Analysis and Research on the Interference of Civil Aviation Radio Navigation Equipment

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Abstract—Aiming at the problem that civil aviation radio navigation equipment is susceptible to interference more and more frequently, through the study of aviation radio interference theory, the categories of civil aviation radio interference are classified, and then the source and harm of radio interference are analyzed, and specific measures to solve the interference problem are proposed. This is of great help to solve the difficult problem of radio interference signals, and is conducive to reducing the probability of civil aviation radio navigation equipment being interfered, thereby ensuring aviation flight safety.

1. Introduction

After decades of development, my country’s civil aviation industry has continued to grow and has now become the world’s leading civil aviation country. Its passenger volume, cargo volume and flight traffic are all showing a rapid growth trend. In 2019, the entire industry completed a total transportation turnover of 129.325 billion ton-kilometers, an increase of 7.2% over the previous year. The total transportation turnover of domestic routes was 82.951 billion ton-kilometers, an increase of 7.5% over the previous year. Among them, the Hong Kong, Macao and Taiwan routes completed 1.690 billion ton-kilometers, down 3.5% from the previous year; the total transportation turnover of international routes was 46.374 billion ton-kilometers, an increase of 6.6%[1].

With the continuous development of radio technology, broadband China, the "Internet +" action plan, "Made in China 2025" and other major national strategies have been implemented one after another. The application of radio technology in broadband communications, Internet of Things, intelligent manufacturing and other fields is expanding. The research and development of the fifth generation mobile communication (5G) system has been carried out in full swing around the world. Various new technologies, services, and equipment are emerging in an endless stream and rapidly popularized, bringing people a convenient and intelligent life experience. The electromagnetic environment is becoming increasingly complex. In addition, some market supervision is not in place, and some "three noes" products and radio equipment assembled and used by criminals have also entered the society, resulting in frequent other radio interferences under the condition of crowded spectrum resources. Interference to the dedicated radio frequency of civil aviation may lead to flight flow control, and aircraft cannot take off and arrive normally; at worst, it may cause the failure of civil aviation ground-to-air communication equipment and navigation equipment, causing the pilot to fail to hear the controller and execute wrong instructions and flight. Deviations in the trajectory, etc2[3].
2. Civil Aviation Radio Interference Theory

2.1 Civil aviation radio navigation equipment
Civil aviation radio navigation equipment mainly includes non-directional beacons, VHF omnidirectional beacons, rangefinders and instrument landing systems. The main frequencies used by civil aviation are: 190kHz-1750 kHz, 108MHz-136.975 MHz, 328.6MHz-335.4 MHz, 960MHz-1215 MHz, 1030MHz-1090 MHz, 1250MHz-1350 MHz, 2700MHz-2900 MHz, 9340MHz-9400 MHz, etc. The frequency dedicated to civil aviation is mainly line-of-sight propagation, and direct wave propagation is the main propagation process. When affected by terrain conditions, it will also have the characteristics of reflection, scattering, and diffraction.

2.2 Definition of radio interference
Radio interference refers to the effect of useless energy generated by a certain emission, radiation, induction or their combination on the reception of radio communication systems, which reduces the performance of the reception effect or fails to receive signals. This effect is called radio interference.

According to the nature of the interference source, it is divided into active interference and passive interference. Passive interference refers to the radio waves formed by the reflection of the ionosphere, the diffraction of obstacles, the reflection of reflectors, and the re-radiation (secondary radiation) of the re-radiator (secondary radiation) during the propagation of electromagnetic waves emitted by the ground station transmitter. Wave, the interference caused by receiving the useful radio signal of this transmitter. Active interference refers to the amount of radio frequency emitted, radiated, induced or leaked by the radiation source of non-aviation navigation equipment or facilities through antennas, feeders, power lines, control lines, housings, output terminals, etc., through conduction or radiation. Interference caused by receiving useful radio signals.

2.3 Types of radio interference

2.3.1 Co-channel interference
Any interference that is sent by other signal sources at the same frequency as the useful signal and enters the receiver's intermediate frequency passband in the same way is called co-channel interference [4][5]. In the mobile communication system, in order to improve the frequency utilization, the same frequency channel must be used repeatedly after a certain distance. This method is often called co-channel reuse. The problem caused by co-channel reuse is co-channel interference. The closer the reuse distance, the greater the co-channel interference, and the higher the frequency utilization; the farther the reuse distance, the smaller the co-channel interference and the lower the frequency utilization. Since the same frequency interference signal and the useful signal are also amplified and detected, when the two signals have carrier frequency difference, it will cause beat interference; when the modulation degree of the two signals is different, it will cause distortion interference; when two signals exist, the phase difference can also cause distortion interference. The larger the interference signal, the smaller the output signal-to-noise ratio of the receiver. When the interference signal is large enough, it can cause blocking interference of the receiver[6][7].

2.3.2 Adjacent channel interference
The so-called adjacent channel interference is the interference caused by signals in or near the radio frequency passband of the receiver that fall into the intermediate frequency passband after frequency conversion. Adjacent channel interference will reduce the signal-to-noise ratio and sensitivity of the receiver; strong interference signals can cause blocking interference in the receiver. When a communication network is composed of many radio stations, the problem of adjacent channel interference is often prone to occur. This kind of interference is mostly caused by the technical indicators of radio equipment that do not meet national standards. In terms of transmitters, if the frequency stability is too poor or the modulation is too large, the transmission spectrum is too wide,
which can cause adjacent channel interference to other radio stations. If the factors that affect the bandwidth of the transmitter are not strictly controlled, it is easy to generate unnecessary out-of-band radiation; in the receiver, when the IF filter is poorly selected, it is easy to cause interference or make the interference serious.

2.3.3 Intermodulation interference
When two or more signals of different frequencies are added to a non-linear device, the non-linear transformation of the non-linear device can generate many combined frequency signals, and some of the combined frequency signals may fall into the receiver. In-band, this forms intermodulation interference. According to the intermodulation location, intermodulation interference can be divided into the following types: transmitter intermodulation interference, receiver intermodulation interference, and intermodulation interference between transmission circuits and communication systems. There are three conditions for the generation of intermodulation interference: first, a fixed frequency combination relationship; second, the interference is sufficiently large; third, there are related stations working at the same time. Technically speaking, it is quite difficult to analyze and find intermodulation interference, and the impact it causes is relatively large, and the damage it poses is also great.

2.3.4 Blocking interference
When there is a strong interference signal in the outside world, although the frequency does not cause intermodulation or co-frequency or adjacent frequency interference, it can still cause useful signal gain due to the nonlinearity of the receiver after it acts on the front-end circuit of the receiver. Decrease (suppressed) or increase the noise, so that the sensitivity of the receiver decreases. This phenomenon is the blocking of the receiver. This interference is called blocking interference.

2.3.5 Bandwidth interference
When the useless power signal sent by the transmitter outside the adjacent frequency band is received by the receiver in the normal working frequency band, the interference that causes the decrease of the system signal-to-noise ratio is called out-of-band interference. Usually can be divided into transmitter spurious frequency interference and receiver spurious frequency interference. A general VHF transmitter uses a crystal oscillator to generate a basic frequency, and after multiple frequency multiplications, a carrier frequency is generated. Due to the non-linear characteristics of frequency multipliers and high-frequency amplifiers, various harmonic components will be generated. Intermediate frequency signals are formed through the combined frequency action. These harmonic components are amplified and emitted to form useless interference signals. The receiver caused interference.
3. Civil Aviation Radio Interference Analysis

3.1 Sources of interference to radio navigation equipment

3.1.1 Illegal installation of radio stations
With the continuous development of social economy, in order to pursue convenience, a large number of cordless phones have been used in the society. In order to improve the efficiency of use, some manufacturers or users will increase their rated power. If the vertical phone is near the airport during the application process, it will cause telephone voice interference to terrestrial stations or airplanes. Especially in the economically underdeveloped areas, especially in the mountainous areas or islands with inconvenient traffic, the telecommunications department may complete the transmission of voice signals through wireless differential transfer in order to ensure communication safety, which may cause interference.

3.1.2 Interference from high-power radio stations
High-power radio stations mainly refer to the broadcasting stations set up by the radio and television departments. Broadcasting stations include voice broadcasting stations (mainly FM broadcasting) and TV broadcasting stations. The transmission power is very large, easily tens of kilowatts, or even several kilowatts; the antenna height is high, and it is mostly set in the "three high" locations (high mountains, high buildings, off towers), and most of the antennas share a tower, which is very easy to cause intermodulation interference; and the transmission frequency band of the FM broadcasting service is 87MHz-108MHz, which is adjacent to the communication and navigation frequency band 108MHz-137MHz, which is a dedicated frequency band for civil aviation radio. Due to the limited frequency resources of radio stations, coupled with the vigorous development of television stations and radio stations in various regions for the needs of publicity work, the radio and television frequencies in various regions have been expanding upwards, and the rapid development of the aviation industry has also led to the downward expansion of civil aviation frequencies. As a result, too many stations are set up in a limited frequency band. During use, similar frequencies interfere with each other. In particular, the fast-developing and large-scale broadcasting and television services can easily interfere with civil aviation services[8][9].

3.1.3 Interference caused by cable TV signal leakage
The carrier of the cable TV programs we usually watch is transmitted through the cable TV system, and some carriers have already occupied the frequency band of civil aviation communication and navigation during use, as shown in Table 1. During the transmission process, the leakage of radio frequency energy will cause interference, and there will be broadcast voice in the frequency band of civil aviation communication and navigation. Through the receiver, the interference signal and the useful signal are equally amplified, detected and output. When the strength of the interference signal reaches a certain limit, it will cause the blocking interference of the receiver.

| Table 1. Comparison of frequency bands used by cable TV and aviation |
|----------------------|-----------------|------------------|
| Cable Supplementary Channel | Frequency Range      | aviation                  |
| Z1                    | 111-118.75MHz    | VOR, LOC            |
| Z2                    | 119-126.75MHz    | Civil aviation distress, airport scene communication |
| Z3                    | 127-134.75MHz    | Civil Aviation Mobile Business |
| Z4                    | 134-142.75MHz    | Civil Aviation Mobile Business |
3.1.4 High-voltage power transmission line interference
High-voltage power transmission line interference is also one of the main interference factors. The corona effect of the power transmission system and the radio noise caused by gap discharge are affected by electromagnetic waves. In practical applications, high-voltage transmission lines, as tall metal objects, will reflect and re-radiate radio navigation signals during the transmission process. Some harmful and wide-band electromagnetic waves will appear during the corona process, and the generated wavebands will change the navigation. The air field pattern of the signal causes passive interference to the aviation system.

3.1.5 Interference caused by internal equipment of civil aviation
In order to ensure the safety of airport flight transportation, the airport and various communication stations set up at the airport need to be equipped with a large number of electronic equipment, and these equipment will generate electromagnetic radiation in the application. The interior of the airport is a complex electromagnetic radiation system, so it must be completely It is impossible to eliminate electromagnetic radiation in the airport, but the interference caused by reasonable application is limited. If it cannot be applied reasonably and scientifically, the electromagnetic compatibility problems generated by it are not handled well, and the use of equipment is improperly managed, which may cause damage to civil aviation. The dedicated radio frequency causes harmful interference and endangers flight safety.

3.2 Harm of interference
Radio interference can affect flight safety through many links, causing direct or indirect harm. The adverse effects caused by this interference can be roughly divided into three situations:

(1) The impact on the work of the ground navigation station. This interference may cause the flying group hovering in the air to receive ground error instructions, which may lead to the possibility of a crash due to an incorrect judgment. Airport navigation systems mostly work in the 117MHz-140MHz range, which is the most easily used frequency band for other communication systems. If other communication systems interfere with the navigation in the terrestrial space, the flight crew may get the wrong indication signal, which will cause the flight trajectory to deviate, which is extremely harmful.

(2) Impact on ground-to-air communications and air traffic control. At present, the communication system used in civil aviation ground-to-air communication makes it susceptible to interference from radio signals. It generally works on VHF and short-band ordinary AM signals and single-sideband signals. Its communication methods are analog signals and voice. Communication, coupled with high flight altitude, long receiving communication distance, and high sensitivity of the aircraft. Such interference signals can easily interfere with ground-to-air communications and affect normal controlled calls. In severe cases, the quality of ground navigation and aircraft communication is extremely poor, and normal instructions cannot be obtained, which can lead to serious consequences. Under normal circumstances, pilots who are not disturbed can correctly talk to the navigation station to obtain information. When there is serious interference, the noise in the channel is too large, and the pilot can’t hear the controller’s commands and misjudges the descending altitude of his own aircraft. Because of the trouble of air traffic control, the serious ones are in danger of crashing, especially when the plane takes off and landing.

(3) The impact on the airborne radio instrument and signal transmission system. Such interference can cause the pilot to operate incorrectly and thus make the flight dangerous. Many airborne equipment is for automatic navigation and to improve the aircraft's take-off and landing capabilities, such as: automatic directional receivers, ranging receivers, VHF omnidirectional beacon and instrument landing receivers. Their working frequency range is medium wave to very high. Frequency bands, some are in the UHF and microwave range. After receiving the interference, the pilot of the aircraft makes wrong judgments and operations, which puts the flight in danger.
4. Conclusion
Through the above research, we can summarize some specific measures to avoid interference:

1) Antenna isolation
In order to avoid interference between different systems affecting the communication quality, it is generally required that the coupling loss between the transmitting and receiving antennas of different systems is greater than the minimum threshold that will cause inter-system interference, and the coupling loss is the isolation\[10\][11].

2) Add filter and anti-jammer
The anti-interference approach is generally to add a filter in the equipment, which is used to suppress high-frequency interference and suppress equipment interference. The former suppresses the influence on the equipment in the alternating current system, and the latter suppresses the interference of the equipment such as high-frequency switches on the alternating current system.

3) Policy measures
The government and relevant radio management departments formulate relevant laws and regulations to regulate and restrict people’s disturbance and illegal use of frequencies. Taking into account the electromagnetic environment, radio stations at all levels operate normally, requiring all units and individuals that use radio stations to consciously Restrict one's own abuse of radio, and formulate some tough rewards and punishments.

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