Early stage of spectrum planning for operation of HAPS at 5.8GHz Band

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Abstract: The feasibility of coexistence between the proposed High Altitude Platform System (HAPS) and the existing Fixed services (FS) in the congested 5.8 GHz band is investigated in this paper. To enhance the spectrum sharing between systems in early stage of spectrum planning, the spectrum emission mask (SEM) and the Protection Ratio (PR) of -17.5 dB as an important sharing criterion in parallel with a novel Minimum Interference Coupling Loss (MICL)as a combination of power spectral density related to the bandwidth of system, Mask discrimination (MD) and additional losses due to the antenna pointing of HAPS are considered in this study. The channel bandwidth of 11 MHz for HAPS and the 1.75, 3.5and 7 MHz ones for FS is considered in the urban area. It is eminent that the physical separation is of the most important factors in the frequency coordination process; hence these separations are determined for co-channel interference scenario. This spectrum sharing study is considered as a giant step toward 4G and beyond 4G services coexistence with HAPS system.

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1. Introduction

By increasing traffic in future, it is necessary for wireless communications to provide backhaul links for femto cells and pico cells in 4G and B4G networks. Accordingly, stipulation of backhaul links via HAPS can be an effective solution and this is the logic behind considering a pair of 80 MHz band for the operation of HAPS gateway link in the 5.8 GHz frequency range. Accordingly, the ITU-R F.5BL6 and CEPT ECC Rep. 156 described the characteristics of HAPS system and HAPS gateway link in 2011[1, 2].

As a result of the radical increase insist for wireless communication applications and the fact that the radio spectrum is a restricted and precious resource, radio spectrum regulation and management have become the center of attention rapidly[3]. Due to the shortage of the frequency spectrum, many bands are allocated for more than one radio service and therefore the sharing studies play a greater role at this juncture. When the spectrum sharing increases more users interfering with each other and consequently the degradation in performance of systems will increase [3]**.** The 5.8 GHz band is currently allocated to FS, Fixed Satellite Service (FSS) and Fixed Wireless Access (FWA) systems to provide point-to-multipoint equipment for a wireless internet service provider (WISP) Solutions, broadband internet access, and IP video scrutiny. Therefore, the impact of the interference of HAPS as a new technology on FS systems and vice versa needs to be studied. The interest for the use of 5850-7075 MHz band for the FS applications has improved due to the large reliability and extensive coverage specially, in the areas with high rain attenuation. Different compatibility studies in the 5.8 GHz band between HAPS and different services such as FSS and terrestrial systems are investigated in **[4-10]**. Moreover, the intersystem interference mitigated by different techniques applied in **[8, 11-21]**. In this paper SEM of both HAPS and FS services are derived due to their bandwidth to investigate the physical separation (separation distance) between systems; and guarantee the feasibility of coexistence between systems without destructive interference in the urban area. This paper is organized as follows: the technical and operational parameters of systems are depicted in section 2. Section 3 is devoted to introduce the novel MICL. Results and comparison between previous ICL and new MICL followed by interference probability of each case is discussed in section 4. Finally, the study conclusions are delivered in Section 5.

2. Systems' Parameters

The HAPS gateway station parameters utilized in this study are taken from Recommendation ITU-R F.1891 [25]; while the required parameters of the FWA are taken based on the Recommendation ITU-R F.758-4. For the FS implementation at 5.8 GHz the antenna diameter of equal or less than 3 meters has been assumed. It is also assumed that the FWA system has the antenna height of 6 meters. Other parameters of HAPS and FS are tabulated in Table 1.

Table 1. HAPS gateway and FS parameters

parameters	FS base station	HAPS gateway
Station height (m)	6	15
Transmission power (dBW)	--------	-19
Channel bandwidth (MHz)	1.75, 3.5, 7, 14	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

Channel bandwidths are defined through SEM which is used as a spectrum sharing model in this paper. Four bandwidths are chosen for FS (1.75, 3.5, 7 and 14 MHz), while the channel bandwidth for HAPS has a fixed value of 11 MHz. Accordingly, the following Table 2 simplifies the SEM for both HAPS and FS systems due to the mentioned bandwidths.

Table 2. SEM type F for HAPS and FS

Frequency offset (MHz)		0	0.5	0.5	0.716	1.06	2	2.5
BW (MHz)		Channel spacing (dB)						
FS	1.75	0	0.875	0.875	1.07	1.59	3.5	4.37
	3.5	0	1.75	1.75	2.49	3.71	7	8.75
	7	0	3.5	3.5	4.99	7.42	14	17.5
HAPS	11	0	5.5	5.5	7.85	11.66	22	27.5

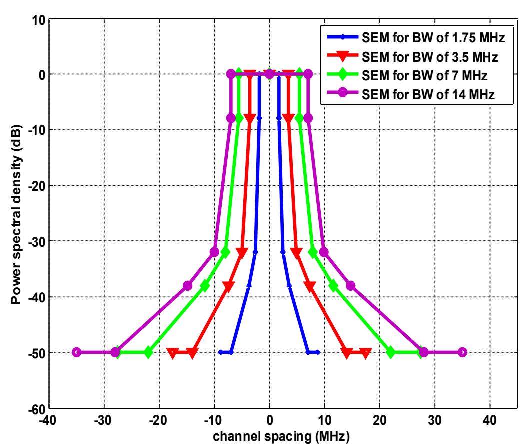

Figure 1. Different spectrum emission masks due to different bandwidths of interferer and victim

Accordingly, the SEM for HAPS and FS with different bandwidths are shown in Figure 1.

As shown in Figure 1, the higher in bandwidth results to the wider SEM. Hence, in case of the 14 MHz FS bandwidth, the HAPS' SEM located inside the SEM of FS. Indeed, MD indicates the effects of transmit spectrum based on receiver emitting signal in co-channel scenario. Moreover, the characterization of the antenna is established to define the radiation pattern as follows:

$$G(\varphi)=\begin{cases} G_{max}-2.5\times 10^{-3}\left[\frac{D}{\lambda}\varphi\right]^2 & for\ 0<\varphi<\varphi_m \\ 39-5\log\left(\frac{D}{\lambda}\right)-25\log\varphi & for\ \varphi_m\leq\varphi<48^{\circ} \\ -3-5\log\left(\frac{D}{\lambda}\right) & for\ 48^{\circ}\leq\varphi<18^{\circ} \end{cases} \quad (1)$$

Where $G(\varphi)$ is a gain relative to the isotropic antenna, φ is an off-axis angle, λ denotes the wavelength and D represents the antenna diameter.

Since the off-axis variation of up to 48 degree is considered in this paper, the additional loss due to the off-axis angle can be reckoned as:

$$G(\varphi)_{loss}=G(5)-G(\varphi) \quad \textbf{(2)}$$

3. MICL Evaluation

The deliberation of interference mitigation technique in the primary phase of spectrum recognition in a congested band is of great benefit; therefore, to reduce the interference power and the required separation distance between systems, the Interference Coupling Loss (ICL) can be an appropriate mitigation technique. The ICL is a combination of MD and additional losses achieved by utilizing the system mitigation technique introduced in [21]. Hence the MICL prediction model as a combination of ICL with additional loss due to the bandwidth variation of victim is introduced in this paper as follows:

$$MICL=P_i+G_t(\varphi)-L_{fi}-L_p+G_v(\varphi)+MD+L_B+add_{loss} \quad (3)$$

where Pi (dBW) represents the interfere transmitted power, $Gt(\varphi)$ and $Gv(\varphi)$ denote the antenna off-axis gain of interferer and victim respectively. $Lfi(dB)$ denotes the interferer transmitter feeder loss, $Lp(dB)$ represents the propagation loss due to free space loss as introduced in [21]. MD is referring to the spectral power decoupling between carriers of systems in co-channel scenario. add_{loss} (dB) is the additional loss due to the antenna pointing of victim and $L_B(dB)$ denotes the attenuation due to the bandwidth variation illustrated in Fig.1.

Consequently, the effect of consideration of attenuation due to the bandwidth variation on required separation distance is illustrated by comparing the results of ICL and MICL in the following subsection.

4. Results and Discussions

According to equation (1) the attenuation due to the variation of antenna pointing angle of FS is summarized in Table3.

Table 3. MICL under different antenna pointing

Angle (degree)	5			10			15			20		
Off-axis Loss (dB)	0			7.5			11.9			15.02		
ICL (dB)	-7.9			-0.4			4			7.12		
d_{ICL}(km)	79.433			50.1			35.237			31.6		
BW (MHz)	1.75	3.5	7	1.75	3.5	7	1.75	3.5	7	1.75	3.5	7
MICL (dB)	23.1	25.1	26.1	30.6	32.6	33.6	34	37	38	37.6	40.1	41.1
d_{MICL}(km)	4.9	4.8	4.33	2.5	1.99	0.2	1.7	1.2	0.12	1.1	0.86	0.08

Comparing the required separation distance for ICL and MICL illustrates the effect of bandwidth variation on the required physical separation. Utilizing the higher bandwidth for the victim decreases the required physical separation dramatically. Comparing the recent results with the one obtained in [21] illustrates that antenna pointing would be a proper mitigation technique in compare with antenna height reduction; although no clear line of sight towards receiver in case of utilizing small receiver antenna height is achieved. In other words, the lower in interference power level is observed due to the off-axis growth rather than the one due to the obstacles.

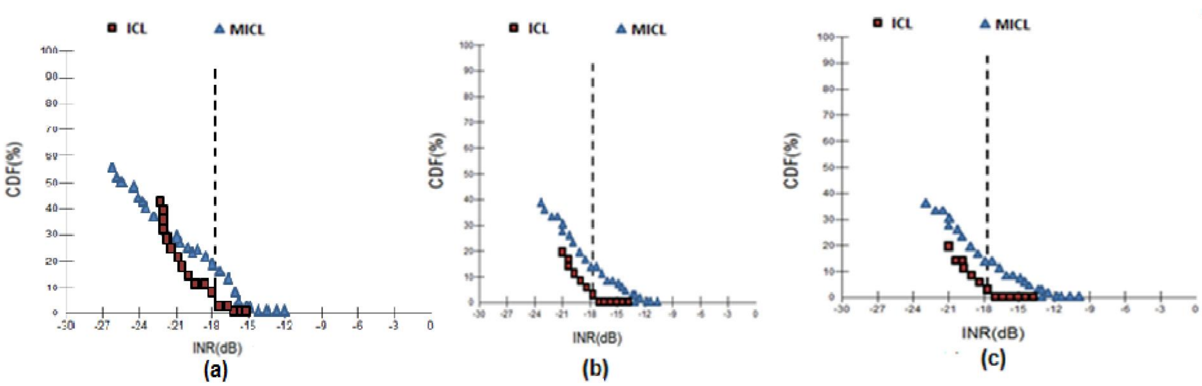

Figure 2. Interference probability of ICL and MICL for FS bandwidths of a)1.75, b)3.5 and c)7 MHz

Figure2 illustrates the nastiest probability related to the ICL; the logic behind this is the reverse relation between attenuation and interference level. Therefore, higher the attenuation, the interference probability will decrease. In the same way, the interference probability caused by MICL has lower value due to the higher attenuation. Consequently, it can be observed that increasing the bandwidth, considering antenna pointing is leading the favorable in lower interference probability of 20%, 16% and 14% followed by antenna pointing of 10%, 4% and 2%.

5. Conclusion

Due to the dependency of coexistence and spectrum sharing to system specifications, propagation model, area of deployment and interference type, the spectrum management is difficult to be achieved. This paper had shed light on the investigation of coexistence feasibility between HAPS gateway station and FS system in 5.8 GHz band. Accordingly, the spectrum emission mask has been used with different channel bandwidths and frequency separations to estimate the effect of increasing the bandwidth on interference probability. Proportional simulation results illustrated that when the channel bandwidth increases less separation distance between interferer and victim is required; and consequently leads to improvement in link budget calculation. Possible coexistence scenario is applied and combination of attenuation due to proper antenna pointing and the one from bandwidth have shown great impact on required separation distance.

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