MATLAB/SIMULINK TECHNOLOGY OF THE SYGNAL MODULATION

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Abstract. The paper discusses the features of modeling and study of the basic modulation techniques on Matlab/Simulink. The methods of analog modeling, as well as amplitude, frequency, phase, and other modulations are given. This allows one to get acquainted with the possibilities of modern computer technology in the field of signal modulation.

1.   Introduction

In the first part of the paper various modulation methods and their Matlab functions have been given. Here we consider the modelling techniques in Matlab/Simulink for the main modulation types. The matter of the problem is not given in detail by the modelling way in the existence literature [1, 2].

2.   Single tone amplitude modulation - AM [3, 4]

Suppose that the modulated signal is $x_M(t) = A_M \cos(\Omega t + \Phi)$ and the supporting signal is given as

$$x_{AP}(t) = A\cos(\omega_0 t + \varphi_0), \tag{1}$$

where $\Omega, \omega_0 -$ are modulated and supporting frequencies, correspondingly.

While realizing the AM modulation to get correct (single polar) result usually twopolar $\pm x_M(t)$ sygnal is replaced in the positive side along the abcissa axis

$$x_{MM}(t) = A_0 + x_M(t). \tag{2}$$

Note that single polar signal is technically easily realizable.

It is known that in AM modulation amplitude A of the supporting signal varies proprtionally to the modulating signal. So putting the expression (2) into (1) instead of A we get the modilated signal

$$x_{MAP}(t) = (A_0 + x_M(t))\cos(\omega_0 t + \varphi_0) =$$
$$= (A_0 + A_M\cos(\Omega t + \Phi))\cos(\omega_0 t + \varphi_0)$$

or

$$x_{MAP}(t) = A_0(1 + m\cos(\Omega t + \Phi))\cos(\omega_0 t + \varphi_0) \tag{3}$$

Here $m = \frac{A_M}{A_0}$, $0 < m < 1$. The ratio of the amplitudes of the modulating and modulated signals is call a modulation coefficient or modulation depth. In the case $m>1$ we observe the absolute modulation.

If one can measure the values A_{min} and A_{max} of the modulating signals practically (by the help for instance oscillograph), then the modulation depth may be computed by the following simple expression

$$m = \frac{A_{max} - A_{min}}{A_{max} + A_{min}}, \qquad 0 < m < 1$$

3. Frequency modulation-FM

Following given above definition in this case the frequency of the modulated signal $x_{AP}(t)$ varies linearly with respect to the modulating signal $x_M(t)$

$$\omega(t) = \omega_0 + kx_M(t). \tag{4}$$

Addion of the constant ω_0 serves for the raising the frequaency.

The whole phase is found by the ingetrating of the expression (4) as follows

$$\varphi(t) = \omega_0(t) + k \int_0^t x_M(t)dt + \varphi_0(t).$$

Here φ_0 is an initial condition.

So, the carrier signal be in the form, $x_{AP}(t) = A\cos(\omega t)$ then FM-Modulated signal will be in the form

$$x_{MAP}(t) = A\cos(\omega t) = A\cos(\omega_0(t) + k \int_0^t x_M(t)dt + \varphi_0.$$

Then in this case the frequency of the modulated signal $x_{AP}(t)$ varies proportionally to the modulating signal $x_M(t)$.

4. Modelling in MATLAB

First consider the AM modulation.

Example 1. Let the passing useful signal be

$$x_M(t) = 3\cos(2\pi t) - \sin\left(6\pi t + \frac{\pi}{4}\right)$$

To get single polar (same sign) infomative signal we add here according to (2) the constant parameter A_0

$$x_{MM}(t) = A_0 + x_M(t).$$

Suppose that $A_0 = 4$.

Let the carrier signal be

$$x_{AP}(t) = A(t)\cos(2\pi f_0 t), \qquad f_0 = 10Hz.$$

Here f_0 is the frequences of the carrier vibrations.

In the amplitude modulation $A(t) = x_{MM}(t)$.

First we solve AM-modulation problem in MATLAB.

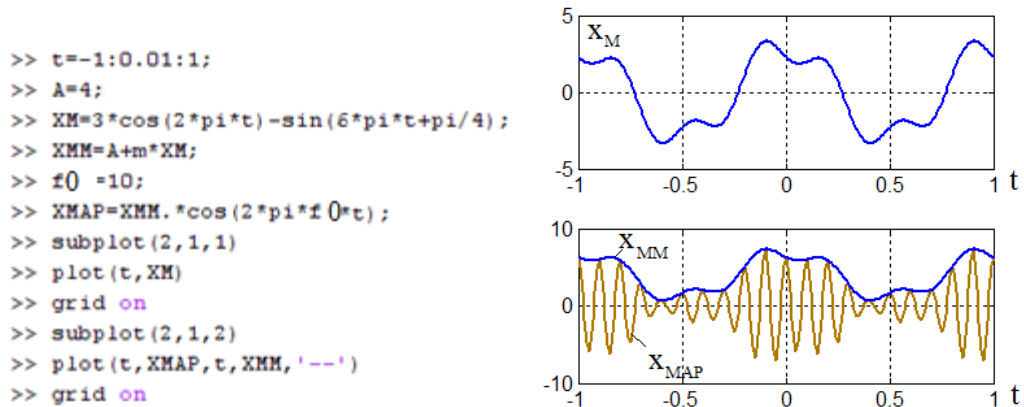In Fig.1 corresponging MATLAB program and and results of the modulation are given.

```
>> t=-1:0.01:1;
>> A=4;
>> XM=3*cos(2*pi*t)-sin(6*pi*t+pi/4);
>> XMM=A+m*XM;
>> f0 =10;
>> XMAP=XMM.*cos(2*pi*f0*t);
>> subplot(2,1,1)
>> plot(t,XM)
>> grid on
>> subplot(2,1,2)
>> plot(t,XMAP,t,XMM,'--')
>> grid on
```


Figure 1.

As we see obtained single polar signal $x_{MM}(t)$ differs from the initial informative twopoalr signal $x_M(t)$ by the constant $A_0 = 4$. This difference can be annulated during *demodulation* (detectiration)

Example 2. Now let's consider AM modulation problem (single tone) taking into account m Suppose that

$$x_M(t) = A_M \cos(\Omega t + \Phi),$$
$$x_{AP}(t) = A(t)cos(\omega_0 t + \varphi_0)$$

In this case due to relation (3) the modulated signal will be

$$x_{MAP}(t) = A_0(1 + m\cos(\Omega t + \Phi))cos(\omega_0 t + \varphi_0).$$

In Fig. 2 for the values $A_0=1$, $\Phi=\varphi_0=0$, $\Omega = 1, \omega_0 = 10$ and m=[0, 0.5, 1] ([0%,50%, 100%]) the MATLAB program and corresponding graphs are given

```
>> Fs=100; % Zamanin diskret/tezliyi (addimi)
>> t=-10:1/Fs:10; % Zaman intervali
>> omega0=10;      % Dasiyici tezlik
>> OMEGA=1;        % Modellesdiren siqn. tezliyi
>> XMAP_0=(1+0*cos(OMEGA*t)).*cos(omega0*t);% m=0%
>> XMAP_50=(1+0.5*cos(OMEGA*t)).*cos(omega0*t); % m=50%
>> XMAP_100=(1+1*cos(OMEGA*t)).*cos(omega0*t);  % m=100%
>> subplot(3,1,1)
>> plot(t,xMAP_0) % Modulyasiya bas vermir
>> plot(t,XMAP_0) % Modulyasiya bas vermir
>> subplot(3,1,2)
>> plot(t,XMAP_50) % Modulyasiya derinliyi 50%
>> subplot(3,1,3)
>> plot(t,XMAP_100) % Modulyasiya derinliyi 100%
>>
```
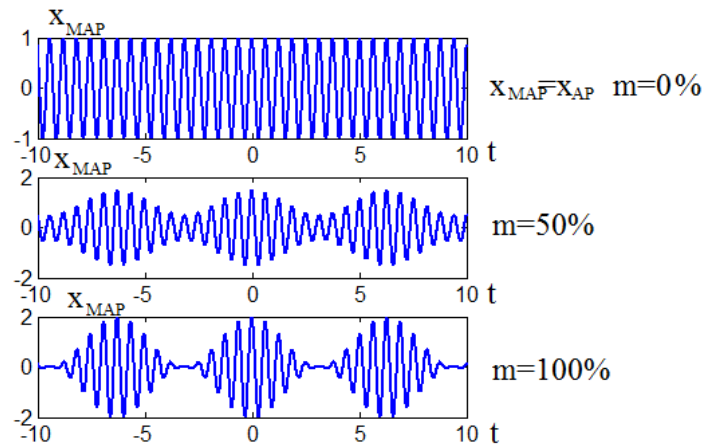
Figure 2.

As we see in the case $m = 0$ the modulation was not arised. This is shown by $x_{MAP} = x_{AP} = \cos(10t)$. By increasing of the values of m the amplitude of the modulated signal x_{MAP} increases, that may couse the super modulation at $m>1$.

5. Modelling in Simulink package

Here we model the AM modulation problem considered in Example 1 in Simulink pachage.

Here the modulationg signal is

$$x_M(t) = 3\cos(2\pi t) - \sin\left(6\pi t + {}^\pi/_4\right)$$

The slidding signal is

$$x_{MM}(t) = A_0 + x_M(t).$$

The carrier signal is

$$x_{AP}(t) = A(t)\cos(2\pi f_0 t), \qquad f_0 = 10 Hz .$$

In Fig. 3 corresponding Simulink scheme and modulated $x_{MAP}(t)$ signal is given.
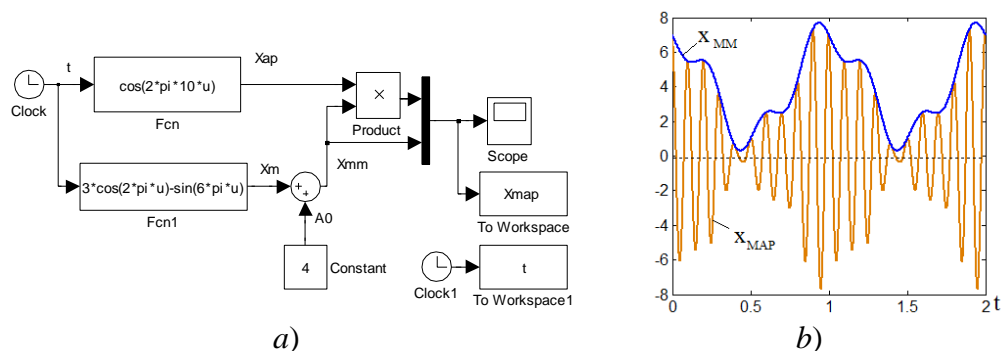

a)   *b)*

Figure 3.

As one can see the result is the same with in Example 1. But here the time vaties in the interval $0 \leq t \leq 2$. Configuration parameters are: Type-Fixed-step, size-0.001, Solver-ode 3.

6.   Angle modulation

Let the carrier signal be

$$x_{AP}(t) = A cos(\omega_0 t + \varphi_0). \quad A = 2, \ \omega_0 = 5kHz. \tag{5}$$

Here ω_0 is an angle frequency in *rad/sec*, φ_0 is an initial phase in *rad*.

Expression (5) may be written in the form

$$x_{AP}(t) = A cos(\theta(t))$$

Here

$$\theta(t) = \omega_0 + \varphi_0$$

is an angle depenging on *rad* and is called a whole phase.

The angle $\theta(t)$ of the carrier signal may also be modulated as its amplitude A.

This is called an **"angle modulation".**

The angle modulation may be realized by two ways.

1. PM-modulation. In this case the phase $\varphi_0(t)$ varies propotionally to the modulating signal $x_M(t)$.

2. FM- modulation. In this case the frequency $\omega_0(t)$ varies propotionally to the modulating signal $x_M(t)$.

5.1. PM-modulation. As is known in PM modulation depending on the modulating signal $x_M(t)$ the phase φ_0 of the signal $x_{AP}(t)$ varies. PM and FM modulations indeed are clously related.

Actually, changing of the phase influences to the frequency and vice versa. To demonstrate this fact suppose the phase varies by the low $\varphi_0 = x_M(t) = A sin(\Omega t), \ A = 10, \ \Omega = 2KHz$. In Fig.4 the corresponding Simulink scheme and modulated $x_{MAP}(t)$ signal is given.

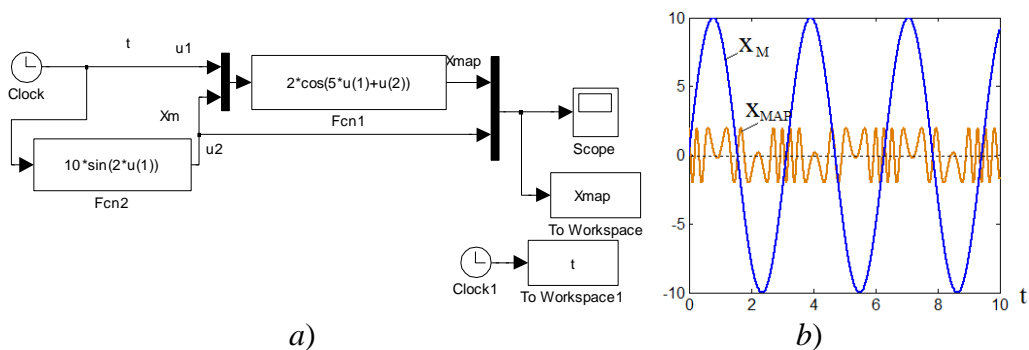
a)   *b)*

Figure 4.

As one can see from this fugure both the frequaency and phase of the modulated $x_{MAP}(t)$ vary.

Now we consider the square impulse sequence as a modulating x_M signal corresponding to the digital code. Since in this case the phase is constant (0 or 1) the frequence does not vary and one can see obviously the variation of the phase of the modulated signal.

The carries and supporting signals are: $x_{AP}(t) = A\cos(\omega_0 t + \varphi_0)$. $A = 2$, $\omega_0 = 10 kHz$.

In Fig. 5 the corresponding Similink scheme and modulated $x_{MAP}(t)$ signal is given.

$a)$ $b)$
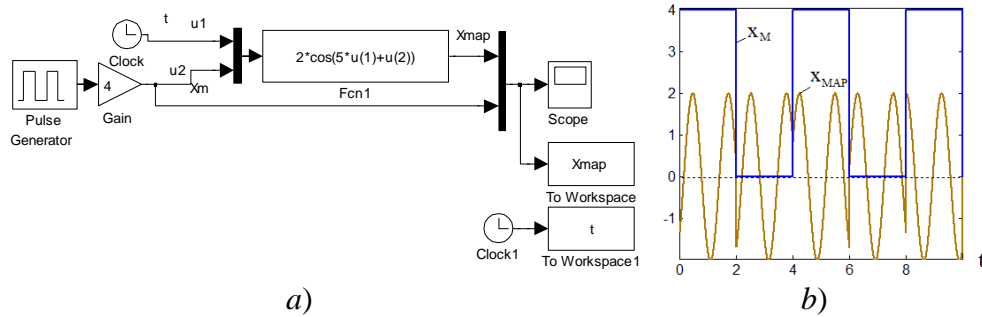
Figure 5.

As we see from the figure the phase changes arise of the modulated signal $x_{MAP}(t)$ in the impulse jumping points. This is observed by the breaking of the fuzziness frequency of the vibrations.

7.   Conclusion

The article discusses the features of modeling and study of the basic modulation techniques on Matlab/Simulink. Methods of analog modeling, in particular amplitude, frequency, phase, and other modulations are given. It makes possible to evaluate the modulation capabilities in the field of modern computer technology and offer more constructive schematic solutions.

References

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