REAL TIME DATA ACQUISITION SYSTEM FOR HIGH ALTITUDE BALLOON LAUNCH AT ADLER PLANETERIUM-A FAR HORIZONS PROJECT

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Abstract – **High Altitude balloon launches are experimental projects undertaken by students, volunteers or amateur astronomers so as to engage in understanding of near space using mathematics science and technology. Most of the circuits for the onboard experimental setups are which hand crafted or off the shelf hence the projects have come to be termed as the " poor mans space program". Chicago's Adler Planetarium, the first planetarium in the United States of America , gives such an opportunity through the Far Horizons project , helping students and volunteers to work side by side with the planetariums' astronomy faculty .The requirement for Adler Far Horizons project is to design a wireless communication system to have real time data acquisition of the data collected by the experiments ,launched in many of its high altitude balloon launches . This paper gives a detailed report on the high level design requirements, link budget analysis, transceiver selection, antenna considerations and interfacing requirements of this wireless data communication system design.**

Index Terms— Ham Radio, IF Filter, J-pole Antenna Micro strip Patch Antenna ,Yagi-Uda Antenna, Parabolic Reflector Antenna

1. INTRODUCTION-FAR HORIZONS OFADLER PLANETERIUM

Far Horizons is a Backend Research Division of Chicago Adler Planetarium. Interns, high schools students and volunteers get hands on experience in designing, executing and testing live project. These projects include sending experimental payloads to the edge for space by using high altitude balloons. These balloons go as high as 100,000 feet an collects very informative data such pressure temperature as well as reading of photons in the upper atmosphere. The circuits for the experimental setups are hand crafted by the students and/or volunteers thus making this a highly informative experience.

The process of launching balloon from start to finish is as follows. Experimental Setups which are to be send with the payload are as explained , designed and tested in the Far Horizons lab .The tested setups are launched using a balloon into the upper atmosphere from a suitable location .The balloon used for these launches are filled with helium for liftoffs. These balloons reach altitudes of 100000 feet and are hence called **Near Space Projects**. The balloon is tracked throughout its flight using a GPS tracker that sends beacons every two minutes, with the exact latitude and longitude coordinates of the balloon.

Fig 1.1 Typical Launching of a High Altitude Balloon

Once the balloon bursts or the payload is released by cutting off the balloon from the payload is returned to earth with the help of a parachute. On touchdown, the payload with the experimental setups is retrieved and data collected.

2. DETAILED DESCRIPTION OF THE EXISITNG SYSTEM

What is Near Space: A high altitude balloon launch basically send the balloon with eh balloon to near space .Near space can be defined as area between airspace and outer space that lies 65000 feet to 325000 feet above sea level . This is area is still very much influence by the gravitational pull of the earth .The pressure here will be close to 1% of that on earth and the temperatures will be as low as -70 degree Celsius.

The diagram below shows the detailed diagram of the launch system is as shown below:

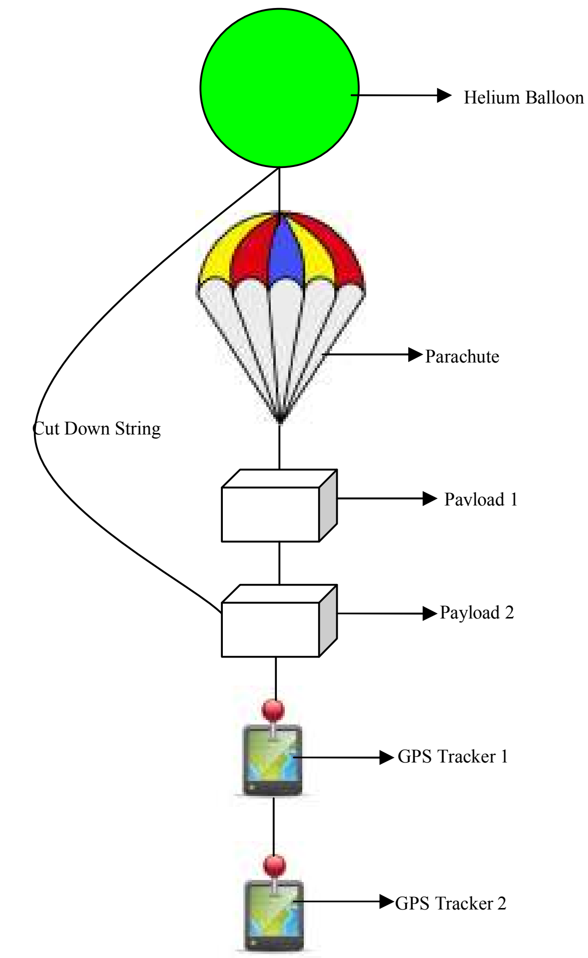

Fig 2.1 High Altitude Balloon Components

Balloon: The balloon is made highly flexible latex material and itself provides the lift that is required when it is filled with helium. The balloon can reach heights of up to 100,000 feet until it burst due to pressure differences.

Recovery System: The parachutes that are used for the recovery of the payload come with a loop seen at the apex to which the payload is attached**.**

Payloads: Payloads consists of experimental setups such as pressure sensor, temperature sensor, Geiger counter etc which is used to take measurements in the upper atmosphere. These retrieve highly valuable data. But this data is currently stored on to an EEPROM or a USB stick and can only been accessed once the payload is retrieved

GPS System: There are two GPS [Global Positioning System] trackers that are launched along with the payloads. These GPS trackers send APRS[Automatic Packet Reporting System] tracking data to Receiver which will be in a van which will be used to track the balloon. Currently this van according to the GPS data will chase the balloon throughout its flight to retrieve the payload as soon as it has landed. The GPS tracker system works in the two meter band which covers the 144.000 to 148.000 Mhz. Smart beaconing can also be enabled in this system for periodic operation and this is what is used by Far Horizons to receive the regular APRS data from the balloon once its launched. In addition to the APRS data the GPRS data also provides NMEA strings. These strings can be used to design a balloon release or cut down system based on distance or altitude The GPS system currently used by Adler is from Big Red BEE and is shown below.

Fig 2.2 GPS System Used By Far Horizons

Camera: A camera is also launched along with the experimental payloads with the high altitude system to take pictures or video of the scend as well as descend of the balloon. Video and photographs retrieved from this system is highly educational as well as very beautiful .The still cameras are timed to take pictures every five seconds.

Cut down System: Every high altitude balloon launch has an emergency cut down system to release the balloon. This cut down system is currently triggered based on time. When triggered the cut down system discharges a small electrical current which melts a nichrome wire. This wire is connected to a string which is attached to the balloon hence release the balloon when the string burns. The cut down system can also triggered based on distance or altitude.

Microcontrollers, A/D convertors and EEPROMS: Microcontrollers known as Basic Stamp II is used for all the programming purposes such as taking measurements from pressure sensor, temperature sensor as well as triggering the cut down system. The A/ D[Analogue to Digital] convertor is used to convert the analog pressure and temperature readings to digital data which is then stored in the EEPROM

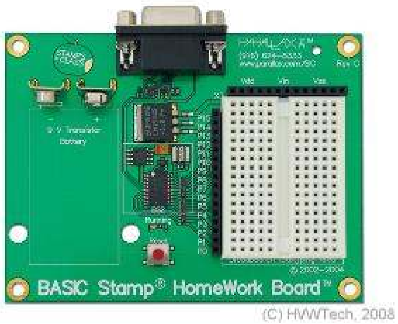

Fig 2.3 Basic Stamp II – MCU used in experimental Setups

Restrictions By FAA: The FAA [Federal Aviation Administration] Regulations state that the entire payload including the camera, experimental circuits and the parachute which is used for the descend once the balloon has released should not weigh more than 12 pounds.

Restrictions by FCC: According to the FCC [Federal Communication Commission] regulations, amateur balloon launches from high altitude can transmit not more than 19.2 kbps. Hence for the time being the proposed bandwidth is not more than 19.2 kbps. The idea is to transmit small amounts of data or snapshots from the onboard camera.

2.1. Requirements By Far Horizons

All the data collected by the payload and a lot he photographs taken by the camera are currently stored in EEPROMS,USB sticks and memory sticks .The data collected can only be retrieved when the payload have been recovered . The requirements of Far Horizon was to explore the possibility of a real time data acquisition system .The communication system design will be done in stages consisting of :

a). **Stage 1:** High Level Design of the Real Time Data Acquisition System including link budget analysis , frequency selection, transceiver option, suitable antenna.

b), **Stage 2**: Design of data collection and interface system to the communication system .

c)**). Stage 3**: Implementation of the downlink Communication System

d). **Stage 4:** Implementation of uplink communication system

This paper details the **Stage 1** of the project. This paper will also have a brief description into the calculations and interfacing requirements in **Stage 2.**

3. HIGH LEVEL DESIGN OF THE COMMUNICATION SYSTEM

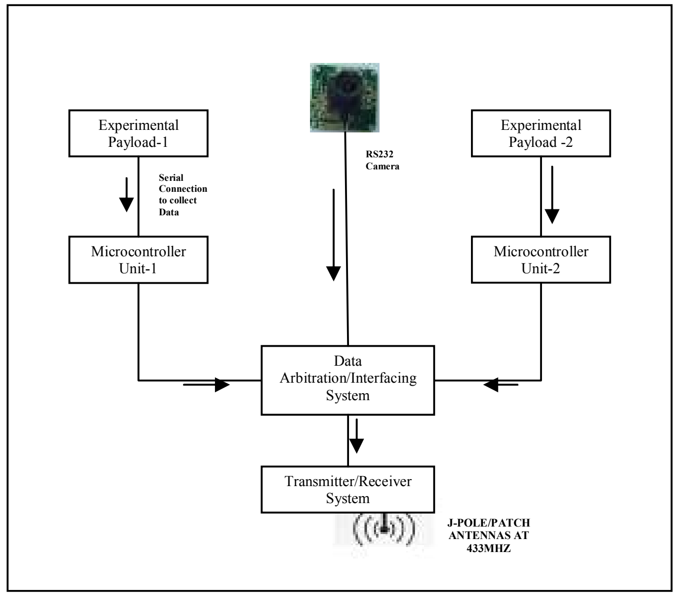

Fig 3.1Communication System Block Diagram – Balloon Station

A wireless live data acquisition system will make the data acquiring a real time process. This can also make control for some of the systems a lot easier like the cut down.

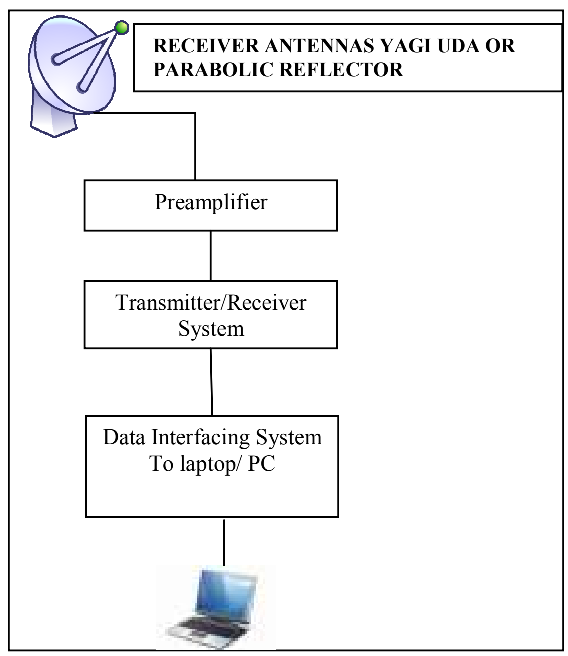

Fig 3.1 Communication System Block Diagram – Mobile/Ground Station

The proposed system is as follows:

1).The frequency considered for uplink and downlink is in the 70cm band range between 430 to 440 MHz. This is in the Amateur Radio Frequency Band and the operator will require a license to use the equipments transmitting an receiving in this frequency

2). There will be a 2 /MHz difference between the uplink and the downlink

3). The proposed modulation for this system is FSK [frequency shift keying].

4). The data will be connected on to a EEPROM using a suitable MCU[Micro Controller Unit] that will programmed to be capable of arbitrating data from various experimental setup as well as from an onboard camera .

5). This will be a line of sight communication system with a vertical distance of about 100000 feet and max horizontal distance of not less than 5 miles but not more than 20 miles at a time .This horizontal distance is so less because the receiving system will be currently mobile van chasing the balloon . The maximum of 20 miles occurs when the ball0on has already been launched, and due to the time taken by the team to pack the equipments and board the chase van .

4. FREQUENCY SELECTION

Two Frequency bands were considered when selecting the appropriate frequency for this project.

ISM Frequency Bands: The ISM [Industrial, Scientific or Medical] band also known as the unlicensed band as most of the users in the frequency band must be tolerant of other frequencies which might cause interference from other ISM equipments. .WDCT is one of the well known examples of applications and equipments using ISM band in the 2.4GHz range. According to the ITU [International Telecommunication Union] - R these bands include:

Frequency Range (HZ)	Center Frequency(Hz)	Availability
6.765 – 6.795 MHz	6.78 MHz	Subject to local Acceptance
13.553 - 13.567 MHz	13.560 MHz	
26.957 - 27.283 MHz	27.120 MHz	
40.66 - 40.70 MHz	40.68 MHz	
433.05 -434.79 MHz	433.92MHz	Region1 only and subject to local acceptance
902 - 928 MHz	915 MHz	Region 2 only
2.400 - 2.500 GHz	2.450 GHz	
5.725 - 5.875 GHz	5.800 GHz	
24 -24.25 GHz	24.125 GHz	
61-61.5 GHz	61.25 GHz	Subject to local Acceptance
122 -123 GHz	122.5 GHz	Subject to local Acceptance
244 -246 GHz	245 GHz	Subject to local Acceptance

Table 4.1 ISM Bands [10]

HAM Radio Frequency Bands: Used by amateur radio enthusiasts for recreation, experimentation, training and communication in case of emergencies. To use any of the frequencies allocated for this band a special license is required by the user. To acquire this license a test is taken by the Ham radio specialists. Amateur Radio Frequency bands are allocated ITU .ITU sets aside a part of every spectrum for Ham radios .ITU also regulates the technical and operational characteristics in HAM radio bands. This is done by dividing the world into regions .Each Region ahs its own allocated set of frequencies in for HAM radio specialists' .United Stated of America lies in ITU regions 2 and the table for the allocation of these license are shown below:

ITU band	Band name	Frequencies (MHz)	
		Lower end	Upper end
5 – LF	2200 meters	135.7 kHz	137.8 kHz
6 – MF	160 meters	1.8	2
7 – HF	80 meters	3.5	4
	60 meters	Channelized - 5.332, 5.348, 5.368, 5.373, 5.405 (USB only)	
	40 meters	7	7.3
	30 meters	10.1	10.15
	20 meters	14	14.35
	17 meters	18.068	18.168
	15 meters	21	21.45
	12 meters	24.89	24.99
	10 meters	28	29.7
8 – VHF	6 meters	50	54
	2 meters	144	148
	1.25 meters	219	220
		222	225
9 – UHF	70 centimeters	420	450
	33 centimeters	902	928
	23 centimeters	1240	1300
	13 centimeters	2300	2310
		2390	2450

	9 centimeters	3300	3500
	5 centimeters	5650	5925
	3 centimeters	10000	10500
10 – SHF	1.2 centimeters	24000	24250
	6 millimeters	47000	47200
	4 millimeters	75500	81000
	2.5 millimeters	119980	120020
	2 millimeters	142000	149000
11 – EHF	1 millimeter	241000	250000

Table 4.2 ITU Region2 HAM Frequency Bands [11]

433MHz used for this project lies in the 70 cm UHF frequency band of the Amateur Radio allocated for the ITU Region 2.

Choice of 70cm Frequency Band: The frequency allocation in the 70 cm radio band for Ham radio lies from 420MHz to 450MHz .70 cm band propagation characteristics that works to its advantage include penetration through buildings, low noise floor and good tolerance to natural and artificial interference .70 cm band is the lowest frequency and in which ionospheric reflection is observed .It is greatly helped by reflections from buildings, airplanes etc.. Topospheric refraction also helps to extend the range of the signal of this frequency.

5. LINK BUDGET ANALYSIS

Link budget calculation is primary analysis required while designing the wireless system Analysis helps to determine the feasibility of the entire system .It also give a heads up on the tradeoffs required to obtain the a complete working system as per the given cost budget and the requirements of the customers .Suitable data rate , effects of range and the modulation methods as well as how they will effect the system can also be determined by this simple calculation .The factors that will come into consideration while determining the link budget will be permitted output power, output power of the transmitter ,antenna gains, free space loss, fading if any, receiver sensitivity , signal to noise ratio, environmental conditions etc .The link budget formula is given below :

Received Power (dBm) = Transmitted Power (dBm) + Gains (dB) − Losses (dB)

Formula 5.1 Link Budget Formula

For the High Altitude balloon communication system the following parameter were considered for the link budget analysis:

1). Transmitter Output Power
2).Gain of the Transmitter Antenna
3).Free space Loss
4). Gain of the Receiver Antenna
4). Receiver Sensitivity

This basically gives the relationship between the output power of the transmitter and the power of the signal at the receiving antennas. This being a line of sight radio system the most prominent loss to expect for this communication will be the FSPL [Free Space Path Loss] .

FSPL is proportional to the square of the distance between the transmitter and the receiver and also proportional to the square of the frequency of the radio signal. In the case of the balloon communication the distance considered will be the slant distance as shown in the figures below. This is called the slant distance calculated using Pythagoras theorem and has been used for calculating FSPL.

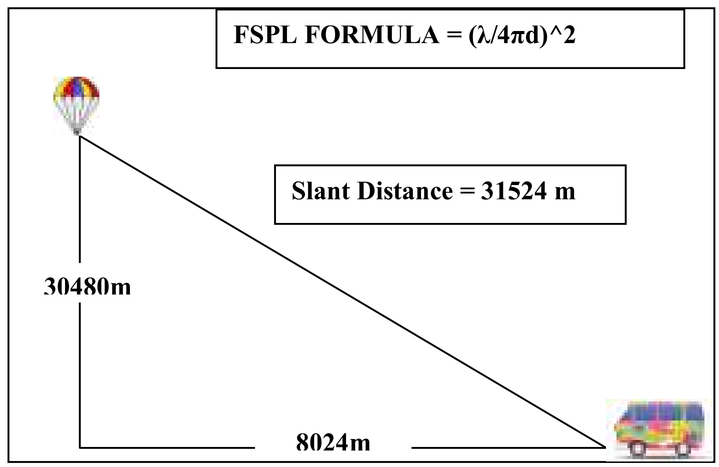

Fig 5.1 Distance Calculation for FSPL

Large number transceivers were considered in the range of 433MHZ to use for this project which had power levels in the range in 10mW.The link budget calculations have been given in the Appendix [1] of the report for reference. From the link budget analysis shown in Appendix [1] it can be observed that there will be a requirement of an amplifier at the transmitter side to boost the signal before sending it. But FAA regulations clearly states that the payload(s) should not exceed more than 12 pounds for a balloon launch. In order to solve this problem it was decided to add a preamplifier at the receiver the link budget analysis after addition of the preamplifier Appendix[2] .Please Refer **Appendix [1]** and **Appendix [2]** for link budget analysis and clarification on requirements of preamplifier

6. TRANSCEIVER SPECIFICATIONS

The transceiver chosen for the communication system come from a large range of TI [Texas Instruments] sub 1GHz transmitters. This transceiver generally used for ISM and SRD (Short Range Distance) applications also has the 433 MHZ ham band frequency that has been chosen for this project .The transmitter which allows this range is the CC1101 from TI. The transmitter pair also comes with the development kit and is known as the CC1101DK433 :

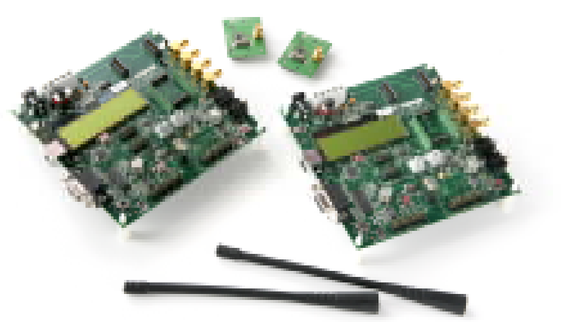

Fig 6.1 CC1101DK433-Development Kit

The advantages of CC1101 transmitter over its predecessors are as follows as quoted from the user manual are as follows:

• Improved spurious response

• Better close-in phase noise thus improved Adjacent Channel Power (ACP) performance

• Higher input saturation level

• Improved output power ramping

• Extended frequency bands of operation in the case of CC1101 387-464MHz and 779 – 928MHz

The transceiver comes with a built in baseband modem which supports various kinds modulation basically in FSK ,The transmitter FIFO[First In First Out] and 64 byte transmitter/ receiver pair can be controlled using an SPI interface . The circuit n diagram of the CC1101 with a few external components is as shown below. The CC1101 can also be used in conjunction with a MCU such as a basic stamp II, Arduino or PIC32 for data input and arbitration between various.

Performance Features of CC1101 Transceiver:

The RF performance features of the TI CC1101 are as follows:

- -116dbm with a 1% error rate at 0.6kBaud at 433 MHz
- Programmable output power at +12dbm
- Programmable data rate up to 0.6 to 600kbaud
- The digital channel filter bandwidth ranges from 58 to 812 KHz
- Low Power consumption

The Integrated modulator Features are:

- Supports 2-FSK, 4-FSK, GFSK, and MSK
- AFC can be used to align the frequency synthesizer to the received signal centre frequency
- Integrated analog temperature sensor

Low Power Consumption Features:

- 200nA sleep mode feature; while 200 microseconds from sleep mode to RX or TX operations as required
- Separate 64 byte RX/TX data FIFO
- The operating temperature of the transceiver lies between -40 to 85 degree Celsius

At 433MHZ the data transfer characteristics is as given below:

- **0.6 k Baud data rate,** Receiver sensitivity -116 dbm
- **1.2 k Baud data rate,** Receiver Sensitivity -112dbM
- **38.4 k Baud data rate,** Receiver Sensitivity -104dbm
- **250 k Baud data rate,** Receiver sensitivity -95 dbm

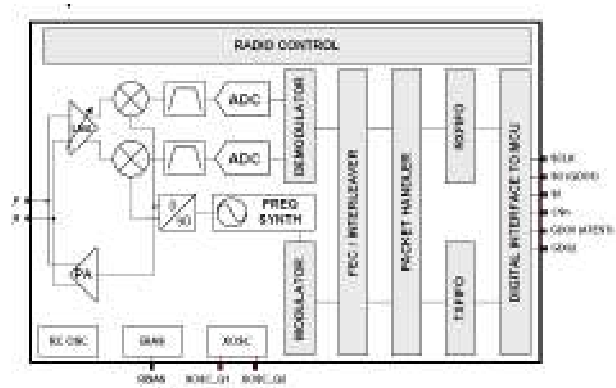

Fig 6.2 Block Diagram of CC1101

Working Characteristics of CC1101:

As shown in the block diagram above ,CC1101 has a low IF[Intermediate Frequency]-receiver .The signal received from he preamplifier will be amplified by the LNA[Low Noise Amplifier] and down converted to IF to be used by the IF receiver of CC1101.AGC, filter channelling and demodulation / synchronization of bits are all digitally performed by CC1101.

In the transmitter part the frequency is directly synchronised by the frequency synthesizer. The reference frequency of the synthesizer is obtained from the crystal oscillator .The digital baseband includes support for channel configuration, packet handling and data buffering.

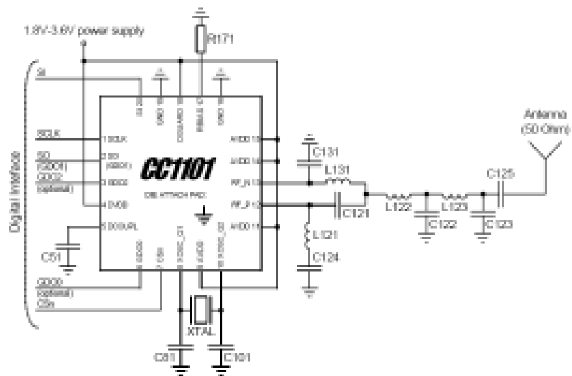

Fig 6.3 Application Circuit of 433MHzCC1101

Receiver Sensitivity, Bandwidth and Baud rates:

When looking at the link budget analysis in the parameter of the receiver is given as follows.

Receiver Characteristic: 0.6kbaud data rate, GFSK, 14.3 KHz deviation, 58 KHz digital filter bandwidth

These parameters say that the bandwidth of the digital filter used to transmit the 0.6 kbaud is about 58 kHz. That is a very large bandwidth transfer such small amount of data and will reduce the SNR of the receiver. But the deviation of the central frequency is given as 14.3 KHz. This states that the central frequency fluctuates between 14.3 KHz and -14.3KHZ .This means that receiver sensitivity fluctuates between these frequencies at 58 KHz bandwidth. It's due to this deviation that the bandwidth used to transfer such a small amount of data is about 58 KHz

7. ANTENNA CONSIDERATIONS

A communication is not complete with out an antenna system, which converts electrical signal to RF electromagnetic waves at the transmitter end propagates through free space. At the receiver end it converts these RF signal to electrical signals. Considering the fact that the balloon position and direction cannot be predicted the use of a directional antenna will not serve the purpose at the balloon .An Omni directional antenna with an ground plane will be appropriate for the high altitude balloon .Ground plane is an electrically conductive surface that allow an antenna to function properly .But the receiver antenna can be highly directive antenna like a yagi antenna or a parabolic reflector type antenna ,which will point to the approximate direction of the balloon .The factors of the antenna that has to be considered is radiation pattern, polarization and impedance matching ,

Two types of antennas have been considered which will be mounted on the balloon:

1).J-pole antenna
2).Patch antenna

J-pole Antenna:

A J-pole antenna is the first antenna to be considered for this project because of its almost Omni-directional radiation pattern and integrated ground plane This antennas were invented by the Germans for use with light weight air balloons and is currently very popular with amateur radio operators .This antenna is very simple to construct .There are a number advantages over the usual normal vertical antennas. Another attributes of this antenna that are very important are that this antenna does not require radials and also provides more gain than normal antennas over a quarter wave vertical .This antenna is ideally suited for VHF and above .

J-pole antenna is normally end fed .The J-pole antenna is end fed using a quarter wave stub of open wire or 300 ohm balance feeder to match the impedance of a normal 50 ohm coaxial cable which will be connected to the transmitting device. The polarization of this antenna is vertical .For a 433MHZ J-pole antenna the dimensions will be:

The J-pole antenna consists the parts show below and along with it are the dimensions of a 433MHz J-pole antenna

A -a long radiating element -19.54 inches
B- a short stub element – 6.48 inches
C- Distance to feed connections – 0.64 inches
D- Distance between elements – 0.61 inches

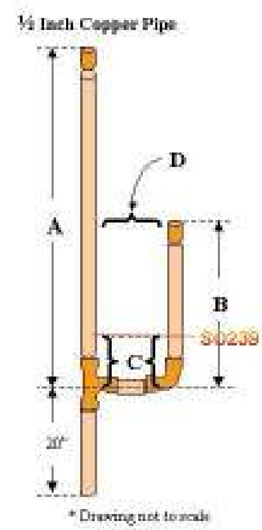

Fig 7.1 Dimensions of 433MHz J-pole antenna

The radiation pattern of the J-pole antenna is as shown below.

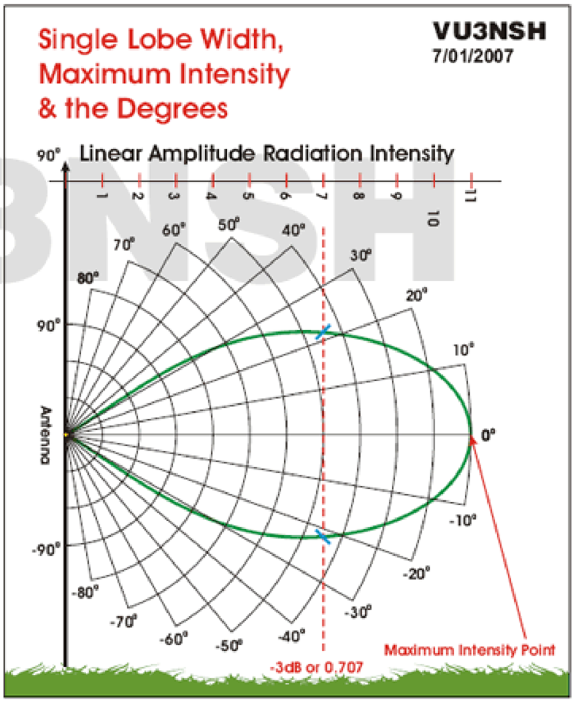

Fig 7.2 Radiation Pattern of J-pole Antenna

This antenna gives an approximate gain between 2.5 to 3 dBi.

The disadvantages of this antenna can be noticed from tis radiation pattern. Even if this antenna is Omni-directional this antenna has a vertical polarization. This makes null right below the antenna. At the time of ascend the transmitter waves will not be propagated properly because of its null directly below it. Another disadvantage is that even at 3db gain the angle of orientation of this antenna will only transmit the signal at an angle of 25 degrees would only be useful if the transmitter is at a farther distance from the receiver.

Patch Antenna:

Due to some of the above mentioned disadvantages of j-pole antennas, one more antenna is being considered for communication from the balloon. This is the patch antenna.

This is a very low profile antenna but with many advantages such as it is light weight inexpensive and very easy to integrate .This antenna like the j-pole also has an integrated ground plane. Another advantage of this antenna over the j-pole antenna is that it can be vertically or horizontally mounted .This is because the polarization is not effected like that of a j-pole antenna when it is horizontally mounted.

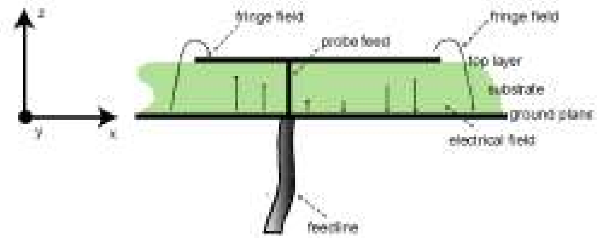

Fig 7.3 Parts of Micro strip Patch Antenna

The drawing shown above gives brief description of the architecture of the patch antenna. Simply put its flat plate over a ground plane which is usually a PC Board .The centre conductor of the coax serve as the feed of the antenna. This couples the electromagnetic energy in and out of the patch .The electromagnetic filed is zero at the centre of the patch, maximum and minimum on either side.

Since the patch antenna can be mounted because the polarization of it can be mounted horizontally at the bottom of the balloon hence helping to better signal to ratio at 3db gain. The radiation pattern of the patch antenna is as shown below is much better than that of the j-pole. In a horizontal mount the radiation pattern will have no null directly below and also when the balloon in flight, it has an angular width of 69 degrees at a 3db gain.

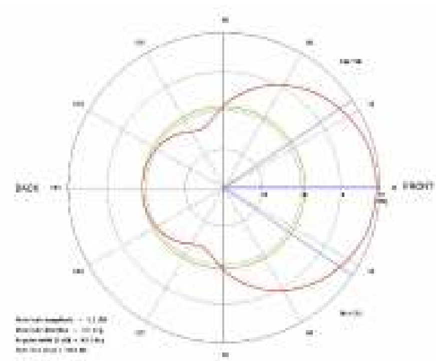

Fig 7.4 Radiation Pattern of Micro-strip Patch Antenna

Receiver Antennas:

As explained before the antenna at the receiver side should be a good directive antenna. A directive antenna can be used to pick up weak RF signals by pointing it to the approximate location of the balloon which can be easily determined by the on board GPS system. The two antennas under consideration for the receiver mobile or base station is the Yagi - Uda antenna and the parabolic reflector type antenna. More investigation on the most suitable type, impedance matching between the transmitter and the receiver antennas etc are required for complete fool proof design of the communication system.

8. BRIEF INTRODUCTION AND CHALLENGES ON INTERFACING THE COMMUNICATION SYSTEM- STAGE 2

As explained earlier the paper, the project is divided into stages and above gives a detailed explanation of the Stage 1 – proposal and design of the Communication System. The second stage of the project is interfacing this communication system with the already existing experimental setups and the camera.

Camera Interfacing System:

A brief calculation of the bit rate, data transfer rate, buffering requirements were performed assuming the communication of transferring only still images from an RS232 camera. Below shown is a brief block diagram of the Camera Interfacing System:

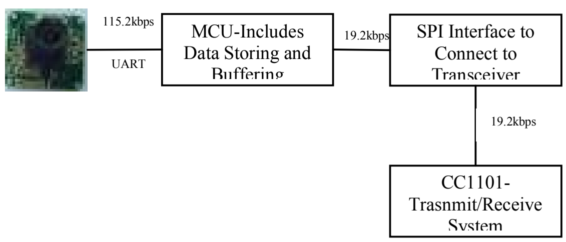

Fig 8.1 Assumed Block Diagram for Camera Interfacing

The formatting of the images taken by the camera was assumed to be 640 x 480 with a 40% compression. This compression and images size was assumed so that images will be comparatively good quality. Currently, the camera on board the high altitude balloon is set to take images every 5 seconds. The images will be transferred from the camera to a MCU using a UART [Universal Asynchronous Transmitter Receiver]. From the camera specification, the camera can transfer a single image at 115.2kbps to the MCU. MCU will be used to store these images. At this compression the entire images will be about 23Kbytes which is about 184kbits per image.

As per the FCC regulations, an amateur wireless system cannot transfer at more than 19.2 kbps. Thus the image cannot be transferred in one go between the transmitter and the receiver station even the transceiver is capable of high data rates at the expense of receiver sensitivity. There will have to be buffering mechanism either at the MCU or at the transceiver. Assuming that the MCU is programmed to buffer and send the images at 19.2 kbps per second.MCU will send these images via an SPI interface to the transceiver. The transceiver will modulate these images and send it to the receiver at 19.2 kbps per second. So the entire images of 186kbits will take about 9 – 11 seconds for the image to be displayed on a screen on the receiver .This is will be a very high latency for a camera that is set to shoot pictures at every 5 seconds.

Challenges likely during Interfacing:

1). Very few off the shelf systems available for interfacing
2). Camera will not the be the only data that will be transmitted to the receiver .Data form the experimental setup should also be transmitted along with the images
3).A data arbitrating system would be designed inoterd to collect the data alternating format various setups and the camera and transferred to the MCU.
4). MCU, on the whole should be designed or available off the sheld that will be able to store the data. At the same time this MCU should be programmed to buffer the data so as tot transfer at 19.2 kbps per second.
5).At the receiver side, there should be yet another buffering mechanism to store the data and the bits of images that have already received, to wait for the rest of the bits before displaying the data or the image.
6).Another challenge will be to reduce the latency between the images that are clicked and the images that will be displayed, either by increasing the compression or by increasing the data rate of the transceiver.

9. CONCLUSION

Stage 1 of the project for real time data acquisition of system for Far Horizons is currently under test. These are test are conducted using the CC1101 transceiver and the development kit in order to check the range of the system and the distance that can be covered with out loss of coverage ,without an amplifier. Line of sight is extremely important to achieve good data transmission which is easily achievable. **Stage 2**, of which a brief introduction has been given in **Section 8,** will be the most challenging part of the project.

Implementing **Stage 1** of this project has covered all parts on how to propose design a full fledged wireless system. It gave hands on approach to practically applying all concepts of a wireless communication system design. The most challenging part was choosing a suitable transceiver system with the frequency that is least effected by interference at the same time will able to transfer data through approximately 40000 meters. The link budget analysis was used to determine the efficiency of using a 433MHz transceiver over this distance under free space loss. Another constraint which is also a challenge. is the fact that FSS allows only 12 pounds for the entire payload. Hence it was important add a preamplifier to the Receiver system instead of an amplifier to the transmitter system at the balloon. Last but not the least the antennas for this project are yet to be chosen after testing the j-pole and the patch antennas.

10. References

[1]http://www.zetatalk.com/nonproft/radio/propagation.htm

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APPENDIX-1 –LINK BUDGET ANALYSIS WITH OUT PREAMPLIFIER

Receiver Characteristic: 0.6kbaud data rate,GFSK,14.3KHz deviation,58Khz digital filter bandwidth				
Receiver Antenna Gain (Gr) (approx)	0		0	
Preamplifier Gain	0		0	
Receiver Noise Figure(Assumed)	10		10	
Receiver Sensitivity at 58Hz			-116	
Signal to Noise Ratio(Assumed)			23	
Required Signal Power			-83	
Transmitter Frequency (MHz)	433	1000000	433000000	
Speed of light	3	100000000	300000000	
Wavelength (meter)			0.692840647	
Wavelength (db))			-1.593666416	
Distance (On the Ground)(m)	8046.72		8046.72	
Distance (Altitude of the Balloon)(m)	30480		30480	
Slant Distance (m)			31524.27799	
4*pi*d			395944.9315	
Free Space Path Loss			-113.5463622	
Transmitter Antenna Gain	0		0	
Transmitter EIRP			30.54636218	
Transmitter Power Required			30	Dbm
This is the power provided by the transmitter/This link budget is calculated with out Antenna Gain				

APPENDIX-2–LINK BUDGET ANALYSIS WITH 18dB PREAMPLIFIER

Receiver Characteristic: 0.6kbaud data rate,GFSK,14.3KHz deviation,58Khz digital filter bandwidth				
Receiver Antenna Gain (Gr) (approx)	0		0	
Preamplifier Gain	18		18	
Receiver Noise Figure(Assumed)	10		10	
Receiver Sensitivity at 58Hz			-116	
Signal to Noise Ratio(Assumed)			23	
Required Signal Power			-101	
Transmitter Frequency (MHz)	433	1000000	433000000	
Speed of light	3	100000000	300000000	
Wavelength (meter)			0.692840647	
Wavelength (db))			-1.593666416	
Distance (On the Ground)(m)	8046.72		8046.72	
Distance (Altitude of the Balloon)(m)	30480		30480	
Slant Distance (m)			31524.27799	
4*pi*d			395944.9315	
Free Space Path Loss			-113.5463622	
Transmitter Antenna Gain	0		0	
Transmitter EIRP			12.54636218	
Transmitter Power Required			12	Dbm
This is the power provided by the transmitter/This link budget is calculated with out Antenna Gain				

APPENDIX-3–QUICK START GUIDE FOR CC1101DK433 [13]

Texas Instruments

SWRU126B
April 2010

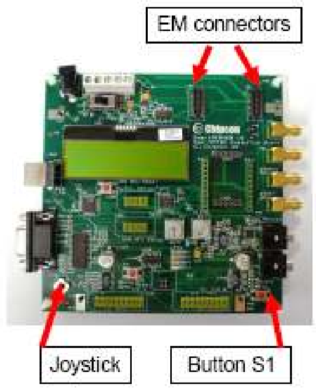
CC1101DK Quick Start Guide

Opening the box and running the Packet Error Rate Test

1. Kit Contents

2 x SmartRF04EB
2 x CC1101EM
2 x Antennas (433 MHz antennas shown)
2 x USB cables
4 x SMA male to BNC female converters
Documentation

2. SmartRF04EB Overview

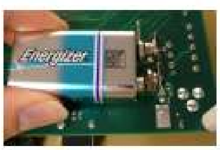


3. Plug EM into SmartRF04EB

Insert a CC1101EM (EM) with an antenna into the SmartRF04EB (EB). The connectors will only fit in one position, so that the EM cannot be inserted the wrong way.

Handle the EM with care. Observe precautions for handling electrostatic sensitive devices.

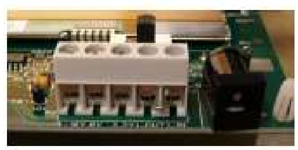
4a. Power: Battery



There are three different ways of applying power to the EB:

The first method involves using a battery, for instance a 9V battery (not included in the kit) connected to the connector on the bottom side of the board.

4b. Power: DC/External



The second method applies DC power using the DC input jack (right in picture, centre is +, sleeve is ground), or by connecting a 4-10V voltage source between the 4-10V and 0V terminals of the power connector (left in picture). It is also possible to connect a 3.3V voltage source between the 3.3V and 0V terminals. The on-board voltage regulators will be bypassed if the 3.3V input terminal is used.

4c. Power: USB

The EB can also be powered from the USB bus.

Note that if multiple power sources are connected, the source with the highest voltage will power the EB. This means that you should disconnect any attached battery when using a lab supply or USB power; otherwise the battery will be drained.

5. Set Power Switch

If a 3.3V source is used as described in 4b above, the switch should be set to the leftmost position. For all other cases, the switch should be set to the rightmost position. This switch can be used to turn off the EB by switching it to the opposite position of that used to turn it on.

6. Packet Error Rate Test

When power is applied to the board, the PER test program will start. You should see the text shown above on the LCD display on both evaluation boards.

Press the button marked S1 (lower right corner) to continue.

7. Set Frequency Band

Select the desired frequency band of operation by using the joystick. The frequency should match the evaluation module and antenna you are using.

Note that the value shown in the display is also the selected value. There is no need to press a button to select or activate the selection.

SWRU126B
April 2010

8. Set Network ID

Push the joystick down to display the screen shown above. This lets you set the ID of the node in case you need to run several PER tests simultaneously and you have multiple development kits. Leave this set to 1 for now.

9. Packet Length

Push the joystick down to display the screen shown above. This lets you set the length of the packets to be transmitted. The packet length will affect the measured packet error rate. Push the joystick left or right to select the packet length you want to use.

10. number of Packets

Push the joystick down to display the screen shown above. This lets you set the number of packets to be transmitted. Set this to the desired value using the joystick.

11. Select RF Settings

Push the joystick down to display the screen shown above. This lets you select preset RF configurations, including modulation and data rate
Preset 0: GFSK, 1.2 kBaud
Preset 1: GFSK, 10 kBaud
Preset 2: GFSK, 38.4 kBaud
Preset 3: GFSK, 250 kBaud

12. Select Mode

Push the joystick down to display the screen shown above. Use the joystick to select master mode. The EB you have configured now will be the master in the PER test.

13. Configure 2nd EB

Perform steps 3 through 11 on the second EB. Push the joystick down until you get the display shown above. Leave this EB in slave mode.

14. Start PER

Push the joystick down on both EBs, and the screen shown above is displayed. Push the joystick right on the slave EB first, and then push the joystick right on the master EB. The PER test will start when the two nodes have successfully connected.

Note that the PER test uses 10 dBm as default output power, so the EBs should be placed at least 1m apart to avoid saturation of the receiver.

15. Run PER Test

The uppermost line of the LCD will show the PER for packets transmitted from the slave to the master, while the second line will show the PER for packets transmitted from the master to the slave.

The PER test will end when the number of packets you selected in step 10 is reached or if 100 consecutive packets are lost.

16. References

Please visit www.ti.com and

http://focus.ti.com/docs/toolsw/folders/print/cc1101dk433.html

http://focus.ti.com/docs/toolsw/folders/print/cc1101dk868-915.html

Download the CC1101DK User Manual, the SmartRF™ Studio software, examples, as well as datasheets, reference designs and application notes.

You will also find a lot of information on the TI E2E forum at http://e2e.ti.com

We hope that you will enjoy working with the CC1101 device.

SmartRF™ Studio

1. Download and Install

Before connecting the EB to your PC, download SmartRF™ Studio from www.ti.com/smartrfstudio. Install the program and follow the instructions in the wizard.

Connect the EB with a CC1101EM to the PC using the USB cable and install the USB driver as described in the manual.

2. Launch SmartRF Studio

Launch SmartRF Studio and double click on the highlighted CC1101 device icon to get complete control of the device from the PC.

3. Configure the Radio

You can now configure the radio, run tests, export register settings and run link tests with another CC1101 on a SmartRF04EB connected to the PC.