FREQUENCY HOPPING SPREAD SPECTRUM
VS.
DIRECT SEQUENCE SPREAD SPECTRUM

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Frequency Hopping vs. Direct Sequence Spread Spectrum Techniques

Spread spectrum technology was first introduced about 50 years ago by the military as a way of sending secure communications. From the beginning it was designed to be resistant to noise, interference, jamming, and unauthorized detection. Spread spectrum transmitters send their signals out over a multiple range of frequencies at very low power, in contrast to narrow band radios that concentrate all of their power into a single frequency. There are several ways to implement spread spectrum transmission, the techniques specified in the IEEE 802.11 Wireless LAN standard are frequency hopping spread spectrum (FHSS) and direct sequence spread spectrum (DSSS). This white paper will discuss each of these spread spectrum techniques and highlight the pros and cons of each.

Frequency Hopping Spread Spectrum Technique

Some wireless local-area network products, such as Raytheon's Raylink™ products, use the frequency hopping method of spreading their signals. The range of available frequencies in the ISM2 (Industrial Scientific Medical) band of 2.400 - 2.483 GHz is divided into a series of 1MHz channels up to 79 separate and distinct channels. Transmissions are sent over each of these channels in what appears to be a random sequence (called a “pseudo-random sequence”) such as channel 1, channel 32, channel 3, channel 56, etc. The radio switches frequencies many times a second, transmitting on each channel for a fixed amount of time, then proceeding on to the next channel in its sequence, covering all of the channels before repeating the sequence. Without knowing how long to stay on each channel (the “dwell time”) and what the hopping pattern is, it is impossible for a non-participating station to receive and decipher the data.

The frequency hopping physical layer has 22 hop patterns to chose from. The frequency hopping physical layer is required to hop across the 2.4GHz ISM band covering 79 channels. Each channel occupies 1Mhz of bandwidth and must hop at the minimum rate specified by the regulatory bodies of the intended country. A minimum hop rate of 2.5 hops per second is specified for the United States.

The use of different hopping patterns, dwell times, and/or number of channels is what allows two disjoint wireless LANs to exist nearby one-another without causing interference and without fear of data from one network being seen by the other.

Direct Sequence Spread Spectrum Technique

The DSSS physical layer uses an 11-bit Barker Sequence to spread the data before it is transmitted. Each bit transmitted is modulated by the 11-bit sequence. This process spreads the RF energy across a wider bandwidth than would be required to transmit the raw data. The processing gain of the system is defined as 10x the log of the ratio of spreading rate (also know as the chip rate) to the data. The receiver despreads the RF input to recover the original data. The advantage of this technique is that it reduces the effect of narrowband sources of interference. This sequence provides 10dB of processing gain that meets the minimum requirements for the rules set forth by the FCC. The spreading architecture used in the direct sequence physical layer is not to be confused with CDMA. All 802.11 compliant products utilize the same PN code and therefore do not have a set of codes available as is required for CDMA operation.

Design and Cost Issues

Current 2 Mbps DSSS products on the market occupy 22 MHz of bandwidth at the first nulls of the main signal lobe. On the other hand, FHSS operates within 1 MHz of bandwidth as a consequence of a FCC mandate. As a result, the circuit design for the DSSS products requires very good passband characteristics for the 22 MHz width. Given a choice of 1 MHz versus 22 MHz, a 1Mhz design is easier to design.

DSSS is typically chipped using BPSK modulation. Since BPSK modulation has both phase and amplitude information, linear amplification is necessary. That means only Class A or Class AB amplifiers can be used. These are relatively low efficiency amplifiers. A lot of the DC power is turned into thermal energy, which has to dissipate. FHSS typically uses GFSK modulation. This is constant-envelope modulation, so a non-linear, high efficiency Class C amplifier is adequate for its use. These characteristics mean that DSSS is more power hungry and harder to build in a smaller enclosure than FHSS systems.

In an indoor radio propagation environment, the measured delay spread statistics have shown that a 100 nSec delay is fairly common. Since this is close to the DSSS chipping rate, there is a potential for inter-chip interference - or in other words, a penalty for performance that may be as much as 10 dB over corresponding Gaussian Channel. Good diversity antennas must be used to overcome some of these problems. FHSS would not see the effects of the 100-nSec delay. For a strong narrow-band jammer environment, FHSS also has a marked advantage if it can avoid the jammed channel by its frequency hopping nature. If it can not avoid narrow band interference, FHSS systems will still degrade its performance gracefully. On the other hand, DSSS systems will immediately loose a connection with narrow band interference.

The FCC rule limits the 20-dB bandwidth of a hopping channel to be 1 MHz wide. To achieve a comparable DSSS data speed, FHSS must use M'ary modulation. The implementation difficulty is exponential. Furthermore, since the required signal to noise ratio (Eb/No) increases greatly for the same bit error rate (BER), the range is reduced. To compound the problem, FHSS has to give up inter-hop synthesizer settling time and demodulator lock-up time where no data transmission can be done. FHSS is also forced to hop within 400 msec. It has to use no less than 75 channels. This means that it is very difficult to get a FHSS system to do 2Mbps and there will be some extra overhead that will affect data throughput. On the other hand, DSSS can do high data rates relatively easily because it uses a larger amount of the bandwidth to pass the data (i.e. it uses a fatter pipe to move the data).

Network Scalability:

DSSS systems only allow 3 channels within the 2.4Ghz ISM band. Therefore, there can only be 3 separate networks within the same area without interfering with each other.

FHSS systems have 79 channels with the 2.4Ghz ISM band. Because of the hopping sequences, many co-located networks can be deployed in the same area without interference and without the co-located networks intercepting the data. This allows for the network to be scaled based on an influx of users in a given area. FHSS systems are ideal for high user density areas such as a corporate office environment.

Conclusions:

In conclusion, frequency hopping spread spectrum and direct sequence spread spectrum techniques are used in IEEE 802.11 wireless LAN systems because they are designed to be resistant to noise, interference, jamming, and unauthorized detection. Direct Sequence Spread Spectrum systems are much harder to build, has high user density limitations and typically costs more to build. It should always have a slight data speed advantages over frequency hopping systems and will have a range advantage. These systems are ideal for data warehouse applications where the data user density is small and range is a critical need.

Frequency Hopping Spread Spectrum systems may have data speed limitations and be shorter in range. FHSS designs are easier to build and therefore cost less. They are very good at avoiding narrow band interference and unauthorized user access due to their frequency hopping nature. They are also scalable in that many separate networks can be co-located in the same area without interfering with each other. Frequency hopping spread spectrum systems are good for high user density areas such as corporate offices, education and healthcare applications.