COMPUTER-INTEGRATED LECTURING IN TELECOMMUNICATIONS TRAINING

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Abstract ¾ *This paper discusses the prevailing climate in both university and industry that necessitates increased use of computer-integrated lecturing in engineering education. Practical examples of this teaching approach are presented drawn from the field of telecommunications. The examples involve graphical user interfaces and animations developed under a MATLAB® platform. Important foundational concepts are introduced and graphically illustrated in a way that is both insightful and intuitively satisfying. These include frequency and time-domain demonstrations of sampling, aliasing, and sampled signal reconstruction, and hence the sampling theorem; visualisation of a range of signal parameters and their effects on the frequency content of the signal, bandwidth concepts, Fourier synthesis, and the inverse relationships between time and frequency; etc.*

Index Terms ¾ Telecommunications, Engineering Education, Computer-integrated lecturing, minimal-mathematics

INTRODUCTION

The last decade witnessed a dramatic growth in the use of computers in homes, spurred by the birth of the Internet and the popularity of computer games and computer-assisted learning. In the 1970s the computer was an expensive, specialist, daunting and detached machine. But by the end of the 1990s it had evolved into an affordable, ubiquitous, easy-to-use, friendly and personal tool for business, education, research, leisure, communication, social interactions and entertainment. An important consequence of this phenomenal development is that to most young people and university entrants, the computer, with all its versatility, now has the friendly image of a television set. Many engineering students who are ill at ease with the traditional chalk-and-talk teaching approach, especially when this is wrapped in mathematics, will readily warm to an approach that makes computers an integral part of the lecture since this employs what is to them a friendly medium of communication. Computer-integrated lecturing can transform a boring session into a fun experience. It also enhances learning through a multi-sensory engagement of the students and, crucially, erects knowledge pegs prior to a more detailed treatment of a topic.

In the sequel, the rationale and benefits of computer-integrated lecturing (CIL) as well the major barriers to its widespread use are outlined. Two of the MATLAB-based software tools being developed for introductory telecommunications classes are discussed as examples of CIL.

RATIONALE AND BENEFITS

Apart from the fun-image of computers discussed above and their potential for multi-sensory engagement, there are a number of other compelling reasons for increased integration of computers into lectures particularly in engineering education:

- **Role of Computers at Work:** Advances in information and communications technology (ICT) have permanently altered the way practising engineers work in the 21st century — more productively using a variety of design, computational and simulation tools [1]-[2]. It has been noted [1] that, "In the past, engineers had only pen and paper, the slide rule and mathematical/statistical tables to help with their calculations. But today's engineer can obtain reliable solutions to mathematical problems using ubiquitous software packages." This sentiment is borne out by the work of Kent and Noss [2] who carried out interviews and observations in a large multidisciplinary engineering consulting firm in the UK. They found that analytical work is done largely by computer software and only 2% of the engineers in the company were analytical specialists able to deal with any non-standard or ambiguous problems. Since the computer plays such a pivotal role in the work of most of today's engineers, it ought to feature more prominently in their training in order to better prepare students for the demands and actual workstyle of modern industry.

- **Declining Mathematics Skills:** Studies in the UK [3] have revealed a steady decline in essential mathematics skills amongst new intakes into engineering departments. The 'chalk-and-talk, maths-first-engineering-second' approach of the 'good old days' is therefore increasingly inappropriate to the type of students becoming prevalent in our universities. A recent survey [4] of students and practising engineers showed that most prefer a minimal-mathematics teaching approach that gives them excellent insight into the engineering problem or concept at hand and a thorough understanding of the interplay of relevant design parameters. The use of computer simulations in classroom situations would allow such students to

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explore the subject, readily posing a lot of 'what-if' questions and interactively receiving answers to them; and in the process erecting crucial pegs on which they can hang a more detailed subsequent treatment of the subject.

- **Recruitment and Retention Challenges:** Many UK engineering departments are having to grapple with recruitment and retention problems as they attempt to widen access to meet both government and own survival targets. Wastage (failure + withdrawal) statistics show students to be most at risk in their first year [4]. It is therefore vital that during the first few lectures, engineering academics succeed in endearing their students to (rather than deterring them from) the study of engineering. The use of computer and software tools would make this task a lot easier.

BARRIERS TO CIL

Extensive use of computers to enhance lectures in the manner described above is currently hampered by a lack of easy-to-use custom off-the-shelf software products designed to explore and simulate the engineering problem or concept of interest at a sufficient depth. A diligent search of the Internet may lead one to free web-based animations of a few engineering topics, but these programs generally offer only a shallow treatment with limited scope for exploring the topic with a range of 'what-if' questions.

Many engineering academics do not have the time and programming skills required to develop suitable software applications to deliver computer-integrated lectures. Therefore until such packages become widely available that require little or no programming skills to use, the computer will not feature in the lectures of most engineering academics beyond their use of well known software packages such as PowerPoint and Blackboard at various levels of sophistication for delivering lecture notes. Many years into the ICT revolution, this continued but avoidable failure to tap the full potential of the computer to enhance the student's classroom experience represents a significant and regrettable disservice to engineering education.

EXAMPLES OF CIL

The following are examples of some of the ongoing software developments being undertaken to support the teaching of telecommunications topics to students and practising engineers at the University of Glamorgan. The package on sampling is suitable for classroom demonstrations with the computer display projected onto a screen at the front of the class. The second package is more suited to laboratory investigations with each student running the program on a MATLAB-equipped PC.

Sampling of Analogue Signals

A MATLAB program was written to allow an animated graphical approach to the important subject of sampling,

which introduces such important concepts as the sampling theorem, Nyquist rate, aliasing, signal reconstruction, etc. in an intuitively satisfying way. Importantly for a student first encountering the topic, matters are not obscured with needless mathematics. Using the software demonstration the student can acquire a clear insight into the underlying physical basis of the sampling process and the interplay of the parameters involved. Mathematics can then be introduced as a means of concisely encapsulating what has been observed. This approach rightly puts engineering first and mathematics second.

The animation program sampling_demo runs at a pace selected by the user. When started it shows an analogue waveform signal. This represents a unique frequency fm — a single value if the user chooses a sinusoidal signal. Taking regular samples of the waveform at a rate fs leads to a loss of this uniqueness. The program demonstrates this by showing one after the other that an infinite range of frequencies nfs ± fm, n = 0, 1, 2, 3, ... will exactly fit the set of samples and that the sum of these sinusoids yields the sampled signal (See screen shot of Figure 1).
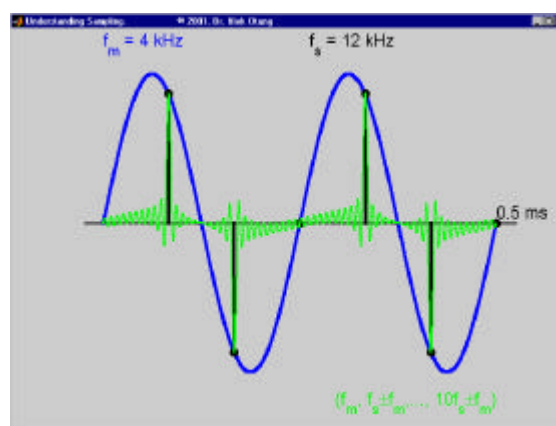

FIGURE. 1

ANALOGUE SIGNAL OF FREQUENCY FM SAMPLED AT RATE FS, AND THE SIGNAL RESULTING FROM A SUM OF SINUSOIDS NFS ± FM, N = 0,1,2,…,10

It follows and is demonstrated by the program that the spectrum of the sampled signal consists of frequencies fm, fs − fm, fs + fm, 2fs − fm, 2fs + fm, ...The program then shows that the original signal can be reconstructed from the samples by using a realisable low pass filter (LPF) to pass only fm. See screen shot of Figure 2. However, if fs−fm (the nearest to fm of all the frequency components contained in the sampled signal) is less than fm, then the LPF recovers a false or alias frequency |fs−fm|. The program demonstrates this aliasing both in the time domain (Figure 3, sinusoid) and frequency domain (Figures 4 and 5, sinusoid and bandlimited signal respectively). By watching this demonstration using different parameter values, the student can clearly see for themselves that the condition for avoiding aliasing is that fs−fm ≥ fm, or fs ≥ 2fm. This is the sampling

theorem. Furthermore, the program illustrates why Nyquist rate fs = 2fm is not used in practice since it requires an ideal reconstruction LPF (Figure 6). The values of fm, fs, n, etc. are user-specified.
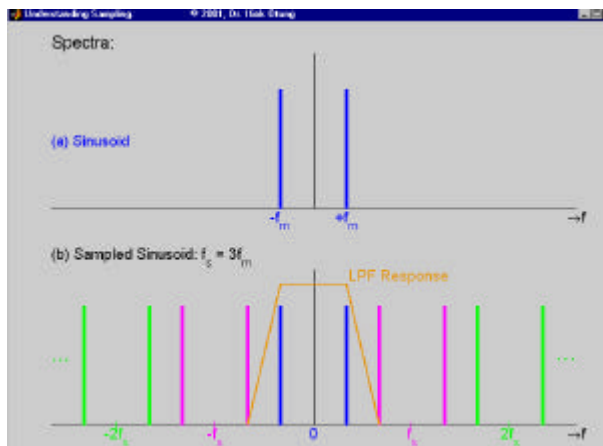

FIGURE 2
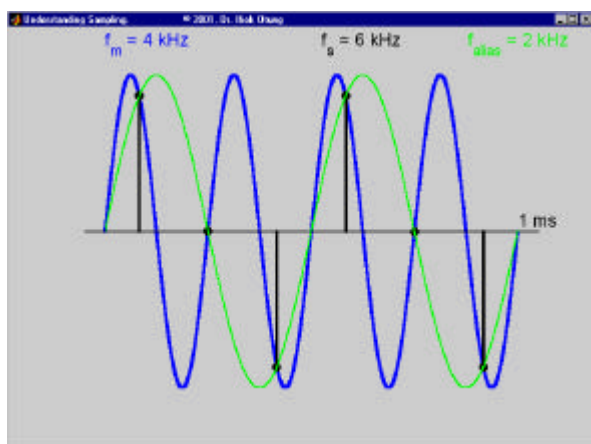RECOVERING ORIGINAL SINUSOID FROM SAMPLED SINUSOID USING A LPF THAT PASSES ONLY FM

FIGURE 3
TIME DOMAIN VIEW OF ALIASING: UNDERSAMPLING A 4 KHZ SIGNAL AT SAMPLING FREQUENCY 6 KHZ YIELDS A 2 KHZ ALIAS FREQUENCY

Signals in Time and Frequency Domains

A MATLAB-based graphical user interface (GUI), Figure 7, was developed for the study of periodic signals and their parameters, Fourier synthesis and bandwidth concepts. When launched in the MATLAB command window by typing periodic_signals at the MATLAB prompt and pressing return, the GUI starts in the '(No synthesis)' mode, allowing the user to explore various periodic signals (rectangular, triangular including sawtooth, shaped, staircase, sinusoidal and arbitrary) and the meaning and role of various parameters such as amplitude, period, duty cycle, phase (sinusoids only), delay, ratio between rise and fall widths (triangular signals only), and number of steps (staircase signals only). Those parameters that are not applicable to a selected 'Signal Type:' are automatically disabled.

To investigate signal phase or delay, the 'Ref. waveform' checkbox should be selected to instruct the program to display the reference waveform with respect to which the phase or delay is defined. Delay is specified as a fraction of the signal period. For example, if the selected signal period is 10 seconds, then a delay of 0.1 means 1s, a delay of 1 means 10s,and a delay of -0.25 means an advance of 2.5 seconds.

The concept of duty cycle is best explored by selecting the rectangular signal type, although other signal types maintain a consistent definition. Selecting a sinusoidal signal type along with a 100% duty cycle generates continuous wave sinusoids, allowing the parameters of this important class of signals to be studied. Choosing other values of duty cycle in conjunction with the sinusoid will generate discontinuous sinusoids in keeping with the definition of duty cycle.

For a study of Fourier synthesis and bandwidth concepts, which allows one to explore the frequency content of any of the signal types with any combination of parameter values, the 'No. of harmonics N:' popup menu is changed from '(No synthesis)' to a value N = 0, 1, 2, ...or 100. By selecting the 'Synthesised' waveform checkbox and gradually increasing N, one can observe Fourier synthesis in action and the distortion effect (0% < power < 100%) of omitting higher frequency components. One can then easily grasp the concept of bandwidth, one definition of which is the range of sinusoidal frequency components that carry say at least 98% of the total signal power. By changing pulse shapes at the same duty cycle, or pulse widths of the same pulse type, one can explore important concepts such as the bandwidth effects of pulse shaping and time-frequency inverse relationships. Furthermore, the effects of important time domain operations such as time reversal and delay on signal spectrum can be interactively examined.

There is an option of either a graphical display of the frequency content of the signal (which shows the amplitude spectrum only), or a tabular display, which gives a listing of the frequency, amplitude and phase of each harmonic n = 0, 1, ..., N. Harmonics of zero amplitude are omitted. For example, since a square wave (a rectangular signal of duty cycle 50%) consists only of odd harmonics, the spectral display shows values for n = 0, 1, 3,...

This GUI can support a number of investigative laboratory sessions, namely
- Periodic Signals and the Sinusoid
- Fourier Synthesis & Signal Bandwidth
- Time-Frequency Domain Relationships

CONCLUSION

A case was made for harnessing the potential of computers to enhance engineering lectures. Properly designed animation and simulation software tools provide a multisensory and fun engagement of students in the study of otherwise tedious engineering topics, allowing them to interactively pose a wide range of 'what-if' questions and to erect crucial pegs on which they can hang a more detailed and mathematical treatment. Two such tools were discussed, one suitable for demonstrating signal sampling in the lecture, and the other for a wide range of laboratory investigations into the time and frequency domain characterisations of periodic signals. The development of such tools is a time consuming exercise and there is a general dearth of ready-to-use commercial products. However, in the current climate of worrying first-year wastage statistics amongst engineering departments, any judicious expenditure on developing computer-integrated lecturing would be a rewarding investment judging by the feedback so far received that these tools make the subject of study enjoyable and easier to follow.
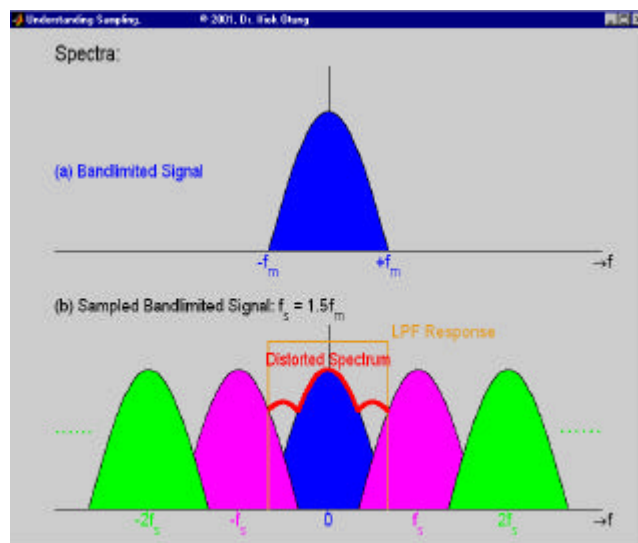

FIGURE 5
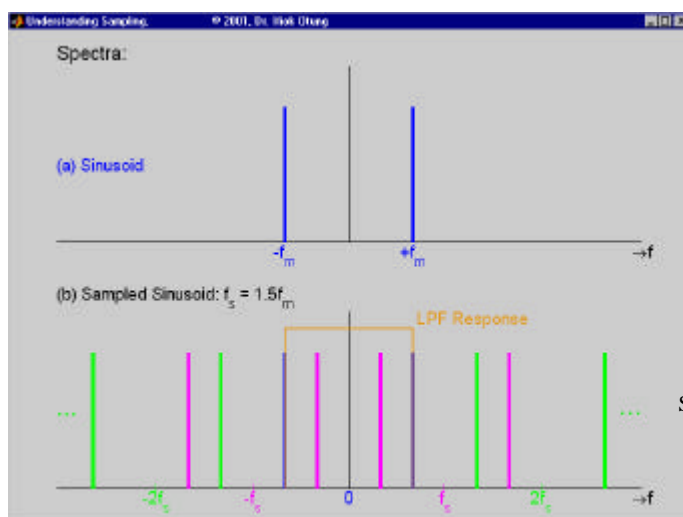ALIAS DISTORTION DUE TO UNDERSAMPLING A BANDLIMITED SIGNAL.

FIGURE 4
FREQUENCY DOMAIN VIEW OF ALIASING DUE TO UNDERSAMPLING A 4 kHz
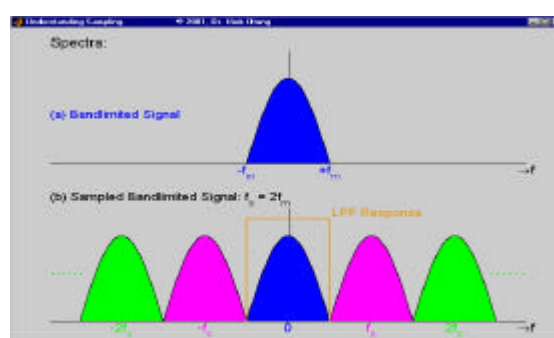SINUSOID AT SAMPLING FREQUENCY 6 kHz. LPF EXTRACTS A 2 kHz ALIAS.

FIGURE 6
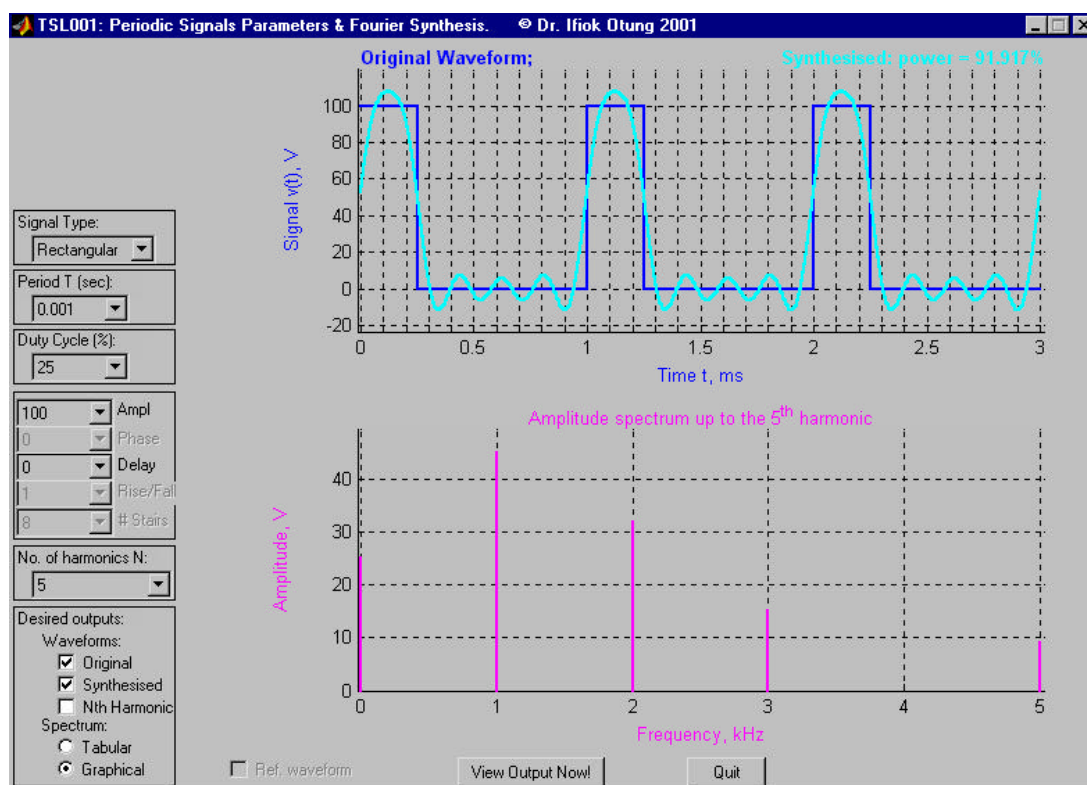SAMPLING AT NYQUIST RATE REQUIRES IDEAL RECONSTRUCTION LPF

FIGURE 7
PERIODIC SIGNALS GUI

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