Using the PRISM® Chip Set for Low Data Rate Applications

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Introduction

The PRISM chip set has been optimized to address high data rate applications with up to 4 MBPS data rates. The PRISM can also be utilized for low data rate applications. To implement low data rate applications (below 250 KBPS) the designer needs to address design considerations in the following areas:

A. Selection of external filtering supporting the PRISM components.

B. Limitations on filter cut off frequencies of the HFA3724 internal Low Pass Filters.

C. Selection of appropriate carrier and clock oscillators to achieve the desired performance, given the HSP3824 internal Acquisition and Tracking loop integration constraints.

The system designer should also evaluate the option where the radio maintains its high data rate configuration but transmits the data using infrequent high data rate burst packets.

Where the system requires that the radio operate at low rates (<250 KBPS), the designer must address the areas highlighted on the PRISM block diagram shown in Figure 1.

Description

A. External IF Filtering

The band pass filters shown between the HFA3624 and the HFA3724 labeled as BPF1a and BPF1b on Figure 1 are centered at IF and filter the spread wideband waveform before demodulation on the receive side and before the final upconversion on the transmit side.

One might think that the TX filter can be avoided but it is required to meet the sidelobe suppression specifications according to FCC requirements.

For the high rate configuration of the PRISM, a recommended implementation is to use SAW BPFs centered at 280MHz with a BW of about 17MHz. This is assuming an 11MHz chip rate (thus 22MHz spread null to null bandwidth). A recommended device that meets these requirements is the ToyoCom TQS-432.

If a low data rate configuration is implemented then substitute IF filters need to be identified that will filter to the channel bandwidth of the spread waveform at the lower chip rate. The designer can use any IF center frequency within the HFA3724 range. The designer must be sure, though, that the identified filter meets the transmission spectral mask requirements for FCC for the 2.4MHz ISM band. SAW filters

PRISM PCMCIA Reference Radio Block Diagram

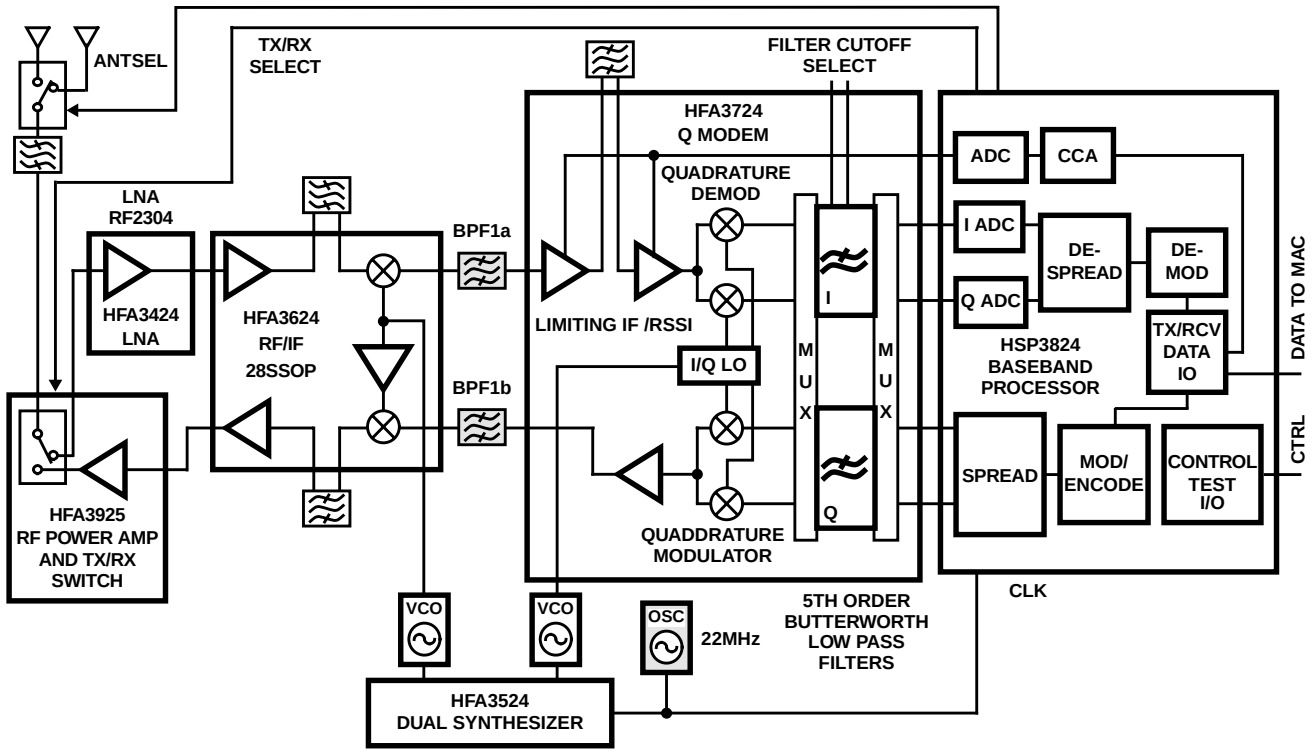


FIGURE 1. PRISM™ CHIP SET BLOCK DIAGRAM

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for PCMCIA applications are not widely available at these specifications and a custom design may be required.

B. Limitations of HFA3724 LPFs

The HFA3724 includes a set of baseband low pass filters as the final filtering stage of the complex spread waveform. These are placed before the In phase (I) and Quadrature (Q) A/D converters for baseband processing. These filters are shown on Figure 1, as LPFs (Rx) and LPFs(TX). There are four cut off frequencies that can be selected for these LPFs. The cut off can be selected to be 17.6MHz (for a chip rate of 22 MCPS), 8.8MHz (for a 11 MCPS rate), 4.4MHz (for a 5.5 MCPS rate) or 2.2MHz (for a 2.75 MCPS rate). In addition these cut off frequencies are tunable through an external resistor by ±20%. The user can select one of the four discrete cut off frequencies. The lowest cut off is set for a spread rate of 2.5MHz chip rate and any chip rates lower than this will require the design of external filtering between the HFA3724 outputs and the HSP3824 A/D inputs. The HFA3724 I and Q LPFs are fifth order Butterworth filters and equivalent external filters need to be designed at the lower cut off specifications.

C. Selection of Carrier Frequency and Clock Oscillators

The HSP3824 performs the baseband demodulation function. The design includes digital signal acquisition and tracking loops for both the symbol timing clock and the carrier frequency.

The primary concern when the radio needs to be operated with a low instantaneous data rate is that it requires a wide bandwidth to accommodate oscillator frequency tolerances.

As an example at 2400MHz and ±25 PPM, the radio frequencies at each end of the link can be off by as much as 120kHz from each other. This offset must be well within the basic data bandwidth of the radio in order for it to be tolerated without degrading the performance of the link. If it is not, a frequency sweep would be needed to find the signals and this is not built into the radio design. Operating the radio with wide data bandwidth and low data rate is inefficient and would cause unacceptable loss in performance.

If the PRISM is used as a spread spectrum system with 11 chips per bit spreading ratio, this then gives it an IF bandwidth of nominally 22MHz null to null at 1 MSPS. We filter to 17MHz to allow closer packing of the channels. While this seems wide compared to the frequency offset, remember that this is a direct spread system. The first stage of processing the signal despreads it and collapses it to the data bandwidth. In PRISM this is done in a time invariant matched filter correlator. This correlator has an FIR filter structure where the PN sequence is substituted for the tap weights. The filter is operated at baseband, so the I and Q quadrature components are separately correlated with the same sequence. The outputs of the I and Q correlators are the vector components of the correlation. These will show a distinct peak in magnitude (compressed pulse) when correlation occurs. Correlation performance falls off when the signal is not stationary (i.e. has offset). The correlator convolves a stationary signal, (the PN sequence) with the input signal. The vector correlation is being rotated throughout the correlation by the offset frequency. This means that the signal correlates at one angle at the start of a symbol and at a different angle at the end. If this angular difference is small, no great loss occurs. The net correlation goes as the vector sum of all the correlation angles between the start and the end of the symbol as shown below. Thus the magnitude falls off to zero if the offset causes a baseband phase rotation of one cycle per symbol. The magnitude is obviously maximum at no offset and falls off about 0.22dB at 45 degrees rotation. This corresponds to the 120kHz offset (~1/8th of 1 MBPS).

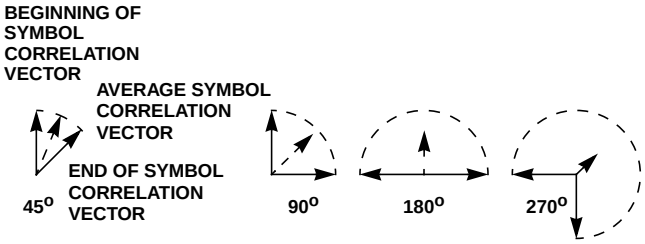


FIGURE 2. PRISM™ CORRELATION PERFORMANCE vs FREQUENCY OFFSET

Crystal oscillators of better than ±25 PPM accuracy can be purchased, but their cost goes up significantly as the tolerances are tightened. Given this offset, we must be sure that the receiver can accept the offset. At a data rate of 250 KBPS, the same offset loss occurs with a frequency offset 1/4th as large. This means that to get the same performance, we need oscillators specified to ±6 PPM. To go lower in data rate means tightening up the specification even further.

Similar consideration needs to be taken for the clocks that are used to run the baseband processor itself. The symbol timing clock tracking algorithm operates over 128 symbol integration intervals. To maintain acceptable BER performance the symbol timing phase drift must be less than 1/8th chip over the 128 symbol integration interval. Remember that we are tracking the peak of the compressed pulse which is 2 chips wide and must keep the straddling loss low by sampling close to the peak. For a 0.25 MBPS data rate, the chip rate is 2.75 MCPS. With this rate, the integration interval is 512ms which translates to an oscillator within ±89 PPM to keep the drift less than 1/8th chip (0.045ms). Since the spread rate to data rate ratio is not changed at the lower data rates, this tolerance is not effected by lower data rates.

HIGH RATE BURST TRANSMISSIONS WITH LOW AVERAGE RATE

Generally, the incentive to use lower data rates is to achieve a given range with the minimum amount of power. We can show that this is also achievable by using the radio in its high data rate design configuration. The PRISM is a packet radio communications device and, as such, can send the data in a short burst with open environment ranges up to 5 miles. This has significant potential for power savings and reduction in interference. In the high data rate configuration the design considerations mentioned above are no longer of concern.

The system approach is to accept the 1 MBPS data rate of the radio as long as the achievable range is acceptable, and use it in a short burst mode which is consistent with its' packet nature. With a low power watch crystal, the controller can keep adequate time to operate either a polled or a time allocated scheme. In these modes, the radio is powered off most of the time and only awakens when communications is expected. This station would be awakened periodically to listen for a beacon transmission. The beacon serves to reset the timing and to alert the radio to traffic. If traffic is waiting, the radio is instructed when to listen and for how long. In a polled scheme, the remote radio can respond to the poll with its traffic if it has any. With these techniques, the average power consumption of the radio can be reduced by more than an order of magnitude while meeting all data transfer objectives.

Even using the 802.11 network protocols, the low data rate can allow low average power operation. The Media Access Controller (MAC) or network processor can operate the radio in the sleep mode except for the times it needs to receive the beacon signals.

The short, fast transmission is good for several reasons. First, if the signal is corrupted for any reason, a retransmission will occur without noticeable delay. Secondly, interference to other spectrum users is of brief duration. Third, and most important, the burst can be sent into small time gaps in the medium, which makes it more effective against certain type of interference in the ISM band. For example, if an 802.11 FH network is operating in the vicinity, it could cause interference with this network. The FH network has, however, a brief guard time when it is hopping and none of its stations are on the air. This time can be used to transmit the burst communications packets. Additionally, the microwave oven has been identified as an interference source of concern within the 2.4GHz ISM band. The oven is a pulsed source with about a 50% duty cycle. The gaps allow messages of about 1000 bytes through at the 1 MBPS rate.

In addition, the system can be set at its sleep mode most of the time to achieve low power consumption. It only needs to operate at full power consumption during the transmission of a packet or during the expected window for received packets.

The communications range achievable depends on the nature of the environment. A line of sight (LOS) path allows the best range. With 1W and 6dB gain in the antennas, you can readily achieve a 5 mile LOS range. The propagation loss at S-band is less than 0.5dB per mile in heavy rain, so weather is not usually of great concern. Antennas with 6dB gain are for fixed installations with one on one links. Mobile and network installations use omnidirectional antennas with around 0dB gain. Indoors, the range is much reduced by extra losses due to walls and other obstructions. The power is also usually reduced to 100mW for interference and safety concerns. These reduce the available range, but most applications will achieve sufficient range (300 ft.).

Antenna diversity is also used in the PRISM design to combat multipath interference. Since the PRISM waveform is wideband by being spread at the chip rate, the 1 MBPS data rate is not a contributor to multipath problems and a lower data rate is of no benefit.

So, in general, unless it is required to use low instantaneous data rates to achieve some other purpose, the packet capabilities of PRISM will serve well for these applications in its normal high data rate design configuration.

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