

10 GHz Microwave Link

By
David Levine
Collin Phelps
Michael Brown
and
Nicholas Tsaparas

A Report
submitted in partial fulfillment
of the requirements of
ELEC 490
Concordia University
November 2002

Table of Contents

1.	INTRODUCTION	1
2.	OBJECTIVE	2
3.	SYSTEM DESIGN	5
3.1	The Antenna	5
3.2	The Gunnplexer	6
3.3	The Intermediate Frequency (IF) Strip	6
3.4	The FSK Demodulator	7
3.5	The Output Buffer	8
3.6	The FSK Modulator	9
3.7	The Attachment User Interface (AUI)	10
3.8	Tuning Considerations	10

4.	TASKS COMPLETED	8
4.1	Design of Subsystems	8
	4.1.1 FSK Modulator	8
	4.1.2 Gunnplexer Assembly	8
	4.1.3 IF Strip	9
	4.1.4 FSK Demodulator	9
	4.1.5 Output Buffer	9
	4.1.6 The AFC Buffer	10
	4.1.7 The S-Meter Circuits	10
	4.1.8 Tuning / Fault Meter	10
4.2	Missing Elements	8
	4.2.1 Missing Components	9
	4.2.2 Incomplete Gunnplexer Assembly	10
	4.2.3 Meters and AUI Ports	10
4.3	Encountered Problems	10
	4.3.1 Isolation of Individual Modules	10
	4.3.2 Mismatch in Sizing of MC-13155 and PCB Socket	10
4.4	Clarification of Last Year's Final Report	11
	4.4.1 Inconsistency in Bandwidth Calculations	11
	4.4.2 Use of Tantalum Capacitors	11
	4.4.3 Disregarding Resistors	11
	4.4.4 Connection of AUI ports	11
	4.4.5 The Role of the TCP/IP and MAC Protocol in Error Correction	11
	4.4.6 Current Op-Amp	11
	4.4.7 OSI Model	11
	4.4.8 How Inductance Arises in a PCB	11

5.	TASKS AT HAND	8
5.1	Completion of the Circuit Boards and Other Components	8
5.2	Testing the Operation of the Circuit Boards	8
5.2.1	Gunnplexer Frequency Calibration	9
5.2.2	FSK Demodulator Calibration	10
5.2.3	FSK Modulator Deviation Adjustment	10
5.2.4	Testing the IF Strip	11
5.2.5	Testing Transceivers in Loop-Back Mode	11
5.3	Testing the Entire System	10
5.3.1	Ethernet Applications	10
5.3.2	Design of Antennas	10
5.4	Other Possible Applications of 10 GHz Link	11
5.5	Summary and Breakdown of Tasks	11
5.5.1	Functionality of System	11
5.5.2	Application of System to Ethernet Network	11
5.5.3	Wireless Transmission	11
5.5.4	Further Experimentation	11
6.	PARTS REQUIRED	12
7.	CONCLUSION	12
	REFERENCES	13
	APPENDIX A: HOW THE AUI CONNECTOR WORKS	14

List of Figures

Fig. 1	Low Frequency Unit.....	3
Fig. 2	High Frequency Unit.....	4
Fig. 3	15 Pin AUI Connector.....	7
Fig. 4	Assembled PCB.....	9

List of Tables

Table 1	Task Allocation.....	27
Table 2	List of Parts and Tools Required.....	28
Table 3	AUI pin connections.....	31
Table 4	Connection Between Two PC Ethernet Cards	31

1. INTRODUCTION

Nowadays, there are many ways for two systems to communicate in a wireless manner. Every different way has its own advantages and disadvantages. In this project, we will be experimenting with a 10 GHz wireless microwave link system. This system has many advantages over many widely used systems. Several of the main advantages are bandwidth usage and potential range of operation.

The 10 GHz link system we will be implementing is based on a model designed by John Miles [1]. The motivation John Miles had for creating the system he created was to be able to remotely access his office's high speed internet connection from home for free. Hence, John Miles' design is primarily geared toward network applications, but the link can ultimately be used for many applications.

This report will outline precisely what the project will entail as well as give a description of how the overall system works and how it was designed.

2. OBJECTIVE

The objective of this project is to successfully implement, test, and apply a working 10 GHz microwave communication link. A microwave link is a wireless communication system that sends and receives information through the conversion of electrical signals to propagating electric fields. An electrical signal is set up by a transmitter and is coupled through a microwave network and propagated into free space with the use of an antenna. The signal then travels through space to a receiver. The receiver has an antenna that will pick up the transmitted electric field and convert it back to an electric signal, which is then interpreted by the receiver's associated circuitry to recover the original signal. Then, using a connection called an **Attachment Unit Interface** (AUI), the signal is routed to a load device. The load device then uses the signal for whatever its application may be. In this project, the first application we will implement is a wireless Ethernet network. Beyond that application, we are hoping to be able to experiment with other possible applications of the wireless link. The project will be carried out in different stages, some of which have been completed to date.

Last year, a team of undergraduate students consisting of Benoît Chapelotte, Dave M. Gunputhram and Damien Avril began work on this very project [2]. They had hoped to get the wireless Ethernet network functional. Unfortunately, as shall be explained, due to time constraints, they were unable to complete all that they had hoped to. They did, however, manage to complete the design and most of the assembly of the main components. Therefore our project will focus less on the design of the system and more on the testing and implementation of it.

As mentioned, the system we are using is based on a design created by John Miles [1] and uses most of the same components.

3. SYSTEM DESIGN

The overall microwave link will have two units: the low frequency transceiver unit and the high frequency transceiver unit. The low and high reflect the frequencies to which each unit is tuned. These frequencies are 10.178 GHz for the low frequency unit and 10.323 GHz for the high frequency unit. It may seem peculiar to label such close frequencies as high and low, but for the ease of explanation, this is how they are labeled. As can be seen, the difference between these two frequencies is 145 MHz. This frequency, called the **Intermediate Frequency (IF)** is what enables the link to operate. The two units have identical circuits, but with one exception. One of the units, in our case the low frequency unit, will be connected to an AFC buffer which regulates the 145 MHz IF required for operation. Either unit could have been chosen to include the buffer, but arbitrarily, the low frequency unit was chosen. To monitor how well the system is tuned, a tuning meter is also utilized on the low frequency board. The overall view of the complete system can be seen below in Figure 1 and Figure 2 [1].

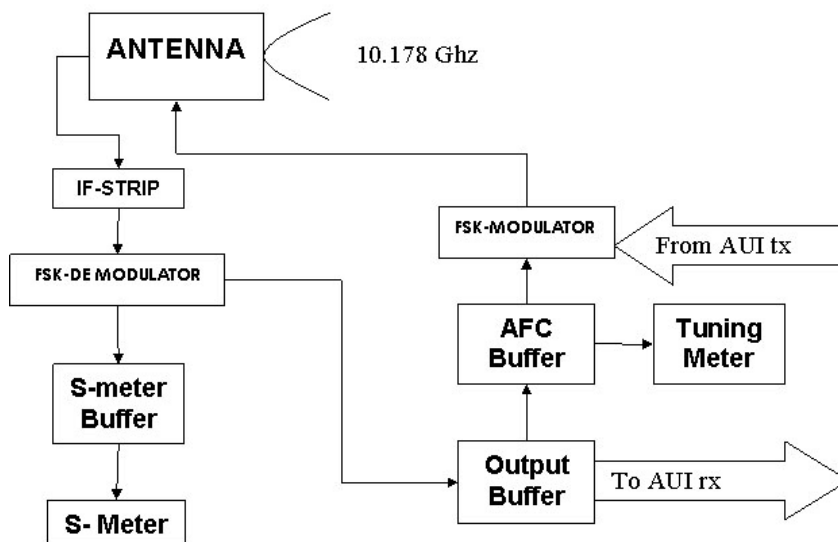


Figure 1: Low Frequency Unit

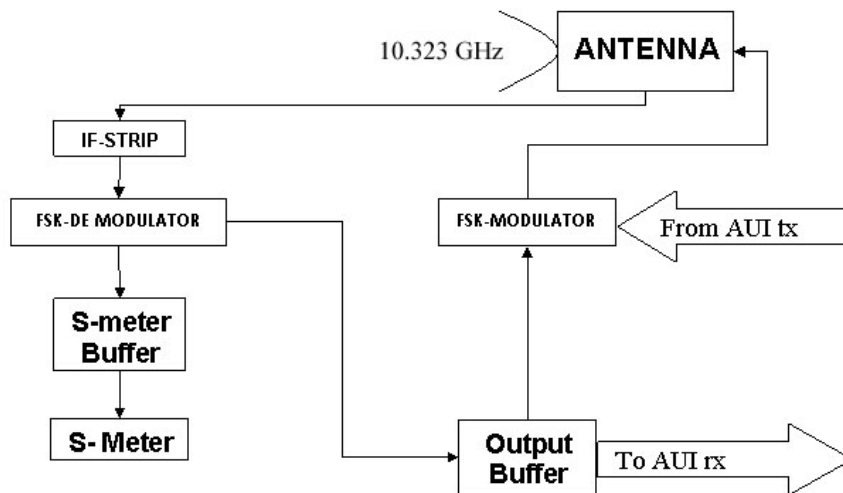


Figure 2: High Frequency Unit

3.1 The Antenna

The system can operate using various antennas and decisions upon choice will depend on application. The testing will initially be done with a direct **X-band** waveguide connection as the transmission line between the transmitter and the receiver to verify the transceiver is functioning properly. X-band waveguides function for frequencies between 8 and 12 GHz, so our 10 GHz application fits in the X-band quite well [1].

3.2 The Gunnplexer

The transmission and reception of signals will be dealt with using 10 GHz Voltage controlled oscillator transceiver modules called Gunnplexers. Ultimately, any type of 10 GHz oscillator could have been chosen, but due to the fact that Gunnplexers are relatively compact and are easily tuned to work with IF circuitry, they are a good choice to be used for this system. A Gunnplexer is located at either end of the wireless link. When transmitting, Gunnplexers will essentially

generate a 10 GHz carrier frequency, slightly tune the oscillator to a desired frequency and transmit that frequency out an X-band waveguide opening. When receiving, Gunnplexers can output a heterodyne signal. It is important to note that there are limitations on the use of Gunnplexers as transceivers for systems. The system will operate in **half duplex** due to limitations that shall be discussed later on. The received signal from our Gunnplexer works in conjunction with an IF Strip to bring our operating frequency from a 10 GHz band signal down to a 145 MHz IF [1].

3.3 The Intermediate Frequency (IF) Strip

After signal transmission, the IF strip plays an important role in receiving the signal. The IF strip is a subsystem that filters disturbances from **Frequency Modulation** (FM) transmissions. The IF Strip uses a high filter and a low pass filter that ultimately form a sort of band pass filter that has a good response between 82 and 210 MHz. Following the IF Strip in the system is the **Frequency-Shift Keying** (FSK) Demodulator [1].

3.4 The FSK Demodulator

The FSK Demodulator is an important part of the overall system. Its purpose is to recover the original signal's waveform from the IF signal. The original signal can be recovered from the IF signal by performing wideband FM demodulation [1].

3.5 The Output Buffer

The output buffer is a system component that level shifts, filters and amplifies the signal prior to routing the signal into the AUI port. This component has as a dual the FSK Modulator. That is to say, the task the output buffer accomplishes is accomplished in the reverse direction by the FSK Modulator. Hence the Output buffer is connected to the receiver side of the system and the FSK Modulator is connected on the transmitter side of the system [1].

3.6 The FSK Modulator

Contrary to what one may believe, the FSK modulator does not perform the opposite task of the FSK demodulator. In fact, by itself, the FSK modulator does not even perform any modulation. The FSK Modulator is actually a system device that prepares the signal for transmission and then sends it off to the Gunnplexer to be modulated. It DC shifts the zero baseline of the original signal to a desired value and amplifies the signal to a desirable value [1].

3.7 The Attachment User Interface (AUI)

The AUI is an interface bus between the transceiver unit lines and the load application. An AUI is a series of pin connectors similar in configuration to connectors commonly found on older Ethernet cards. When receiving, the AUI port prepares the desired signal to be applied to an application load and sends the appropriate information to the appropriate pin. When transmitting, the AUI port transfers an input signal from the load device to the FSK Modulator. Figure 3 shows what the AUI connector looks like [1].

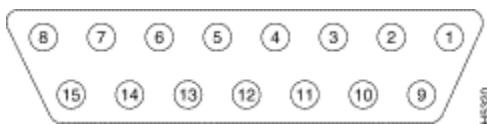


Figure 3: 15 Pin AUI Connector

3.8 Tuning Considerations

The essential IF is tuned and monitored using an AFC buffer, and tuning meter. This will regulate the IF gap between the low and high frequency units. Thus a 145 MHz gap is always respected while operating. This circuitry only needs to be included on one end of the microwave link because the actual frequency that each unit operates at is not important, provided that it stays within the **Armature Band** (10 – 10.5 GHz). What is important is to maintain a 145 MHz IF between the two units. So, if one day, one of the units changes its operating frequency, we can still tune our system to get back our 145 MHz gap [1].

The Link itself is tested and tuned using a **Strength Meter** (S-meter) buffer and S-meter. Components that act as monitoring devices to incoming signals are also included. All the tuning elements are only used on the lower input printed circuit board [1].

4. TASKS COMPLETED

As mentioned, this project was started by a team of students last year. They managed to put together many pieces of the system. They also made a nice system design. All the subsystems previously described were put together on a **Printed Circuit Board (PCB)**. The design of the PCB was carried out using EAGLE software. In the PCB design, the subsystems were grouped together to form three larger circuit blocks called “Board 1”, “Board 2” and “Board 3”. Figure 4 shows the actual PCB that was manufactured.

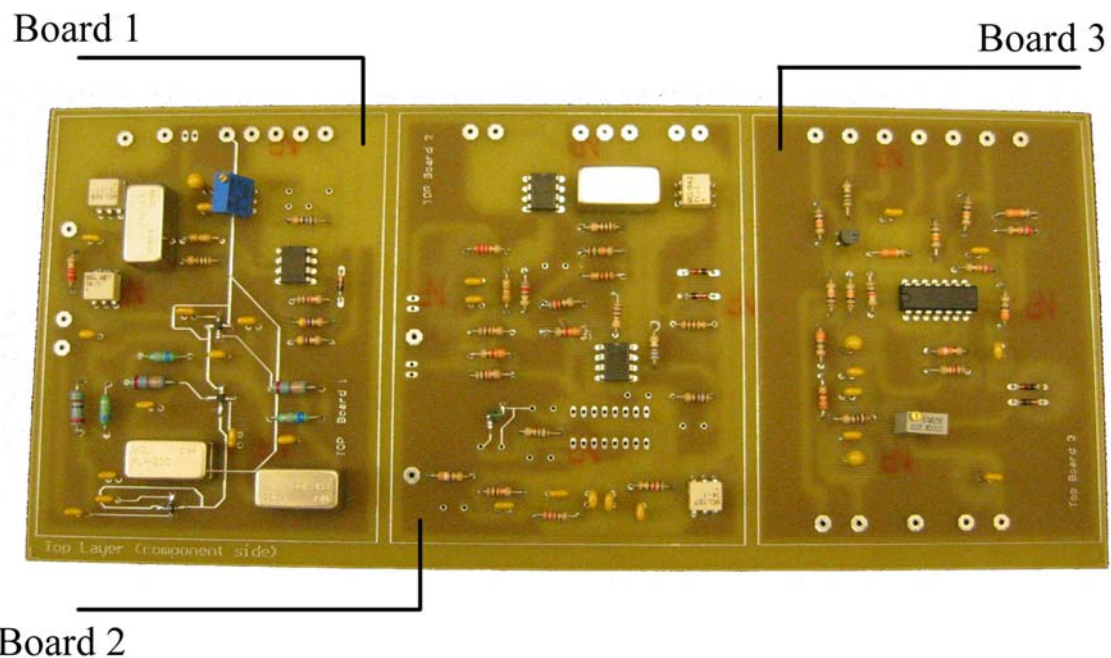


Figure 4: Assembled PCB

Once the design was complete, it was sent out for fabrication. Two identical boards were manufactured and shipped back to the University. All available components were then mounted.

4.1 Design of Subsystems

The following is a description of how the team designed each individual subsystem, how they are interconnected and what components were used in the design. The physical location of each subsystem is also discussed.

4.1.1 FSK Modulator

This FSK modulator, which sets up the signals to be modulated by the Gunnplexer system at a carrier frequency in the 10 GHz band, is designed using a Mini-Circuits PLP-21.4 low-pass filter, and a Burr-Brown OPA603 non-inverting current feedback amplifier. A Mini-Circuits T2-1 balun transformer is also used to better match the output of the low-pass filter to the AUI input. This circuit is located on Board 1 of our PCB and is connected to the varactor diode terminal input of the Gunnplexer through a 47Ω resistor [2].

4.1.2 Gunnplexer Assembly

The Gunnplexer assembly consists of a T4-1 Balun transformer, several resistors and capacitors chosen to meet the necessary specifications, and the Gunnplexer itself. Though currently, no Gunnplexer is connected to the circuitry, there are terminals on the circuit board ready to connect to the three diodes of a Gunnplexer. The Gunn diode terminal is connected directly to a terminal for bias voltage which is in parallel with a $4.7\mu\text{F}$ Tantalum capacitor and a $0.1\mu\text{F}$ ceramic capacitor. The Mixer diode terminal is connected to a T4-1 balun, which, on the other side, is directly connected to the IF strip input. The varactor diode terminal, as mentioned above connects directly to output of the FSK modulator circuitry. This entire circuit is located on board 1 [2].

4.1.3 IF Strip

The IF strip, which as we know, connects to the mixer diode input terminal after having been matched with a balun, works at an operating frequency of 145 MHz. The IF segment of the system has two jobs: filtering and amplification. The IF strip is the third subsystem that has been integrated into the design of Board 1 of the PCBs [2].

The filters used are a PHP-100 High Pass Filter and a PHP-200 Low Pass Filter and the amplifiers used are MMIC MAR-6. Two such amplifiers are needed in the IF strip. All components in the IF strip were used in compliance with the specifications set forth by John Miles [2].

4.1.4 FSK Demodulator

Once the received signal has passed through the IF strip, it can then be demodulated. The FSK demodulator is the subsystem that performs this task. The FSK demodulator was designed using a Mini-Circuits MAR-4 operational amplifier, a T4-1 balun and a Motorola MC13155 microchip and is located on Board 2 of the PCBs [2].

4.1.5 Output Buffer

The output buffer is connected to the output ports of the FSK demodulator on one end, and to the input of the AUI port on the other end. It is designed using four main components: two OPA603 amplifiers, a PLP-21.4 low-pass filter, and a T1-1 balun transformer. The output buffer is located on Board 2 in conjunction with the FSK demodulator [2].

4.1.6 The AFC Buffer

The AFC Buffer is designed using a National Instruments LM324 operation amplifier chip, which contains four identical op-amps, one of which is used to monitor the differential output of the FSK demodulator. Another op-amp on the same chip is used to connect to the tuning and fault meter. Though the AFC buffer is only necessary at one end of the system, both PCBs have AFC buffer circuits included on Board 3 [2].

4.1.7 The S-Meter Circuits

The S-meter buffer connects to the FSK demodulator at pin 12 of the MC-13155 chip. It uses one of the LM324 op-amps off the same chip as the AFC buffer. The output of the S-meter buffer connects, through the S-meter circuitry to a panel terminal. The panel terminal is meant to be connected to an S-meter display panel. Like the AFC buffer, only one S-meter circuit is required, but S-meter circuitry is located on Board 3 of both PCBs [2].

4.1.8 Tuning / Fault Meter

The tuning and fault meter connects to the AFC buffer and to a pair of terminals, across which a 0-100 μ A current meter shall be placed. The tuning meter is the last subsystem located on Board 3 of the PCBs [2].

4.2 Missing Elements

Despite last year's team having put much work into the design and implementation of the overall system, there are still many missing pieces and many aspects that have not been taken care of.

4.2.1 Missing Components

The PCBs are not complete. There are various resistors and capacitors that have yet to be added to the circuit. The MC-13155 too was never added to the circuit. The reason for this is because the chip did not arrive in time for last year's team's deadline to submit the final report [2].

4.2.2 Incomplete Gunnplexer Assembly

Though the Gunnplexer system was designed and analyzed on paper, last year's team did not ever actually set up the Gunnplexer module. That is to say, no Gunnplexer was ever connected to the appropriate terminals of "Board 1".

4.2.3 Meters and AUI ports

Thirdly, the tuning meters and S-meter displays have not been purchased, nor has anything been set up to interface with the tuning circuits. Also, no AUI ports were purchased or connected to the appropriate terminals of "Board 2".

As a result, of all this, the boards have actually never been tested and no information is available that may or may not suggest that they will function correctly.

4.3 Encountered Problems

4.3.1 Isolation of individual modules:

It was recommended by John Miles to have each subsystem in the overall design enclosed individually. Doing so minimizes potential RF interference each subsystem would have with every other subsystem. Unfortunately, as mentioned earlier, the PCBs were designed to have three large circuit blocks each with several subsystems integrated into them. Miles specifically points out that the IF strip and the FSK demodulator are pieces that should be isolated. However, in our design, the IF strip and the FSK modulator are integrated on the same section of board and cannot be separated. Similarly The FSK demodulator is attached to the output buffer, and it too cannot be separated. It is possible that the system will still function correctly regardless. However, it is equally possible that the system will not work as a result of interference.

4.3.2 Mismatch in Sizing of MC-13155 and PCB Socket

Since the final report was submitted last year, the MC-13155 microchips have arrived. However, there is a mismatch between the sizing of the chip and the sizing of the socket on the PCB where the chip is supposed to go. This mismatch can be resolved using an Aries Electronics 35000X SOIC to DIP adapter. However, using such an adapter may potentially lead to unwanted interference.

4.4 Clarification of Last Year's Final Report

Upon reviewing last year's team's final report, several things they had written about were unclear. In this section, such issues will be clarified.

4.4.1 Inconsistency in Bandwidth Calculations

In the final report, bandwidth is given as both 60 MHz and calculations are done using 40 MHz. The bandwidth of 60 MHz was calculated using Carson's Rule for FM bandwidth. However, the amplifier they are designing for is not in the modulated FM band, rather, it is in the demodulated Ethernet band, which is 40MHz. Ultimately, this does not really matter because the op-amps used have a BW of 160MHz. This is more than enough to accommodate the 40MHz that is coming off the MC13155.

4.4.2 Use of Tantalum Capacitors

Our design seems to take a liking to tantalum capacitors. It found that, for this application the electrolytic capacitors greater than 1 μF can be either aluminum or tantalum. As a general rule of thumb, for capacitances greater than or equal to 1 μF , tantalum capacitors will be used. The MC-13155 chip also seems to like tantalum bypass capacitors. It is most probably for this reason that certain tantalum capacitors were originally used.

4.4.3 Disregarding Resistors

On p. 27 of the final report, we see that a $220\ \Omega$ resistor was neglected in calculating the turn ratio of a balun. Doing this completely changes the values obtained. It is true that the $220\ \Omega$ appears in parallel with 450 ohms for a total of about 150 ohms. The 4:1 match to 50 ohms is just an approximation based on two things: what Motorola shows in Figure 16 of the MC-13155 data sheet and the fact that 4:1 is a more standard value for matching transformers than 3:1, which would be a more appropriate transformer to use.

4.4.4 Connection of AUI ports

For the application of our project we will have to connect two computers through the AUI connector. To do this you cannot use a patch cable, a cable that connects each pin to the same pin on the other end. A crossover cable must be used. In the case of our project, the crossover cable would only have to connect to 4 of the 15 pins as illustrated in the table below. The remaining pins are not needed, but Pins 1, 8, 11 and 14 may have to be bonded together in order for the network card to detect the presence of another card attached to it. Also it may be possible that the network cards that we will use may require a few milliamps of current be used from the +12V offered from pin 13. Since an AUI port has separate pins for transmit and receive, it has the potential for full duplex, although most applications will only use half-duplex. See **Appendix A** for more information on how AUI ports work [6].

4.4.5 The Role of the TCP/IP and MAC Protocol in Error Correction

For Ethernet connections, the protocol used is TCP/IP which accounts for certain error correction. The TCP/IP protocol will continue with the regular error finding that it supports. However because we are using an AUI connection, The requirement for precision error detecting will be done by the AUI. Also The Full

duplex feature, which TCP allows, will not be used because of the half-duplex nature of the signal received at the AUI port. As for the role the **Media Access Control** (MAC) protocol will have in this project, the initial scope John Miles set forth was to create a Wireless MAC Ethernet Link. However the scope of our project has been broadened to allow for any data communication, the MAC protocol will only be necessary if our transmitted signal is Address Resolution Protocol (ARP) from a host or Reverse Address Resolution Protocol from a guest (RARP). ARP, and RARP are two of the techniques that occur in the location and connection of 2 computers in a network environment under MAC protocol conditions

4.4.6 Current Op-Amp

Last year's final report makes reference to a current op-amp. An op-amp in general is a circuit element that performs certain signal processing applications. Usually, it is used to increase the amplitude of an input voltage using external voltage sources. However, a current op-amp does not exist. The correct terminology is current feedback op-amp. In contrast with conventional op-amps, the current feedback approach provides nearly constant bandwidth and settling time over a wide range of closed loop voltage gains. The current op-amp fore mentioned is simply a current feedback op-amp, which is a common active circuit component.

4.4.7 OSI Model

In the final report, something called OSI is mentioned as being the network model used in this project. OSI stands for **Open System Interconnect**. It is the standard model for networking protocols and distributed applications. This model was set forth by the International Standard Organization (ISO), and is commonly called ISO / OSI. The model consists seven network layers, where each layer carries information detailing how and where information is being transmitted throughout the network.

4.4.8 How Inductance Arises in a PCB

Parasitic inductors are formed across connections between layers of a PCB called vias. The value of the inductance is a function of the diameter of the via and the height, or spacing between layers. Combinations of vias that act like inductors in series will cause inductance to increase. There are also trace-to-trace inductors that come about because the traces on a PCB are not infinitely thin and nearby traces can cause inductive coupling.

5. TASKS AT HAND

This section outlines the work that must be done in order to get from where our system currently stands to a working product. The first step is, of course, to complete the circuit assembly. The next stage is the testing of all the individual subsystems. A complete description on how to test these systems is included. Beyond that, the remainder of the work will be to get the overall system to work for a square wave input, for an Ethernet input and to explore other possible applications of the system.

5.1 Completion of the Circuit Boards and Other Components

The first thing that must be done is the completion of the circuit boards started by last year's team. The most important addition to the PCBs is the mounting the 35000X adapter onto the circuit board and the mounting of the MC-13155 chip onto the adapter. All the missing capacitors and resistors must also be mounted on to the PCBs.

The S-Meter and the Tuning/Fault Meter also must be completed. The circuitry needed for these meters has been included on "Board 3". All that we must do is attach a digital 200 mV panel meter to the S-Meter output terminal and a 100 μ A analog current meter to its terminals to complete the tuning/fault meter system [1].

5.2 Testing the Operation of the Circuit Boards

5.2.1 Gunnplexer Frequency Calibration

The first thing that must be done to get the 10 GHz link to work is tuning the Gunnplexers. The Gunnplexers must be tuned to an appropriate frequency in the Armature Band and must be set so that the frequencies of the two units are in fact separated by 145 MHz. One thing that must be noted is that when the supply voltage for the Gunn Diode is too low, the diode will heat up and possibly get damaged.

Before connecting any supply voltage to the Gunnplexers, a bypass capacitor of at least $0.1\mu\text{F}$ must be connected between the two terminals of the Gunn diodes. Applying a +5V DC to the Gunnplexer varactor diode will establish the center IF frequency. To keep power supply noise out of the system, the +5V should pass through a $10\text{ K}\Omega$ resistor followed by a $0.1\mu\text{F}$ bypass capacitor. In order to accurately calculate the output frequency of the Gunnplexers, the output should pass into a microwave frequency counter. To adjust the operating frequency of the Gunnplexers we use its mechanical tuning screw. Turning the screw clockwise will decrease the transmission frequency while turning it counter-clockwise will increase the transmission frequency. The goal here is to set one Gunnplexer to any chosen frequency and set the other to a frequency 145 MHz higher or lower. In our case, we shall tune the lower of the two frequencies [1].

5.2.2 FSK Demodulator Calibration

In order for the MC13155 to operate in the appropriate frequency band, we must choose an appropriate capacitor, inductor and resistor for the LC quadrature tank circuit. John Miles specifies that he uses a home made inductor, a 22pF capacitor and a 180 ohm resistor. The inductor was made of #22 enameled

copper wire wound three times around a screwdriver shaft to make its shape. A 145 MHz sine wave as a source signal should be applied to the input of the MC13155. An oscilloscope should be attached to pins 4 and 5 of the MC13155 to monitor the differential voltage between these two pins. By stretching and compressing the coils of the inductor, we will change the differential voltage between the two pins. The goal here is to achieve a differential voltage of about 10 to 20 mV. Once this is achieved the tank circuit is properly tuned and ready to use with the demodulation circuit [1].

There is, theoretically, a more precise way to determine the requirements for the components of the tank circuit. By following the equations given in the MC13155 datasheet, we can obtain values for our components. To determine the necessary capacitance value, C , the documentation suggests using an external capacitance of at least 20 pF. Since 22 pF is the closest value available, this is what should be used. The MC13155 also has internal capacitance. This is in the order of about 3 pF which results in a total capacitance of 25 pF for the tank circuit. From this value, we can use equation (1) to calculate the needed inductance.

$$L = \frac{\left(\frac{1}{2\pi}\right)^2}{C_p f_c^2} \quad (1)$$

Where $C_p = 25$ pF and $f_c = IF = 145$ MHz. Plugging these numbers into Equation 1. results in an inductance of 48nH. The closest standard inductor is 50nH.

We also know that for the **Quadrature (Q)**:

$$Q = \frac{f_c}{BW} \quad (2)$$

We know that, in practice, the maximum bandwidth of any signal we will be using is 40 MHz.

Therefore:

$$Q = \frac{145\text{MHz}}{40\text{MHz}} = 3.6$$

The total resistance value of the tank circuit is given by [3]:

$$R_T = Q(2\pi f_c L) \quad (3)$$

$$R_T = 3.6(2\pi \times 145\text{MHz} \times 50\text{nH})$$

$$R_T = 164\Omega$$

Knowing the internal resistance of the MC13155 is 3200Ω we can determine the necessary resistor in our tank circuit using:

$$R_{ext} = \frac{R_{int} R_t}{R_{int} - R_T} \quad (4)$$

$$R_{ext} = \frac{3200\Omega * 164\Omega}{3200\Omega - 164\Omega}$$

$$R_{ext} = 173\Omega$$

The closest standard value to resistance to this resistance is 180 ohms.

5.2.3 FSK Modulator Deviation Adjustment

This step is not all that critical since all it determines is the gain of the OPA603 amplifier. To conduct this adjustment, a 550-ohm variable potentiometer is set to 220-ohms and is used to set a gain of roughly 3.5 times the magnitude of the input signal. At this point it is also a good idea to check and see if the amplified waveform is similar to that of the input waveform to ensure proper transmission [1].

5.2.4 Testing the IF Strip

To test the IF strip all we are looking for is the designed signal gain of 40 dB. To do this we apply a signal of known amplitude at a frequency of 145 MHz to the input of the IF strip and attach a spectrum analyzer to its output. On the analyzer we should be able to observe a 40 dB gain compared to that of the input signal [1].

5.2.5 Testing Transceivers in Loop-Back Mode

It is possible to test the individual transceivers in what is known as loop-back mode. Gunnplexers have a local echo characteristic, meaning the signal it sends out is also received by itself. We can use this property to test modulation and demodulation at the same time. We can simply apply an input 10MHz square wave or sine wave signal to the input terminal of the transceiver. The output terminal of the same transceiver should carry the same input signal. If this works for multiple input signals, then the circuit should be working properly [1].

5.3 Testing the Entire System

After testing the individual subsystems of our circuit we will now have to test the system as a whole. In other words, we must set up the system so that the two Gunnplexer transceivers can communicate with one another. We test this by connecting them to each other through an attenuated X-band waveguide. The goal here is to be able to have a seamless connection between the two units using the AUI interfaces as input and output terminals. We would like to be able to transmit a signal at one end of the microwave link and receive the identical signal at the other end of the link. This test must be performed in both directions to ensure correct operation. We first perform this test using a 10 MHz square wave as our input signal.

5.3.1 Ethernet Applications

Once we get the system working, we can then replace the square wave input with an Ethernet connection. For this setup, we will connect each of the units to a computer system with AUI compatible network cards. This test is going to be somewhat more involved, as there are factors that must be considered before manipulating Ethernet signals. Nevertheless, if the link is working, the computers should act as though they were connected directly to one another using the appropriate crossover network cable.

5.3.2 Design of Antennas

After we get the system working through a waveguide, we would like to actually get the system to be wireless. We will design and use horn antennas to do this. We will attach a horn antenna to each Gunnplexer and test the system for operations over short distances. Once we get the link to work at close range, we will move the two transceivers further apart to see what kind of range we can achieve with this system.

5.4 Other Possible Applications of 10 GHz Link

Upon successful completion of a wireless Ethernet network, we will want to explore other possible applications of this 10 GHz microwave system. A logical extension to such a system would be to attempt to transmit an audio signal over the link. If this is successful the next step after that would be to see if we can transmit a video signal over the link. The goal in being able to send audio or video signals over the link is to then be able to send both audio and video simultaneously.

Since, as mentioned earlier, our system only operates in half-duplex we would like to examine the possibility of converting it to full-duplex. This would allow us to create an Ethernet connection that would not have any collisions, and hence, better bandwidth. A major advantage of having a full-duplex system is that it would allow us to have a wireless control system or maybe even allow high bandwidth videoconferencing. Essentially, the possibilities are endless.

5.5 Summary and Breakdown of Tasks

5.5.1. Functionality of System

The goal in this task is to go from what the system we currently have to a fully operational communication link. It involves:

- a. Completion of all circuitry
- b. Testing the individual subsystems
- c. Testing the overall system

5.5.2. Application of System to Ethernet Network

This task consists of taking the functional microwave link and applying it to an Ethernet application. This task includes:

- a. Setup of functional computer network
- b. Setup of AUI interface
- c. Testing of network

5.5.3. Wireless Transmission

The goal in this task is to successfully transmit a signal across a wireless medium, and then improve the range of the system. Subtasks include:

- a. Wireless link setup
- b. Antenna Design
- c. System Testing

5.5.4. Further Experimentation

The last task should all else be working, is to put the finishing touches on the system and experiment with other possible system applications.

- a. System cosmetics
- b. Experimentation with audio and video signals across the link

The following is a proposed timeline for completion of these tasks, as well as a breakdown of who will be working on what.

6. PARTS REQUIRED

Part / Tool Description	Manufacturer	Model #	Quantity
25 k Ω Potentiometer		RV2	2
820 Ω Resistor	-	-	1
2 pF Capacitor	-	-	3
3 pF Capacitor	-	-	6
100 pF Capacitor	-	-	4
SOIC to Dip Adapter	Aires Electronics	16-350000-10	1
10GHz Gunnplexer	M/A-Com	MA87728-M01	2
Digital 200mV Voltmeter	???	???	1
Analog 100uA Ammeter	???	???	1
Power Supply	High Power	SFX-201M2	2
Voltage Regulator -12V	National Semiconductor	LM7912	1
Voltage Regulator -8V	National Semiconductor	LM7908	1
Voltage Regulator -5V	National Semiconductor	LM7905	1
Voltage Regulator +5V	National Semiconductor	LM7805	1
Voltage Regulator +8V	National Semiconductor	LM7808	1
Voltage Regulator +9V	National Semiconductor	LM7809	1
Voltage Regulator +12V	National Semiconductor	LM7812	1
Voltage Regulator Heat sinks	-	-	7
PC Board for Regulator Circuit	-	-	2
15 pin AUI connector port	-	-	2
Digital Multimeter			2
GHz range Frequency Counter			1
Spectrum Analyzer			1
Power Meter			1
10 MHz Waveform Generator			1
Oscilloscope, 100 MHz BW			1
Bench Power Supply			2
X-Band Waveguide			1
X-Band Horn Antenna			2

Table 2: List of Parts and Tools Required

7. CONCLUSION

To conclude this report, we can say that we are proceeding optimistically through this project. We feel very strongly that we will be able to successfully set up a working microwave link. We also understand that it is entirely possible that various factors may set us back in trying to implement this system. Nevertheless, we will take each challenge as it comes.

There is still much work to be done. We look forward to having much progress to report at the end of Phase 2.

8. REFERENCES

- [1] John Miles, "An Experimental 10-Mbits/s Microwave Data Link"
<http://www.qsl.net/ke5fx/uwave.html>
(current November, 2002)
- [2] Benoît Chapelotte, Dave M. Gunputhram and Damien Avril, *10-GHz Microwave Link*, Tech. Report ELEC 490, Electrical and Computer Engineering Dept., Concordia University, Montreal, 2002
- [3] Motorola, "MC13155 wideband FM IF subsystem IC"
<http://www.qsl.net/ke5fx/uwave/mc13155.pdf>
(current November, 2002)
- [4] B. P. Lathi, *Modern Digital and Analog Communication Systems*, Third Edition, Oxford University Press, 1998
- [5] David M. Pozar, *Microwave Engineering*, Second Edition, John Wiley and Sons Inc., New York, 1998
- [6] Cisco Systems, "AUI Technical Specifications"
http://www.cisco.com/univercd/cc/td/doc/product/lan/14201220/14_1220u/csspec.htm, (current November 2002)

APPENDIX A: HOW THE AUI CONNECTOR WORKS

The following tables detail the connection made to an AUI port, and the relevant ports to ensure proper transmission when connecting two PC Ethernet card together.

Pin	Label	Description
1	GND	Ground
2	CI+	Positive AUI differential collision-data input
3	TX+	Positive AUI differential transmit-data input
4	GND	Ground
5	RX+	Positive AUI differential receive-data output
6	GND	Ground
7	NC	
8	GND	Ground
9	CI-	Negative AUI differential collision data
10	TX-	Negative AUI differential transmit-data input
11	GND	Ground
12	RX-	Negative AUI differential receive-data output
13	+12V	12V supply for external MAU
14	GND	Ground
15	NC	

Table 3: AUI pin connections

PC A	PC B
Pin 3	Pin 5
Pin 5	Pin 3
Pin 10	Pin 12
Pin 12	Pin 10

Table 4: Connection Between Two PC Ethernet Cards