



# Mars Exploration Oriented Design and Simulation of Relay Communication

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**Abstract.** In the deep space communication, traditional point-to-point communication system would no longer meet the requirements of long-distance information transmission and Mars exploration will mainly use the way of relay communication to transmit scientific exploratory data. On the basis of analyzing link visibility and link distance of on-orbit relay satellite, this paper proposes a new way of relay communication which can provide longer visible time and the capacity to cover Mars probe uniformly. The link visibility and link distance of the two relay communication way are simulated by STK, and the link performance of through link and the two relay way is simulated. The simulation results show that the relay constellation scheme which cover Mars probe uniformly reach higher performance in the link visibility and link coverage. Otherwise, the SNR of relay link can get 3 dB performance improvement. Compared with through link, relay constellation scheme that cover Mars probe uniformly can link performance based on obviously improving link visibility, which can be better applied to future Mars exploration.

**Keywords:** Deep communication · Mars exploration · Relay constellation · Link performance

## 1 Introduction

In the 21st century, with Mars Express, Mars Odyssey, Mars Scout Orbiter, Spirit and Opportunity, Phoenix and other Mars orbiters or Mars detectors successfully exploring Mars one after another, Mars exploration has gradually become the focus of global attention. During deep space exploration activities, a large amount of scientific exploration data needs to be returned to the earth. There are two main communication connection methods between the Mars target detector and the ground station: one is the point-to-point communication system, and the other is the relay communication system. The traditional point-to-point communication system has already been difficult to ensure the timely transmission of a large amount of detection data such as high-definition images and videos. Therefore, it will be a very advantageous choice to use the relay communication system to transmit various data and status information, and enhance the effectiveness of data transmission [2, 3].

With the increasing frequency of Mars exploration and exploration missions becoming more complex, the large amount of data transmission brought by the high-

definition video and pictures in Mars exploration poses greater challenges to the relay satellites. Current Mars orbiter will not be able to meet the increasing demand for data transmission in the future, which requires longer relay transmission time and higher link reliability. Therefore, this paper studies a Mars relay system with longer visible time and higher link coverage.

## 2 Scene Construction and Simulation of On-Orbit Mars Orbiter

In order to analyze the relay communication performance of the Mars orbiter, a Mars relay network simulation scenario is built referring to the on-orbit Mars orbiter parameters. The parameters of the Mars orbiter in the simulation scenario refer to the Mars Global Prospector (MGS), Mars Odyssey and Mars Reconnaissance Orbiter (MRO); the Mars detector selects Curiosity as the reference, and the deep space station refers to China Kashi ground station. The parameters of Mars orbiter, Mars detectors and ground station are shown in Table 1 and Table 2.

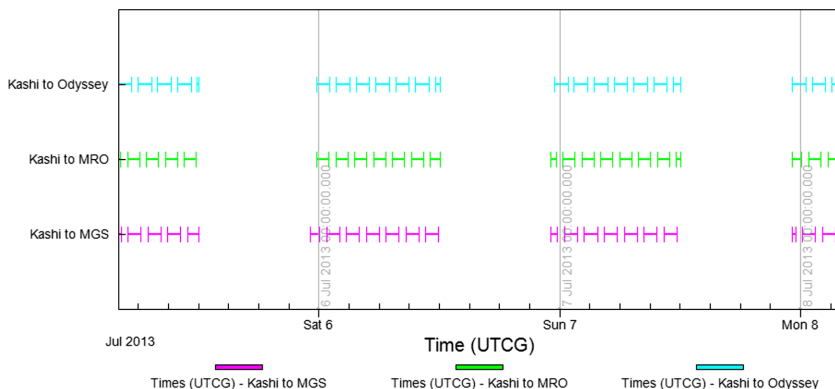
**Table 1.** Orbital parameters of Mars orbiter.

Parameter	MGS	Odyssey	MRO
Track height (km)	400	400	Near Mars 255 Away from Mars 320
Track inclination (deg)	93	93.2	92.7
Ascension (deg)	210	75	225

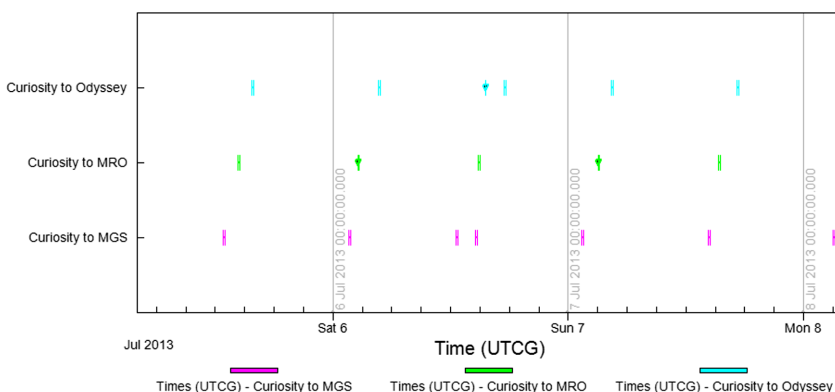
**Table 2.** The parameters of Mars detector Curiosity and Kashi Station.

Name	Geographic location	Antenna elevation
Curiosity	5.45 °S, 137.8 °E, Mars	Min 10°
Kashi	39.5 °N, 75.9 °E, Earth	Min 10°

The Mars relay network simulation scenario of the Mars detector-Mars orbiter-ground station is built using STK. The link analysis module “Access” in STK was used to simulate the visible time and link distance of communication link. The start time of simulation is set to July 5, 2013, and the duration of simulation is 3 days. The visible time period of the link between Mars orbiter and Kashi station or Curiosity is shown in Fig. 1 and Fig. 2, where the horizontal continuous line segment indicates that the ground station or Curiosity and Mars orbiter are visible. The visible time and average distance of the link between Mars orbiter and Kashi station or Mars orbiter are summarized in Tables 3, 4 and 5.



**Fig. 1.** Visible time period between MGS, Odyssey, MRO and Kashi Station



**Fig. 2.** Visible time periods between MGS, Odyssey, MRO and Curiosity

**Table 3.** Visible time and link coverage between MGS, Odyssey, MRO and Kashi stations.

Name	Min duration (s)	Max duration (s)	Mean duration (s)	Total duration (h)	Link coverage
MGS	1701	4662	4243	25.93	36.01%
Odyssey	90	4857	4061	25.95	36.04%
MRO	910	4266	3831	24.48	34%

**Table 4.** Link coverage in visible time between MGS, Odyssey, MRO and Kashi Station.

Name	Min duration (s)	Max duration (s)	Mean duration (s)	Total duration (h)	Link coverage
MGS	444	715	617	1.20	1.67%
Odyssey	230	710	589	0.98	1.36%
MRO	483	593	536	0.89	1.24%

**Table 5.** The average distance between Mars orbiter and Kashi station or Curiosity link.

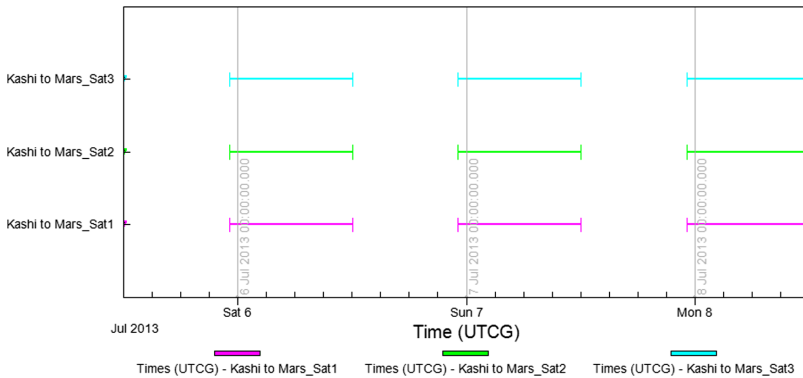
Name	Kashi (km)	Curiosity (km)
MGS	$3.66 \times 10^8$	886
Odyssey	$3.66 \times 10^8$	882
MRO	$3.66 \times 10^8$	654

### 3 System of Covering Mars Relay Constellation Uniformly

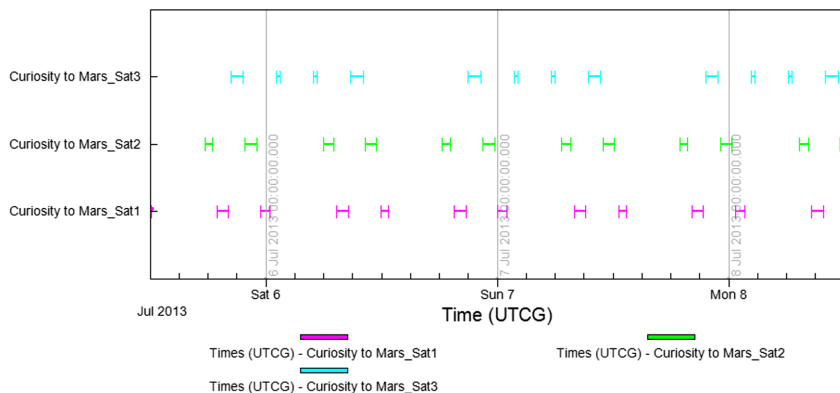
It is obvious that the link coverage of Mars orbiters to Mars detectors is low from Table 4. In order to increase the visible time of the target detector, a relay constellation system with covering time uniformly is designed. The relay constellation system consists of three satellites on an orbit plane, the three relay satellites are evenly distributed, with a phase interval of  $120^\circ$ . The constellation system consists of three evenly distributed satellites on an orbit plane with the orbital inclination of  $115.567^\circ$  and the satellite orbital height of 3590 km. Three satellites in the relay constellation system under uniformly covering are evenly distributed in an orbit plane. The specific orbit parameters of the three satellites in the constellation system are shown in Table 6. The Mars detector and deep space station still refer to the positions of Curiosity and Kashi station. Figure 3 and Fig. 4 show the visible time period of Mars orbiter and Kashi station or Curiosity respectively.

**Table 6.** Satellite orbit parameters of the relay constellation system under uniformly covering.

Name	Track inclination (deg)	Ascending intersection (deg)	True close angle (deg)
Mars-Sat1	115.567	145.113	0
Mars-Sat2	115.567	145.113	120
Mars-Sat3	115.567	145.113	240



**Fig. 3.** Visible time period between Mars\_sat1, Mars\_sat2, Mars\_sat3 and Kashi station



**Fig. 4.** Visible time period between Mars\_sat1, Mars\_sat2, Mars\_sat3 and Curiosity

The visible time and average distance between Mars orbiter and Kashi station or Curiosity are shown in Tables 7, 8, and 9.

**Table 7.** Visible time and link coverage between Mars\_sat1, Mars\_sat2, Mars\_sat3 and Kashi station.

Name	Min duration (s)	Max duration (s)	Mean duration (s)	Total duration (h)	Link coverage
Mars_Sat1	259	46413	34542	38.38	53.31%
Mars_Sat2	260	46143	34542	38.38	53.31%
Mars_Sat3	259	46414	34543	38.38	53.31%

**Table 8.** Visible time and link coverage between Mars\_sat1, Mars\_sat2, Mars\_sat3 and Curiosity.

Name	Min duration (s)	Max duration (s)	Mean duration (s)	Total duration (h)	Link coverage
Mars_Sat1	349	4403	3522	11.74	16.31%
Mars_Sat2	1469	4385	3523	11.74	16.31%
Mars_Sat3	1288	4612	3020	10.07	13.99%

**Table 9.** Link average distance between Mars\_sat1, Mars\_sat2, Mars\_sat3 and Kashi Station or Curiosity.

Name	Kashi (km)	Curiosity (km)
Mars_Sat1	$3.659 \times 10^8$	4745
Mars_Sat2	$3.659 \times 10^8$	4784
Mars_Sat3	$3.659 \times 10^8$	4614

Comparing the data of the above three tables with Tables 3, 4, and 5, it can be seen that when the Mars orbiter increases orbit height, the link visible time and the coverage of the link of the Mars orbiter in the Mars relay constellation system under uniformly covering has been greatly improved, and the visible time of the Mars detector-Mars orbiter and Mars orbiter-ground station has been increased, which is conducive to the transmission of information and data in Mars exploration. In addition, in this relay communication system, the communication opportunities between the relay satellite and the target detector are equal, which is conducive to periodic planning.

## 4 Conclusion

This paper aims at the characteristics of deep space communication, especially the long distance and complicated communication environment in Mars exploration, uses STK to build a Mars relay network simulation scenario with reference to the orbit parameters of the on-orbit relay satellites of the United States and Europe, and analyzes link visibility and link distance of the mode. Then, a relay system with long visible time and uniformly covering the Mars detectors is proposed. The simulation results show that the link visibility and link coverage are significantly improved compared to the previous relay method.

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