Methodology for Coexistence of High Altitude Platform Ground Stations and Radio Relay Stations with Reduced Interference

S.H.A.Al-Samhi, N.S.Rajput

Abstract— This paper propounds a novel scheme of mitigation for reducing co-channel interference between HAPGS (High Altitude Platform Ground Station) and radio relay stations. Firstly, in terms of the deployment parameters such as distance between HAPGS, elevation angle of the HAPGS as well as that the azimuth angles of the radio relay station. Then, the effects on radio relay station are due to the rainy conditions between HAPGS and radio relay stations. All calculations are done by using Matlab following the ITU-R recommendations. The results show the interference to noise ratio caused at radio relay station from HAPGS decrease, when distance between HAPGS and radio relay stations increases. The minimum separation distance required to obtain an optimum interference is shown for various azimuth angles in clear sky and rainy conditions.

Index Terms— High Altitude Platform Station, Network Architecture, Coverage of HAPS, Off Axis Angle, Elevation Angle, radio relay stations, Path loss.

◆

1 INTRODUCTION

It has always been a dream of communications engineers to be able to develop a wireless network that, while covering a wide area, would also have low propagation delay and little multipath fading. Recently, a new way for providing wireless communications services emerged. Based on airships or aircraft positioned in the stratosphere at altitudes from 17 to 25km [1, 12], the technology is known as high altitude platforms (HAP) or stratospheric platforms (SPF) as depicted in Fig.1.The platform position allows the HAPS-based system to provide better channel conditions than satellite. A Line Of Sight (LOS) condition is achievable in almost all the coverage area, thus less shadowing areas than terrestrial systems. Therefore, HAPs require much less transmission power for a given Quality of Services (QOS) [1]. Fundamentally, HAPs perform efficiently on tasks that are currently handled using terrestrial and satellite systems. Various applications of HAPs include telecommunication broadcasting services, surveillance, weather monitoring, remote sensing and so on [2].

HAPS bear the advantage of both satellite and terrestrial communication systems such as low cost, large coverage area, rapid deployment, board band capability, large system capacity, low propagation delay and clear line of sight signal paths offered by high elevation angles. The coverage area of single HAPS depends on the elevation angle and the altitude. A multi beam antenna is used for the purpose to cover many subscriber ground stations by single HAPS with high frequency reuse efficiency [3].

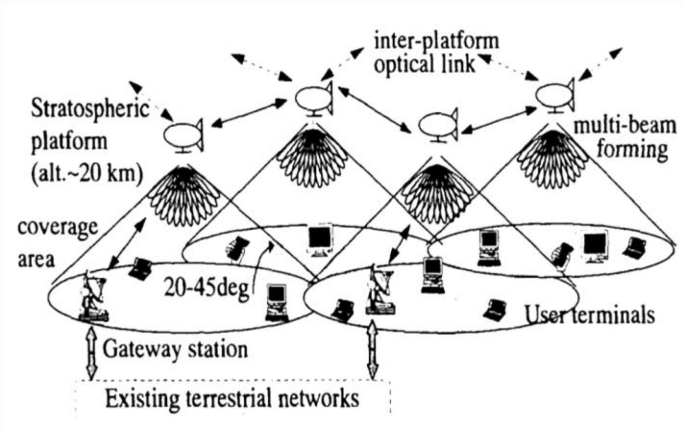

Fig.1. Overview of HAPS network

Therefore, calculation of interference between HAPS and the number gateway station on the ground becomes essential for the region falling under logic coverage area of HAPS. There are three main zones under HAPS footprint that depend on the elevation

---

- *Saeed Hamood Ahmed Al-Samhi is currently pursuing masters degree program in Electronics Engineering, Indian Institute Technology .Banaras Hindu University, Varanasi, U.P.-221005, INDIA, YEMEN Nationality. His area of interest is in the field of wireless communication, Communication via satellite and HAPS, MIMO Technology.* PH-8960127512. E-m*ail: saeed.hamood.ece10@itbhu.ac.in, and saeedalsamhi@gmail.com.*
- *Navion Singh Rajput is currently Assistance professor in Electronics Engineering, Institute Technology .Banaras Hindu University, Varanasi, U.P.-221005, INDIA. His research interests include application of neural networks and PR techniques in the area of wireless sensor networks and MIMO-HAP communication engineering,*PH-945390577.E-mail: nsrajput.ece@itbhu.ac.in

angle of HAP User Terminals (HUTs), Urban Area Coverage (UAC), Suburban Area Coverage (SAC), and Rural Area Coverage (RAC) as show in Fig.4.

In this paper, a scheme is proposed to mitigate co-channel interference from HAPs ground station with radio relay stations that is Fixed Wireless Access (FWA) terminal, by taking into account the high directivity of antenna on the platform and considering the FWA system parameters. The directivity of antenna depends on the elevation angle and a small elevation angle has high gain, narrower beam width, and a small side lobe level.

2 HAPS NETWORK ARCHITECTURE

HAPS has the capability of carrying a large variety of wireless communication payloads that can deliver high capacity broadband services to end users. The high –level HAPS telecommunication network architecture is shown in Fig.2. There are two types of links between the payload and the ground equipment: gateway link and user link. For the user link, the communication is between the platform and the user terminals on the ground in a cellular arrangement permitting substantial frequency. A HAPS gateway link is defined as a radio link between relatively fixed HAP platform and a HAPS gateway station on the ground, located in the (UAC).

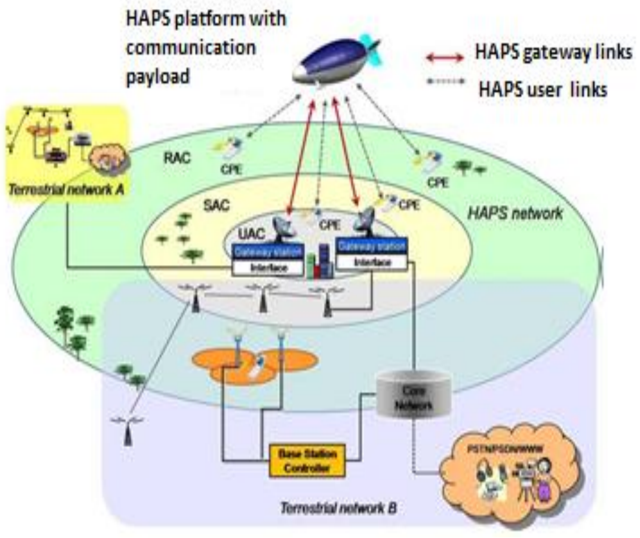

Fig.2. Architecture of HAPS

There are three proposed architectures for HAPS communication systems. The difference between them is mainly on network infrastructure involved. They are stand alone HAPs system, integrated HAPs terrestrial system, and integrated terrestrial HAPs satellite system [4, 5].The differences between the coverage areas of HAPs are discriminated in the Fig.4.

3. HAPS SPECTRUM ALLOCATION

On the allocation of frequency bands, stringent conditions of a non-interference and protection basis are imposed between the HAPS systems using the same or adjacent frequency bands. The right frequency must be chosen to avoid interference with other existing communication systems. Interference mitigation techniques are required to enable frequency sharing between the HAPS system and other services as shown in Fig.3.

WRC-2000 held in Istanbul, has decided that the following frequency bands may be used for the usage of next generation mobile communication based on SPF system worldwide on a co-primary basis. In region 1 and 3:

- 1885 – 1980 MHz: 95 MHz bandwidth
- 2010 – 2025 MHz: 15 MHz bandwidth
- 2110 – 2170 MHz: 60 MHz bandwidth

In region 2:

- 1885 – 1980 MHz = 95 MHz bandwidth
- 2110 – 2160 MHz = 50 MHz bandwidth

Finally, in the WRC-2000, use of the 31 GHz and 28 GHz bands was permitted for the fixed services (FS) by using SPF in some countries as follows:

- 27.5 – 28.35 GHz (850 MHz bandwidth for downlink) Sharing with conventional FS (fixed services), mobile services (MS), and uplink fixed satellite services (FSS).
- 31.0 – 31.3 GHz (300 MHz bandwidth for uplink) Sharing with conventional FS and MS. Adjacent with science services (SS) using passive sensors in the bands of 31.3 – 31.8 GHz.

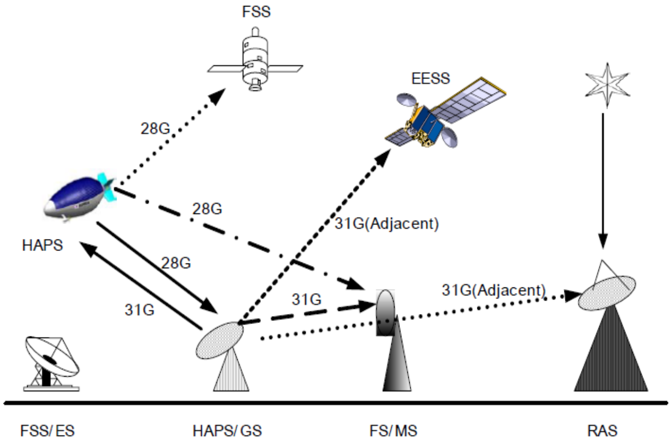

Fig.3.Interference from HAPS into other Communication systems with frequency used

4 HAPS COVERAGE

The coverage area of single HAP depends on the elevation angle and the altitude. Single HAPS is capable of delivering remarkable coverage measuring 400km radius of ground area which is equivalent to 258 ground terrestrial tower. This exceptional coverage achieved by using cells that are beamed through from the aircraft's special digital beam forming antenna and communication on board. HAPS total coverage area is divided into three zones as shown in Fig.4. These zones are necessary to ensure that users have consistent broadband service across HAPS wide footprint of about 1000km in diameter. The zones are described below.

A. Urban Area Coverage (UAC)

Urban Area Coverage is defined as area, 36 to 43 km, out from point directly under the platform [3]. The relative elevation angle is from 30° to 90° and there is line-of-sight communication.

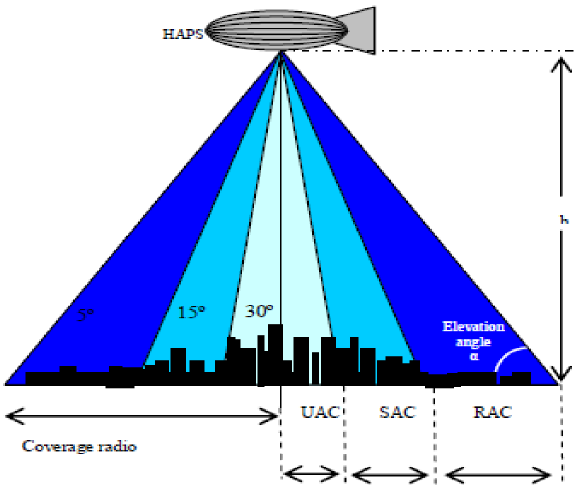

Fig.4. Coverage area for a system based on HAPS

B. Suburban Area Coverage (SAC)

Suburban Area Coverage extends from UAC to76.5km or 90.5km, depending on the operating altitude [3].The relative angle of elevation is from 15° to 30° and the obstacles near the receiver cause signal shadowing and attenuation of direct signals.

C. Rural Area Coverage (RAC)

Rural Area Coverage is reserved for dedicated high-speed point to point access and wide-area application at lower frequency bands [3]. The relative angle of elevation is between 5° and 150.

5 ADVANTAGES OF HAPs OVER EXISTING TERRESTRIAL AND SATELLITE TECHNOLOGIES

The development of communications services from HAPs will lead to many possible applications. HAPs have the following potential advantages over terrestrial and/or satellite architectures [6, 7]:

- Relatively low cost upgrading of the platform.
- Rapid deployment
- Broadband capability using the mm-wave LMDS bands;
- Large area coverage (compared with terrestrial) - long range terrestrial links are severely affected by rain attenuation (see below) and obstructions to the line-of-sight paths;
- Very large system capacity, smaller cells than satellite, with link budgets considerably more favourable.
- Flexibility to respond to traffic demands through extensive and adaptable frequency re-uses.
- Ideally suited to multimedia services, broadcast, and multi-cast;
- Low propagation delay, compared with satellites;
- Fewer problems with obstructions in the Line of Sight (LOS) paths compared with terrestrial;
- Less ground-based infrastructure required than with terrestrial;
- Lower launch costs than satellites.

6 INTERFERENCE PROPAGATION PATHS

The interference propagation path space and terrestrial stations of the three broadband systems in the Fig.5 are: C1- interference from HAPs to terrestrial receivers, C2-interference from terrestrial transmitters to HAPs, A1-interfernce from terrestrial transmitters to HAPGS (HAP Ground Station), and A2-interfernce from HAPGS to terrestrial receivers, F-interference from earth to HAPGS, E – interference from HAPS to GEO (Geostationary Earth Orbits) satellite receiver, B1-interference from earth station to HAPS, B2-interference from HAPGS to GEO satellite receiver [8]. Co-channel interference arises because several users utilize the same frequency. Interference is due to the antenna radiation pattern side lobes and the contribution from the main lobes can be meaningful in case of beam overlap. The high altitude platform system is based on multi-spot antenna beams and looks like a cellular system where each beam is a cell.

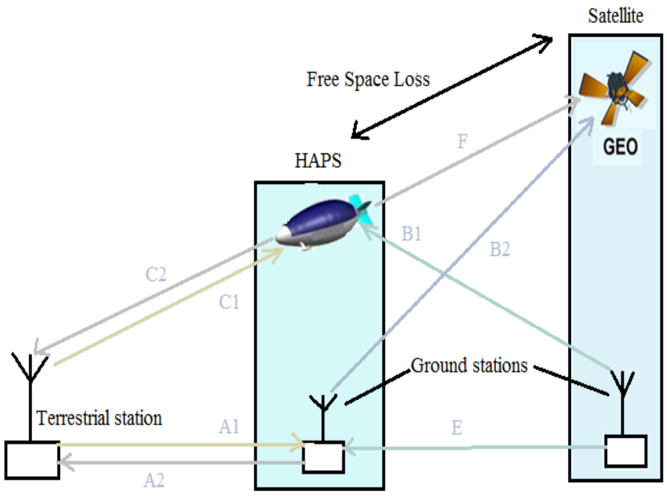

Fig.5. Interference propagation paths between space, HAPS and terrestrial stations

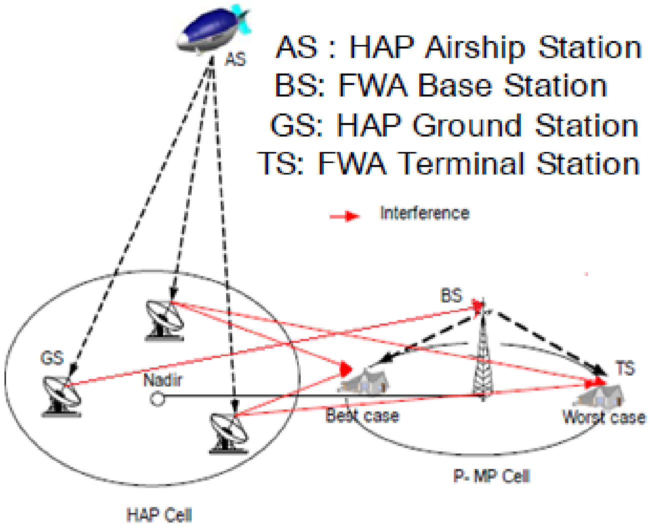

Fig.6.Interference from HAPGS to FWA (P-MP)

6.1 Interference from HAPGS to FWA Terminals

The interference power from HAPS ground station to FWA station, I (dB (W/MHz)), is obtained by equation (1):

$$I = P_{TX_{GS}} - L_{fTX_{GS}} + G_{TX_{GS}}(\theta_{H-F}) - L_S - L_{ATM} - L_{Obs} + G_{RX_{FWA}}(\theta_{F-H}) + L_{fRX_{FWA}} \quad (1)$$

Where:

P_{TX-GS} : Transmission power density from HAPGS (dB (W/MHz))

L_{fTX-GS} : Feeder loss of HAPS ground station (dB)

$G_{TX-GS}(\theta_{H-F})$: Antenna gain of HAPGS toward the direction of FWA station (dBi)

Ls: free space loss between HAPGS and FWA station (dB)

$$L_S = 20\mathrm{Log}\left(\frac{4\pi d \text{ X } 1000}{\lambda}\right) \quad (2)$$

L_{ATM}: Atmospheric absorption loss between HAPGS and FWA station (dB),

L_{Obs}: shielding loss between HAPGS and FWA station (dB)

$G_{RX-FWA}(\theta_{F-H})$: Receiving antenna gain of FWA station towards the direction of HAPGS (dB)

$L_{fRX-FWA}$: Feeder loss in FWA station (dB).

The ratio of interference power to the receiver thermal noise, I/N, is obtained by equation (3):

$$I/N = I - 10\log\,(293\ k \times 10^{NF_{10}} \times 10^{6}\ \ dB \quad (3)$$

Where:

K: Boltzmann's constant = 1.38 × 10–23(J/K)

NF: noise figure of FWA station (dB).

The basic model for estimating the interference from a HAP ground station into a P-MP terminal station is shown in Fig.6. Multiple HAP ground stations and multiple P-MP terminal stations are distributed randomly with a Rayleigh distribution for height in the multiple cell coverage area of the HAP. For each ground station transmitter, a terminal station receiver is randomly placed within the line of sight and at an arbitrary angle. Interference from HAPGS downlinks can be minimized by taking into account high directivity antennas on the platforms. Taking in to account FWS system parameters it could be possible to mitigate the interference by HAPS platforms through the use of specific coordination area or power flux density limits.

6.2 Rain attenuation

Rain has a direct impact on the quality of system as it attenuates the signal by absorbing or scattering radiations. The geometry of rain scattering interference is presented in Fig.7. Attenuation due to rainfall is one of the most important constraints in the performance of HAPs system in tropical regions which have high intensity of rain rate. Rain attenuation is significant and must be taken into consideration for the calculation of carrier to noise ratio.

Rain attenuation causes the absorption and scattering of microwave signal which results in several degradations [9, 10, and 11], of signal energy in consequence, this results in several degradation for carrier signal that is transmitted from HAPs airship and increases the system noise power. The specific attenuation,Y_R Canbe computed using equation(4):

$$Y_R = KR^{\alpha}\ \mathrm{db/km} \quad (4)$$

Where K and α are frequency-dependent coefficients and R is the rain rate (mm/hr).The effective path length,d_{eff} of the link is obtained by multiplying the actual path length d by a distance factor r as shown:

$$d_{eff} = d \text{ x } r \quad (5)$$

The value of r is computed by using equation (6):

$$r = \frac{1}{1+{}^{d}/_{d_0}} \qquad (6)$$

$$\text{Where:} d_0 = 35e^{-0.015 r R_{0.01}} \qquad (7)$$

The rain attenuation exceeded for 0.01% of the time, so $A_{0.01}$ is computed in equation (8):

$$A_{0.01} = Y_R d_{eff} \text{ dB} \qquad (8)$$

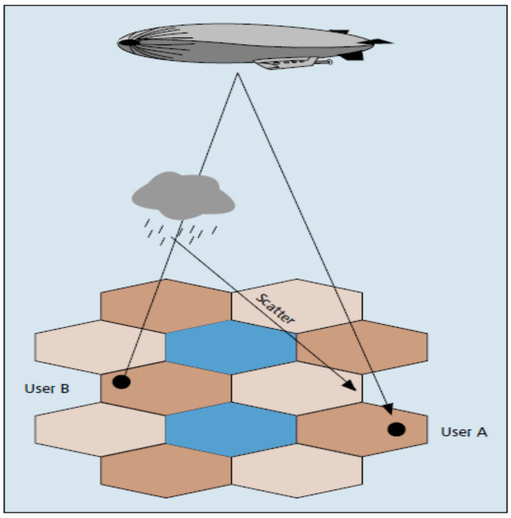

Fig.7. Geometry of rain scattering

7 HAPS IN TELECOMMUNICATION APPLICATIONS

HAPs can also be applied for telecommunication applications such as fixed, broadband wireless applications (BWA), for integration with 3G/4G mobile systems and depicted in Fig.8, also for providing multicast, broadcast services (DVB-H) [12].More specifically:

1. BWA: provides potentially very high data rates in terms of mega bits per second.

The spectrum allocation for HAPs worldwide for the provision of BWA services consists of a pair of 300MHz bands in the 47/48GHz band, although the 28/31GHz is also specified in much of Asia. Many services can be provided, including but not limited to: ISDN access, web browsing, high-resolution video conferencing, large file transfers, and Ethernet LAN bridging. A BWA communications system typically supports various types of user terminals fixed, portable and mobile. The typical bit rate of the access link is a few Mbps for most fixed and portable terminals, while a several hundred Mbps link is available for limited fixed terminals with antennas larger than typical ones [12].

2. 3G/4G: In addition to broadband wireless access at 47/48GHz and 28/31GHz, ITU has also endorsed the use of HAPs in the IMT-2000/UMTS spectrum for the provision of 3G mobile services. HAPs and UMTS systems will use the same RTTs (Round Trip Times) and provide the same functionality and meet the same service and operational requirements as traditional terrestrial tower-based UMTS systems. The HAPs systems can be designed to, replace the tower base station network with a "base station network in the sky") or can be integrated into a system that employs traditional terrestrial base station towers, satellites and HAPs [12, 13].

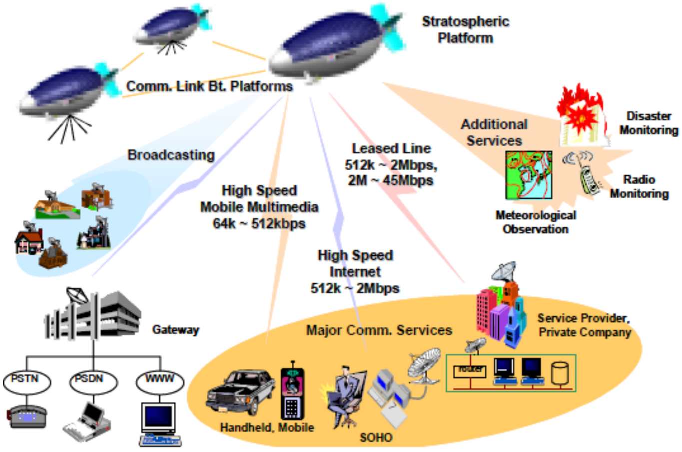

Fig.8. applications and services of HAPS

3. Multicasting/Broadcasting: The DVB-H, handheld version of DVB-T, has been demonstrated in Oxford, UK. Similar to any other terrestrial-based wireless systems, the reception quality of DVB-T and DVB-H is highly dependent on the type of environment (urban / suburban / rural). To reduce the percentage of outage areas (blank spots), higher communication link margin and/or higher tower and/or larger number of towers are required. HAPs located at high altitude could potentially be used as an alternative solution for DVB/DAB repeater/transmitter [12].

8 SIMULATION RESULT AND DISCUSSION

These graphs are plotted using MATLAB in order to show the relationship between I/N and the separation distance and the azimuth angle in clear sky and rainy conditions.

The most important thing of this study is to get the minimum separation distance needed for optimum interference to noise ratio.

8.1 Relation between I/N and separation distance for clear-sky condition

Fig.9. shows the graph of I/N versus distance between HAP ground station and the FWA station for various azimuth angles in clear sky condition. From the Fig.9 it can be seen that interference to noise ratio decreases when separation distance increase for several azimuth angles. When azimuth angle is 30^0 , the minimum separation distance required to get optimum I/N is 182km and when azimuth angle equal to 90^0 , the minimum separation distance to get optimum I/N is 50km for getting optimum interference -10dB.

Finally, for azimuth equal to 150^0 or above, the minimum separation distance required for obtaining optimum I/N is 5km.

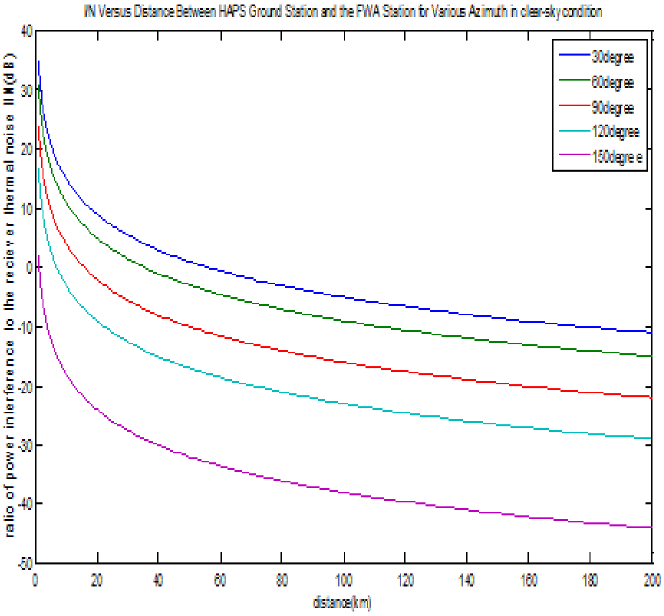

Fig.9. I/N versus separation distance for various azimuth in clear sky

8.2 Relation between I/N and separation distance for rainy condition.

Fig.10. shows the graph of I/N versus distance between HAP ground station and the FWA station for versus azimuth angles in rainy condition.

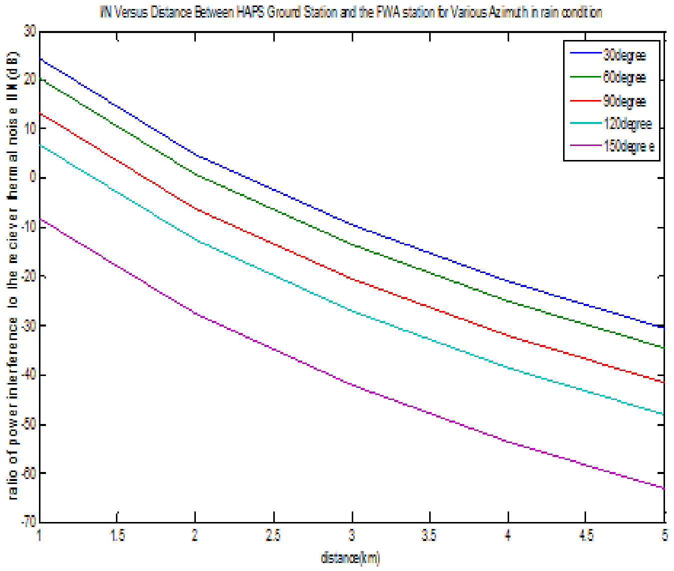

Fig.10. I/N versus separation distance for various azimuth in rainy condition

8.3 Relation between I/N and azimuth of FWA station

Fig.11. depicts I/N versus azimuth from the receiving antenna of FWA station at fixed distance of 5 km. It is evident that if azimuth is less than 40^0 and above 150^0, then I/N is constant, but from 40^0- 150^0, I/N decreases. Therefore, the effect of varying the azimuth angle on I/N depends greatly on the antenna gain of FWA station.

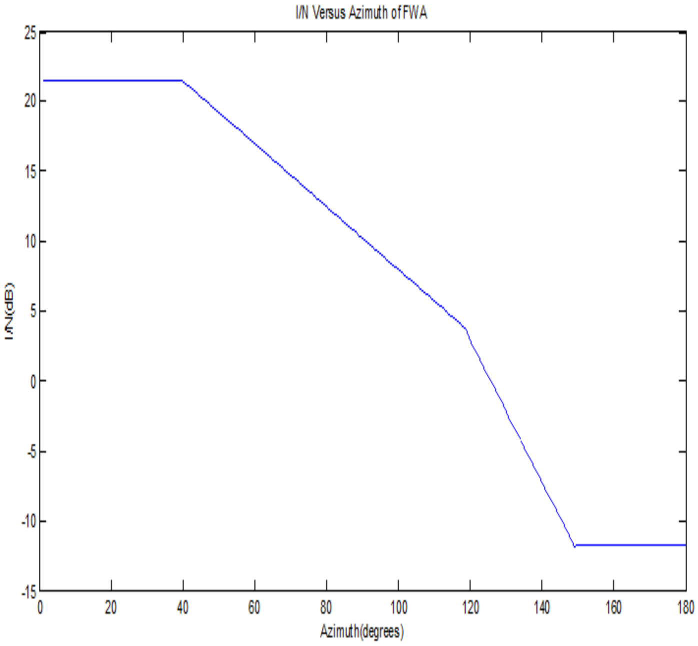

Fig.11. I/N versus azimuth angle from FWA station at fixed distance 5km.

9 CONCOULATION

The interference caused at the FWA station from HAPS ground station is evaluated with all the results as computed using Matlab. In the clear sky condition as shown in Fig.9, the optimum I/N decreases when the separation distance increases for various azimuth and for azimuth equal to 150^0 or above, the minimum separation distance to obtain optimum I/N is 5km. In the rainy condition as shown in Fig. 10, the interference to noise ratio is relatively small if compared to the case in the clear sky condition. Therefore, for any azimuth equals to 150^0 or above, I/N is very small, so the interference power is not significant at the FWA station. Thus the effect of rain attenuation must be taken in the consideration. Since the antenna gain is constant for azimuth less than 40^0 and above 150^0, the value for I/N stays constant within this range as shown in Fig.11, but for azimuth between 40^0 to 150^0, the I/N decreases. Hence the effect of varying the azimuth angle on I/N depends greatly on the antenna gain of FWA station.

REFERENCE

[1] Ruiz.J.L and Zavala.A.A and Leon.B.B," Co- channel interference for terrestrial and HAPS system in cellular structure ", robotics and automotive mechanics conference, IEEE, CERMA 2009/83, 2009.
[2] Yang and A. Mohammed," Wireless communication from HAP: applications, deployment and development", Blekinge institute of technology, karlskrona, SE3719, Sweden, 2011.
[3] Rec.ITU-RF.1500,"Preferred Characteristics of systems in the fixed service using High Altitude Platform Operating in the bands 47.2-47.5GHZ and 47.9-48.2 GHz", 2000.
[4] ITU-R F.1569, "Technical And Operational Characteristics For The Fixed Service Using High Altitude Platform Stations In The Bands 27.5-28.35 GHz And 31-31.3 GHz", 2002.
[5] A. Mohammed and Z. Yang, "Broadband Communications and Applications from High Altitude Platforms" International Journal of Recent Trends in Engineering, Vol 1, May 2009.
[6] Awoniyi, Oluwaseyi Oluwadare, "Stratospheric channel modelling", Department of Electrical Engineering Blekinge Institute of Technology Karlskrona, Sweden ,May 2007.
[7] T.C.Tazer&D.Grace,"High- Alttitude platforms for wireless Communications"IEEE Electronics&Com.Eng.J,vol.13, pp.127-37, june2001.
[8] Vasilis F. Milas and Dr Philp Constantinou, "Interference Environment between High Altitude Platform Networks (HAPN), Geostationary (GEO) Satellite and Wireless Terrestrial Systems", Wireless Personal Communications, Springer, PP257-274, 2005.
[9] Rec. ITU-R P.530-12, "Propagation data and prediction methods required for the design of terrestrial line-of-sight systems", 2007.
[10] N.S.Rajput, K.Singh and S.H.A.AL.Samhi,"parametric mitigation of co-channel interference between HAP Ground station and FWA using neural networks "proc AIATA-2011, IT.BHU, 2011.
[11] S.H.A.Al-Samhi, N.S.Rajput," Mitigation of Co-Channel Interference between High Altitude Platforms(HAP) ground stations and Fixed Wireless Access (FWA)Stations", in Proc.ICCLSP-2012,MERI,PP.71,January-2012.
[12] A. Widiawan and R. Tafazolli, "High Altitude Platform Station (HAPS): A Review of New Infrastructure Development for future Wireless Communications", Wireless Personal Communications, 42: 387-404,
[13] S.H.A.Al-Samhi, N.S.Rajput," Interference Environments between High Altitude Platform Station and Fixed Wireless Access Stations", IJERA, Vol.2.pp. 1508-1513, Mar-Apr, 2012.
[14] Rec. ITU-R F.1609-1, "Interference evaluation from fixed service systems using high altitude platform stations to conventional fixed service systems in the bands 27.5-28.35 GHz and 31-31.3 GHz", 2006.
[15] ECC Report 156,"Condition for possible co-existence between HAPS and Gateway links and other services/systems in the 5850-7075 MHz band" , Cardiff, January 2011.