Using the PRISM Chip Set for Timing Measurements (Ranging)

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Many applications use the properties of Direct Sequence Spread Spectrum to establish accurate timing which is useful for ranging and time dissemination. DS receivers use a wide bandwidth and correlation techniques to measure the time of arrival of signals to a high degree of accuracy. While the PRISM™ chip set was not designed specifically for this, it does, however, have all the required assets to do medium accuracy time of arrival measurements.

It is quite simple to use the PRISM radio for accurate timing measurements. All of the timing information is available from the HSP3824 Baseband Processor. At the sending end, the asynchronous rising edge of TX_PE will reset the counter of the internal transmit state machine which will output the header and data a fixed amount later. This is timed to within one MCLK (22MHz), so there is an ambiguity of 0.5 MCLK (45ns) in this time. Additionally, the setup to hold time of TX_PE to MCLK is not specified in the data sheet. This can, however, be included in the calibration measurements. Thus, all you have know is the offset between MCLK and the source timing to get even better resolution. This offset can be sent in the data portion of the message. The length of the preamble and header is fixed (128 + 64 = 192), so the start of data is at a fixed offset in bits.

On the receive side, MD_RDY is output after the CRC-16 check. Thus it indicates the precise time the first bit of the data part of the message is received. This is, of course, 192 bits after the arrival of the first bit of the packet. The MD_RDY offset from MCLK also needs to be taken into account to resolve the overall offset between the correlation and the signal timing to within a fraction of MCLK. On the data sheet, this is listed as t_{D3} which has a maximum value of 25ns.

The accuracy the receiver is going to get in capturing the asynchronous correlation peak in the header is ±0.25 MCLK or about 11ns. To improve on this, more heroic processing can be attempted. Over the length of the message, the timing can be refined further by averaging, as long as there is an offset between the RX and TX clocks. That is, the timing will slowly drift and be reset, allowing the external system to judge when in the process the timing was at the peak. Since this occurs half way between resets, it is not too hard to find. Thus, the ultimate receive time accuracy is probably about 0.1 MCLK or 5ns. This ultimate accuracy will take some extra computation to achieve.

To the time of arrival measurement you need to add the propagation delay of ~1ns per foot, delays in the RF and IF filters and in other devices in the path. The propagation delay could be longer if a multipath signal is the one chosen by the receiver due to the direct path being blocked.

In using this capability, the designer will need to take accurate measurements to calibrate the delays encountered in the PRISM hardware. Since the baseband processor is a state machine, its delays will be fixed offsets from the MCLK with minor variations over temperature and production tolerances.

Figure 1 shows some of the elements of the delay. The scale is not accurate; specifically, the clock rate is grossly under represented for clarity.

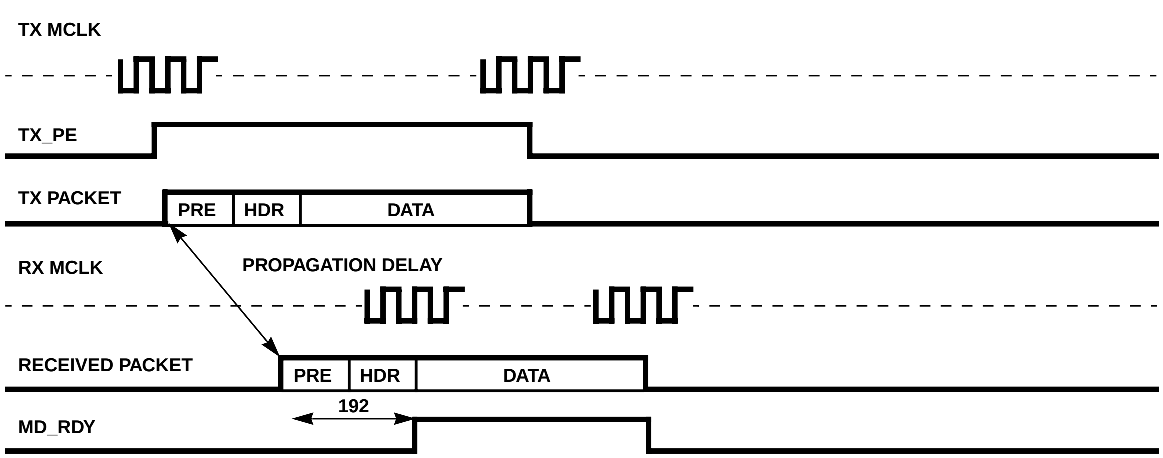

FIGURE 1.

The total delay from initiation to response is as follows:

$T_D = t_{T\text{-}M} + t_{D2} + t_{Tx} + t_{IF} + t_{RF} + 192\mu s + t_{PROPAGATION} + t_{RF} + t_{IF} + t_{Rx} + t_{MCLK} + t_{D3}$

Where:

T_D = total delay (TX_PE to MD_RDY)

$t_{T\text{-}M}$ = delay from TX_PE to next rising edge of MCLK

t_{D2} = MCLK to TXCLK delay

t_{Tx} = delay through the transmit state machine to IF

t_{IF} = IF filter and amplifier delays

t_{RF} = RF filter and amplifier delays

192µs = length of preamble and header

$t_{PROPAGATION}$ = propagation loss due to speed of light (about 1ns per foot)

t_{RF} = RF filter and amplifier delays

t_{IF} = IF filter and amplifier delays

t_{Rx} = delay through the receive processing from IF

t_{MCLK} = accuracy of tracking the actual received timing to the local MCLK

t_{D3} = MCLK to MD_RDY delay

All processing operations are timed by the transmit and receive MCLKs (22MHz) which can be also slaved to or shared with the source's and sink's clocks. If 802.11 compliant operation is not needed the MCLK can be other than 22MHz to allow sharing with the application.

The resolution can be improved over the techniques discussed above by using many round trips and averaging. This technique has the interrogator and transponder send the message around the loop many (hundreds) times to achieve fine resolution by noise averaging. The accuracy should be improved by the square root of the number of times around the loop. This only interpolates over the one chip timing resolution and does not do anything for static offsets in the equipment, however.

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