Spectrum Management for Coexistence of High Altitude Platform System (HAPS) and Fixed Services in 5.8GHz Band

Mastaneh Mokayef, Tharek Abd. Rahman, R. Ngah, Yasser Zahedi, Mohsen Khalily

Wireless Communication Center (WCC), Universiti Teknologi Malaysia (UTM),81310 Skudai, Johor, Malaysia
m.mastaneh@gmail.com

Abstract: The theoretical base behind the spectrum management of High Altitude Platform System (HAPS) as an innovative promising technology is classified under the worst case (WC) prediction model to indemnify the fortification of the existing services. Accordingly, this paper sheds light on the spectrum sharing of coexistence between High Altitude Platform System (HAPS) and the Fixed Services (FS) that are intended for future applications. Hence, an inclusive intersystem interference theoretical model is proposed in this paper to depict the WC scenario in terms of a minimum coupling loss (MCL). The coexistence between HAPS and FS is then investigated and consequently, new Minimum Interference Coupling loss (MICL) model is introduced by combination of bandwidth attenuation plus antenna pointing and clutter height variation of the victim. The spectrum sharing has evaluated based on the Interference to Noise Ratio (INR). Accordingly, optimistic results obtained at this juncture illustrate the feasibility of coexistence of both systems in 5.8 GHz band in early stage of spectrum management.

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1.Introduction

An escalating insists for broadband mobile communications, has led to the rapid development of the conventional terrestrial and satellite wireless communications systems. Recently, an innovative technology has attracted the attention for providing mobile communications known as High Altitude Platform System (HAPS). HAPS is a quasi-stationary platform proposed to operate in the stratosphere at altitude of about 17 to 50 km beyond the surface of the Earth (Likitthanasate,2005; Yang,2008; Abbas,2008). HAPS is proposed to be a resource of providing prospect wireless communications due to its distinctive characteristics as an individual or complementary network to satellite and terrestrial systems. On the other hand, due to the coexistence and sharing of the same or adjacent frequency band, the already existing system (FS) will face intersystem interference that leads to degradation in performance of the system. Hence the intersystem interference is considered as the major preventive factor in the performance of communication systems. Accordingly, the factors such as physical and frequency isolations, data traffic flowing, power level of transmitter and receiver system and also the data rate have a great role in controlling the intersystem interference between systems. Consequently several studies done by Wörfel (2012); Grace (2002); Park (2003); Castanet (2003); Amin (1997); and Eklund (2002) focused on investigating the interference issues and the mitigation techniques to reduce the degradation in performance of the systems operating in the same or adjacent frequency bands.

Accordingly, the probability of existing wireless operators utilizing similar or dissimilar frequency bands for the matched technologies increases rapidly. Although the suggested frequency band for HAPS operation is 5850-7075 MHz band for tropical countries and the region with high rain attenuation; hence, this study sheds light on the investigation of coexistence and sharing between HAPS and FS service in the aforementioned band. The main purpose of this study is to demonstrate the ability of utilizing HAPS in the frequency band already utilized heavily by FS services to create a high-speed, top-notch and secure communication especially in the tropical regions with high rain rates.

Rest of this paper is organized as follows. Section 2 studies the interference and sharing scenarios and proper assumptions related to the location of systems. Moreover, system parameters are highlighted in this section. Section 2 consists of all assumptions and technical parameters related to the systems. Statistical and deterministic results are illustrated in section 3. Finally, the conclusion is presented in Section 4.

2. Scenarios and Assumptions

The scenario consists of a distinct HAPS and a single FS base station situated inside the urban area coverage (UAC) of HAPS as shown in Figure 1. The interference emissions from HAPS system to FS are investigated to evaluate the performance of the victim service.

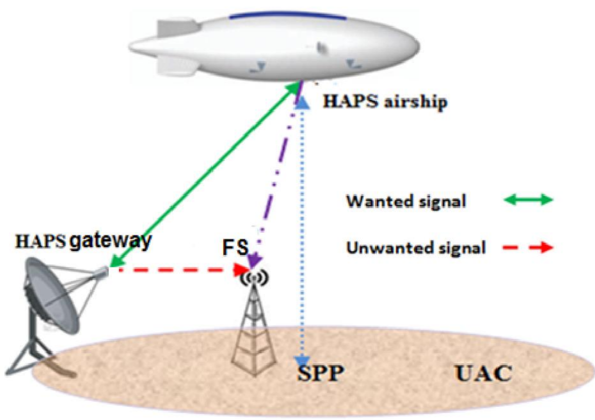


Figure 1. Coexistence and sharing scenario

2.1 Kinetics of composting processes

A directional antenna for the HAPS and FS station is considered to distribute the essential data rates over elongated distances. Alternatively, the FS base station is assumed to be located randomly in a locus of points inside the UAC pointing the HAPS base station. The antenna gain for HAPS and FS are derived from ITU-R.Res.221 and ITU-R.F699 respectively. Moreover, the free space loss (Wörfel, 2012) is considered in this paper as a proper propagation model calculated as follows:

$$L_p = 92.4 + 20\log(d_{km}) + 20\log(f_{GHz}) \quad (1)$$

where $d(km)$ represents the separation distance between HAPS and FS; whereas the $f(GHz)$ stands for the carrier frequency. The reckoned propagation path loss is then used in evaluating the coming interference in the victim side. The last assumption in this paper is the utilized modulation technique, which is 64 QAM for both systems. To control the intersystem interference between systems in the early stage of spectrum classification, the required isolation in dB is investigated by MCL as follows:

$$MCL = P_i + G_i + G_v - L_p - I_{TH} - A_{loss} \quad (2)$$

where $P_i(dBW)$ is the interferer transmit power, $G_i(dBi)$, $G_v(dBi)$ are gains of interferer and victim respectively; $A_{loss}(dB)$ stands for the additional losses due to the clutter height or other natural situations such as gaseous loss ; and $I_{TH}(dB)$ is the interference threshold level. Consequently, the required physical isolation can be calculated as:

$$d_{km} = 10^{\frac{MCL-92.4-20\log f(GHz)}{20}} \quad (3)$$

where $MCL\ (dB)$ denotes the Minimum Coupling Loss and $f(GHz)$ represents the targeted link frequency in GHz.

To estimate the interference level and required mitigation technique between systems before the system deployment, the new Minimum Interference Coupling Loss (MICL) is introduced in this study as follows:

$$MICL = L_p + S_{BW} + Mit_{loss} \quad (4)$$

where $S_{BW}(dB)$ denotes the spectral density level relative to the bandwidth of victim, $Mit_{loss}(dB)$ is the loss due to the mitigation techniques. The relative frequency offset of spectral density levels in different points are calculated as follows:

$$\text{spectral density points}\begin{cases} A\,(MHz) = 0.5\,\Delta F \\ B\,(MHz) = 0.5\,\Delta F \\ C\,(MHz) = 0.714\,\Delta F \\ D\,(MHz) = 1.66\,\Delta F \\ E\,(MHz) = 2.0\,\Delta F \\ F\,(MHz) = 2.5\,\Delta F \end{cases} \quad (5)$$

where, A, B, C, D, E and F denote the frequency reference points with lowest to highest level respectively. ΔF (MHZ) represents the channel spacing. The actual carrier frequency of 0MHz is considered in this research. The mitigation loss due to the antenna height is calculated as follows:

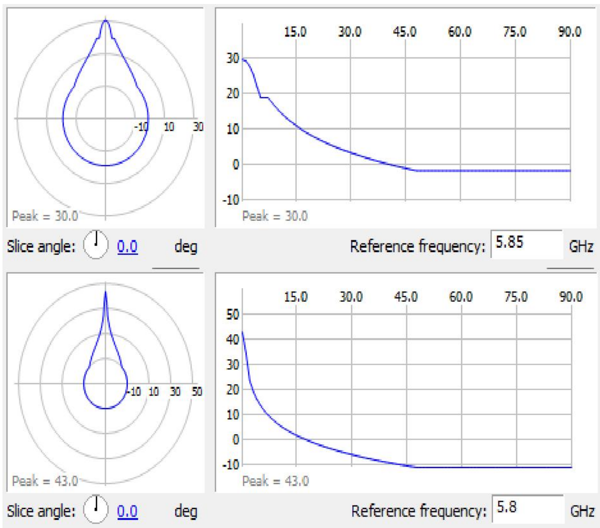
$$A_h = 10.25\,e^{-d_k}\left[1 - \tanh\left[6\left(\frac{h}{h_a} - 0.625\right)\right]\right] - 0.33 \quad (6)$$

where d_k is the distance from the nominal clutter point to the victim receiver in kilometers; h_a is the nominal clutter height in meters. Finally, h denotes the antenna height above the local clutter height in meter. Moreover, the gain loss due to the antenna pointing variation as calculated in ITU-R S.731 is considered in this study.The important system parameters for HAPS and FS base stations are tabulated in Table 1.

Table 1. Technical characteristics of HAPS and FS

parameters	**FS base station**	**HAPS gateway**
Station height (m)	6	15
Transmission power (dBW)	------	-19
Channel bandwidth (MHz)	1.75	11
Transmission loss (dB)	3	4.1
Antenna peak gain (dBi)	45	47
Antenna elevation angle (degree)	0	30
Antenna pattern	ITU-R.F699	ITU-R Res 221

The HAPS system under consideration in this paper is benefitted from the following practical antenna pattern based on Resolution 221 (Rev.WRC-07) shown in Figure2.



Antenna performance has a significant impact on wanted and unwanted signal levels. Hence Figure 2 defines both communication systems illustrating the performance of their antennas.

3. Results and Discussion

The obtained results are categorized into statistic and deterministic results. The MCL reckoned and accordingly the statistical results obtained and tabulated; while the MICL resulted the deterministic results followed by enhanced results of Monte Carlo approach. The logic behind the order of these categories is to get a full understanding of the effect of the mitigation techniques in the early stage of spectrum planning.

3.1 Statistic Results

According to the calculations in previous section, the minimum separation distance can be translated as the distance between HAPS gateway station and FS services where the transmitting HAPS airship is 22 km away from the HAPS gateway station as shown in Figure1.

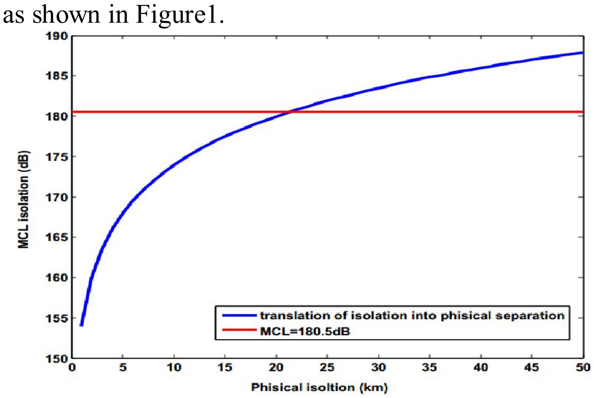


Figure 2. Translation of isolation into physical separation.

Refer to the technical parameters and formulas mentioned in section 2; the MCL has a threshold value of 180.5 dB. The intersection between MCL line and the threshold line in Figure 3 depicts the required separation distance. Applying the physical isolation between systems, the MCL value reduces; hence, the physical isolation is considered as an interference mitigation technique.

3.2. Deterministic Results

Contemplation of interference mitigation technique in the initial stage of system deployment and spectrum classification is the main purpose of this research. The MICL is introduced to determine the required isolation between interferer and victim services before their operation. The effect of different clutter height and antenna pointing on the required physical isolation is illustrated in Figure 4.

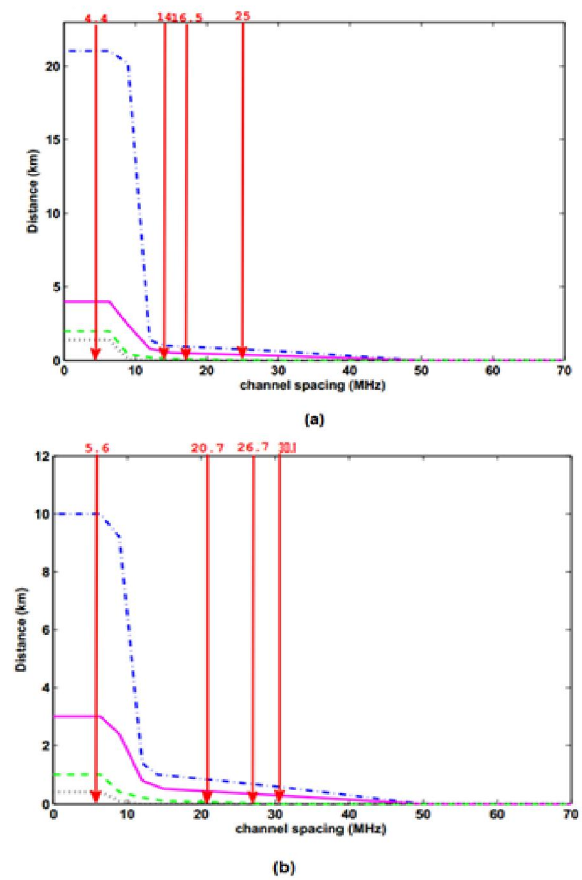


Figure 2. Translation of isolation into physical separation.

As depicted in Figure 4 part (a) Minimizing the clutter height results to the decrement in free space path loss and consequently decreases the required physical isolation dramatically. Separation between carriers also leads to the feasibility of coexistence between systems. Although combining the 0.875 MHz, 1.07 MHz, 1.59 MHz 3.5 MHz and 4.37 MHz of frequency offset to the previous channel spacing leads to the great advantage in minimizing the separation distance. When the FS clutter height rises, interference from the HAPS gateway increases to its higher level due to the LOS clarity between the transmitter and victim receiver; hence, the increment in required separation distance is observed.

For the FS clutter height of 20 m, 15 m and 10 m and 5 m the physical isolation of 22 km, 4 km, 2 km and 1.4 km are required respectively. In part (b) of Figure 4 the effect of antenna pointing on physical isolation is depicted in which the decrement in the required physical isolation can be observed clearly. The logic behind this is the movement of the radiation pattern peak away from the interference path. Comparisons between both mitigation techniques illustrate the lower physical isolation when the antenna pointing applied as a mitigation technique. Table 2 illustrates the required physical isolation for different mitigation techniques.

Table 2. Co-channel interference scenarios constrains under MICL using antenna pointing and antenna height.

Coexistence scenario	Antenna off-axis degree	Antenna height (m)	MICL antennapointing/height (dB)		Separation distance (km)	
Co-channel	0	20	5.6	4.4	10	22
	10	15	20.7	14	3	4
	20	10	26.7	16.5	1	2
	30	5	30.1	25	0.4	1.4

3.3 Monte Carlo Assessment

The statistical analysis is done for the mitigation techniques of clutter height and antenna pointing with the uniform distribution is applied herein to verify the MICL results.

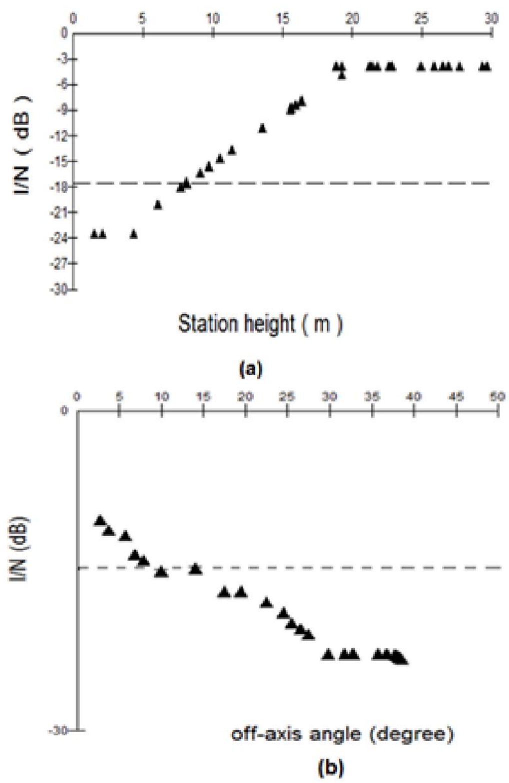


Figure 3. Statistical distribution of INR for different clutter height and antenna pointing.

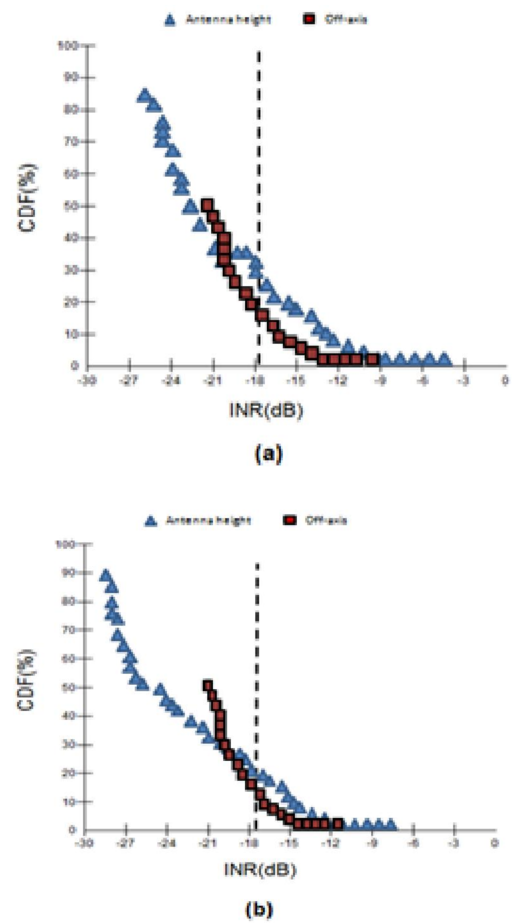


Figure 4. Simulation CDFs of antenna height and antenna pointing.

Figure 5 indicates that by increasing the clutter height from 7 m sufficient INR level is accomplished. To clarify, as antenna height increases the interference level grows noticeably. The logic behind this is the LOS clarity between the interferer transmitter and victim receiver which is reckoned in (8). On the other hand, Statistics illustrated in Figure 5 confirm that the sharing ability increases due to the off axis increment in victim side. The reduction in INR level due to the changing of FS main beam direction more than 5 degree shows that the possibility of sharing between systems increases noticeably.

3.4. Statistical CDF Based Model

The interference probability is an approximation of trials that have unsatisfactory INR level of more than -17.5 dB. Interference probability for different bandwidths of victim is depicted in Figure 6. From the first view, it can be observed that the antenna off-axis is leading the favorable in lower interference probability of 21% and 11%, and subsequently antenna height of 31% and 22% correspondingly. The worst probability is related to the antenna height; the logic behind this is the directional relation between antenna height and interference level. Hence, higher the antenna height, the interference probability will also increase. Similarly, the interference probability caused by off-axis variation and antenna height variation are illustrated in Figure 6. Comparing the obtained results illustrates that the off-axis variation reduces the interference probability to the lower level rather than the antenna height levels.

4. Conclusion

Through the obtained deterministic and statistics results the location and height of FS is scanned and controlled considering the prediction models to avoid the harmful interference in early stages of spectrum management. In this paper, the worst case scenario of interference is translated into the MCL. Moreover, to assist the coexistence and spectrum sharing the ICL is combined with antenna pointing and clutter height. The obtained deterministic results were then enhanced by Monte Carlo approach to clarify the feasibility of coexistence and sharing constrains in early stage of spectrum management. Consequently, it can be concluded that the variation in antenna pointing specially in off-axis of victim will result to the lower physical isolation rather than the one of clutter height variation.

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Corresponding Author:
Mastaneh Mokayef
Wireless Communication Center (WCC), Universiti Teknologi Malaysia (UTM),81310 Skudai, Johor, Malaysia
Emails: m.mastaneh@gmail.com

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