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COURSE ON BASIC TELECOMMUNICATIONS SCIENCE

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Communications Signal Simulator Signal-Signal

Examples

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COMMUNICATIONS SIGNAL SIMULATOR SIGNAL - SIGNALS - EXAMPLES

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SIMULATION EXAMPLES

1 INTRODUCTION

On the disc there are files to demonstrate the operation of the system, to show a number of different types of modulation and to demonstrate the effect of different channels. All the examples on the disc have been set up for a sampling rate of 8Mb/s. The first examples show how to generate waveforms and spectra.

2 WAVEFORMS AND SPECTRA

On starting up the system it should be set up for

a new simulation	1
sampling rate, Mb/s	8
number of blocks	1
number of units	1
waveforms to be plotted	1

The **set up units** menu will be displayed.

2.1 Sine waves

In this section the procedure for calling up unit data from file, running the simulation, and displaying the results will be explained in detail.

On the examples disc is a file **sine**. The data in this file will produce the simulation of a sinusoidal signal. To get this data key in **G** and then the filename **sine**.

The file will be read from the disc. The sampling rate for which the file was made is displayed, then the block number of the data when filed

is given, in this case 1. At this stage a different block number can be entered. However for this demonstration the data should be in block 1 so enter 1.

The sampling frequency, 8MHz, and the number of steps which will be used when the system is run are displayed followed by the data for the block read from the file. In this case there is just one line of data for the sine wave generator. The entries in the different different columns will be explained later. The system is now ready to run.

Press **Enter** enough times to return to the main menu.

To run the simulation key in **2**. A message appears to show that the system is running. A * will show for every 100 steps taken. When the run is complete the elapsed time is shown. Press **Enter** to return to the main menu.

Key in **A** to go to the analyser menu.

To show the sine wave key in **1**. A message appears to say that there is only one waveform which will be displayed twice. If there is more than one waveform two at a time can be displayed. A scale factor must be entered. Enter 1.

The sine wave will be displayed. There are four traces on the display, two for each waveform. As this sine wave is a real baseband signal only a real component is shown.

Press **Enter** to return to the analyser menu.

Key in **4** to generate a frequency spectrum. The spectrum controller menu will be displayed.

First the waveform for which the spectrum is to be generated must be chosen. Key in **1**. Next enter the busline on which the waveform occurred. In this case there is only one so enter 1.

To generate the spectrum of a time waveform the forward transform is required. In the Fourier transform procedure all waveforms are treated as complex. Key in **2**. A message appears to show that the transform is being generated.

From the menu choose a linear or a dB scale plot of amplitude. For a dB plot key in **5**. Then enter a Y scale factor, try 1.

The dB plot is scaled so that the maximum valued displayed is 0dB. In this case two lines appear at ±1MHz. For a real signal the double sided spectrum about zero frequency is displayed.

In the bottom of the display the numerical value of the maximum line is shown.

Press **Enter** to return to the analyser menu. Press **Enter** again to return to the main menu.

This procedure is to be followed to display other waveforms.

2.2 Setting up a new simulation

Follow the above procedure until the **Set up units** menu appears. This menu and the menus called from it are used to set up units. A two tone sine wave generator will be set up. For a real signal generator key in **2**. For a two tone generator key in **3**. A series of entries must now be made for the data about this unit. Try the following.

Unit number	1
Output busline	1
Amplitude 1	1
Frequency 1	1
Amplitude 2	0.5
Frequency 2	0.5

The **set up units** menu will reappear. Enter **d** to display the data about the unit just set up. The unit data is shown. The items shown are

1	unit number
twot	abbreviated name of the unit
23	a reference number for the two tone generator
	2 as it is a real signal, the menu number
	3 as the two tone generator is the third unit in that menu
0	no input on input 1
0	no input on input 2
1	the output busline for output 1, only one output
0	no output on output 2

The next six numbers correspond to the variable data for the unit. In this case the amplitudes and frequencies for the two tones.

Press **Enter** until the main menu appears. Run the simulation and observe the waveforms and spectrum as before. There will be four spectral lines displayed for ±1 and ±0.5 MHz. As the 0.5MHz line has half the amplitude it is 6dB down. On the linear display of the spectrum the 0.5 Mhz lines are shown with an amplitude of 0.5.

Return to the main menu.

2.3 Two real waveforms

Key in **3** to alter the system and **4** to change the number of blocks and units. Enter 1 block and 2 units. Key in **d** to display the units set up. The previous two tone generator is shown and a blank unit. To make a second entry key in **1** to **change units**, the **Set up units** menu appears.

Key in **2** for another real signal generator. Try **4** for a square wave generator. This will be unit 2 with an output on busline 2. Try an amplitude of 1, fundamental frequency of 0.125, and a bi-polar signal. Enter 0 for delay. Go back to the main menu.

Run the system and display the waveforms. In this case two real waveforms are shown.

Go to the frequency spectrum option, choose which waveform for which the spectrum is to be generated. Try the waveform on busline 2, the square wave. Display the spectrum on a linear scale. The harmonically decreasing spectrum of the square wave is shown. As the bi-polar square wave was set up there is no zero frequency or d.c. component.

Go back to the main menu and then to the change system menu. Key in **5** to change a parameter. The units set up are shown. To change the square wave from bi-polar to uni-polar enter the number of the unit to be changed, unit 2. Key in **2** to change a parameter. The third parameter is to be changed from 1 to 0. Change the parameter. Press **Enter** until the main menu is shown.

Run the system and generate the spectrum for the square wave. There will now be a d.c. component in the spectrum.

Return to the main menu and file the block set up. Key in **f** followed by a file name. Try TEMP to see what happens. Upper or lower case letters can be used. The data is filed and the main menu appears.

To view the file key in **4** to got to the directory menu. To list the file key in **6** followed by the usual DOS command, **type temp.dat**. The file will be listed.

3 MODULATION

In this section the modulation of carriers using real waveforms will be demonstrated. There are limitations in using real waveforms because the sampling frequency has to be great enough to reproduce the carrier frequency. The section on complex signals will show examples using the complex envelope when the carrier frequency is immaterial.

3.1 Amplitude modulation

Set the system for 2 blocks and 3 units in each block. Get the file of units **ramtx** and make it block 1, get the file **ramrx** and make it block 2. Block contains two real sine wave generators and a mixer, block 2 contains an amplitude detector and a lowpass filter.

Run the simulation. The block number for the block for which the waveforms are to be stored must be entered. Only one block can be stored on any one run. Enter 1 and observe the waveforms for this block. The system set up produces a d.s.b.s.c. waveform.

Repeat the run storing block 2. Block 2 forms an envelope detector. Note that the envelope detector does not reproduce the original modulating signal. Generate the spectrum of the output waveform. Note the frequencies in the spectrum. The output contains a d.c. component and components at 0.25 and 0.5 MHz and no component at the original modulating frequency.

3.2 Frequency modulation

The files for this simulation are **rfmrx** and **rmfmtx**. Set up the system with two blocks, 2 units in block 1 and 3 units in block 2. To generate the f.m. wave a v.c.o. is used. To demodulate the f.m. a pulse integrating system is used.

Run the system, observe the waveforms and the spectra of the frequency modulated wave and those in the receiver.

4 COMPLEX SIGNALS

In the simulation of bandpass signals the complex envelopes of the signals are used. The sampling rate required is then that appropriate to the rates of change of the envelope, not the centre frequency of the passband. A short mathematical description of the complex envelope of a signal is given in the appendix to the notes on the Simulator.

Bandpass signals are often generated my the modulation of a carrier wave by an information signal. It is natural to think of the carrier frequency as the centre frequency of the pass band. However in some cases such as when analysing the effect of an interfering signal more than one carrier frequency is involved. In that case a pass band which includes both signals is required and the centre frequency of that pass band may be different from either carrier frequency. The carrier frequencies will be offset from the centre frequency of the pass band. In the simulation it is the relative frequencies which are important.

The following examples illustrate the use of complex frequencies and band pass signals.

4.1 Centre frequency oscillator

The file for a centre frequency oscillator is **cfo**. Set up the system with the data in this file which is for a single unit. Run the simulation. Observe the waveform. The display shows a constant level in the real part and zero in the imaginary part. This is correct for an oscillator at the centre frequency and in phase with the nominal reference signal at that frequency.

Generate the spectrum for this signal. The spectrum is a single line at the centre frequency.

From the main menu go to the complex signal generator menu. Change the centre frequency oscillator to have a phase of 45°. Run the simulation. In this case the waveform has equal components in the real and imaginary parts. The magnitude spectrum is the same as before.

4.2 Offset frequency oscillator

From the complex signal generator menu set up an offset frequency oscillator. Use a sampling rate of 8Mb/s, an oscillator offset frequency of 0.25MHz and an initial phase of 0°. Run the simulation and observe the waveform. The waveform is a sine wave in both the real and the imaginary parts. There is a phase shift between the two parts. The real part

is a cosine wave and the imaginary part a sine wave.

Generate the magnitude spectrum of this signal. The magnitude spectrum is a single line at the offset frequency.

Change the offset frequency to -0.25Mhz. The spectral line moves to -0.25MHz.

4.3 Amplitude modulation

In the simulator analogue and digital signal modulators are provided. A demonstration of amplitude modulation is provided with the unit data in the file **amtxrx**. Load this file which contains three units. The units are a real sine wave generator for the information signal, an a.m. full carrier modulator, and an a.m. envelope detector.

Run the simulation and observe the waveforms. The carrier frequency is at the centre frequency and so the only frequency observed is the modulating frequency. The carrier amplitude is 1V so the modulating waveform has a constant level added to it of 1V. The demodulator is an envelope detector which has an output including the d.c. level added to the information signal in the modulator.

The magnitude spectrum shows the carrier and two sidebands as expected.

4.4 Frequency modulation

The file **fmtxrx** includes four units. The units are a real noise generator, a filter to determine the noise bandwidth, the f.m. modulator and a f.m. demodulator. Set up the system for one block and four units, load the data and run the system.

Observe the waveforms. The noise generator generates independent samples at each sampling interval. The lowpass filter reduces the noise bandwidth to 0.25MHz. The output waveform is the same as that of the noise at the input to the modulator although the scale is different. The output waveform of the modulator shows frequency changes.

Generate the spectrum of the noise at the output of the filter. The spectrum is approximately symmetrical about the centre frequency. Generate the spectrum of the signal at the output of the modulator. Note that this is *not* symmetrical. It is easy to demonstrate this asymmetry by simulation but difficult to derive analytical expressions for random modulation.

5 PHASE LOCKED LOOP

The files **pll, pll1, pll2** contain data for a phase locked loop demonstration. The data is for one block and 5 units in the block. The units are an offset frequency oscillator, a mixer, a blank unit in **pll** or an integrator in the other two files, a voltage controlled oscillator, and a CRO unit to display the output of the control voltage. Set up the system. Note that on loading the data the sampling frequency is set to 128 Mb/s. Run the system. The on-line display shows the control voltage altering as the v.c.o. is pulled into phase with the input signal from the offset frequency oscillator.

Reduce the sampling rate to 32 Mb/s. Run the system. Use the analyser to view the waveforms of the offset frequncy oscillator and the v.c.o. The v.c.o. output can be seen to be brought into phase lock with the input signal. There is a phase difference between the two waveforms. Observe the control voltage and note that when in lock there is a steady offset voltage which brings the v.c.o. to 1 MHz, the input frequency.

Get the data from **pll1**. This replaces the blank unit with an integrator. Note the way in which the v.c.o. is brought into lock. Observe the variation in the control voltage.

Get the data from **pll2**. Run the system. The lowpass filter in the control loop has a longer time constant altering the lock-in time.