New Modeling and Simulation Platform for Communications Systems:

(I) Double Sideband Suppressed Carrier AM Modulator DSB-SC

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Abstract— **The main goal of this paper is to introduce a new platform for the implementation and simulation of communication systems. SCILAB/SCICOS is an open source software for conducting communication system related experiments, aiming to provide an experimentation platform for research on communication theories. Double Sideband Suppressed Carrier (DSB-SC) Modulator is modeled and simulated using this platform.**

Keywords- double sideband modulator; filter design; SCILAB; SCICOS; modeling; simulation.

I. INTRODUCTION

Recent experiments of the communications theory are heavily relying on software for the purpose of simulating various communication systems. The widely used platforms are Matlab/Simulink [1-3] and SystemView [4-6]. However, these simulation platforms are proprietary ones, thus imposing restrictions on scalability and flexibility. For these reasons, it has been decided to develop an open source simulation platform that is based on SCILAB/SCICOS [7] which can be used to model and simulate the communications theory systems.

SCILAB is an open-source software that specializes in scientific computation. SCICOS provides a dynamic-model graphical simulator based on the SCILAB computing kernel. SCILAB is an interpreted language with dynamically typed objects. SCILAB runs, and is available in binary format, for the main available platforms: Unix/Linux workstations (the main software development is performed on Linux workstations), Windows, and MacOSX. MacOSX users can also install SCILAB using fink.

Compiling SCILAB from the source code is also possible and is fairly straightforward. SCILAB can be used as a scripting language to test algorithms or to perform numerical computations. But it is also a programming language, and the standard SCILAB library contains around 2000 SCILAB coded functions. SCILAB programs are thus quite compact and most of the time smaller than their equivalents in C, C++ or Java.

SCICOS contains a graphical editor that can be used to construct block diagram models of dynamical systems. The blocks can come from various palettes provided in SCICOS or can be user-defined. A tutorial for the use of SCILAB/SCICOS, with special emphasis on modeling and simulation tools divided into two parts, is provided [8]. The first part concerns SCILAB and includes a tutorial covering the language features, the data structures and specialized functions for creating graphics, importing and exporting data and interfacing external routines. The second part is dedicated to the modeling and simulation of dynamical systems in SCICOS. This type of modeling tools is widely used in the industry because of the modular and reusable mode features.

II. DOUBLE SIDEBAND SUPPRESSED CARRIER AM MODULATOR DSB-SC

Many digital modulation techniques are DSB-SC with a digital message signal. Therefore, it is appropriate to review this basic analog modulation. DSB-SC is the simplest form of amplitude modulation, generated by a mixer. This consists of an audio source combined with the frequency carrier, as shown in Figurer 1. The message signal $m(t)$ is multiplied with a high frequency carrier $c(t) = A_c \cos(2\pi f_c t)$, where A_c is the carrier amplitude and f_c is the carrier frequency, to provide a DSBAM signal modulated output s(t) as follows:

$$s(t) = c(t) \cdot m(t) = A_c m(t) \cos(2\pi f_c t) \qquad (1)$$

Note that the amplitude of $s(t)$ is $Am(t)$, which varies according to the message signal $m(t)$, hence the name “amplitude modulation”. In other words, the message signal is now being carried in the amplitude of the DSB-AM signal. The generation of $s(t)$ is achieved by the modulator shown in Figure 1. The voltage multiplier shown in Figure 1, is commonly referred to as the mixer.

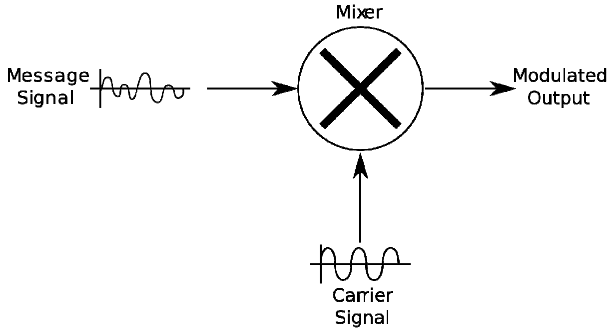


Fig. 1. DSB-AM modulator.

If the message signal $m(t) = \cos(2\pi f_0 t)$ is a sinusoid at frequency $f_0 << f_c$, the DSB-AM signal as given by (1) is:

$$s(t) = Am(t)\cos(2\pi f_c t)$$

$$= A\cos(2\pi f_0 t)\cos(2\pi f_c t) \qquad (2)$$

$$= \frac{A}{2}\cos[2\pi(f_c - f_0)t] + \frac{A}{2}\cos[2\pi(f_c + f_0)t]$$

Since $m(t) = A_m \cos(\omega_m t)$ and $c(t) = A_c \cos(\omega_c t)$, thus

$$s(t) = c(t).m(t) = \frac{1}{2}A_c A_m([\cos(\omega_c - \omega_m)t]$$

$$+[\cos(\omega_c + \omega_m)t]$$

A plot of s(t) in (2) is shown in Figure 2. Note that a phase reversal occurs at the point where m(t) goes negative. The spectrum in the frequency domain region can be written as follows:

$$s(f) = \frac{A}{2}[M(f - f_c) + M(f + f_c)] \qquad (3)$$

When the message signal m(t) is deterministic and has M(f) as its Fourier transform, then the Fourier transform S(f) of the DSB-AM signal s(t) in (1) can be evaluated using the modulation properties [9].

In DSB-SC it is observed that there is a symmetry in the Band structure. So, even if one half is transmitted, the other half can be recovered at the receiving end. By doing so, the bandwidth and power of transmission is reduced by half.

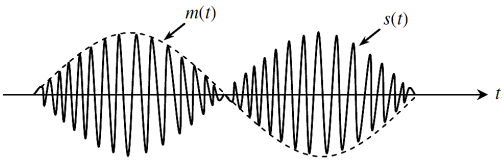


Fig. 2. DSB-AM with a sinusoidal message signal.

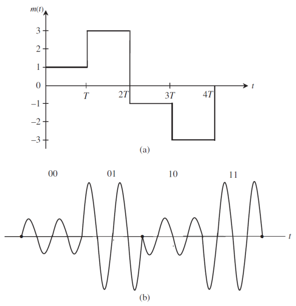


Fig. 3. (a) Message signal; (b) DSB-SC signal.

III. GENERATE DSB SIGNAL USING SCILAB/SCICOS

Before generating the DSB signal, it's important to test the sinusoid generator block by connecting it directly to the scope (FFT) as illustrated in the SCICOS block diagram shown in Figure 4.

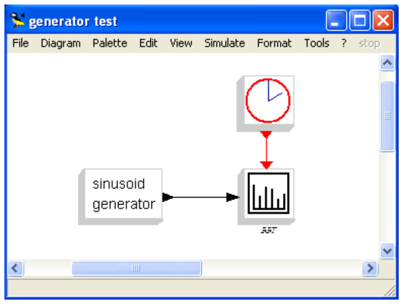


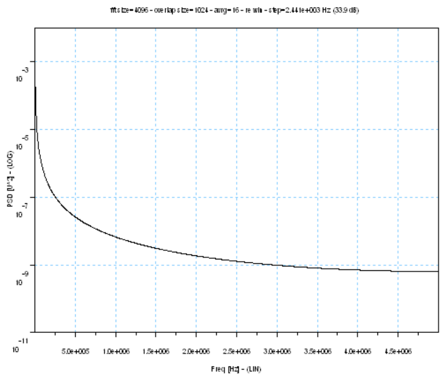
Fig. 4. Test the sinusoid generator

It is found that no results are obtained except when starting with the following values: **Clock_c Period** $= 1\times10^{-7}$ sec, **Clock_c Ini Time** $= 1\times10^{-7}$ sec and **Sampling period (Scope)** $= 1\times10^{-7}$ sec.

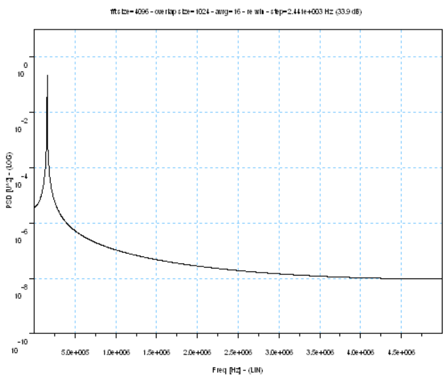
To simulate a diagram, it is sufficient to select the Run operation from the Simulate menu. Simulation parameters can be set by the Setup operation in the same menu. Running the simulation for the system shown in Figure 4 leads to the opening of a graphics window and the display of a sinusoidal signal. This window is opened and updated by the FFT block. The simulation result is given in Figure 5. In this case, the Sinusoid Generator Frequency (rad/s) is 10^3, 10^6 and 10^9 respectively. The simulation can be stopped using the stop button on the main SCICOS window, subsequent to which the user has the option of continuing the simulation, ending the simulation, or restarting it.

Figure 6 illustrates a SCICOS block diagram employed to generate a DSB signal. To get time-domain and frequency-domain responses, one can build the SCICOS block diagram shown in Figure 7.

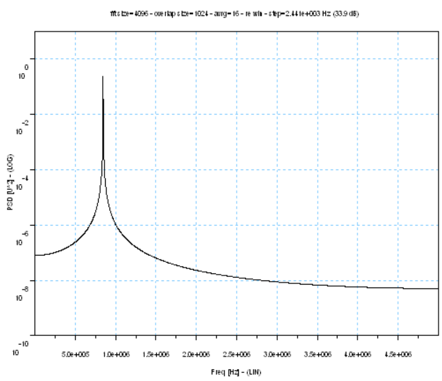
Figures 8 and 9 portray results obtained using SCILAB codes to describe the DSB signal. It should be noted that although it is possible to modulate any signal over a sinusoid, it's preferred to use a low frequency sinusoid to modulate a high frequency sinusoid without loss of generality.



(a)



(b)



(c)

Fig. 5. Results for different Sinusoid Generator Frequency (rad/s), (a) 1×10^{3}, (b) 1×10^{6} and (c) 1×10^{9}

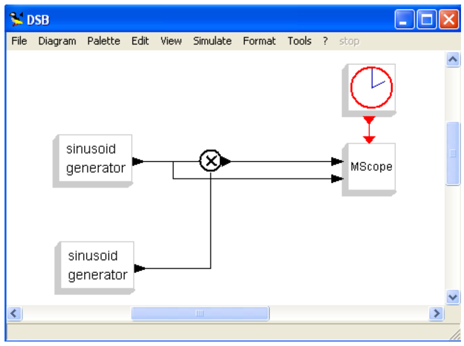


Fig. 6. SCICOS block diagram to generate DSB signal (time-domain)

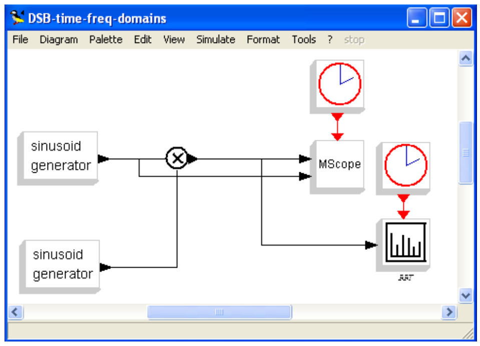


Fig. 7. SCICOS block diagram to generate DSB signal (time-domain and frequency-domain responses)

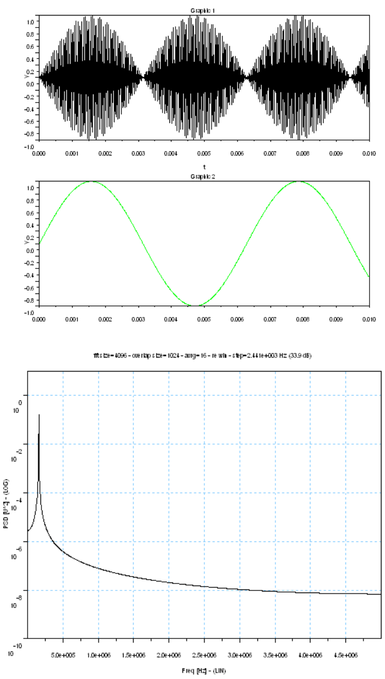


Fig. 8. Time-domain and Frequency-domain responses for DSB signal

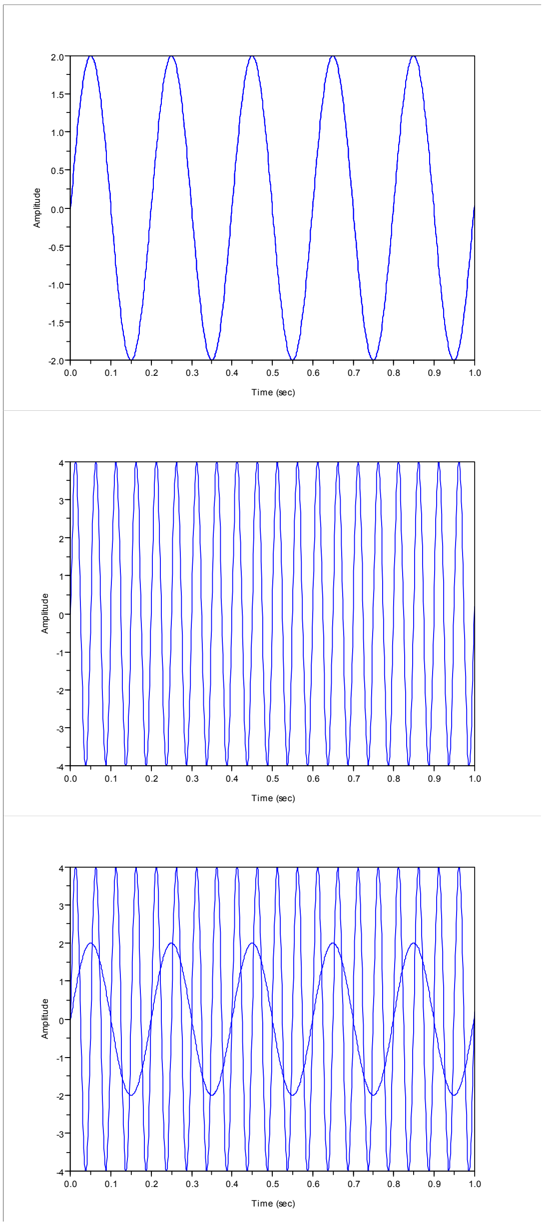


Fig. 9. DB sinusoid Signals

For demodulation, the audio frequency and the carrier frequency must be exact, otherwise distortion is created. DSB-SC can be demodulated if the modulation index is lower than one. This is best shown graphically. Figure 11 illustrates the message signal that may modulate onto a carrier, the equation for this message signal is

$$s(t) = (1/2)\cos(2\pi 800t) - (1/2)\cos(2\pi 1200t).$$

While Figure 12 illustrates the carrier, in this case, $c(t) = \cos(2\pi 5000t)$.

Finally, Figure 13 represents the phase modulated signal with respect to time.

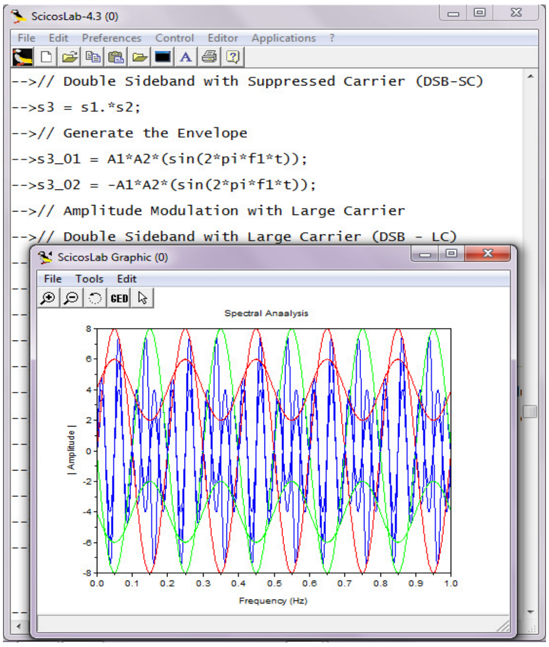


Fig. 10. Run SCILAB codes, results the Spectral Analysis for Double Sideband with Suppressed Carrier

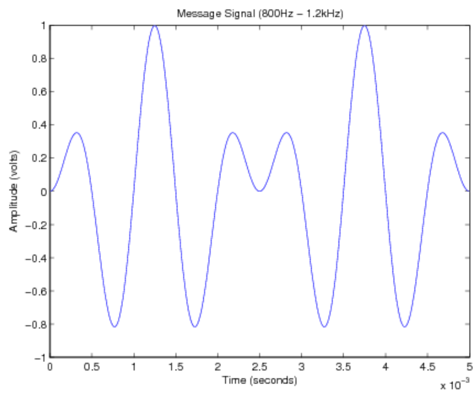


Fig. 11. The message signal, $s(t) = (1/2)\cos(2\pi 800t) - (1/2)\cos(2\pi 1200t)$.

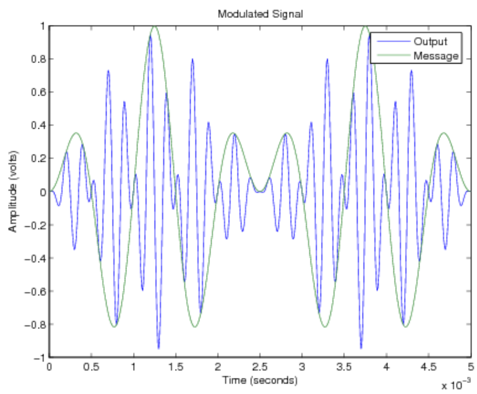


Fig. 12. The carrier, $c(t) = \cos(2\pi 5000t)$

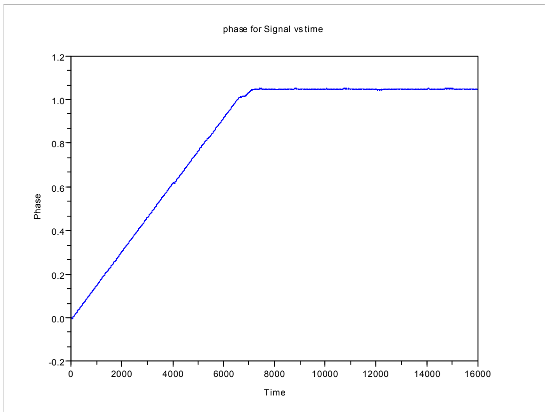


Fig. 13. The phase for signal vs time

IV. CONCLUSION

In SCILAB, objects are never declared or allocated explicitly; they have a dynamic type and their sizes can dynamically change according to the operators or functions applied. SCICOS provides a modular way to construct complex dynamical systems using a block diagram editor. SCICOS diagrams are compiled and simulated efficiently using a graphical editor/simulator based on the SCILAB computing kernel. SCICOS handles, in particular, the interaction between continuous-time dynamics and system events including events associated with the timing of a discrete-time clock. Such events affect the way the numerical solver, which integrates the continuous-time dynamics, should be called. Handling efficiently such matters by hand for complex dynamical systems can be extremely difficult. It is suggested that the DBS modulator can be simulated by this new platform. In amplitude modulation the amplitude of a high-frequency carrier is varied in direct proportion to the low-frequency (baseband) message signal. In this paper, the DSB was examined as a type of linear modulation schemes for both time and frequency domains, and emphasis was given to characteristics such as signal spectrum, power, bandwidth, demodulation methods, complexity and receivers.

The SCICOS library of reusable modules (blocks) is used in the considered model, The SCICOS formalism, which must be respected in designing blocks and submodels, guarantees that modules constructed separately and interconnected can work harmoniously together as a large number of blocks are already available in SCICOS palettes. SCICOS is more than a modeling and simulation program. It contains many functionalities to help the designer optimize model parameters, validate models, generate C code, etc.

The carrier frequency may be suppressed or transmitted at a relatively low level. This requires that the carrier frequency be generated, or otherwise derived, at the receiving site for demultiplexing. This type of transmission is known as Double Sideband - Suppressed Carrier (DSB-SC). In a modulation process, a high frequency sinusoid is modified in accordance to the message signal to be transmitted. The high frequency sinusoid is the carrier and the message signal is the modulating signal. The modified carrier signal is the modulated signal. A consequence of modulation is a translation or shifting of the message spectrum to a higher frequency band. Message signals, by nature, are low frequency or baseband signals. A baseband signal is a signal whose spectrum is positioned close to DC (ω=0). This type of modulation is double sideband suppressed carrier, or DSB-SC. The carrier must be reinserted at the receiver, however, to recover this modulation. In the time and frequency domains, DSB-SC modulation appears as shown in Figures 8-10. The carrier is suppressed well below the level of the sidebands.

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