Square Law Modulation And Demodulation Scheme For AM

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I. Objective

Our objective is to generate AM waves using square law modulation and demodulation scheme.

So for that we are covering the entire relative topic on what is square law modulation and how we generate AM waves etc.

Coming to know ,first of all

A. What is a Communication System ?

- Communication is the process by which information is exchanged between individuals through a medium.
- Communication can also be defined as the transfer of information from one point in space and time to another point.
- The basic block diagram of a communication system is as follows.

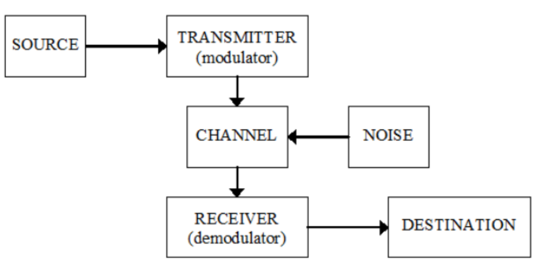

Fig. 1. A Sample Communication System

The figure shows specific processes to generate a communication system.Those are

- Transmitter: Couples the message into the channel using high frequency signals.
- Channel: The medium used for transmission of signals
- Modulation: It is the process of shifting the frequency spectrum of a signal to a frequency range in which more efficient transmission can be achieved.
- Receiver: Restores the signal to its original form.
- Demodulation: It is the process of shifting the frequency spectrum back to the original baseband frequency range and reconstructing the original form

So,next we study Modulation in detail.

B. Modulation

Modulation is a process that causes a shift in the range of frequencies in a signal.

- Signals that occupy the same range of frequencies can be separated.
- Modulation helps in noise immunity, attenuation - depends on the physical medium.

The below figure shows the different kinds of analog modulation schemes that are available

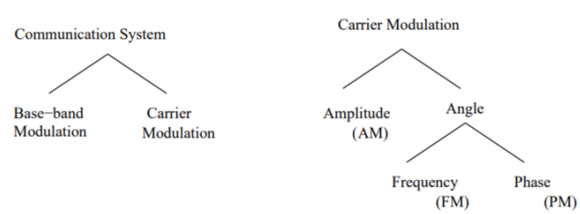

Fig. 2. Different Kinds Of Modulation

Modulation is operation performed at the transmitter to achieve efficient and reliable information transmission.

For analog modulation, it is frequency translation method caused by changing the appropriate quantity in a carrier signal.

It involves two waveforms:

- A modulating signal/baseband signal – represents the message.
- A carrier signal – depends on type of modulation.

Once this information is received, the low frequency information must be removed from the high frequency carrier.

This process is known as "Demodulation".

C. Need For Modulation

- Baseband signals are incompatible for direct transmission over the medium so, modulation is used to convey (baseband) signals from one place to another.
- Allows frequency translation:
  - Frequency Multiplexing
  - Reduce the antenna height
  - Avoids mixing of signals
  - Narrowbanding
- Efficient transmission
- Reduced noise and interference

D. Types Of Modulation

Three main types of modulations:

1) Analog Modulation:

- Amplitude modulation : Example: Double sideband with carrier (DSB-WC), Double- sideband suppressed carrier (DSB-SC), Single sideband suppressed carrier (SSB-SC), vestigial sideband (VSB)
- Angle modulation (frequency modulation and phase modulation)
  Example: Narrow band frequency modulation (NBFM), Wideband frequency modulation (WBFM), Narrowband phase modulation (NBPM), Wideband phase modulation (NBPM)
- Pulse Modulation
  - Carrier is a train of pulses
  - Example: Pulse Amplitude Modulation (PAM), Pulse width modulation (PWM) , Pulse Position Modulation (PPM)
- Digital Modulation
  - Modulating signal is analog
    * Example: Pulse Code Modulation (PCM), Delta Modulation (DM), Adaptive Delta Modulation (ADM), Differential Pulse Code Modulation (DPCM), Adaptive Differential Pulse Code Modulation (ADPCM) etc.
  - Modulating signal is digital (binary modulation)
    * Example: Amplitude shift keying (ASK), frequency Shift Keying (FSK), Phase Shift Keying (PSK) etc

Now We are focusing on Amplitude Modulation .

E. Amplitude Modulation

Amplitude Modulation is the process of changing the amplitude of a relatively high frequency carrier signal in accordance with the amplitude of the modulating signal (Information).

The carrier amplitude varied linearly by the modulating signal which usually consists of a range of audio frequencies. The frequency of the carrier is not affected.

- Application of AM - Radio broadcasting, TV pictures (video), facsimile transmission
- Frequency range for AM - 535 kHz – 1600 kHz
- Bandwidth - 10 kHz

F. Various forms of Amplitude Modulation

- Conventional Amplitude Modulation (Alternatively known as Full AM or Double Sideband Large carrier modulation (DSBLC) /Double Sideband Full Carrier (DSBFC)
- Double Sideband Suppressed carrier (DSBSC) modulation
- Single Sideband (SSB) modulation
- Vestigial Sideband (VSB) modulation

G. Time Domain and Frequency Domain Description

It is the process where, the amplitude of the carrier is varied proportional to that of the message signal. Let m (t) be the base-band signal, m (t) tends to M (omega) and c (t) be the carrier, c(t) = Ac cos(omegac t). fc is chosen such that fc is greater than W, where W is the maximum frequency component of m(t). The amplitude modulated signal is given by

$$s(t) = Ac[1 + k\ _a m(t)]cos(\omega\ _c t)$$

Fourier Transform on both sides of the above equation

$$S(\omega) = \pi\ Ac/2\ (\delta(\omega - \omega c) + \delta(\omega + \omega c)) + k_a Ac/\ 2\ (M(\omega - \omega c) + M(\omega + \omega c))$$

ka is a constant called amplitude sensitivity.

kam(t) less than 1 and it indicates percentage modulation.

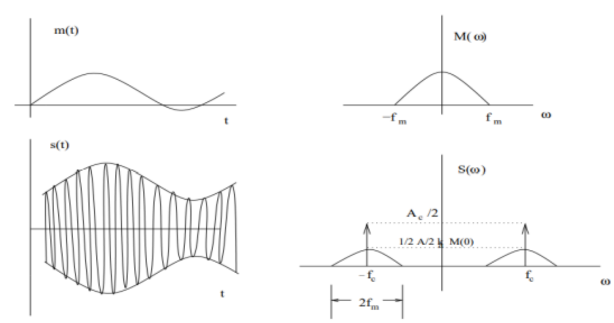

Fig. 3. Amplitude modulation in time and frequency domain

H. Generation of AM Waves

There are two methods to generate AM waves

- Square-law modulator
- Switching modulator

II. Square Law MOdulator

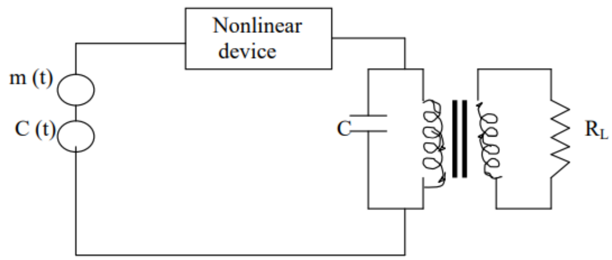

Fig. 4. Square Law Modulator

A Square-law modulator requires three features: a means of summing the carrier and modulating waves, a nonlinear element, and a band pass filter for extracting the desired modulation products. Semi-conductor diodes and transistors are the most common nonlinear devices used for implementing square law modulators. The filtering requirement is usually satisfied by using a single or double tuned filters.

When a nonlinear element such as a diode is suitably biased and operated in a restricted portion of its characteristic curve, that is ,the signal applied to the diode is relatively weak, we find that transfer characteristic of diode-load resistor combination can be represented closely by a square law :

$$V_0(t) = a_1 V_i(t) + a_2 V_i^2(t) \quad \ldots\ldots\ldots\ldots\ldots\ldots(i)$$

Where a_1, a2 are constants

Now, the input voltage $V_i(t)$ is the sum of both carrier and message signals

i.e., $V_i(t) = A_c \cos 2\pi f_c t + m(t) \quad \ldots\ldots\ldots\ldots\ldots (ii)$

Substitute equation (ii) in equation (i) we get

$$V_0(t) = a_1 A_c [1+k_a m(t)] \cos 2\pi f_c t + a_1 m(t) + a_2 A_c^2 \cos^2 2\pi f_c t + a_2 m^2(t) \ldots\ldots\ldots (iii)$$

Where $k_a = 2a_2/a_1$

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Now design the tuned filter /Band pass filter with center frequency fc and pass band frequency width 2W.We can remove the unwanted terms by passing this output voltage V0(t) through the band pass filter and finally we will get required AM signal.

$$V_0(t) = a_1 A_c [1+2a_2/a_1\, m(t)] \cos 2\pi f_c t$$

Assume the message signal m (t) is band limited to the interval $-W \le f \le W$

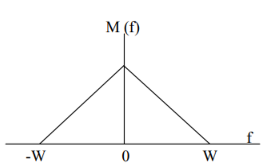

Fig. 5. Spectrum of message signal

The Fourier transform of output voltage $V_O(t)$ is given by

$$V_O(f) = a_1 A_C/2[\delta(f-f_c) + \delta(f+f_c)] + a_2 A_C [M(f-f_c) + M(f+f_c)]$$

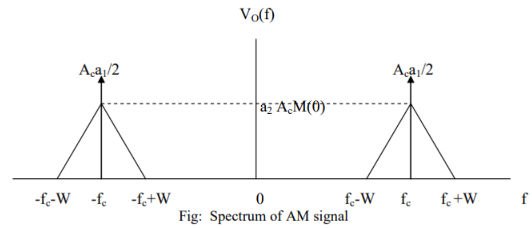

Fig. 6. Spectrum of AM signal

The AM spectrum consists of two impulse functions which are located at fc and minusfc and weighted by Aca1 divided by 2 and a2Ac divided by 2, two USBs, band of frequencies from fc to fc plus W and band of frequencies from minusfc minus W to minusfc , and two LSBs, band of frequencies from fc minus W to fc and minusfc to minus fc plus W.

A. *Demodulation of AM waves:*

Demodulation is the process of recovering the information signal (base band) from the incoming modulated signal at the receiver. There are two methods to demodulate AM signals. They are:

- Square-law detector
- Envelope detector

III. Square-law detector

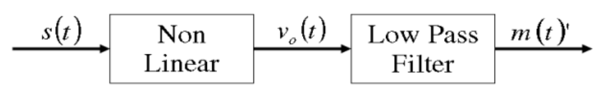

Fig. 7. Square Law Detector

A Square-law modulator requires nonlinear element and a low pass filter for extracting the desired message signal. Semi-conductor diodes and transistors are the most common non-linear devices used for implementing square law modulators. The filtering requirement is usually satisfied by using a single or double tuned filters.

When a nonlinear element such as a diode is suitably biased and operated in a restricted portion of its characteristic curve, that is ,the signal applied to the diode is relatively weak, we find that transfer characteristic of diode-load resistor combination can be represented closely by a square law

Now design the low pass filter with cutoff frequency f is equal to the required message signal bandwidth. We can remove the unwanted terms by passing this output voltage V0 (t) through the low pass filter and finally we will get required message signal.

$$V_0(t) = a_1 V_i(t) + a_2 V_i^2(t) \quad \ldots\ldots\ldots\ldots\ldots\ldots\text{(i)}$$

Where a_1, a2 are constants

Now, the input voltage $V_i(t)$ is the sum of both carrier and message signals

i.e., $V_i(t) = A_c [1+k_a m(t)] \cos 2\pi f_c t \quad \ldots\ldots\ldots\ldots\ldots\text{(ii)}$

Substitute equation (ii) in equation (i) we get

$$V_0(t) = a_1 A_c [1+k_a m(t)] \cos 2\pi f_c t + 1/2\, a_2 A_c^2 [1+2 k_a m(t) + k_a^2 m^2(t)] [\cos 4\pi f_c t] \ldots\ldots\ldots\text{(iii)}$$

$$V_0(t) = A_c^2 a_2 m(t)$$

The Fourier transform of output voltage $V_O(t)$ is given by

$$V_O(f) = A_c^2 a_2 M(f)$$

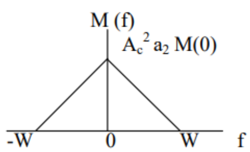

Fig. 8. Spectrum of AM signal

IV. Block Diagrams And Description

Generation of an AM signal by a square law modulator and verifying the signal power of a received signal, which has undergone with amplitude modulation at the transmitter and mixed with an AWGN of zero mean and 0.2 variance during transmission.

This code is divided into 4 sub parts:

- Generate message and carrier signal
- Amplitude modulation using carrier square law demodulator
- Noise addition
- Demodulation of the transmitted signal

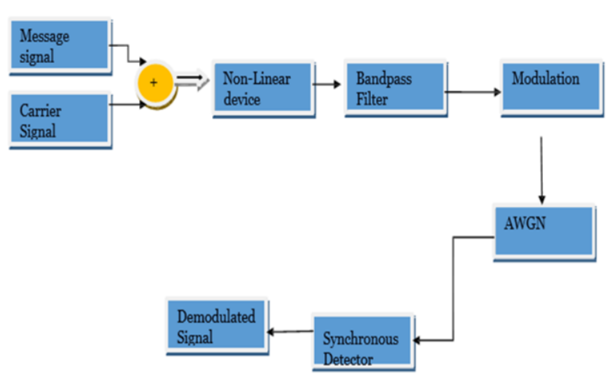

Fig. 9. Block Diagram which shows the square law modulation and demodulation in generating the AM waves as output

AWGN :A basic and generally accepted noise model is known as Additive White Gaussian Noise (AWGN), which imitates various random processes seen in nature.

V. Simulation Results And Graphs

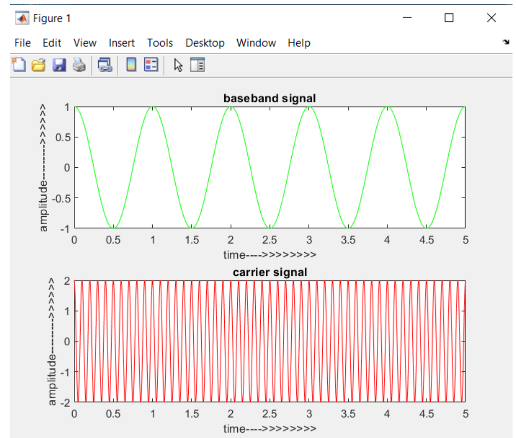

Fig. 10. baseband signal and carrier signal

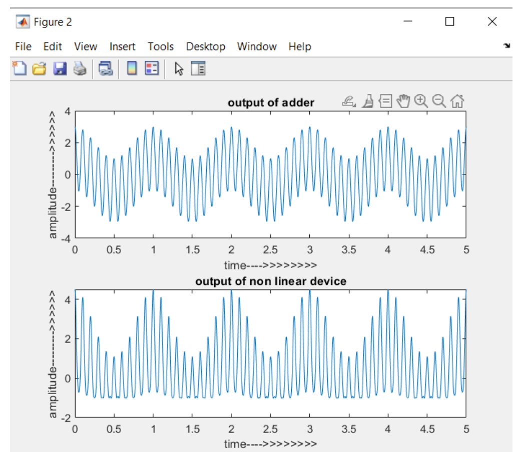

Fig. 11. output of adder and nonlinear device

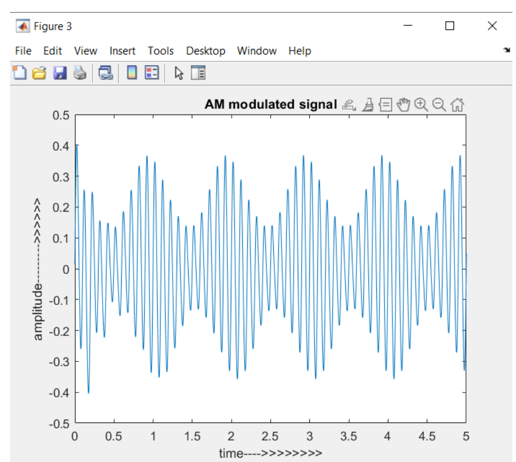

Fig. 12. AM modulated signal

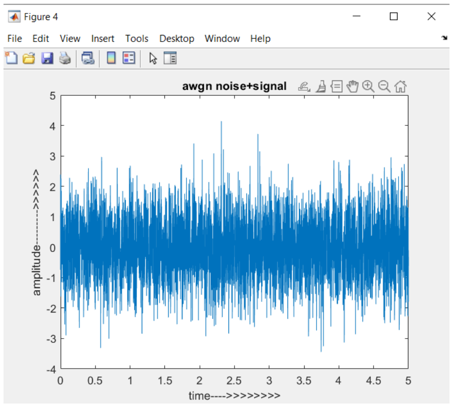

Fig. 13. AWGN noise is added to AM signall

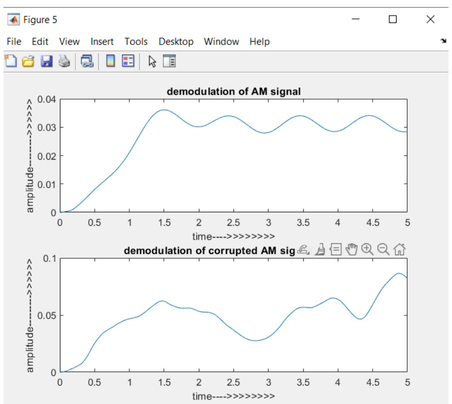

Fig. 14. demodulation of AM signal (without noise) and demodulation of corrupted AM signal(with AWGN)

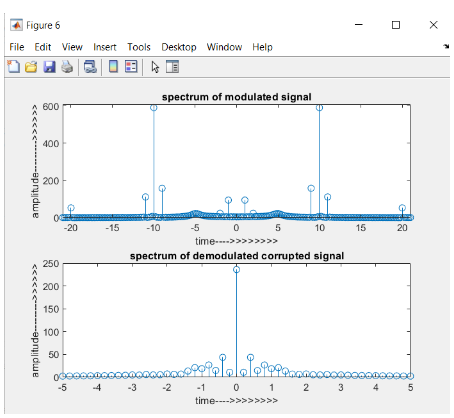

Fig. 15. spectrum of AM signal and Spectrum do demodulated corrupted signal (with AWGN)

```
Command Window
signal power of modulated signal
    0.0323

signal to noise ratio
    0.1615

noise power added to the modulated signal
    0.0311

signal power of demodulated courrupted signal
    0.0026
```

Fig. 16. command window output

VI. Inferences

Generated an AM signal by a square law modulator and verified the signal power of a received signal, which has undergone with amplitude modulation at the transmitter and mixed with an AWGN of zero mean and 0.2 variance during the transmission.

VII. Conclusions

VIII. Appendix : Matlab Code

```matlab
clc;
close all;

fs = 1000; %sampling frequency
fc = 10; %carrier signal frequency
fm = 1; %baseband signal frequency
am = 1; %amplitude of message signal
ac = 2; %amplitude of carrier signal
t = 0:1/fs:5/fm;

m = am*cos(2*pi*fm*t); %baseband signal
c = ac*cos(2*pi*fc*t); %carrier signal

figure(1)
subplot(211)
plot(t,m,'g')
xlabel('time---->>>>>>>>');
ylabel('amplitude--------->>>>>>');
title('baseband signal');
subplot(212)
plot(t,c,'r')
xlabel('time---->>>>>>>>');
ylabel('amplitude--------->>>>>>');
title('carrier signal');

%output of the adder
v1 = m+c;

%output of the non linear device
a1 = 0.9;
a2 = 0.2;
v2 = a1*v1 + a2*(v1.^2);

figure(2)
subplot(211)
plot(t,v1)
xlabel('time---->>>>>>>>');
ylabel('amplitude--------->>>>>>');
title('output of adder');
subplot(212)
plot(t,v2)
xlabel('time---->>>>>>>>');
ylabel('amplitude--------->>>>>>');
title('output of non linear device');

%bandpass filter with cutoff frequency fc
[b,a]=butter(1,[((fc-fm)/fs),((fc+fm)/fs)]);
y=filter(b,a,v2);
% k = (2*a2*ac)/a1;
% y = a1*(ac+k*m).*cos(2*pi*fc*t);

figure(3)
plot(t,y)
xlabel('time---->>>>>>>>');
ylabel('amplitude--------->>>>>>');
title('AM modulated signal');

%powers
disp('signal power of modulated signal')
signal_power = spower(y(1:length(t))); %power in modulated signal
disp(signal_power)
variance = 0.2;
disp('signal to noise ratio')
snr1 = signal_power/variance;  % signal to noise ratio
```

```
disp(snr1)
snr_lin = 10^(snr1/10);   %linear SNR
disp('noise power added to the modulated signal')
noise_power = signal_power/snr_lin; %compute noise power
disp(noise_power)

%adding noise to the modulated signal
z = awgn(y,snr1);

figure(4)
plot(t,z)

xlabel('time---->>>>>>>>');
ylabel('amplitude--------->>>>>>');
title('awgn noise+signal');
%synchronous detection
demod=y.*c;
demod1=z.*c;
[b,a]=butter(3,0.001);
dm=filter(b,a,demod);       %demodulation of AM signal
dm1=filter(b,a,demod1);     %demodulation of corrupted AM signal

figure(5)
subplot(211)
plot(t,dm)

xlabel('time---->>>>>>>>');
ylabel('amplitude--------->>>>>>');
title('demodulation of AM signal');
subplot(212)
plot(t,dm1)

xlabel('time---->>>>>>>>');
ylabel('amplitude--------->>>>>>');
title('demodulation of corrupted AM signal(awgn)');
%power in demodulated corrupted signal at reciever side
disp('signal power of demodulated courrupted signal')
signal_power1 = spower(dm1(1:length(t)));
disp(signal_power1)

%spectrums
 N = length(y);
 x=abs(fft(y,N));
 f=((-(N-1)/2):(N-1)/2)*(fs/N);
 q = fftshift(x);
 figure(6)
 subplot(211)
 stem(f,q);
 axis([-21 21 0 610])
 title('spectrum of modulated signal');
 xlabel('time---->>>>>>>>');
 ylabel('amplitude--------->>>>>>');

 N1 = length(dm1);
 x1=abs(fft(dm1,N1));
 f1=((-(N1-1)/2):(N1-1)/2)*(fs/N1);
 q1 = fftshift(x1);

 subplot(212)
 stem(f1,q1);
 axis([-5 5 0 250])
 title('spectrum of demodulated corrupted signal');
 xlabel('time---->>>>>>>>');
 ylabel('amplitude--------->>>>>>');
```