TAF Journal of Advances in Technology and Engineering Studies JATER
2016, **2**(5): 164-169

PRIMARY RESEARCH

Analysis of interference of unmanned aircraft system (UAS) and fixed service at frequency band 12.5-12.75 GHz by considering the factor of rain attenuation

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Index Terms
Unmanned Aircraft Systems (UAS)
Unmanned Aerial Vehicle (UAV)
Drone
Rain Attenuation

Received: 26 July 2016
Accepted: 20 September 2016
Published: 27 October 2016

Abstract— This paper proposed the analysis of interference between Drone (Unmanned Aircraft System) and Fixed Service (FS) by considering the factor of rain attenuation. The analysis of interference is the use of same frequency by two different systems between UAS and FS. The frequency sharing or the compatibility between the two systems (UAS and FS) is modelled by the interference between those two systems. The main problem of the Unmanned Aircraft (UA) or Unmanned Aerial Vehicle (UAV) deployment is the compatibility with the other UAV and incumbent system. One of the allocation FSS spectrums in the region 3 (Asia and Oceania Region) is in the band 12.5 - 12.75 GHz. This frequency band is shared with the frequency of FS (Fixed Service). This paper analyzes the interference by calculating and simulating the scenario of interference with rain attenuation. The scenario of interference is observed when some of UAVs or UA flights are above the area of FS. The simulation is conducted to investigate the interference from the UAV emission into the FS receiver. The results of simulation should present that the interference from the UAV is not harmful to the FS.

I. INTRODUCTION

Unmanned Aircraft Systems (UAS) is a new technology with tremendous potential for military applications and civil applications. UAS is part of the growth of urban civil and military applications in the future. This technology is mature enough to be integrated in civil society. The UAS importance of scientific applications has been fully demonstrated in recent years. Whatever the mission undertaken by the UAS is, the amount and its use will significantly increase in the future. UAS today plays an increasing role in many public missions such as border surveillance, wildlife surveys, military training, weather monitoring, as well as for law enforcement in the local area [1].

Challenges such as lack of on-board pilots to see and avoid other aircraft and very significant growth in the use of UAS. Seamless Performance (seamless) of Unmanned Aerial Vehicle (UAV) or Unmanned Aircraft (UA) or also known as drones and commercial aircraft in the room that did not separate (non-segregated space) has become important in the development of UAV in the future. The reliability of the communication channels has become an important factor in the performance of UAV. The communication channels consist of Unmanned Aircraft Control Station (UACS) and satellites as well as satellites and unmanned aircraft.

The study [2] has been modeling UAS spectrum compatibility and Fixed Service (FS) at a frequency of 12.2 to 12.5 GHz in ideal conditions with one UAV unit and one FS regardless of rain attenuation. Where compatibility between UAS and FS is modeled by interference between the two systems.

The results showed that the interference from FS to UAV or otherwise of UAV to FS is not over the limit (threshold). The implication from 12.2 to 12.5 GHz frequency should be safely used for UAS.

Things that make the background of this study were to evaluate the global spectrum that has been set for the UAS at WRC-15 (World Radiocommunication, 2015). Then, this research is also based on the implementation plan of UAS

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for surveillance applications in Indonesia. Implementation should be reviewed in detail related to the characteristics of regions in Indonesia with a tropical climate and high rainfall levels.

Fig 1 shows the condition Beyond Line of Sight (BLOS) of the UAS. Where there are four links used as a channel of communication between the UA and UA stations via satellite. Link 1 and 4 are the channel of communication between the UAS Control Station (UACS) and satellite. These links do not require system compatibility. This is due to the same characteristics with the system of Fixed Satellite Service (FSS). Link 2 and 3 are the channel of communication between the satellite and the UA. This link requires compatibility between UAS system with the FSS, FS, and the Broadcasting Satellite System (BSS). Compatibility is necessary because of the electromagnetic emission of a UA that will cause interference in other systems [2].

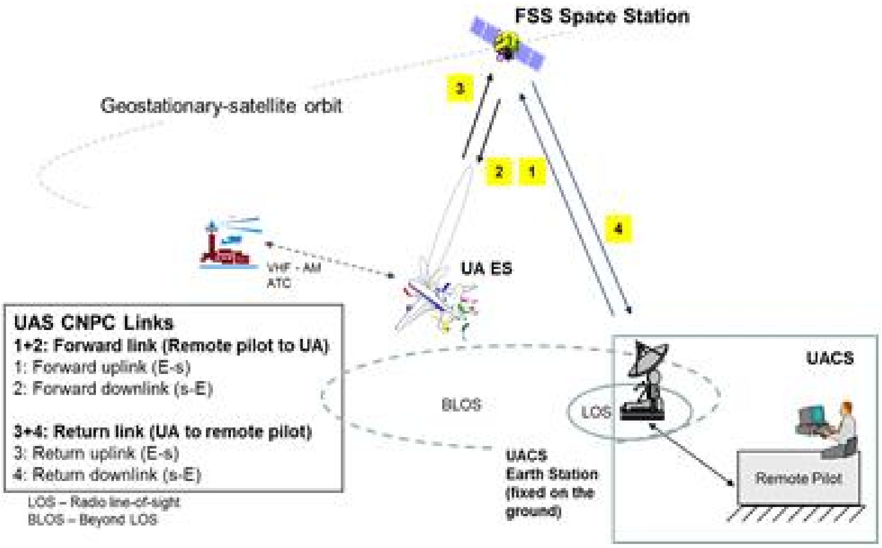

Fig. 1 . Elements of UAS architecture with FSS [3]

At WRC-15, it has been established that the UAS duty station FSS geostationary satellite network operating in the 10.95 to 11.2 GHz frequency band (Space-to-Earth), from 11.45 to 11.7 GHz (Space-to-Earth), from 11.7 to 12.2 GHz (Space-to-Earth) in region 2, from 12.2 to 12.5 GHz (Space-to-Earth) in region 3, 12.5 to 12.75 GHz (Space-to-Earth) in regions 1 and 3 and 19.7 to 20.2 GHz (Space-to-Earth), and in the frequency band from 14 to 14.47 GHz (Earth-to-Space) and 29.5 to 30.0 GHz (Earth-to-Space), can be used for the UAS CNPC links in non-segregated airspace, with the requirements specified in resolves [3] been fulfilled. The spectrum is now a major focus of observation in one of the frequency bands which operates in region 3 in frequency from 12.5 to 12.75 GHz.

This study aimed to evaluate the frequency spectrum that is used in BLOS communication systems on drones with rain attenuation. The current stage has led to the frequencies used by satellite communication systems in the region 3. Then, this study will analyze the use of the frequency spectrum identified for UAS with drones and the effect of rain attenuation. The analysis is based on documents that have been ratified by the ITU and other references.

II. INTERFERENCE AND RAIN ATTENUATION

The scenarios used in this study are shown in figure 2. Interference signals to be designed consist of two things, namely:

1. Interference between the FS transmitter and the UA receiver with rain attenuation.
2. Interference between the UA transmitter and the FS receiver with rain attenuation.

UA electromagnetic emissions would interfere the system in FS. It is due to these two systems that work in the same frequency. UA uses FSS frequency to operate. Then, when the UA passes through the area with FS terrestrial system, there will be interference. Both systems have their

ISSN: 2414-4592
DOI: 10.20474/jater-2.5.4

protection. Protection is assessed from the interference I/N.

This scenario simulates the effect of interference from FS to UA with percent of time parameter. When UA is within range of each FS antenna gain, and if there is a direct connection with the radiation pattern of the antenna, there will be interference. In the event of interference, there will be a loss in both systems, UA and FS. This interference is due to direct connection expressed by equation of Free Space Path Loss (FSPL), and will be shown in graph that represents interference ratio I/N by percent of time.

Then the second scenario simulates the impact of interference from UA to FS with UA altitude parameters during flight. This interference is due to direct connection expressed by equation FSPL, and assessed the level I/N with UA altitude variation relative to the ground level (the lowest level of the tower FS).

Interference itself is a disorder of interferer signals (aggressor signals) to the victim signal (the affected interference signal) in the same frequency band [5]. Interference will not occur if the wave or beam of an antenna is not the wave of the receiving object antenna. Fundamentally, the interference is same with transmission signal from the transmitter to the receiver. However, the difference between them is in the case of annoying or not. Interference can cause the performance of a victim device to decline and the level of sensitivity will decrease [5]. Interference between the two systems occurs when the range is within Line of Sight (LOS). The interference is inevitable, but the levels and thresholds have been set so that the interference between the two systems is permitted. Equation (1) shows the general equation interference [5]. This equation is a common and basic one in calculating interference. This equation may have additional variables based on the model used.

$$I = P_{interferer} + G_{interferer} + G_{victim} - L – L_{others}$$

$P_{interferer}$ variable is the power of a system that serves as interferer or interference. $G_{interferer}$ transmitter gain variable of system is the interferer or the interference. G_{victim} receiver gain variable of the system is the victim or who performs interference. The L variable is FSPL which has a function of distance and percent of time function. L formula will vary on the type of scenario in the study. The equation for the variable L is indicated by (2). L_{others} variable is the loss of the two systems which interfere with each other. This loss can be a feeder loss, damping the fuselage, rain attenuation, and others.

$$L = 92,5 + 20\log(f) + 20log(d) + 2,6(1 - e^{\text{-d)}/10})log(p/50)$$

Equation (2) shows the propagation loss equation from one system to the other [6]. Variable f is the frequency which has the unit GHz. The variable d is the slant range or a direct path as shown in Fig 3. p is the percent of time. Percent of time is the length of exposure to interference wave from an interferer to the victim. The duration of exposure is assessed from a certain time. For example, the percent time per 24 hours, 1 week, 1 month, or 1 year. There are two functions to determine the propagation loss, which is a function of distance (d) and the percent of time (p). Both of these functions become important in building a simulation.

This interference was assessed by parameters of UAV altitude for UAV is an active object. This causes the UAV to adjust the flying height when crossing areas with signal coverage of the tower FS. This scenario began to be observed in the worst case of interference i.e. 20% (long-term) and 0.01% (short-term).

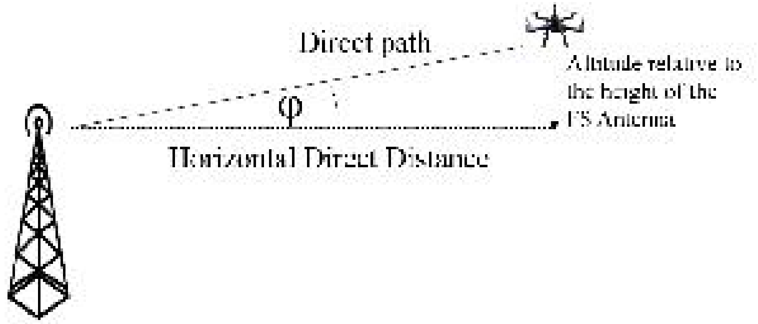

Fig. 2 . Scenarios of interference between the two systems

ISSN: 2414-4592
DOI: 10.20474/jater-2.5.4

Long-term interference is interference that restricts long exposure to interference as much as 20% of a given time. The exposure is continuous; if not continuous, the interference becomes harmless. The time given in this study was 24 hours. So long exposure of long-term interference in a day is about 4.8 hours. Interference limit set by the ITU is equal to -10 dB for long-term interference. This means that if within the time limit of 20% or more which interference does not exceed, -10 dB is still allowed, but if it has passed the -10 dB, it can cause damage to the receiver part of the system.

Short-term interference is interference that restricts long exposure to interference as much as 0.01% of a given time. The exposure is continuous; if not continuous, the interference becomes harmless. The time given in this study was 24 hours. So long exposure of short-term interference in a day is about 8.6 seconds. Interference limit set by the ITU is 20 dB for short-term interference. This means that if within the time limit of 0.01% or more which interference does not exceed, 20 dB is still allowed, but if it has passed 20 dB, it can cause damage to the receiver part of the system.

In the communication system, the electromagnetic waves pass across a link, the power will decline as some phenomena such as diffraction, scattering, reflection, and attenuation are caused by substances contained in the atmosphere such as oxygen, clouds, water vapor, fog, and rain. Of the many substances in the atmosphere, water is the most dominant factor. This is because water has a dielectric constant close to 1. Consequently, if the conditions on the track are rainy, then the propagation of radio waves interferes with rain attenuation caused by absorption and scattering by rain. Scattering is a phenomenon of signal scattering in all directions due to particles bumping smaller signal than the wavelength of the signal itself. Generally, the size of raindrops is in the range 0.1 to 5 mm. When compared to the wavelength (λ) of radio waves at a frequency of 10-100 GHz which ranges from 30 µm - 3 mm, the scattering signal is clearly inevitable.

Here is a simple technique that can be used to estimate the long-term statistics of rain attenuation [7]:

Step 1: Obtain the rain rate R0.01 exceeding 0.01% of the time (with an integration time of 1 minute). If this information is not available from local sources of long-term measurements, an estimate can be obtained from the information given in Recommendation ITU-R P.837.

Step 2: Calculate the specific attenuation, γR (dB/km) for the frequency, polarization, and rain rate of interest using Recommendation ITU-R P.838.

Step 3: Calculate the effective path length, deff, of the link by multiplying the actual path length d by a distance factor r.

TABLE 1

Rain attenuation at 0.01%

	Rain Attenuation at 0,01% (dB)	
Rain Rate (mm/h)	Rain Height, HR 600m	Rain Height, HR 900m
Very light rain: 0,25	0,0076	0.0125
Light rain: 1	0,0357	0.0583
Moderate rain: 4	0,1616	0.2585
Heavy rain: 16	0.6787	1.0461
Very heavy rain: 50	2.0375	2.9675
Extrem rain: 100	4.0076	5.7299

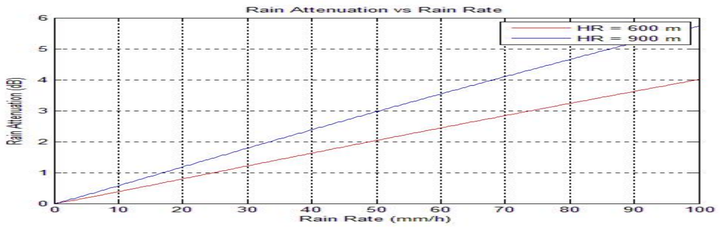

Fig. 3 . Rain attenuation against rain rate

ISSN: 2414-4592
DOI: 10.20474/jater-2.5.4

Table 1 shows the rain attenuation with the height of FS 50 m, rain height 600 m and 900 m, rain rate 0.25 mm/h, 1 mm/h, 4 mm/h, 16 mm/h, 50 mm/h, and 100 mm/h. Fig. 3 shows the rain attenuation graph against rain rate at 600 m and 900 m rain height.

III. RESULTS AND DISCUSSION

Interference from the first UA to FS is shown in Fig. 4 and Fig. 5, where there is a graph I/N against UA elevation relative to FS. There are seven conditions on the graph:

- Without rain attenuation
- Very light rain, rain rate : 0.25 mm/h
- Light rain, rain rate : 1 mm/h
- Moderate rain, rain rate : 4 mm/h
- Heavy rain, rain rate : 16 mm/h
- Very heavy rain, rain rate : 50 mm/h
- Extreme rain, rain rate of 100 mm/h

This scenario is assumed to cause horizontal separation with relative distance from drone to the ground UA FS tower located at a distance of 1 km. Fig. 4 shows the results of short-term interference and Fig. 5 shows the results of long-term interference. The x-axis shows the height of UA relative to FS. Y-axis shows the value of I/N or the ratio between interference and noise on victim receivers. The simulation results indicate the I/N at the short-term criteria in rainy conditions or when no rain attenuation is below threshold (20 dB), so interference is not harmful despite being right in the main lobe of the FS antenna. Different results are shown on the criterion of long-term, where the I/N is passing through the threshold (-10 dB). Considerable power of the UA (50 Watt) into the cause of the I/N at the long-term criteria exceeded the threshold at a certain height.

Fig. 4 and Fig. 5 show that at the same altitude, the I/N at the simulation without rain attenuation is greater than the one obtained in rainy conditions. This is because the rain attenuation results in loss to electromagnetic waves from the UA, so that interference to FS systems as a victim receiver will be smaller. And in the heavy rain, precipitation levels (rain rate) would be even greater, this has resulted in loss of rain attenuation that will be greater as well.

Fig. 4 and Fig. 5 show a declining graph from the left side to the right side, it indicates that the interference will be lower if the height of the UA is increased. Because the higher UA will be further away from the lobe radiated by the antenna FS.

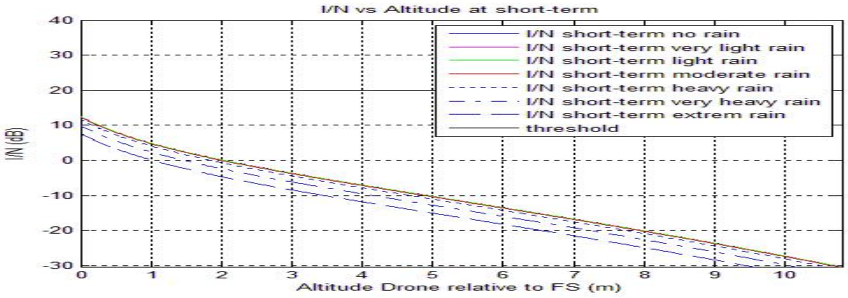

Fig. 4 . 4 I/N short-term vs height of UA relative to FS

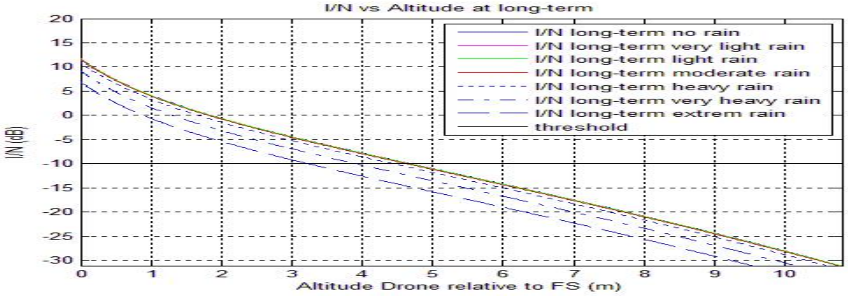

Fig. 5 . 5 I/N long-term vs height of UA relative to FS

IV. CONCLUSION

This study is to analyze the interference of UAS spectrum and FS with rain attenuation as part of the BLOS requirements. Interference will be experienced by drones as they passed in the coverage area from FS systems that share the same frequency band. The radiation pattern of the FS, based on the recommendation of ITU, plays an important role in measuring the level of interference.

Interference of drones (UAS) to the FS system has certain threshold interference criteria and the height limit for the safety of flying. It is also influenced by the weather conditions with the rain attenuation. However, the frequency of 12.5 to 12.75 GHz is safe to use while noticing the flying height limit of drones.

ACKNOWLEDGMENTS

This research was supported by PT Telekomunikasi Indonesia Tbk. We thank our colleagues from University of Indonesia who provided insight and expertise that greatly assisted the research, although they may not agree with all of the interpretations/conclusions of this paper. We thank Muhammad Suryanegara for assistance with methodology and for comments that greatly improved the manuscript.

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