DESIGN AND IMPLEMENTATION OF GROUND STATION TRANSMITTER AND RECEIVER UNIT OF A SATELLITE SYSTEM

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CERTIFICATE OF CORRECTNESS AND APPROVAL

Certified that the work contained in this thesis “Design and implementation of Ground Station Transmitter and Receiver Unit of a Satellite System”, was carried out by Sara Jamil, Bilal Mahmood and Asad Hayat under the supervision of Asst Prof Engr Maj. Fazal Ahmed for the fulfillment of Bachelor of Telecommunication Engineering, is correct and approved.

Approved by

(Asst Prof Engr Maj. Fazal Ahmed)

Project Directing Staff(DS)

Military College of Signals (MCS)

Dated: 19 June, 2015

ABSTRACT

DESIGN AND IMPLEMENTATION OF GROUND STATION TRANSMITTER AND RECEIVER UNIT OF A SATELLITE SYSTEM

Aim of the project was to develop a communication network for transmission and reception of voice and telemetry information. Initially, it was accepted as part of Pakistan National Student Satellite-1(a project initiated by SUPARCO), but due to delay in funding instead of space/military grade components, normal off the shelf low cost components have been utilized to achieve almost the same results as envisaged through PNSS-1. We have designed and implemented a ground station transmitter and receiver unit of a satellite system. Ground station transmitter unit involves modulation, up conversion and amplification of the voice signal and its interfacing with an antenna. Signal is transmitted at a frequency of 114MHz. A prompt signal is transmitted using BPSK modulation at 415 MHZ to the telemetry side of the payload unit to start transmission with output power of 1W whereas ground station receiver unit includes two modules.

A) Demodulation of FM signal

Voice signal coming from the payload transmitter which is having a frequency of 110 MHz is down converted, demodulated and amplified and is fed to the speaker jack.

B) Demodulation of BPSK signal:

It receives the sensor data in digital form from the payload transmitter having frequency of 433MHZ. This data will include humidity of the payload, its temperature and current readings. After down conversion and demodulation of the received data it is displayed on LCD using Atmel.

We humbly dedicate our work to the Lord of the worlds

Whose knowledge extend over the heavens and the earth

and to the Holy Prophet (P.B.U.H)

ACKNOWLEDGEMENTS

Firstly we humbly pay our gratitude to Almighty Allah, the most beneficent and merciful. We are grateful to all those people who have helped us in the completion of this project, especially to our supervisor Asst Prof Engr Maj Fazal Ahmed for being a torch bearer for us. His expertise in this field has always been a source of inspiration for us. We are grateful to him for providing us an opportunity to perform our BE final year project under his supervision. We are really thankful to his contribution in our project work. We are also grateful to Dr. Adnan Ahmed Khan and our families for their constant support in our hard times, we can never forget that.

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LIST OF ABBREVIATIONS

VCO………………………...Voltage Control Oscillator

BPF………………………….Band Pass Filter

FM…………………………..Frequency Modulation

BPSK………………………..Binary Phase Shift Keying

LCD…………………………Liquid Crystal Display

FSK…………………………Frequency Shift Keying

RF………………….. ……….Radio Frequency

SUPARCO ………………… Pakistan Space and Upper Atmosphere Research Commission

VSWR ……………………… Voltage Standing Wave Ratio

Chapter 1

INTRODUCTION

1.1. BACKGROUND

In Pakistan SUPARCO has been pursuing close cooperation and collaboration with the academia of the country. For this SUPARCO has taken initiative in the form of Pakistan National Student Satellite Program(PNSSP). PNSSP comprises a series of satellite which will be designed by students of different universities of Pakistan. PNSS-1 is first of this series envisaged to be launched in 2016. Our project is a prototype of two modules of PNSS-1. The motivation behind this project is that this will not only help us (students) to gain industry experience but will also help our space industry as they are facing problem of shortage of skilled manpower. Main objective of project was to design and implement a prototype of ground station transmitter and receiver unit for Pakistan National Student Satellite-1.

1.2. PROJECT DESCRIPTION:

The ground station transmitter and receiver unit designed by us is a prototype of the original design specified by SUPARCO. Aim of the project was to develop a communication network for transmission and reception of voice and telemetry information. Initially, it was accepted as part of Pakistan National Student Satellite-1(a project initiated by SUPARCO), but due to delay in funding instead of space/military grade components, normal off the shelf low cost components have been utilized to achieve almost the same results as envisaged through PNSS-1. We have designed and implemented a ground station transmitter and receiver unit of a satellite system. Ground station transmitter unit involves modulation, up conversion and amplification of the voice signal and its interfacing with an antenna. Signal is transmitted at a frequency of 114MHz. A prompt signal is transmitted using BPSK modulation at 415 MHZ to the telemetry side of the payload unit to start transmission with output power of 1W whereas ground station receiver unit includes two modules.

B) Demodulation of FM signal

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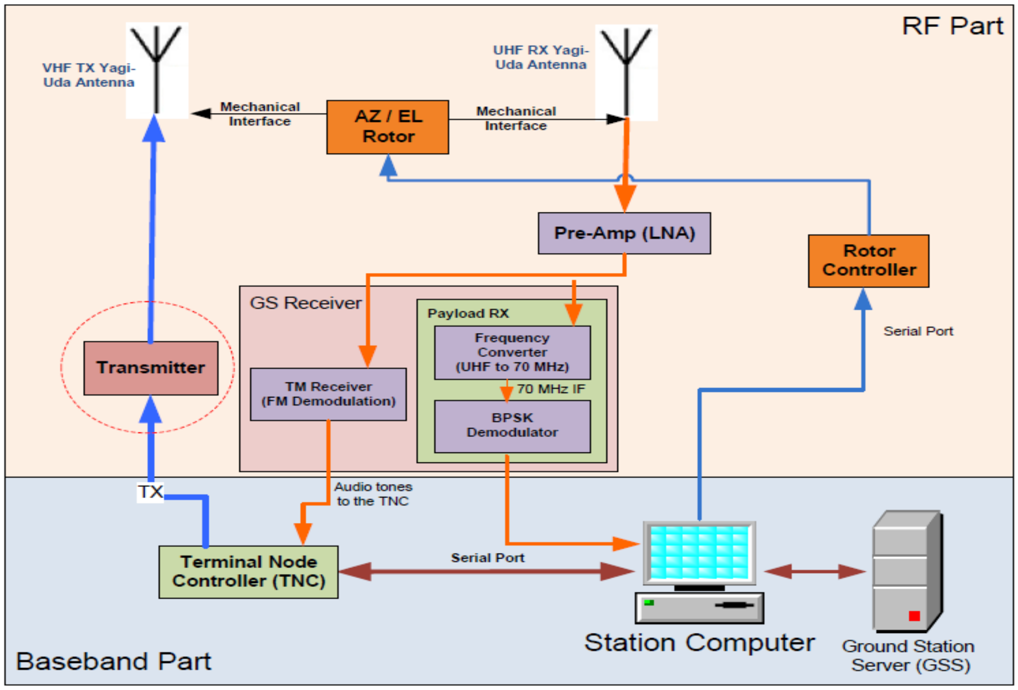


Figure 1.2.1 BASIC DESIGN APPROACH

This diagram shows basic design approach of ground station transmitter and receiver. We have developed a communication network between the satellite and the ground station. Ground station transmitter is capable of transmitting voice signal to the satellite and the receiver receives the voice signal through FM demodulation and it also receives telemetry information that is about current, humidity and temperature through binary phase shift keying demodulation and displays it on an LCD. Rotor controller shown in figure has nothing to do with our project.

1.3. APPLICATIONS:

1. All the telemetry information can be monitored on the ground station and satellite can be made to remain within its orbital window.
2. Furthermore we are using frequency modulation [2] that is widely used by the broadcasting industry as it resilient to noise.
3. FM is used in mobile applications as it can withstand signal level variations.

4. Due to FM modulation, transmitters efficiency level will be higher as non-linear amplifiers will be used.
5. The RF generator in a microwave oven, electro surgery and induction heating are similar in design of RF transmitters.
6. BPSK finds its application in many different fields of mobile and satellite communication.
7. The space industry of Pakistan is facing problems regarding trained workers. So by choosing this project we have tried to overcome this problem to some extent.

1.4. SCOPE, OBJECTIVES, SPECIFICATIONS AND DELIVERABLES OF THE PROJECT

1.4.1. SCOPE :

1. Understanding and designing of the Ground Station Transmitter and Receiver Unit.
2. Simulation of various blocks.
3. Implementation with help of ATMEL 89C51 microcontroller.
4. Interfacing and implementation of different blocks efficiently.
5. BPSK demodulation for receiving telemetry information
6. FM for the voice signal transmission

1.4.2. GOALS:

1. Stand alone hardware
2. Modularity in Design

3. Optimization of the design for a specific frequency and output power
4. Maximum Utilization of existing heritage
5. Communication of Telemetry information
6. Cost Effective
7. Efficient communication of audio signal
8. Power Efficient

1.5. SPECIFICATIONS :

Ground station transmitter and receiver are having following specifications.

1. Signal is transmitted at a frequency of about 114 MHz.
2. Frequency modulation and demodulation technique is used.
3. It can filter out undesired signals and noise.
4. ATMEL 89C51 microcontroller is used for the reception of telemetry signals and transmission purposes using receiver module xy-djm 5v.
5. The output from payload transmitter carrying the sensor information that is of temperature, humidity of the satellite is received and viewed on an LCD.
6. 100% hardware platform
7. Custom solution
8. Easily configurable
9. Cost effective solution

1.6. DELIVERABLES:

MODULE 1:

Transmission and reception of the voice signal with help of FM.

MODULE 2:

1. A complete unit which receives telemetry information with help of BPSK
2. LCD interfacing
3. ATMEL 89C51 microcontroller.

Chapter 2

LITERATURE REVIEW/BACKGROUND STUDY

2.1. BACKGROUND

SUPARCO has taken initiative in the form of Pakistan National Student Satellite Program(PNSSP). PNSSP comprises a series of satellite which will be designed by students of different universities of Pakistan. PNSS-1 is first of this series envisaged to be launched in 2016. Our project is a prototype of the ground station unit of PNSS-1. Ground Station transmitter unit includes transmission of payload data to antenna for onward transmission to Satellite and ground station receiver unit includes reception of the data coming from the satellite with accuracy and monitoring of the received data.

2.2. LITERATURE VIEW:

Following papers helped us in understanding the design and implementation of ground station transmitter and receiver.

We got the basic idea of all the components used and their functions by the detail study of "Essential basic guide for wireless communication".

Handbook of Space Technology by Wilfried Ley, Klaus Wittmann, Willi Hallmann helped us in understanding the design for the reception of the telemetry commands.[12]

According to R. J. Trew, "High-Frequency Solid-State Electronic Devices," IEEE Transactions on Electron Devices, vol. 52, no. 5, pp. 638-649, May 2005. This paper helped us in making ground station transmitter and receiver design .It also tells us about the various stages that are present in design and how we will be able to send and receive signal in VHF band. Along with the above paper there is another one which is L. Samoska, S. Church, K. Cleary, A. K. Fung, T. Gaier, P. Kangaslahti, R. Lai, J. Lau, X. B. Mei, M. M. Sieth, R. Reeves, and P. Voll, "Cryogenic MMIC low noise amplifiers for W-band and beyond," inProc. 22nd International Symposium on Space Terahertz Technology, Tucson, AZ, April 2011. Both of these papers helped us in understanding the working.

The IIT Madras Student Satellite Project was started by a team of students who were inspired with an idea to build a small satellite and launch it into orbit. They wish is to make a meaningful contribution to science and technology and its learning . They have their own payload and ground station unit they send the payload unit in space by the use of Helium balloons and are able to receive the communication up to their standards.

We have studied about different modulation techniques like FSK and BPSK etc and learnt different coding methods. [15]

We studied about different microcontrollers and finally selected ATMEL 89c51 [11] which is an eight bit microprocessor and its in system reprogrammable flash memory was 4k bytes which was fulfilling our requirements. ("Complete Microcontroller Portfolio to meet your every day design need" (n.d.) retrieved from http://www.atmel.com/products/microcontrollers/)

Chapter 3

MATHEMATICAL MODELLING

3.1. MATHEMATICAL EXPRESSION

Following formulae are used to calculate capacitance.

$$f_1 = \frac{1}{2\pi\sqrt{R_1 C_1}}$$

$$f_2 = \frac{1}{2\pi\sqrt{R_5 C_1}}$$

And in order to calculate inductance we used following formula that is

X=1/LC

After knowing the inductance we calculated its turns by using online inductor turns calculator.

Chapter 4

MODEL DESIGN

4.1. OVERVIEW

We have developed a communication network between the satellite and the ground station for telemetry purpose. Ground station transmitter is capable of transmitting voice signal to the satellite and the receiver receives the voice signal through FM demodulation and it also receives telemetry information that is about current, humidity and temperature through binary phase shift keying receiver module xy-djm 5v and displays it on an LCD.

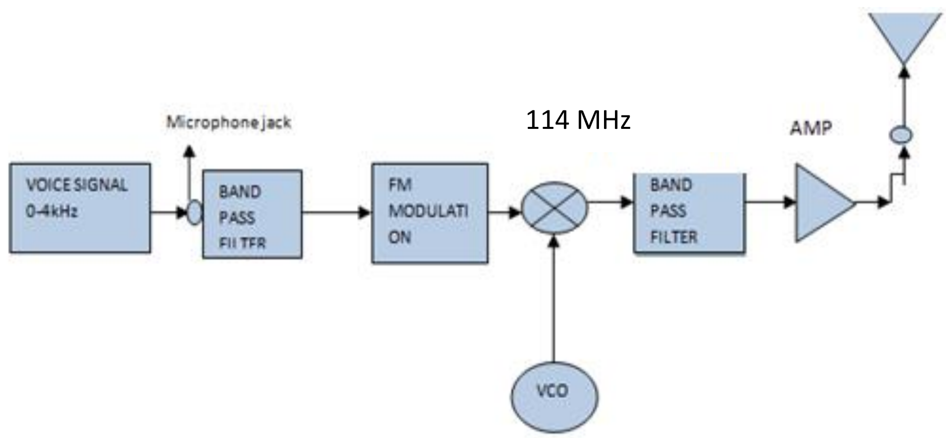


Figure 4.1. BLOCK DIAGRAM OF GROUND STATION TRANSMITTER UNIT

This is the block diagram of ground station transmitter unit. Here voice signal is received through microphone jack. That is frequency modulated and range of frequencies will be generated by the VCO and these are mixed with the modulated signal using mixer. Then band pass filter passes frequencies that are in the range of

114 MHz. These frequencies are then passed through amplifier for power amplification. This signal is interfaced with antenna for onward transmission.

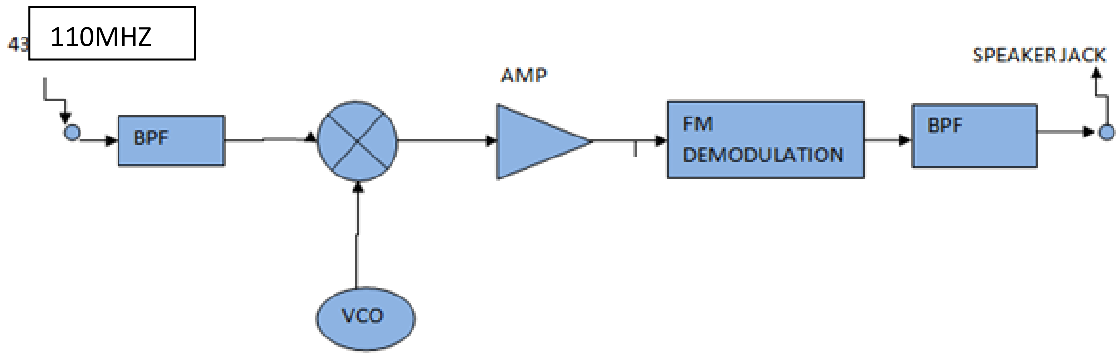


Figure 4.2. BLOCK DIAGRAM OF GROUND STATION RECEIVER(MODULE 1)

An antenna is interfaced with a connector which receives signals which are in the range of 110-112 MHz. Band pass signal is added to remove noise. This signal is then down converted using oscillator and mixer. It then undergoes frequency demodulation and passed through a band pass filter again to remove any noisy signal. Afterwards signal is heard through a speaker jack.

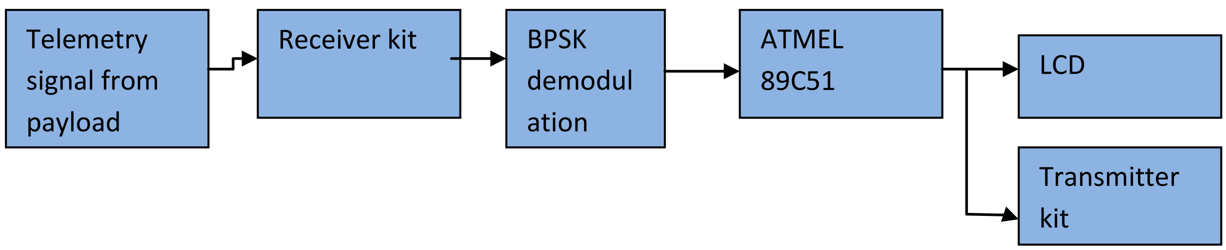


Figure 4.3. BLOCK DIAGRAM OF GROUND STATION RECEIVER(MODULE 2)

Transmitter kit sends a one bit control signal to the payload transmitter to send the sensor’s data in order to know about the condition of satellite. Sensor’s data coming from the payload transmitter is then received by the receiver kit. This data is down converted and demodulated using binary phase shift keying and then ATMEL 89c51 is used to convert it to digital form and that is then be displayed on an LCD. Another control bit will be sent to the payload transmitter to forward more data indicating previous data has been received.

Chapter 5

ELECTRICAL DESIGN AND DEVELOPMENT

5.1. WORKING OF GROUND STATION TRANSMITTER*:*

Ground station transmitter unit involves modulation, up conversion and demodulation. Working of ground station transmitter unit is explained below.[5]

1. Audio signal received from the microphone has very low level so it needs to be amplified. So for that a common emitter configuration of a bipolar transistor is used.

2. Oscillations are produced by the circuit of capacitor and inductor.

3. When this signal passes through the oscillator, frequency of oscillator circuit varies with that of input producing a frequency modulated signal.

4. This signal is then passed to the antenna for onward transmission.

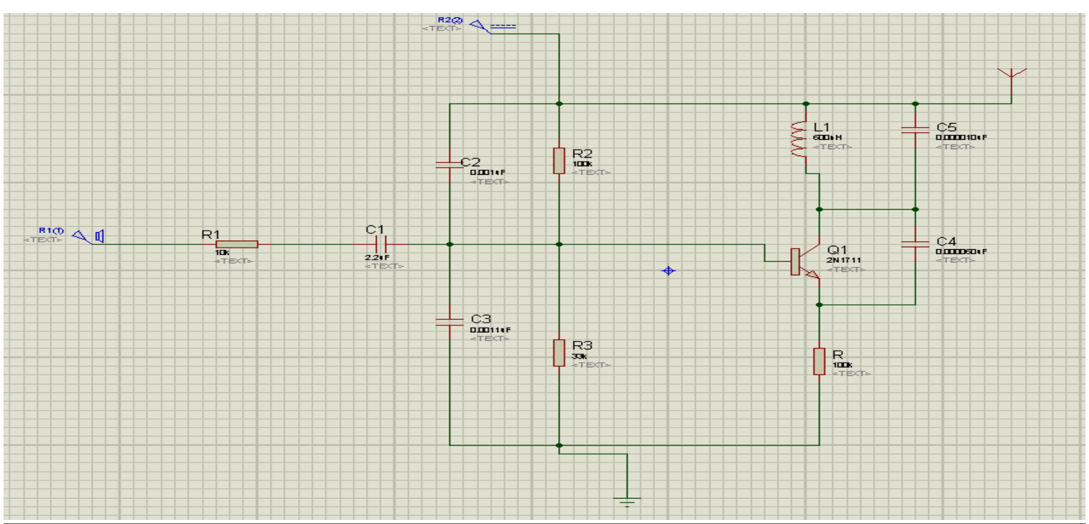
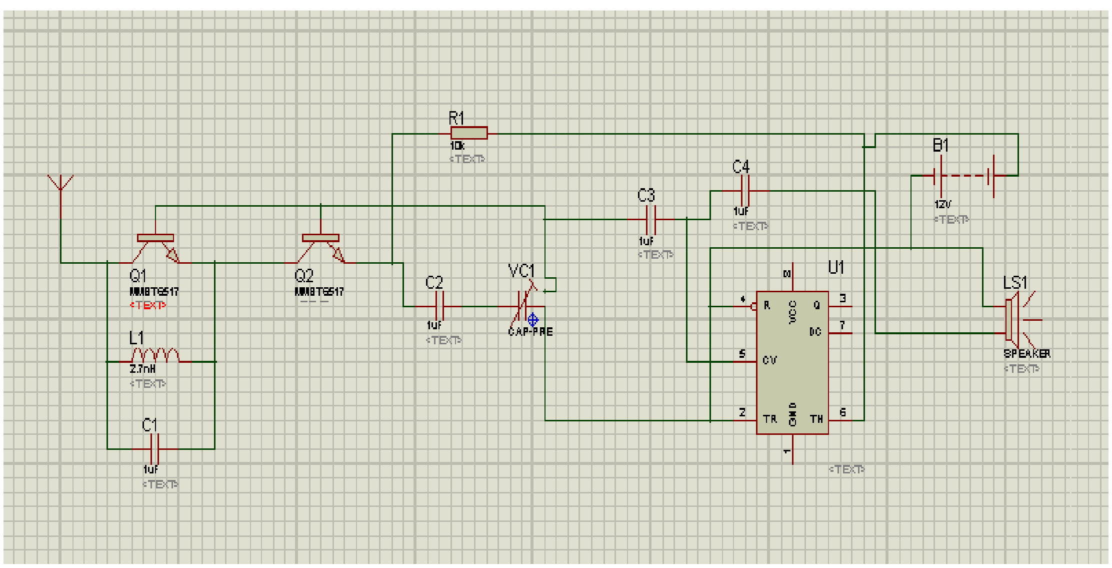


Figure 5.1.CIRCUIT DIAGRAM OF TRANSMITTER

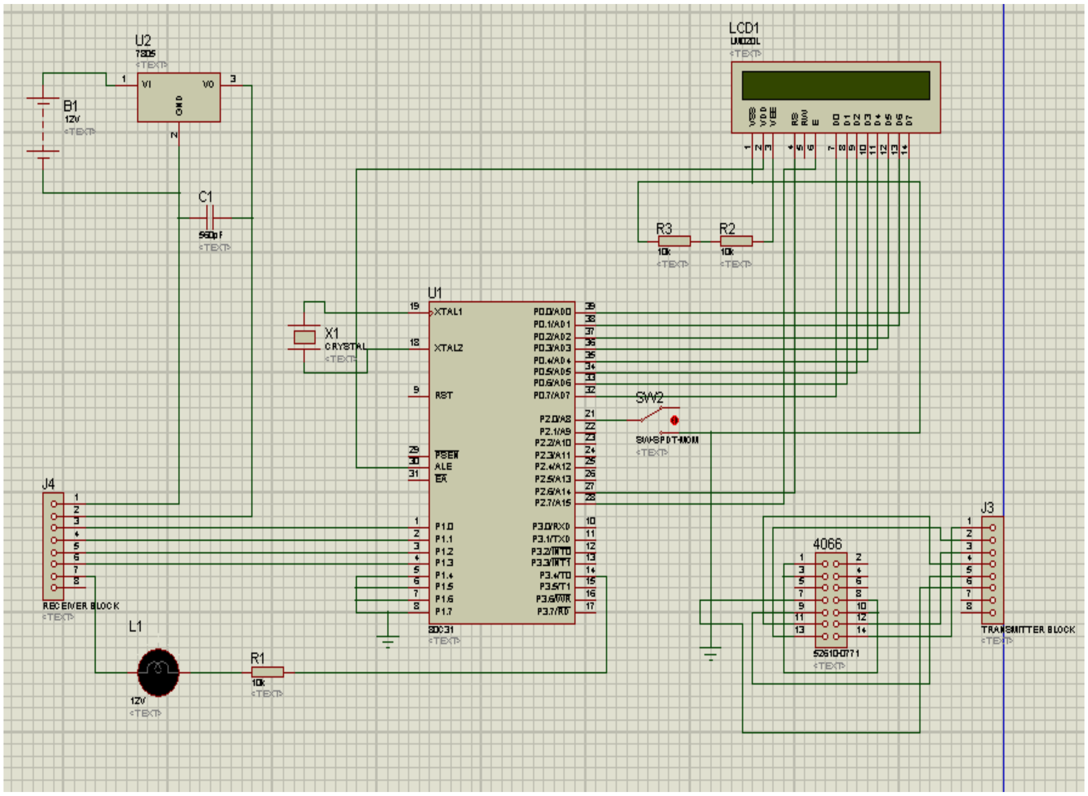
In this figure the circuit diagram of transmitter is shown. It's operating voltage is 9 Volts. Tank circuit in this will generate carrier and capacitors are used to remove noise. The capacitors at the end of the circuit couple the signal to the antenna.[6],[7]

5.2. WORKING OF GROUND STATION RECEIVER:

1. RF signal coming from the payload transmitter is demodulated and passed to the speaker jack.
2. RF telemetry signal coming from the payload transmitter having a frequency of 433 MHz is received using RF receiver kit.
3. Then this signal is passed through BPSK encoder and demodulation.
4. ATMEL 89C51 is programmed to receive the data signal and display the output on an LCD screen.
5. Control bit will be send to the payload transmitter to forward updating data. Also indicating that the previous data has been received.



<u>5.2. CIRCUIT DIAGRAM OF RECEIVER (MODULE 1)</u>



<u>Figure 5.3. CIRCUIT DIAGRAM OF RECEIVER (MODULE 2)</u>

In this figure sensor data of current, humidity and temperature is received by the receiver kit and is then passed to the ATMEL 89C51.

Atmel 89c51 has analog to digital converters which are attached to LCD. So the received data is displayed on LCD. When data is received and new data is required switch is turned on and a control bit is again sent to the payload receiver through transmitter kit.

5.3. COMPONENTS SPECIFICATION:

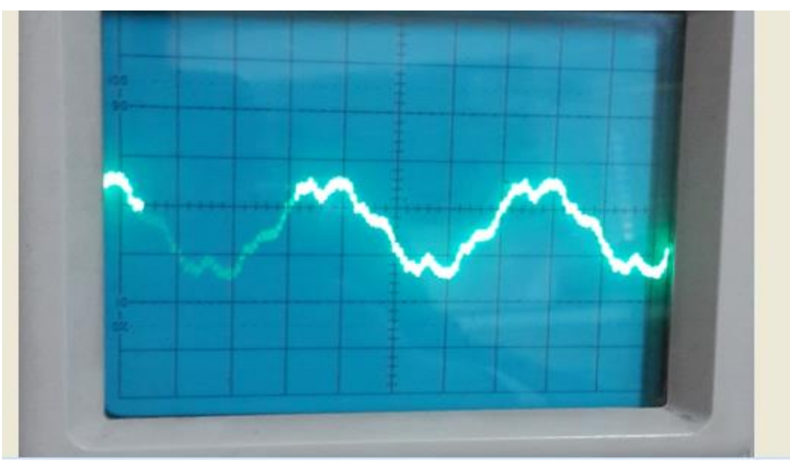
The components which will be used in this project are:

1. Transistor C945.
2. Capacitors of different capacitances like 2.2Uf, 102, 10Pf, 6pF.
3. Resistors like 10,100,33 k ohms

4. 9 Volt battery
5. Microphone
6. ATMEL 89C51 [8]
7. Receiver and transmitter kits
8. CMOS analog switch CD4066
9. Voltage regulator LM7805
10. LM 386N-1

5.4. STEPS TAKEN FOR IMPLEMENTATION:

Firstly we implemented the transmitter circuit shown in figure 3. Problems which we faced while implementing this transmitter was making of the inductor. It was really hard to decide the no. of turns in order to meet the required frequency. Different frequency harmonics were handled and we removed noise. Another problem which we faced while making the modulator was that the internal resistance of the breadboard was affecting the output of the modulator. So by analyzing different circuits we came to know about it, so we used a veroboard instead of a breadboard.



5.4. SHOWING OUTPUT OF MODULATOR DESIGNED USING BREADBOARD

Afterwards we headed towards implementation of receiver unit. For that we studied about different components in order to make the receiver unit and selected those which are specified above.

Chapter 6

6.1.TECHNIQUES STUDIED FOR MODULATION AND DEMODULATION

We have approached the project by first designing the frequency modulator circuit and after that we have designed a transmitter and receiver for voice channel. Next step was to receive the telemetry information with help of ATMEL 89C51. Temperature, current and humidity are being monitored. This information is received with help of BPSK demodulation and displayed on an LCD.

6.2. FM / FSK Modulator

This is the first task that we had done for our project. When long signals are transmitted, the high frequency part of the digital signal easily attenuates and causes distortion. Therefore, before transmission the signal has to be modulated, and for that purpose we used FSK. To achieve effective transmission FSK technique is used to modulate the data signal to two different frequencies. At the receiver, the data signal was then recovered using these two different frequencies of the received signal. The modulated digital signal is shown below.

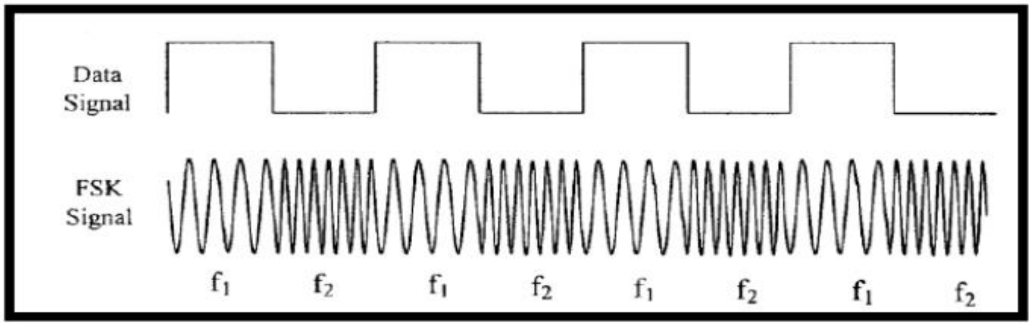


Figure 6.1. The signal waveforms of FSK modulation [13].

In order to achieve this FSK modulation we have used 2206 IC, which is a waveform generator. The circuit diagram of the FSK modulator by using 2206 IC is shown and being implemented.

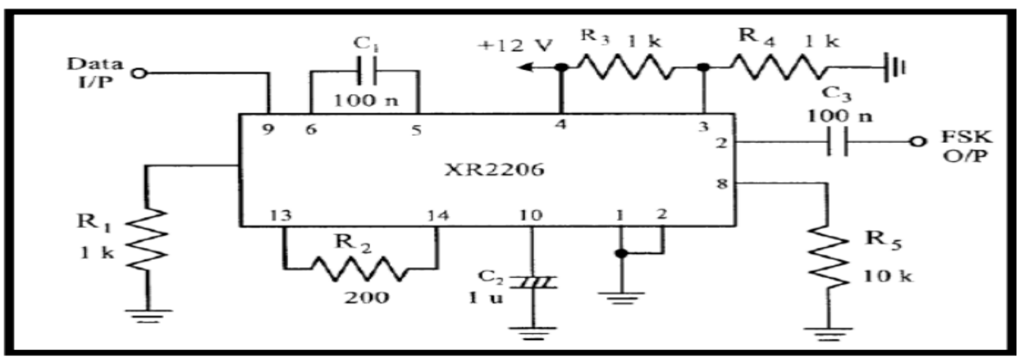


Figure 6.2. Circuit diagram of FSK modulator by using 2206 IC [14]

In these figure resistors R3, R4 comprise a voltage divided circuit. The main function of the voltage divided circuit is to let the negative voltage waveform of the 2206 IC operates normally. The oscillation frequency of 2206 IC is determined by resistors R1 and R5. Its oscillation frequencies are

$$f_1 = \frac{1}{2\pi\sqrt{R_1C_1}}$$

$$f_2 = \frac{1}{2\pi\sqrt{R_5C_1}}$$

There is an internal comparator in 2206 IC. when we provide 5V input , the output frequency is f1, and when the input is 0V, the output frequency is f2. We can utilize the TTL signal at pin 9 to control the output frequency to be f1 or f2. By using the variable resistor we can adjust the frequency according to our desired requirement. In our case f1 is 1200 Hz and f2 is 2200Hz.

Despite of doing the FSK we have also approached the problem of transmission of voice signal with help of frequency modulation (FM).This is being achieved with help of Colpitts Oscillator [9].

Demodulation technique which we studied was firstly using XR2211[3] because of its following salient features

6.2.1.FEATURES

1. Wide Frequency Range, 0.01Hz to 300kHz
2. Wide Supply Voltage Range, 5V to 12V
3. FSK Demodulation, with Carrier Detection
4. Wide Dynamic Range, 10Mv to 3V rms
5. Adjustable Tracking Range, +1% to 80%
6. Excellent Temp. Stability, +50ppm/°C, max.

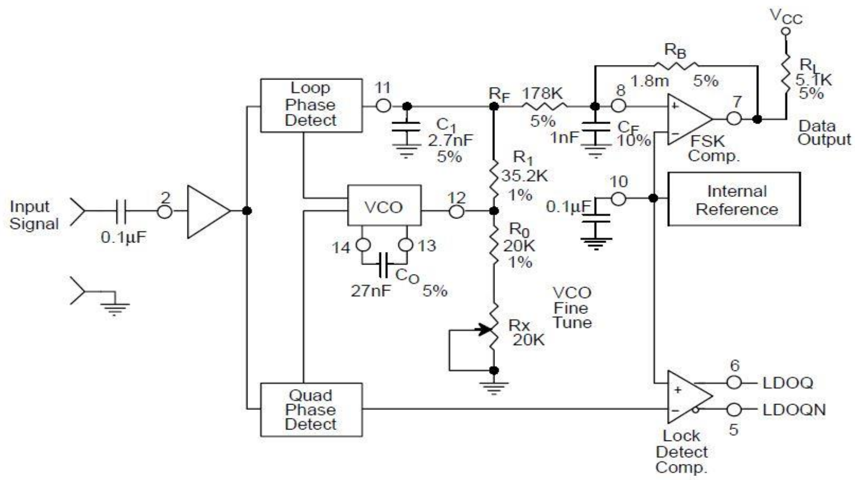


Figure 6.3. CIRCUIT FOR DEMODULATION

In the above figure FSK demodulation is done. Ro and Co set the central frequency of PLL. R1 is used in order to set the system bandwidth and resistor Rb produces positive feedback across FSK comparator so that rapid transition between logic states can occur.

The microcontrollers that we have mentioned earlier are used to receive the signal.

6.2.2.BPSK DECODER AND DEMODULATOR:

BPSK demodulator kit which we have used is xy-dmj 5V and its specifications are given below.

Tx Technical Specifications: Working voltage: 3V-12V Working current: 20-28mA. Working temperatur: -10 degree to +70 degree Resonance mode: sound wave resonance (SAW) Working frequency: 315MHz-433.92MHz, customized frequency is available. Transmission distance:>500m,sensitivity to -103dBm, in open areas. Transmission power: 25mW (315MHz at 12V) Frequency error: +150kHz (max) Velocity: ≤10Kbps

RX Technical Specifications:

Working voltage: 5.0VDC Static current:4mA Working temperatur: -10 degree to +70 degree Working principle: single chip superregeneration receiving Working frequency: 315MHz-433.92MHz, customized frequency is available(266-433MHZ). Bandwidth: 2MHz (315MHz, having result from testing at lowing the sensitivity 3dBm) Sensitivity: excel –100dBm (50Ω) Transmitting velocity: <9.6Kbps (at 315MHz and -95dBm)

6.3. SIMULATIONS

```
clear all;
close all;

f = 200; % sine wave frequency
fs = 100; %sampling frequency of the sine wave

t = 0:1/fs:1; % defining time

%defining phase shifts for BPSK signals
phase1 = 0;
phase2 = pi;

N = input('enter the number of bits to be modulated: N = ');

% random signal generation
Bit_stream=round(rand(1,N));

time = [];
digital_signal = [];
PSK = [];
carrier_signal = [];

%Signal generation
for ii = 1:1:N

%the original digital signal is
if bit_stream(ii) == 0
bit = zeros(1,length(t));
else
bit = ones(1,length(t));
end

digital_signal = [digital_signal bit];

%Generating the BPSK signal
if bit_stream(ii) == 0
```

```
bit = sin(2*pi*f*t+phase1);
else
bit = sin(2*pi*f*t+phase2);
end
PSK = [PSK bit];

%Generation of carrier wave
carrier = sin(2*f*t*pi);
carrier_signal = [carrier_signal carrier];

time = [time t];
t = t + 1;

end

subplot(2,1,1);
plot(time,digital_signal,'r');
grid on;
axis([0 time(end) -0.5 1.5]);

subplot(2,1,2);
plot(time,PSK);
grid on;
 axis([0 time(end) -2 2]);
axis tight;
```

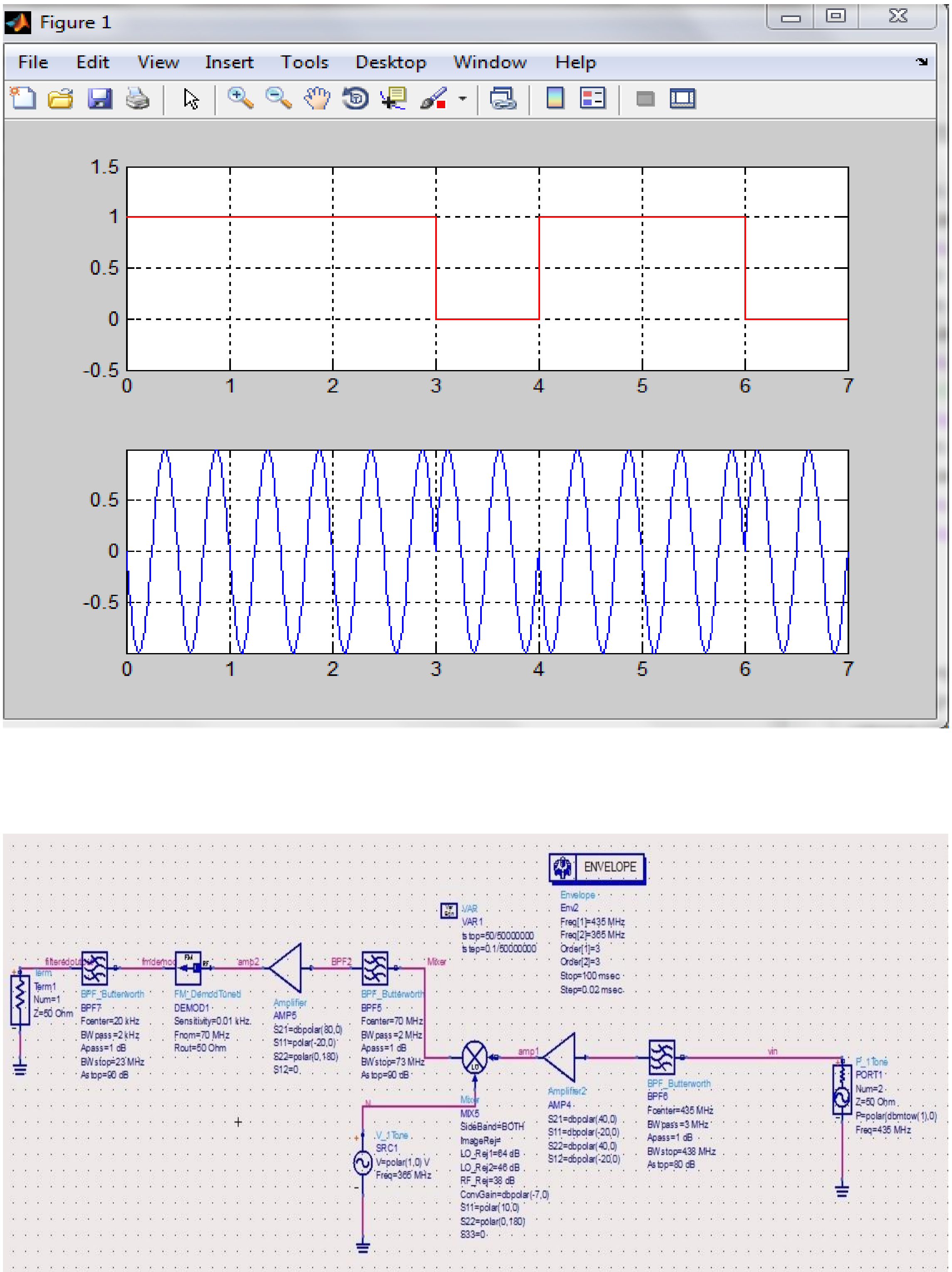


Figure 6.3.1. SIMULATION OF RECEIVER BLOCK

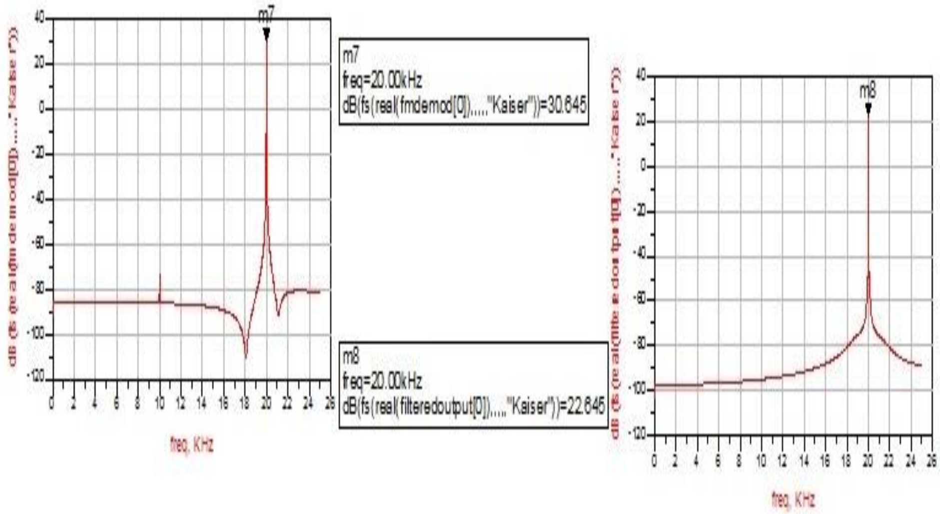


Figure 6.3.2. RESULTS OF RECEIVER UNIT

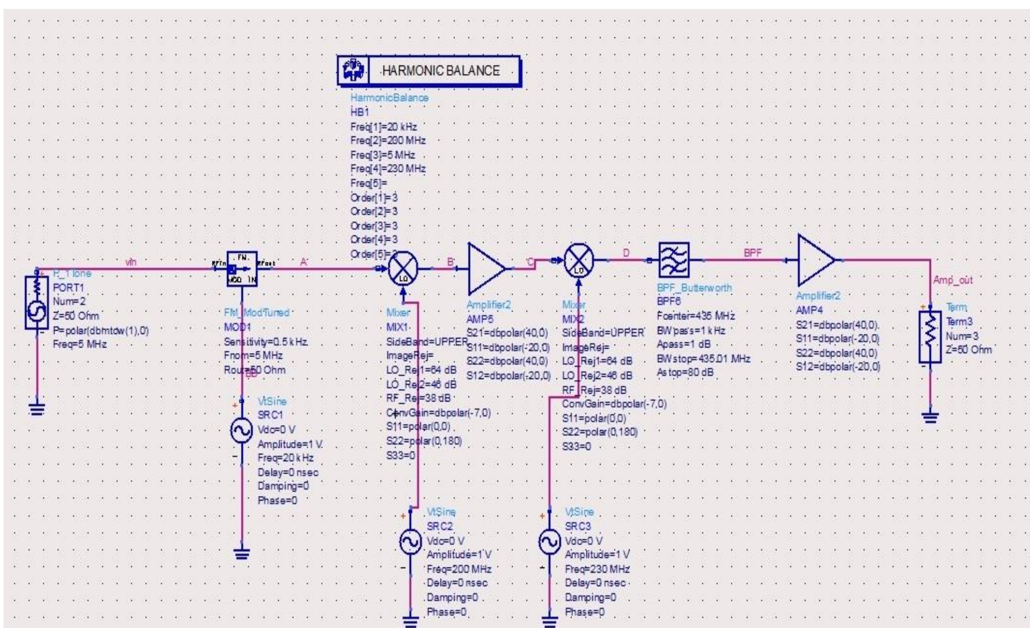


Figure 6.3.3. SIMULATION OF TRANSMITTER UNIT

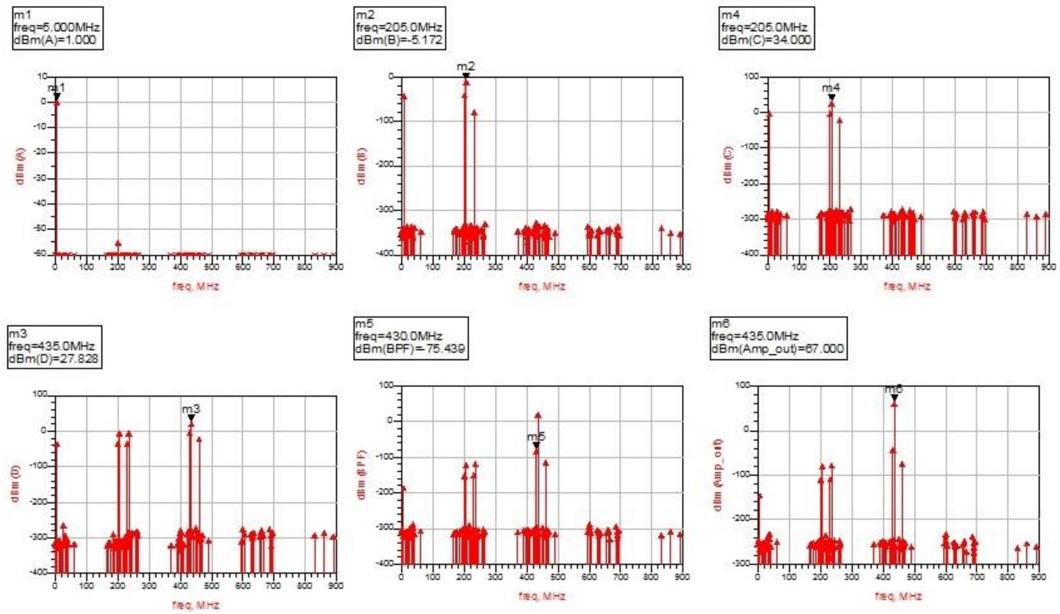


Figure 6.3.4. SIMULATION RESULTS OF TRANSMITTER UNIT

Chapter 7

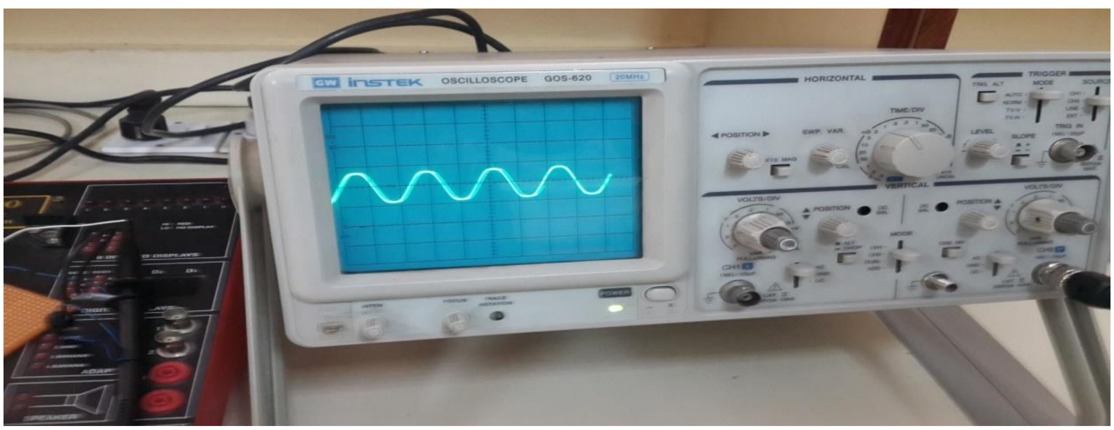
7.1.PROJECT ANALYSIS AND EVALUATION

All results and simulations are shown below.

<u>Input Signal:</u>

When input given was 5 volts.

<u>Modulated Signal Using IC XR-2206:</u>



<u>Figure 7.1. FSK MODULATED SIGNAL WHEN INPUT GIVEN IS 5 VOLTS</u>

<u>INPUT SIGNAL:</u>

When input signal was 0 Volts.

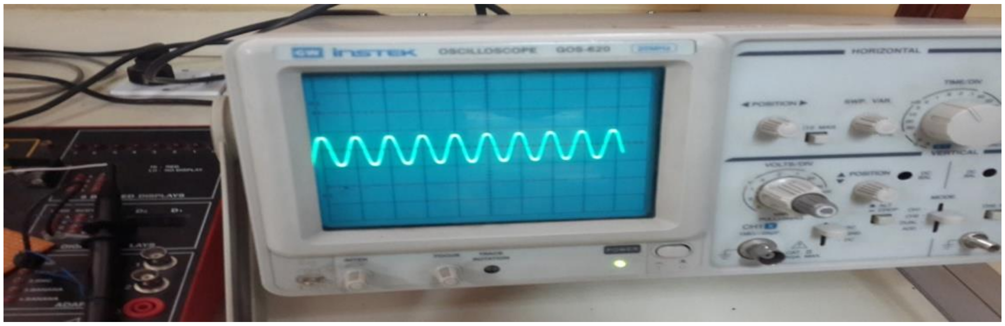


Figure 7.2. FSK MODULATED SIGNAL WHEN INPUT GIVEN IS 0 VOLT

OUTPUT SIGNAL:

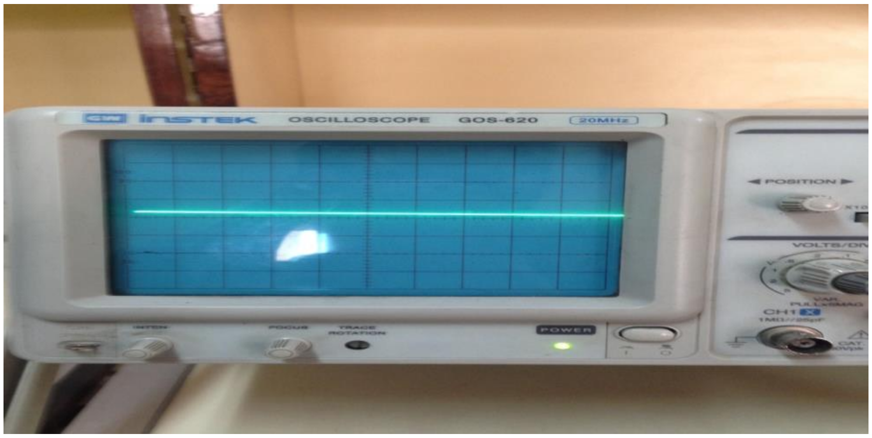


Figure 7.3. DEMODULATED OUTPUT WHEN INPUT IS 0 V

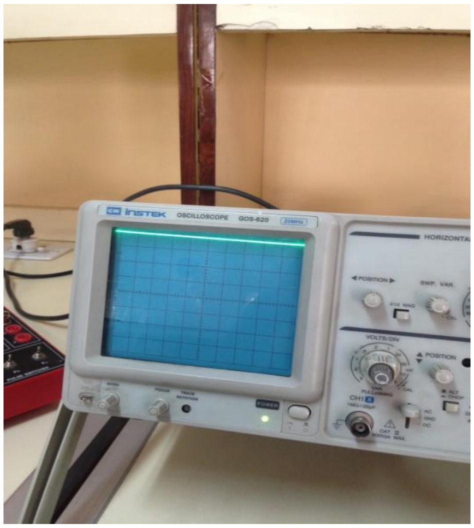


Figure 7.4. DEMODULATED OUTPUT WHEN INPUT IS 5 V

Chapter 8

8.1.RECOMMENDATION FOR FUTURE WORK

8.1.1.Recommendation for Future Work

As we have already mentioned before that this project will serve as a prototype for the Pakistan National Student Satellite-1. Pakistan National Student satellite-1 is first of the series of satellites envisaged to be launched in 2016 by SUPARCO. . It will be a good development for Pakistan, enhancing the economy and will open job opportunities. This will students to gain knowledge and experience about space technology and will also help the space industry as they are short of skilled manpower.

With help of this project, not only the students will take interest but it will be very helpful for different industries as well. Most of industries will start to focus on this vast project and will definitely show their interest for the prosperity of the country which is the ultimate goal.

This project will help the research department in the sense that they can monitor the satellite and know about its condition and extract different information by introducing more information about sensors like voltage, pressure and heat etc. In case satellite drifts away from its orbital window, commands should be sent so that it moves back to its original position. Proper tracking of satellite can be done with help of GPS modules.

Chapter 9

CONCLUSION

1.1. Overview

So we have designed a prototype for two modules of Pakistan National student satellite-1. It develops a communication network between a payload segment of satellite and ground station. Ground station transmitter is capable of transmitting voice signal to the satellite through FM modulation and the receiver receives the voice signal through FM demodulation and it also receives telemetry information that is about current, humidity and temperature through binary phase shift keying and displays it on an LCD.

9.2. Objectives achieved

Following objectives are being achieved:

1) Understanding and designing of the ground station transmitter and receiver unit
2) Achieving frequencies that are 110 and 114 MHz for audio and 434 MHz for receiving telemetry
3) Implementation with help of microcontroller
4) BPSK demodulation for receiving telemetry information
5) FM for the voice signal transmission
6) Interfacing different blocks efficiently

9.3. Limitation

First limitation of the project is that redundancy must be provided for example if a capacitor or inductor fails to work then there should be another that can work.

Secondly, if HPA and driver amplifiers were used then transmission range would have been increased but due to non-availability of some amplifiers like SMA231 etc they are not being used for this particular project.

9.4. Applications

Applications of the project include FM modulation, BPSK demodulation. It can be used for animal tracking and in various mobile applications. The RF generator in a microwave oven, electro surgery and induction heating are similar in design of RF transmitters. The space industry of Pakistan is facing problems regarding trained workers. So by choosing this project we have tried to overcome this problem to some extent.

APPENDIX A:

```
#include <AT89X51.H>

#include <string.h>

#include <lcd.h>



bit ok = 0;

bit valid = 0;

char incomming = 0;

char j = 0;

char s_buf = 0;

char counter = 0;

char array[6] = 0;

bit start = 0;

char temp = 0;

char hum = 0;

char amp = 0;

void seial(void)

{

  if(counter == 0)

  {
```

```
        temp = SBUF;
        counter++;
  }

  else if(counter == 1)
  {
        hum = SBUF;
        counter++;
  }
  else if(counter == 2)
  {
        amp = SBUF;
        counter = 0;
  }
}
void main(void)
{
SCON = 0x50; // serial port mode 1
TMOD = 0x22; // timer 0 and timer 1 mode 2 ( 8 bit auto reload )
ES     = 1;    // enable serial port interrupt
TH1  = -3;  // reload count for 9600 baud 13
```

```
TR1  = 1;   // start timer 1

EA = 1;          // enable global interrupt



   print_lcd("     Welcome    ");

   delay_ms(2000);

   print_lcd("Press button to ");

   print_lcd("receive data    ");

   if(P2_0 == 0)

   {

            SBUF = '@';

   }

   clear();

   print_lcd("Please wait    ",1);

while(1)

{

            print_lcd(" temp  Hum  Amp ",1);

            print_lcd(temp, hum, amp);


 }
```

APPENDIX B:

DEMONSTRATION OUTLINE:

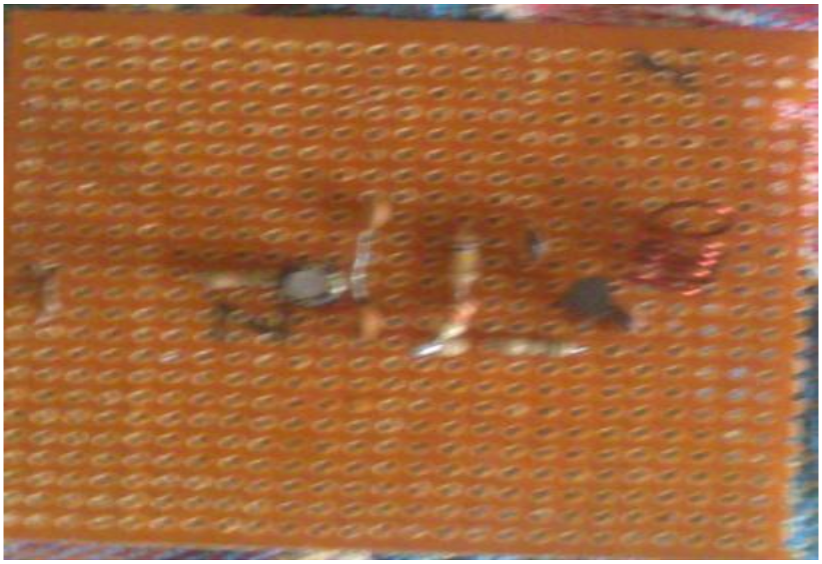


Figure GROUND STATION TRANSMITTER

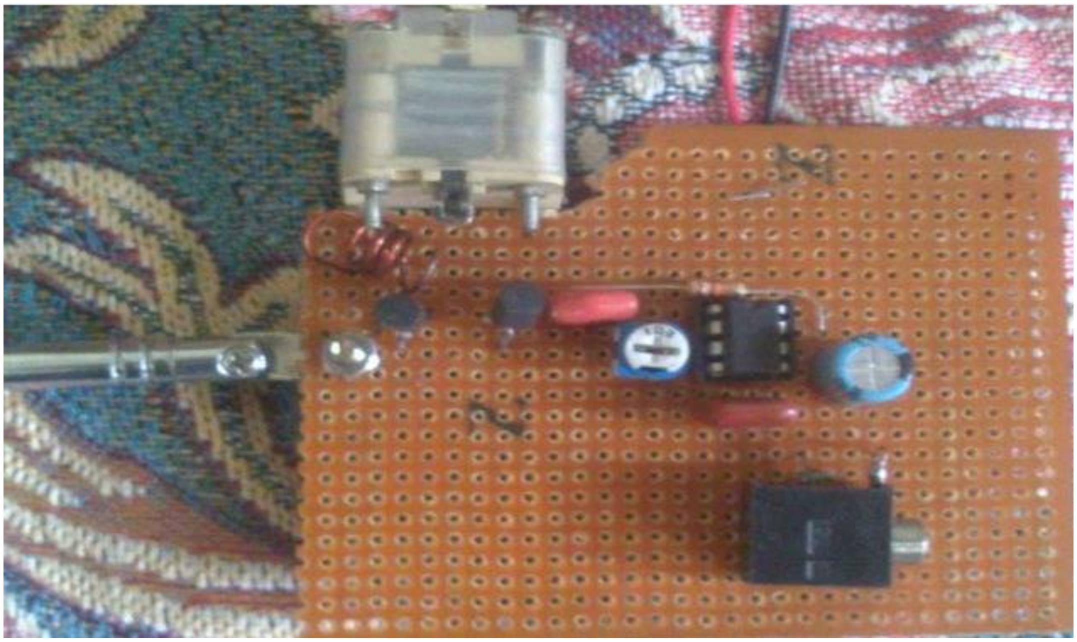


Figure GROUND STATION RECEIVER UNIT

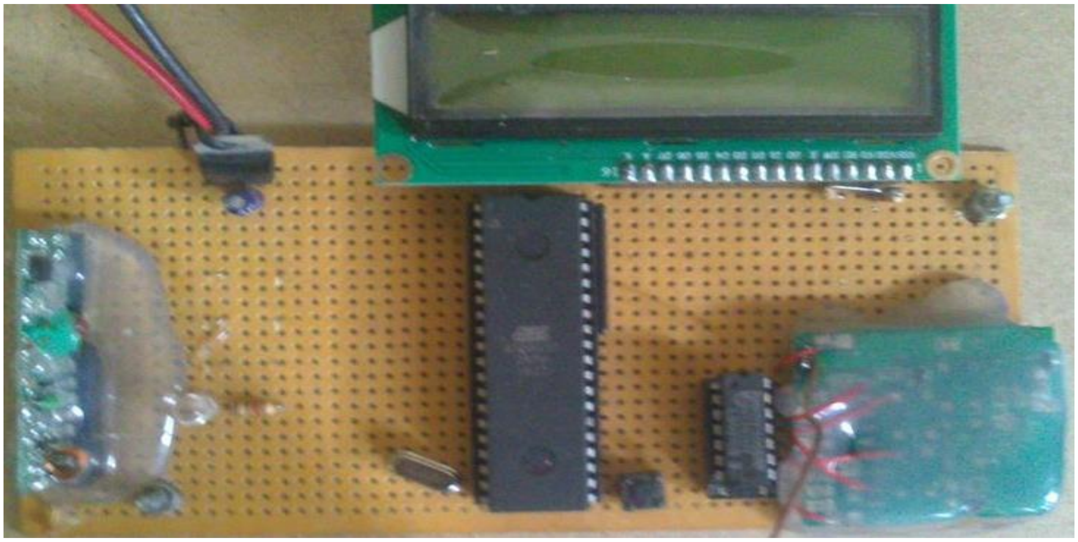


Figure GROUND STATION RECEIVER MODULE 2

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