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SPREAD SPECTRUM PROCESS USING DIRECT SEQUENCE SPREAD SPECTRUM (DSSS) AND FREQUENCY HOPPING SPREAD SPECTRUM (FHSS)

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ABSTRACT

This paper presents spread spectrum process using Direct Sequence Spread Spectrum (DSSS) and Frequency Hopping Spread Spectrum (FHSS). DSSS is type spread spectrum the most widely known and most widely used. Mean while, in FHSS the data is modulated directly onto a single carrier frequency, but that carrier frequency hops across a number of channels within the RF band using a pseudo-random hopping pattern. We compare between DSSS and FHSS in terms of channel, narrowband interference, main parameters, co-location, security and cost. DSSS performance better in terms of cost and this system is recognized most easily implementation, while FHSS superior in narrowband interference, co-location channel and security.

***Keywords*:** Narrowband, spread spectrum, DSSS, FHSS, channel.

INTRODUCTION

Spread spectrum is a modulation method applied to digitally modulated signals that increases the transmit signal bandwidth to a value much larger than is needed to transmit the underlying information bits (Goldsmith, 2005). The spread spectrum technique was developed initially for military guidance and intelligence requirements (Stalling, 2003). By the end of World War II, spectrum spreading for jamming resistance was already a familiar concept to radar engineers (Bernard, 2001). Most current 2.4 GHz SS systems are compliant with the Institute of Electronics and Electrical Engineers (IEEE) 802.11 standard (Spasojevic, 2000). Spread spectrum technology allows to bring a number of the same information as that can be transmitted using the narrowband carrier signal and spreaded the signal on a frequency range much greater. 1 MHz may be used on the 10 watt with narrowband, but the spread spectrum can be used 20 MHz at 100 mw. By using the frequency spectrum is wider, the possibility may be that the data will corrupted or jamming. Jamming efforts against a narrowband signal in a spread spectrum likely will be defeated by a small piece of information into the frequency range of narrowband signals. Most of the digital data will be received perfectly. Radio RF spread spectrum that there can be reproduced a small amount of data lost due to narrowband interference. Many implementation of spread spectrum technology is different, but only two types approved by the Federal Communications Commision (FCC) that is the direct sequence spread spectrum (DSSS) and frequency hopping spread spectrum (FHSS). To further the spread spectrum technique is more discussion of the following added.

ABSTRACTDIRECT SEQUENCE SPREAD SPECTRUM (DSSS)

Direct sequence spread spectrum is one of the most widely used types of spread spectrum technology, owing its popularity to its ease of implementation and high data rates (Joshua, 2005). Most of the equipment or the Wireless LAN device on the market uses DSSS technology. DSSS is a method for sending data in which sender and recipient system are both on the set wide frequency is 22 MHz. Divides the available 83.5 MHz spectrum (in most countries) into 3 wide-band 22 MHz channels. The IEEE 802.11 standard calls for use of the 2.4 GHz ISM band ranging from 2.400 to 2.497 GHz. In the United States and Europe, the range from 2.4000 to 2.4835 GHz is specified as the total frequency space available The IEEE further specifies that the DSSS supported by IEEE 802.11 devices should implement differential binary phase shift keying (DBPSK) at 1 Mbps and differential quadrature phase shift keying (DQPSK) at 2 Mbps. DBPSK and DQPSK are modulation techniques that use phase-based modulation

How DSSS Works

In DSSS the data signal is combined with a code word, which is known as chipping code, and the combined signal is used to modulate the RF carrier, resulting in a transmitted signal spread over a wide bandwidth. Cipping code also called the processing gain. Processing gain a high signal to increase the resilience against interference. The process direct sequence to begin with a carrier by modulation with a code sequence. Sum of chips in the code will determine how big the spreading occurs, and sum of chip per bit and code rate will determine the data rate.

Direct Sequence System

IEEE set on the use of DSSS data rates 1 or 2 Mbps in the 2.4 GHz Industrial Scientific and Medical (ISM) band, under the 802.11 standard. While the 802.11b standard specified data rate of 5.5 and 11 Mbps. IEEE 802.11b tools that work on 5.5 or 11 Mbps capable of communicating with the tools that 802.11 work on 1 or 2 Mbps 802.11b standard provides for backward compatibility. In 2003, the IEEE 802.11g standard providing a 54 Mbps data rate using the ISM frequencies. The advantage of 802.11g over 802.11a is that it is backward-compatible with 802.11b.

Channel

In the direct sequence spread spectrum system uses a definition of a more conventional channels. Each channel is a band that frequensi the adjacent 22 MHz wide. Channel 1, for example, the work frequency of 2.401 GHz to 2.423 GHz (2.412 GHz ± 11 MHz); channel 2 working of 2.406 to 2.429 GHz (2.417 ± 11 MHz), etc. Figure 3 illustrates this description.

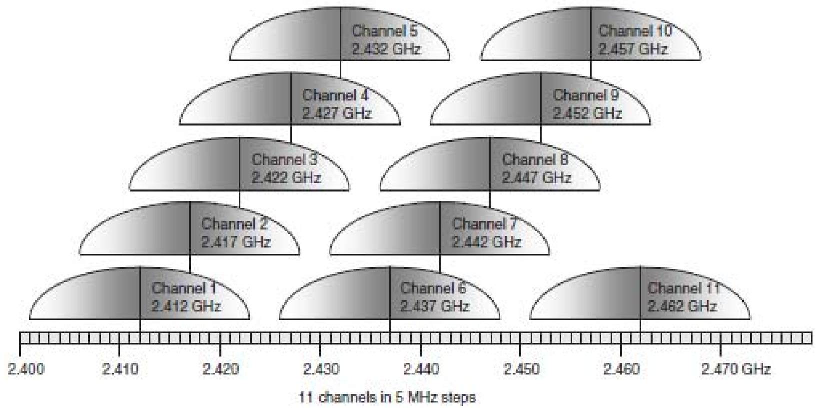

Figure 1: DSSS channel allocation

To better understand how legacy 802.11, 802.11b and 802.11g radio are used, it is important to understand how the IEEE standard divides the 2.4 GHz ISM band into 14 separate channels, as listed in table 1. Although the 2.4 GHz ISM band is devide into 14 channels, the FCC or local regulatory body designates which channels are allowed to be used. Table 1 also show what channel are supported in a sample of a few countries. The regulations can vary greatly between countries (David, 2009). Diagram in Table 1 includes a complete list of channels that are used in the U.S., Europe and Japan. The 802.11b standard defines a total of 14 frequency channels of which 1 through 11 are permitted in the U.S, 13 in Europe and 14 in Japan. Can be seen that channels 1 and 2 overlapping with a significant scale. Each frequency listed in this chart is considered a central frequency. From this central frequency, is added and reduced to get a 11 MHz channel with a width of 22 MHz used. Now easily seen that the channels in the proximity can be overlapping significantly.

Table 1: Determining the frequency channel DSSS

Channel	Center Frequency (GHz)	U.S.	Europe	Japan
1	2,412	x	x	x
2	2,417	x	x	x
3	2,422	x	x	x
4	2,427	x	x	x
5	2,432	x	x	x
6	2,437	x	x	x
7	2,442	x	x	x
8	2,447	x	x	x
9	2,452	x	x	x
10	2,457	x	x	x
11	2,462	x	x	x
12	2,467		x	x
13	2,472		x	x
14	2,484			x

System with the use of DSSS channels overlapping the channel will cause interference between the-system. Because the frequencies nodal distance of 5 MHz and channels has a wide 22 MHz, the channels may only be placed in the same location if distance of channels 5, separate from one another. For example, channels 1 and 6 does not overlapping, channel 2 and 7 does not overlapping, etc. There is a maximum of 3 systems sequence may direct that that can be placed on the same location as channels 1, 6 and 11 are channels that are not overlapping theoretically. Three non overlapping channels that is depicted in Figure 2.

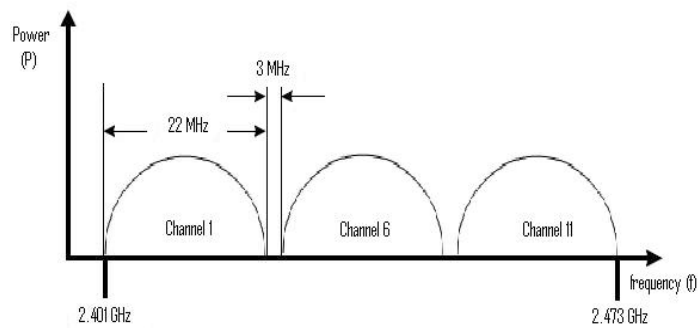

Figure 2: DSSS non-overlapping channels

Narrowband Interference

An interfering signal would appear in the channel between the transmitter and the receiver. In the receiver, the multiplier with the spreading code is the second spreading code that the DSSS signal encounters, which cancels the transmitter spreading. This is, however, the first spreading process that the interference encounters (Bruce, 2008). The interference behaves as if it is at the transmitter: It is spread, becoming itself a direct-sequence spread-spectrum signal. That is, the interference simultaneously becomes spread as the data signal is despread. Filtering the now-narrowband data signal with a narrowband fi lter rejects much of the power in the now-wideband spread-interference signal. Only a portion of the interfering signal power remains in the bandwidth of the data signal, and this portion appear as a noise floor in the passband. As long as there remains sufficient signal-to-noise ratio in the receiver to successfully demodulate the despread data signal, the DSSS system rejects the narrowband interferer. This continues as long as the preceding qualifier is met: sufficient despread signal to noise ratio at the detector. The data are recovered following the demodulator.

FREQUENCY HOPPING SPREAD SPECTRUM (FHSS)

Frequency Hopping Spread Spectrum is a spread spectrum technique that uses a special frequency to transmit data more than 83 MHz. Frequency agility depends on the ability to switch the radio frequency transmission of a sudden in the use of radio frequency (RF) bands. Divides the available 83.5 MHz spectrum (in most countries) into 79 discrete 1 MHz channels

How FHSS works

In FHSS the data is modulated directly onto a single carrier frequency, but that carrier frequency hops across a number of channels within the RF band using a pseudo-random hopping pattern. Pseudorandom sequence is a list of some frequency where the carrier will jump at the specified time interval before going repeatedly. Transmitter using the hop sequence to select the transmission frequency.

Frequency Hopping System

It is the job of the IEEE to create standards of operation within the confines of the regulations created by the FCC. The IEEE standards regarding FHSS systems describe :

- what frequency bands may be used
- hop sequences
- dwell times
- data rates

The IEEE 802.11 standard specifies data rates of 1 Mbps and 2 Mbps. In order for a frequency hopping system to be 802.11 compliant, it must operate in the 2.4 GHz ISM band, and operate between 2.402 and 2.480 GHz.

Channel

In frequency hopping system will work using a special pattern called a leap channel. Some of the frequency hopping system allows the creation of a pattern that leap tailored to the needs (custom hop patterns), and systems of the other allows synchronization between the system to completely eliminate collusion or impact in an environment that is used together. Although it is possible to have up to as many as 79 dots synchronization access that occupies a location at the same time, but with a lot of this pattern, each frequency hopping radio will require a precise synchronization with all the other radio in order not to disrupt each other frequency hopping radio in the area. The cost for a set of such a system is burdensome and generally not seen as an option. If use a radio that synchronization, the expenditure only allow a maximum 12 system occupy the location together. If use a radio non-synchronization, the system 26 can be placed together in the location of a Wireless LAN, this amount is considered to be the maximum amount in a Wireless LAN to the traffic levels medium. Increased communication traffic in a significant or shipping large files on a regular basis to provide practical limitations on the number of systems that occupy the same location as the maximum 15. More than 15 frequency hopping system that is in this environment will disrupt each other up to the level where collusion of signals will begin to reduce the aggregate throughput of the Wireless LAN. Figure 3 depicts the frequency hopping system using a hop sequence of the five frequency bands above 5 MHz (Pangera, 2007). In the example below, the sequences are:

1. 2.449 GHz
2. 2.452 GHz
3. 2.448 GHz
4. 2.450 GHz
5. 2.451 GHz

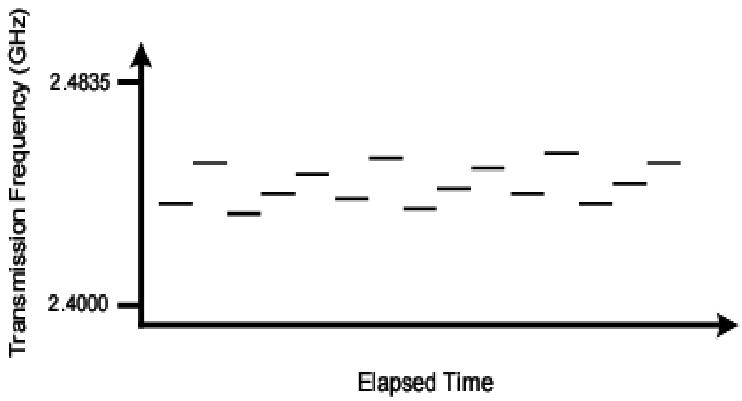

Figure 3: FHSS with five frequency (Akin, 2003)

After emit radio bearer information at 2.451 GHz, the radio will repeat the hop sequence (the order jump), and then start again from the frequency of 2.449 GHz. The process repeated sequence leap will continued until the complete information received. On the receiving, hop sequence radio waves must be synchronization of the sender so that the frequency of receiving the right and on time too. Then the signal is received demodulation and used on the computer of the recipient.

Narrowband Interference

If one hop encounters a narrowband interferer within the narrowband filter, then the communication on that channel can be jammed if all three interference conditions described earlier are met. On the next hop the narrowband interferer will be moved away from, or “avoided.” This allows the receiver’s selectivity filter to reject the narrowband interferer. The ultimate amount of interference rejection is therefore set by the performance of the receiver selectivity filter.

COMPARISON BETWEEN DSSS AND FHSS

In this section we compare DSSS and FHSS in terms of the channel and narrowband interference. In add on, we also compare the main parameters of spread spectrum include co-location, security and cost.

Channel

We discuss extensively about the channel in section 3. Based on this DSSS defines using 2.4 GHz ISM with total of 14 frequency channels of which 1 through 11 are permitted in the U.S, 13 in Europe and 14 in Japan. Each channel in DSSS with a widht of 22 MHz and space between channel of 5 MHz. To use DSSS systems with overlapping channel (e.g, channel 1 and 2) in the same physical space would cause interference between the systems. DSSS systems using overlapping channel should not be co-located because there will almost always be a drastic or complete reduction in throughput. Because the center frequencies are 5 MHz apart, and the center frequencies for non-overlapping channels must be at least 25 MHz apart, channel should be co-located only if the channel numbers are at least five apart. While, In FHSS defines using 2.4 GHz ISM with space between channel of

1MHz. FHSS typically using 26 hop patterns standard from FCC. Severally Frequency Hopping systems enable creation a custom hop patterns and even enable synchronization between systems up to 79 dots synchronization access that occupies a location at the same time.

Narrowband interference

Direct sequence spread spectrum (DSSS) and frequency hopping spread spectrum (FHSS) technologies have different physical mechanisms for rejecting narrowband interference. Because of these physical differences, they perform differently in the presence of the same levels of narrowband interference (Earl, 2009). Narrowband interference at DSSS in the same channel is reduced by the processing gain (PG) and for FHSS not reduced, but then in a different channel has no influence. FHSS technology's advantages include a larger resistant against narrowband interference. DSSS systems may be more affected by narrowband interference compared FHSS system because the system uses bands near the 22 MHz wide, not 79 MHz as used on the FHSS system.

Main parameters

DSSS is defined (in IEEE 802.11) in the 2.4 GHz band as operating on one of 14 possible carriers (country specific bands have different number of frequencies, defined in IEEE 802.11 and IEEE 802.11.b). The selected carrier (channel) is Differential Binary Phase Shift Keying (DBPSK) for data rate 1 Mbps and Differential Quaternary Phase Shift Keying (DQPSK) for data rate 2 Mbps modulated with a channel width of 22 MHz. The rates defined in IEEE 802.11 are 1 Mbps and 2 Mbps. IEEE 802.11.b adds to DSSS the rates of 5.5 Mbps and 11 Mbps (in the 2.4 GHz band), while keeping the channel width at 22 MHz (Frequency, 2009). FHSS is defined (in IEEE 802.11) in the 2.4 GHz band as operating over 79 frequencies ranging from 2.402 GHz to 2.480 GHz (country specific bands have different frequencies, defined in IEEE 802.11 and IEEE 802.11.b). Each of the frequencies is Gaussian frequency Shift Keying (GFSK) modulated, with a channel width of 1 MHz. 2-GFSK for data rate 1 Mbps and 4-GFSK for data rate 2 Mbps

Co-location

Co-location refers to the ability to place multiple devices in an environment so that they will cause little or no interference to each other. The maximum number of non-overlapping service sets that can be created using DSSS technology is three. The center channel frequencies must be spaced by 25 MHz in order to be considered non-overlapping by the IEEE standards. The reality is that there is still some level of overlap, but the interference is so minimal that it is not considered in most installations. In North America and most of Europe, the three non-overlapping channels that can be used in the same service area simultaneously are 1, 6, and 11 with maximum total data rates 33 Mbps in service area. FHSS systems can be co-located by using hopping sequences that result in infrequent simultaneous channel usage. In other words, the hopping sequences will be arranged in such a way that there are very few times, if any, where two different service sets are trying to dwell on the same channel. When they do land on the same channel, the interference will only last the length of one dwell time. Since there are 79 channels, it is theoretically possible to synchronize 79 service sets in one service area without ever having any two of them dwelling on the same channel. However, due to costs involved with this synchronization, most environments will max out at 12 co-located systems. With maximum total data rates 24 Mbps in service area.

Security

IEEE 802.11 compliant DSSS systems use one well known spreading sequence of 11 chips, and can modulate one of the 14 channel defined in the standard. As the sequence used is apriori known, the carrier frequency is fixed for a given system, and the number of possible frequencies is limited, it would be quite easy for a listener to “tune in” on the DSSS transmission. Message protection should be achieved by encrypting the data. This option increases the price of the product, while lowering its performance, because of the processing power needed for the encryption process. DSSS pushes data through a binary encoding process that spreads the data by combining it with a multibit pattern or pseudo-noise code. The resulting data is now somewhat hidden and inflated. This data is modulated and then sent out over multiple frequencies (which typically consist of about 22 MHz of bandwidth) at the same time. Since the original data bit was encoded into 11 bits, the data is more resilient to air loss because the data has a tremendous amount of redundancy.

In FHSS, the frequencies to be used in the hopping sequence may be selected by the user. In the unlicensed band, any group of 26 frequencies or more (out of the 79 available) is legal. To “tune in”, a listener should know the number of frequencies selected in the system, the actual frequencies, the hopping sequence, as well as the dwell time. The FHSS modulation acts as a layer 1 encryption process. FHSS systems, the transmitter and the receiver hop from one frequency to another in prearranged synchronized patterns. The hops occur frequently with very little time being spent on any one frequency. This reduces the possibility of interference with other devices and enables several overlapping FHSS systems to be operational at the same time (Merrit, 2002).

Cost

At the time of implementing a Wireless LAN, the benefits of DSSS technology may need to be more superior than the FHSS system, especially if only have a tight budget. The cost to implement a direct sequence system is much lower compared with the cost of frequency hopping system. DSSS equipment now widely available in the market, and by many usage help lower the cost. Some years ago, this equipment can only be accessed by customers in the form of a company. Now, the PC card, which according to the 802.11b standard with a very good quality can be bought with a price less than $ 100 (Price, 2009). FHSS card that matches the 802.11 standard has the typical price ranges from $ 200 to $ 600 in the market nowadays that are dependent on the manufacturer and the standards that can be used by the card (Price, 2009).

Summary

For quick reference, Table 2 summarizes the comparison of DSSS and FHSS.

Table 2: Summary comparison of DSSS and FHSS

	DSSS	FHSS
Channel	- 2.4 GHz - Amount 14 channels - Width of 22 MHz. - Spaced with 5 MHz.	- 2.4 GHz - Amount 79 channels - Width of 1 MHz. - Spaced with 1 MHz.
Narrowband interference	narrowband interference in the same channel is reduced by the processing gain (PG).	- narrowband interference in the same channel is not reduced - narrowband interference in a different channel has no influence
Main parameters	- Modulated by DBPSK and DQPSK are very power efficient - Data rates in IEEE 802.11 are 1 Mbps and 2 Mbps, in IEEE 802.11b are 5.5 Mbps and 11 Mbps.	- Modulated by GFSK is less power efficent in narrowband operation - Data rates are 1 Mbps and 2 Mbps.
Co-location	- Maximum of 3 co-located networks - Maximum data rates 33 Mbps	- Maximum of 12 co-located networks - Maximum data rates 24 Mbps.
Security	Secure Low	More secure High

CONCLUSION

Decision to use of direct sequence spread spectrum or frequency hopping spread spectrum depends on the actual environment in which the system will be deployed. Along with considerations on the some factors such as security and cost. DSSS equipment now widely available in the market, and by many usage help lower the cost.

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