WirelessUSB™ LS Theory of Operation

WirelessUSB LS System Overview

WirelessUSB™ LS adds to the existing WirelessUSB portfolio a low-cost 2.4-GHz wireless solution that enables the wireless gaming console peripheral device market and displaces the 27-MHz solutions currently used for low-end retail PC Human Interface Device (HID) applications. A WirelessUSB LS system typically consists of a WirelessUSB LS Bridge and at least one WirelessUSB LS HID. The host PC is not aware of the wireless connection, since the interface to the host acts like a normal wired USB HID connection. Therefore, there is no special software required on the host PC in order to support WirelessUSB LS.

Figure 1 is a block diagram of the WirelessUSB LS radio.

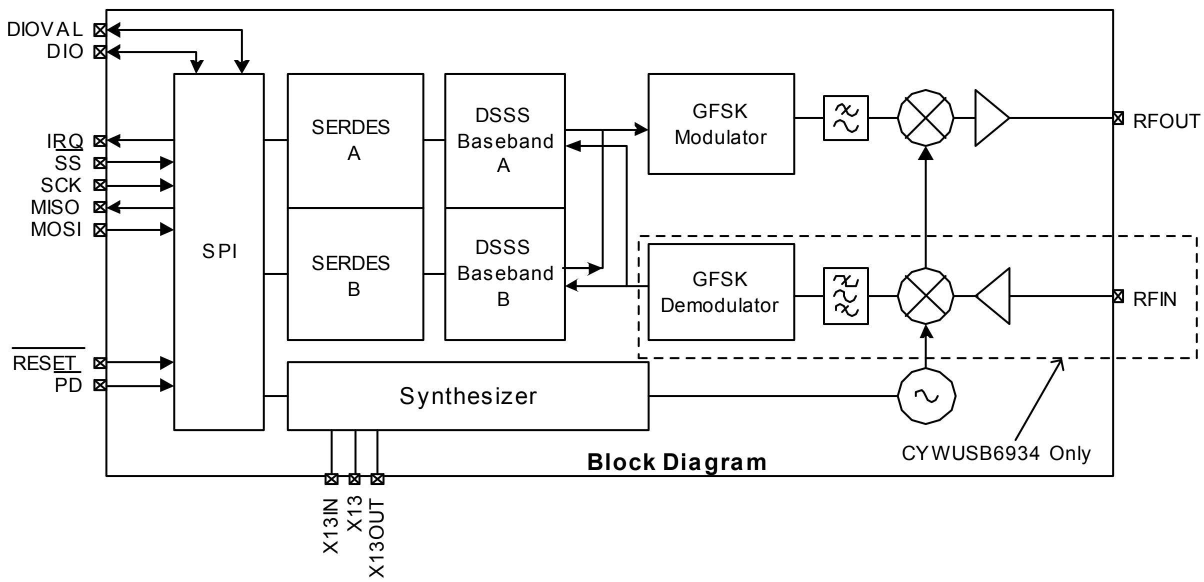

Figure 1. WirelessUSB LS Block Diagram

Direct Sequence Spread Spectrum

WirelessUSB LS utilizes a 2.4-GHz direct sequence spread spectrum (DSSS) radio interface. DSSS generates a redundant bit pattern for each bit to be transmitted. This bit pattern is called a "chip" or a pseudo noise code. Notice in *Figure 2* that the pseudo noise code is a binary signal that is produced at a much higher frequency than the data that is to be transmitted. Because it has a higher frequency, it has a large bandwidth that spreads the signal in the frequency domain (i.e., it spreads its spectrum). The nature of this signal makes it appear that it is random noise.

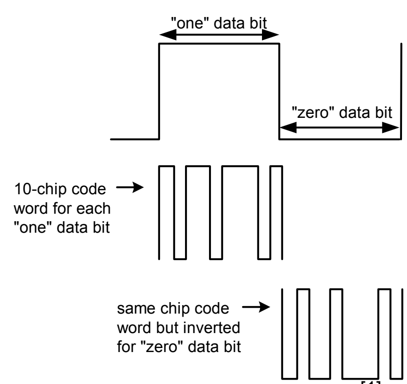

Figure 2. Pseudo Noise Code[1]

Note:

1. *Figure 2* shows the concept of PN Codes using 10 chip PN codes for illustration purposes only. The LS uses 32 chip and 64 chip PN Codes.

Contrast the spread waveform of a DSSS signal with the narrowband waveform of a traditional radio signal, both represented in *Figure 3*. The wide bandwidth provided by the pseudo noise code allows the signal power to drop below the noise threshold without losing any information. This allows DSSS signals to operate in noisy environments and reduces the interference caused by traditional narrowband signals. The longer the chip is, the greater the probability that the original data can be recovered, and, of course, the more bandwidth required. See the section below on Gold Codes for more information on the 32-bit and 64-bit pseudo noise codes used in WirelessUSB LS.

The receiver uses a locally generated replica pseudo noise code and a receiver correlator to separate only the desired coded information from all possible signals. A correlator can be thought of as a very special matched filter: it responds only to signals that are encoded with a pseudo noise code that matches its own code. Thus a correlator can be "tuned" to different codes simply by changing its local code. This correlator does not respond to man-made, natural, or artificial noise or interference. It responds only to signals with identical matched signal characteristics and encoded with the identical pseudo noise code. Even if one or more bits in the chip are damaged during transmission, statistical techniques embedded in the radio can recover the original data without the need for retransmission.

Auto Correlation

Auto correlation is the correlation of a variable with itself over successive time intervals, in our case the pseudo noise code. Pseudo noise codes should have a high autocorrelation factor so that the receiver's correlator correctly matches the received pseudo noise code with its own code. For example, if "1010" was used as the pseudo noise code, the following sequence shows that the correlator would match the code in two separate time positions (**1010** – 0101 – **1010** – 0101). If "1001" was used instead, the correlator would only match the code in a single time position allowing the correlator to correctly process the incoming data stream (1001 – 0011 – 0110 – 1100). WirelessUSB LS uses pseudo noise codes that have a high auto correlation factor (see section on Gold Codes).

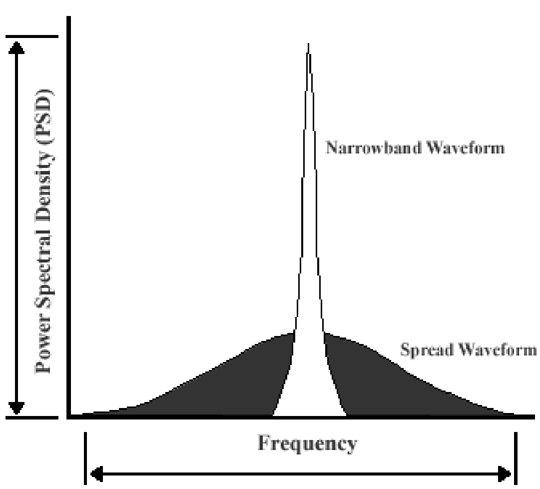

Figure 3. Spread Signal

Cross Correlation

Cross correlation is the statistical correlation between two different signals as a function of relative time between the signals. In other words, cross correlation measures how unique different pseudo noise codes are. If pseudo noise codes are used that have a low cross correlation factor their signals will not interfere with each other. For example, if "1001" and "1100" are used as pseudo noise codes, if "1100" is time shifted it becomes "1001" and can be incorrectly matched to by the correlator looking for "1001" and not "1100." If "1001" and "1011" are used instead, "1011" will never be incorrectly matched by the correlator looking for "1001" because these two pseudo noise codes never match no matter how they are shifted. WirelessUSB LS uses pseudo noise codes that have a low cross correlation factor (see section on Gold Codes).

Gold Codes

WirelessUSB LS uses sets of Gold Codes as pseudo noise codes in order to enable multiple devices to simultaneously transmit on the same frequency. Gold Codes exhibit high auto correlation and minimal, well defined, cross correlation levels with all other members of the set. Gold Codes are excellent pseudo noise codes for code division multiple access (CDMA) systems.

WirelessUSB LS can use 32-bit or 64-bit Gold Codes. There are pros and cons to each code length. 32 bit Gold Codes allow a data rate of 32-kbps, while 64-bit Gold Codes allow a data rate of 16 kbps. On the other hand, using 64-bit Gold Codes has a greater probability of recovering the data due to the longer chip length. Analysis has shown that in order to avoid more than one false correlation in one "day" of use, the maximum number or errors allowed in a 64-bit code is ten, and for 32-bit codes it is one. Tolerance to errors can be improved through the use of error correction techniques implemented in firmware. Also there are twice as many 64 bit Gold Codes as there are 32-bit Gold Codes. (There are about fifty 64-bit Gold Codes that can be used by WirelessUSB LS.)

Frequency Division Multiple Access

WirelessUSB LS not only separates transmissions by code, it also separates transmissions by frequency. WirelessUSB LS divides the 2.4-GHz ISM band into 79 distinct frequency channels. This allows devices to transmit distinct signals by either using a unique pseudo noise code or a unique frequency. Two signals will not interfere unless they are using the same frequency channel and the same pseudo noise code. Observe that signals A and B in *Figure 4* use the same Gold Code but transmit on different frequencies, while signals C and D transmit on the same frequency but use different Gold Codes. Theoretically, hundreds of WirelessUSB LS devices could be operating in the same physical space at the same time.

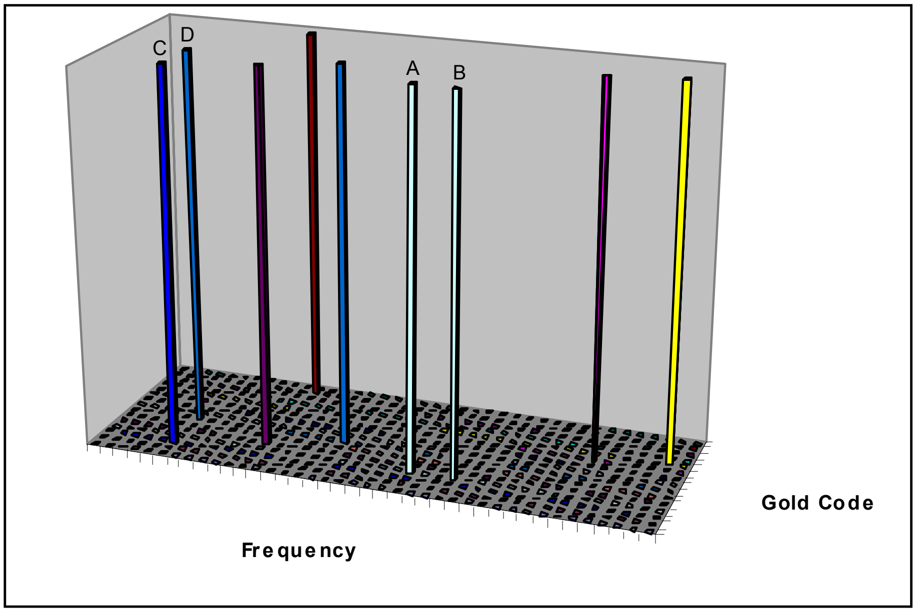

Figure 4. Frequency – Pseudo Noise Code Combination

WirelessUSB LS Systems

There are two varieties of WirelessUSB LS devices: transmit-only devices and transceiver devices. Transmit-only HID devices are used in 1-Way WirelessUSB LS networks, while transceiver HID devices are used in 2-Way WirelessUSB LS networks. Bridge devices always use the WirelessUSB LS transceiver. The current 1-Way and 2-Way WirelessUSB LS HID protocols are targeted at 1-to-1 and 2-to-1 networks. The protocol is executed in external Microcontrollers that interface to the WirelessUSB-LS Chip. Many other applications including non-HID and N:1 HID applications can easily be implemented with WirelessUSB LS, but different protocols may be more applicable.

WirelessUSB LS 1-Way HID Networks

WirelessUSB LS 1-Way networks utilize a communication protocol that emphasizes transmitter simplicity and is an ideal low cost, low power wireless solution for HID applications. Each HID device contains a WirelessUSB LS transmitter while bridges contain a WirelessUSB LS transceiver as shown in *Figure 5*. For more information please read *WirelessUSB LS 1-Way HID Networks*.

WirelessUSB LS 2-Way HID Systems

WirelessUSB LS 2-Way networks contain a back channel allowing a HID to receive messages from the bridge. This back channel allows WirelessUSB LS 2-Way HIDs to establish a connection to the bridge, receive Ack/Nak messages from the bridge and receive Data messages from the bridge. All devices in WirelessUSB LS 2-Way networks contain transceivers as shown in *Figure 6*. For more information please read *WirelessUSB LS 2-Way HID Networks*.

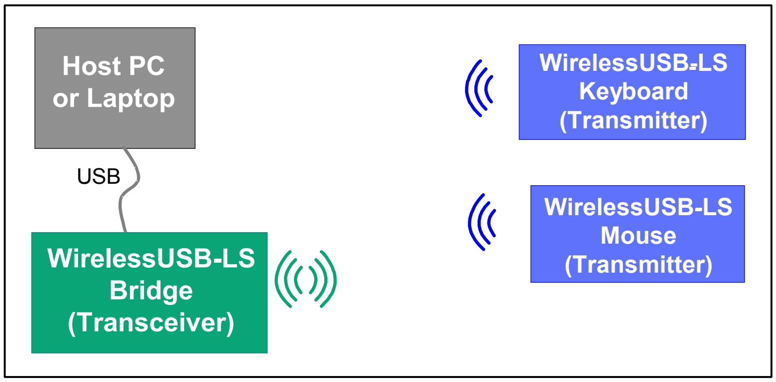

Figure 5. 1-Way WirelessUSB LS HID System

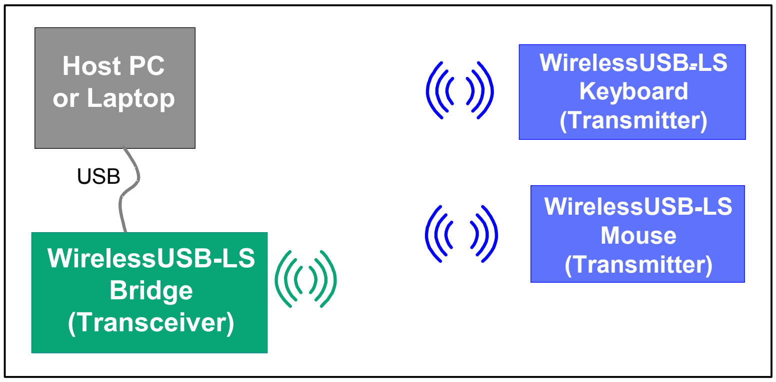

Figure 6. 2-Way WirelessUSB LS HID System

Other WirelessUSB LS Non-HID Systems

- Non-HID applications may benefit from customized protocols specifically designed for each network.
- Non-HID networks could use a polling scheme to reduce the amount of overlapping HID transmissions. WirelessUSB LS is flexible and robust enough to be used in a variety of environments including barcode scanners, Point of Sale (POS) terminals, TV remotes, and wireless gamepads with rumble packs.

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