International Journal of Future Generation Communication and Networking
Vol.6, No.6 (2013), pp.47-60
http://dx.doi.org/10.14257/ijfgcn.2013.6.6.06

Design of Layered Aerospace Time Synchronization Architecture and Time Synchronization Links Budget Comparison

Huang Feijiang[1], Li Xiaoyong[2], Sun Liping[1], Sheng wang[1],
Zhang Wenxi[1] and Liu Guangcan[1,*]

[1]Department of Electronics and Communication Engineering Changsha University
No.98 Hongshan Road, Changsha 410022, China
[2]School of Information and Electronic Engineering, Zhejiang University of Science and Technology
No.318 Liuhe Road, Hangzhou 310023, China

ccsuhfj@163.com

Abstract

The rapid development of various kinds of aerospace application systems requires the appropriate high-accuracy time and frequency standard. In order to establish suitable time and frequency standard in aerospace, based on the establishment of aerospace satellite visual model, we simulate the satellite visual time of 3-layer satellite constellation, including GEO satellite(Geostationary Earth Orbit), IGSO (Inclined GeoSynchronous Orbit)satellites and MEO(Medium Earth Orbit) satellites. The visual features of this satellite constellation have been gained. Combining with the major influencing factors of satellite clock offset error, we study the layered aerospace time synchronization architecture and give the advantage of the architecture and the choice of time synchronization method. Starting from the establishment of the time synchronization link demand, we simulate the variation range of intersatellite distance of the layered aerospace time synchronization architecture, and give budget results of GEO-GEO link in laser band and GEO-IGSO and GEO-MEO links in S-band and Ku-band. The results show that GEO-GEO link can achieve to more than 3Gb/s data transmission rate on condition that the transmitting power is 0.5W, the antenna diameter is only 20cm; if the S-band transmission rate is in excess of 2Mb/s, when the antenna is 1m in diameter, the transmitting power needed is about 50W. In the Ka-band, 1m antennas only need 1W transmitting power to provide an intersatellite data transmission rate higher than 2Mb/s. Research results serves as reference for the establishment of layered aerospace time synchronization architecture and improvement of time synchronization precision.

Keywords: *Satellite constellation, Aerospace time synchronization architecture, Intersatellite communication, Link budget*

1. Introduction

With the rapid development of aerospace technology, space application has taken on various forms. Aerospace integration is becoming a basic trend of development in the field of aerospace [1, 2]. How to realize time synchronization between all spacecrafts, between spacecrafts and ground facilities and how to allow all systems to conduct cooperative work

---

[*] Corresponding Author: Liu Guangcan, E-mail:ccsuhfj@163.com

ISSN: 2233-7857 IJFGCN

under the unified time will be major issues to be solved in the process of aerospace integration. In the current aerospace application, as the time reference is established on the ground, most of spacecrafts for the aerospace technological activities have to conduct time synchronization with their own ground station independently. This method will be affected by short synchronization time and low synchronization accuracy. Furthermore, under unusual circumstances, once the ground station is been destroyed, the whole system will be in danger of falling into paralysis. However, the establishment of high-accuracy time frequency standard in aerospace will solve the problem effectively. The present aerospace applications mainly focus on satellite network system structure, space information transmission model, intersatellite link performance design and simulation, routing algorithm of multi-layer satellite network, *etc.*, [3-8]. There are few researches on establishment of aerospace high-accuracy time frequency standard and aerospace time synchronization architecture, and on time synchronization link budget.

On the basis of simulation of satellite visible time and the variation range of the intersatellite distance of an 3-layer satellite constellation, this paper presents a new layered aerospace time synchronization architecture, doing research on the choice of time synchronization method and the intersatellite link budget in laser band, S-band and Ka-band in accordance with this time synchronization architecture.

2. Component and Visual Simulation of Satellite Constellation

2.1. Component of Satellite Constellation

Satellite constellation is composed of GEO, IGSO, and MEO satellites. They form the GEO satellites layer, IGSO satellites layer and MEO satellites layer. Among them, GEO satellites layer and IGSO satellites layer have three satellites and MEO satellites layer has 24 satellites. By using the simulation tool STK(Satellite Tool Kit),we establish the satellite constellation model. The 3D stereogram is shown in Figure 1[9].

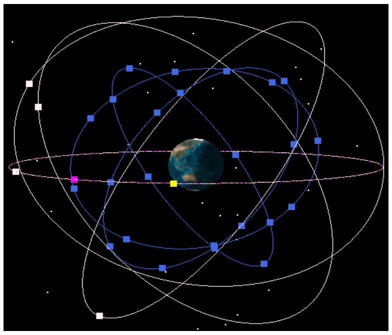


Figure 1. 3D Structure of Satellite Constellation

In order to realize time synchronization among satellite constellation, we must consider two factor: for one thing, physical visibility has to be achieved between satellites; for another, on the basis of physical visibility, requirements on electromagnetic wave power for the normal communication have to be met.

2.2. Satellite Mutual Visual Model

For those two earth-around-rotating satellites, after the determination on locations of satellites at any time in the space, they can only achieve visibility when they are both above the same plane which is tangent to the earth surface. The extreme situation is that both of them are in the tangent plane, as shown in Figure 2[10].

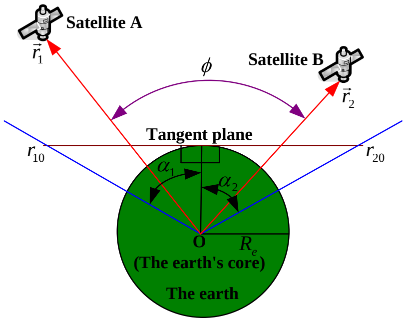


Figure 2. Mutual Visual Model of Satellite

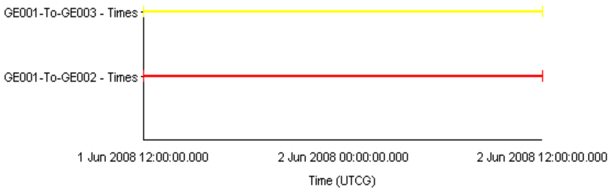
Therefore, the visibility function to describe that whether these two satellites can achieve visibility is gained. The visibility function Ψ is as follows:

$$\psi = \alpha_1 + \alpha_2 - \phi \qquad (1)$$

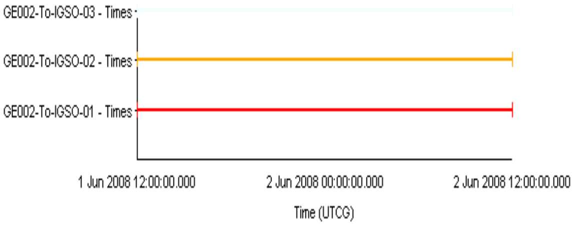
In formula (1), α_1 and α_2 are the maximum visibility angle; Φ is the angle between the two satellites position vector. When $\Psi>0$, the two satellites can achieve visibility. Otherwise, there is no visibility.

2.3. Visual Time Simulation of Satellite Constellation

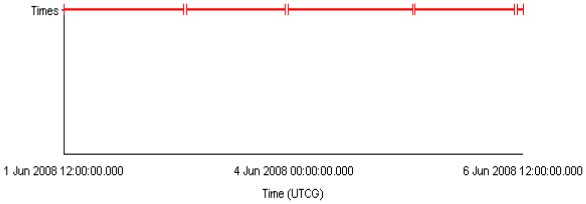
Based on the above satellite mutual visible models, the simulations of four typical visible situations in satellite constellation have been done with the help of satellite simulation tool software STK. The results are shown in Figure 3[11]. The statistical results of concrete are shown in Table 1[12].



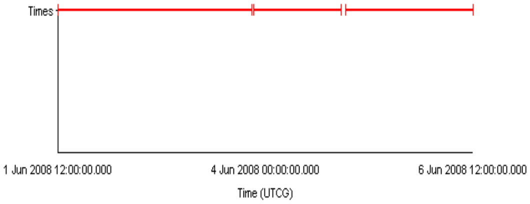
(a) Visual time for GEO Satellites



(b) Visual Time for GEO Satellites Layer and IGSO Satellites Layer



(c) Visual Time for GEO Satellites Layer and MEO Satellites Layer



(d) Visual Time for IGSO Satellites Layer and MEO Satellites Layer

Figure 3. Simulation of Four Typical Visual Times in Satellite Constellation

Table 1.The Percentage of Satellite Mutual Visual Time and Simulation Cycle

Link types	The percentage of satellite mutual visual time and simulation cycle
GEO-GEO	100%
GEOIGSO	100%
GEO-MEO	97.47%
IGSO-MEO	98.55%

From the Figure 3 and Table 1, it can be seen that 24-hour visibility is possible between GEO satellites, and between GEO satellites layer and IGSO satellites layer; the minimum visual time between GEO satellites layer and MEO satellites layer takes 97.47% of the whole MEO satellites simulation cycle, meaning in the whole simulation cycle, GEO satellites layer and MEO satellites layer can achieve visibility in 97.47% of the time; IGSO satellites layer and MEO satellites layer can have mutual visibility in 98.55% of the total simulation cycle.

3. Design of Aerospace Time Synchronization System Based on Layered Architecture

3.1. The Major Influencing Factors of Satellite Clock Offset Error

When every satellite in 3-layer satellite constellation has loaded atomic clock, clock offset error of satellite is comprised of clock offset parameters measurement error and extrapolation error. Under the condition that frequency stability of satellite clock cannot be guaranteed, the length of extrapolation time of satellite clock offset will seriously affect the accuracy of clock offset of satellite clock. Satellite clock offset extrapolation model is normally the quadratic polynomial about time [13].

$$\Delta t = a_0 + a_1(t - t_{oc}) + a_2(t - t_{oc})^2 \tag{2}$$

In formula (2), Δt is satellite clock offset, t_{oc} is starting point reference time of model, and a_0,a_1 and a_2 are respectively phase deviation of satellite clock relative to standard time (clock offset), frequency deviation of clock relative to actual frequency (clock rate) and frequency drift of clock (change rate of clock rate, drift). In it, error of quadratic item (or high order term) coefficient is mainly represented by frequency stability. Unstable clock will cause high fitting error which influence will drastically increase with the length of extrapolation time. When the satellite clock has bad frequency stability, the shorter extrapolation time will give rise to higher accuracy of extrapolation satellite clock offset [14]. On the basis of normal intersatellite communication required by intersatellite link antenna tracking direction and satellite transmitting power, the length of synchronization time among satellites will also have great influence on the accuracy of satellite clock offset.

3.2. Design of Layered Aerospace Time Synchronization System

According to the comparison of visual time simulation results on 3-layer satellite constellation and analysis of the major influencing factors of satellite clock offset error, we can establish a layered aerospace time synchronization architecture, with the GEO satellites as the time synchronization source of 3-layer satellite constellation. In this architecture, GEO satellites realizes intersatellite time synchronization with IGSO satellites and MEO satellites with the establishment of intersatellite link, increasing the time length of synchronization of IGSO satellites and MEO satellites in the whole operation cycle, decreasing clock offset extrapolation time of IGSO satellites and MEO satellites, boosting time synchronization accuracy of IGSO satellites and MEO satellites. First the system realizes high precision time synchronization among GEO satellites; based on this, system achieves high precision time synchronization with GEO satellites and IGSO satellites; at last, both of the satellites conduct high precision time synchronization with MEO satellites, really implementing GEO satellites, IGSO satellites and MEO satellites time synchronization. Eventually, accurate aerospace system time frequency standard could be established by 3-layer satellite constellation. The schematic diagram of time synchronization architecture is shown in Figure 4. In the diagram, line or curve represent intersatellite time synchronization links. We draw seven MEO satellites.

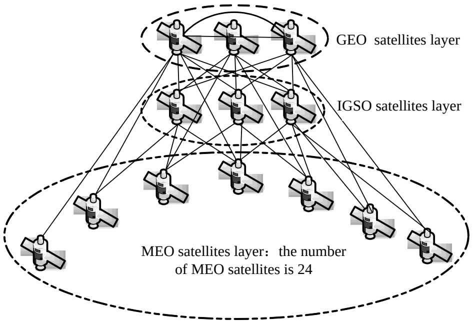


Figure 4. Schematic Diagram of Aerospace Time Synchronization System based on Layered Architecture

3.3. The Advantage of Layered Aerospace Time Synchronization system and the choice of Time Synchronization methods

The advantage of layered aerospace time synchronization system structure is that it can lower the difficulty of the autonomous running and managing of the entire system structure.

This system structure can synchronize the time in the GEO satellite with the reference time in the ground station through the successive, real-time and highly precise time synchronization between GEO satellite and the ground station, thus realizing the synchronization with UTC. When losing contact with the ground station, the highly precise time synchronization between GEO satellites can ensure the time synchronization precision of the whole constellation. In this way, when the constellation is making autonomous synchronization, the synchronization time is long; the satellite clock offset error extrapolation time is short and the synchronization precision improves correspondently. Especially when the satellite clock has poor stability and ground station can't be distributed globally, this synchronization system structure can lower the stability requirements on satellite clock.

From the above analysis, it can be seen that the choice of the intersatellite time synchronization methods suitable for the time synchronization system structure has a great importance on the time synchronization precision. According to the composition characteristics of layered aerospace time synchronization system structure, when the satellite time synchronizes with the ground time, the satellite-to-ground two-way time synchronization method can be adopted to improve the satellite-to-ground time synchronization precision because it offsets influence of additive latency such as propagation path and when there are enough ground-satellite time synchronization stations, reverse-positioning method can be used.

When lack of ground station support, it is relatively easy to point, acquire and track the time synchronization signals because the GEO satellites of the same orbit keep stationary and the link elevation and azimuth change is small. Therefore, one of the most precise time synchronization methods used between GEO satellites is laser time synchronization plan to assure highly precise time synchronization between time synchronization sources.

According to the autonomous running requirements of the layered aerospace time synchronization system structure, the two-way time synchronization method can be used in the time synchronization in the constellation motion satellites. This method doesn't need to know the precise location of two synchronized satellites in advance and it can offset the influence of the additive latency such as propagation path; instead, it studies the dynamic two-way time synchronization used in motion satellites according to the characteristics of the intersatellite satellite motion to meet the precision requirements of the constellation time synchronization [15].

4. Simulation of the Variation Range of Intersatellite Distance of the Layered Aerospace Time Synchronization Architecture

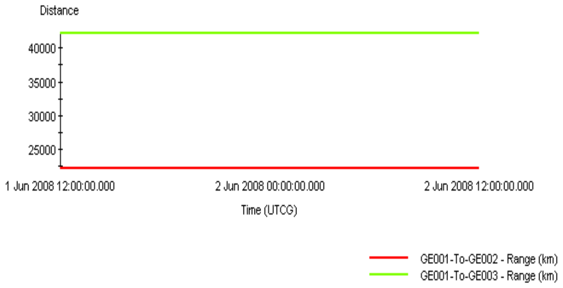
Through the above analysis, it can be seen that the time synchronization of the layered aerospace synchronization architecture is conducted mainly through the intersatellite links. The performance of intersatellite time synchronization link has great influence on the accuracy of the architecture, so the design and budget analysis for intersatellite link must be conducted, so as to meet the requirements of time synchronization signals and information transmission among satellites. On basis of simulation given intersatellite distance in the architecture, we study the link budget of GEO-GEO, GEO-IGSO and GEO-MEO.

4.1. Major Parameters of Intersatellite Link budget

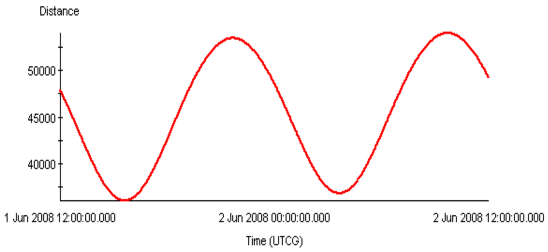
An intersatellite link can be considered as a special wave beam of a multi-beam antenna. This wave beam does not point at the earth's surface but rather at other satellites. Intersatellite links include those between satellites of the same orbit altitude and those between satellites of different orbit altitudes. Intersatellite links between satellites of the same orbit altitude can be further divided into intra-orbit intersatellite links within the same orbit plane and inter-orbit intersatellite links within different orbit planes. The azimuthal angle, elevation, and intersatellite distance between two satellites having intersatellite links are usually subject to variations with time. Variations of the azimuthal angle and elevation require the automatic tracking capability of the satellite antennas. Variation of the link distance requires the automatic power control capability of the antennas. Therefore parameters determining the difficulty of the establishment of intersatellite links of a satellite constellation include dynamic variation ranges and rates of azimuthal angle, elevation, and intersatellite distance[16]. This paper is focused on the analysis of the communication performance of intersatellite links established between different layers of the layered aerospace synchronization architecture. Therefore the variation range of intersatellite distance is one of the major parameters for the intersatellite link budget.

4.2. Simulation of the Variation Range of Intersatellite Distance of the Architecture

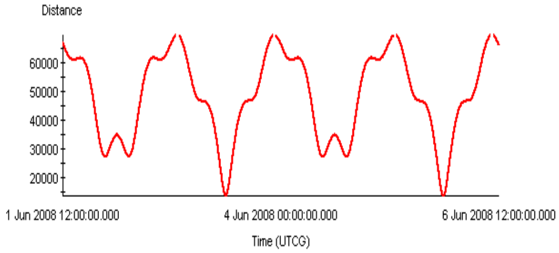
In order to obtain the rules of the variation of distances of interlayer links of the architecture, an simulation tool STK(Satellite Tool Kit) is used to simulate the variation of intersatellite distance within the architecture. Figure 5 shows the simulation results [17].



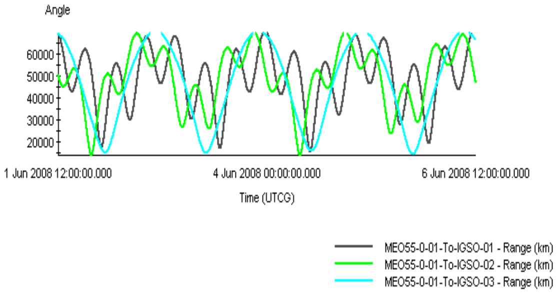
(a) Rules of the variation of intersatellite distance between GEO and GEO



(b) Rules of the variation of intersatellite distance between GEO and IGSO



(c) Rules of the variation of intersatellite distance between GEO and MEO



(d) Rules of the variation of intersatellite distance between IGSO and MEO

Figure 5. Rules of the Variation of Intersatellite Distance within the Layered Aerospace Time Synchronization Architecture

In order to analyze and compare the communication performance of intersatellite links of the layered time synchronization architecture within various frequency bands, the specific variation ranges of four typical intersatellite links of the architecture are simulated. Table 2 sum up the simulation results[17].

Table 2. Three Typical Intersatellite Distance of the Layered Aerospace Synchronization Architecture

Link types	Distance (Unit: km)	
	dc(min)	dc(max)
GEO-GEO	22180.984160	42164.167065
GEO-IGSO	377.3	53957.058485
GEO- MEO	13670.1	69457.960023

From Figure 5 and Table 2, we can sum up the following rules of the variation of intersatellite distance within the architecture: the intersatellite distance of GEO-GEO remains the same; the intersatellite distance of GEO-IGSO and GEO-MEO decreases and increases for many times within a wide range of variation, which has brought certain difficulties to the establishment of intersatellite links.

5. Intersatellite Link Budget Method

5.1. Intersatellite Laser Link Budget Method

In order to achieve the continuous high precision time synchronization between GEO satellites, it is necessary to build intersatellite laser time synchronization link and finish the exchange of time synchronization data. Thus it is necessary to perform detailed calculation and analysis on the laser link. This calculation mainly considers that the laser optical communication is adopting Heterodyne PSK/QPSK modulation and demodulation techniques and can achieve fine tracking in pointing, acquiring and tracking (PAT) of GEO intersatellite. After the communication link is established, GEO satellite can make use of the laser intersatellite link's performance of exchanging high-speed data. According to given condition, the laser link budget formula can be obtained [18]:

$$r_b = \frac{P_R}{18hv} \tag{3}$$

In this formula P_R is the received optical power; v is the incoming ray's frequency whose unit is hertz (Hz), h=6.626×10-34J·s is the Planck constant. Assuming the antenna's gain for launching and receiving are respectively G_T and G_R, the optical transmitter's power is P_T, through which can calculate the optical power P_R received by receiver's antenna is:

$$P_R = P_T + G_T + G_R - [L_P + \Sigma_L + S_F] \tag{4}$$

The calculation of G_T and G_R can reference literature 18.

5.2. Intersatellite Microwave Link Budget Method

Suppose the satellite A transmitting power is P_t, antenna gain is G_t; for satellite B, the receiver antenna gain is G_r, the received signal power is P_r, and carrier wavelength is λ; in the calculation, if only the free space loss, ignoring other link loss, the formula for calculating the intersatellite links can be obtained as follows[19]:

$$P_r = P_t G_t G_r \left(\frac{\lambda}{4\pi d_c}\right)^2 \tag{5}$$

Where: the value G_t and G_r can be obtained by the following formula:

$$\begin{cases} G_t = \dfrac{4\pi}{\varphi_c^2} \\ G_r = \dfrac{4\pi}{\lambda^2} A_e \end{cases} \tag{6}$$

Φ_c indicates the beam width of transmitting antenna, which depends on the antenna diameter D and transmitting frequency; A_e indicates the antenna effective aperture area, which is the product of actual aperture area and antenna efficiency, formula is as follows:

$$\phi_C = \frac{\lambda}{D} \tag{7}$$

$$A_e = \frac{\pi}{4} D^2 \eta \tag{8}$$

By substituting (5) into (6), (7) and (8), obtaining:

$$P_r = \frac{\pi P_t D^4 \eta}{4\lambda^2 d_c^2} \tag{9}$$

Total noise power N of the receiver side is:

$$N = \kappa T_e B \tag{10}$$

Where, k indicates the Boltzman constant, whose value is 1.38×10^{-23}J/K. T_e indicates the equivalent noise temperature, and B indicates the carrier bandwidth. Through formula (9) and (10), C/N can be obtained:

$$\frac{C}{N} = \frac{P_r}{N} = \frac{\pi P_t D^4 \eta}{4N\lambda^2 d_c^2} \tag{11}$$

In the digital signal transmission, E_b/N_0 depends on the carrier to noise ratio (C/N) of the receiver. Therefore, through the relationship between C/N and E_b/N_0, the relationship between E_b/N_0 and each parameter of the link can be obtained:

$$\frac{E_b}{N_0}=\frac{C}{N}\cdot\frac{B}{r_b}=\frac{\pi P_t D^4\eta}{4\kappa T_e\lambda^2 d_c^2 r_b} \qquad (12)$$

Where, r_b indicates the intersatellite information transmission rate. Thus in the link budget analysis, values optimization of each parameter can be achieved, so as to meet performance requirements for intersatellite time synchronization link.

6. Intersatellite Link Budget Results of the Laered Aerospace Time Synchronization Architecture

6.1. GEO-GEO Laser Link Budget Results

Suppose that the GEO satellites are all equipped with reflective telescope of a certain diameter and have already targeted at each other and achieved the fine tracking, the optical maser wavelength adopts laser of λ=1.55μm. In the calculation of formula (4), taking S_F as 5dB, the value of $\sum_L$ is 7dB[18].The given maximum GEO-GEO laser link intersatellite distance is 42164.167065 km. In the condition of above given parameters, we can calculate the laser time synchronization link budget results. The results of GEO-GEO laser time synchronization link is shown in Table 3[20].

Table 3. GEO-GEO Link Laser Band Budgets Results

r_b(b/s) P_T / D	0.1 W	0.5 W	1 W	2 W
0.20 m	6.29×10^{8}	3.15×10^{9}	6.29×10^{9}	1.26×10^{10}
0.25 m	1.54×10^{9}	7.68×10^{9}	1.54×10^{10}	3.07×10^{10}
0.30 m	3.18×10^{9}	1.59×10^{10}	3.18×10^{11}	6.37×10^{10}

As can be seen from Table 3, since there is no existence of atmosphere's impact of attenuation, refraction, bending or beam tearing on laser in GEO-GEO laser time synchronization link, only considering the light absorption of optical device, inaccurate beam position brought by unstable satellite attitude, under the condition that the transmitting power is 0.5W, the antenna diameter is only 20cm, the data transfer rate can achieve to more than 3Gb/s.

6.2. GEO-MEO and GEO- IGSO Microwave Links Budget Results

Let the design of intersatellite links using binary phase shift keying (BPSK) as modulation mode, if the required bit error rate (BER) is not more than 10^{-5}, taking the 2dB of implementation margin into account, thus obtained E_b/N_0 is 11.6dB. The equivalent noise temperature (*i.e.*, T_e) of satellite receiver is 1000K, and receiving antenna efficiency η is 65%[19, 21]. Without taking intersatellite antenna pointing error into account, conduct calculation and analysis for the S-band and Ka-band performance of link GEO-MEO and link GEO-IGSO through formula (12), obtaining the relationship among satellite transmitting power, antenna diameter, and intersatellite information transmission rate.

6.2.1. S-band Links Budget Results: When S-band and frequency 2.4GHz is used for intersatellite link carrier, put the given parameters and maximum intersatellite communication distance into formula (12), the GEO-MEO and GEO-IGSO link budget results are shown in Table 4 and Table 5[22].

Table 4. GEO-MEO Link S-band Budgets Results

P r_b(*b/s*) *D*	0.1 W	1 W	5 W	50 W
0.25 *m*	16.5	165.3	826.3	8.3×10^{3}
0.50 *m*	264.4	2.6×10^{3}	1.3×10^{4}	1.3×10^{5}
1.00 *m*	4.2×10^{3}	4.2×10^{4}	2.1×10^{5}	2.1×10^{6}

Table 5. GEO-IGSO Link S-band Budgets Results

P r_b(*b/s*) *D*	0.1 W	1 W	5 W	50 W
0.25 *m*	27.4	273.8	1.4×10^{3}	1.4×10^{4}
0.50 *m*	438.2	4.4×10^{3}	2.2×10^{4}	2.2×10^{5}
1.00 *m*	7.0×10^{3}	7.0×10^{4}	3.5×10^{5}	3.5×10^{6}

Analyzed the results of Table 4 and Table 5, which show that in S-band 2.4GHz carrier, under the preset intersatellite transmission system, link parameters, transmission loss and without regard to the error of the intersatellite pointing accuracy, the intersatellite links can meet a certain high data rate requirements. When required transmission rate should reach 2Mb/s above and the antenna with a diameter of 1m is used, the required transmitting power for GEO, IGSO and MEO satellite shall be about 50W. Therefore, when using S-band carrier, relatively larger antenna and transmitting power are required, in order to meet the requirements of intersatellite links data transfer rate in the time synchronization architecture, which makes higher requirements for the performance of the satellite.

6.2.2. Ku-band Links Budget Results: Currently with the continuous development of the intersatellite communication, the requirements for information transfer rate are getting higher and higher. So the building of intersatellite links at Ka-band is considered, which has very little free space loss, and the requirements for the antenna and transmitting power are also low. Under the preset intersatellite transmission system, link parameters, transmission loss and without regard to the error of the intersatellite pointing accuracy, with Ka-band 30GHz carrier, to conduct re-calculation and the budget results for link GEO-MEO and GEO-IGSO are as shown in Table 6 and Table 7 [17].

Table 6. GEO-MEO Link Ka-band Budgets Results

P r_b(*b/s*) *D*	0.1 W	1 W	5 W	50 W
0.25 *m*	2.6×10^{3}	2.6×10^{4}	1.3×10^{5}	1.3×10^{6}
0.50 *m*	4.1×10^{4}	4.1×10^{5}	2.1×10^{6}	2.1×10^{7}
1.00 *m*	6.6×10^{5}	6.6×10^{6}	3.3×10^{7}	3.3×10^{8}

Table 7. GEO-IGSO Link Ka-band Budgets Results

P r_b**(b/s)** **D**	0.1 W	1 W	5 W	50 W
0.25 *m*	4.3×10^{3}	4.3×10^{4}	2.1×10^{5}	2.1×10^{6}
0.50 *m*	6.8×10^{4}	6.8×10^{5}	3.4×10^{6}	3.4×10^{7}
1.00 *m*	1.1×10^{6}	1.1×10^{7}	5.5×10^{7}	5.5×10^{8}

Results of Table 6 and Table 7 shows that when with the maximum distance among satellites link in GEO-MEO and GEO-IGSO, with only 1W transmitting power and the antenna with a diameter of 1m, the 2Mb/s above intersatellite transfer data rate can be met. It can reduce the requirements for satellite antenna and transmitting power, and can improve the intersatellite data transfer rate within the layered aerospace time synchronization architecture.

7. Conclusions

With the consideration of requirements on highly accurate time frequency of all kinds of aerospace application systems, aerospace time synchronization system and time synchronization method based on layered architecture are designed and the correspondent time synchronization link performance budget is analyzed. This layered time synchronization architecture adopts GEO satellite as its time synchronization source. GEO satellites realizes intersatellite time synchronization with GEO satellites, IGSO satellites and MEO satellites with the establishment of intersatellite link. Ultimately, the layered aerospace high-accuracy system time frequency standard is constructed. The link budget is performed on the communication performance of GEO-GEO, GEO-IGSO and GEO-MEO intersatellite links without regard to the intersatellite pointing error. The results show that GEO-GEO link can achieve to more than 3Gb/s on condition that the transmitting power is 0.5 W, the antenna diameter is only 20cm. If the S-band transfer rate is in excess of 2Mb/s, when the antenna is 1m in diameter, the transmitting power needed is about 50W. In the Ka-band, 1m antennas only need 1W transmitting power to provide an intersatellite data transfer rate higher than 2Mb/s. By taking advantage of the layered aerospace time synchronization architecture and its time frequency standard, high-accuracy time service can be provided for various aerospace application systems.

Acknowledgements

This study was supported by Hunan Provincial Natural Science Foundation of China(No.11JJ3072), Scientific Research Fund of Hunan Provincial Education Department of China(No.13A115, No.11B015, No.10C0413), and Science and Technology Planning Project of Changsha of China (No. K1008012-11).

References

[1] W. Xiaohai, “The Development of Space-based Integrated Information Network”, Aerospace China, vol. 1, **(2007)**.

[2] D. Kun and L. Shiwen, “A System Structure Model of Space-Based Networks”, Microelectronics & Computer, vol. 4, no. 21, **(2004)**.

[3] B. Jianjun, P. Wei and L. Zexin, “Research on the Dynamic Characteristics of the MEO/LEO Satellite Constellation Network”, Computer Engineering & Science, vol. 9, no. 27, **(2006)**.

[4] J. W. Lee, T. W. Kim and D. U. Kim, “Satellite over Satellite(SOS) Network: A Novel Concept of Hierarchical Architecture and Routing in Satellite Network”, Proc. 25th Annual IEEE Conference on Local Computer Networks, Tampa, FL, **(2000)** November 8-10.
[5] D. Hongyong, “Design of Connectivity Simulation Model of Satellite Communication Link”, Journal of System Simulation, vol. 4, no. 19, **(2007)**.
[6] W. Liang, Z. Naitong, W. Yang, C. Haibin and L. Hui, “Geometric Characters of Inter Satellite Links Between MEO Layer and LEO Layer in MEO/LEO Networks”, Chinese Space Science and Technology, vol. 1, no. 24, **(2004)**.
[7] B. Jianjun, L. Xicheng, L. Zexin and P. Wei, “A distributed hierarchical routing porotcol for Non-GEO satellite networks”, Proc.of International Conefrence on Parallel Proeessing Workshops, Montreal, QC, Canada, **(2004)** August 8.
[8] Y. Xianqing, F. Mingyue, Z. Yang and L. Xueshan, “A Destruction-resistant Routing Algorithm of Satellite Network Based on GEO/MEO Constellation”, Computer Science, vol. 8, no. 34, **(2007)**.
[9] F. Huang, G. Liu, X. Li and W. Sheng, “Research on reforming the teaching of satellite communications based on STK”, World Transactions on Engineering and Technology Education, vol. 2, no. 11, **(2013)**.
[10] Z. Gengxin and Z. Hang, “Satellite Mobile Communication System”, Beijing: Posts & Telecom Press, China, **(2001)**.
[11] H. Feijiang, Y. Jun, L. Xiaochun, S. Qingxiao and Z. Yongbin, “Study on Aerospace Layering Time Synchronization Architecture and Time Synchronization Algorithm”, Advanced Materials Research, **(2012)**, pp. 546-547.
[12] H. Feijiang, L. Xiaochun, L. Guangcan, S. Liping, C. Weibing and W. Yingde, “Time Synchronization Algorithm and Performance Analysis of Time Synchronization Link Based on Aerospace Layering Time Synchronization Architecture”, International Journal of Advancements in Computing Technology (IJACT), vol. 1, no. 5, **(2013)**.
[13] S. Huli and Z. Yan, “New Ideas and Methods of Error Design”, Science Press, China, **(2007)**.
[14] X. Qifeng, “Satellite Constellation of Local Navigation System”, Engineering of Surveying and Mapping, vol. 1, no. 10, **(2001)**.
[15] H. Feijiang, L. Xiaochun, W. Haitao and B. Yujing, “An Algorithm of Dynamic Two-way Time Transfer Based on Intersatellite Range Variation”, Geomatics and Information Science of Wuhan University, vol. 1, no. 35, **(2010)**.
[16] L. Gang, “Research on the Key Technologies of Networking in the NGSO Satellite Mobile Communication Systems”, Doctoral Dissertation,University of Electronic Science and Technology of China,**(2010)**.
[17] H. Feijiang, Y. Jun, L. Xiaochun, S. Qingxiao, Z. Yongbin, C. Jianyun and H. Zhuli, “Performance Analysis of Intersatellite Links Based on 3-Layer Satellite Networks”, Computer Engineering & Science, vol. 4, no. 34, **(2012)**.
[18] J. Chang and F. Xiaolin, “The Study of Laser Communicafion and Tracking Technology in Space”, Telemetry & Telecontrol, vol. 9, **(2005)**.
[19] M. O. Kolawole, Satellite Communications Engineering, Marcel Dekker,Inc, USA, **(2002)**.
[20] F. Huang, X. Lu, J. Yang, Q. Shan, J. Chen and Y. Zhou, “Analysis of GEO Intersatellite Laser Time Transfer and Link Performance”, 2011 International Conference on Electronic & Mechanical Engineering and Information Technology, Harbin, Heilongjiang, China, **(2011)** August 12-14.
[21] D. Roddy, Satellite Communications(3rd), McGraw-Hill,Inc, USA, **(2001)**.
[22] H. Feijiang, L. Xiaochun, L. Guangcan, W. Yingde, S. Liping and L. Zhengda, “Autonomous Time Synchronization Algorithm and Time Synchronization Link Performance Analysis in the Satellite Constellation”, International Conference on Wireless Communications, Networking and Mobile Computing, Chendu, Sicuan, China, **(2010)**September 23-25.

Authors

HuangFeijiang, he received his M.S. degree in circuit and system (2003) from Guanxi Normal University and Ph.D. degree in astrometry and celestial mechanics (2009) from Graduate University of Chinese Academy of Sciences. Now he is a associate professor in Department of Electronics and Communication Engineering of Changsha University. His current main research interests include time synchronization, satellite navigation and intersatellite links.

Sun Liping. She received her B.S. degree (1995) and M.S. degree (2002) in physics education from Hunan Normal University. Now she is a associate professor in Department of Electronics and Communication Engineering of Changsha University. Her current main research interests include photoelectric information engineering.

Liu Guangcan. He received his B.S. degree in photoelectrical imaging technology (1982) and Ph.D. degree in optical engineering (2007) from Beijing Institute of Technology. Now he is a professor in Department of Electronics and Communication Engineering of Changsha University. His current main research interests include satellite navigation and positioning technology and image processing.