Preliminary Exploration of the Reliability of Civil Aviation ATC Communication Network

Le Zhang*

Civil Aviation Flight University of China, Chian Sichuan, China, 618307

*Corresponding author e-mail: skyctr01@163.com

Abstract. In this paper, the factors affecting the reliability of the Air Traffic Control (ATC) communication system in operation are analyzed. From the perspective of the ATC communication network characteristics, the ideas and methods for reliability research on the ATC communication system are proposed. At the same time, the civil aviation communication network is taken as an example to explore the construction of the backup system for the communication network, the steps of evaluation methods, and the reliability management ideas.

Keywords: ATC Communication, Reliability, Backup System, Management Method

1. Introduction

For the purpose of the communication network, it can be divided into two major categories: private communication network (dedicated network) and public communication network (public network)\textsuperscript{[1-2]}. As a supplement to the public network, dedicated network mainly refers to the communication network built in some industries, departments, or units to meet the needs of organizational management, safety production, scheduling, etc. There are over 100 kinds of dedicated networks in China. Except for large-scale dedicated networks such as railway, electric power \textsuperscript{[3-4]}, oil and highway, which are self-built lines, most of the dedicated networks are built by renting public network lines. Professional management has been established for large-scale dedicated networks, and most of the small-scale dedicated networks are based on ancillary management. The trunk lines are implemented by renting the lines of operators. The civil aviation air traffic control (ATC) dedicated network falls in the small private communication network, including partial self-built lines\textsuperscript{[5-6]}. In the field of civil aviation air traffic control communication transmission, due to its inherent life and death industry characteristics, more requirements are proposed for the transmission reliability of the communication network. The reliability of the transmission network not only needs to reflect the level of general transmission means but also needs to be improved according to the unique demand of
the civil aviation ATC industry.

2. Definition of communication network reliability

2.1. Definition of communication network reliability
The national standard defines the reliability of products: the ability of products to complete the specified functions under the specified conditions and within the specified time interval. As an integrated system, the communication network has its inherent characteristics. The reliability of the network can be defined as the ability of the communication network to fulfill the normal communication requirements of users in the actual continuous operation process. For the reliability of a network, more emphasis is placed on determining the communication effect from the perspective of users.

2.2. Reliability index of communication system
The reliability of the communication system refers to the survivability of the network under the specified conditions and within the specified time under the external damage of human or non-human and the effect of internal aging. Reliability is an essential technical performance index no matter in the planning and design of the network or in the operation and maintenance stage.

Survivability and survivability are the first two reliability-related network reliability indexes. The invulnerability of the network indicates the reliability of the network system under artificial action. The survivability of a network is generally represented by the connectivity probability. With the development of the communication industry in the later period, the effectiveness index has become increasingly crucial in the construction process of the network transmission network. The effectiveness of the network is a reliability index based on the network performance, which represents the degree of the network system meeting the requirements of the communication performance under the condition of the failure of network components. Currently, the research on survivability, survivability, and effectiveness mainly focuses on the characteristics, and the principal means to solve the problems of these three characteristics are to build redundant systems and backup systems, etc.

The reliability evaluation of the communication system is usually measured by MTBF (mean time between failure), MTTF (mean time to failure), MTTR (mean time to restore), availability A and unavailability u. The relationship is as follows:

\[
MTBF_i = MTTF_i + MTTR_i \\
A_i = \frac{MTTF_i}{MTBF_i} \\
\mu_i = \frac{MTTR_i}{MTBF_i}
\]  

The communication network is usually guaranteed through the establishment of a redundant system and independent backup system to ensure the reliability of the communication network. However, there are still a series of problems to be solved in the construction, such as which indicators to build the redundancy and backup system, and how to evaluate them. These are the problems to be solved and the focus of this paper.

2.3. Factors affecting the reliability of the communication network
The communication network is a complex integrated system composed of transmission, exchange, terminal facilities, signaling process, protocol, and corresponding operation support system. There are many factors affecting security, which can be divided into internal factors and external factors.

Internal factors: equipment reliability, network engineering design, organization and maintenance management, etc.

3. Civil aviation ATC communication system
According to the actual requirements of the system, the system architecture design is given, and the overall architecture of the ATC automation system is shown in Figure 1.

The dedicated network established by the civil aviation ATC industry is mainly used to transmit safety and confidential information, carry out real-time internal organization production, real-time dispatching and command management data communication processing equipment, which consists of two sets of redundant processing equipment composed of router, line distributor, asynchronous port converter (N-port) and data communication processor (DCP) to ensure the reliable transmission and processing of the access information. The data communication processor (DCP) adopts a redundant structure to complete all information input/output processing of the system other than the radar signal input/output on LDW, receive and process AFTN, AIDC, QNH, SMR, MLAT and other information output by router and N-port. Meanwhile, a dedicated line mode is provided to transfer the AIDC control screen with an automatic processing system of adjacent control center; input and output flight dynamic data and AFTN information to N-port.

![Figure 1. general contract of the system](image)

The primary users of the ATC automation system are ATClers. According to different control positions, ATClers are divided into the tower controller, approach controller, area controller, and Station Dispatching controller (as shown in Table 1 below). Due to the different functions of the above
roles, there are some differences in the functional requirements of ATC automation.

**Table 1. Responsibilities of civil aviation administrators**

| ATCler                  | Duties or functions                                                                                                                                 |
|-------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------|
| Tower controller        | Responsible for providing ATC services for airport traffic. Coordinate the takeoff and landing of the aircraft and the use of the runway; provide the crew with information about meteorological elements such as wind, temperature, air pressure and related flights over the airport; control aircraft, vehicles, and personnel operating in the maneuver area of the airport except the runway; Issue release permits to aircraft; maintain contact and coordination with other relevant units. |
| Approach controller     | Sequencing and guiding aircraft arriving, landing, taking off and joining the route, and maintaining contact and coordination with other relevant units.    |
| Regional controller     | Responsible for providing control services for aircraft on the route, mainly for aircraft operating in an extensive range above 6,000 meters, ensuring flight intervals, transferring aircraft in this area to other control areas, or aircraft flying from other control areas Guide to approach. |

4. **Methods to improve the reliability of civil aviation communication network**

The reliability of the civil aviation communication system has its own characteristics as well as the common characteristics of the general communication system. Domestic studies focus on the reliability of the communication power system, bus system, and data transmission in communication; while foreign studies focus on the reliability algorithm of the communication system (including Boolean algebra, neural network, recursive algorithm, etc.) and system reliability analysis.

The basic idea of reliability evaluation of civil aviation ATC communication network system: use MTBF, MTTF, MTTR, and other parameters to evaluate the reliability of basic products (including equipment, instruments, hardware and software platforms), use non-redundant system, fully redundant system, partial redundant system, and standby system to evaluate the reliability of the system or subsystem, and then assess the whole network according to the topological structure of the system Reliability level of network system.

With the rapid development of ATC industry, the essential services carried by the communication network are increasing day by day, and the task of improving the reliability of the communication network is increasingly urgent. The standby system means that there are multiple components or task function modules with the same functions in the system. When one of them fails, the other is put into operation through fault monitoring or conversion device to undertake the function of the failed component; only the same fault of the primary system and all standby systems result in the failure of the whole system. The system life is the sum of the life of all components or task function modules.

The ATC industry adopts the standby system to guarantee the service. Currently, mainly the “Dual ground-to-air communication” mode is used to transmit the communication network (including the satellite link and the ground two independent links), and the access equipment also adopts their independent systems. Assuming that all components are the same, the reliability of the system is as follows:

$$R_s(t) = e^{−\frac{\lambda t}{2!} + \frac{(\lambda t)^2}{2!} + \cdots + \frac{(\lambda t)^{N−1}}{(N−1)!}}$$  \hspace{1cm} (2)

Two standby systems (record 1 and 2) are taken as examples. The system availability as and mtffs
are as follows:

\[ A_i = A_1 + A_2 A_2 \]

\[ MTTF_i = \frac{1}{\lambda_1} + \frac{1}{\lambda_2} \]  \hspace{1cm} (3)

5. Conclusions

The reliability of the communication network is a comprehensive reflection of various factors and a combination of management and technology. In this paper, the concept of ATC communication reliability is proposed. The primary and standby transmission modes commonly used in civil aviation ATC are analyzed. As a security industry, ATC requires analysis of the network reliability from all levels to strengthen the construction of communication network hardware and the optimization of network topology gradually. Meanwhile, it is necessary to enhance the safety management of the communication network. As the system becomes larger in scale and more complex, human influence on reliability is increasing. It is necessary to strengthen the research on personnel reliability and ergonomics so that the network management level can adapt to its technical level and realize the unification of advanced technology and scientific management. The ultimate goal is to provide a communication network with high performance, efficiency and reliability for ATC services.

References

[1] Ge, X. , & Han, Q. L. (2017). Distributed formation control of networked multi-agent systems using a dynamic event-triggered communication mechanism. IEEE Transactions on Industrial Electronics, 64(10), 8118-8127.

[2] Zhang, L. , Liu, X. S. , Pang, J. , Xu, D. , & Leung, V. (2015). Reliability and survivability analysis of artificial cobweb network model used in low-voltage power-line communication system. IEEE Transactions on Power Delivery, 31(5), 1-1.

[3] Nikolic, G. S. , Stojcev, M. K. , Nikolic, T. R. , Petrovic, B. D. , & Dimitrijevic, B. R. (2017). Implementation and evaluation of 2d se-c-ded forward error correction scheme in wireless sensor networks. Microelectronics Reliability, 78, 161-180.

[4] Edel, C. , Pimentel, E. C. G. , Plieschke, L. , Emmerling, R. , & K.-U. Götz. (2015). Short communication: the effect of genotyping cows to improve the reliability of genomic predictions for selection candidates. Journal of Dairy Science, 99(3), 1999-2004.

[5] Wang, Z. , Zeljic, K. , Jiang, Q. , Gu, Y. , & Wang, Z. (2016). Dynamic network communication in the human functional connectome predicts perceptual variability in visual illusion. Cerebral Cortex, 28(1), 1-15.

[6] Krzysztof Rusek, Piotr Guzik, & Piotr Chołda. (2016). Effective risk assessment in resilient communication networks. Journal of Network and Systems Management, 24(3).