Design of FM Modulation and Demodulation Circuit Based on Matlab

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Abstract: FM is widely used in communication systems. FM is widely used in high-fidelity music broadcasting, television audio signal transmission, satellite communications and cellular telephone systems. The design is mainly use MATLAB integrated environment M files to prepare the formula in order to achieve FM modulation and demodulation process. Then, it will draw out of the baseband signal, carrier signal and modulated time domain waveform signal. After that, it will draw out the superimposed signal with noise signal separately, the coherent demodulated signal and the time domain waveform of the demodulated baseband signal. Finally, the relationship between the bit error rate and the signal-to-noise ratio after the FM baseband signal is passed through the channel and the modulation and demodulation system will be drawn out. Then, waveform will be compared through theoretical results to analyze the correctness of the simulation modulation and demodulation system and the impact of noise on signal demodulation. In this design, the system development platform is Windows Vista while the tools used is MATLAB 7.0. The program was running on the platform to complete the observation of FM modulation and demodulation as well as the demodulation of the superimposed noise. The FM signal through the noise channel, modulation and demodulation system simulation purposes was achieved through this design.

Key words: FM; modulation; demodulation; MATLAB 7.0; noise

Preface

This circuit is designed to implement the DSB signal modulation and demodulation process. The modulation and demodulation of the signal plays an important role in the communication system. The modulation process is a process of moving the spectrum by moving the spectrum of the low frequency signal to the carrier frequency position. The demodulation is the inverse of the modulation which is the process of restoring the modulated signal to the original baseband signal. The receiving end of the signal is to reduce the modulated signal by demodulation to read the information sent by the sender. So the demodulation of the signal on the system transmission efficiency and transmission reliability has a great impact. Modulation and demodulation methods often determine the performance of a communication system. Double-side DSB signals demodulation using coherent demodulation method is widely used in carrier communication and short-wave wireless telephone communication.

1.The purpose and requirements of circuit design

1.1 The purpose of circuit design

The communication principle of analog signal modulation and demodulation, digital baseband signal transmission, digital signal modulation and demodulation, analog signal sampling, quantization and coding together with the principle of the best reception of signals were mastered through the 'FM modulation and demodulation system design and simulation' circuit design. Application of principle design FM modulation and demodulation system and then carry out simulation.

1.2 circuit design requirements

It is required to be proficient in the application of MATLAB language to write basic communication system applications, analog modulation system, digital baseband signal transmission system modeling, design and simulation. All the simulation with MATLAB program (that is, only the form of code cannot be achieved with SIMULINK), the system through the channel are assumed to be white Gaussian noise channel. Analog modulation requires the program to draw the modulation signal, carrier, modulated signal, demodulation signal waveform, digital modulation requirements to draw the bit error rate with the signal to noise ratio curve.

2.FM modulation and demodulation system design

The purpose of communication is to transmit information. The role of a communication system is to send information from an information source to one or more destinations. For any communication system, can be regarded as by the sender, channel and receiver three parts (shown in Figure 1).

Figure 1 General model of the communication system

Information source (referred as the source) is the role of a variety of information into the original signal. According to the type of message different sources are divided into analog sources and digital sources. The purpose of the transmitting device is to generate a signal suitable for transmission, even if the characteristics of the transmitted signal match the channel characteristics. It has the ability to resist noise and have sufficient power to meet the needs of long-distance transmission.

The information source and the sending device are collectively referred as the sending end.

The original electrical signal of the lower frequency which is transmitted directly by the sender is called the baseband signal. The baseband signal usually should not be transmitted directly in the channel. Therefore, at the transmitting end of the communication system, the spectrum of the baseband signal is shifted (modulated) into the frequency range suitable for channel transmission. This is the process of modulation.

After the signal is transmitted through the channel, the receiving end with the signal amplification and inverse conversion function moves (demodulates) the modulated signal to the original frequency range. This is the demodulation process.

The process of transmitting signals in the channel is always disturbed by noise, and there is no noise when there is no transmission signal in the communication system. Noise always exists in the communication system. Since such noise is superimposed on the signal, it is sometimes referred to as additive noise. The noise is harmful to the transmission of the signal, which can distort the analog signal. In the course of this simulation, we assume that the channel is a Gaussian white noise channel.

Modulation in the communication system has a very important role. In one aspect, the spectrum of the baseband signal can be moved to a desired position by modulation to convert the modulated signal into a modulated signal suitable for channel transmission or for channel multiplexing. On the other hand, modulation can improve the signal through the channel when the anti-jamming capability. At the same time, it is also related to transmission efficiency. To be specific, the bandwidth of the modulated signal generated by the different modulation schemes is different. Therefore, the modulation affects the utilization of the transmission bandwidth. It can be seen that the modulation method often determine the performance of a communication system. In the simulation process, we choose to use FM modulation method for modulation.

The modulation process is a process of moving the spectrum by moving the spectrum of the low frequency signal to the carrier frequency position while the demodulation is to move back the signal spectrum at the carrier frequency and to recover the original baseband signal without distortion. In the simulation process, we choose to use non-coherent demodulation method for demodulation.

2.1 FM modulation model establishment

Figure 2 FM modulation model

Among them, m(t) referred as the baseband modulation signal, set the modulation signal

Set the sine carrier for

The signal transmission channel is a Gaussian white noise channel, the power referred as .

2.2 Modulation process analysis

In the modulation, the frequency of the modulation signal is to control the carrier frequency changes. The carrier instantaneous frequency offset with the modulation signal is proportional to the change that is,

In the formula, is the FM sensitivity ().

The phase offset is now

You can get the FM signal

Modulation signal generated by M file:

```
dt = 0.001;                % Set the time step
t = 0: dt: 1.5;            % Generates the time vector
am = 15;                   % Set the modulation signal amplitude ← Can be changed
fm = 15;                   % Set the modulation signal frequency ← Can be changed
mt = am * cos (2 * pi * fm * t);  % Generates the modulation signal
fc = 50;                   % Set carrier frequency ← Can be changed
ct = cos (2 * pi * fc * t);    % Generates the carrier
kf = 10;                   % Set the FM index
int_mt (1) = 0;            % Integrate mt
For i = 1: length (t) -1
int_mt (i + 1) = int_mt (i) + mt (i) * dt;
end
sfm = am * cos (2 * pi * fc * t + 2 * pi * kf * int_mt);  % modulation, generating modulated signal
```

Figure 3 FM modulation

2.3 FM demodulation model is established

The demodulation of the modulation signal is divided into coherent demodulation and non-coherent demodulation. Coherent demodulation is only applicable to narrowband FM signals and there is need to synchronize the signal with limited scope of application. However, non-coherent demodulation does not require synchronization of signal and is applicable for the NBFM signal and WBFM signal. Therefore, the FM system is the main demodulation method. In the simulation process, we choose to use non-coherent demodulation method for demodulation.

Figure 4 FM demodulation model

Non-coherent demodulator consists of limiter, frequency discriminator and low-pass filter. The block diagram is shown in Figure 5. Limiter input is the FM signal and noise, the limiter is to eliminate the received signal in the amplitude may be the distortion then bandpass filter is used to limit the out-of-band noise as the allow the FM signal to pass through successfully. The discriminator in the frequency discriminator converts the FM signal into an amplitude modulated frequency modulated wave then detects the envelope by the envelope detector and finally extracts the modulation signal through the low pass filter.

2.4 Demodulation process analysis

Set the input FM signal as

The function of the differentiator is to convert the FM signal into amplitude modulation and frequency modulation. The differential output is

The effect of envelope detection is to detect the modulation signal from the amplitude variation of the output signal. Envelope detector output is

is called as the frequency sensitivity () which is the signal amplitude of the modulated signal corresponding to the amplitude of the modulation after passing the low-pass filter in addition to DC capacitors, isolated the useless DC, can get

Differentiator achieved through the program, the code is as follows:

```
For i = 1: length (t) -1                 % Accept the signal through the differentiator
diff_nsfm (i) = (nsfm (i + 1) - nsfm (i)) ./ dt;
End
diff_nsfmn = abs (hilbert (diff_nsfm));      % hilbert transform, find the absolute value of
                                             the instantaneous amplitude (envelope
                                             detection)
```

Through the M file to draw out two different signals to noise ratio demodulation output waveform is as follows:

Figure 5 FM demodulation

2.5 Gaussian white noise channel characteristics

Set the signal of sine wave through the additive white Gaussian noise channel as

Among them, the probability distribution of the value of white noise n(t) obeys the Gaussian distribution.

MATLAB itself comes with the internal functions randn of the standard Gaussian distribution. The randn function produces a random sequence that obeys the mean of and the variance of of the Gaussian distribution.

The sine wave is passed through the additive Gaussian white noise channel then signal referred as

The useful signal power is

Noise power is

SNR satisfies the formula

Then can get the formula

We can use this formula to set the variance of Gaussian white noise easily.

In this simulation process, we choose two different signals of 10db and 30db to noise ratio to show the difference, the time domain diagram shown in Figure 7 and Figure 8.

Figure 6 Time-domain diagram of modulated signals with no noise

Figure 7 Time-domain diagram of the modulated signal with small SNR Gaussian white noise

Figure 8 Time-domain diagram with a large signal-to-noise ratio Gaussian white noise modulated signal

2.6 Modulation of anti-noise performance of FM system

From the previous analysis we can see that the demodulation of the FM signal has two types which are coherent demodulation and non-coherent demodulation. Coherent demodulation is only applicable to narrowband FM signals and requires synchronization signals. Non-coherent demodulation is suitable for narrowband and wideband FM signals without the need of synchronization signals. Since the primary demodulation is the FM system, only non-coherent demodulation system anti-noise performance will be discussed here. The analysis model is shown in Figure 9.

Fig.9 Anti-noise performance analysis model of FM system

The bandpass filter in the figure is used to suppress noise outside the signal bandwidth. n(t) is the Gaussian white noise with zero mean and unilateral power spectral density. It will become a narrow band Gaussian noise after passing bandpass filter. The limiter is intended to eliminate the distortions that may occur in the amplitude of the received signal.

Set the FM signal to

The input power is

The input noise power is

So, the input signal to noise ratio is

In the large signal to noise ratio conditions, the signal and noise interaction can be ignored. Then, the signal and noise can be counted separately. Here, we can get the demodulator output signal to noise ratio

In the above equation, A is the amplitude of the carrier, is the frequency of the frequency modulator, the highest frequency of the modulation signal m(t) and is the noise unilateral power spectral density.

If we consider m(t) as the case of a single frequency cosine wave, we can get the system gain of the demodulator as

When considering the broadband frequency modulation, the bandwidth signal is

Then can get

It can be seen that the signal-to-noise ratio gain of the broadband FM system is high when the signal-to-noise ratio is large which is proportional to the cube of the FM index. It is abvious that increase the FM index, the FM system can make the anti-noise performance improved rapidly.

3.Simulation implementation

Figure 10 Program flow chart

3.1 MATLAB source code

```
% FM modulation and demodulation system
% Frequency modulation and demodulation of the Matlab demo source
% Can be arbitrarily changed to the original modulation signal function m (t)
% Information Engineering    Chen Li Dan    07323202
% * * * * * * * * * * * * * * * * * * * * * * * * * *
%****************initialization*****************
Echo off
Close all
Clear all
Clc
% ****************************************
* * * * * * * * * * * * * * * * * * * * * * * * * *
% *************** FM modulation ******************
dt = 0.001;                    % Set the time step
t = 0: dt: 1.5;                % Generates the time vector
am = 5;                        % Sets the modulation signal amplitude
fm = 5;                        % Get the modulation signal frequency
mt = am * cos (2 * pi * fm * t);              % Generates the modulation signal
fc = 50;                       % Set the carrier frequency
ct = cos (2 * pi * fc * t);             % Generates the carrier
kf = 10;                       % Set the FM index
int_mt (1) = 0;
for i = 1: length (t) -1
int_mt (i + 1) = int_mt (i) + mt (i) * dt;         % Integrate the signal m (t)
End                                 % Modulation, generating a modulated signal
sfm = am * cos (2 * pi * fc * t + 2 * pi * kf * int_mt);  % modulation signal
```

```
% ****************************************
* * * * * * * * * * * * * * * * * * * * * * * * *
% ************ add Gaussian white noise *************
sn1 = 10;                 % set the signal to noise ratio (small signal to noise ratio)
sn2 = 30;                 % set the signal to noise ratio (large signal to noise ratio)
sn = 0;                   % Set the signal to noise ratio (no signal to noise ratio)
db = am ^ 2 / (2 * (10 ^ (sn / 10)));   % Calculate the variance of the corresponding Gaussian white noise
n = sqrt (db) * randn (size (t));       % Generates Gaussian noise
nsfm = n + sfm;           % Generates a modulated signal containing Gaussian
                  noise % Over channel transmission)
% ****************************************
* * * * * * * * * * * * * * * * * * * * * * * * *
% *************** FM demodulation ******************
For i = 1: length (t) -1           % The accept signal is processed by the differentiator
diff_nsfm (i) = (nsfm (i + 1) - nsfm (i)) ./ dt;
End
diff_nsfmn = abs (hilbert (diff_nsfm));   % hilbert transform, find the absolute value of the instantaneous amplitude (envelope detection)
zero = (max (diff_nsfmn) -min (diff_nsfmn)) / 2;
diff_nsfmn1 = diff_nsfmn-zero;
% ****************************************
* * * * * * * * * * * * * * * * * * * * * * * * *
% ************* Time domain to frequency domain conversion *************
ts = 0.001;          % Sampling interval
fs = 1 / ts;         % Sampling frequency
df = 0.25;           % The desired frequency resolution is used in the Fourier transform
%, It represents the minimum frequency interval of the FFT
% ***** Find the Fourier transform of the modulation signal m (t)*****
m = am * cos (2 * pi * fm * t);  % original tone signal
fs = 1 / ts;
if nargin == 2
n1 = 0;
Else
n1 = fs / df;
End
n2 = length (m);
n = 2 ^ (max (nextpow2 (n1), nextpow2 (n2)));
m = fft (m, n);
m = [m, zeros (1, n-n2)];
df1 = fs / n;             % The above procedure is to find the Fourier transform of
              the modulated signal u
M = M / fs;               % scale, easy to observe the overall image in the frequency shop
f = [0: df1: df1 * (length (m) -1)] - fs / 2;% time vector corresponding to the frequency vector

% *********** on the adjusted signal u seeking Fourier transform *********
fs = 1 / ts;
if nargin == 2
n1 = 0;
Else
n1 = fs / df;
End
n2 = length (sfm);
n = 2 ^ (max (nextpow2 (n1), nextpow2 (n2)));
U = fft (sfm, n);
u = [sfm, zeros (1, n-n2)];
df1 = fs / n;             % The above is the Fourier transform of the modulated signal u
U = U / fs;               % scaling
% ****************************************
% ****************************************
% * * * * * * * * * * * * * * * * * * * * * * * * *
% ************** Show the program ****************
disp ('press any key to see the original modulation signal, carrier signal and modulated signal curve')
pause
% ************* figure (1) ****************
figure (1)
subplot (3,1,1); plot (t, mt);      % Draw the time domain of the modulated signal
xlabel ('time t');
title ('time domain map of modulation signal');
subplot (3,1,2); plot (t, ct);      % plot the time domain of the carrier
xlabel ('time t');
title ('Carrier Time Domain Graph');
subplot (3,1,3);
plot (t, sfm);                      % Draws the time domain graph of the modulated signal
xlabel ('time t');
title ('time domain map of modulated signal');
% ****************************************
disp ('press any key to see the original modulation signal and the modulated signal in the frequency domain within the graphics')
pause
% *********** figure (2) *******************
figure (2)
subplot (2,1,1)
plot (F, abs (fftshift (M)))        % fftshift: Moves the DC component in the FFT to the
                  center of the spectrum
xlabel ('frequency f')
title ('Spectrum of Original Modulation Signal')
subplot (2,1,2)
plot (f, abs (fftshift (U)))
xlabel ('frequency f')
title ('Spectrum of modulated signal')
% ****************************************
disp ('press any key to see the original modulation signal, no noise conditions, the signal has been modulated and demodulated signal curve')
pause
% ************* figure (3) ****************
figure (3)
subplot (3,1,1); plot (t, mt);      % Draw the time domain of the modulated signal
xlabel ('time t');
title ('time domain map of modulation signal');
subplot (3,1,2); plot (t, sfm);     % Draw the time domain graph of the modulated signal
```

xlabel ('time t');

title ('time - domain diagram of modulated signal without noise');

nsfm = sfm;

For i = 1: length (t) -1 % The accept signal is processed by the differentiator

diff_nsfm (i) = (nsfm (i + 1) - nsfm (i)) ./ dt;

End

Diff_nsfmn = abs (hilbert (diff_nsfm)); % hilbert transform, find the absolute value of the instantaneous amplitude (envelope detection)

zero = (max (diff_nsfmn) -min (diff_nsfmn)) / 2;

diff_nsfmn1 = diff_nsfmn-zero;

subplot (3,1,3); % Draws the time domain diagram of the demodulated signal under noisy conditions

plot ((1: length (diff_nsfmn1)) ./ 1000, diff_nsfmn1. / 400, 'r');

xlabel ('time t');

title ('time - domain diagram of demodulated signal without noise');

% **

disp ('press any key to see the original modulation signal, small signal to noise ratio Gaussian white noise conditions have been modulated signal and demodulated signal has been modulated signal curve')

pause

% ************** figure (4) *****************

figure (4)

subplot (3,1,1); plot (t, mt); % Draw the time domain of the modulated signal

xlabel ('time t');

title ('time domain map of modulation signal');

db1 = am ^ 2 / (2 * (10 ^ (sn1 / 10))); % Calculate the variance of the corresponding small signal-to-noise ratio Gaussian white noise

n1 = sqrt (db1) * randn (size (t)); % Generate Gaussian white noise

nsfm1 = n1 + sfm; % Generates modulated signals containing Gaussian noise (% Over channel transmission)

For i = 1: length (t) -1 % The accept signal is processed by the differentiator

diff_nsfm1 (i) = (nsfm1 (i + 1) - nsfm1 (i)) ./ dt;

End

diff_nsfmn1 = abs (hilbert (diff_nsfm1)); % hilbert transform, find the absolute value of the instantaneous amplitude (envelope detection)

zero = (max (diff_nsfmn) -min (diff_nsfmn)) / 2;

diff_nsfmn1 = diff_nsfmn1-zero;

subplot (3,1,2);

plot (1: length (diff_nsfm), diff_nsfm); % plot the time-domain map with small signal-to-noise ratio Gaussian white noise

xlabel ('time t');

title ('Time - domain diagram with small signal -to-noise ratio Gaussian white noise modulated signal');

subplot (3,1,3); % Draw a time domain diagram with a small SNR Gaussian white noise demodulation signal

plot ((1: length (diff_nsfmn1)) ./ 1000, diff_nsfmn1. / 400, 'r');

xlabel ('time t');

title ('Time domain map with small signal - to - noise ratio Gaussian white noise demodulation signal');

% **

disp ('press any key to see the original modulation signal, large signal to noise ratio Gaussian white noise conditions have been modulated signal and demodulated signal has been modulated signal curve')

Pause

% ************** figure (5) *****************

figure (5)

subplot (3,1,1); plot (t, mt); % Draw the time domain of the modulated signal

xlabel ('time t');

title ('time domain map of modulation signal');

db1=am^2/(2*(10 ^ (sn2 / 10))); % Calculate the variance of the corresponding large signal-to-noise ratio Gaussian white noise

n1 = sqrt (db1) * randn (size (t)); % Generate Gaussian white noise

nsfm1 = n1 + sfm; % Generates modulated signals containing Gaussian noise (signal through channel transmission)

For i = 1: length (t) -1 % The accept signal is processed by the differentiator

diff_nsfm1 (i) = (nsfm1 (i + 1) - nsfm1 (i)) ./ dt;

End

diff_nsfmn1 = abs (hilbert (diff_nsfm1)); % hilbert transform, find the absolute value of the instantaneous amplitude (package % detection)

zero = (max (diff_nsfmn) -min (diff_nsfmn)) / 2;

diff_nsfmn1 = diff_nsfmn1-zero;

subplot (3,1,2);

plot (1: length (diff_nsfm1), diff_nsfm1); % is plotted with large signal-to-noise ratio Gaussian white noise % of the time domain map

xlabel ('time t');

title ('Time - domain map with large signal-to-noise ratio Gaussian white noise modulated signal');

subplot (3,1,3); % draw with high SNR Gaussian white noise demodulation signal % of the time domain map

plot ((1: length (diff_nsfmn1)) ./ 1000, diff_nsfmn1. / 400, 'r');

xlabel ('time t');

title ('Time - domain map with large signal-to-noise ratio Gaussian white noise demodulation signal');

% **

%*****************End******************

3.2 Simulation results

In conclusion

Through the simulation of mobile communication system, the working principle of OFDM system and the interference in the transmission process are simulated and analyzed. The basic working principle of OFDM system is clarified, which lays the foundation for improving the efficiency of mobile communication and further reducing the signal interference.

OFDM system is suitable for multi-service, highly flexible communication system, the spectrum utilization is high, and the system stability is good. At present, OFDM has been widely used in Europe and Australia, digital broadband audio systems and digital broadband video systems, OFDM-based communication technology, enabling the transmission process to achieve low latency, high-speed data transmission. 54Mbit/s bandwidth is basically able to meet the majority of users on the wireless network requirements. With the continuous improvement of OFDM technology, its application will be extended to various fields.

For the fourth generation of mobile communication standards, OFDM still has many problems to be solved, select OFDM as the fourth generation of mobile communication core technology, the main reasons include high spectral efficiency, anti-noise ability, suitable for high-speed data transmission factor.

Experience

This graduation design is an important part of cultivating our students' comprehensive use of the knowledge, discovering, proposing, analyzing and solving practical problems and exercising practical ability. It is a concrete training and investigation process for the practical ability of our students. Looking back on the communication circuit design, from the topic to the finalization, from theory to practice, in a whole week of the day, I there is more bitter than sweet. However, I have learnt a lot of the things. I have learnt how to consolidate the previously learned theoretical knowledge and expanded my practical knowledge that was no written in the books. This graduation design makes me understand that the combination of theory and practice is very important; only the theoretical knowledge is far from enough. The only way is to learn how to combine the theoretical knowledge and practice together. The only method to provide better social service, we have to draw conclusions from the theory as to improve their practical ability and independent thinking ability. I have encountered many problems while studying this design, since this is the first time to carry out this study. Besides, I have also realized my shortcomings while carrying this design process. The knowledge which I have learnt was not thorough enough and I have not mastered them. After this graduation design, I must revise all the knowledge I have learnt in the past. The curriculum design has finally completed, I have encountered a lot of problems and all finally solved under the assistance of teachers and friends. I would like to thank all of them sincerely.

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