Design of Wireless Communication System to Cover Specific Area by Using HAPS
(SULAYMANIYAH - IRAQ AS A MODEL)

Kanar R. Tariq, Mohammed B. Majed and Zaid A. Hamid
College of Science and Technology
University of Human Development – Sulaymaniyah - Iraq

ABSTRACT-**This paper is meeting the principles of how to design coverage area for Sulaymaniyah city, using a new technology, which named HAPS. It started with small introduction for HAPS with its advantages, compare it with terrestrial and satellite systems, and specify requirements for design. Such as, specify the center of coverage area to find the coordinates. Then, supposed the coverage area for the city, elevation angle, and the location of earth stations which will connect HAPS with other networks and reduce the Interference with Fixed Services (FS) and Fixed Satellite Services (FSS).Mitigation technique of interference is given. Also, path loss and fading loss has been applied to meet the geographic of Sulaymaniyah city.**

Key words—high-altitude platform (HAP), co-channel interference, fractional degradation in performance (FDP), terrestrial microwave link (TML), frequency sharing criteria.

I. 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].The technology is known as high altitude platforms (HAP) or stratospheric platforms (SPF) as depicted in Figure1, 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 [3]. 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 [4].
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.
The paper is organized as follows: in section I, we give an introduction to the HAP concept in wireless communications with its advantages, compare it with terrestrial and satellite systems. In section II and III, an overview of communication applications from HAPs, coverage zone, frequency allocations, well-known HAP research activities and trials are given. In section IV and V, main characteristics of HAP system has been denoted, specify requirements for design in Sulaymaniyah city. Finally, conclusion is given in section VI.

II. HAPS COVERAGE GEOMETRY

HAPS

The coverage area of single HAP depends on the elevation angle and the altitude as shown in Figure 1. A multi beam antenna is used for the purpose to cover many subscriber ground stations by single HAPs with high frequency reuse efficiency [4].

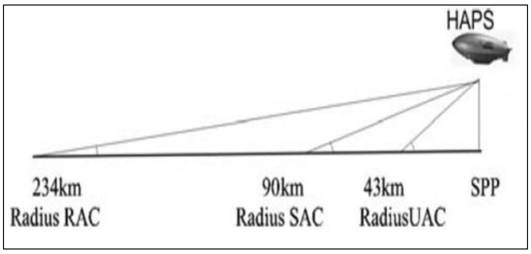

Figure 1. Coverage area for a system based on HAPS

Single HAPS is capable of delivering remarkable coverage measuring 400km radius of ground area which is equivalent to 258Km 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 Figure1.This exceptional coverage achieved by using cells that are beamed through from the aircraft’s special digital beam forming antenna and communication on board.

III. 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 Figure .3 [2][9].

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.

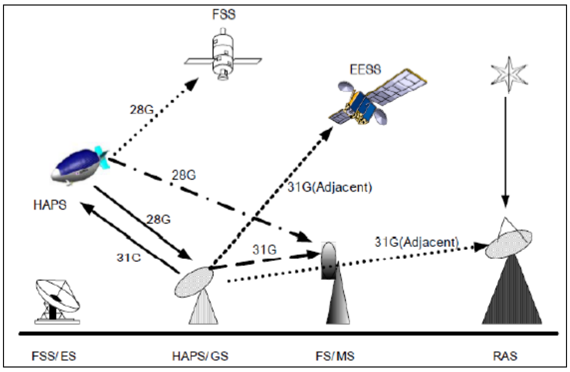

Figure 2.Interference from HAPS into other Communication systems with frequency used

IV. METHODOLOGY FOR EVALUATION OF THE IMPACT OF COCHANNEL INTERFERENCE FROM HIGH-ALTITUDE PLATFORMS TO TERRESTRIAL MICROWAVE LINKS

The methodology described in this section provides a model for the evaluation of the impact of co-channel interference from the downlink (stratosphere-to-Earth) emissions of HAPs to the reception of terrestrial point-to point (P-P) systems. Spectrum sharing between high-altitude platform networks and terrestrial systems involves time varying phenomena such as HAP's movement, interference geometry, propagation conditions, and HAPN traffic allocation during day and night [7].

In such cases it is appropriate to model the effects of interference in terms of *fractional degradation in performance* (FDP) [2]. The outage probability of a digital system can be written in the following form [9]:

$$P_o = C\left[10^{-\frac{DFM}{10}} + 10^{-\frac{TFM}{10}} + 10^{-\frac{\frac{C}{I}-CNC}{10}}\right] \quad (1)$$

where C is a constant depending on climate, terrain and link parameters, DFM is the dispersive fade margin in dB, TFM is the thermal fade margin in dB, C / I is the ratio of unfaded signal power to the noise-equivalent value of interference power in dB, and CNC the value of carrier-to noise ratio at which the performance criterion is just met in dB [5][6].

Considering that:

a) Modern digital systems usually have dispersive fade margins larger than their thermal fade margins; the first term in equation (1) can be ignored for interference.

b) Since the difference in decibels between the unfaded carrier-to-noise ratio and the critical carrier-to-noise ratio (CNC) is the thermal noise fade margin (TFM), the fractional increase in P_o , the probability of exceeding the performance objective, is equal to the ratio of the interference power I to the noise power N_T.

We conclude that the fractional increase is equal to I/N_T, for a constant interference power I. Such an increase in P_o will be designated as a fractional degradation in performance (FDP). If an interferer caused an interference power I_i for a fraction of reference period I_f , and was absent for the remainder of the period, the incremental FDP due to this interference is given by:

$$\Delta P_{o,i} = \frac{I_i F_i}{N_T} \quad (2)$$

The FDP due to a set of events [8][9], where the I_{th} event consists of the fraction of time that the interference had a power I_i is given as:

$$FDP = \sum \Delta P_{o,i} = \sum \frac{I_i F_i}{N_T} \quad (3)$$

Where the summation is taken over all interference events. Considering the interference geometry, depicted in Figure 3[10], where ϴ is the discrimination angle between the direction of the main beam of HAP towards the HAPUT and the direction of the interfered terrestrial station, **φ** is the discrimination angle between the azimuth of the TML (T1-T2) and the direction towards the HAP.

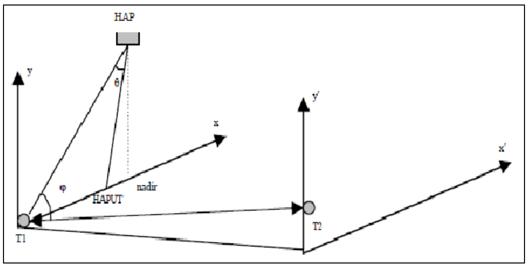

Figure 3. Geometry of interference between HAP and TML

The interference power from the HAP to the terrestrial receiver is obtained by the following formula [10]:

$$I_{(H-T)} = P_{H-T} + G_H(\varphi) + G_T(\varphi) - FSL_{(H-T)} - L_{feeder} - L_{Atomospheric} \qquad (4)$$

V. METHODOLOGY

a) **Location:** according to Sulaymaniyah Map, and after studying area. The center of coverage area location's coordinates of HAPS will be as shown in Figure 4:

Figure 4. HAPS coverage area in Sulaymaniyah city's map

(Lon: $45^o.26$ E, Lat: 35^o33 N)

Altitude of HAPS: as known, the range of HAPS altitude between 17km and 22km. So, we will supposed to put the station on an altitude of 21km as clarify in (Figure 4)

b) Foot print: according to whole area of Sulaymaniyah, the foot prints of coverage area shown in (Google map), the area of Sulaymaniyah (17023km^2)

By Elevation Angle: we can calculate the distance (Radius) by equation 5 and 6:

$$d1 = \frac{Altitude}{tan(\theta_1)} = \frac{21\ km}{tan(54)} = 15.257km \qquad (5)$$

$$d2 = \frac{Altitude}{tan(\theta_2)} = \frac{21\ km}{tan(33)} = 32.337km \qquad (6)$$

In the proposed scenario of covering Sulaymaniyah city by HAPS , our design include (FS) and (FSS) and used same frequency that we want to use in HAPS system to investigate the interference , by assuming the positions of fixed services as:

FS 1: Lon: 44.7E Lat: 35.33N
FS 2: Lon: 44.8E Lat: 35.2N
FSS: Lon: 44.81E Lat: 35.5N

So, the proposed scenario is to install the HAPS System in the Sulaymaniyah city and put the two ground stations with elevation angles (54 and 33) degree, and the distance that we have (d1 and d2), in term of getting lowest interference with FS and FSS systems.

Also, the HAPS ground station will be fixed in the following location:

GS1: Lon: 45.43E Lat: 35.33N (Ɵ=54 degree)
GS2: Lon: 44.91E Lat: 35.33N (Ɵ=33 degree)

So we have enough distance with respect to the total area of the city then also the enough distance between FS and FSS. Figure 5 illustrate the whole scenario with expected system interference.

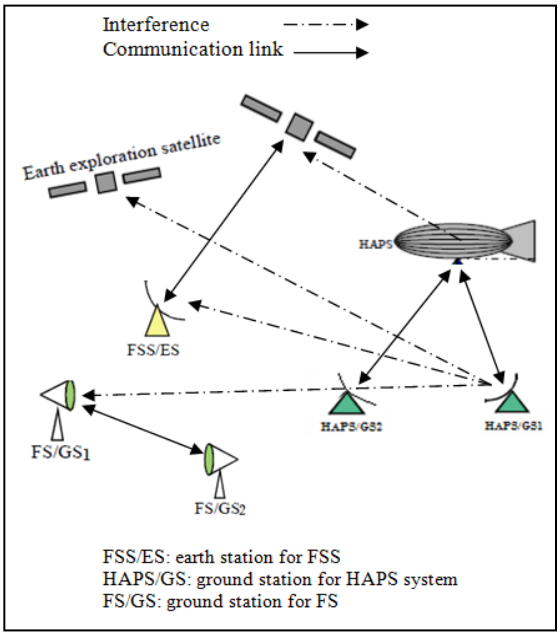

Figure 5. Scenario of Interference situation including HAPS, FSS, FS.

Thus, general interference mitigation techniques must be taking in our consideration for the development of a system using HAPS [11].

1) *Increasing minimum operational elevation angle:* Interferences from the FSS earth station to the HAPS ground station that between FS ground station and HAPS ground station could be reduced by increasing minimum operational elevation angle of HAPS ground station so as to increase antenna separation angle toward ground

stations for other services. As a result, required separation distance could be shortened.

2) *Improvement of radiation patterns of antennas on board HAPS and their ground stations* Interference from the HAPS airship to the satellite space segment could be reduced by pattern shaping of each beam of multibeam antenna on board HAPS airship, because the pattern shaping improves main-lobe and side lobe characteristics. (Figure 6) [4][11]

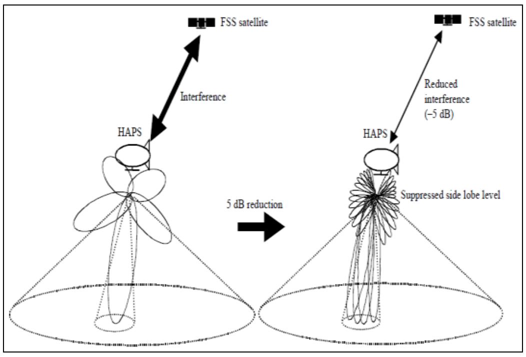

Figure 6. Improvement of Radiation pattern

Development of radiation pattern (gain suppression in the elevation angle smaller than the minimum operational elevation angle in HAPS system) of the antenna in the HAPS ground station is also effective to reduce interference between the HAPS ground station and stations on the ground in other services.

HAPS are supposed to provide a variety of communication services for different kinds of users and special antenna requirements need to be addressed, depending on the application targeted for the system. Indeed, the antenna characteristics have to match different, and often opposite, properties/requirements of the applications. For instance, on-board operating radars require narrow-beams and broadband antennas, whereas broadcasting payloads need relatively wide beams and narrowband antennas.

A typical on-board antenna design would seek low power consumption, high reliability, and minimum weight and size. This would lead to an architecture which places most of the communication sub-system on the ground in order to limit the station components only to a multichannel transponder, associated antenna and interfaces. For communications delivered from HAPS, a consistent number of spot beams will be required, and these may be produced either by an ensemble of horn antennas or some form of phased arrays. Side lobe performance is an important issue, which will affect inter-cell interference and system capacity. Different types of antennas can be used in HAPS system for example we can use (Argus® DualPol® Antenna, 2300–2700 MHz, 32° horizontal beam width, variable electrical tilt) which have pattern shown in figure 7.

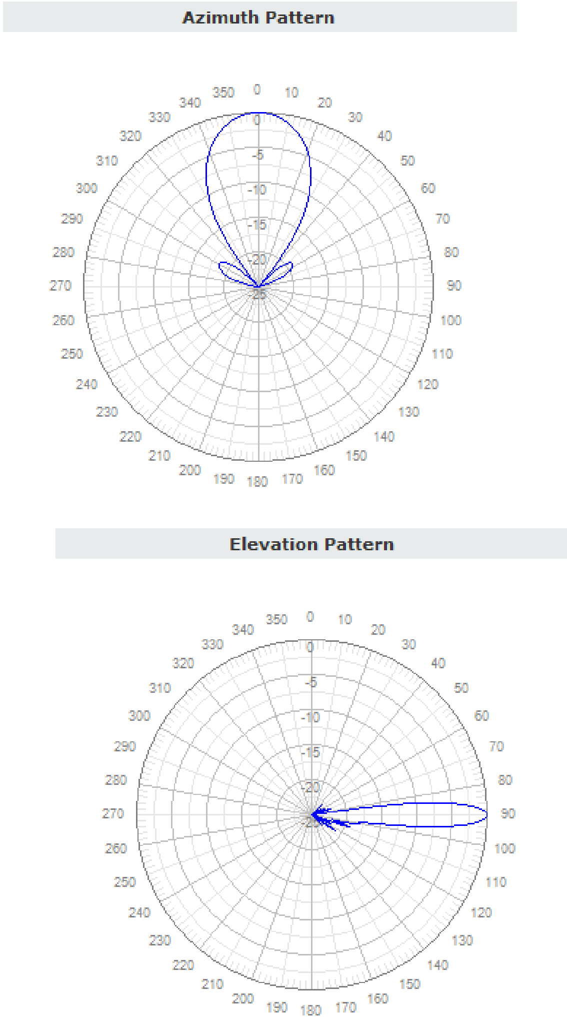

Figure 7. Radiation pattern DualPol .Antenna

3) *Shielding effect by HAPS airship envelope:* This effect is given from the metal coating of HAPS airship envelope. Interference calculation between HAPS airship and satellite space segment is reduced by taking into account shielding effect to the side-lobe and back-lobe beam characteristics of the antenna on board the HAPS airship.

4) *Dynamic channel assignment:* DCA is the interference mitigation scheme, which searches a non-use frequency or time slot and utilizes it, not so as to give the interference to other services and not so as to be received from other services. When communication systems operate on a demand-assignment basis, DCA using self-controlled scheme is effective for sharing with other services.

5) *Automatic transmitting power control (ATPC)*: In the radio communication system using higher frequency band, the system design takes into account the rain attenuation. To compensate the attenuation, the transmission power is increased by the value of rain. The ATPC scheme has the function to control the output

power in monitoring the weather condition or receiving power. The transmission power is increased under the rain condition and it is decreased under the clear-sky condition. Since the ATPC is essentially the scheme to avoid the unnecessary higher transmission power of signal, the ATPC is useful from the viewpoint of the interference reduction [11].

VI. CONCLUSION

In this paper, we gave in overview of HAPS and the beneficial of using HAPS in wireless communication applications in were large coverage area, high capacity and cost-effective deployment compared with other established systems. The scenario of covering Sulaymaniyah city has been proposed by suggesting adding two earth stations to connect with HAPS for more reliability. Also, mitigation technique has been applied for systems interference, and the appreciate solution to reduce interference to noise ratio when the FS and FSS stations is separate away from HAP/GS. The worst interference exists when elevation angle from HAPS toward (FSS/GS, FS/GS) station is equal to elevation angle from HAPS toward HAP/GS; as well as, if the gain of FSS and FS station is large it will help to reduce the interference. Furthermore, the path loss and fading loss has been calculating depend on the geographical area of Sulaymaniyah city, and the weather of city as well. So the expected availability will be 99.99%, and this network will cover whole city area by different telecommunication services.

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