ELEN90057 Communication Systems Workshop 2

This workshop is worth 4% of the overall subject assessment and should be completed in pairs. Seeking or providing detailed assistance from/to people other than your workshop partner is collusion - see http://academichonesty.unimelb.edu.au/plagiarism.html

One **joint** report per pair, containing your worked solutions, SIMULINK code and outputs should be submitted. All reports should come with a School of Engineering cover-sheet attached with your name, Student ID and signature, and be submitted to your demonstrator's designated pigeon hole in level 4, EE (south stairwell). Please indicate your workshop time and day.

Note that you may be called in at random to verbally explain your results and solutions.

Note that for all TIMS workshops, only authorised results can be used in your report. They must be collected during your designated lab session, signed by your demonstrator and attached with your report at the end.

AIMS:
This workshop will be your introduction to the TIMS unit. It is designed to help you to develop modelling and experimental skills for the following TIMS workshops. In particular, you are asked model both DSBSC and AM signals. Although you are already familiar with these concepts analytically, here, you need to demonstrate them in hardware and perform adequate spectral analysis on the output signals.

EQUIPMENT:
One Standard Emona TIMS unit with the following additional modules:

- Audio Oscillator, Multiplier X 2, Tuneable LPF, Utilities, Adder, Speech Module, and Quadrature Utilities

Assorted cables and leads - standard patch cables and BNC-BNC cables

Oscilloscope and Spectrum Analyser - Tektronix TDS220 digital scope with FFT function

1. Introduction to TIMS (6 marks)

TIMS is a Telecommunications Instructional Modelling System. The name says it all - it is a modular system that allows the modelling of various telecommunication systems. It can support the modelling of both analogue and digital signals, as well as representing various transmission media.

Being a modular system, the TIMS unit and modules can be arranged, interchanged and explored in any order. In this experiment we will first generate a modulated waveform and explore its features, then demodulate it to attempt to prove regeneration.

One important labelling system used in TIMS is the colour coding for analogue and digital signals. Analogue inputs or outputs are YELLOW, while digital ones are RED. Unless performing analogue to digital or digital to analogue conversions, it helps to adhere to this colouring scheme by using appropriate cables (although technically not vital, as the patch cables are identical).

Another goal of these experiments is to develop your report writing skills. It is useful to discuss your methodology with reasonable detail, so that your experimental data can be recreated if necessary. It is highly recommended that before presenting results for any particular section that you present a **configuration of the circuit** being studied, as well as any pertinent **equipment settings** that are used to obtain your results.

The first task is to familiarize yourself with the modules to be used in this workshop - they will help you to construct the functional blocks required, and may also give you an insight into potential configuration alternatives to create new scenarios!

The easiest way to learn about the TIMS applications is through experimentation. Try a few modules out - They are extremely self-explanatory!!!

a) Discuss the min/max values for properties such as Voltage, Frequency and Gain for VARIABLE DC, MASTER SIGNAL, AUDIO OSCILLATOR, ADDER, QUADRATURE UTILITIES and MULTIPLIER. As well as noting the key characteristics, provide some details as to any variation to the nominal specifications provided. (i.e., compare with Module Descriptions.)

2. DSBSC Generation (13 marks)

DSBSC can be generated by multiplying the message signal $m(t)$ with a high frequency sinusoidal carrier $v_c(t) = A_c \cos(2\pi f_c t)$. For simplicity, we assume that the message signal is a two-tone sinusoid signal with fundamental frequency f_m, where $2f_m \ll f_c$

$$m(t) = \frac{1}{2}\cos(2\pi \cdot f_m t) + \cos(2\pi \cdot 2 f_m t)$$

a) Find time-domain expressions for the upper sideband and lower sideband of the output DSBSC signal $s(t)$. Find the Fourier transform $S(f)$ of the DSBSC signal. How many spikes are we expecting in the frequency domain $-\infty < f < \infty$?

b) Use appropriate TIMS modules to generate and save/photograph a time-domain representation of the DSBSC signal with $f_c = 100\text{ kHz}$ and $f_m = 2\text{ kHz}$. Note that to stabilize the waveform on the oscilloscope, appropriate triggering may be required.

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c) By using the FFT functionality of the Tektronix Oscilloscope, observe and save/photograph the spectra (frequency domain representation) of the above signal (noting magnitudes and frequencies). Comment on any discrepancies between your experimental results and the analytical result obtained in *a)*.

Demonstrator's Signature

d) Modify the fundamental frequency of the message and comment on the effect on the DSBSC signal in both the time- and frequency-domains. What frequency ranges are available for the message using the AUDIO OSCILLATOR? Discuss any potential implications that this range may have. For instance, could our equipment be used to interfere with local AM radio stations?

3. DSBSC Demodulation (16 marks)

Recovery of the DSBSC signal requires a copy of the carrier to be generated at the receiver and to be synchronised with the transmitter carrier signal. Ideally, this sinusoid signal should have exactly the same frequency f_c and possibly a small phase offset φ, compared to the transmitter carrier, i.e., $\tilde{v}_c(t) = A_c \cos(2\pi f_c t + \phi)$. To down-convert the signal back into baseband, $\tilde{v}_c(t)$ can be simply multiplied with DSBSC signal $s(t)$. The resulted signal will then go through a lowpass filter, where all the high frequency terms are rejected. This method is commonly referred to as the coherent demodulation method.

(In a laboratory environment, it is a simple matter to use a "stolen carrier" directly from the transmitter, for demonstration purposes. In commercial practices, this synchronised carrier must be regenerated locally at the receiver end. Methods of phase-locking two carrier signals will be investigated in later workshops.)

a) Find time- and frequency-domain expressions for the received signal after the DSBSC signal has mixed (been multiplied) with the "stolen carrier". In the frequency domain, how many spikes are we expecting now? Observe and save/photograph the signal spectra after "down-converting" to verify your result.

b) What range of values can we choose for the 3-dB bandwidth of the lowpass filter?

c) Choose appropriate TIMS modules to build up a DSBSC demodulator and recover the message signal. Use both channels of the oscilloscope to save/photograph, and compare the output waveform with the input message signal (e.g., amplitude, frequency, etc.).

Demonstrator's Signature

d) Find a time-domain expression for the Hilbert transform of $s(t)$, denoted by $\hat{s}(t)$. Show explicitly that the Hilbert transformer-based demodulator (see lecture notes) yields a scaled version of the message. [Hint: you may wish to use the fact that $\cos^2(2\pi ft) + \sin^2(2\pi ft) = 1$.]

e) Choose appropriate TIMS modules to implement the Hilbert transformer-based de- modulator and recover the message signal. Save/photograph and compare the output wave- form with the results obtained in *c)* (e.g., amplitude, frequency, etc.).

Demonstrator's Signature

4. AM Modulation (11 marks)

A unique property of AM is that the envelope of the modulated signal has the same shape as the message. The main difference between AM and DSBSC is the DC offset that occurs in the AM signal.

Assuming the same message $m(t)$ and carrier $v_c(t)$ signals are used, compare the DSBSC and AM expressions and discuss how one can be achieved from the other with appropriate TIMS modules.

a) Find the largest theoretical value of μ that can be used for the message $m(t)$ from Q3. (Hint: $\cos(2x) = 2\cos^2 x - 1$).

b) Use appropriate TIMS modules to generate and save/photograph a time-domain representation of an AM signal, where same message $m(t)$ and carrier $v_c(t)$ as in **part 2** are used. Provide two graphs of the TIMS-generated AM waveforms, for μ less than and for μ larger than the maximum value in *b)* above. Discuss any relevant features of your graphs.

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c) By using the FFT functionality of the Tektronix Oscilloscope, observe and save/photograph the spectra of the above signals noting magnitudes and frequencies.

Demonstrator's Signature

5. AM Demodulation (2 marks)

While DSBSC requires complicated coherent demodulation circuitry, recovery of the AM can be simply done using a non-coherent (i.e. asynchronous) demodulation method, with the help of an envelope detector. TIMS can implement this via the RECTIFIER (contained in the UTILITIES module) and the TUNABLE LOWPASS FILTER.

Using both channels of the oscilloscope, compare the output waveform with the input message signal in time-domain. Then use the FFT functionality to compare them in frequency- domain. (Notice that in order to remove the DC offset contained in the demodulated signal, you may wish to set the oscilloscope in AC mode to reject any DC component in the input signal.)

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6. Advanced Section (2 marks)

Time permitting, replacing the message $m(t)$ with the output of the SPEECH MODULE, and repeat the DSBSC or AM experiments above. Use the Run/Stop feature of the scope to save /photograph the modulated & demodulated voice signals in time-domain.

Demonstrator's Signature