On the performance of reconfigurable intelligent surface-assisted UAV-to-ground communication systems

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ABSTRACT

In this study, to reduce the average symbol error rate, and improve coverage and reliability of unmanned aerial vehicles (UAVs) to ground communication systems. In this case, we propose a reconfigurable intelligent surfaces (RISs) assisted for UAV to ground communication scheme, where radio frequency (RF) signal generator sends an unmodulated carrier signal from UAVs to the RIS. At reconfigurable intelligent surface, the RIS modulates each signal, and RIS is as a signal generator. We carry out a performance analysis of UAV-to-ground communication systems with RIS-assisted and without RIS for subcarrier quadrature amplitude modulation (SC-QAM) technique. The analytical expressions of average symbol error rare (ASER) and average channel capacity (ACC) is derived. From the results, it is show that with RIS assisted can effectively improve the reliability and coverage of the UAVs to ground communication systems.

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1. INTRODUCTION

Unmanned aerial vehicle (UAVs) communication is playing an important role and required in several working environments. UAVs communication systems are a promising system to support the high-speed connections of the fifth-generation wireless and next generation wireless communication networks [1]. With the advantages of UAVs, such as small size and flexibility, UAVs are used for perform networking in communication difficult to reach networking and in communication network that is disabled.

Currently, research on the 5G wireless communication systems using UAVs are researched and deployed more. In [2], analyse the performance evaluation of the UAV to UAV communication system that is spatially random UAVs. In [3], outage performance of UAV-aided relaying system with radio frequency energy harvesting of different urban environmental parameters. In [4], the drone as a relay station to archive the maximum throughput. The reconfigurable intelligent surfaces (RISs) have recently been shown to significantly improve the performance of non-line-of-sight wireless communication systems. RISs technology has been studied and used for several wireless communication systems in the past few years [5]-[18]. The advantage of the RIS technique is to provide the wireless networks several advantages over relay technologies [19]-[27].

This study, we set up analytic expressions and study on the performance of UAV-to-ground communication systems with RISs assisted. We theoretically analysis the average channel capacity (ACC) and average symbol error rate of signal-to-noise ratio (SNR) of communication systems. The study is organized into the following sections: section 2 presents the system and channel model, section 3 presents the analysis on the performance, section 4 presents results and discussions, and we conclude the study in section 5.

2. SYSTEM AND CHANNEL MODELS

The RIS-assisted UAV communication systems under study is shown in Figure 1, where the signal from source (UAV) transmitted to the destination (D) after reflection on a RIS element. At this stage, in [5] we use amplify and forward (AF) method and in this case, the UAV successfully the received signal. Then, the UAV sends the AF signal to D through an UAV to ground communication link.

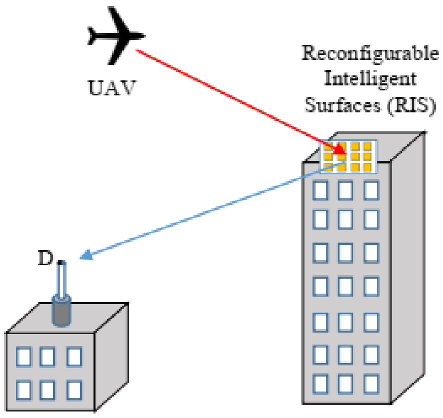

Figure 1. Diagram of RIS assisted UAV to ground wireless communication link

In the first, the source node (UAV) send the signal to the destination node (D), the received signal at destination can be given by:

$$y_D = gx + n \tag{1}$$

In which:
- $n \sim CN(0, N_0)$: the additive white gaussian noise (AWGN) noise
- x: the signal from source
- g: the gain of channel

$$g = \frac{1}{\sqrt{L_{UD}}}\beta_{UD}e^{\xi_i} \tag{2}$$

The signal-to-noise ratio at destination can be given by:

$$\gamma_D = \frac{|\beta_{UD}|^2 P_U}{N_0 L_{UD}} \tag{3}$$

Where $L_{UD} = 10\,log\,1\,0(l_{UD}^{\alpha}) + A$ is the path loss, P_U is the transmit power of the UAV, $L_{UD} = L_{UR} + L_{RD}$ is the total distance from UAV to destination D, in there L_{UR} is the distance from UAV to RIS module, L_{RD} is the distance from RIS module to destination D. In [6], the probability density function of γ_D can be written.

$$f_{\gamma_D}(\gamma_D) = \frac{(1+K)e^{-K}}{\bar{\gamma}} exp\left[-\frac{(1+K)\gamma_D}{\bar{\gamma}}\right] \times I_0\left(2\sqrt{\frac{K(1+K)\gamma_D}{\bar{\gamma}}}\right) \tag{4}$$

In (4), $\bar{\gamma} = \frac{P_U}{N_0 L_{UD}}$ where K is the Rician fading factor.

3. ANALYSIS ON THE PERFORMANCE
3.1. Average symbol error rate

In the second, we analyze the performance of UAV to ground communication systems with the average symbol error rate and average channel capacity. Average symbol error rare (ASER) of systems using subcarrier quadrature amplitude modulation can be given by [7].

$$P_{se} = \int_0^{+\infty} P_e(\gamma) f_\gamma(\gamma) d\gamma \quad (5)$$

In with, The conditional error probability (CEP), $P_e(\gamma)$. With using QAM modulation, the CEP can be presented as:

$$P_e(\gamma) = 1 - [1 - 2q(M_I)Q(A_I)\sqrt{\gamma}]\left[1 - 2q(M_Q)Q(A_Q\sqrt{\gamma})\right] \quad (6)$$

In with:
- $A_I = \left(6/\left[(M_I^2 - 1) + r^2(M_Q^2 - 1)\right]\right)^{1/2}$
- $A_Q = \left(6r^2/\left[(M_I^2 - 1) + r^2(M_Q^2 - 1)\right]\right)^{1/2}$
- $q(x) = 1 - x^{-1}$
- $Q(x) = 0.5\, erfc(x/\sqrt{2})$: the Gaussian Q-function.
- $r = d_Q/d_I$: the decision distance ratio of quadrature to in-phase.
- M_I, M_Q: in-phase and quadrature signal amplitudes, respectively.

The PDF of signal-to-noise ratio, $f_\gamma(\gamma)$, can be given by:

$$P_{se}(\gamma) = 2q(M_I)\int_0^{+\infty} Q(A_I\sqrt{\gamma_D})\frac{(1+K)e^{-K}}{\bar{\gamma}} exp\left[-\frac{(1+K)\gamma_D}{\bar{\gamma}}\right] \times I_0\left(2\sqrt{\frac{K(1+K)\gamma_D}{\bar{\gamma}}}\right) d\gamma_D +$$
$$2q(M_Q)\int_0^{+\infty} Q(A_Q\sqrt{\gamma_D})\frac{(1+K)e^{-K}}{\bar{\gamma}} exp\left[-\frac{(1+K)\gamma_D}{\bar{\gamma}}\right] \times I_0\left(2\sqrt{\frac{K(1+K)\gamma_D}{\bar{\gamma}}}\right) d\gamma_D -$$
$$4q(M_I)q(M_Q)\int_0^{+\infty} Q(A_I\sqrt{\gamma_D})Q(A_Q\sqrt{\gamma_D})\frac{(1+K)e^{-K}}{\bar{\gamma}} exp\left[-\frac{(1+K)\gamma_D}{\bar{\gamma}}\right] \times I_0\left(2\sqrt{\frac{K(1+K)\gamma_D}{\bar{\gamma}}}\right) d\gamma_D \quad (7)$$

3.2. Average channel capacity

The second performance parameter is average channel capacity is considered as average value and a random variable, $\langle\bar{C}\rangle$. The ACC can also be represented by average spectral efficiency (ASE). Assuming that the optical channel is perfect channel state information is available at both the receivers and transmitters. The ASE can be estimated as [8]:

$$\langle\bar{C}\rangle = \int_0^{\infty} Blog_2(1+\gamma) \times f(\gamma)d\gamma, \text{ [bit/s/Hz]} \quad (8)$$

In with:
- B: the channel's bandwidth
- $f_\gamma(\gamma)$: the pdf of SNR

The ASE of communication system can be given by:

$$\langle\bar{C}\rangle = \int_0^{\infty} Blog_2(1+\gamma) \times \frac{(1+K)e^{-K}}{\bar{\gamma}} exp\left[-\frac{(1+K)\gamma_D}{\bar{\gamma}}\right] \times I_0\left(2\sqrt{\frac{K(1+K)\gamma_D}{\bar{\gamma}}}\right) d\gamma_D, \text{ [bit/s/Hz]} \quad (9)$$

4. NUMERICAL RESULTS AND DISCUSSIONS

Using the (7) and the (9), we present numerical results and discussions for ASE and ASER of the RIS-assisted UAV-to-ground communication systems. In this analysis, the constants and parameters are presented in Table 1. Figure 2, illustrates the ASER versus signal-to-noise ratio for with RIS and without RIS. The ASER is presented as a function of SNR under several value of link distances. In these figure it is clearly depicted that the ASER of the system with RISs assisted is obviously lower.

Figure 3, illustrates the ASE performance versus signal-to-noise ratio with RIS and without RIS under several value of link distances. As it is shown that, the system's ASE of system is improved significantly with the RIS-assisted communication link. The impact of the RIS assisted, ASE on the performance of system is more significant in high of SNR regions than in low regions.

Table 1. System constants and parameters

Parameter	Symbol	Value
Laser wavelength	λ	1550 nm
Photodetector responsivity	$\Re$	1 A/W
Modulation index	κ	1
Total noise variance	N_0	10^{-7} A/Hz
Quadrature amplitude modulation	$M_I \times M_Q$	8×4
Receiver aperture diameter	D	0.06 m
Index of refraction structure	C_n^2	$10^{-15}\ m^{-2/3}$

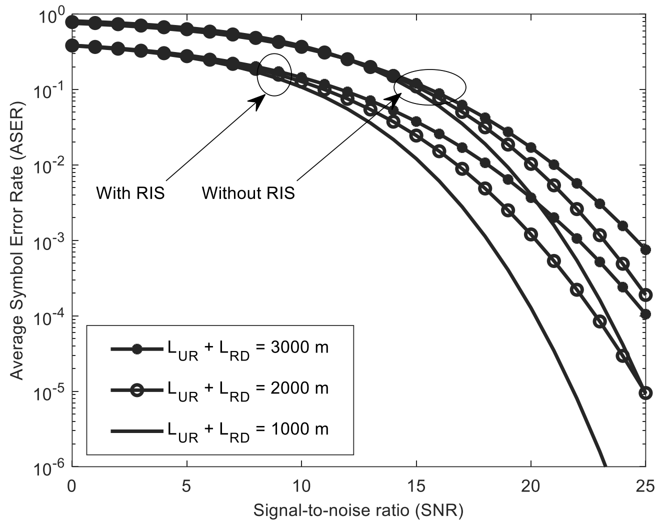

Figure 2. ASER performance versus SNR with RIS and without RIS

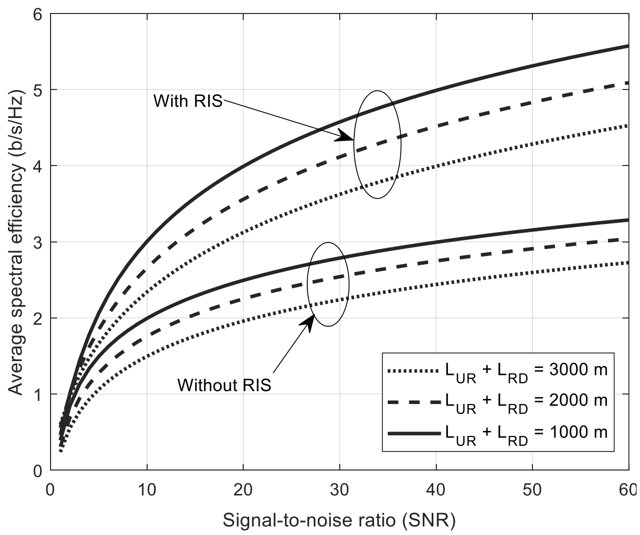

Figure 3. ACC performance versus SNR with RIS and without RIS

5. CONCLUSION

This study analyze the performance of RIS-assisted UAV-to-ground wireless communication system with subcarrier quadrature amplitude modulation was proposed. We analyzed the average symbol error rate and average channel capacity of systems. With the numerical results, it is showed that RIS-assisted can significantly reduce the ASER and the system's ASE is improved significantly.

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