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 Figure 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:

\[
s(t) = c(t) \cdot m(t) = A_c m(t) \cos(2\pi f_c t)
\]

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

\[
s(t) = Am(t)\cos(2\pi f_c t) = A\cos(2\pi f_0 t)\cos(2\pi f_c t)
\]

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

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

\[
s(t) = c(t)m(t) = \frac{1}{2}A_cA_m\left[\cos(\omega_c - \omega_m)t\right]
\]

\[
+ \left[\cos(\omega_c + \omega_m)t\right]
\]

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:

\[
s(f) = \frac{A}{2}\left[M(f - f_c) + M(f + f_c)\right]
\]

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.

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### 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.

It is found that no results are obtained except when starting
with the following values: \( \text{Clock_c Period} = 1 \times 10^{-7} \) sec ,
\( \text{Clock_c Ini Time} = 1 \times 10^{-7} \) sec and \( \text{Sampling period (Scope)} = 1 \times 10^{-7} \) 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.

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

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
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.
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 ($\omega=0$). 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.

REFERENCES