# SAW-BASED HYBRID TRANSCEIVERS IN SLAM PACKAGING WITH FREQUENCY RANGE FROM 200 TO 1000 MHZ

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ABSTRACT---Short range unlicensed RF links have become extremely popular all around the world. Some examples of these links include automotive keyless entry, wireless security systems, computer data links, ID cards and remote meter reading. The new transceiver described in this paper is ideally suited for these applications. It takes advantage of a new architecture that uses a single ASIC and two SAW devices. The entire transceiver is enclosed in a surface mount package with dimensions of 10.2 by 7.06 by 2.03 mm. The device is capable of either OOK or ASK modulation with data rates exceeding 100 kb/s. The sensitivity of the receiver at 1.2 kb/s is -105 dBm. The receiver architecture takes advantage of amplifier sequencing, which allows a stable RF gain of 85 dB at the incoming RF signal frequency of interest. The sequencing of the amplifiers effectively gates crosstalk out of the SAW filters allowing out-of-band rejection levels approaching 100 dB. The transmitter uses the same two SAW devices employed in the receiver for frequency stabilization and harmonic filtering.

## INTRODUCTION

In today's wireless world, going wireless is associated with eliminating cumbersome wires and cables making it possible to roam with fully operational systems. There are three basic wireless requirements in today's market. The first is represented by cellular phone systems which have a relatively long range of a few kilometers. The second is represented, for example, by unlicensed spread spectrum systems, with up to one watt output power, that serve needs such as local area networks and typically have an intermediate range of over 300 meters. The third is the short range unlicensed system that has a range of from 1 to 100 meters. The variety of applications for short range wireless systems far surpasses that of the long and intermediate range systems. Short range applications include automotive keyless entry, garage door openers, wireless security systems, data links, wireless barcode readers, ID cards, remote meter reading, animal tagging, in-house arrest systems, wireless keyboards, wireless mice and wireless joysticks. More and more of these short range applications are now requiring two way links [1].

The new transceiver discussed in this paper was designed to address the needs of the short range wireless applications. Some of the desired attributes of the receivers and transmitters used in these systems include low cost, very low power consumption, miniature size, no adjustments, good frequency stability, good range, the ability to operate in a crowded frequency spectrum and ease of application by engineers with limited RF training.

## CURRENT TRANSMITTER AND RECEIVER TECHNOLOGIES

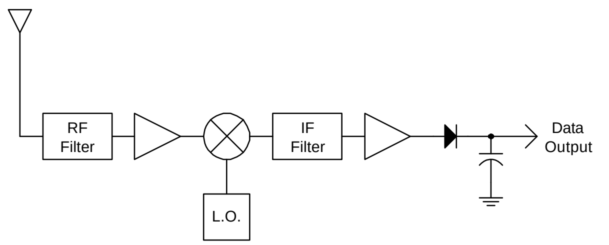
### *Transmitters*

Current low power transmitter technologies include inductor/capacitor (LC) stabilized oscillators, SAW stabilized oscillators and crystal stabilized frequency synthesizers. LC stabilized transmitters exhibit poor frequency stability and reliability and are rapidly being replaced by SAW stabilized transmitters. Crystal stabilized frequency synthesizers have greater frequency accuracy than SAW transmitters but consume more power, have more spurious frequencies, are physically larger and cost more than SAW stabilized transmitters. The additional cost, power consumption and size of frequency synthesizers are only justified if the system utilizes a narrow band receiver that requires the additional frequency accuracy.

### *Receivers*

The receiver technology that has been the companion for the LC transmitter is the LC stabilized superregenerative receiver due to its very wide reception bandwidth. Like the LC transmitter, this receiver is rapidly being replaced by other receiver technologies due to its poor frequency stability, reliability and out-of-band rejection of unwanted signals. Desirable attributes of the superregenerative receiver are its very low power consumption and low cost.

Another popular receiver technology in the wireless arena has been the superheterodyne receiver, see Figure 1. This receiver achieves the stable gain necessary to achieve high



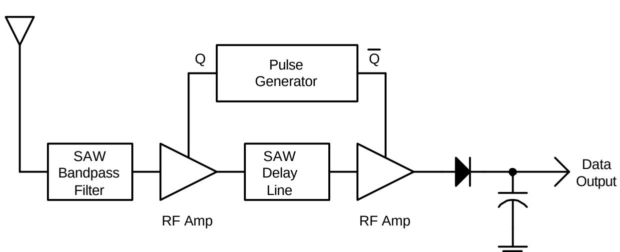

sensitivity through simple frequency diversity. By splitting the gain between an RF amplifier and an IF amplifier, the stability issue is resolved. The RF amplifier and the IF

Figure 1
Superheterodyne Receiver

amplifier are not at the same frequency, so the feedback from the IF amplifier output to the RF amplifier input does not cause a stability problem. Even more stable gain can be achieved with such a receiver by increasing the number of conversions or IF’s. In addition, the RF filter and the IF filter allow more rejection of unwanted signals than could be achieved by cascading RF filters, with their inherent crosstalk, once again due to frequency diversity. The advantages of this receiver architecture are good sensitivity, good out-of-band rejection and frequency agility. The disadvantages are large physical size, high power consumption, the need for a stable local oscillator, oscillator radiation, mixer spurious responses (especially the image frequency), critical circuit board layout and cost. The relatively large physical size is due to the need for either a SAW device or a crystal to stabilize the local oscillator, a SAW or other technology for an RF filter and a SAW, ceramic or LC IF filter. Due to the relatively low frequency of the IF filter, it can be quite large. The high power consumption is primarily due to the local oscillator. It must develop an RF level high enough to drive the mixer into non-linearity while minimizing intermodulation and cross-modulation in the mixer.

*Amplifier Sequenced Hybrid Receiver*

A basically new, totally SAW based receiver architecture



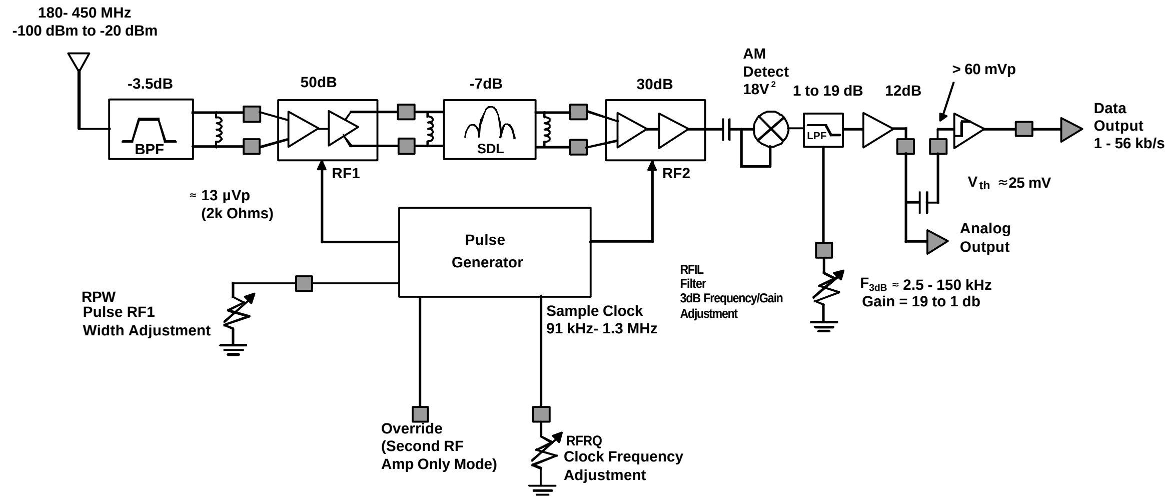

for short range application was introduced by RFM three years ago [2,7]. This new receiver achieves the same results as the superheterodyne receiver, but it uses the principle of time diversity rather than frequency diversity.

Figure 2
ASH Receiver Simplified Block Diagram

Figure 2 is a simplified block diagram of the new amplifier sequenced hybrid (ASH) receiver. The incoming signal is first selected by the SAW band-pass filter and then applied to the first RF amplifier. This RF amplifier is turned on by the pulse generator. The output of the RF amplifier is then applied to the input of a SAW delay line. The second RF amplifier is turned off when the first amplifier is on and vice versa. When the signal is emerging from the delay line, the first amplifier is turned off and the second amplifier is turned on. The output of the second amplifier is then applied to a detector circuit. Gains similar to that of a superheterodyne receiver can be achieved with this receiver with excellent stability. Since the two amplifiers are not on at the same time, feedback from one amplifier to the other does not cause the circuit to become unstable. A typical delay used in the delay line is 0.5 microseconds allowing ten or more samples per bit at data rates up to 100 kilobits per second. This gating pulse is then simply removed from the data signal with a low pass data filter following the detector.

Filtering in this receiver is provided by both the SAW bandpass filter and the SAW delay line. The out-of-band rejection of both the SAW bandpass filter and the delay line filter is approximately 50 dB each. Normally, two filters at the same frequency would be limited in out-of-band rejection to much less than the resultant cascaded 100 dB by the crosstalk level that could be achieved with a particular circuit layout. However, crosstalk around the delay line filter is effectively gated out by the switching of the amplifiers. Crosstalk around the SAW bandpass filter is effectively eliminated by providing a single-ended connection to the antenna and a differential connection to the RF amplifier, taking advantage of common-mode rejection. The result is a receiver with sensitivity similar to a superheterodyne receiver and approximately 100 dB of rejection to undesired out-of-band signals.

The ASH receiver architecture has many advantages over previous architectures, including the superhetrodyne receiver. All of the functions, except the two SAW devices, are included in a single custom integrated circuit. Since the SAW devices are at RF rather than a low IF, they are extremely small in size [3]. This makes it possible to include the entire receiver in a small hybrid package. No adjustments are needed since the frequency of the receiver is entirely determined by the two SAW devices. No RF oscillators are included in the ASH receiver, completely eliminating concerns about LO radiation, mixer spurious responses and the associated DC power consumption. A




further reduction in DC power consumption is obtained due to the switching of the RF amplifiers. The RF amplifiers consume more power than the rest of the active circuitry, so the fact that the two amplifiers are never on at the same time reduces the power consumption by at least 50%.

Figure 3
ASH Receiver Functional Block Diagram

Figure 3 is a functional block diagram of the ASH receiver including the custom IC, SAW devices, various control resistors and baseband coupling capacitor. The diagram also shows the gain and loss values for the signal path. Beginning at the antenna port, the SAW front-end filter has a typical insertion loss of 3.5 dB, greater than 50 dB out-of-band rejection and a minimum bandwidth of 500 kHz. This filter was realized using SAW coupled-resonator technology [4]. Figure 4 shows the frequency response of one of these filters at 433.92 Mhz. The output of the SAW

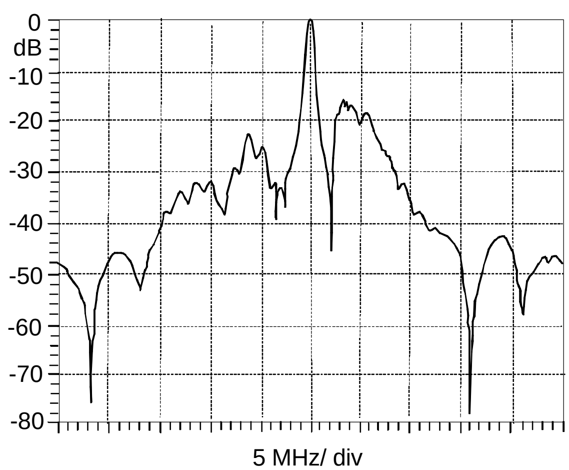



Figure 4
433.92 MHZ SAW Coupled Resonator Filter

filter is differentially coupled to the first switched RF amplifier which has a gain of 50 dB. The output of the first amplifier is differentially coupled to the SAW delay line. The delay line is realized using low loss single phase unidirectional transducer (SPUDT) technology [5]. It has a delay of 0.5 microseconds, a bandwidth of 1.5 MHz, a typical insertion loss of 7 dB and greater than 50 dB out-of-band rejection. Figure 5 shows the frequency response of one of these delay lines at 433.92 MHz. The output of the

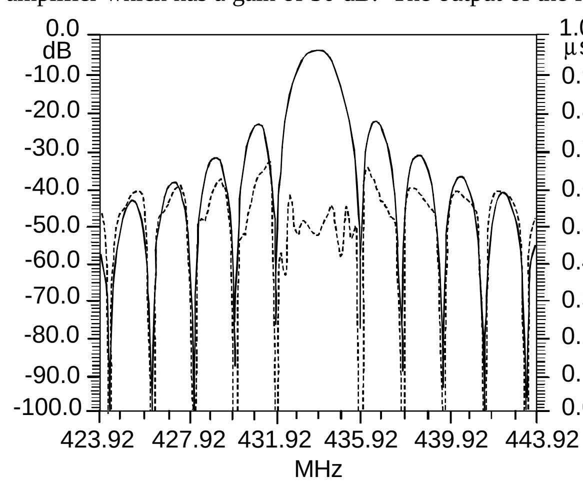
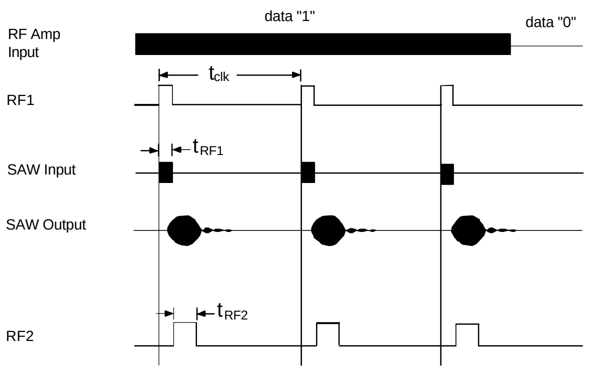



Figure 5
433.92 MHZ SAW Delay Line

delay line is differentially coupled to the second switched amplifier which has a gain of 30 dB. The two switched RF amplifiers, RF1 and RF2, are switched on and off by an on-chip pulse generator whose rate and pulse width are controlled by the resistors RFRQ and RPW. The output of the second amplifier drives a square law detector realized using a Gilbert cell. The Gilbert cell drives a 3 pole, .05 degree equiripple low-pass gyrator filter. The bandwidth of

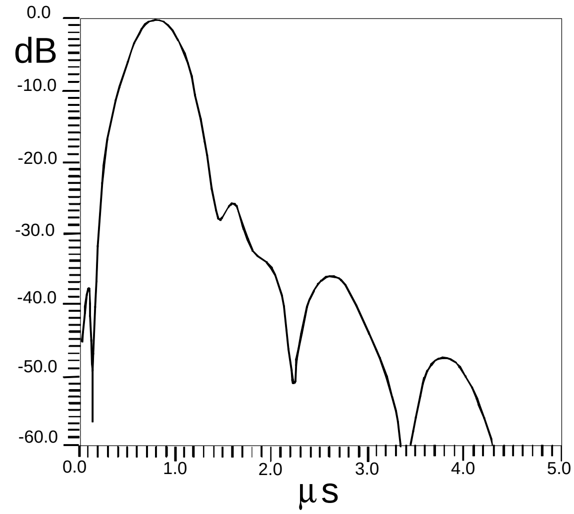



this filter is set by the value of the resistor, RFIL, over the range of 2.5 to 150 kHz. The output of the filter is capacitively coupled to a data slicer with a fixed threshold. The output of the data slicer is capable of driving a single CMOS gate.

Figure 6 is a diagram of the sequential gain timing. The

Figure 6
Sequential Gain Timing

first line represents the OOK (on/off keyed) modulated RF signal at the input to the first RF amplifier. A data “1” is carrier on and a data “0” is carrier off. The “RF1” line




represents the clocking of the first RF amplifier. When the pulse is high, the amplifier is turned on and vice versa. The “SAW Input” line represents the RF pulses applied to the input of the delay line. The “SAW Output” line represents the RF output of the SAW delay line and the “RF2” line represents the clocking of the second RF amplifier. This

Figure 7
SAW Delay Line Response to 0.5 us RF Pulse

figure also illustrates that the data is sampled many times per bit by the switching of the two RF amplifiers. As described before, the two RF amplifiers are clocked sequentially to prevent feedback instability in the receiver. The second RF amplifier is turned on immediately after the

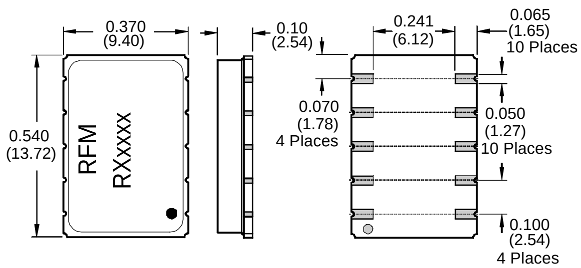
| | | | |
|---|---|---|---|
| Frequency | 433.92 MHz | 916.5 MHz | |
| Modulation | OOK | OOK | |
| Sensitivity | -100 dBm | -80 dBm | (1.2 kb/s data rate) |
| Out-of-band rej. | 100 dB | 85 dB | |
| RF bandwidth | 500 kHz | 500 kHz | (minimum) |
| Max Data Rate | 20 kb/s | 20 kb/s | |
| Max Signal* | -10 dBm | -10 dBm | |
| Det Saturation* | -80 dBm | -60 dBm | |
| DC Voltage | 2.7 to 3.5 volts | | |
| DC Current | 1.2 mA | 3.0 mA | (maximum) |

*Although the receiver saturates at a level of -80 dBm, it can still easily handle desired signals up to -10 dBm, because the modulation is OOK. When the receiver saturates, its data output goes high, indicating a data “1”. When the incoming RF carrier drops to zero level, the receiver drops out of saturation and the data output goes low, indicating a data “0”.

**Table I**
**ASH Receiver Performance**

first amplifier is turned off. The “on” time of the second amplifier is approximately 1.1 times the “on” time of the first amplifier since the delay line stretches the pulse time to some extent. To illustrate the pulse stretching by the delay line, Figure 7 includes the time response of a 0.5 microsecond SAW delay line to a 0.5 microsecond RF pulse.

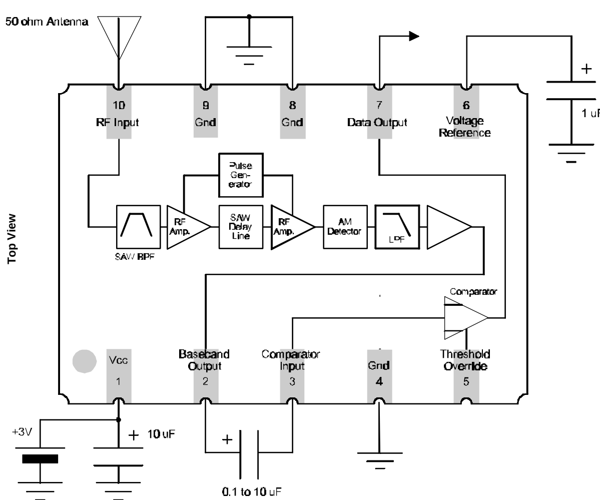
The performance of the resulting ASH receiver is outlined




in Table I.

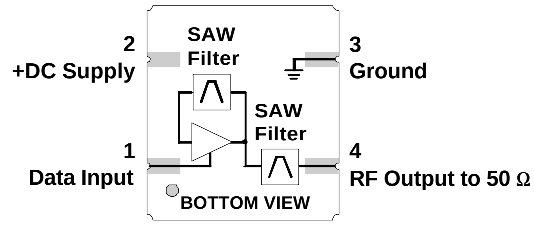
Thus, the performance of this receiver is excellent. For example, the sensitivity is on par with and the DC current drain is one fifth of that currently achieved with superheterodyne IC-based receivers. In addition, the entire ASH receiver is housed in the small 13.7 by 9.4 by 2.54 mm ceramic surface mount package of Figure 8. Figure 9

Figure 8
ASH Receiver Surface Mount Package




is a block diagram of the resulting receiver showing electrical connections to the package. The two pulse generator control resistors and the low pass filter control resistor, see Figure 3, are included inside the surface mount package. The only external components required are three non-critical capacitors, a DC power source and an antenna. The receiver has a single 50 Ohm RF input and its output is CMOS compatible data.

Figure 9
ASH Receiver Electrical Connections

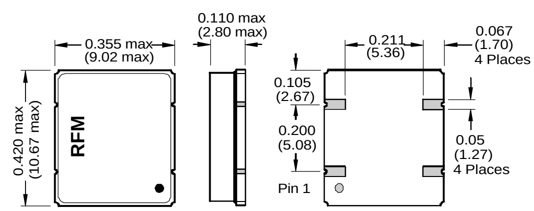



*SAW Hybrid Transmitter*

The companion SAW hybrid transmitter (HX) for the ASH receiver is illustrated in the block diagram of Figure 10 [6]. The oscillator simply consists of an amplifier with a SAW coupled resonator as the feedback element. Using a coupled resonator with its inherent 180 degree phase shift

Figure 10
HX Block Diagram and Electrical Connections

across its 3 dB bandwidth as the feedback device eliminates the need for additional phase shifting elements in the oscillator loop. A second identical SAW is used to filter the output of the oscillator to attenuate its harmonics. These




SAW’s are designed to have 50 Ohm input and output impedances and do not require impedance matching components. The transmitter was designed for ease of use by the engineer and for easy compliance with regulatory agency requirements for radiated harmonic levels. The OOK modulation input is CMOS compatible and the RF output impedance is 50 Ohms. The hybrid is packaged in a ceramic surface mount package, as shown in Figure 11, with dimensions of 10.7 by 9.0 by 2.8 mm. The only

Figure 11
HX Surface Mount Package

external components required are a decoupling capacitor, a DC power source and an antenna. The resulting transmitter has an RF output level of 0 dBm, harmonics 45 to 50 dB below the carrier, peak current consumption of 8 mA at 3 volts, a maximum data rate of 19.2 kb/s and a frequency range of from 300 to 930 MHz.

## NEW SAW-BASED HYBRID TRANSCEIVER

*Meeting Requirements*

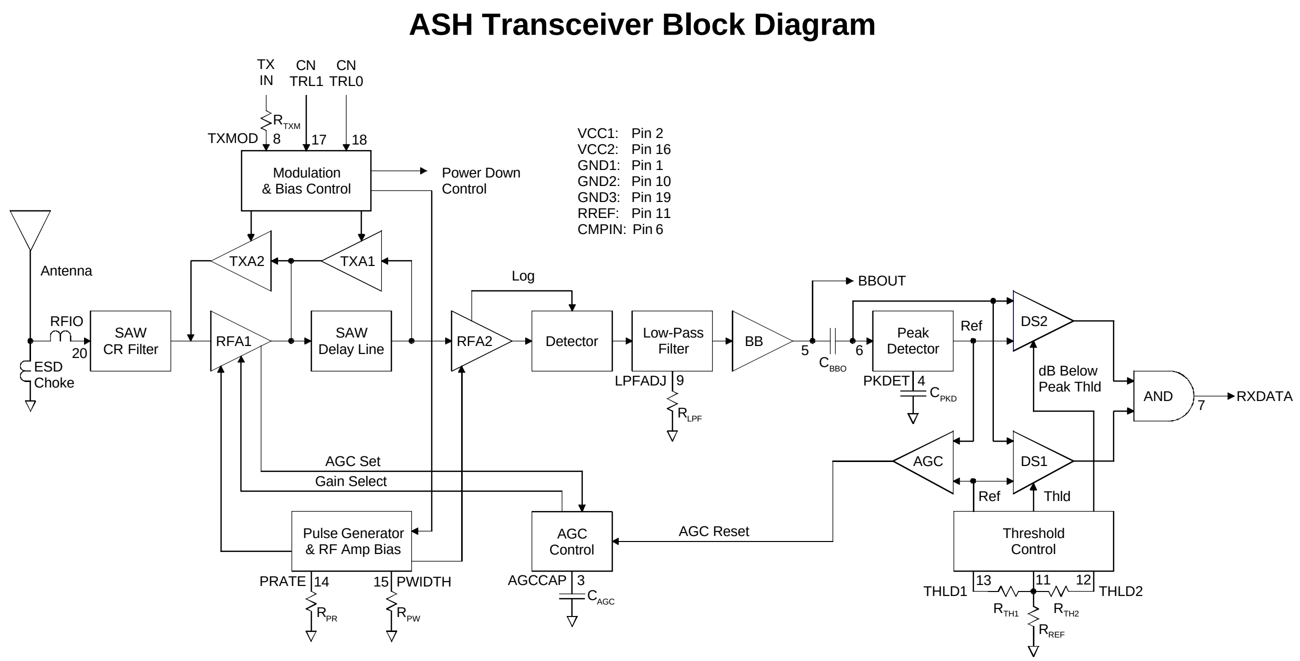



Figure 12

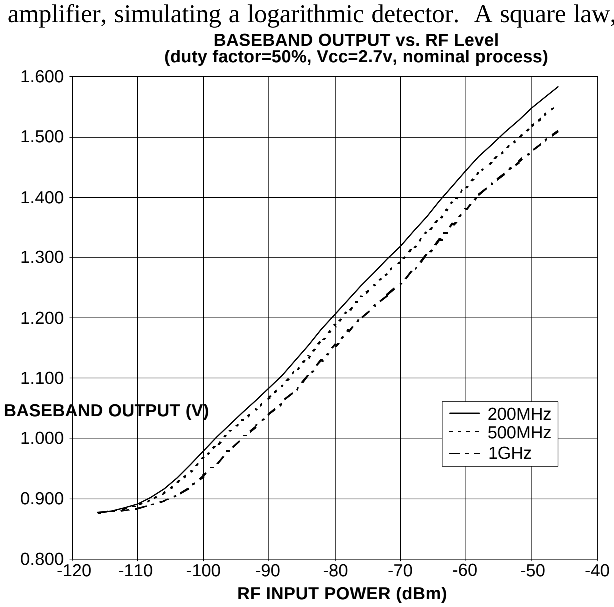
The development of a small hybrid transceiver was driven by the market requirement for short range wireless data links with two-way communication capability. Other requirements included smaller size than the present hybrid receiver and transmitter; lower cost than using separate receiver and transmitter modules; higher data rates (115 kb/s); full receiver sensitivity from 300 to 1000 MHz; a much higher in-band RF saturation level than the present receiver; low current consumption; the capability to work with either OOK or ASK (amplitude shift keyed) modulation and allowing the customer to have access to pulse generator, low pass filter bandwidth, threshold and transmitter power controls.

In order to decrease the size and cost of the transceiver compared to using separate receivers and transmitters, it was very desirable to use the same two SAW devices utilized in the ASH receiver for the transmitter. Referring to the transceiver block diagram of Figure 12, this was accomplished by adding a pair of amplifiers to the custom IC, TXA1 and TXA2, that are turned on in the transmit mode [8]. TXA1 and the SAW delay line used in the receiver form the transmitter oscillator, TXA2 is the transmitter output amplifier and the receiver's input SAW coupled resonator filter acts as the harmonic filter on the transmitter output. Of course, the RF amplifiers in the receiver are disabled in the transmit mode. Using the SAW delay line for frequency stabilization in the transmitter also increases the data rate over that obtained in the HX using a SAW coupled resonator. The Q of the 0.5 microsecond delay line is lower than that of the coupled resonator allowing the new transmitter to be OOK modulated at data rates up to 38 kb/s, double that of the HX. The typical rise time for the modulated oscillator is 7 to 8 microseconds. For higher data rates, ASK modulation is used. This is accomplished by leaving the oscillator amplifier, TXA1, on while modulating TXA2. The typical rise time for the modulated transmitter output, in the ASK mode, is less than 1.0 microsecond. The power output of the transmitter is controlled by the value of the user accessible resistor, Rtxm, in series with the modulation input port. Thus, the ASH receiver architecture was very easy to convert to a transceiver by reusing the same two SAW devices utilized in the receiver to stabilize the center frequency and provide harmonic filtering in the transmitter. Since the same IC provides both the transmit and receive functions and both functions share the same SAW devices, both the size and cost of the new transceiver have been minimized. The new transceiver was designed to take full advantage of the characteristics of SAW coupled resonator and delay line devices to simultaneously simplify and improve performance compared to competing technologies [3].

The original ASH receiver has less sensitivity at 900 MHz than at 434 MHz due to the limited gain bandwidth of the

RF amplifiers in the custom IC. The amplifiers in the new custom IC for the transceiver have a 3 dB bandwidth exceeding 1000 MHz. Thus, the sensitivity at 900 MHz is approximately the same as that at 434 MHz. In order to increase the RF saturation level of the receiver in the new transceiver, it was necessary to make three changes to the original ASH receiver.

Referring to Figure 12, the first change was in the detector. The present receiver uses a single square law detector following the second RF amplifier. This detector and the RF amplifier itself saturate at a receiver input level of -80 dBm. This problem was addressed in the transceiver by using distributed detection along the entire second amplifier, simulating a logarithmic detector. A square law,




Gilbert cell detector was also used at the output of the last amplifier. The outputs of all of these detectors were then summed together and fed into a 3 pole gyrator low pass filter with improved dynamic range, but otherwise similar to the filter used in the original receiver. Thus, as each of the detectors reach saturation level, the outputs of the previous detectors still function. Figure 13 is a plot of the RF input level at the input to RFA1 versus the detected level at the baseband output. Note that the horizontal axis is in dBm while the vertical axis is linear, so the plot indicates a very close approximation to a logarithmic detector.

Figure 13
Transceiver RF Input vs Detected Output

The second change was in the receiver's gain distribution, see Figure 12. The gain in the first RF amplifier, RFA1, was decreased from 50 dB, in the original receiver, to 35 dB, and the gain in the second RF amplifier, RFA2, was increased from 30 dB to 50 dB. This change improved the receiver in two areas. The gain increase of 20 dB in RFA2 increased the log detector range by 20 dB over what could be obtained with a 30 dB gain block, and the gain decrease of 15 dB in RFA1 increased the RF input level that could be handled without saturation by 15 dB, at the delay line input.

The third change was to include an optional AGC (automatic gain control) system in the new transceiver. Even though the saturation level was greatly increased by the two changes previously discussed, the receiver will still saturate at approximately -45 dBm due to saturation in the final stage of RFA1. Referring to Figure 12, a simple stepped AGC was included in the new receiver. When the output level of the final stage of RFA1 is one to two dB into compression, it sets a flip-flop in the AGC control circuit that changes the gain of RFA1 from 35 dB to 5 dB. This increases the RF input level required to saturate the receiver by another 30 dB to -15 dBm. The AGC circuit resets RFA1 back to full gain when the detected signal level multiplied by 0.8 in the baseband circuit drops below the threshold reference for the "fixed" reference data comparator. In that it can be disabled by the user, the AGC function is optional.

There are two reasons for wanting the new receiver to work with either OOK or ASK modulation. The first is the inability of the transmitter to OOK modulate at rates higher than 38 kb/s and the resulting need for ASK rather than OOK modulation to reach 115 kb/s. The second is the demonstrated capability of systems using ASK to operate in the presence of high level amplitude modulated, in-band interfering signals. The new receiver can easily operate with OOK modulation. Operation with ASK modulation is greatly enhanced by the saturation improvements discussed previously. It is necessary that the receiver not saturate on an ASK signal level that represents a data "0", carrier low, or it would not be able to discern the difference between a "1" and a "0".

At higher data rates, it is also highly desirable that distortion in an ASK signal due to frequency band-limiting by either filters in the receiver or in the transmitter does not prevent slicing the detected signal at the correct level to get good data reproduction at the output of the data comparator. The logarithmic detector can make band-limiting distortion even worse. This type of distortion is handled very well in the new receiver with the addition of a data slicer, DS2, see Figure 12, whose threshold is positioned approximately 6 dB below the peak of the detected pulse. This is accomplished by using a peak detector to find the top of the pulse and offsetting the threshold by 6 dB using the slope of the logarithmic detector to determine the correct DC offset from the peak. The output of DS2 drives the input to an AND gate. The other input to the AND gate comes from a

| | | | | |
|---|---|---|---|---|
| Frequency Range | | 300 MHz to 1000 MHz | | |
| Data Rate | 1.2 kb/s | 2.4 kb/s | 115 kb/s | |
| Modulation | OOK | OOK | ASK | |
| | | RECEIVER | | |
| Sensitivity | -105 dBm | -102 dBm | -85 dBm | (50% sampling) |
| Sensitivity | -100 dBm | -97 dBm | NA | (17% sampling) |
| Out-of-band rej. | 100 dB | 100 dB | 100 dB | |
| RF Bandwidth | 500 kHz | 500 kHz | 500 kHz | (minimum) |
| Max Signal | 0 dBm | 0 dBm | -15 dBm* | |
| Det Saturation | -45 dBm | -45 dBm | -45 dBm | |
| Det Sat w/AGC | -15 dBm | -15 dBm | -15 dBm | |
| DC Voltage | | 2.4 to 3.5 volts | | |
| DC Current | 2.5 mA | 2.5 mA | 7.0 mA | (50% sampling) |
| DC Current | 1.5 mA | 1.5 mA | NA | (17% sampling) |
| | | TRANSMITTER | | |
| Power Output | 0 dBm | 0 dBm | 0 dBm | |
| DC Voltage | | 2.4 to 3.5 volts | | |
| DC Current | | 11 mA peak | | |
| Operating Temperature | | -40 to +85 degrees C | | |

*The maximum signal level of -15 dBm with ASK assumes the AGC circuit is enabled and the on to off ratio is at least 10 dB.

**Table II**
**ASH Transceiver Performance**

fixed threshold comparator, DS1, similar to the one used in the original ASH receiver. Both comparator outputs must be high before the gate outputs a high. This prevents noise spikes from either of the comparators from appearing at the data output of the receiver unless both comparators see them. A discussion about how these AND'ed comparators work under all of the possible data conditions will not be included here, since it would require more space than is available for this paper.

Once again, it is optional to the user whether he uses the peak detector referenced comparator or not by either enabling it or disabling it. The fixed reference threshold level for DS1 is set by the user using the external resistor, Rth1. The offset from the peak detector level for comparator DS2 is set by the user using external resistor, Rth2.

Finally, to address the issue of low current consumption, first, the sequencing of the RF amplifiers in the ASH receiver architecture reduces the current consumption by at least 50%. At low data rates, the current consumption can be reduced even further by reducing the duty cycle of the RF amplifiers below 50%. This is accomplished by decreasing the pulse rate in the pulse generator while maintaining the same pulse width. The penalty that must be paid for this lower duty cycle is a decrease in the sensitivity of the receiver that follows the relationship, 10(Log(RFA1 duty factor)). Thus, a 10% duty factor would decrease the sensitivity of the receiver by 10 dB over that which could be obtained with RFA1 on 100% of the time. Second, the new transceiver was designed to have a "power down" mode that is invoked by pulling the CNTRL1 and CNTRL0 ports to a CMOS low, see Figure 12. The "power down" control turns both the receiver and the transmitter off so that the only current drawn is the leakage current of the IC. If this mode is used, the receiver is periodically turned on to see if a recognizable wake-up code is being transmitted. If the receiver detects such a code, it remains on to receive the data that follows. An example would be turning the receiver on for 10 ms every second. This would reduce the average current consumption of the receiver by a factor of 100. The new receiver typically consumes 1.5 ma of current when set up for a 2.4 kb/s data rate; thus, a reduction by a factor of 100 would reduce the average current consumption to 15 microamps. This makes the transceiver useable in lithium coin cell powered devices such as ID cards.

*Transceiver Performance and Characteristics*

Figure 14

The performance of the resulting transceiver is summarized in Table II. Referring to Table II, the performance of the receiver in the new transceiver exceeds the performance of the original ASH receiver in the areas of sensitivity, detector saturation level, frequency range and data rate. In addition, unlike the original receiver, it can operate with either OOK or ASK modulation. The transmitter modulation rate exeeds that of the original HX by a factor of 2 in the OOK mode, and the new transmitter has ASK modulation capability.

The final surface mount package dimensions for the complete transceiver are 10.2 X 7.06 X 2.03 mm. The case outline drawings for the new hermetic package are shown in Figure 14. Figure 15 includes a package outline, simplified block diagram, required external components and external electrical connections for the hybrid transceiver. The external components and electrical connections of Figure 15 configure the device for either OOK or ASK modulation and make use of every available option. Note that the number of external components has increased to 13 compared to a total of 4 for the original ASH receiver and hybrid transmitter combined. As was stated previously, it was desirable to allow the end user access to pulse generator, low pass filter bandwidth, threshold and transmitter power controls. This accounts for the majority of the additional external components.

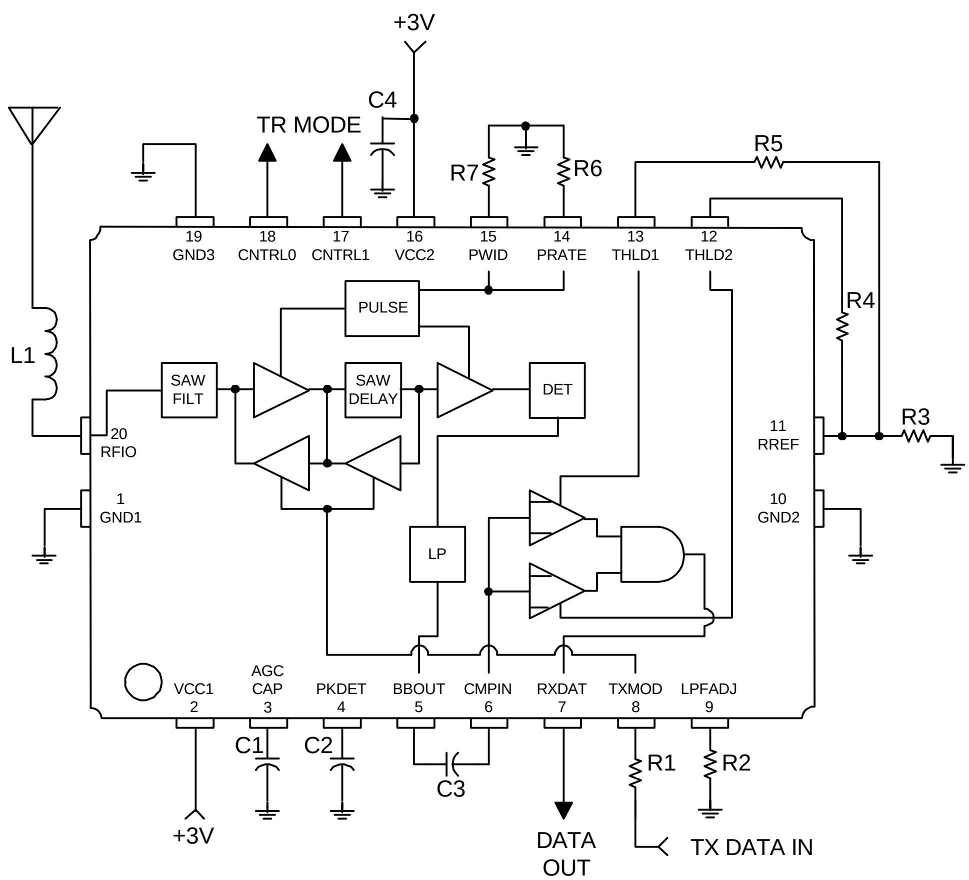
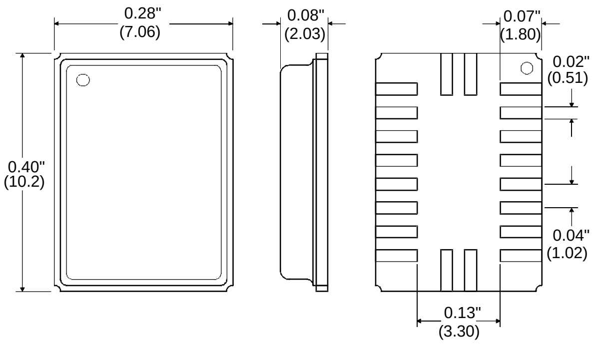



Figure 15
ASH TRANSCEIVER ELECTRICAL CONNECTIONS

**ASH Transceiver Outline Drawing**




Referring to Figure 15, capacitor C1 sets the time constant for the AGC release, C2 sets the time constant for the peak detector, C3 is the coupling capacitor between the baseband output and the comparator input and C4 is for decoupling on the power supply line. The transmitter peak power output is adjusted with R1 and the low pass filter bandwidth is adjusted with R2. R3 is a reference resistor to aid in the setting of the two comparator threshold levels with R4 and R5. R6 and R7 set the pulse rate and pulse width of the sampling pulse generator. Finally, L1 matches the impedance of the external antenna to the input impedance of the SAW filter. The availability of these adjustment points makes the transceiver very versatile.

## CONCLUSION

A fundamentally new transceiver architecture was conceived and successfully realized. The receiver sensitivity was improved 5 dB, to -105 dBm, at a 1.2 kb/s data rate, and its dynamic range was improved 65 dB over the previous technology. Its data rate was increased by a factor of 5, to 115 kb/s, and it is capable of either OOK or ASK modulation. Finally, its full sensitivity frequency range was increased from 450 MHz to 1000 Mhz.

The transceiver was designed around the capability of SAW's rather than designing the transceiver first, with the required SAW specifications coming as an afterthought [3]. The delay of a SAW delay line was used as a storage element to create a time diversity receiver while using its amplitude characteristics to perform a filtering function. The same delay line's phase characteristics were then used to create the transmitter oscillator. On the antenna port, a SAW coupled resonator filter was used as a preselector filter on the receiver input, and it was used to filter out harmonics on the output of the transmitter. The use of the same two SAW devices in both the receiver and the transmitter made it possible to include the entire transceiver in a 10.2 X 7.06 X 2.03 mm surface mount package. The components inside the hybrid package consisted of a custom IC containing all of the active transmitter and receiver functions, the two SAW devices and three small coils.

The small size, low power consumption, high data rate, high dynamic range, excellent sensitivity, excellent selectivity and low cost of the new transceiver make it useful for wireless short range applications involving watches, ID cards, hand-held apparatus, computers, computer peripherals, tags and many more applications.

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