SPREAD SPECTRUM FOR WIRELESS SYSTEMS USING PIC BASED MICRO-CONTROLLERS AS A SPREADER

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Spasov G., Ribov B., Spread Spectrum for Wireless Systems using PIC Based Micro-Controllers as a Spreader. *DSSS (Direct Sequence Spread Spectrum) is a spread spectrum approach that mixes the transmitted data with pseudo-random noise – the PN-code. This results in the expansion of the data bit into multiple bits, and results in a wider frequency spectrum – a "spread spectrum".*

By using different PN-codes, a larger number of transmission streams, and therefore users, are allowed in the same frequency band. The multiple streams do not interfere with each other provided their PN-codes differ sufficiently. Receiver uses a sliding correlator to compare PN-codes and identify individual transmission streams in designing wireless ICs. As a result, the transmitted energy per bandwidth is less than in narrow band transmission.

This paper describes implementation of PIC16F84 as a spreader micro-controller. All low-cost PIC based micro-controllers can be used, too.

PN code used in this paper is an 11-bit code sequence called the Barker Code. It gives processing gain of 10.4 dB theoretically.

Keywords: Wireless LAN, DSSS, Spread Spectrum, Barker Code

1. Abstract

The term "***spread spectrum***" simply means that the energy radiated by the transmitter is spread out over a wider amount of RF spectrum than would otherwise be used. By spreading out the energy, it is far less likely that two users sharing the same spectrum will interfere with each other. This is an important consideration in an unlicensed band, which why the regulatory authorities imposed spread spectrum requirements on radios which transmit over –1dBm (about 0.75mW) in the following bands:

TABLE 1. WORLD WIDE UNLICENSED FREQUENCY ALLOCATION RF POWER LIMITS

BAND	FCC REGS (US)	ETSI (EUROPE)	MPT (JAPAN)
902-928MHz	<1000mW	N/A	N/A
2400-2483.4MHz	<1000mW	<100mW	N/A
2471-2497MHz	N/A	N/A	<10mW/MHz
5725-5875MHz	<1000mW	<100mW	N/A

In the U.S., these bands are collectively designated as Industry, Science and Medicine (ISM) bands. Operation in these bands with approved devices does not require an FCC license. By waiving licensing requirements, these bands have been made generally accessible to virtually anyone. This is mainly why the ISM bands are so important for commercial and customer applications.

2. Spread Spectrum methods

As mentioned above, radios employing spread spectrum methods are allowed to radiate up to 1.0W (30dBm) of RF energy, as compared to less than 1mW for non-spread radios. There are two common types of spread spectrum systems. The easiest to understand is Frequency Hopped Spread Spectrum (FHSS). In this method, the carrier frequency hops from channel to channel in some pre-arranged sequence. The receiver is programmed to hop in sequence with the transmitter. If one channel is jammed, the data is simply retransmitted when the transmitter hops to a clear channel. The major drawback to FHSS is limited data rate. In the 2.4GHz band, FCC regulations require that the maximum occupied bandwidth for any single channel is 1MHz. This effectively limits the data rate through this type of systems about 1Mbps.

By contrast, Direct Sequence Spread Spectrum (DSSS) systems in the ISM bands provide much higher data rates [1]. DSSS systems do not jump from frequency to frequency. Instead, the transmitter actually spreads the energy out over a wider portion of the RF spectrum. This can be accomplished by combining the data stream with a much higher rate Pseudo Random Numerical (PRN) sequence via an XOR function (Figure 1).

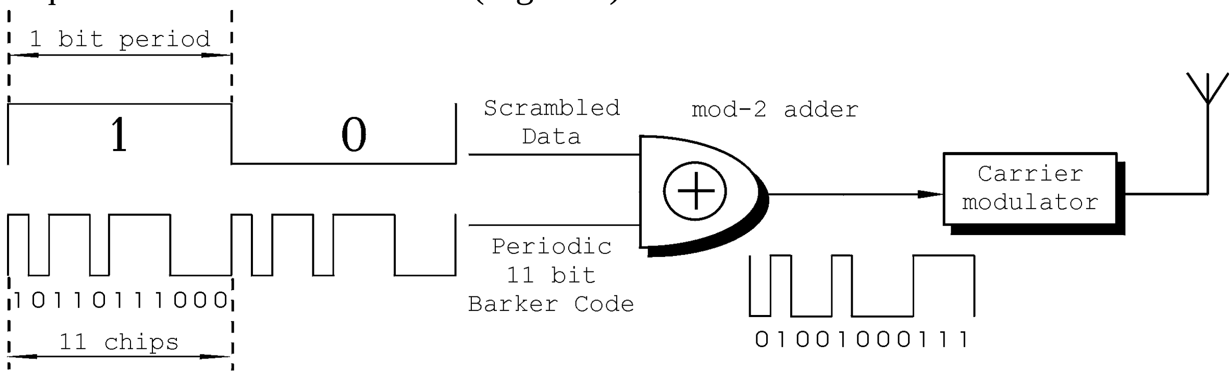


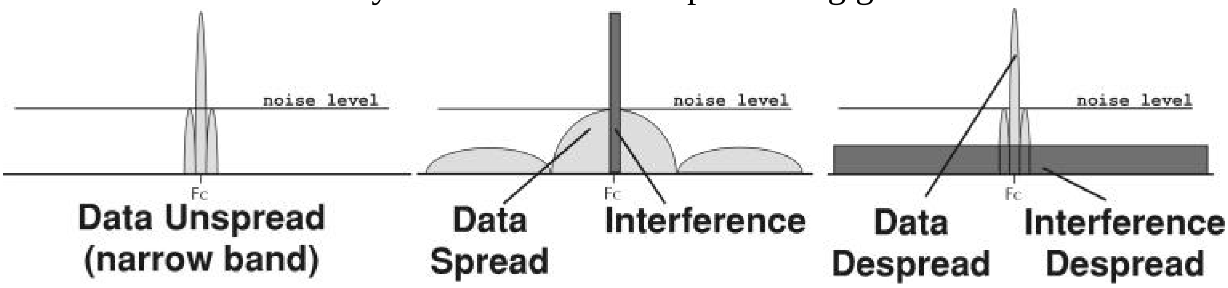
Figure 1 – Combining PRN sequence and data

The result is a digital stream at the same rate as the PRN. When the higher speed digital stream modulates the RF carrier, the result is a spreading of the RF energy.

The individual 1's and 0's that make up the PRN are called "chips". They are distinct from the "bits" in the data stream because chips are predetermined by the PRN sequence and hence, contain no information. The ratio of the chip rate (C) to the data rate (R) is called processing gain. It can be 7, 11, 13, 15, 16 or higher chips/bits. The IEEE 802.11 Standard specifies an 11 chip PN sequence (Barker code), which will be used for this example.

$$\text{Processing Gain} = 10\log_{10}\left(\frac{C}{R}\right) = 10.4dB \qquad (1)$$

If viewed on a spectrum analyzer (Figure 2), the de-spreading process would cause the received spectrum to decrease in width by a factor of 11:1, while at the same time causing the peak in the spectrum to increase in amplitude by the same amount. This is why this effect is called processing gain.



a) b) c)

Figure 2 – DSSS allows data to be transmitted below the noise level

Table 2 summarizes the characteristics of both types of systems. (DSSS and FHSS)

TABLE 2. COMPARISON OF DSSS AND FHSS CHARACTERISTICS [1,2]

DSSS	FHSS
Good range resolution	Poor range resolution
Less interference on other systems	More interference on other systems
Bandwidth tied to chipping rate	Bandwidth tied to transmitter tuning range
Can operate below noise floor	Must have positive SNR
Susceptible to near-far degradation	Better near-far performance
More efficient coherent modulation (uses more bits per symbol)	Less efficient non-coherent modulation
Requires linear amplification; higher cost	Can use non-linear amplifiers, easier to implement

3. PN Codes

PN codes with the mathematical properties required for implementation of a DSSS radio are:

Maximum Length Sequence

Maximum length sequences (m-sequences), are PN sequences that repeat every 2^n-1, where '**n**' is an integer, they are implemented by shift registers and Exclusive OR gates, they are governed by primitive polynomials, and possess good randomness properties including a two-valued autocorrelation function.

For example the 7-chip PN sequence is governed by the primitive polynomial generator:

$$c_7(x) = 1 + x^2 + x^3 \qquad (2)$$

And the output chips are given by:

0 0 1 0 1 1 1 0 0 1 0 1 1 1 **0 0 1 0 1 1 1** 0 0 1 0 1 1 1 0 …

As another example, the 15-chip PN sequence is governed by the primitive polynomial generator:

$$c_{15}(x) = 1 + x^3 + x^4 \qquad (3)$$

And the output chips are given by:

0 0 0 1 0 0 1 1 0 1 0 1 1 1 1 0 0 0 1 0 0 1 1 0 1 0 1 1 1 1
0 0 0 1 0 0 1 1 0 1 0 1 1 1 1 …

Barker Codes

Barker Codes are short unique codes that exhibit very good correlation properties. These short codes with **N** bits, with N=3 to 13, are very well suited for DSSS applications. A list of Barker Codes is tabulated in Table 3.

Willard Codes

Willard codes, found by computer simulation and optimization, and under certain conditions, offer better performance than Barker Codes. A list of Willard Codes is tabulated in Table 3.

The inverted or bit reversed versions of the codes listed on Table 3 can be used since they still maintain the desired autocorrelation properties.

TABLE 3. BARKER AND WILLARD CODES

N	BARKER SEQUENCE	WILLARD SEQUENCE
3	**110**	**110**
4	**1110** or **1101**	**1100**
5	**11101**	**11010**
7	**1110010**	**1110100**
11	**11100010010**	**11101101000**
13	**1111100110101**	**1111100101000**

Processing gain as function of code length is shown in Table 4. Note that big codes give much gain.

TABLE 4. PROCESSING GAIN

Code length (chips)	Processing gain (dB)	Code length (chips)	Processing gain (dB)
3	4.77	11	10.41
4	6.02	13	11.14
5	6.99	15	11.76
7	8.45	16	12.04

4. Implementation

This paper present the construction of a PIC16F84-based module as a SPREADER for wireless communication devices.

The PIC16F84 is a low cost, high performance CMOS 8-bit FLASH RISC microcontroller with integrated 68 bytes of RAM, 64 bytes of EEPROM, 1k Flash Program Memory, 13 I/O pins and other features [3] that make it suitable for Spreader Module. Basic function of this module is to combine synchronously received data from host controller with 11-bit Barker Code.

Data comes from pin 4 on J1. U1 generates clock signal CLK to J1 when line PTT is high (active – transmit).

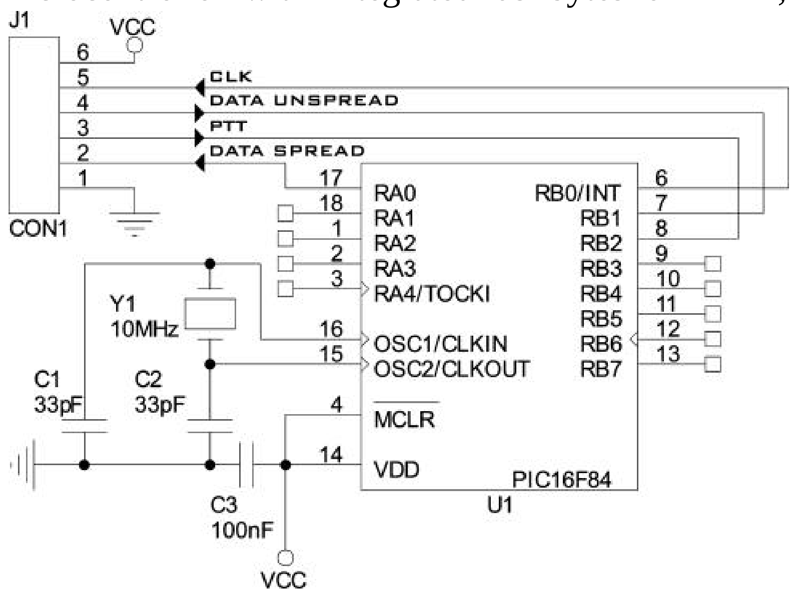


Figure 3 – Circuit diagram

Host controller generates PTT when there is data for transmitting. Then U1 generates CLK signal to get current bit from data stream /DATA UNSPREAD/. Then U1 calculates product stream by Bitwise Exclusive OR (XOR) of unspread data bit and Barker Code. This bit stream is sent out to pin 2 on J1.

Figure 4 shows block diagram of the microcontroller's program. Initialize routine sets I/O ports direction, oscillator type, and some timing parameters for the microcontroller.

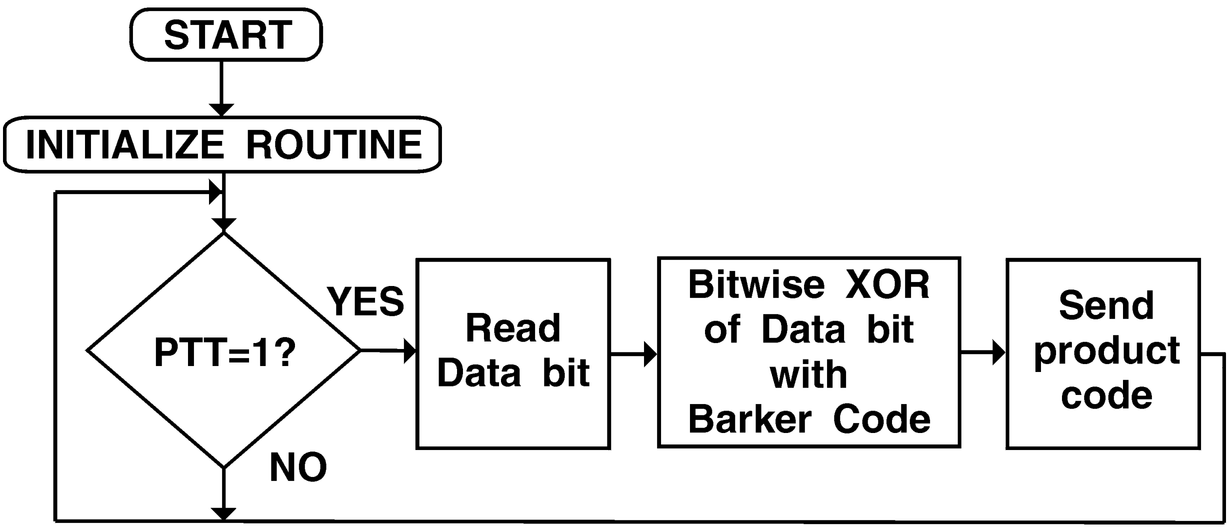


Figure 4 – Block diagram

Then the program checks for active PTT signal (pin 8). If PTT is inactive, program loops. If active then CLK is generated by set bit 0 of PORT B (pin 6). After a while data bit is read from pin 7 (bit 1 of PORT B). Program XORs

Barker Code with the meaning of readed data bit and send the result bitwise on PORT A, bit 0 (pin 17) . When the last product bit is send program loops.

5. Conclusion

The FHSS system have proven that their performance was not as highly dependent on distance and number and type of partitions as DSSS systems. DSSS systems allows data to be transmitted below the noise level. DSSS systems do not interfere with each other. DSSS systems transmit less power than FHSS and "Narrow Band" systems.

6. References

[1] A Peek Into Pandora's Box: Direct Sequence vs. Frequency Hopped Spread Spectrum, Morrow, Robert K. Jr. Proceeding of the 8th Virginia Tech/MPRG Symposium on Wireless Personal Communications, 1998 p.339-248

[2] Spread Spectrum Systems with Commercial Applications 3rd Edition, Dixon, Robert, Wiley, 1994

[3] Microchip PIC16F8X Data Sheet, Microchip Technology Inc., 1998