Session 2247

DEVELOPING COST-EFFECTIVE LABORATORY EXERCISES FOR TELECOMMUNICATIONS PROGRAMS

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Abstract

Telecommunications equipment that are commonly utilized in industry are generally expensive and it is becoming increasingly more difficult for universities to afford even some of the most basic of these equipment for their laboratories. As a result, Engineering Technology programs have had to resort to alternative means of providing the requisite laboratory training for their students. One such effective alternative is to use simulations to give students a hands-on experience of specific technologies. Many standard software packages, as well as specialized packages that are available for use in Telecommunications Engineering Technology programs, can be utilized to emphasize particular telecommunications theories or to simulate specific technologies. This paper discusses the approaches used in the Telecommunication programs at Pennsylvania State University Wilkes-Barre, and Southern Polytechnic State University.

Introduction

In an ever evolving technological world, there is a need for university and college programs to keep up with the developments in industry. This is especially true for those educational institutions that offer programs in the engineering technologies, engineering, and computer related fields. Since the graduates from these institutions form the pool of new employees for industry, it is important that industry contributes ideas on the preparation of the graduates. Industry constantly functions at the cutting edge of technology. As such, it can be expected that suggestions from industry will be based on current technological applications. In order for graduates to be sufficiently well prepared for the work place, they will need to be instructed on the latest developments in industry. It is for reasons such as these that many programs utilize Industrial Advisory Committees (IAC) who can provide an industrial perspective to the institutions.

The IAC forms an essential component to the administration of academic programs in providing advice on current industrial practices and the direction technology may take in the foreseeable future. Such information contributes in designing laboratory exercises that are appropriate for technological courses. Through this approach, students get the opportunity to learn aspects of industrial practices before graduation. This helps to create a seamless transition from the academic environment to the industrial setting.

In the recent past, the Telecommunications industry has experienced phenomenal growth due to developments in computing. Computers have now been incorporated in many telecommunications hardware products. Wireless applications, a necessary component in telecommunications, are experiencing resurgence along with the growth of the telecommunications industry. For some years past, the greater effort in industry was concentrated on building the infrastructure. Currently while there is still the need for some building and maintenance of the infrastructure, there is a high emphasis on operation of the systems. The growth in the industry has therefore created the need for the type of graduate who can support the construction of the telecommunications infrastructure, and equally importantly, to operate the systems. These graduates need to be practical oriented individuals who have the capability of assembling together the components and modules of equipment, connecting and testing them to make sure that they work effectively as an assembled unit, and to run them.

Due to the more complex nature of the telecommunications equipment these days, the current industry requirement calls for a change of emphasis in the preparation of graduates. While they still need to understand the equipment in terms of how they function and how to assemble them, it has become paramount that the graduates are proficient in operating the equipment. The central core of modern telecommunications equipment is a computer, and this calls for a graduate who is not only computer literate, but also has the expertise of an information technology specialist.

The cost of procuring the type of equipment used in the industry can be quite prohibitive for many engineering technology programs. The problem has been compounded by the current economic environment which makes it more difficult for universities to afford even the most basic of the necessary equipment for their laboratories. Fortunately many standard software packages, as well as specialized packages are available for use in Telecommunications Engineering Technology programs. These packages can be utilized to emphasize particular telecommunications theories or to simulate specific technologies. This paper will look at how two institutions have utilized some of these available software packages to emphasize key concepts of particular telecommunications theories.

Examples of Telecommunications Software Programs

As a result of the fact that universities are unable to afford expensive equipment that are used in industry, one effective alternative is to use simulations to give students a hands-on experience of specific technologies. The approach becomes very appropriate if these simulation packages are to be found in industry as well.

I. Ansoft Serenade Student Version Software[1]

One such simulation package that is used in the Penn State Wilkes-Barre Telecommunications Program is the student version of the Ansoft Serenade, a package that is used in industry and costs several thousand dollars to industry. This software is used to simulate electromagnetic problems and to design microwave components and systems.

The University Program of Ansoft Corporation makes the Serenade Student Version (SV) software readily available to universities. This software product has proved to be very useful as a teaching aid in the laboratory and serves as a powerful design and analysis tool for RF and microwave systems engineering students. It can also be used for optoelectronic design. The analytical capabilities are broadly categorized as linear and nonlinear. The analytical methods used in this product include noise analysis, stability analysis, digital modulation analysis, statistical analysis, scattering matrix[2] and spectrum analysis to name a few. It has an extensive active and passive library of manufacturer's parts. The design utilities include transmission lines with an extensive media support, filter synthesis and Smith chart. It is capable of optimization and tuning. Possible systems that can be designed are numerous and an example is given below.

As an instructional aid, the user's guide is presented in a step-by-step format which takes the first time user through all the steps essential to becoming competent in its application. The examples manual contain many examples that will give students more than sufficient practice in the topics covered to complement classroom exercises which may be based on student projects. A reference manual effectively completes the supporting documentation, providing detailed information on the analytical methods used.

II. SystemView by Elanix

A simulation package that is used by the Southern Polytechnic State University (SPSU) Telecommunications Program is the SystemView[3] simulation software package by Elanix Corporation. This software package is used in industry by companies such as 3Com and TRW, among others, for system level product design, development and testing. This software package is used for simulation of systems and application in communications, digital signal processing and controls. Some example systems and applications include the following[4]: 3G, Bluetooth, 802.11, Wireless Communications, GSM, CDMA, TDMA, IS-95, Modems, QPSK, QAM, FSK, Spread Spectrum, Audio Processing, Radar, Sonar, Signal Analysis, Signal Intelligence, Digital Receivers, Beamforming, and Direction Finding.

The university program of Elanix corporation makes the full professional version of their SystemView software available to universities for a minimal annual licensing fee. Additionally, an evaluation version of the software can be downloaded from their website. This evaluation version lacks the full functionality of the professional version, but for institutions with a license agreement, enrolled students can be provided with a temporary license to upgrade the evaluation version into a fully functional professional version.

This software product is another valuable teaching aid in the laboratory. It offers a powerful design and analysis tool for RF and telecommunications systems. Among the features of this product are the following[4]:

- Full complement of logic functions, switches, and non-linear devices
- Complete libraries of sources, sinks, functions, operators, and MetaSystems
- External and internal signal sources and sinks

- Distortion-true RF/Analog design including amplifiers, mixers, and Op Amp circuits
- Mixed time-continuous and time-discrete systems
- Extensive library of analog filters including multi-pole Bessel, Butterworth, Chebyshev, and Linear Phase
- Spectra: magnitude, squared magnitude, spectrum analyzer (mWatts in 50 ohms and Watts in ohms), power spectral density (mW/Hz, 50 ohms and W/Hz, 1 ohm), phase (modulo 180 degrees), phase (unwrapped) in degrees, group delay in seconds, real, imaginary
- Unlimited support for embedded, multi-level subsystems (design hierarchy)
- Graphical FIR filter design, including lowpass, bandpass, highpass, band-reject, Hilbert (90 degree phase shift), and differentiators
- Bit-true DSP design and code generation

The software comes with a full online user's guide along with several examples of simulations that can readily be incorporated into or modified for new designs. There are also sample designs available from the Elanix website. These examples were generated by Elanix staff or were submitted by users in academia and from the industry. These examples help to develop better student understanding of the applications of the software. Other documentation available provides details of all the libraries included in the software package.

III. Example of Ansoft Serenade Utilization in Support of Course Content

Components of the *Wireless Systems* course at Penn State Wilkes-Barre deal with transmission lines, RF amplifiers and antennas. Current technology incorporates the planar format which helps in miniaturization. In microwave applications, edge-coupled microstrip lines[5] can be used to make filters. In classroom instruction, this forms a useful extension on the application of transmission lines, a lesson which may be started by discussing the wire pair etc. The edge-coupled microstrip lines filter is one of the exercises that can be performed with the Serenade SV software.

The example in Figure 1 shows a two port four-coupled line sections forming a filter. This figure also shows a Substrate Media control block which gives parameters such as the thickness of the substrate on which the filter is constructed, the dielectric permittivity of the substrate and the height of the cover which indicates the structure is not open to free space. Other details required but not shown are the type of metal used, for example copper, the loss tangent for the material which indicates that the effective dielectric permittivity is used. Next is the Frequency control block which gives the starting frequency and the final frequency, and the steps in-between. Next is the Variable control block where all the variables are listed. This block is also used for optimization. Figure 2 shows the transmission (S21) and reflection (S11) coefficients of the filter circuit. The analysis is done by use of scattering parameters.

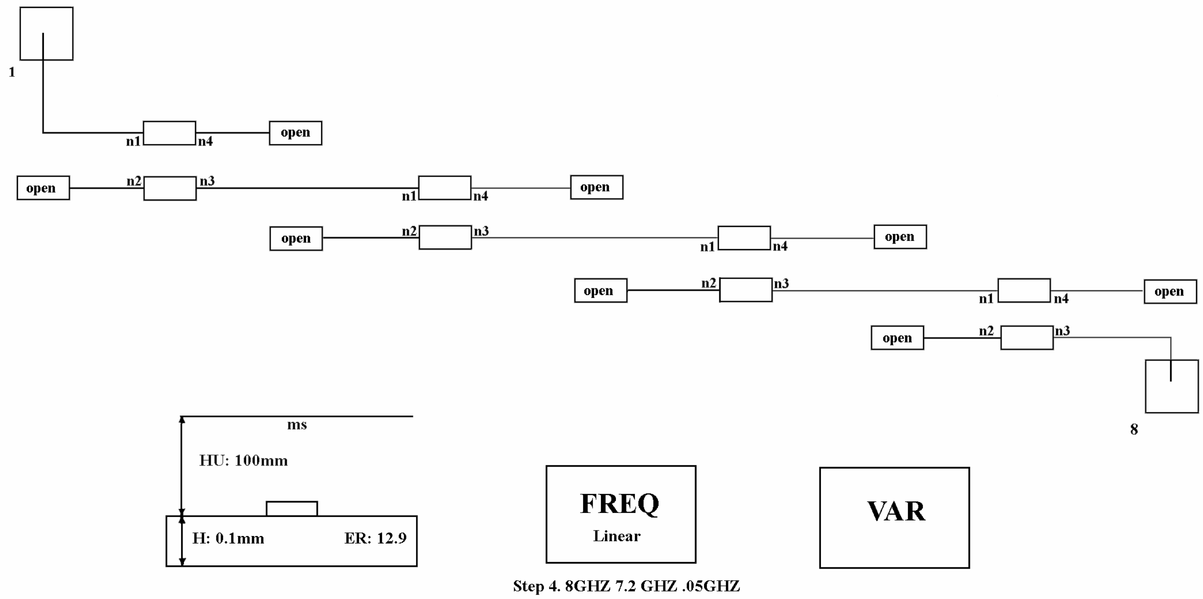

Figure 1. Edge-Coupled Filter

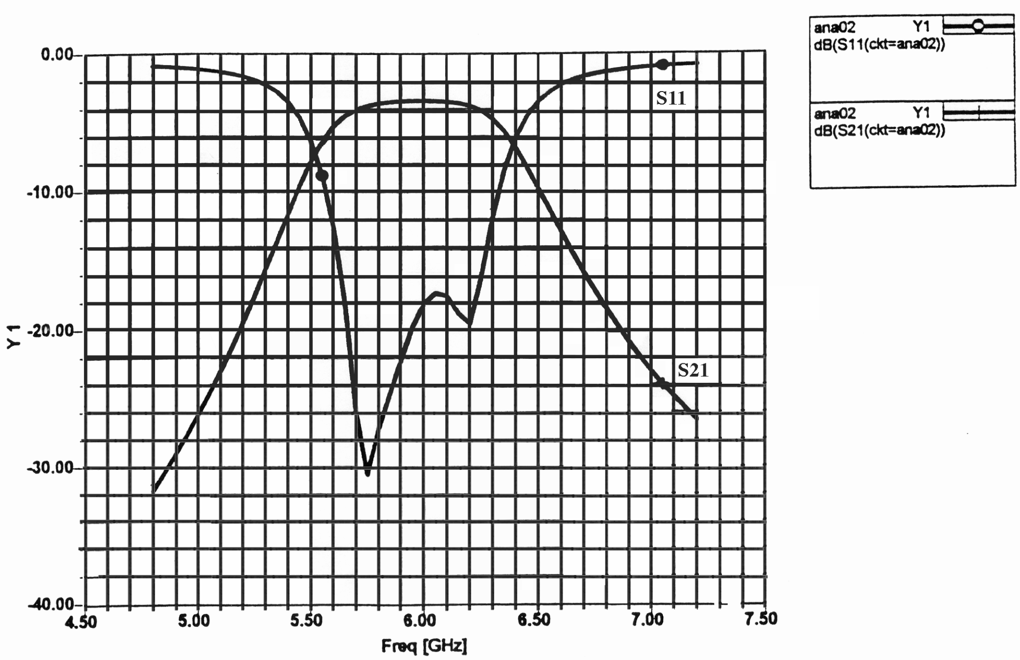

Figure 2. Transmission (S21) and Reflection (S11) Coefficients of the Filter versus Frequency.

IV. Example of SystemView utilization for Signal Analysis

In designing electronic communication systems, one usually finds it necessary to analyze and predict the performance of the circuit or system based on the voltage distribution and frequency components of the information signal. Fourier analysis forms the basis of this signal analysis and is fundamental to an understanding of many aspects of telecommunications systems such as filtering and bandwidth. Signals that are encountered in telecommunication systems can often be represented by combinations of sine and cosine waves[6].

Components of the *Data Communications* course at Southern Polytechnic State University deal with Fourier signal analysis and experiments have been developed based on the use of SystemView. The example in Figure 3 shows a setup for simulating the Fourier analysis of different signal waveforms. This simple experiment can be used to complement classroom instruction in Fourier theory. The output of the signal source is applied to a Butterworth low-pass filter and the output of the filter is then examined as the cut-off frequency of the filter is varied. In Figure 3, the source signal is a periodic pulse train with a frequency of 1 kHz, amplitude of 10 volts, an offset of -5 volts, a pulse width of 0.5 milliseconds and a phase of 0□. The filter is an IIR filter with a cut-off frequency set to 500 kHz.
Sink 1 provides a display of the original waveform and sink 3 is the output of the Butterworth low-pass filter.

SystemView allows for the display of the source signal and the filtered output signal in its Analysis Window. Plots of these signals are provided in Figure 4. It is also possible to overlay the plots for a graphical comparison of the source signal and the filtered output signal. SystemView also allows for the display of the spectra of the signals. Figure 5 is an expanded plot of the spectra of the filtered output waveform. Examination of the spectra allows the student to identify harmonics in the signal waveform and their location in the frequency domain.

Variation of the cut-off frequency of the low-pass filter allows one to examine the effects of band-limiting. As an example, the cut-off frequency of the filter is reduced to 8 kHz and the output signal is again analyzed. Figure 6 shows the source waveform and the filtered output waveform for this case. Figure 7 is the expanded view of the filtered output signal spectra showing the reduced harmonic content in the filtered output signal.

SystemView provides a graphical analysis to complement the mathematical analysis of signal waveforms. In the SPSU telecommunications program, the analysis provided via SystemView is compared with the analysis obtained from using mathematical programs like Mathcad or Matlab. These tools enable the student to quickly relate the theory to practical applications and get a better understanding of the course material related to Fourier Analysis.

Proceedings of the 2005 American Society for Engineering Education Annual Conference & Exposition

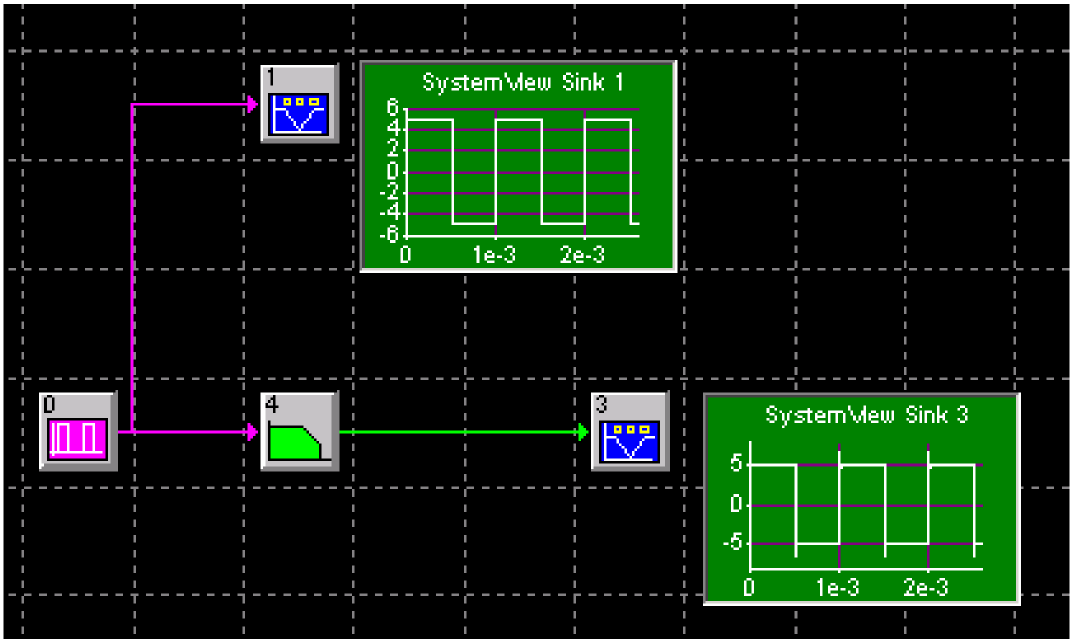

Figure 3. SystemView Fourier signal analysis simulation setup

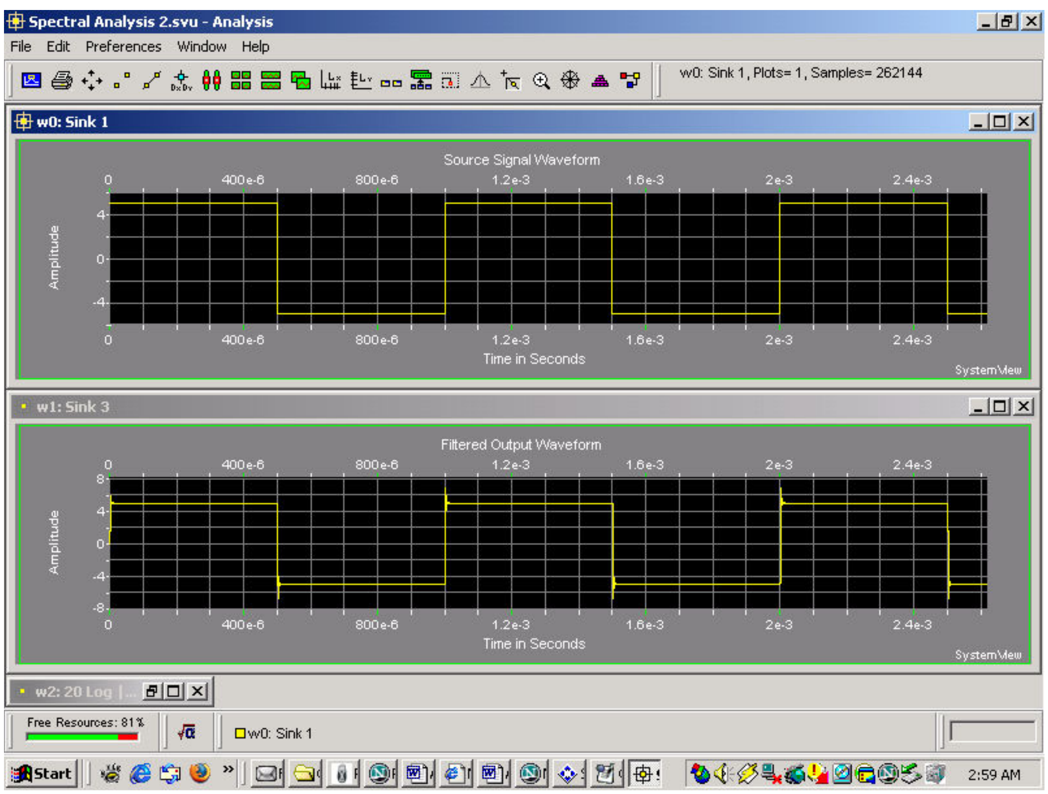

Figure 4. SystemView Analysis Window showing source signal and filtered output signal
(Source frequency = 1 kHz, filter cut-off frequency = 500 kHz)

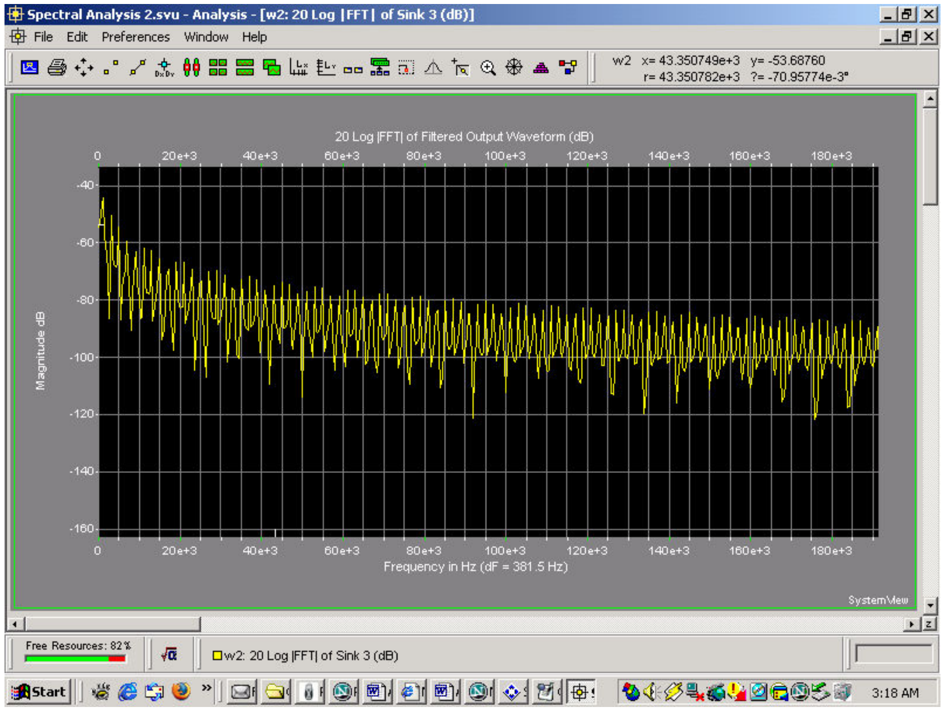

Figure 5. Expanded view of the spectra of the Filtered Output Waveform

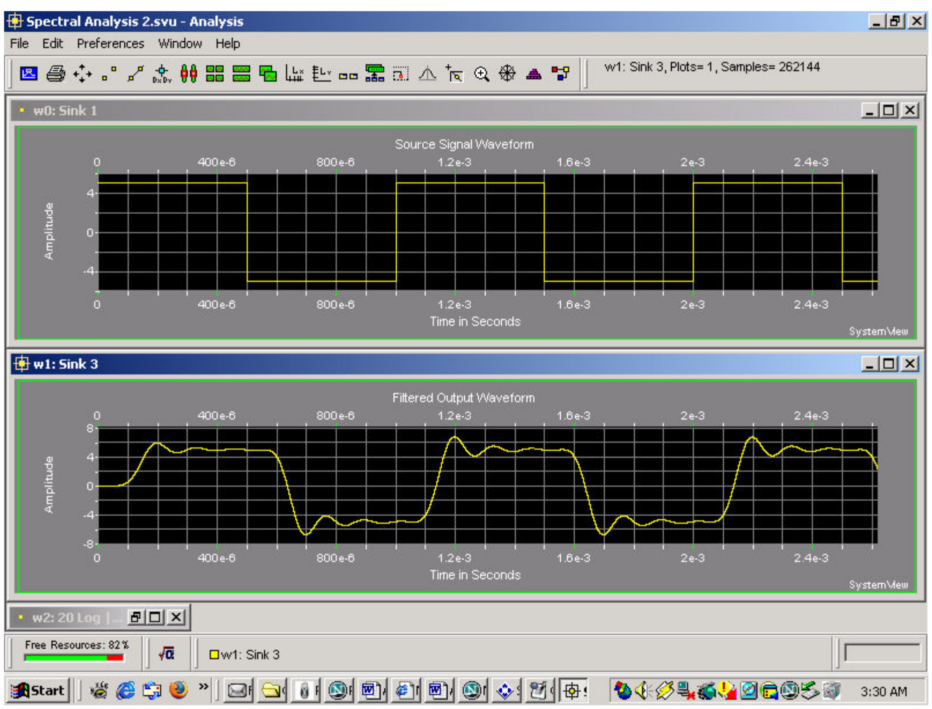

Figure 6. SystemView Analysis Window showing source signal and filtered output signal (Source frequency = 1 kHz, filter cut-off frequency = 8 kHz)

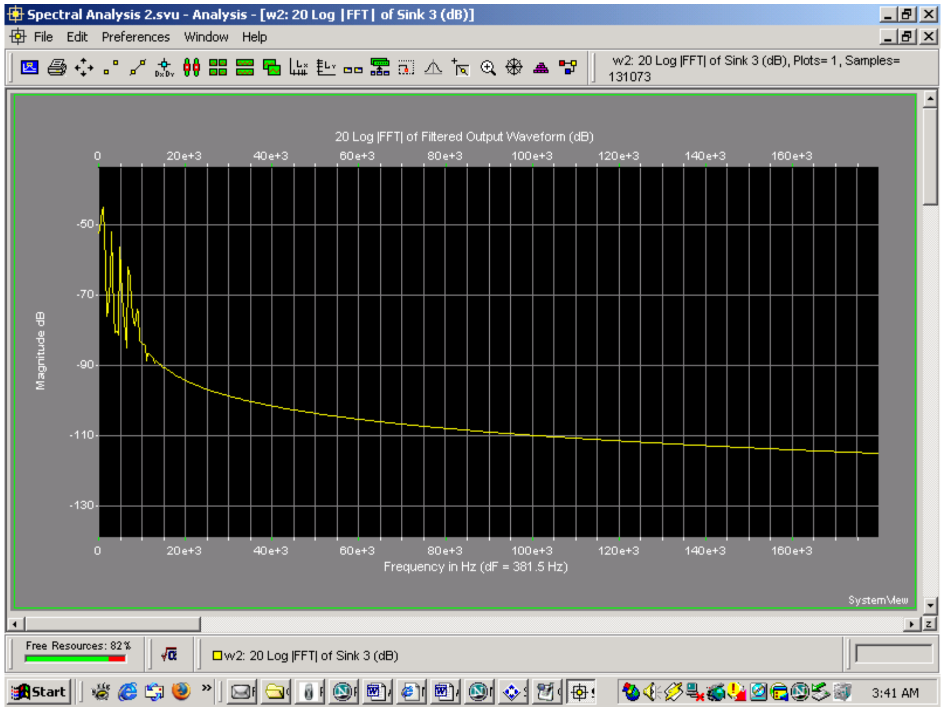

Figure 7. Expanded view of the spectra of the Filtered Output Waveform

Conclusion

There are currently a variety of standard and specialized simulation software packages available for use in the telecommunications industry. Whilst these packages are normally expensive, costing in the thousands of dollars, many companies offer university programs that allow universities to procure the software packages for a small fraction of the cost or through licensing agreements. This allows universities to train their students with the same packages that are utilized in the industry and provide additional hands-on training tools for developing key concepts from the classroom theory. This paper has discussed two examples of the use of these types of simulation packages in the telecommunications programs at Penn State Wilkes-Barre and at Southern Polytechnic State University. It is shown that very simple simulation experiments can be utilized to enhance the learning experience of the students to assist them in grasping key theoretical concepts presented in the classroom. It is evident that with the current trend in the economy and funding of institutions, one can expect to see increased use of simulation tools in many engineering technology programs. This will be particularly true for telecommunications engineering technology programs where the necessary equipment can be prohibitively expensive to procure.

References

[1] Ansoft Serenade SV Software Documentation, Ansoft Corporation
[2] Robert E. Collin, *Field Theory of Guided Waves*, McGraw-Hill, 1960
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[5] K. C. Gupta, R. Garg and I. J. Bahl, *Microstrip Lines and Slotlines*, Artech House; 1979
[6] Wayne Tomasi, *Electronic Communication Systems: Fundamental Through Advanced*, 5th edition, Prentice-Hall, 2004.

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