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Research on reforming the teaching of satellite communications based on STK

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ABSTRACT: With the aim of improving the efficiency of teaching satellite communications, the content and features of satellite communications education have been analysed and outlined in this article. Also presented is research carried out on the features of satellite simulation software, as well as the application of such software in satellite communications education. Advanced is the idea that advantage can be taken of the satellite simulation software STK (Systems Tool Kit) to reform the teaching of satellite communications, and provide specific application examples. The results of this teaching reform show that students' interest in satellite communications has been increased; and that students can better grasp the basic knowledge and theories of satellite communications. This article provides references to the reform of teaching satellite communications. It is necessary to reinforce the research on the application of the STK software in satellite communications education.

INTRODUCTION

Satellite communications is one of the specialised direction courses for students majoring in communication engineering, as well as an important elective course for students majoring in information technology at the authors' universities. In modern society, information technology is developing rapidly. Satellite communication, which cultivates communication engineers plays an indispensable and essential part in communication education. To improve the level of expertise and practical skill, to cultivate a rigorous scientific attitude and scientific working methods, it is of great significance for students to master systematic and comprehensive theories, as well as skills relevant to satellite communications.

Satellite communications has abundant content, as well as highly systematic knowledge and requires a large amount of practice. Thus, it is not adequate that practitioners just have a comprehension of theoretic knowledge [1][2]. As a consequence, it is necessary to conduct research into the efficiency of teaching satellite communications. This article concerns the research carried out into making use of the satellite simulation software STK (Systems Tool Kit) to promote the practical teaching of satellite communications by analysing the features of such teaching in line with the current status of satellite simulation software.

THE MAJOR TEACHING CONTENT AND TEACHING FEATURES OF SATELLITE COMMUNICATIONS

Major Teaching Content of Satellite Communications

The contents of the course mainly include basic theory, satellite communication components, key technologies, satellite communication networks, satellite positioning and the navigation systems. Also, discussed in the course is the latest business technologies, such as the Internet and satellite Internet involved in the satellite communication system, and the latest developments in technology. Through this course, students should master not only the basic principles, systematic structure and performance features of satellite communications, but also have a solid foundation in the design, operation and application of satellite communications, as well as carry out further research on satellite communications. Moreover, students also should understand the application of modern communication technology and the development status of satellite navigation technology [1].

Features of Satellite Communications Teaching

Satellite communications courses have, as pre-requisites, courses such as communication theory, electromagnetism, microwave technology, electronic circuits, and so on. Only through mastering the knowledge in those courses are students able to learn satellite communications. Many colleges and universities usually arrange their satellite communications courses during the fourth academic year and the class hours are usually too few. The total class hours are 32, including 28 for learning theory and four for practicals. As can be seen, the total class hours are relatively few and most are used for learning theory. Clearly, the time spent on practical work is small. The equipment necessary for the practical teaching of satellite communications is costly and, as a result, it is difficult to carry out practical teaching of satellite communications.

Nowadays, most colleges and universities adopt the cramming method in teaching satellite communications in which students passively listen to lectures on theory. However, this course does require considerable practical learning. The relevant theoretical knowledge is both abstract and intricate. Teaching that depends simply on class lectures will make students feel bored and students' interest will not be aroused. Thus, the teaching objectives will not be met [3]. Hence, one of the prominent directions for satellite communications education is to intensify the practical teaching using a satellite simulation tool.

SIMULATION TOOLS IN THE TEACHING OF SATELLITE COMMUNICATIONS

Satellite Simulation Tool

With the development of satellite communications technology, the structure and scale of satellite constellations is becoming more complicated and the application of satellites more diversified. Experience alone is not enough to plan and design a satellite network. Network simulation technology can be adopted to simulate the behaviours of a satellite networks, so as to evaluate and predict the performance of the network. Therefore, the adoption of network simulation technology is an effective way to improve the reliability and accuracy of the planning and design of a satellite network. However, in conducting satellite network simulation, the first and most important thing is to select an appropriate simulation tool.

Currently available simulation tools have different functions. Therefore, it is necessary to comprehensively consider all kinds of requirements and to select appropriate simulation tools. Satellite simulation can be divided into satellite network constellation simulation and satellite network protocol simulation. Common constellation simulation tools include SaVi and STK (Systems Tool Kit, formerly called Satellite Tool Kit). Common network protocol simulation tools include OPNET NS-2 (Network Simulator), among others [2-4].

The Features of STK Satellite Simulation Software

STK (Systems Tool Kit) is a design package for satellite simulation developed by America's AGI (Analytical Graphics, Incorporated). At present, STK is the most advanced satellite analysis and visual tool in the aerospace industry. STK not only provides the analytical engine used for computation, but also can display multiform 2D maps including satellites, carrier rockets, missiles, aeroplanes, vehicles on the ground, targets, and so on. STK also possesses a 3D visualisation module, which provides the tool and other modules with a leading 3D display environment. STK is sold as an elementary or professional edition, with many types of component. The elementary edition of STK offers mainly core functions, including the creation and display of a satellite orbit, the determination of satellite visibility and satellite coverage.

The creation of the orbit function handles various types of orbit, as well as quickly and accurately confirming the orbital positions of satellites at any time. The visibility analysis function will calculate whether the satellite is visible at any time between two arbitrary points. The coverage range analysis calculates the coverage of the earth by the satellite, as well as the position of the satellite itself. The professional edition of STK is an expansion of the elementary edition. The major functions include orbit prediction, position adjustment, various co-ordinate types and co-ordinate systems, various remote sensor types, visibility restraint and a database of cities and ground stations, as well as of fixed stars [4][5]. Based on the above, STK is used as the simulation software in conducting the practical teaching of satellite communications.

THE APPLICATION OF STK IN THE TEACHING REFORM OF SATELLITE COMMUNICATIONS

Application of STK in the Teaching of Satellite Orbit Parameters

To show how an earth-centred inertial co-ordinate system works and to confirm the position of a satellite in space at any time, two groups of Keplerian orbit parameters (six in total) are involved [1][6]. These parameters include three that determine the position, as well as direction of the orbital plane i.e. Ω (dextral ascending node right ascension), i (orbital inclination), ω (argument of perigee) and three parameters determining the geometrical shapes of orbital plane and the kinetic characteristics i.e. e (orbital eccentricity), a (semi-major axis of the orbit) and M (mean anomaly) or t_p (perigee passage time).

Because comprehension of the above parameters requires students to possess a spatial imaging ability, some students cannot fully understand them after just learning the theory in class. In order to help students to intuitively and clearly understand the parameters of a satellite orbit, a satellite constellation was developed using the STK simulation software.

The constellation consists of satellites in GEO (Geostationary Earth Orbit), IGSO (Inclined Geosynchronous Satellite Orbit) and MEO (Middle Earth Orbit). The 3D stereogram is shown in Figure 1.

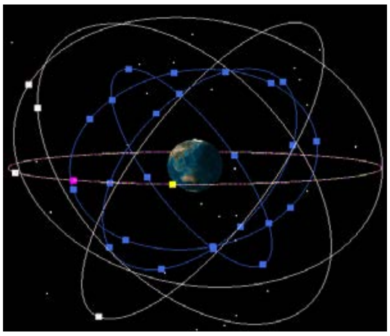

Figure 1: 3D structure of the satellite constellation.

The 2D distribution of sub-satellite points of the constellation satellites is shown in Figure 2.

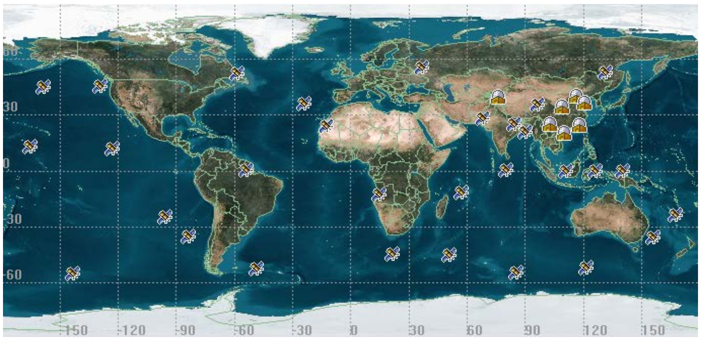

Figure 2: The 2D distribution of sub-satellite points of constellation satellites.

When any one of the six parameters is changed, the corresponding changes can be clearly seen in the 3D diagram and changes will also happen to relevant sub-satellite points. Via such demonstration, students can acquire a deeper understanding of the knowledge of orbit parameters. As well, during breaks in learning, students can make use of the software to set their own orbits and observe the changes brought about by the change of parameter, in 3D and 2D diagrams. As a result, the theory will become more specific and clearer, which will be beneficial in enhancing teaching efficiency.

Application of STK to the Teaching of the Visual Model between the Satellite and the Ground

Successful communication between the satellite and the ground is based on the precondition that the satellites and the ground station should be visible to each other. To explain the communication between the satellite and the ground, it is reasonable to establish a visibility calculation model of the satellite and the ground stations. Factors used in the calculation model are shown in Figure 3 [6].

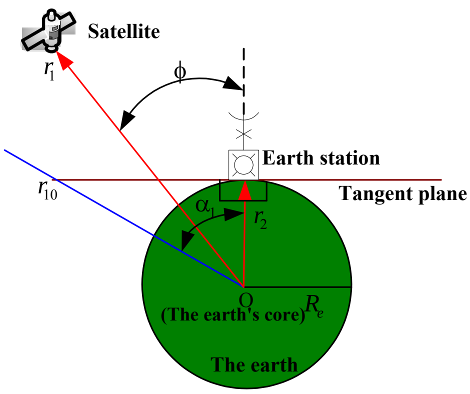

Figure 3: The visibility calculation model of the satellite and ground time synchronisation stations.

Referring to Figure 3, the visibility function describing whether the satellite and ground stations can be visible to each other is as follows:

$$\psi = \alpha_1 - \phi \tag{1}$$

Based on the calculation results of Equation (1), $\Psi > 0$ signifies that the ground is visible to the satellite. The point where $\Psi = 0$ is the point where the satellite rises or falls across the circumscribed horizontal plane. When the value of Ψ shifts from a positive value to a negative one, the satellite is rising, or *vice versa*. Thus, this determines the visible time of the ground time synchronisation station for the satellite.

In terms of the above model, the analysis of visible conditions of the satellite and the ground is conducted in a 2D plane. However, the authentic visible conditions of the satellite and the ground should be a 3D stereogram. In the teaching process, use is made of the STK software to simulate the visible time of Xi'an Station for a GEO satellite and an IGSO satellite during 24 hours. The lowest visible elevation of the ground station is 5°. The simulation results are shown in Figure 4 and specific statistical results are shown in Table 1.

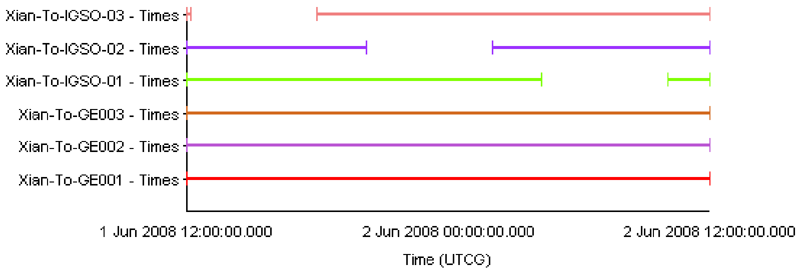

Figure 4: The visible time of Xi'an Station for GEO satellite and IGSO satellite.

Table 1: Statistical table of the visible time of Xi'an Station for GEO satellite and IGSO satellite (simulation period: 1 June 2008 12:00:00.000 - 2 June 2008 12:00:00.000, unit: hour).

GEO01	GEO02	GEO03	IGSO-01	IGSO-02	IGSO-03
24	24	24	18.205	18.211	18.202

According to the results shown in Figure 4 and Table 1, it is possible to determine the visible time of Xi'an Station for satellites. When the ground stations or satellites are different, the changes of visible time can be clearly observed. Such a method can help students to further consolidate their understanding of the model.

Application of STK in Teaching the Changing Laws of the Links between Ground and Satellite

The links between satellite and ground are the foundation for establishing satellite communication. The changing laws governing the links between the satellite and the ground decide the range of launching power required from the ground for the satellite. In teaching, it is possible to make use of the basic theory of satellite communication to establish a model of distance between the ground and the satellite. The formula is as follows:

$$d = \sqrt{R_e^2 \bullet (\sin E)^2 + 2 \bullet h \bullet R_e + h^2} - R_e \bullet \sin E \tag{2}$$

The parameters in the formula are described by Wu et al [1]. From Equation (2), it can be seen there are many factors affecting the change of distance between the ground and the satellite. It is difficult to directly analyse the specific changes of the distance from the formula. After establishing a relevant model with the aid of STK, it was easy to simulate the changes of distance between the ground and the satellite. Figure 5 shows the changing laws of distance between Xi'an Station and MEO satellite during the visible period using the STK simulation.

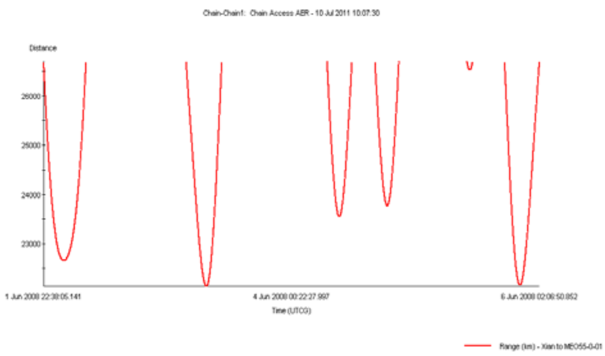

Figure 5: Changing laws of distance between Xi'an Station and MEO satellite during the visible period.

From Figure 5, it can be seen that the changes of distance between Xi'an Station and an MEO satellite during the visible period have the following laws: as the satellite moves, the distance repeatedly becomes smaller and, then, becomes larger. Such simulation results can more vividly show the changing laws of the distance between the ground and the satellite. Consequently, students can better comprehend the influence of distance changes on launch power.

CONCLUSIONS

In the teaching of satellite communications, the introduction of Systems Tool Kit software into practical teaching will help students to better understand difficult theoretical principles, as well as abstract, intricate conceptions and barely observed phenomena. This is because STK can simulate such aspects and vividly show the results with the aid of 2D and 3D diagrams, with plentiful figures and statistics.

The introduction of STK is also helpful in deepening students' understanding of knowledge related to satellite communications and it boosts their interest in learning. This will facilitate the mastering by students of the basic principles, system structure, communication system and performance features of satellite communications. By virtue of the advantages of STK, students will have a solid foundation in the design, operation and application of satellite communications, as well as ability to further research satellite communications.

The above research provides references to reforming the teaching of satellite communications. In the future, it will be essential to reinforce the application of STK in reforming the teaching of satellite communications.

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