SPREAD SPECTRUM SIGNALS

3.1 Principles of spread-spectrum communications:

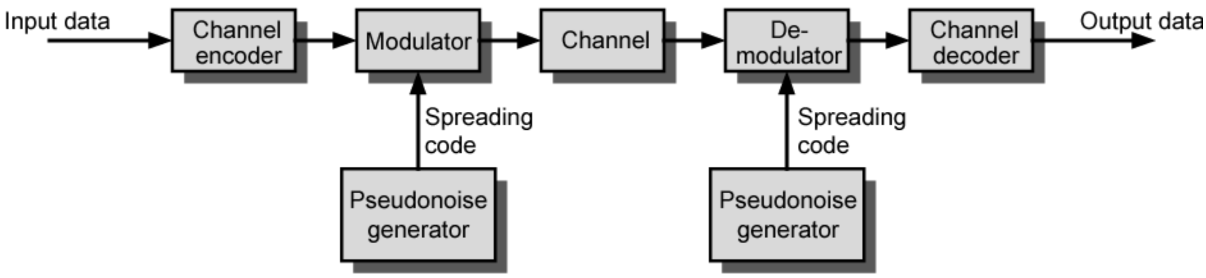
Digital transmission schemes which provide satisfactory performance and an adequate bit rate can be arranged into two categories.

• In applications like satellite communications, these schemes provide efficient usage of the limited power available.

• In applications such as mobile wireless, where the schemes achieve efficient usage of the limited bandwidth available for the service in demand.

However, both schemes are narrowband and vulnerable to hostile jamming and radio interference. The novelty of the spread-spectrum concept is that it provides protection against such attacks. This concept is based upon exchanging bandwidth expansion for anti-jamming capability.

The bandwidth expansion in spread spectrum is acquired through a coding process that is independent of the message being sent or the modulation being used. The spread spectrum, unlike FM, does not combat interference originated from thermal noise. The trade-off between signal-to-noise ratio (SNR) and data bit rate (or bandwidth) in the spread-spectrum scheme can be demonstrated by the following.



General model of spread spectrum digital communication

A spread spectrum modulation produces a transmitted spectrum much wider than the minimum bandwidth required. There are many ways to generate spread spectrum signals. We are going to introduce some of the most common spread spectrum techniques such as direct sequence (DS), frequency hop (FH), time hop (TH), and multicarrier (MC). Of course, one can also mix these spread spectrum techniques to form hybrids which have the advantages of different techniques. Spread spectrum originates from military needs and finds most applications in hostile communication environments.

In some situations it is required that a communication signal be difficult to detect, and difficult to demodulate even when detected. Here the word 'detect' is used in the sense of 'to discover the presence of'. The signal is required to have a low probability of intercept - LPI.

In other situations a signal is required that is difficult to interfere with, or 'jam'. The 'spread spectrum' signal has properties which help to achieve these ends. Spread spectrum signals may be divided into two main groups - direct sequence spread spectrum (DSSS), and frequency hopping spread spectrum (FHSS). This experiment is concerned with demonstrating some of the principles of the first.

Advantages of Spread Spectrum (SS) Techniques:

a) Reduced interference: In SS systems, interference from undesired sources is considerably reduced due to the processing gain of the system.

b) Low susceptibility to multi-path fading: Because of its inherent frequency diversity properties, a spread spectrum system offers resistance to degradation in signal quality due to multi-path fading. This is particularly beneficial for designing mobile communication systems.

c) Co-existence of multiple systems: With proper design of pseudo-random sequences, multiple spread spectrum systems can co-exist.

d) Immunity to jamming: An important feature of spread spectrum is its ability to withstand strong interference, sometimes generated by an enemy to block the communication link. This is one reason for extensive use of the concepts of spectrum spreading in military communications.

3.2 Types of spread spectrum techniques:

a) Direct sequence spread spectrum
b) Frequency hopping spread spectrum
c) Time hopping
d) Hybrid spread spectrum

a) Direct sequence spread spectrum:

Principle of DSSS:

Consider the frequency translation of a baseband message (of bandwidth B Hz) to a higher part of the spectrum, using DSBSC modulation. The resulting signal occupies a bandwidth of 2B Hz, and would typically override the noise occupying the same part of the spectrum. This makes it easy to find with a spectrum analyzer (for example), and so the probability of intercept is high. A local carrier, synchronized with that at the transmitter, is required at the receiver for synchronous demodulation. The recovered signal-to-noise ratio is 3 dB better than that measured at its original location in the spectrum. This 3 dB improvement comes from the fact that the contributions from each sideband add coherently, whereas the noise does not. This can be called a 3 dB 'processing gain', and is related to the fact that the transmission bandwidth and message bandwidth are in the ratio of 2:1.

In a spread spectrum system literally thousands of different carriers are used, to generate thousands of DSBSC signals each derived from the same message. These carriers are spread over a wide bandwidth (much wider than 2B Hz), and so the resulting DSBSC signals will be spread over the same bandwidth.

If the total transmitted power is similar to that of the single DSBSC case, then the power of an individual DSBSC in the spread spectrum case is thousands of times less. In fact, over the bandwidth occupied by one of these DSBSC signals, it would be literally 'buried in the noise', and difficult to find with a spectrum analyzer (for example).

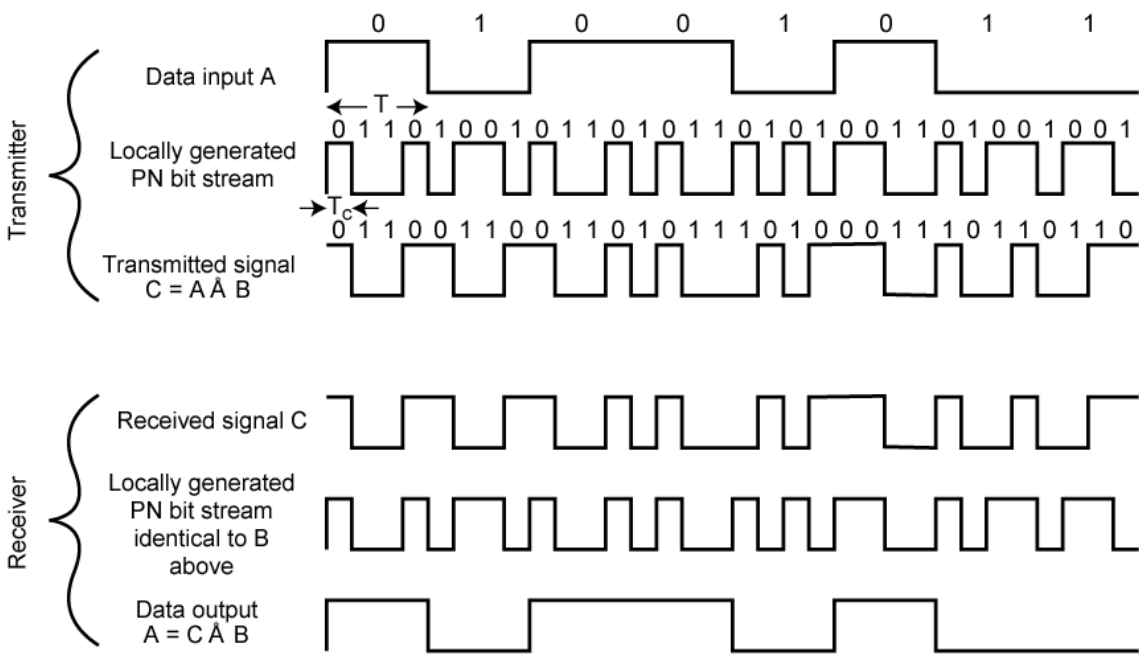
Instead of the total transmitted power being concentrated in a band of width 2B Hz, the multiple carriers have spread it thinly over a very wide bandwidth. The signal-to-noise ratio for each DSBSC is very low (well below 0 dB). To recover the message from the transmitted spread spectrum signal all that a receiver requires is thousands of local carriers, at the same frequency and of the same relative phase, as all those at the transmitter. All these carriers come from a pseudo random binary sequence (PRBS) generator.

Given a stable clock, and a long sequence, it may be shown that the spectrum of a pseudo random binary sequence generator is a good source of these carriers. A second PRBS generator, of the same type, clocked at the same rate, and appropriately aligned, is sufficient to regenerate all the required local carriers at the receiver demodulator.

In the spread spectrum context the PRBS signal is generally called a PN – pseudo noise - signal, since its spectrum approaches that of random noise.

Having the correct sequence at the receiver means that the message contributions from each of the thousands of minute DSBSC signals combine in phase – coherently - and add up to a finite message output. Otherwise they add with random phases, resulting in a (very) small, noise-like output.

Direct Sequence Spread Spectrum Example:



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