A Brief Tutorial on Spread Spectrum and Packet Radio

Introduction

The communications standard for wireless local networks, IEEE 802.11, uses spread spectrum and packet radio techniques and these are features which are not common knowledge. The first term, spread spectrum, indicates a radio frequency modulation technique where the radio energy is spread over a much wider bandwidth than needed for the data rate. We do this to get some benefits that are not readily apparent. The easiest spread spectrum technique to explain is frequency hop (FH). In this technique, the channel being used is rapidly changed in a pseudo random pattern so that the communications appears to occupy a wide bandwidth over time. See Figure 1. This spreads the energy out so that the average power in any narrow part of the band is minimized. Of course, the transmitting and receiving radios need to synchronize their hopping patterns so that they hop together.

As an example, 802.11 specifies that we use the ISM band at 2.4GHz. The ISM band is 83MHz wide and has been subdivided into 1MHz channels for the FH specification. The FCC insists that any spread spectrum FH radio operating in this band must visit at least 79 of the channels at least once every 30 seconds. This works out to a minimum hop rate of 2.5 hops per second.

The next form of spread spectrum is called Direct Spread (DS) and this is the other form of spread spectrum allowed by the FCC in this band. With DS, the data is mixed (XOR) with a high rate pseudo random sequence before being PSK modulated onto the RF carrier. This high rate sequence can be many orders of magnitude higher in rate than the data. In the ISM band, it is limited to not less than a 10:1 spreading ratio. This high rate phase modulation spreads the spectrum out while dropping the power spectral density. This means that this kind of signal will interfere less with narrow band users. It also has some interference immunity to those narrow band emitters. The receiver processing of DS signals begins with despreading the signals. This is done by mixing the spread signal with the same PN sequence that was used for spreading. See Figure 2A. This collapses the desired signal to its original bandwidth and form. It meanwhile spreads all other signals that don't correlate with the spreading signal. Thus a narrowband interference will get spread in this operation and will not fit through the narrow data filter. See Figure 2B. When the signal energy is collapsed to the data bandwidth, its power spectral density is increased by the amount of the processing gain which is proportional to the bandwidth reduction. Thus a signal that was received at or below the noise floor, is now above the noise and can be demodulated.
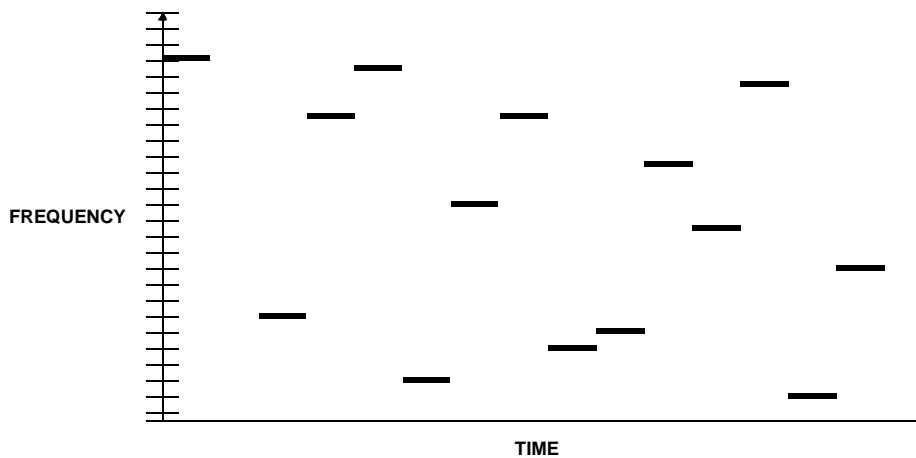

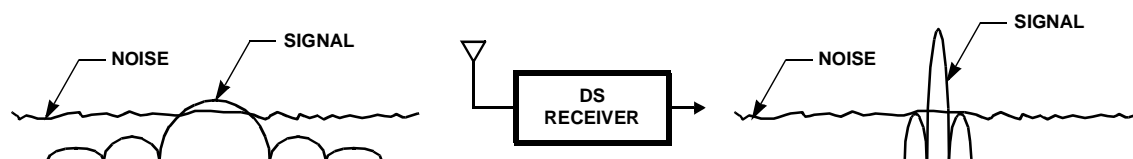**FIGURE 1. FH SPREAD SPECTRUM**

FIGURE 2A. LOW POWER DENSITY
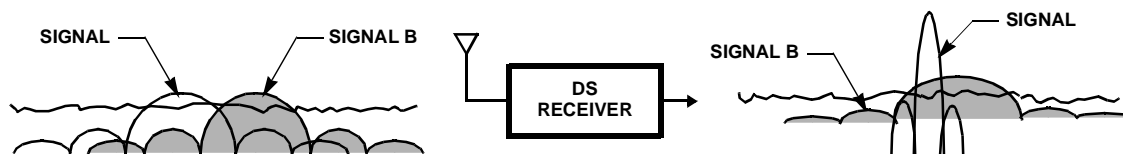

FIGURE 2B. INTERFERENCE REJECTION

FIGURE 2C. MULTIPLE ACCESS

FIGURE 2. DIRECT SEQUENCE SPREAD SPECTRUM PROPERTIES

Finally, DS spread spectrum can allow more than one user to occupy the same channel through a feature called multiple access. Each DS receiver collapses only correlated signals to the data bandwidth. Other, non correlated signals will remain spread in this step. When the desired signal is filtered to the signal bandwidth, only a small fraction of the undesired signal remains. See Figure 2C.

The term packet radio or packet communications is common where the communications medium is not well controlled. There are numerous reasons why a radio communications link may be interrupted, such as the microwave oven. [1] The microwave oven radiates in the middle of the ISM band with a 50% duty cycle and a pulse rate locked to the power line. Thus it is off for 8ms every 16ms. These off periods allow the transmission of bursts (or packets) of 1000 bytes at a time. Frequency hopping also means that the radio communications is interrupted every 400ms while the sending and receiving radios are retuned. The breaking up of a large block of data into small "packets" is a common technique in communications to insure that error free communications can take place even with interruptions. [2] If the medium is corrupted intermittently, a large block of data will never make it through without errors. In the packet technique this block is broken into small packets that each have some error detection bits added. Then, if an error is detected, a retransmission of the small packet that was corrupted will not unduly burden the network. This packet communications technique has short control packets that check to see if the medium is clear, the other end is ready to receive and, to request a retransmission if a packet did not get through correctly. See Figure 3. All of this requires some

overhead expense that reduces the net system throughput. Packet length can be optimized to minimize overhead while insuring the greatest throughput with data integrity.

When continuous data is packetized, the instantaneous rate must increase since the time allowed for data transmission is reduced. This allows time for the packet protocol interchange, packet headers and other overhead. Packet communications can be used with various access protocols such as carrier sense multiple access (CSMA) or time division multiple access (TDMA). CSMA allows asynchronous communications, but requires each communicator to first establish that the medium is not busy. It then establishes the link with an interchange consisting of a request to send (RTS), followed by a clear to send (CTS), the data packet and acknowledgment or not (ACK/NAK). TDMA allows synchronous communications where each user is allocated a time slot to communicate in. The network overhead in this scheme is in the wasted time when some users have nothing to send and in the packets from the controller necessary to allocate the time slots.

The combination of spread spectrum and packet communications for the 802.11 wireless local area networks allows robust communications in a crowded and noisy band.
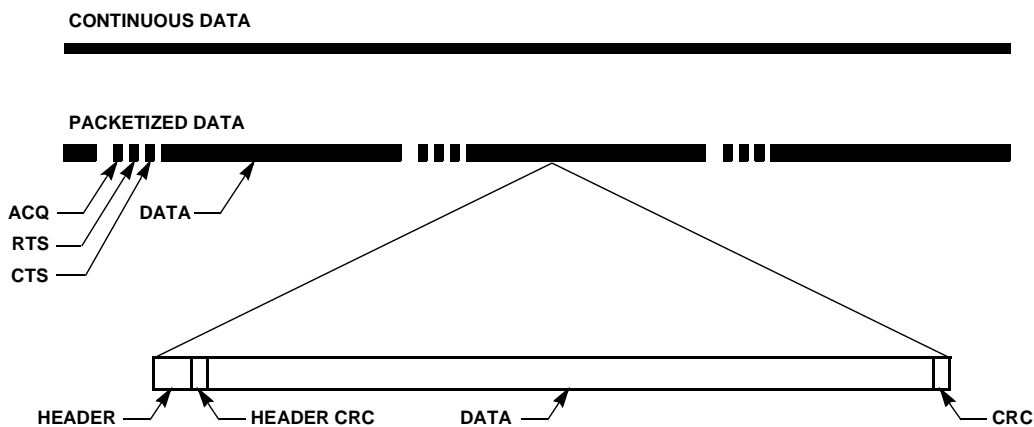
CONTINUOUS DATA

PACKETIZED DATA

ACQ

RTS

CTS

DATA

HEADER

HEADER CRC

DATA

CRC

FIGURE 3. PACKET TRANSMISSION

References

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[1] The 2.4GHz ISM band has been called the Junk band because it is already contaminated by oven emissions. Years ago, 2.43GHz was allocated to the microwave oven and it was felt that no one else would ever want to co-occupy this band. As pressure to allocate more spectrum to communications was felt, the FCC set up rules for unlicensed Instrumentation, Scientific and Medical (ISM) operation in this "worthless" band.

[2] Remember the days of typewriters where typing a whole page without error was a trying experience. The first word processor that allowed you to look over and correct each sentence before committing it to paper was a real breakthrough.

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