarithmic amplifier, said means comprising at least a further capacitor.

7. An LTCC package comprising the receiver as defined in claim **1** which is manufactured in a ceramic material substrate and wherein the at least one capacitor and at least a further capacitor are external to the package.

8. The LTCC package according to claim **7**, wherein by comprising a microcontroller manufactured in said ceramic material substrate, said receiver being adapted to interact with said microcontroller.

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