Interference Environment between High Altitude Platform Station and Fixed Wireless Access Stations

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Abstract—High Altitude platform station (HAPS) technology is a new technology that can perform the tasks currently handled using terrestrial and satellite systems. Anew broadband telecommunication systems has been recently proposed for provision of fixed, mobile and personal services adopting the use of high altitude platform station placed in a fixed position in the stratospheric layer at heights from 17-25 km. This paper examines the interference between HAPS and FWA (fixed wireless access). Hence the characteristic of the interference from single HAPS toward FWA based station established appropriate separation distance and off axis angle of FWA to avoid harmful interferences. The effect of interference on FWA depend on the parameter as elevation angle of the HAPS, elevation angle HAPS ground station as well as that the azimuth angles of the FWA station .Calculations are done by using MATLAB software following the ITU recommendation. Result shows interference reduces when separation distance between HAPS ground station and FWA station increase as well as the off axis angle of FWA station gain large will help to reduce the interference.

Key words: HAPS; FWA; Network and Component of HAPS; Interference between HAPS and FWA.

I. INTRODUCTION

High Altitude Platform station is the name of technology for providing wireless narrowband and broadband telecommunication services as well as broadcasting services with either airships or airplanes. HAPS is operating in the stratosphere at altitudes of typically 17-25km [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 [2,3]. HAPS bears 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. In this paper, a scheme is proposed to mitigate co-channel interference from HAPS to FWA terminal, by taking into account the high directivity of antenna on the platform and by considering the off axis angle of FWA base station . This paper is divided into nine parts: Section I gives brief introduction about systems based on HAPS; in Section II architecture of HAPs is described. Altitude Platform of the HAPS, is covered in section III and Sections IV, describes the component of the HAPS communication systems. Coverage of HAPS in section V. HAPS spectrum allocation described in section VI and the interference from HAPS to FWA is described in Sections VII. Then, 4G services via HAPS described in section VIII. The result discussions are taken up in section IX. Finally, section X, conclusion of this work.

II. HAPS NETWORK ARCHITECTURE

The HAP-based based wireless systems could be the third infrastructure followed by terrestrial-based and satellite-based systems. These three systems could be integrated in the future to construct the more powerful network infrastructure by making up the weakness of each other. There are three proposed architectures for HAPS communication systems. The difference between them is mainly on network infrastructure involved as shown in Fig.1.HAPS has the capability of carrying a large variety of wireless communication payloads that can deliver high capacity broadband services to the end users. They are stand alone HAP system, integrated HAP terrestrial system and integrated terrestrial HAP satellite system [4, 5].

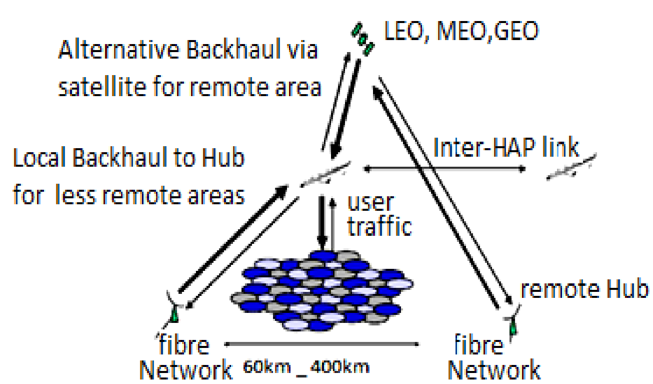

Fig.1. Architecture of HAPS

1. Stand alone HAP system

HAPs are potential to be a standalone system in many applications, weather monitoring, and disaster surveillance as shown in Fig. 2. In rural or remote areas, it is rather expensive and inefficient to deploy terrestrial systems. A backbone link could be established by fiber network or satellite depending on the applications.

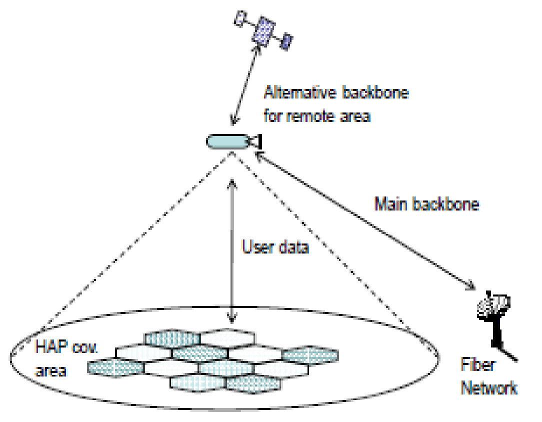

Fig.2. A stand-alone HAP system

2. Integrated Terrestrial-HAP-Terrestrial System

Fig.3. HAPs are taking into account more macro cells and serve a large number of high- mobility users with low data rate. The HAP network can be connected to terrestrial system network through a gateway .Due to its wide coverage area and competitive cost of deployment, HAPs could be employed to provide services for areas with sparse population density, where it would be expensive to deploy fiber or terrestrial networks.

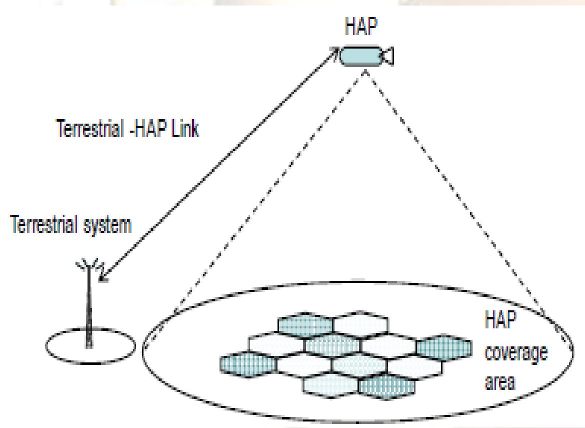

Fig.3. Integrated HAP-Terrestrial system

3. Integrated Terrestrial-HAP-Satellite System

The network architecture is shown in Fig.4. It is composed of links between satellite and terrestrial system. It can provide fault tolerance, and thus support a high Quality of Service. The most important feature of this kind is that it takes the advantage of the best features of both HAPs and satellite communication systems. First, the capabilities of the satellite to broadcast and multicast are used to transmit information from fiber network to the HAPs network deployed. Secondly, HAPS improve the satellite performance over the earth by providing a better delivering system. Inter-platform communications can be established for extending coverage area.

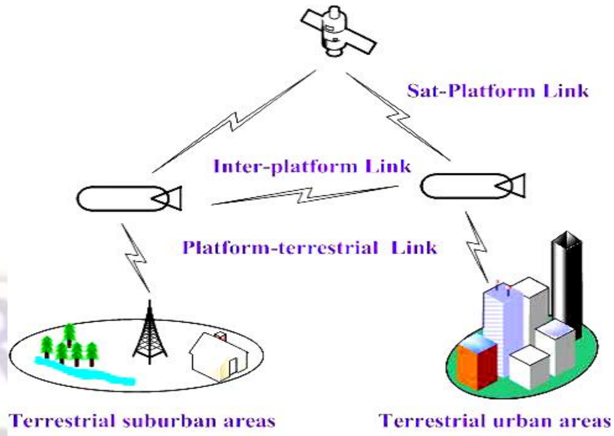

Fig.4. Integrated Terrestrial-HAP-Satellite systems

III. ALTITUDE PLATFORM OF THE HAPS

The main reasons for the position of HAPS are: Firstly, these altitudes are above aviation air lines. Secondary, average wind speed is sufficiently low as shown in fig.5, while the extremely low ambient density of greater altitudes would render the placement of a vehicle unfeasible. Also airships are more susceptible to wind or pressure variations and they have to compensate for the drift. However, it is rather difficult to finely control the attitude of an airship remotely. Third, the platform position allows the HAPS based system to provide better channel conditions because the distance from HAPS is much smaller than that to satellite, since LOS conditions is achievable in almost all the coverage area. Thus less shadowing areas are generated than terrestrial systems. On the other hand , decrease distance to HAPS compare to satellite ,significant the path loss decrease, low transmit power for given QOS [1].

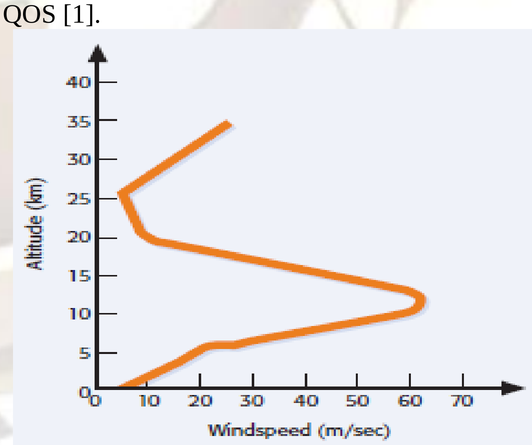

Fig.5. *Wind velocity with respect to altitude*

IV. COMPONENT OF HAPS COMMUNICATION SYSTEMS

A HAPS communication system consists of sky and ground segments [6]. The sky segment includes mainly the platform and the onboard communications payload. Fig.6, gives an atypical communications system via HAPS.

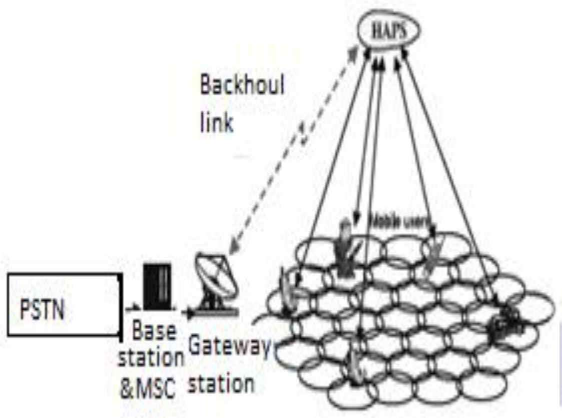

Fig.6. HAPS system configuration

1. Platform

The HAPS is a flying aircraft (manned or unmanned).the aircraft is kept relatively stationary with respect to the ground by flying in a tight circle, while the airships will employ station keeping technology to counteract movements due to wind and remain stationary. The size of the platform determines the capacity of the platform in carrying a certain maximum payload weight at certain altitude.

2. Energy Supply

The preferred from of energy source is solar power, since for buoyancy in the thin atmosphere. HAPS are designed to have large surfaces suitable for lining solar panels. The main problem is the storage of energy for overnight use. The Regenerative Fuel Cell (RFC) has been identified as the preferred of providing continuous source of power for HAPS based communications systems as compared to traditional batteries because it is lighter and has the ability to provide power in the day and night. During the day, hydrogen and oxygen undergo an electrochemical reaction to generate electrical power and water. The hydrogen and oxygen are extracted from the water by electrolysis and stored for the regeneration of electrical power at night.

3. Communication Payload

The HAPS telecommunications payload consists of multi beam light–Wight reflector or phased array antennas transmit/receive antennas for gateway links with ground switching stations, and very large bank of processors that handle receiving, multiplexing, switching and transmitting functions. The payload can utilize various multiple access techniques CDMA, TDMS. Antenna subsystem is one of the key components of a HAPS communications payload. It projects cells from the HAPS onto ground typically in a cellular pattern. This makes the HAPS communications system is sensitive to co-channel interference depending on the choice of multiple access and reuse factor. The high performance of antennas are required to support high spectral efficiency and also required to limit unwanted out –of –band emission. The main considerations in the design of a HAPS antenna are operation frequency, side-lobe requirements, system coverage, system capacity, platform capability, platform stability and reliability [7].

4. Ground Segment

The sizes of the HAPS coverage area and of the spot beams within the coverage area are determined by the antenna array which designed to match the demand for capacity within any selected coverage area. A HAPS system may provide mobile cellular coverage or fixed wireless services to region ranging from high density urban area to low density rural areas. The HAPS user terminals will be designed to share the same radio interface as traditional terrestrial systems and, therefore, a single handset will work with both a HAPS and traditional terrestrial towers. This will enable regional and worldwide roaming with single handset.

V. HAPS COVERAGE GEOMETRY HAPS

The coverage area of single HAP depends on the elevation angle and the altitude as shown in fig.4. A multi beam antenna is used for the purpose to cover many subscriber ground stations by single HAPs with high frequency reuse efficiency [4].

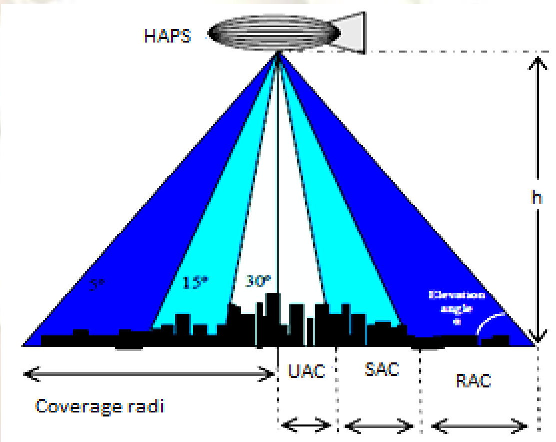

Fig.7. Coverage area for a system based on HAPS

Single HAPS is capable of delivering remarkable coverage measuring 400km radius of ground area which is equivalent to 258 ground terrestrial tower. There are three main zone under HAPS footprint that depend on the elevation angle of HUTs (HAP User Terminal), Urban Area Coverage (UAC), Suburban Area Coverage (SAC), and Rural Area Coverage (RAC) as shown in table.1.This exceptional coverage achieved by using cells that are beamed through from the aircraft's special digital beam forming antenna and communication on board.

VI. HAPS SPECTRUM ALLOCUTION

Frequency is closely related to specifications of radio communication equipment and radio link parameters and quality. International telecommunication union (ITU) has allocated spectrum around 48/47 for global service, and the another frequency depend on the region as table.1.HAPS services operate at 600MHZ at 48/47 GHZ frequency worldwide allocation from the ITU except in Asia where it operates at 31/28 GHZ, though it can be deployed in some 3G services which are around the 2GHZ range [8].

Table.1
Frequency allocation for HAPS

Frequency band	Areas	Direction of the link	Services	Services to be shared with
47.9–48.2 GHz 47.2–47.5 GHz	Global	Up and downlinks	Fixed service	Fixed and mobile services Fixed satellite service (uplink) Radio astronomy band neighboring
31.0–31.3 GHz	40 countries worldwide (20 countries in Asia, Russia, Africa, etc. and in Region 2)	Uplink	Fixed service	Fixed and mobile services Space science service in some areas Space science service band (passive) neighbouring
27.5–28.35 GHz[1]	40 countries worldwide (20 countries in Asia, Russia, Africa, etc. and in Region 2)	Downlink	Fixed service	Fixed and mobile services Fixed satellite service (uplink)
1885–1980 MHz 2010–2025 MHz 2110–2170 MHz	Regions 1 and 3	Up and downlinks	IMT-2000	Fixed and mobile services (in particular, terrestrial IMT-2000 and PCS)
1885–1980 MHz 2110–2160 MHz	Region 2	Up and downlinks	IMT-2000	Fixed and mobile services (in particular, terrestrial IMT-2000 and PCS)
Region 1: Europe, Africa, Russia, the Middle East, and Mongolia Region 2: North and South America Region 3: Asia, except for the Middle East, Pacific countries, and Iran				
[1] The use of this band will be reviewed in WRC-07 after further sharing studies with fixed satellite services				

VII. INTERFERENCE FROM HAPS TO FWA STATION

For interferences calculation, atmospheric absorption loss, free space loss, feeder loss and rain attenuation are account for the total loses. The propagation attenuation due to atmospheric gases in the slant path between HAPS airships and ground stations has been estimated using the minimum propagation attenuation due to atmospheric gases [9]. Atmospheric absorption loss, L_{atm}, is the losses due to atmospheric absorption. In the path between a HAP and terrestrial terminals, atmospheric gases including water vapor cause attenuation, which depends on the distribution along the path of meteorological parameters such as temperature, pressure and humidity, and thus varies with the geographic location of the site, the month of the year, the height of aground terminal above the sea level, the elevation angle of the slant path and the operating frequency [9]:

$$L_{atm} = {21.21}/{[1 + 0.95050\theta + 0.030650\theta^2 + h(0.3381 + 0.44660\theta) + h^2(0.2331 + 0.11690\theta)]} \quad (1)$$

Where

θ= Elevation angle (degree)

h=Ground station altitude above sea level (km)

Attenuation due to rainfall is one of the most important constraints in the performance of line of sight microwave link above a certain threshold frequency. Rain attenuation causes the absorption and scattering to microwave signal results in severe degradation of the receive signal level.

The specific attenuation, YR is computed using [9] using the power –law relationship:

$$Y_R = KR^{\alpha} \quad db/km \quad (2)$$

Where K and α are frequency-dependent coefficients and R is the rain rate (mm/hr).Values of the coefficients K and α are determined as function of frequency (GHZ) in the range between 1 to 1000GHZ.In the linear and circular polarization and for all path geometries, K and α are express as blow:

$$K = {[K_H + K_V + (K_H - K_V)COS^2\theta COS2\tau]}/{2} \quad (3)$$

$$\alpha = K_H\alpha_H + K_V\alpha_V + (K_H\alpha_H - K_V\alpha_V)COS^2\theta COS2\tau]/2K \quad (4)$$

Where

Θ = path elevation angle

τ = polarization title angle relative to the horizontal

The coefficient, K_H, K_V, α_H,and α_V for horizontal polarization and vertical polarization are given from[10].

The effective path length d_{eff} is computed by:

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

The value of r is computed by using equation

$$r = \frac{1}{1 + {d}/{d_0}} \quad (6)$$

Where: $d_0 = 35e^{-0.015rR_{0.01}}$ (7)

The rain attenuation exceeded for 0.01% of the time, so $A_{0.01}$ is computed as

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

The interference power from the spot beam of HAPS airship to FWA station, I(dB(W/MHz)), is obtained by equation (9).

$$I = P_{Tx-H_mB_n} + G_{Tx-H_mB_n}\left(\theta_{H_mB_{n-F}}\right) - L_s - L_{ATmHm\ -F} + G_{Rx-FWA}\left(\theta_{F-H_m}\right) - L_{fRx-FWA} \quad (9)$$

Where:

$P_{Tx-H_mB_n}$: Transmission power density of spot beam (Bn) of HAPS (Hm) (dB(W/MHz))

$G_{Tx-H_mB_n}\left(\theta_{H_mB_{n-F}}\right)$: Antenna gain of spot beam of HAPS airship toward the direction of FWA station (dBi)

L_s: Free space pass loss between HAPS airship and FWA station (dB) shown in the following:

$$L_s = 20\log\left(\frac{4\pi d \times 1000}{\lambda}\right) \quad (10)$$

d: distance between HAPS airship and FWA station (km)

λ= wave length (m)

$L_{ATmHm\ -F}$: Atmospheric absorption loss between HAPS airship and FWA station (dB)

$G_{Rx-FWA}\left(\theta_{F-H_m}\right)$: receive antenna gain of FWA station toward the direction of HAPS airship (dBi)

$L_{fRx-FWA}$: Feeder loss of FWA station in the receive side (dB)

The ratio of the interference power to the receiver thermal noise, I/N, is obtained by equation.

$$I/N = I - [10log(293 \times KTB + NF)] \quad dB \quad (11)$$

Where: K: Boltzmann's constant =1.38×10^{-23}(J/K)

B= bandwidth, T= 293K (room temperature)

NF: noise figure of FWA station (dB).

VIII. 4G SERVICES VIA HAPS

4G communication systems require high data rates and high capacity communications links with appropriate QoS at low cost. The ITU Working Group 8 illustrated the benefits from

3G/4G services via HAPs [11], declaring that HAPs can facilitate various types of mobile, fixed, and portable terminals and use different frequency bands for establishing backhaul links. 4G systems will include actually existing and emerging fixed and mobile networks including broadcasting. A single base station on the platform with a wide beam width antenna could provide of service over large sparsely populated areas. The benefits such as offering coverage in a large area, quite direct propagation paths without obstacles and elimination of the expensive resources spent in ground station installations, maintenance and wire installations underground[12]. HAPs also avoid the need for large terrestrial infrastructure because 3G/4G services require smaller cell sizes and hence more ground based infrastructure.

IX. Results and Discussion

These graphs are plotted using MATLAB in order to show the relationship between I/N and the distance from HAPS nadir to FWA under clear sky and rainy conditions. The most important thing of this study is to get enough separation distance needed to reduce I\N from HAPS nadir to FWA base station.

1. Relationship between I\N and Distance from FWA to the HAPS nadir.

At the difference in elevation angle of HAPS to FWA, the I\N is calculated by MATLAB.Table.2, shows a nonlinear relationship in Fig.8. I\N increase constantly until about 40km from the HAPS nadir, then reached up to the peak point and decrease down as the distance increase. When I\N reached to the peak point it mean the elevation angle of HAPS toward FWA is equal to the elevation angle of HAPS toward HAPS ground station. Finally, when FWA base station is separate away from HAPS ground station, interferences will gradually decrease.

Table.2

Result that calculated by MATLAB for change elevation angle

Elevation /off axis	20^0			30^0			60^0		
	I	d	I/N	I	d	I/N	I	d	I/N
0	-108.4	58.4	16.5	-128.3	40	-3.4	-138.3	23	-13.4
30	-134.3		-9.5	-154.3		-29.4	-164.3		-39.4
90	-141.3		-16.5	-161.3		-36.4	-171.3		-46.4

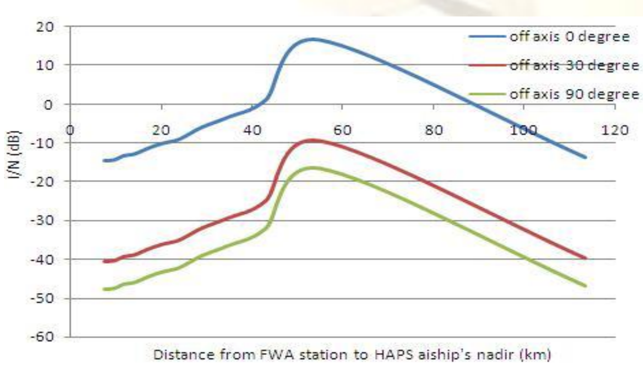

Fig.8. I\N ratio versus from FWA to HAPS nadir

2. Relationship between I\N and FWA base station angle under clear sky.

The result calculated by MATLAB as Table.3. When the elevation angle from HAPS to FWA is 200 the I\N decrease drastically from 0^0 to 10^0 FWA angle ,then more than 10^0 the I\N drop gradually as Fig.9.

Table .3

Result that calculated by MATLAB in clear sky condition

FWA angle direct to HAPS	Gain of FWA antenna toward HAPS	Power interference	I/N(dB)
0	15	-108.4	16.5
30	-11	-134.4	-9.48
60	-16	-139.4	-14.48
90	-18	-141.40	-16.48

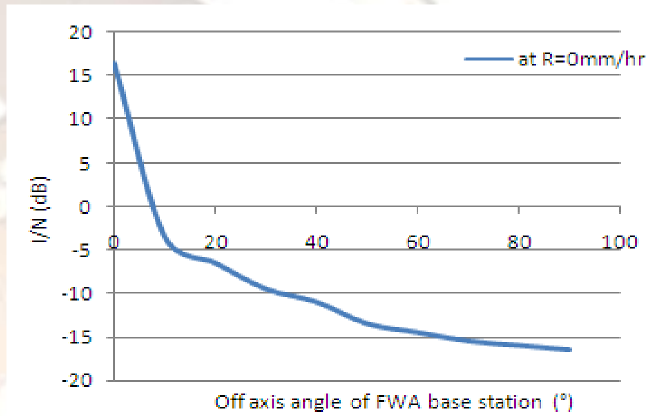

Fig.9. I\N versus FWA angle at 200 elevation angle in clear sky condition

X. CONCLUSION

The interference caused on the FWA station from HAPS is evaluated with all the results as computed using MATLAB. In this paper the interferences examined from HAPS to FWA station. The appreciate solution to reduce interference to noise ratio when the FWA station is separate away from HAPGS. The worst interference exists when elevation angle from HAPS toward FWA station is equal to elevation angle from HAPS toward HAPGS; as well as if the gain of FWA station is large it will help to reduce the interference.

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