

# **Deployment of Dual Band Unmanned Aerial Vehicles (UAVs)**

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## **DEDICATION**

**This thesis is dedicated to our beloved parents and teachers.**

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## **Abstract**

Unmanned Aerial Vehicles (UAVs) have tremendous applications such as agriculture, commercial, scientific activities, policing, recreation, servile, delivering goods, photogrammetry etc. But there are many challenges to operating UAVs for variation of weather. When used it vastly, there is a challenge of management of UAVs because of limited bandwidth. In this case, we have proposed a dual band UAV i.e mm wave and microwave. Generally, the bandwidth is more in mm waves than microwave frequency band. So, we surely communicate in mm wave frequency bands. But the Signal-to-Interference-Noise-Ratio(SINR) value is less at high frequency. The UAVs communication is poor at frequency more than 54 GHz where the Signal-to-Interference-Noise-Ratio(SINR) value is less than the average threshold SINR value about -75.97 dB. Then we will switch to the microwave frequency band. The Channel switching mainly depends on the respective bandwidth. Generally, UAV uses 2.4 GHz bandwidth.

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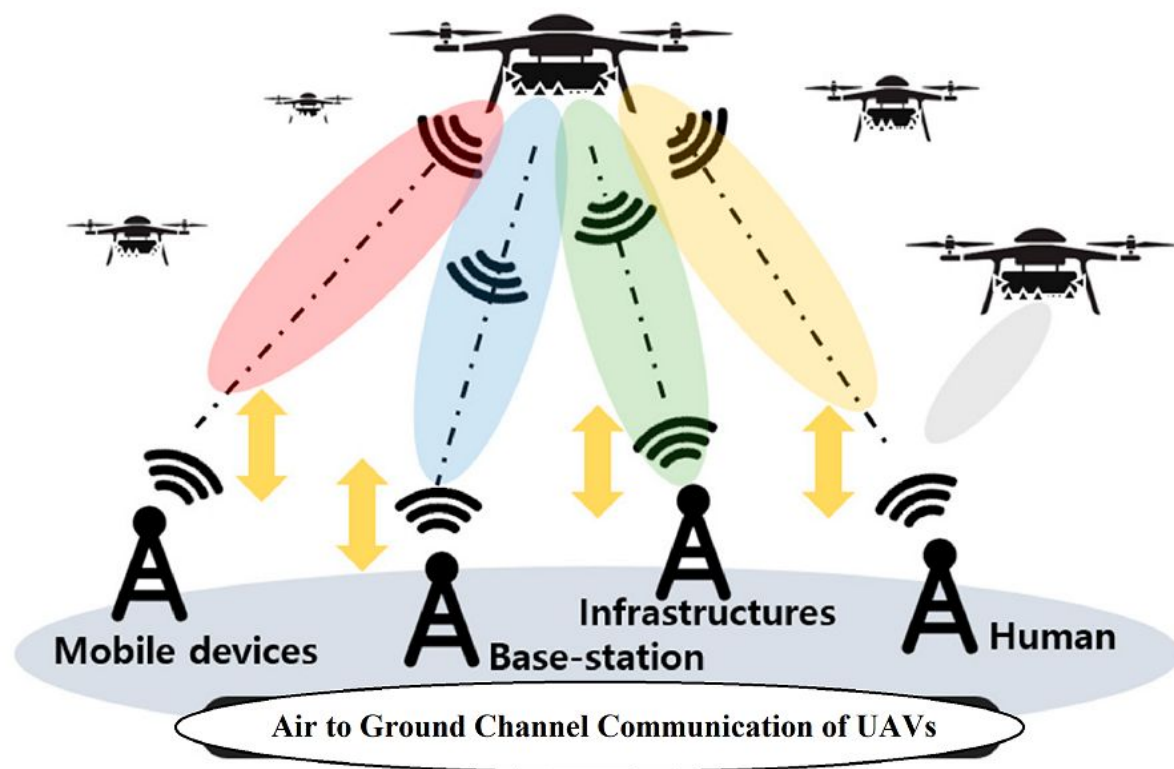
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# Chapter-01

## Introduction

### 1.1: Unmanned Aerial Vehicle (UAVs)

Unmanned Aerial Vehicle simply means the aircraft that is guided autonomously or by remote control. UAVs are used in various applications such as military surveillance, Telecommunications agriculture, commercial, scientific activities, policing, recreation, servile, delivering goods, photogrammetry etc. there are many kinds of UAVs . But UAVs need wide bandwidth. We can operate the UAVs in both microwave frequency band and mmWave frequency band. The microwave frequency band capacity is less than mmWave frequency band. Generally, mmWave uses high frequency spectrum. On the other hand, the prognosis of oncoming capacity crisis [1] of the microwave is often seen in various research.



## Fig-1.1: Air to Ground Channel Communication of Unmanned Aerial Vehicles (UAVs).

Table 1.1 Available bandwidth for different ranges in UAV channels.

Electromagnetic spectrum			
Name	Wavelength	Frequency (Hz)	Photon energy (eV)
Gamma ray	< 0.02 nm	> 15 EHz	> 62.1 keV
X-ray	0.01 nm – 10 nm	30 EHz – 30 PHz	124 keV – 124 eV
Ultraviolet	10 nm – 400 nm	30 PHz – 750 THz	124 eV – 3 eV
Visible light	390 nm – 750 nm	770 THz – 400 THz	3.2 eV – 1.7 eV
Infrared	750 nm – 1 mm	400 THz – 300 GHz	1.7 eV – 1.24 meV
<b>Microwave</b>	1 mm – 1 m	300 GHz – 300 MHz	1.24 meV – 1.24 $\mu$ eV
Radio	1 m – 100 km	300 MHz – 3 kHz	1.24 $\mu$ eV – 12.4 feV

### 1.2: Brief history of UAVs

The Unmanned Aerial Vehicles basically found from the battle zone. The robotized aeronautical vehicle at first used for warfighting which occurred in July 1849 filling in as an inflatable carrier . The essential judgment use of air power in oceanic flying . Austrian forces use 200 ignitable inflatables for preventing Venice City.

The inflatables were delivered predominantly from the land; a couple inflatables were delivered from the Austrian pontoon SMS Vulcano . In case the city in any occasion dropped one bomb; regardless, if the breeze changes after delivery, by and large inflatables miss their goal, and that reason a couple inflatables are moved back over on Austrian lines and the delivered in transport Vulcano. UAV advancements started their trip from the exactly on schedule of the 1900s and were fundamentally used for giving practice centers to planning military furnished power. UAVs directly off the bat envisioned the ideal season of 1990s and UAV development continued during World War I .Firstly,the Dayton-Wright Airplane Company found a pilotless aeronautical torpedo that would detonate at a planned time. Nikola Tesla depicted a quick of pilotless flying war vehicles in 1915.The most reliable undertaking at an energized UAV was A. M. Low &#39;s &quot;Aerial Target &quot; in 1916. During and after World War I UAVs are following, including the Hewitt-Sperry Automatic Airplane . This improvement moreover energized the progression of the Kettering Bug by Charles Kettering from Dayton, Ohio. This was from the outset suggested as a pilot less plane that would pass on a perilous payload to a booked target. The principle pilotless vehicle was made by film star and model-plane devotee Denny in1935. More outside during World War II – used both to get ready unfriendly to plane hefty weapons masters and to fly attack missions. Nazi Germany made and used countless UAV plane during the war. Fly engines entered organization of UAVs after World War II in vehicles, for instance, the Australian GAF Jindivik , and Teledyne Ryan Firebee I of 1951, while associations like Beech made their Model 1001 for the U.S. Maritime power in 1955.

For sure, even they used insignificant more than far away controlled planes during the Vietnam War . In 1959, the U.S. Aeronautics based military , stressed over losing pilots over their foes zone began preparing for the usage of pilotless planes. Masterminding the inquiry began to uplift after the Soviet Union murdered a U-2 of each 1960. Every so often later, an extraordinarily assembled UAV program started under the code name of &quot;Red Wagon &quot;.The August 1964 conflict in the Tonkin Gulf between oceanic units of the U.S. besides, North Vietnamese Navy . Regardless, America gave the particularly described UAV ( Ryan Model 147 , Ryan AQM-91 Firefly , Lockheed D-21 )used their first war missions of the Vietnam War . Right when the Chinese government see the photographs of set down U.S. UAVs through Wide World

Photos, the authority U.S. response was "no remark and quote;. During the Decay(1967–1970)of the fundamental vital UAVs presented with perception cameras were first attempted by the Israeli information, and it successfully brought photos from over the Suez stream. This was the initial go through that key UAVs, which could be delivered and shown up on any short runway were made and attempted in war. In the 1973 Yom Kippur battle , Israel used UAVs as traps to animate limiting forces for wasting expensive adversaries of plane rockets. After the 1973 Yom Kippur war, several key people from the gathering that developed this early UAV joined a little new business that wanted to shape UAVs into a business thing, unavoidably purchased by Tadiran and provoking the progression of the chief Israeli UVA. During the 1973 Yom Kippur War , Soviet-gave surface-to-air rocket batteries in Egypt and Syria made strong damage Israeli warrior planes . That time Israel planned the first UAV with progressing surveillance. The photos and radar trap given by these UAVs helped Israel to thoroughly vanquish the Syrian air insurances close to the start of the 1982 Lebanon War , as an ensuing in no pilots cut down.

The initial go through UAVs were used as proof-of-thought of super-speed post-hinder controlled excursion in war-flight diversions included aurous, riddle advancement based, three-dimensional push vectoring flight control, stream controlling UAVs in Israel in 1987. In 1973, the U.S. military definitively announced that they had been using UAVs in Southeast Asia (Vietnam). More than 5,000 U.S. pilots had been executed and more than 1,000 more were missing . The USAF perception cameras see that fly thrive around 3,435 UAV missions during the war. to a detriment of around 554 UAVs lost to all causes.

The decay and downsizing of material headways during the 1980s and 1990s, energy for UAVs created inside the higher layer of the U.S. military. During the 1990s, the U.S. DoD gave a consent to AAI Corporation close by Israeli association Malat. The U.S. Maritime power bought the AAI Pioneer UAV that AAI and Malat became together. Tremendous quantities of these UAVs saw organization in the 1991 Gulf War .

UAVs disseminated the opportunity of costless, more skillful engaging machines, deployable without risk to aircrews. Starting ages fundamentally included observation planes , yet some passed on battle equipment, for instance, the General Atomics MQ-1 Predator , that dispatched AGM-114 Hellfire air-to-ground rockets . CAPECON was an European Union

undertaking to make UAVs, running from 1 May 2002 to 31 December 2005 Starting in 2012, the USAF used 7,494 UAVs – pretty much one out of three USAF planes. The Central Intelligence Agency similarly worked UAVs In 2013 at any rate 50 countries used UAVs. China, Iran, Israel, Pakistan, and others arranged and manufactured their own collections.

### 1.3: UAVs Applications

- Ambient Environment Testing: Indoor climate Testing, Lighting Testing, Noise Testing, Whole Body Vibration Testing.
- Automatic Identification Systems inspection, Performance testing and maintenance.
- Coating test laboratory.
- Condition Monitoring: Traditional Visit-Based Methods, Real-Time monitoring via a Remote Data Center
- Dropped Objects Inspection and Program Audits
- ESP Hull Gauging
- Fire Extinguishing Systems
- Inspection/Maintenance
- Home Office and Agents ISO9001 Certification
- Hull Gauging
- In-Water Survey
- Inflatable Life Rafts, Inflatable Lifejackets, Hydrostatic Release Units, Inflatable Rescue Boats, Marine Evacuation Systems
- In-Service Hull Stability Verification
- Inspection of Low Location Lighting Systems

- Inventory of Hazardous Materials
- Lifeboats, Launching Appliances, On-Load Release Gear, and Davit Launched Liferaft Automatic Release Hooks
- Measurement of Noise Level Onboard
- Non-Destructive Examination
- Offshore Facility Inspection/Monitoring
- Radio Communication Equipment Maintenance
- Remote Inspection Techniques: Unmanned Aerial Vehicles, Remote Operated Vehicles, Robotic Crawler, Unmanned Robotic Arm
- RO/RO Ships Door Examination
- Self-Contained Breathing Apparatus Maintenance
- Shore-Based Maintenance of Satellite Emergency Position Radio Beacons
- Sound Pressure Level Measurement of Public Address & General Alarm Systems on Board Ships
- Tightness Testing of Closing Appliances with Ultrasonic Equipment
- Tightness Testing of Primary and Secondary Barriers of Gas Carriers with Membrane Cargo Containment Systems
- Underwater Noise Measurement
- Voyage Data Recorder (VDR) and Simplified VDRs Maintenance
- Aerospace.
- Military
- Reconnaissance
- Attack
- Demining

- Civil
- Archaeology
- Cargo transport
- Conservation
- Healthcare
- Film making
- Journalism
- Law enforcement
- Scientific research
- Search and rescue
- Surveillance
- Inspections
- Surveying
- Agriculture
- Construction
- Passenger transport
- Photography and so on.

#### 1.4 Research Objectives :

Now-a-days Unmanned Aerial Vehicles aren't used widely. But it's needs and applications are increasing day by day. There is a need to allocate a frequency band to communicate with UAVs. An UAVs performance is good at microwave frequency band with limited bandwidth.

The mm wave uses a high frequency spectrum. Hence the bandwidth is wider than microwave frequency. But the UAVs communication trends are poor with the increasing frequency. When the UAV communication will be poor at a threshold value, then it switches to microwave frequency band.

## 1.5 Thesis outlines

The chapter -1 described about Unmanned Aerial Vehicles (UAVs) and also background, applications of it. Then here mentioned about the research objectives and also the thesis outlines. Chapter -2 covers the literature review of the thesis. In chapter-3 covers the most important part that discusses the climate factors and the proposed model. We considered various noises which can alter the signal of the drones. We have collected the rain rate (mm) statistics of Chittagong region. Here shows the switching technique from mm wave to microwave frequency ranges by a flow chart. Then we consider a SINR formula to calculate the SINR for various parameters. In chapter – 4 illustrates the results numerically, provides quantitative measures of the threshold SINR value for both microwave and mm wave. Conclusion and future work are summarized in chapter -5.

## **Chapter 2**

### **Literature Review**

#### **2.1 Literature Review**

The automated flying vehicles (UAVs) properly known as automatons . It is quickly developing in a wide scope of remote systems administration application. (UAVs) concede a few key expected applications in remote frameworks. Crisis effectiveness of remote organization for example UAVs can be conveyed to supplement existing cell framework by giving extra ability to hotspot regions just as to give network inclusion in crisis and public security circumstances. Then again UAVs can work as flying versatile terminals inside the cell organization . Automated Aerial Vehicles (UAVs) have different applications including Military, Surveillance and Monitoring, Rescue tasks, Telecommunications, Delivery of Medical supplies and so on. Here we utilize double band correspondence, for example, microwave band and millimeter wave band.

#### **2.2 Methodology**

1. Topic Selection: The ability to develop a good thesis topic is an important skill. Selecting a good topic for a thesis may not be easy. It must be narrow and focused enough to be interesting, yet broad enough to find adequate information. My selected topic for this thesis is “Channel Modeling for Unmanned Aerial Vehicles (UAVs)”. So before selecting this topic, main focus points were- a) what my final goal should look like, b) what is brainstorm for ideas, c) will this topic be enabled to understand the literature, d) is it flexible to work.

2. Survey: Overview implies investigations of the plan and reenactment of UAV channel model and related review information assortment strategies and techniques for improving the outcomes. Principle focuses on review where to gather, accumulate and partner indispensable

papers which were identified with this postulation.

3. Literature Review: A writing survey is a book of an insightful paper, which incorporates the current information including meaningful discoveries, just as hypothetical and methodological commitments to a specific subject. A writing audit has following destinations – a) It overviews the writing in picked territory of study, b) It combines the data in that writing into an outline. c) It fundamentally examines the data assembled by recognizing holes in current information. For this proposition.

4. Objective : The target of this proposal is one of the significant components for directing any theory since it helps in deciding the chance of leading the examination. As a rule, theory destinations depict what we hope to accomplish by a subject of title. In accomplishing objective from proposition, four vital destinations are here-a) to recognize zones where postulation proof could have the most effect. b) To guarantee that current proposal proof is utilized ideally. c) To build up a new proposition to add to program arranging and assessment. d) To help with building information at a great level. For this postulation the fundamental goals are - a) to investigate the plan of UAV channel modeling . b) To contrast the exhibition of reception apparatus' boundaries and regard to reference papers. c) To dissect and accomplish the aftereffect of recreation.

5. Output from transmitter: The yield from transmitter was appropriately estimated by mimicking the transmitter side components

6. System simulation and results: In the wake of utilizing these boundaries great execution is estimated from the framework. The recreation is completed for various boundaries.

7. Conclusion :

Select the feasible formula for the signal to interference noise ratio (SINR). Formulate the microwave and millimeter wave frequency. Consider a threshold SNIR value for millimeter waves. Calculate SINR for multiple frequency (GHz) by using Microsoft excel .Prepared a MATLAB code for getting value . Simulate the obtained results in MATLAB Describe below.

## 2.3 Paper Review

- Research paper on : Rain attenuation prediction for terrestrial microwave link in bangladesh

Weakening because of downpour is a few bars in planning satellite connection in recurrence more than 10GHz . There is a huge variety in precipitation across Bangladesh and the downpour fall rate in rainstorm season is 4 to 8 times higher contrasted with that in dry season . Hence the downpour weakening isn't the same in all areas of Bangladesh, rather it fluctuates from season to season.

The downpour weakening in Q and V groups is a lot higher ( about 32% in Q band and 46% in V band) at that point the current Ka band. The distinction in weakening the nation over is about 12% when the most extreme is seen at Sylhet and the last an incentive at rajshahi locale. it is additionally discovered that the ITU downpour rate expectation model can't anticipate the downpour rate appropriately for a subtropical nation the Bangladesh since it is discovered that its anticipated downpour rate is 6% lower then the forty years normal downpour pace of the driest locale of Bangladesh and the relating impact on the downpour rate can't give the exact worth.

To guarantee 99.99% accessibility of the system, the necessary most noteworthy normal blur edges of 156dB and 124dB are accounted for in sylhet and the base estimations of 138dB and 109dB in rajshahi for V and Q groups individually. The required blur edge differs impressively over the year. The necessary edge for 99.99% is more than 140dB for V band and Q band for around a half year.

Since giving such a colossal connection edge is to some degree financially unfeasible with the flow of innovation the accessibility will shift with the season in a year, During dry season higher accessibility can be delighted in yet in storms this will go down. However setting a satellite in a lower longitude builds the earth station rise edge, which diminishes the measure of blur edge required, furthermore a satellite can be propelled in which the all out number of

transponders will be gathered into two classifications. one working in a lower recurrence band and the other in Q/V band.

During the storm season, the lower recurrence band will be utilized and the EHF band will be in working mode in the dry season. Communicating higher force during precipitation and diminishing that in other time can likewise decrease the impact of downpour in the nature of satellite help.

- Research paper on : Rain Attenuation Prediction Analysis and Contour Map Design over Bangladesh

In this paper, the downpour lessening is investigated and a form map is planned with respect to three separate groups. From the shape maps, the weakening just as the necessary data is perceptibly explained. The data from these guides will be a decent primer plan device for both earthbound and earth-satellite microwave joins and furthermore give wide thought of downpour weakening for RF engineers.

These guides can be promptly used by radio frameworks specialists to survey rapidly and precisely the impact of the predominant radio wave engendering factor on satellite and other important framework structure. We expect the paper will be valuable for an architect to assess the proper compelling isotropically emanated power also, the collector qualities for the aforementioned groups furthermore, send signals with blur edge.

- Research paper on : A Tutorial on UAVs for Wireless Networks Applications, Challenges, and Open Problems

The utilization of flying stages, for example, automated aeronautical vehicles (UAVs), famously known as drones.

Drones are quickly growing. In specific, with their intrinsic credits, for example, mobility, flexibility, and versatile elevation, UAVs concede a few key likely applications in remote frameworks. From one perspective, UAVs can be utilized as ethereal base stations to upgrade inclusion, capacity, reliability, and vitality productivity of remote organizations. Then

again, UAVs can work as flying portable terminals inside a cell organization. Such cell associated UAVs can empower a few applications running from real-time video real time to item conveyance. In this paper.

An extensive instructional exercise on the likely advantages and utilizations of UAVs in remote interchanges is introduced. In addition, the significant difficulties and the key tradeoffs in UAV-empowered remote organizations are completely explored. Specifically, the key UAV difficulties, for example, three-dimensional sending, execution analysis, channel displaying, and vitality proficiency are investigated alongside delegate results. At that point, open issues and potential examination bearings relating to UAV interchanges are presented. At long last, different investigative systems and numerical apparatuses, for example, enhancement hypothesis, AI, stochastic calculation, transport hypothesis, and game hypothesis are depicted. The Use of such devices for tending to remarkable UAV issues is likewise introduced.

This instructional exercise gives key rules on the best way to dissect, streamline, and plan UAV-based remote correspondence frameworks.

- Research paper on : Millimeter-Wave Communications: Physical Channel Models, Design Considerations, Antenna Constructions and Link-Budget

In this paper, we looked into the remarkable mmWave engendering attributes, including the free-space way misfortune, climatic constriction, downpour and foliage lessening, material entrance also, other spread components. We at that point inspected the mmWave channel models and talked about the mmWave correspondence frameworks' necessities, and difficulties. At long last, we gave an outline on the significant plan rules, for example, framework radio wire plan contemplations followed by the simple connect spending examination of mmWave.

Interchanges, where we investigated the base required number of radio wires all together to accomplish a particular information rate, such as 3Gbps.

- Research paper on : Realistic Estimation of Signal-to-Noise Ratio in Microwave Receivers

This paper has introduced a hypothetical and reasonable investigation for the assessment of SNR in a microwave collector. As a contextual investigation, a broadband SDLVA working in 2-18 GHz with a high unique scope of 75 dB is thought of. The hypothetical disarrays caused because of RF SNR of an independent locator and that of an entire beneficiary is settled and their relationship with the video SNR is assessed by thinking about TSS, OSS, and the clamor figure. Besides, useful estimations are made and to resolve the constraints of log slant related with COTS microwave beneficiaries is redressed. A definition is proposed which remunerates the video SNR. This approves the hypothetical idea that SNR should increment with expanding the information signal force - even if there should arise an occurrence of microwave recipients which have a restricted video yield. The investigation can be utilized to examine SNR and SNR<sub>video</sub> in any COTS microwave recipient.

- Research paper on : A Survey on 5G Millimeter Wave Communications for UAV-Assisted Wireless Networks

In this paper, we have introduced a thorough writing overview zeroing in on the present status of-the-workmanship accomplishments in the combination of 5G mmWave interchanges into UAV assisted remote organizations. By dissecting and checking on the existing exploration endeavors, we initially acquainted a novel taxonomy with the front line arrangements from seven angles. We at that point surveyed existing articles identified with UAVassisted remote organizations and interchanges just as 5G mmWave correspondences, and further analyzed our review with them. Accordingly, we gave a concise diagram of key specialized focal points and difficulties just as potential applications in 5G mmWave interchanges for UAV-helped remote organizations.

The conceived scientific categorization, we reviewed in detail the best in class issues, arrangements, and open difficulties of incorporating mmWave correspondences into UAV-helped remote organizations.

We additionally inferred a few exercises learned from these exploration exercises. At last, we pinpointed a few open issues and laid out promising exploration headings. We trust that

this review is ideal and valuable for the intrigued analysts and experts to focus their examination exercises on this zone for the advancement of people to come to remote organizations.

- Research Paper on : A Primer on Spatial Modeling and Analysis in Wireless Networks.

In this paper The presentation of remote organizations relies basically upon their spatial design, since got signal force and obstruction rely basically upon the separations between various transmitters and beneficiaries.

This is especially obvious in developing organization standards that may incorporate femtocells, hotspots, transfers, blank area gatherers, and lattice draws near, which are frequently overlaid with conventional cell networks. These heterogeneous ways to deal with giving high-limit network access are portrayed by haphazardly found hubs, sporadically sent framework, and unsure spatial arrangements because of elements like portability and impromptu client introduced passageways. This significant move is simply starting, and it requires new configuration moves toward that are strong to spatial irregularity, similarly as remote connections have for quite some time been intended to be powerful to blurring. The goal of this article is to show the intensity of spatial models and explanatory strategies in the plan of remote organizations, and to give a passage level instructional exercise.

- Rehash paper on : Communication and Coordination for Drone Networks

In this paper we showed an elevated level engineering for the plan of multi-UAV frameworks that comprise of vehicles with on-board sensors and installed preparing, and detecting, coordination, and communication networking blocks.

We introduced a framework consisting of quadrotors and exhibit its potential in a fiasco situation. From a few certifiable tests, we have seen that for viable plan of multi-UAV networks, particularly for dynamic applications, unique center ought to be given to better characterizing the communications between the plan blocks what's more. Effective assessment techniques It is hard to assess the reliance of the plan hinders too as the general exhibition of the multi-UAV frameworks. Test systems are helpful somewhat, be that as it may, genuine elements of the framework can't be completely gotten a handle on with just test systems, consequently exploratory testbeds are required. A few testbeds exist to assess multi-UAV

control calculations. Be that as it may, there is still an absence of testbeds to assess the detecting, communication networking, furthermore, coordination calculations for the multi-UAV frameworks. At any rate, the effect of flight elements on correspondence joins, detected information quality, and the effect of little scope vehicle qualities, for example, short flight times and low payload on coordination can be better demonstrated by means of contribution from genuine world tests. Self-rule and client cooperation At last, most applications require some self-sufficiency in the flight activity of the UAVs. While this might be ideal for single-UAV applications, self-sufficient flight activity is required for multi-UAV frameworks.

Self-rule assists with improving and theoretically the UI. With self-sufficiency and a productive client interface plan, the clients can zero in on the general mission and needn't bother with managing individual UAVs (as we have shown with our guide based UI). Strategies to accomplish elevated levels of self-governance and low degrees of client collaboration are required. While there are as yet many open issues for accomplishing an ideal multi-UAV framework, we are sure that the applications UAVs are sent for will keep on expanding and different UAVs will involve our skies sooner rather than later.

- Research Paper on : Joint Altitude, Beamwidth, Location and Bandwidth Optimization for UAV-Enabled Communications

In this paper, examined the aggregate force minimization issue in uplink UAV-empowered correspondences. We appeared that the whole force first declines and afterward diminishes with the beamwidth. Mathematical outcomes indicated that the uplink total force execution can be improved by the proposed calculation.

## 2.4 Summary

Here we look at the reviews of many thesis papers in UAVs related such as to survey rapidly and precisely the impact of the predominant radio wave engendering factor on satellite and other important framework structures. This surveyed existing articles identified with UAVassisted remote organizations and interchanges just as 5G mmWave correspondences,

and further analyzed our review with them. Accordingly, we gave a concise diagram of key specialized focal points and difficulties just as potential applications in 5G mmWave interchanges for UAV-help. the plan of multi-UAV frameworks that comprise vehicles with on-board sensors and installed preparing, and detecting, coordination, and communication networking blocks. the aggregate force minimization issue in uplink UAV-empowered correspondences. We appear that the whole force first declines and afterward diminishes with the beamwidth. The presentation of remote organizations relies basically upon their spatial design, since signal force and obstruction rely basically upon the separations between various transmitters and beneficiaries. Here we work Deployment of Dual Band Unmanned Aerial Vehicles system that means we worked in this paper An UAVs performance is good at microwave frequency band with limited bandwidth. The mm wave uses a high frequency spectrum. Hence the bandwidth is wider than microwave frequency. But the UAVs communication trends are poor with the increasing frequency. When the UAV communication will be poor at a threshold value, then it switches to microwave frequency band.

## 2.5 Objectives :

- Our main objective is to use dual band communication (microwave , millimeter wave) for UAVs to provide a network.
- Coverage in emergency and public safety situations.
- When the signal quality is too weak to communicate, then the network channel automatically switches millimeter waves to microwave.

## Chapter 3

### System Model

#### 3.1: Introduction

To calculate Signal-to-Interference-Ratio (SINR) there are concerns about various parameters such as free space temperature, multiple attenuation, free space loss, rain rate data, microwave frequency, mm wave frequency and so on.

#### 3.2: Free Space

The free space, another name is atmosphere. Which divided by 4 layers

- Troposphere: Troposphere that we live in near the surface of the earth. This layer is the lowest layer of earth's atmosphere. It distances between 0-12 kilometer from earth sea level. The temperature of the troposphere generally decreases as altitude increases. The average environmental lapse rate is a drop of about 6.5°C for every 1km in increased height. And its maximum temperature is 15°C<sup>[3][4]</sup>.
- Stratosphere: Stratosphere is the second layer of the atmosphere. This layer borders between the stratosphere and troposphere. Its distance is between 12 to 50km. The stratosphere temperature will decrease with altitude and the top of the stratosphere has a temperature of about -3°C (26.6°F)<sup>[5][6][7][8]</sup>
- Mesosphere: Mesosphere is the third layer of the atmosphere. It's directly above the stratosphere and directly below the thermosphere. Its distance is between 50-80km. Here, temperature decreases as altitude increases. It is known as the coldest layer in the atmosphere layer where temperature is -90°C (-130°F)<sup>[9]</sup>.
- Thermosphere: Thermosphere is the 4<sup>th</sup> layer in the earth where it is directly above the mesosphere and below the exosphere. This layer is between 80-500km. This layer is

the only one layer where temperature increased due to distances. Its temperature is 1500<sup>0</sup>C (2700<sup>0</sup>F). This layer another name is the warmest layer in the all of atmosphere layer<sup>[10]</sup>.

### 3.3: Rain Rate 2019 For Chittagong Region

**TABLE 3.1: RAIN RATE STATISTICS OF CTG REGION<sup>[11]</sup>**

<b>Month</b>	<b>Rain Rate(mm)</b>
January	5.6
February	24.4
March	54.7
April	147.4
May	298.6
June	607.3
July	727
August	530.6
September	259.3
October	184.8
November	67.5
December	11.9
Average	243.25

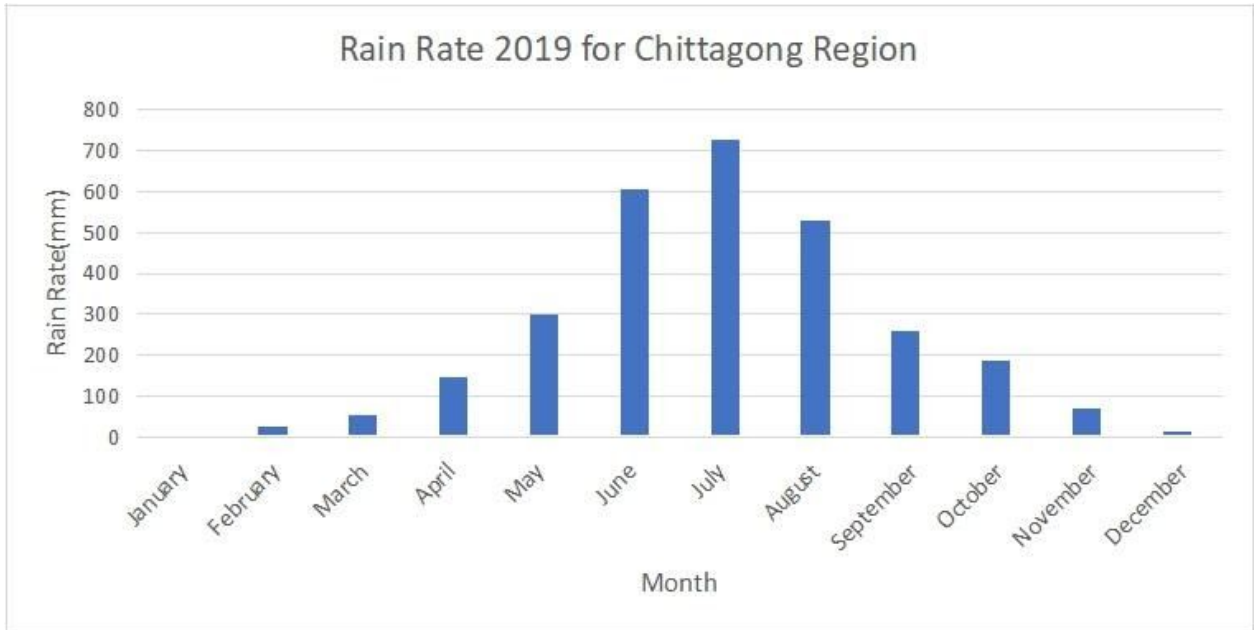


Fig 3.1: Rain Rate 2019 For Chittagong Region

### 3.3: MicroWave and Millimeter Wave

- **Microwave:** Microwaves are a form of electromagnetic radiation with wavelengths ranging from about one meter to ten millimeters with frequency between 3GHz to 30GHz<sup>[12][13][14][15][16][17]</sup>.
- **Millimeter Wave:** Millimeter Wave is known as extremely high frequency. International Telecommunication Union (ITU) designation for the band of radio frequencies in the electromagnetic spectrum from 30GHz to 300GHz<sup>[12][13][14][15][16][17]</sup>

### 3.4: Various Attenuation

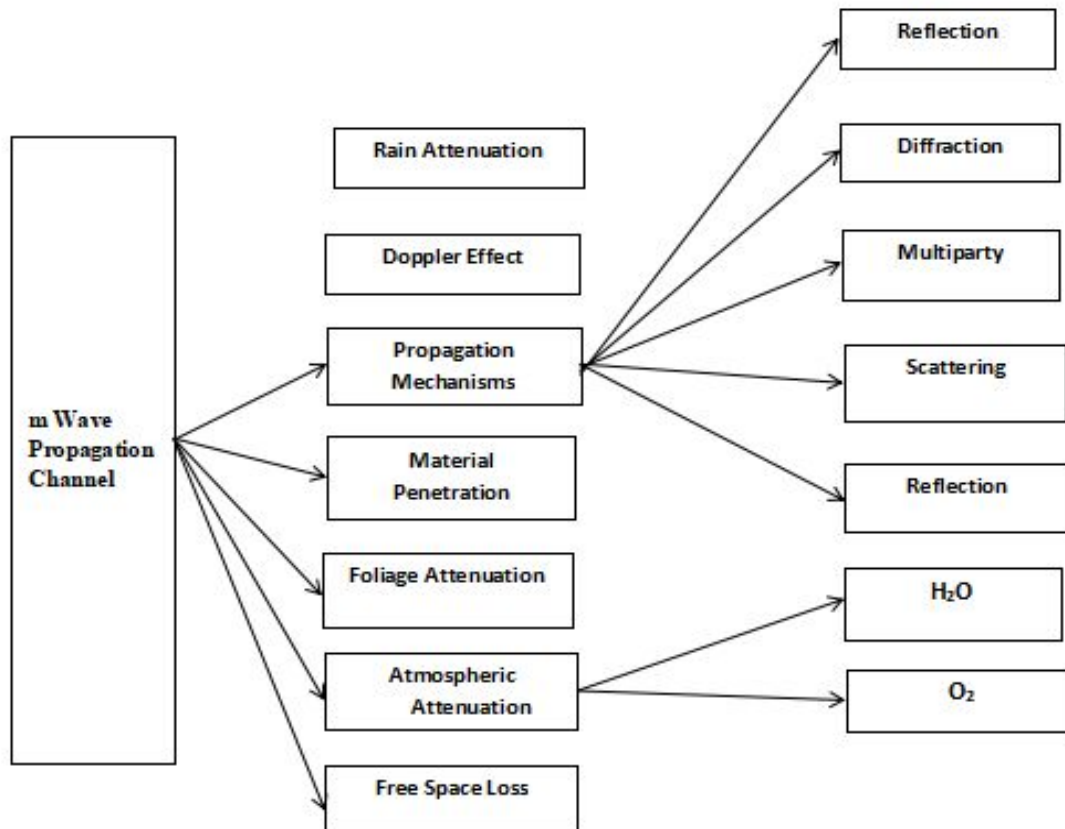


Fig-3.2 Multiple loss path for mmWave propagation channel.

- 3.5.1: The specific attenuation

The particular lessening  $R(\text{dB/km})$  is gotten from the downpour rate  $R$  (mm/h) utilizing the force law

relationship:

$$Y_R = (kR)^\alpha \quad \dots\dots\dots (3.1)$$

Where  $k$  and  $\alpha$  depends on frequency and polarization<sup>[2]</sup>.

Qualities for the coefficients  $k$  and are resolved as elements of recurrence,  $f$  (GHz), in the range

from 1 to 1 000 GHz, from the accompanying conditions, which have been created from bend fitting to control law coefficients got from dissipating computations:

$$\text{Log}_{10}^k \sum_{j=1}^4 (a_j \exp [- (\frac{\text{Log}_{10} f - b_j}{c_j})^2 ]) + m_k \text{Log}_{10} f + c_k \quad \dots\dots\dots (3.2)$$

$$\alpha \sum_{j=1}^5 (a_j \exp [- (\frac{\text{Log}_{10} f - b_j}{c_j})^2 ]) + m_\alpha \text{Log}_{10} f + c_\alpha \quad \dots\dots\dots (3.3)$$

Where,

$f$ : frequency (GHz)

$k$ : either  $k_H$  or  $K_V$

$\alpha$ : either  $\alpha_H$  or  $\alpha_V$

Qualities for the constants for the coefficient  $k_H$  for even polarization are given in Table 3.2 and for the coefficient  $K_V$  for vertical polarization in Table 3.2. Table 3.4 gives the qualities for the constants for the coefficient  $\alpha_H$  for level polarization, and Table 3.3 gives the qualities for the constants for the coefficient  $\alpha_V$  for vertical polarization.

TABLE 3.2  
Coefficients for  $k_V$

$j$	$a_j$	$b_j$	$c_j$	$m_k$	$c_k$
1	-3.80595	0.56934	0.81061	-0.16398	0.63297
2	-3.44965	-0.22911	0.51059		
3	-0.39902	0.73042	0.11899		
4	0.50167	1.07319	0.27195		

TABLE 3.3  
Coefficients for  $a_H$

$j$	$a_j$	$b_j$	$c_j$	$m_a$	$c_a$
1	-0.14318	1.82442	-0.55187	0.67849	-1.95537
2	0.29591	0.77564	0.19822		
3	0.32177	0.63773	0.13164		
4	-5.37610	-0.96230	1.47828		
5	16.1721	-3.29980	3.43990		

TABLE 3.4  
Coefficients for  $a_V$

$j$	$a_j$	$b_j$	$c_j$	$m_a$	$c_a$
1	-0.07771	2.33840	-0.76284	-0.053739	0.83433
2	0.56727	0.95545	0.54039		
3	-0.20238	1.14520	0.26809		
4	-48.2991	0.791669	0.116226		
5	48.5833	0.791459	0.116479		

For linear and circular polarization, and for all path geometries, the coefficients in equation (3.1) can be calculated from the values given by equations (3.2) and (3.3) using the following equations:

$$k = [k_H + k_V + (k_H - k_V) \cos^2 \theta \cos 2\psi] / 2 \dots \dots \dots (3.4)$$

$$a = [k_H a_H + k_V a_V + (k_H a_H - k_V a_V) \cos^2 \theta \cos 2\psi] / 2k \dots \dots \dots (3.5)$$

Frequency-dependent coefficients for estimating specific rain attenuation using equations (3.4), (3.5) and (3.1)

TABLE 3.5

The value of  $k_H$ ,  $a_H$ ,  $k_V$  and  $a_V$  for various frequencies

Frequency (GHz)	$k_H$	$a_H$	$k_V$	$a_V$
1	0.0000259	0.9691	0.0000308	0.8592
1.5	0.0000443	1.0185	0.0000574	0.8957
2	0.0000847	1.0664	0.0000998	0.9490
2.5	0.0001321	1.1209	0.0001464	1.0085
3	0.0001390	1.2322	0.0001942	1.0688
3.5	0.0001155	1.4189	0.0002346	1.1387
4	0.0001071	1.6009	0.0002461	1.2476
4.5	0.0001340	1.6948	0.0002347	1.3987
5	0.0002162	1.6969	0.0002428	1.5317
5.5	0.0003909	1.6499	0.0003115	1.5882
6	0.0007056	1.5900	0.0004878	1.5728
7	0.001915	1.4810	0.001425	1.4745
8	0.004115	1.3905	0.003450	1.3797
9	0.007535	1.3155	0.006691	1.2895
10	0.01217	1.2571	0.01129	1.2156

<b>Frequency (GHz)</b>	<i>kH</i>	<i>aH</i>	<i>kV</i>	<i>aV</i>
11	0.01772	1.2140	0.01731	1.1617
12	0.02386	1.1825	0.02455	1.1216
13	0.03041	1.1586	0.03266	1.0901
14	0.03738	1.1396	0.04126	1.0646
15	0.04481	1.1233	0.05008	1.0440
16	0.05282	1.1086	0.05899	1.0273
17	0.06146	1.0949	0.06797	1.0137
18	0.07078	1.0818	0.07708	1.0025
19	0.08084	1.0691	0.08642	0.9930
20	0.09164	1.0568	0.09611	0.9847
21	0.1032	1.0447	0.1063	0.9771
22	0.1155	1.0329	0.1170	0.9700
23	0.1286	1.0214	0.1284	0.9630
24	0.1425	1.0101	0.1404	0.9561
25	0.1571	0.9991	0.1533	0.9491
26	0.1724	0.9884	0.1669	0.9421
27	0.1884	0.9780	0.1813	0.9349
28	0.2051	0.9679	0.1964	0.9277

29	0.2224	0.9580	0.2124	0.9203
30	0.2403	0.9485	0.2291	0.9129
31	0.2588	0.9392	0.2465	0.9055
32	0.2778	0.9302	0.2646	0.8981
33	0.2972	0.9214	0.2833	0.8907
34	0.3171	0.9129	0.3026	0.8834
35	0.3374	0.9047	0.3224	0.8761
36	0.3580	0.8967	0.3427	0.8690
37	0.3789	0.8890	0.3633	0.8621
38	0.4001	0.8816	0.3844	0.8552
39	0.4215	0.8743	0.4058	0.8486
40	0.4431	0.8673	0.4274	0.8421
41	0.4647	0.8605	0.4492	0.8357
42	0.4865	0.8539	0.4712	0.8296
43	0.5084	0.8476	0.4932	0.8236
44	0.5302	0.8414	0.5153	0.8179
45	0.5521	0.8355	0.5375	0.8123
46	0.5738	0.8297	0.5596	0.8069
47	0.5956	0.8241	0.5817	0.8017
48	0.6172	0.8187	0.6037	0.7967

TABLE 3.5 (continued)

Frequency (GHz)	$kH$	$aH$	$kV$	$aV$
49	0.6386	0.8134	0.6255	0.7918
50	0.6600	0.8084	0.6472	0.7871
51	0.6811	0.8034	0.6687	0.7826
52	0.7020	0.7987	0.6901	0.7783
53	0.7228	0.7941	0.7112	0.7741
54	0.7433	0.7896	0.7321	0.7700
55	0.7635	0.7853	0.7527	0.7661
56	0.7835	0.7811	0.7730	0.7623
57	0.8032	0.7771	0.7931	0.7587
58	0.8226	0.7731	0.8129	0.7552
59	0.8418	0.7693	0.8324	0.7518
60	0.8606	0.7656	0.8515	0.7486
61	0.8791	0.7621	0.8704	0.7454
62	0.8974	0.7586	0.8889	0.7424
63	0.9153	0.7552	0.9071	0.7395
64	0.9328	0.7520	0.9250	0.7366
65	0.9501	0.7488	0.9425	0.7339
66	0.9670	0.7458	0.9598	0.7313

67	0.9836	0.7428	0.9767	0.7287
68	0.9999	0.7400	0.9932	0.7262
69	1.0159	0.7372	1.0094	0.7238
70	1.0315	0.7345	1.0253	0.7215
71	1.0468	0.7318	1.0409	0.7193
72	1.0618	0.7293	1.0561	0.7171
73	1.0764	0.7268	1.0711	0.7150
74	1.0908	0.7244	1.0857	0.7130
75	1.1048	0.7221	1.1000	0.7110
76	1.1185	0.7199	1.1139	0.7091
77	1.1320	0.7177	1.1276	0.7073
78	1.1451	0.7156	1.1410	0.7055
79	1.1579	0.7135	1.1541	0.7038
80	1.1704	0.7115	1.1668	0.7021
81	1.1827	0.7096	1.1793	0.7004
82	1.1946	0.7077	1.1915	0.6988
83	1.2063	0.7058	1.2034	0.6973
84	1.2177	0.7040	1.2151	0.6958
85	1.2289	0.7023	1.2265	0.6943
86	1.2398	0.7006	1.2376	0.6929

TABLE 3.5 (*end*)

<b>Frequency (GHz)</b>	<i>kH</i>	<i>aH</i>	<i>kV</i>	<i>aV</i>
87	1.2504	0.6990	1.2484	0.6915
88	1.2607	0.6974	1.2590	0.6902
89	1.2708	0.6959	1.2694	0.6889
90	1.2807	0.6944	1.2795	0.6876
91	1.2903	0.6929	1.2893	0.6864
92	1.2997	0.6915	1.2989	0.6852
93	1.3089	0.6901	1.3083	0.6840
94	1.3179	0.6888	1.3175	0.6828
95	1.3266	0.6875	1.3265	0.6817
96	1.3351	0.6862	1.3352	0.6806
97	1.3434	0.6850	1.3437	0.6796
98	1.3515	0.6838	1.3520	0.6785
99	1.3594	0.6826	1.3601	0.6775
100	1.3671	0.6815	1.3680	0.6765
120	1.4866	0.6640	1.4911	0.6609
150	1.5823	0.6494	1.5896	0.6466
200	1.6378	0.6382	1.6443	0.6343
300	1.6286	0.6296	1.6286	0.6262
400	1.5860	0.6262	1.5820	0.6256
500	1.5418	0.6253	1.5366	0.6272

600	1.5013	0.6262	1.4967	0.6293
700	1.4654	0.6284	1.4622	0.6315
800	1.4335	0.6315	1.4321	0.6334
900	1.4050	0.6353	1.4056	0.6351
1 000	1.3795	0.6396	1.3822	0.6365

- 3.5.2: Effective path length ( $D_{eff}$ )

Due to efficient measurement of attenuation. effective path length,

$$D_{eff} = \frac{d}{1 + \frac{d}{d_0}} \dots\dots\dots(3.6)$$

Here d is the actual length of terrestrial link and  $d_0 = 35 e^{-1.5}$  for Bangladesh<sup>[2]</sup>, as the rainfall is above 100 mmh<sup>-1</sup>.

- 3.5.3: Path attenuation

The path attenuation exceeded for 0.01% of the time is given by

$$A_{0.01\%} = Y_R D_{eff} \dots\dots\dots(3.7)$$

- 3.5.4: AWGN noise

At the point when the communicated signal goes through a channel, AWGN commotion influences this sign. It contains a uniform nonstop recurrence range over a specific recurrence band <sup>[19]</sup>In every remote correspondence frameworks, added substance white Gaussian commotion (AWGN) is frequently utilized as a model of commotion. AWGN channel is really a numerical model that speaks to physical wonders in which the main disability is the direct expansion of background noise a consistent ghostly thickness (communicated as Watts per Hertz of data transfer capacity) and a Gaussian circulate.

- **3.5.5: Free Space Loss**

In remote correspondence, free-space way misfortune (FSPL) is the misfortune in signal quality of an electromagnetic wave that would result from a view way through free space (typically air), without any impediments close by to cause reflection or diffraction. It does exclude factors, for example, the addition of the receiving wires utilized at the transmitter and beneficiary, nor any misfortune related with equipment blemishes.

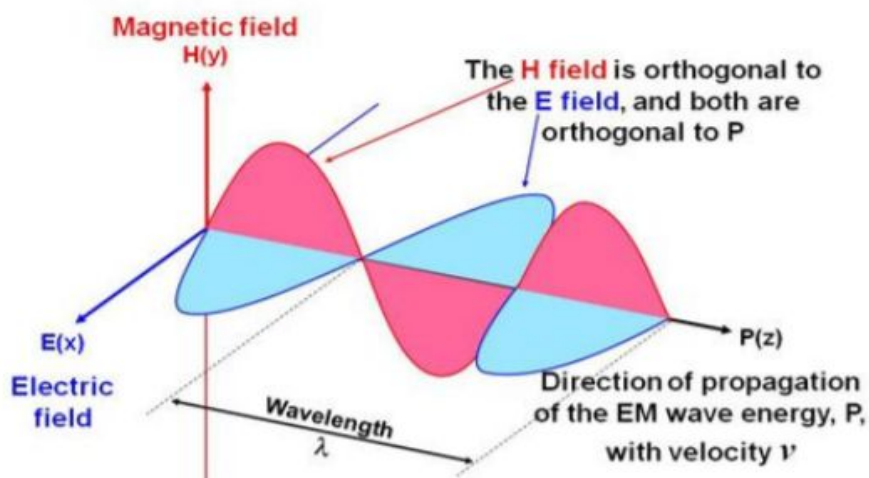


Fig:3.3 Direction of electromagnetic wave propagation

The Free Space Loss can be calculated by,

$$F_L = 96.58 + 20 \log F(\text{GHz}) + 20 \log D(\text{mile}) \dots \dots \dots (3.8)$$

$$= 92.45 + 20 \log F(\text{GHz}) + 20 \log D(\text{km}) \dots \dots \dots (3.9)$$

- **3.5.6: Noise Floor**

Noise floor is the signal which adding up all unwanted signals including thermal noise, atmospheric noise and noise from components used. The noise floor can be calculated by using following formula<sup>[18]</sup>,

Noise Floor =  $KT B$  ;

Where,  $K$  = Boltzman Constant( $1.3806504 \times 10^{-23} \text{ jk}^{-1}$ )

$T$  = Temperature in kelvin

$B$  = Bandwidth of the Receiver

Consider  $n$  clients in a zone In a crisis situation, it is expected that there are  $n$  clients in region  $D$ . The client arrangement is characterized as . The data transfer capacity asset block required by every client is characterized as Partition of clients into  $K$  groups as indicated by the necessary data transmission of client correspondence. At that point,  $k$  UAVs are sent to the assigned area to go about as the harmed ground base station to continue correspondence. The UAVs' directions are characterized as . The underlying situation of the UAV is . The UAV will be conveyed to . During the organization, the flying rate of UAV is . The Euclidean separation of UAV flight is: The flight season of UAV is:  $T_i = d_i v_i$  .

### 3.6 : Algorithm & Flow chart

step-1: Start the program

step-2: Input the  $P_t$ ,  $G_t$ ,  $G_r$ ,  $\lambda$ ,  $\pi=3.1416$ ,  $N_t$ ,  $B$  step-3: Calculate the SINR value from  $SINR = \frac{P_t * G_t * G_r * (\lambda)^2}{16(\pi^2) * N_t * B}$

step-4: If  $SINR < \text{Threshold SINR}$ , then switch the communication channel to microwave channel. Go to step-6.

step-5: Otherwise stay on mm wave channel

step-6: Stop

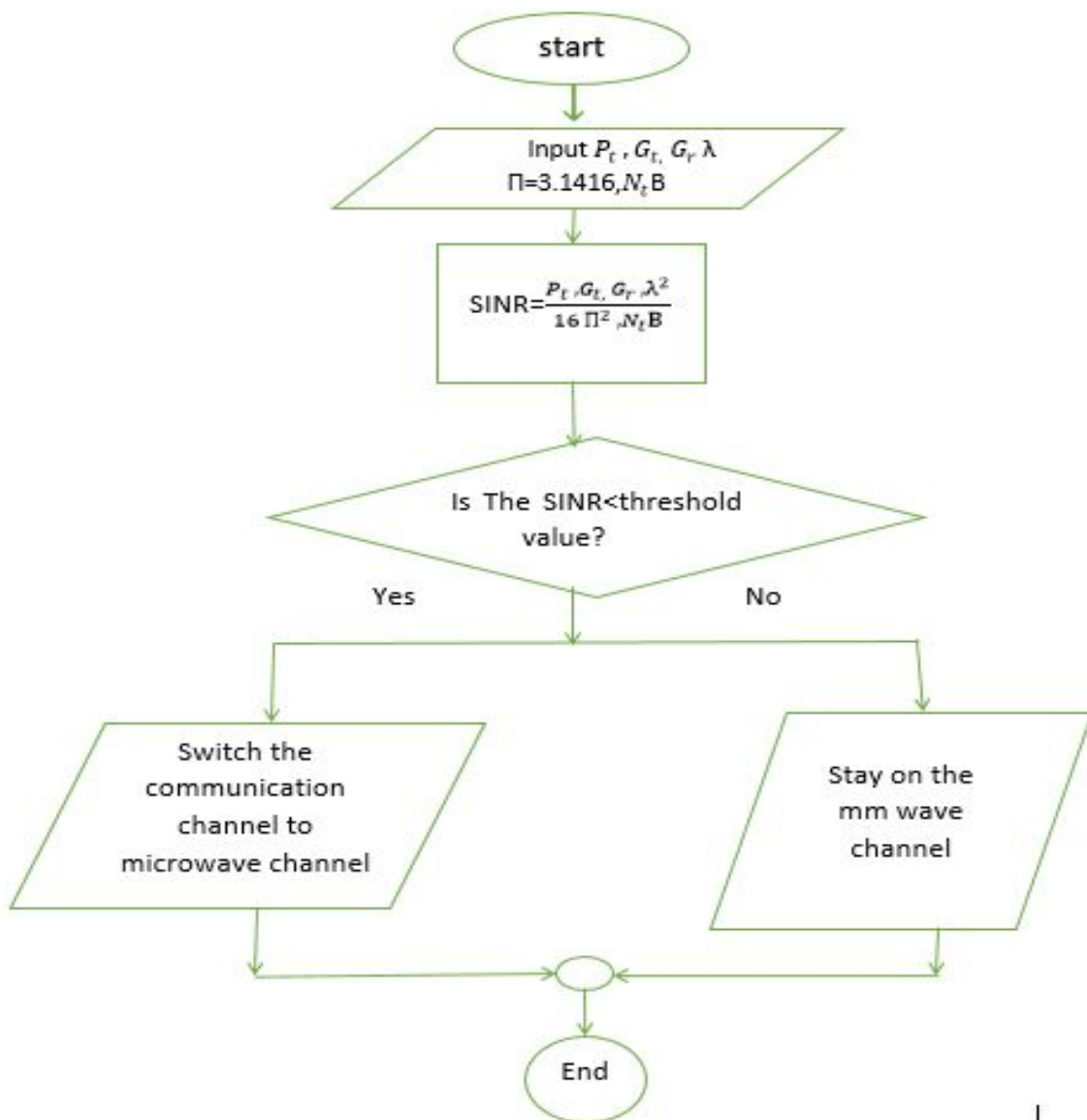


Fig 3.4 : Flowchart of mmwave to microwave convert system.

We wanted to explain by this flowchart how a signal would change from a millimeter wave to a microwave. This is discussed below When UAV continues to provide the signal through the millimeter wave, if the value of SINR goes below threshold SINR value the signal channel will change and become a microwave signal and if the value of SINR is above threshold SINR value then the signal will continue to pass through the millimeter wave.

### 3.7: Proposed Model :

VAV A standard mechanized plane is made of light composite materials to reduce weight and augmentation versatility. A computerized ethereal vehicle structure has two segments, the robot itself and the control system. The nose of the robotized flying vehicle is the spot where all the sensors and navigational systems are available. A standard mechanized plane is made of light composite materials to diminish weight and additional portability. A robotized ethereal vehicle system has two segments, the machine itself and the control structure. The nose of the mechanized flying vehicle is the spot all the sensors and navigational structures are accessible. The sign to-impedance notwithstanding uproar extent (SINR) (in any case called the sign to-fuss notwithstanding check extent (SNIR)) is a sum used to give theoretical maximum cutoff points on channel limit (or the movement of information move) in far off correspondence structures, for instance, associations. Intently looking like the sign to-uproar extent (SNR) used as often as possible in wired correspondences structures, the SINR is portrayed as the force of a particular indication of interest apportioned by the whole of the impedance power (from the different interfering signs) and the power of some establishment commotion. If the power of uproar term is zero, by then the SINR diminishes to the sign-to-check extent (SIR). On the other hand, zero impedance diminishes the SINR to the SNR, which is used less every now and again while making mathematical models of far off associations, for instance .

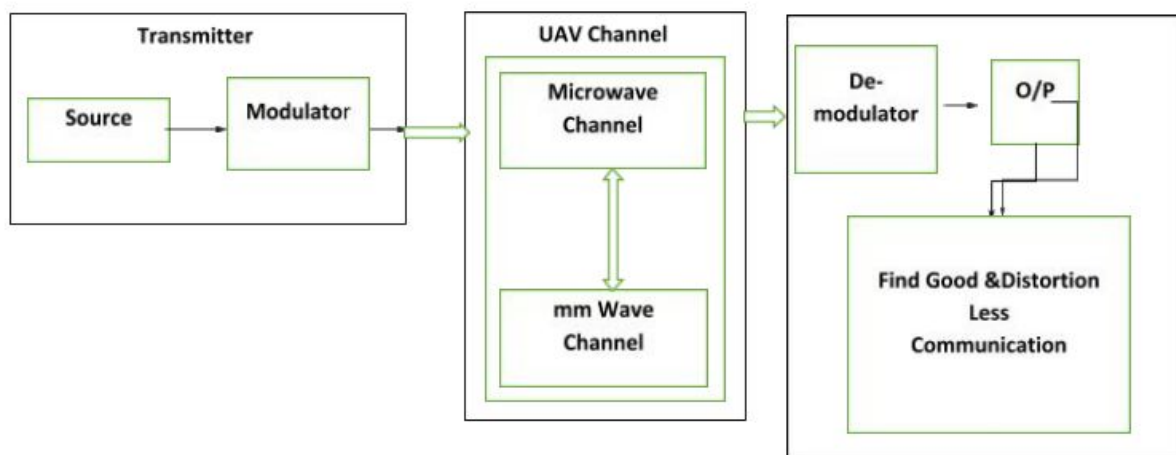


Fig 3.5 : Block diagram of mmwave to microwave switching technique.

We see a block diagram with three parts such as Transmitter,UAV Channel, Demodulator, output . Here source and Modulator is the transmitter part . Now we provide one signal in source part then this signal modulate and goes to UAV channel now we see what is modulator A modulator is a circuit that joins two distinct signs so that they can be pulled separated later and the data got.when this signal stay UAV channel first time this signal is millimeter wave channel we assume a treshore value .when this signal stay below this treshore value then this signal convert microwave channel.

Next step this signal Demodulator and Provide output now we see what is a demodulator . A demodulator is an electronic circuit (or PC program in a product characterized by radio) that is utilized to recuperate the data content from the regulated transporter wave. There are numerous kinds of balance so there are numerous sorts of demodulators.

### 3.8 : Signal to Interference Noise Ratio (SINR)

Signal to Interference plus Noise Ratio (SINR) gives the information transfer rate. It is generally used in wireless communication. Another thing is that Signal-to-Noise-Ratio (SNR) is used in wired communication. SINR is defined as the certain signal power divided by the sum of interference power and the noise. Zero interference reduces the SINR to SNR, which is used less when developing mathematical models of wireless networks such as cellular networks<sup>[20]</sup>.

$$\blacktriangleright \text{SINR} = \frac{P_t G_t G_r \lambda^2}{16 \pi^2 N_t B} \dots\dots\dots ( 3.10 )$$

Where, P<sub>t</sub>= Transmitter Power

G<sub>t</sub>= Transmitter Gain

G<sub>r</sub>= Receiver Gain

N<sub>t</sub>= Noise

B= Bandwidth

λ= wavelength

► Here,

$$\lambda = \frac{c}{f}; \dots\dots\dots (3.11)$$

$c$  = Velocity of the light ( $3 \times 10^8 \text{ ms}^{-1}$ )

$f$  = Frequency

$$N_t = G + A_{0.01\%} + FL \dots\dots\dots (3.12)$$

$G$  = White Gaussian Noise

$A_{0.01\%}$  = Rain Rate

$FL$  = Free Space Loss

It is the quantity to get theoretical upper bounds to calculate the channel capacity in wireless communications like networks in telecommunication engineering and also information technology. The performance of wireless communication is directly related to the RF conditions. In equation (3.10), we considered the transmitter power, transmitter gain, receiver gain and all noise in db; bandwidth in GHz. The total noise  $N_t$  is the combination of white Gaussian noise, rain rate and free space loss.

## Chapter 4

### Simulation Results

#### 4.1: Introduction

The performance of Unmanned Aerial Vehicles (UAVs) is required to demonstrate through the simulation with graphical representation. In this chapter, they have given some graphs to assume the actual scenario of Signal-to-Interference-Ratio with respect to the frequency spectrum.

#### 4.2: Simulation Results

By simulating the research results we can reach a decision. Otherwise it is difficult for us to make a verdict regarding it. There are so many simulating software are available like MATLAB, COMSOL Multiphysics, Simul8, SimScale, AnyLogic etc. From all mentioned simulation software we have chosen MATLAB.

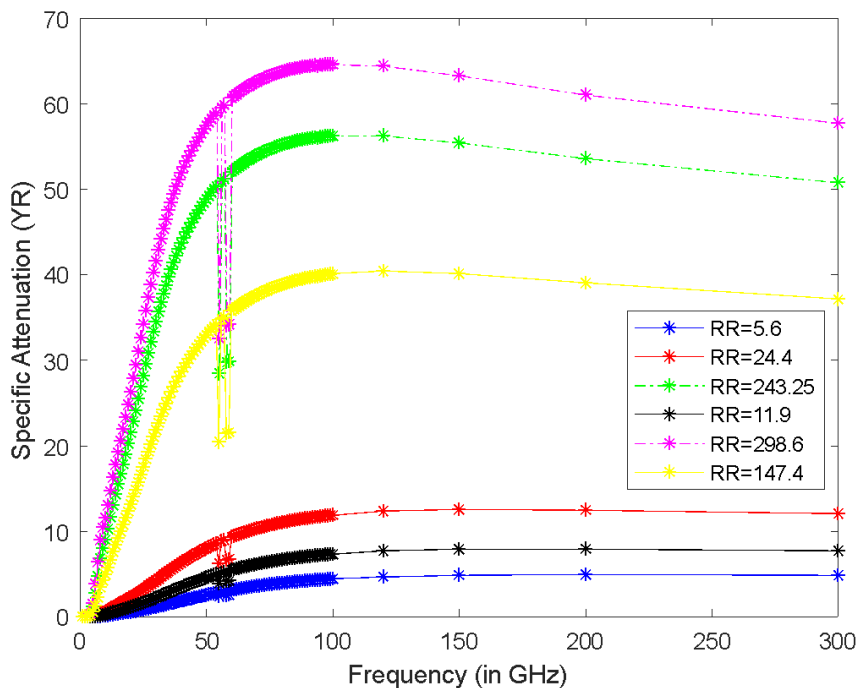


Fig-4.1: Frequency vs Specific Attenuation (YR) for different rain rate (mm) in Chittagong

At first, here plot about Signal-to-Interference-Ratio (SINR) and Rain Rate ( $A_{0.01\%}$ ) versus Microwave Frequency spectrum. Initially, when the frequency is lower i.e 1 GHz and the rain rate also lower level, then the SINR value is around 114.01 dB. At the maximum frequency at microwave range, the SINR value is about 55.51716 dB which is so much enough for reception of the signal from ground station or from other UAVs.

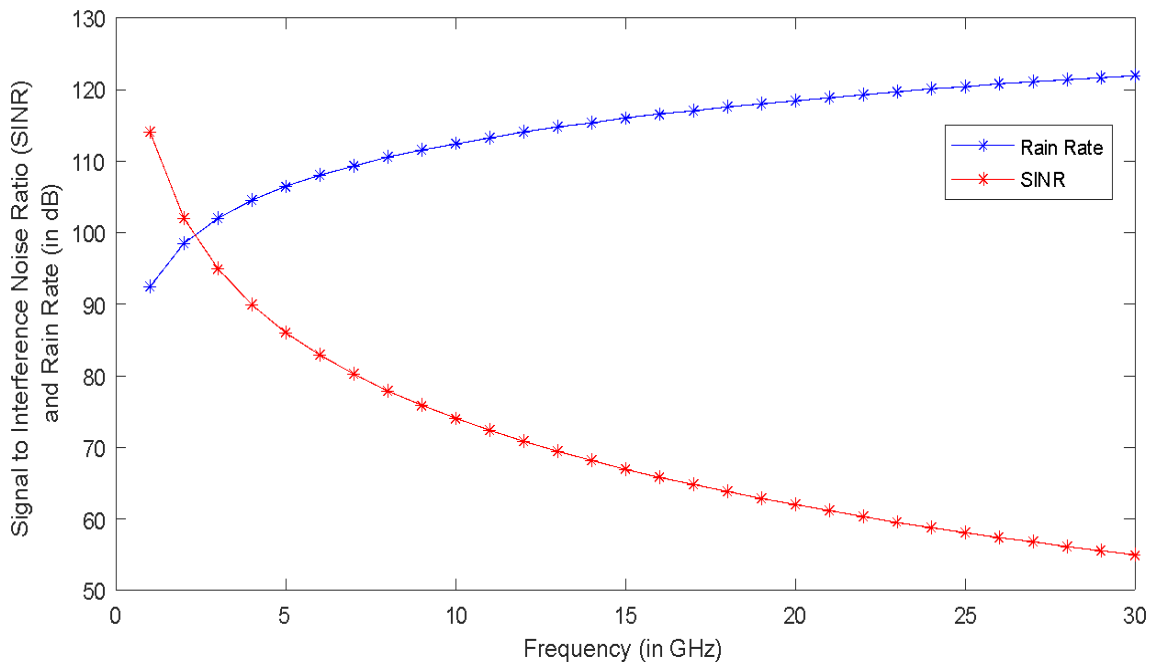


Fig-4.2: Frequency vs SINR and Rain Rate in Chittagong.

Then simulate SINR and Rain Rate ( $A_{0.01\%}$ ) versus mm Wave frequency spectrum. The SINR value decreases smoothly with the increasing frequency. But at a threshold value of SINR, then it decreases with increasing frequency.

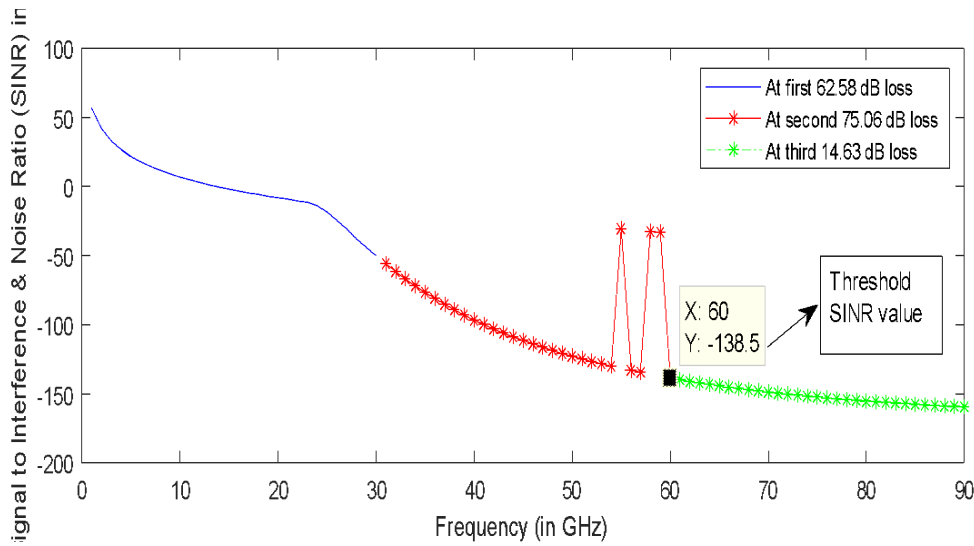


Fig-4.3: Frequency vs SINR for variable BW .

We already know that mmWave frequency spectrum is very wide. So, here data transmission speed is also more wide. So it is very good for gigabit speed communication. Here are three separate curves. They have plotted frequency versus signal-to-interference-noise-ratio for various losses. Here it is also mentioned that, we have plotted that for variable bandwidth. There have taken the frequency spectrum 0-90 GHz. At first, the gap decreases from SINR value 57 dB to almost -50db where the frequency spectrum lies in microwave frequency. But it fluctuates after 54 GHz frequency. So, here we considered -138.5 dB as threshold SINR value at 60 GHz frequency.

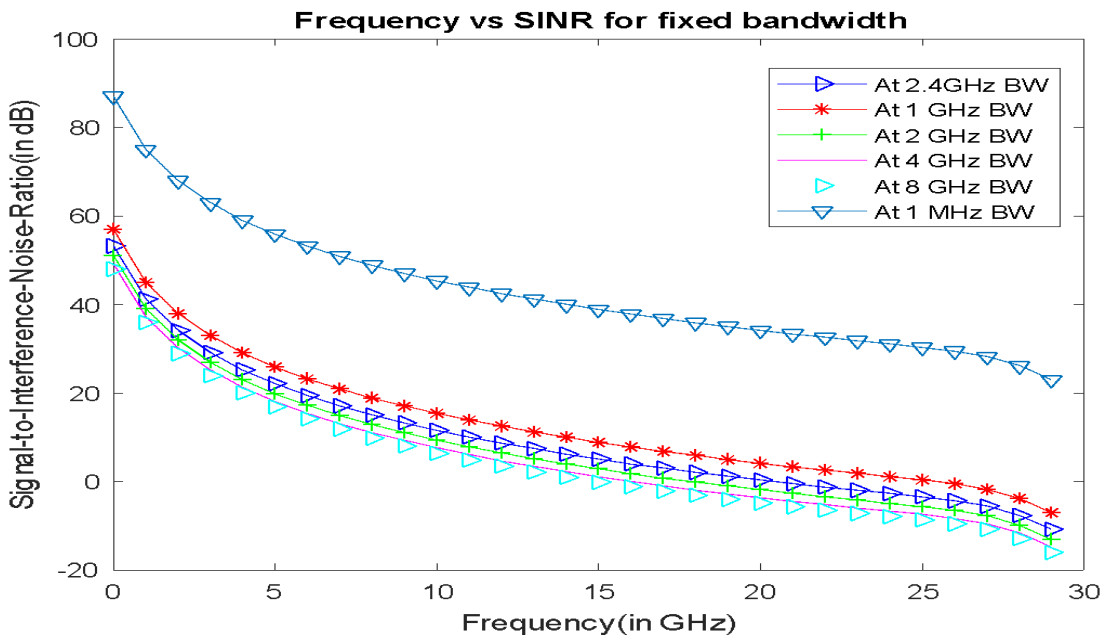


Fig-4.4: Frequency vs SINR for various Bandwidth at microwave Frequency.

The microwave frequency range starts at a single GHz frequency upto 30 GHz. Fig-4.4 shows the SINR value according to microwave frequency range for various bandwidth. We have seen clearly that the SINR value is so much good when the UAV communicates at 1 MHz frequency band. And the SINR value is lower at 8 GHz bandwidth. Although it also provides better UAV communication.

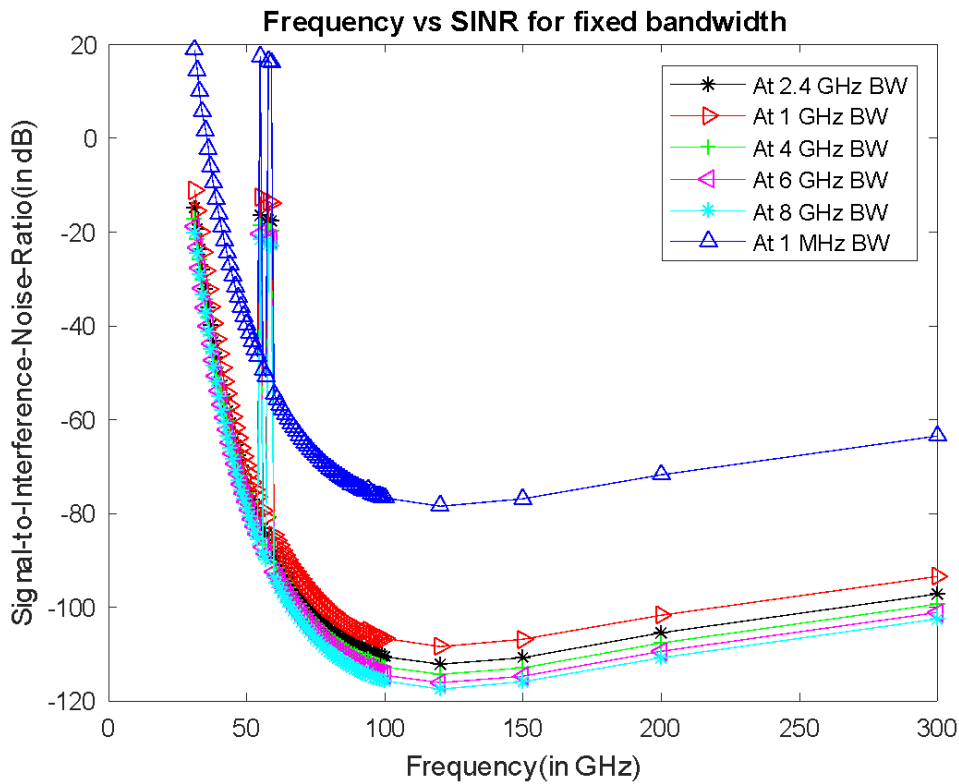


Fig-4.4(a): Frequency vs SINR for various Bandwidth at mm wave Frequency.

At last figure, they simulate the SINR versus both microwave and mm Wave frequency. Here we have seen that the SINR value is decreasing with increasing the value of frequency. The SINR values are comparatively more high in microwave frequency than mm wave frequency. The SINR values of mm wave frequencies are decreasing with the increasing frequency. At a threshold SINR value 14.92537 dB, the transmit and receive signal of UAVs are poor enough over communication media. Then it needs to be switched to a microwave frequency band.

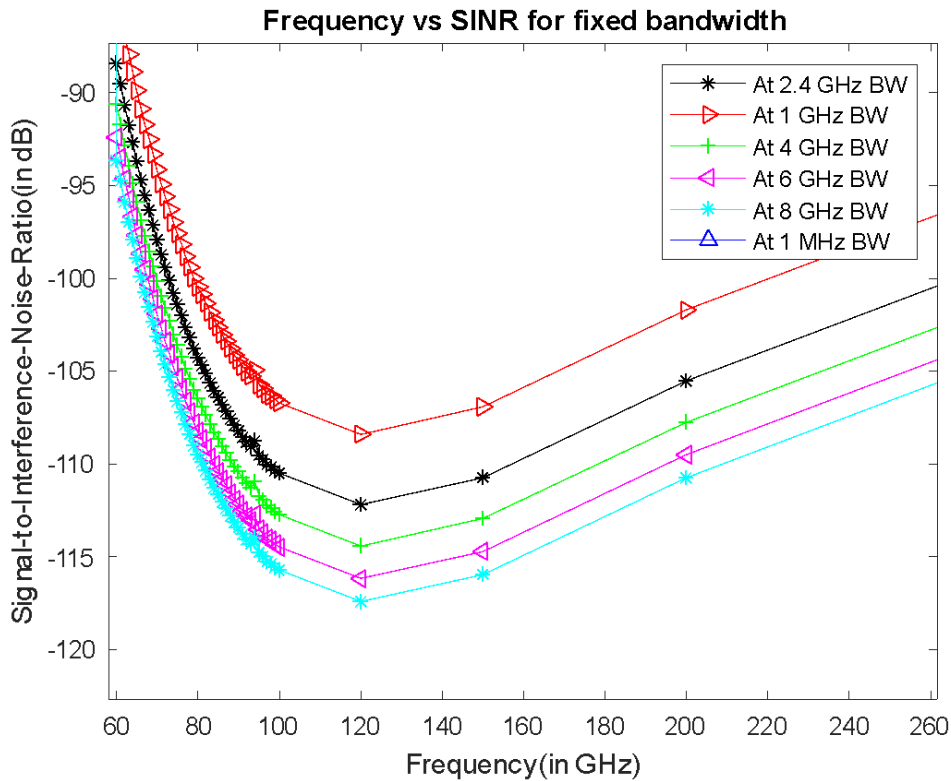


Fig-4.4 (b): Zoom in figure of Frequency vs SINR for various Bandwidth at mm wave Frequency.

Fig-4.4(b) shows the zoom in figure of Fig-4.4(a) Frequency vs SINR for various Bandwidth at mm wave Frequency. For a wide range of frequencies, the curves are not clear in fluctuating portions and also after fluctuating curves. However, the fig-4.4(a) clearly shows that the SINR value is decreasing for frequency range 31 GHz- 120 GHz. But after 120 GHz the SINR value increases slightly.

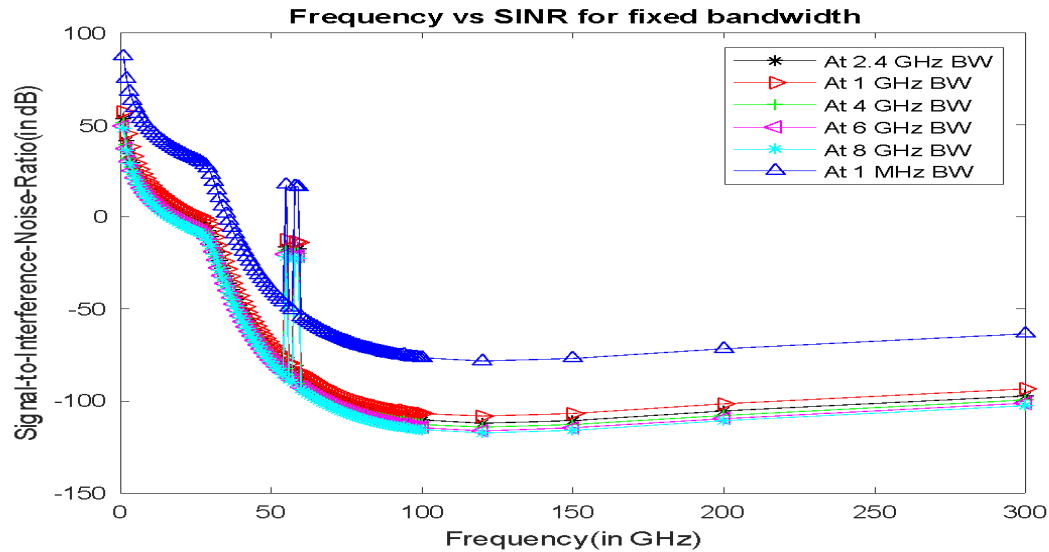


Fig-4.5: Frequency vs SINR for various Bandwidth at both microwave and mm wave Frequency

The above is nothing else than just plotting the frequency vs Signal-to-Interference-Noise-Ratio (SINR) for both microwave and mm wave frequency bands. It is the total summary of above mentioned figures i.e Fig-4.4, Fig-4.4(a), Fig-4.4(b). Assuming Threshold SINR:

In this section we will consider the threshold SINR value from our output results for various BW. Our total output graph is fig-4.5. The SINR value for various BW in microwave and also mm waves we have seen. Now, we analyse and assume the threshold SINR value for various BW. In Fig-4.5, there are 6 graphs we have plotted. Here the “BLACK” marked curve plotting for showing and calculating the SINR vs frequency at 2.4 GHz BW. Similarly, the “RED” marked curve plotting at 1 GHz BW; the “Green” marked curve plotting at 4 GHz BW; the “MAGENTA” marked curve plotting at 6 GHz BW; the “CYAN” marked curve plotting at 8 GHz BW; and the “BLUE” marked curve plotting at 1 MHz BW. The threshold SINR value is about -76.54 dB for used BW 1 GHz where the operating frequency is 54 GHz [Fig-4.6 (a)]. Similarly, The threshold SINR value is about -46.54 dB for used BW 1 MHz where the operating frequency is 54 GHz [Fig-4.6 (b)]. The threshold SINR value is about -82.56 dB for used BW 4 GHz where the operating frequency is 54 GHz [Fig-4.6 (c)]. The threshold SINR value is about -85.56 dB for used BW 8 GHz where the operating frequency is 54 GHz [Fig-4.6 (d)]. The threshold SINR value is about -84.32 dB for used BW 6 GHz where the operating frequency is 54 GHz [Fig-4.6 (e)]

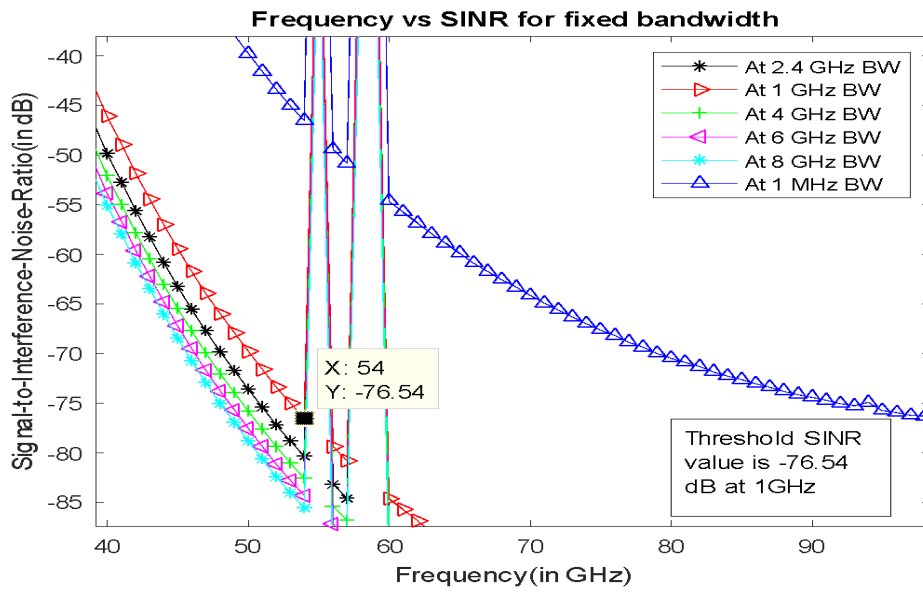


Fig-4.6(a): Zoom in figure of Frequency vs SINR for mm wave ranges at 1 GHz

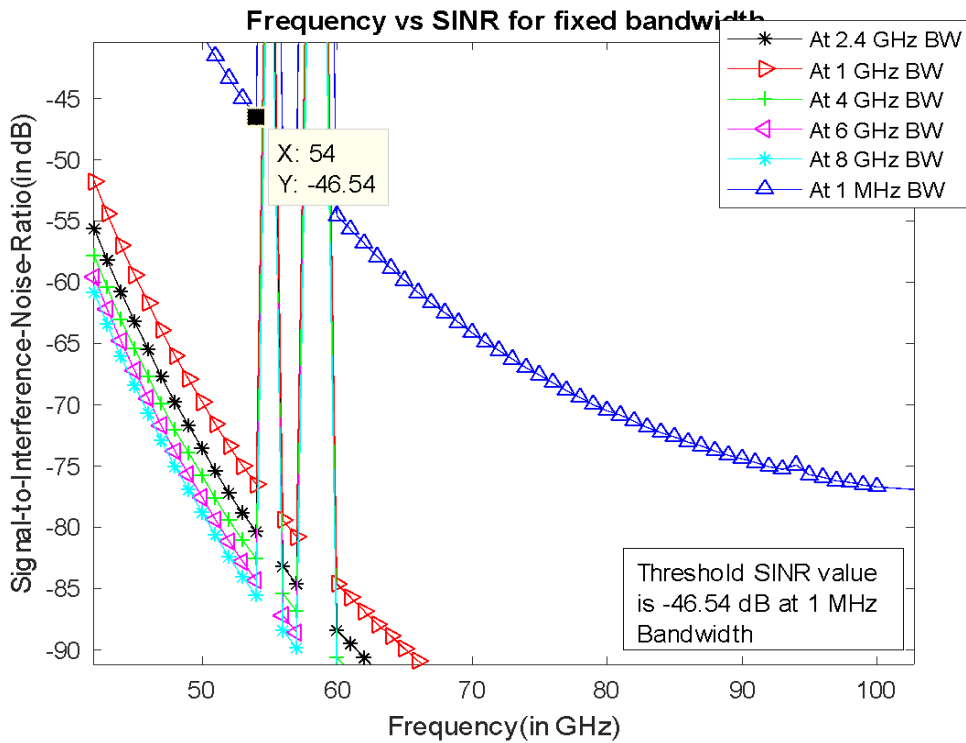


Fig-4.6(b): Zoom in figure of Frequency vs SINR for mm wave ranges at 1 MHz.

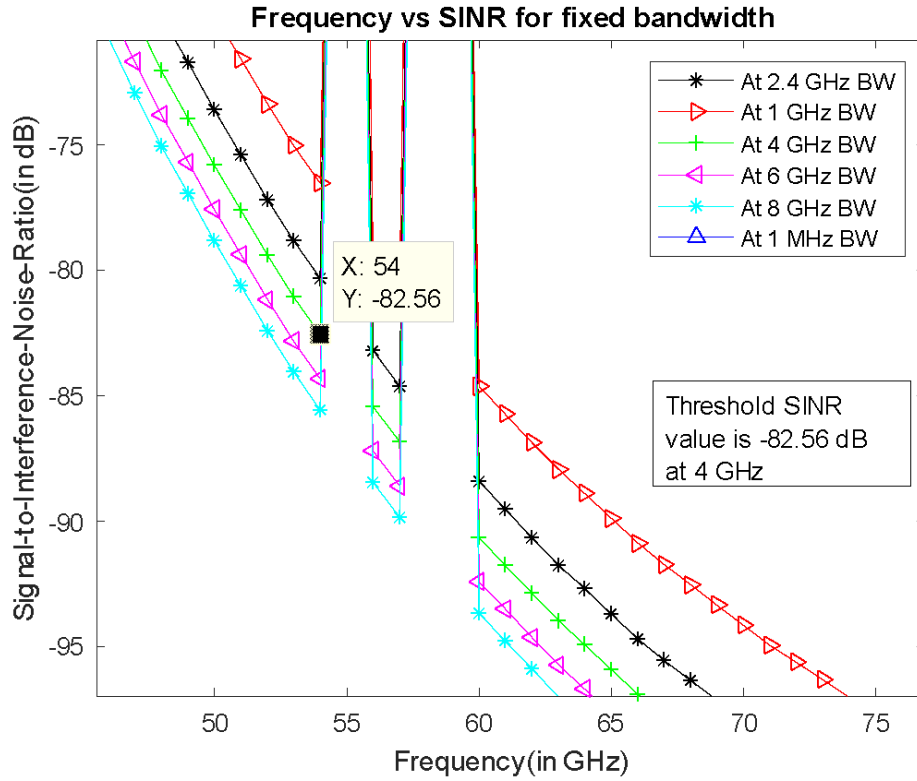


Fig-4.6(c): Zoom in figure of Frequency vs SINR for mm wave ranges at 4 GHz.

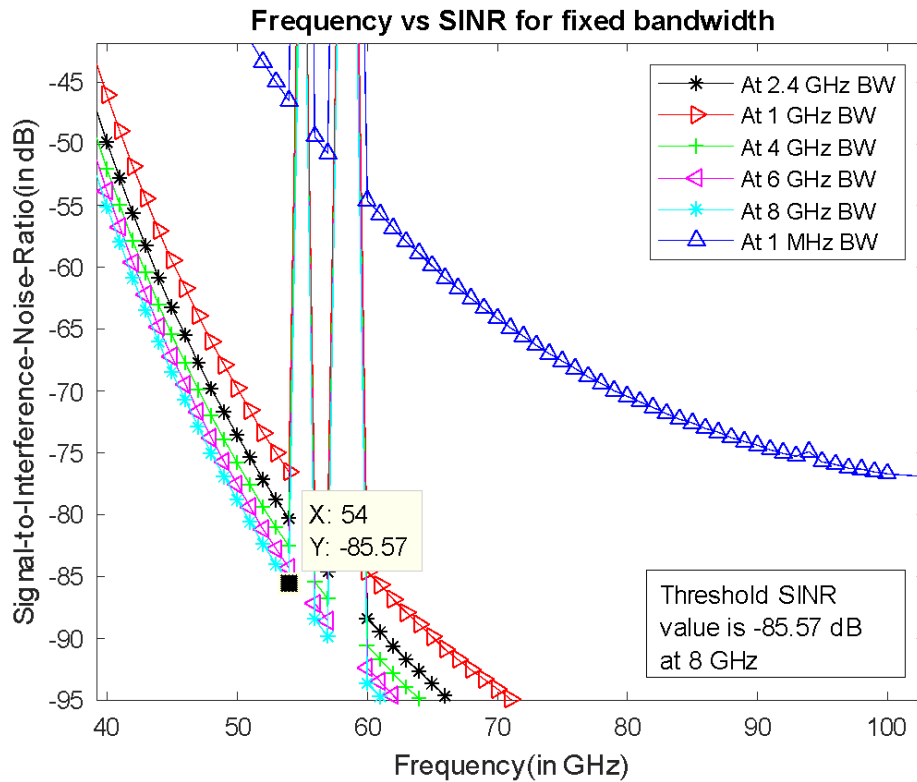


Fig-4.6(d): Zoom in figure of Frequency vs SINR for mm wave ranges at 8 GHz.

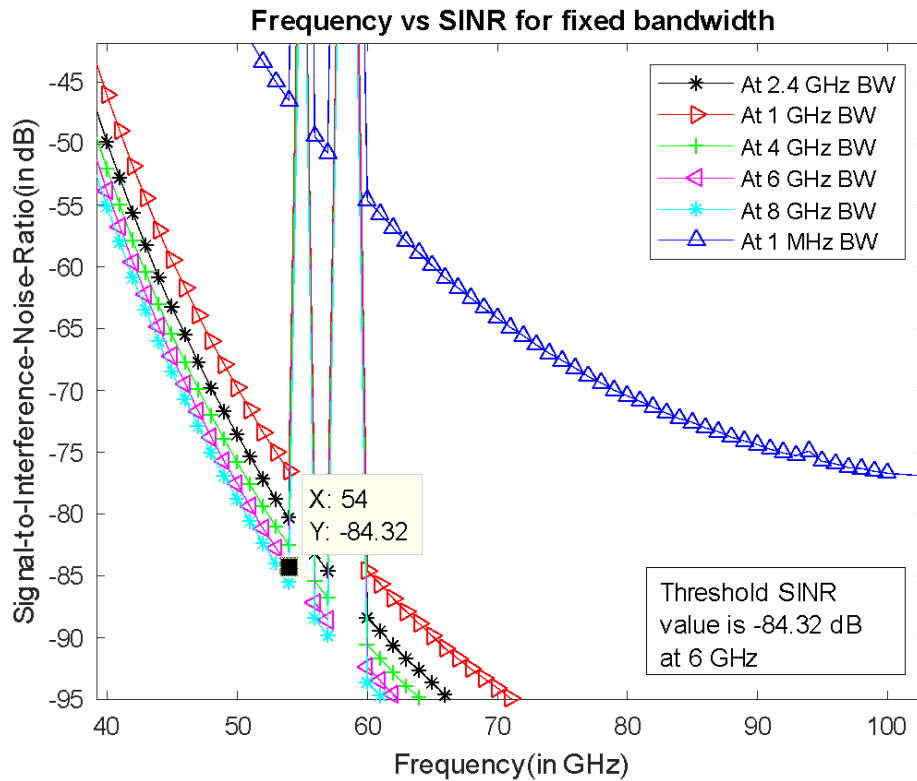


Fig-4.6(e): Zoom in figure of Frequency vs SINR for mm wave ranges at 6 GHz.

Finally we have reached a decision that, The UAVs communication is poor at frequency more than 54 GHz where the Signal-to-Interference-Noise-Ratio(SINR) value is less than the average threshold SINR value about -75.97 dB. So, the communication channel switches mmwave to microwave channel to continue the communication among the connected devices.

## Chapter 05

### Conclusion and Future Opportunity for Research

#### 5.1: Conclusion

In this research, we have deployed dual band Unmanned Aerial Vehicles. Here we have considered various climate factors which mainly interrupt the signal. There have been various factors which change the signal quality like rain attenuation, gauss's loss, floor noise, free space loss, path loss and so on. By considering all of them we have launched a dual band Unmanned Aerial Vehicles commonly known as drones. Here use a well known Signal-to-Interference-Noise-Ratio (SINR) evaluating formulae. For massive communication purposes, drone communication is not efficient at microwave frequency band. But it is more and more flexible and also smooth communication is built on mm wave frequency bands. Because it has so much wide bandwidth. But the mm wave frequency spectrum has a disadvantage too i.e weak signal issue. At a level of communication frequency range, the mm wave spectrum provides bad communication. This time it (UAV) will change the channel using handoff technique i.e it switched from mm wave channel to microwave channel.

#### 5.2: Future Works

In given table-5.1, there are throughput measurements of aerial Wi-Fi networks <sup>[21]</sup>. Data speed can be calculated for UAVs with respect to mmWave and microwave by using this data. Moreover, the researcher can do research about UAV communication with cellular links.

**Table 5.1 : Future work**

<i>Technology</i>	<i>Link</i>	<i>Topology</i>	<i>Throughput</i>
802.11a ( $P_{tx}=20$ dBm)	A2G G2A A2A	Single hop Single hop	UDP- 14 mbps (350m), 29 mbps (50m) TCP- 10 mbps (500m), 17 mbps (100m)
802.11n ( $P_{tx}=12$ dBm)	A2G G2A	Single hope	TCP- 10 mbps (500m), 100 mbps (100m)
802.11ac ( $P_{tx}=10$ dBm)	A2G G2A	Single hope	TCP- 5 mbps (300m), 220 mbps (50m)
802.11a+ 802.11s ( $P_{tx}=12$ dBm)	A2G G2A A2A	Multi hop Multi hop	1 hop- 5 mbps (300m) 2 hop- 8 mbps (300m, infrastructure mode) 2 hop- 5 mbps (300m, mess mode)

Besides, any researcher could forward this research by adding the switching techniques, adjusting the UAV to the cellular communication. The research field of UAVs is more open and emerging for the researcher. So many research opportunities have been described in an article titled “ A Tutorial on UAVs for wireless Networks: Applications, Challenges, and Open Problems ”<sup>[22]</sup> such as channel modeling, deployment of UAVs, Performance analysis, cellular network planning with UAVs, resource management and energy efficiency, trajectory optimization, cellular connected UAV-UEs.

## Chapter 6

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