MAKERERE UNIVERSITY

DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

DSSS iLab Manual

Theory

Direct sequence spread spectrum (DSSS) is a variation of the DSBSC (Double side band suppressed carrier) scheme with a pulse train called a pseudo-noise sequence or just PN sequence for the carrier instead of a simple sine wave. Remember that pulse trains are actually made up of infinitely many sine waves (the fundamental and harmonics). That being the case, spread spectrum is really the DSBSC modulation of a theoretically infinite number of sinusoidal carrier signals. The result is a theoretically infinite number of pairs of tiny sidebands about a suppressed carrier.

In practice, not all of these sidebands have energy of significance. However the fact that the message information is distributed across so many of them makes spread spectrum signals difficult to deliberately interfere with or "jam". To do so, you have to upset a significant number of sidebands which is difficult, considering their infinite number.

Spread spectrum signals are demodulated in the same way as DSBSC signals using a product detector.

Importantly, the product detector's local carrier signal must contain all the sine waves that make up the transmitter's pulse train at the same frequency and phase. If this is not done, the tiny demodulated signals will be at the wrong frequency and phase and so they won't add up to reproduce the original signal. Instead, they will reproduce a garbage signal that looks like noise.

The only way for the receiver to generate the right number of sine waves at the right frequency is to use a pulse train with an identical sequence to that used by the transmitter. Moreover it must be synchronized. This issue gives spread spectrum another of its advantages; the transmitted signal is effectively encrypted.

Of course, with trial and error, it's possible for an unauthorized person to guess the correct PN sequence to use for their receiver. However, this can be made difficult by making the sequence longer before it repeats itself i.e. by making it consist of more bits or chips. Longer sequences can produce more combinations of unique codes which would take longer to guess using a trial and error approach.

Increasing the sequence's chip-length has another advantage. To explain, the total energy in a spread spectrum is distributed between all of the tiny DSBSC that make it up (though not evenly because not all the sine waves that make up the carrier's pulse train are of the same amplitude). Fourier analysis shows that the greater the number of chips in a sequence before repeating, the greater the number of sine waves of significance needed to make it.

That being the case, using more chips in the transmitter's PN sequence produces more DSBSC signals and so the signal's total energy is distributed more thinly between them. This in turn means that the individual signals are many and extremely small. In fact, if the PN sequence is long-enough, all of these DSBSC are smaller than the background electrical noise that's always present in free space. This fact gives spread spectrum yet another important advantage. The signal is difficult to detect.

In summary:

Direct Sequence Spread Spectrum communications is distinguished by three key elements:

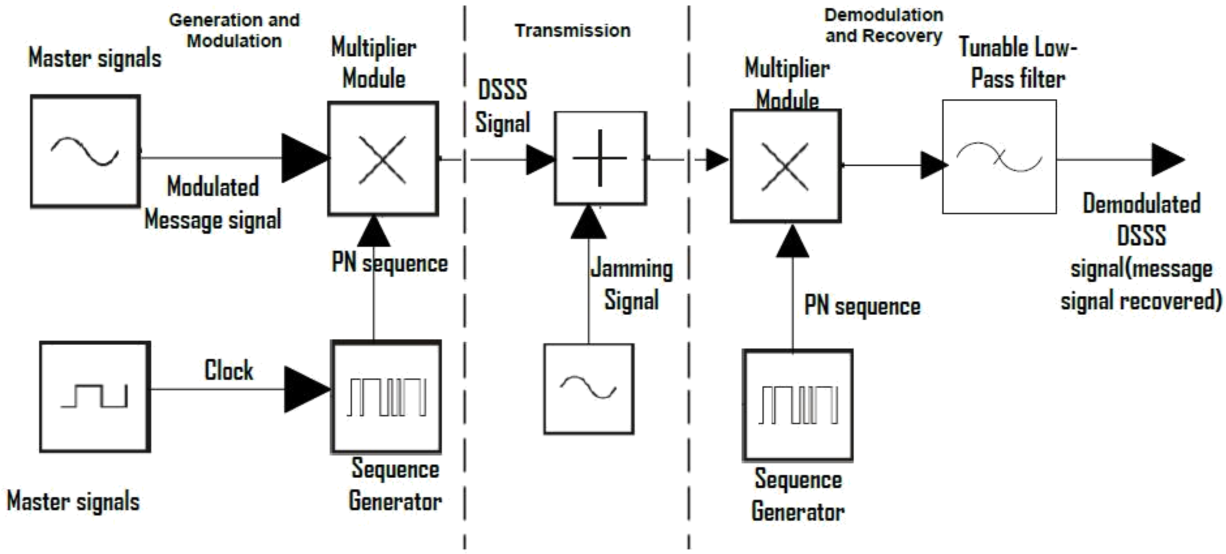
1. The Spread Spectrum signal occupies a bandwidth much greater than that which is necessary to send the information. This results in many benefits, such as immunity to interference and jamming and multi-user access.

2. The bandwidth is spread by means of a code or "noise" signal which is independent of the data. This noise signal is a pseudorandom sequence of 1 and −1 values, at a frequency much higher than that of the original signal and is multiplied with the data being transmitted to achieve the DSSS signal.

3. The receiver synchronizes to the code to recover the data with aid of a product detector (because $1 \times 1 = 1$, and $-1 \times -1 = 1$). The use of an independent code and synchronous reception allows multiple users to access the same frequency band at the same time as is the case in CDMA.

The DSSS laboratory

In this experiment, a simple message signal is generated, transmitted as a DSSS signal based on the DSSS mathematical model and then later recovered using a product detector (Circuit 1). You will study the nature and properties of a DSSS signal, the importance of using a correct PN sequence to recover the message and DSSS' immunity to deliberate interference.



Circuit 1: DSSS circuit

Experiment Procedure

1. On a networked computer, browse to http://ilabs.mak.ac.ug/dsss. This is the URL for accessing the Lab client.
2. There are three buttons, click "Download Lab Manual". This should do just that.
3. Then Click "Download DSSS iLab". This should download a zipped file. It contains an executable version of the DSSS iLab. All you have to do is unzip and install it on a Windows computer. Make sure the computer has speakers or you can hear sound via ear/headphones, and run *setup.exe* to install it.
4. Install the Lab and run the DSSSiLab.exe either in the C:/Program files(x86)/DSSS folder or from the shortcut installed on the desktop. You do not have to be connected to internet to install/run the Lab
5. Follow the steps in the Lab Manual below and note down your observations.
6. After performing the Lab, browse to http://ilabs.mak.ac.ug/dsss. Then Click the "Assessment Button". Fill in your credentials, answer the questions and click "Submit" at the end. You may only attempt this assessment **ONCE** and you **can NOT** attempt it halfway and resume at a later time. Therefore, make sure you have a stable internet connection before attempting the assessment. Read up on DSSS, CDMA and Spread Spectrum Technology beforehand as well.
7. You may experiment with the Lab as much as you please afterwards. Cheers and good luck.

Part A – Generating a DSSS signal using a simple message

As DSSS is basically just DSBSC with a pulse train for the carrier instead of a simple sinusoid, it can be generated by implementing the mathematical model for DSBSC as shown in the "Generation and Modulation" section of Circuit 1.

The following procedures, may apply to both Simulation and CDMA modes of the experiment unless otherwise stated.

1. Activate the DSSS Simulation mode by going to the respective Tab
2. On the top right side of the screen, push the corresponding lever marked *Data Acquisition* **ON**.
3. Look for the *speakers* button and click it. The green led indicator lights when it's ON.
   Please note that the *speakers* button in the Simulation Tab and the one in the CDMA Tab should not be ON at the same time.
4. Select the message signal Type from the **Input Signal** control.
5. Set the message signal's Frequency and Amplitude using the correspondingly labeled **Fill Slides.**

Observe the power spectrum of the message signal on the Acquired Signal Power Spectrum Graph.

Is the message signal narrow band or wideband?

Observe the shape of the PN sequence in time domain i.e. on the PN Sequence graph.

Observe the shape of its Power Spectrum on the PN Sequence Power Spectrum graph i.e. in frequency domain. How does it compare with that of the message signal?

Based on its power spectrum, is the PN sequence baseband or wideband?

What other common signals are known to have this shape of Power Spectrum?

5. In the **Simulation mode**, generate a very short PN sequence by setting its **Sequence Length** to 3.

Describe the new shape of the PN sequence Power Spectrum. Why does it appear like this?

6. Still in Simulation mode, slowly increase the sequence length from 3 to 62 as you observe the effect on the shape of the PN sequence Power Spectrum.

How does the shape of the PN sequence Power Spectrum vary with sequence length? Why does this behavior occur?

Part B – Observation of DSSS signals in time and frequency domain

7. Observe the time **DSSS signal** graph.

Why does the DSSS signal look like the message signal but broken into random chips?

8. Vary the PN sequence length from short to long as you study the DSSS signal's Power Spectrum.

How does the DSSS power spectrum compare with that of the PN sequence in terms of shape and bandwidth?

Part C – Using the product detector to recover the message

The multiplier module and TLPF (Low Pass Filter) in the "Demodulation and Recovery" section of Circuit 1 implement a product detector which recovers the original message from the DSSS signal. To facilitate this, a PN sequence used for the modulator's carrier is "stolen" for the product detector's local carrier.

9. Slowly slide the TLPF cut-off and stop when the message signal has been recovered and is just about in phase with the original.
10. Shift the **Change PN sequence** Lever to the UP position. This will put different PN sequences at Transmitter and Receiver (the sequences are now generated using two different algorithms). In the CDMA Experiment mode, the **Change PN Sequence** lever makes the PN sequences the same but are now not synchronized

Compare the recovered message with the original message signal.

What happens to the recovered signal when the transmitter and receiver PN sequences are not the same?

Does use of a wrong or out-of-synch PN sequence give an incorrect recovered signal? Why is this so?

Part D – DSSS and deliberate interference (jamming)

Interference occurs when an unwanted electrical signal gets added to the transmitted signal (typically in the channel) and changes it enough to change the recovered message. Electrical noise is a significant source of intentional interference. However, sometimes noise is deliberately added to the transmitted signal for purpose of interference or "jamming" it.

11. In either the DSSS simulation or CDMA modes, you may deliberately add noise by clicking the *Add Noise* button. You can then choose a *Noise Type*, and adjust the amplitude & frequency while observing the waveforms.

Does the jamming signal interfere with the recovery of the message? Why is this so?

Give the other benefits of spread spectrum communication

List any four applications of spread spectrum communication

Part E – Code Division Multiple Access (CDMA)

CDMA is a practical multiple access scheme based on spread spectrum communication. It allows many users on one channel to communicate within the same bandwidth at the same time.

Briefly explain how CDMA works

Experiment:-

1. In the **DSSS Simulation** Tab, make sure that the *Data acquisition*, *Speakers* and *Noise* buttons are all set to OFF.
2. Go to the **CDMA Experiment** Tab.
3. You must switch **ON** the *speakers* button **BEFORE** you switch **ON** the *Data Acquisition* button**.**
4. This CDMA Experiment has been designed to prove that two different users can communicate using the same channel by using CDMA. As such, the two users are being represented by two audio songs.

Observe the power spectrum of the message signal on the Acquired Signal Power Spectrum Graph.

Is the message signal narrow band or wideband?

Observe the shape of the PN sequence in time domain i.e. on the PN Sequence graph.

Observe the shape of its Power Spectrum on the PN Sequence Power Spectrum graph i.e. in frequency domain. How does it compare with that of the message signal?

Based on its power spectrum, is the PN sequence baseband or wideband?

5. Generate a very short PN sequence by setting its **Sequence Length** to 3.

Describe the new shape of the PN sequence Power Spectrum. Why does it appear like this?

6. Slowly increase the sequence length from 3 to 62 as you observe the effect on the shape of the PN sequence Power Spectrum.

How does the shape of the PN sequence Power Spectrum vary with sequence length? Why does this behavior occur?

9. Shift the **Change PN sequence** Lever to the UP position. The PN sequence applied to the two audio signal but the sequence applied to the second signal is “Out of Phase” with the one applied to the first one. For example PN sequence to audio 1 maybe at 22 kHz while PN sequence to audio 2 is at 44 kHz. On the receiver end, by changing the receiver PN sequence to 22kHz, audio 1 only will be received and by changing it to 44kHz, audio 2 only will be received.
10. Explore the concept above by flipping the **Change PN sequence** Lever up or down. Adjust the LPF upwards or downwards of 2kHz and listen to what happens to the audio signals. (This is what happens in Bass and stereo speakers)

Compare the recovered message with the original message signal.

11. You may deliberately add noise by clicking the *Add Noise* button. You can then choose a *Noise Type*, and adjust the amplitude & frequency while observing the waveforms.

Does the jamming signal interfere with the recovery of the message? Why is this so?

Point out one limitation of CDMA.