Research of Tunnel Full Band FM Broadcast Application

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Abstract. The paper analyzes the advantages and disadvantages of the existing information service methods in the tunnel, and proposes the use of full-band FM broadcast for emergency information release. It can also cooperate with other systems to achieve integrated information release. This achievement forwards FM signals outside the tunnel in daily situations, and uses full-band FM to implement emergency information insertion in emergency situations, which not only improves the daily information service level but also implements the function of emergency warning, and effectively improves the level of tunnel safety.

Keywords: Tunnel; Information release; FM broadcast; Full band; Insertion.

1. Foreword

With the rapid growth of China's economy, the construction of highway tunnels is changing with each passing day. At the end of 2018, there were 17,738 highway tunnels and 17.24 million meters in China, which has become the country with the largest number of tunnels and the largest mileage in the world. Due to narrow roads, poor light, single visual scenes, narrow and closed spaces, and prone to "black hole effects" when entering and exiting the tunnel, traffic accidents often occur in the tunnel, causing a large number of casualties and economic losses. According to research, rear-end collisions in tunnels account for approximately 60.1% of the total number of accidents, and traffic accidents at the entrance and exit of tunnels account for approximately 58% of the total. However, most rear-end collisions and tunnel entrance accidents can be avoided by early warning. This paper proposes a method for providing emergency information by using FM broadcast insertion. A full-band FM broadcast system is built in the tunnel to provide FM signals for users in the tunnel under daily conditions. In emergency situations, the full-band emergency insertion is realized, and the radio of any frequency band can receive the emergency signal. The system does not increase the cost of the driver and passenger, and realizes the emergency interruption of usual services. It was applied on the Yan-Chong Expressway for 2022 Beijing Winter Olympics and achieved good results.

2. Tunnel Information Release Methods

2.1. Tunnel Information Service Demand Analysis

Because of the special environment in the tunnel, the driver and crew who enter or are driving in the tunnel have special requirements for information service content. In a normal road network environment, travelers need the overall operating status of the road network, such as congestion, weather, and other large-scale planar information. Travelers in tunnels need faster and more accurate point-like information, such as specific accidents location, lane, fire location, etc. The traffic information content of the highway tunnel should have the following characteristics:
2.1.1. Accurate. The specific pile number, lane, and the size of the incident, etc., the released traffic information is consistent with the actual situation, which can make the road users a basis for travel decisions.

2.1.2. In Time. In order to prevent secondary accidents in the tunnel, such as rear-end collisions, after the accident, the information needs to be sent to the affected crew members in timely manner. If delayed or outdated information is released, it will not only serve road transportation, but It takes up a lot of communication resources, misleads road users, and may even cause serious consequences.

2.1.3. Effective. The traffic information released should be combined with the information content and release technology, it should be short and concise to avoid overly detailed description. If you need to switch the content display through multiple screens for more than the effective reading time of the driver, driver cannot obtain complete traffic information.

2.1.4. Specification. When publishing information through different media and technologies, the terms and descriptions should be concise, correct, and standardized, without redundant information, to avoid distracting the driver's attention.

2.2. Existing Expressway Tunnel Traffic Information Release Methods

In order to improve the information service level of the tunnel, the transportation industry has deployed a large amount of information publishing equipment at the tunnel entrance and inside the tunnel, mainly including variable information boards, variable speed limit signs, radio and cable broadcasting, etc. Publishing various static and dynamic information in text or graphics. Releasing speed limit information through variable speed limit signs. Drivers can listen to traffic information through radio broadcasts. In addition, cable broadcasts set up in highway tunnels can play prompt information and warning Information, such as turning on the headlights of vehicles entering the tunnel, and slowly moving vehicles to prevent accidents.

2.3. Analysis of the Effects of the Existing Tunnel Information Publishing Means and Existing Problems

Drivers and passengers in the tunnel need a variety of service information, including basic tunnel information, traffic restriction information, traffic flow information, road condition information, control information, and event information. All kinds of information have different effects through different publishing methods. For example, traffic flow information is most direct through the red, yellow, and green of the image, event control information is the fastest and most efficient through voice broadcast, and line-limit information is the shortest through text as shown in Table 1

![Table 1. Traffic information requirements of highway tunnels.](image)

| Traffic information description object | Traffic information expression media |
|---------------------------------------|------------------------------------|
|                                       | Text  | Image | Audio |
| Basic tunnel information              | ★     | ★★    | ★     |
| Access restriction information        | ★★    | ☆     | ★     |
| Service Information                   | ★★    | ★     | ☆     |
| Traffic flow information              | ★     | ★★    | ★     |
| Traffic information                   | ☆     | ★     | ★★    |
| Weather information                   | ☆     | ★     | ★★    |
| Regulatory information                | ★★    | ☆     | ★     |
| Event information                     | ☆     | ★     | ★★    |
| Responses                             | ☆     | ★     | ★★    |

Remarks: ★★: The effect is better; ★: The effect is average; ☆ The effect is not good

Through analysis, different information using different publishing methods will have different effects. Now the text and images in the tunnel are released through the variable information board, and the voice
information is released through cable broadcasting. Although some effects have been achieved, there are still some of the problems shown in Table 2:

| No. | Problem                                | Details                                                                 |
|-----|----------------------------------------|-------------------------------------------------------------------------|
| 1   | Poor anti-interference ability         | Tunnel echoes and noise are large, and the cable broadcast effect is poor when an emergency occurs, which is likely to cause secondary accidents. |
| 2   | Poor system linkage                    | The tunnel emergency broadcast system is separated from other tunnel systems and cannot be linked with other systems. |
| 3   | Single means of information release    | Cable information is used to publish event information, with a single channel and weak service capabilities. |
| 4   | Poor manageability                     | You can only manage broadcast content at a special place with a special person, you cannot effectively manage the broadcast audio source, and you can't use APP to perform remote playback control. |
| 5   | Can't meet the driver and passenger service needs | Most drivers and passengers driving at high speeds obtain information through the radio. There is no FM signal when entering the tunnel, which affects the driving experience. |

3. Using Full-band FM Broadcast to Solve Tunnel Emergency Information Service Problems

Through analysis, it is found that although the information release methods in the tunnel have been diversified, there is no good solution for how to accurately release accident information in emergency situations. With the increase of vehicles, the existing broadcast channels will increasingly focus on traffic broadcasts, and it has become a habit for drivers and passengers to listen to programs with car radios. At the same time, considering that there is no FM signal in the tunnel, it is considered to have a broadcast in the tunnel. The function of FM broadcasting can not only meet the needs of the crew and passengers, but also meet the emergency information service of the tunnel. The use of full-band FM broadcasting to solve tunnel emergency information services has the following advantages:

3.1. Does Not Increase User Costs

With the improvement of the level of road information service, more and more information distribution methods are implemented by special vehicle terminals. If the special vehicle terminals are implemented through after-installation, it will bring increased costs to users and will encounter great resistance. Each vehicle is equipped with a car radio. At the same time, users are used to listening to radio programs. If the radio broadcasts traffic information, it meets user habits and does not increase costs.

3.2. Daily Information Service

Because of the closed space of the tunnel, the broadcast signal is shielded in the tunnel, forming a blind spot. Nowadays, when driving a vehicle, many drivers are often accustomed to listening to the radio to understand road conditions or relieve driving fatigue. When the vehicle enters a tunnel, the broadcast signal is interrupted, which greatly affects the user experience. Tunnel FM broadcasting can achieve seamless coverage of FM signals inside and outside the tunnel.

3.3. Linkage for Emergency Information Services in Emergency Situations

If the tunnel FM radio has an emergency interruption function, when an emergency event occurs, an emergency signal is inserted at the front end of the tunnel. No matter what frequency band in the tunnel, the radio can receive emergency information, so that users can respond in advance and greatly reduce secondary The accident happened.
4. Composition of the Tunnel Full Band FM Broadcasting System

4.1. System Components
The broadcasting system consists of four components which are the front-end receiving equipment, the full-band broadcasting base station, signal transmission and transmission links.

4.1.1. Front-end Broadcasting Receiver. Filtering and amplifying the FM broadcast signals received from the antenna, then convert the signals into electrical signals and transmit to the transmission network. Achieving the management and dialogue application of the FM broadcasting system of the tunnel control office, as well as the extension of controller inside the tunnel, such as the partition management, terminal status, scheduling operation, queue management, music management, audio source selection, broadcast management, recording monitoring, recording query and alarm management, etc.

4.1.2. Full-band Broadcasting Base Station. The FM broadcasting base station restores the electric signal to a broadcast signal and amplifies it, and emission by the transmitting antenna.

4.1.3. Transmitting Antenna. FM signal emission inside the tunnel can use two methods: antenna or leaky cable.

4.1.4. Network. IP network or independent optical fiber network between the FM broadcasting front-end and the tunnel broadcasting base station.

4.2. System Functions
4.2.1. FM Signal Emission Outside the Tunnel. Transmit the FM signal from outside the tunnel to inside the tunnel, to achieve the seamless connection of the FM signal of outside and inside the tunnel, as well as in multiple frequency bands. Allows drivers and passengers on board can continue listening to radio programs when drive through the tunnel.

4.2.2. The Group Carrier Full-band Broadcasting Emergency Insertion. In case of emergency (traffic congestion, traffic accidents, fires, etc.), the FM radio module can work in the group carrier mode, within the radio receiving frequency range (88-108MHz), the extension of controller inside the tunnel can simultaneously generate one hundred FM radio signals. Every 200KHz each signal and the content of each signal is all the same. In this case, when the vehicle enters the tunnel, no matter which frequency the radio is at, it can listen to the content of the tunnel control office broadcasting, and it can timely and effectively broadcast the useful information to all the passengers.

4.2.3. Mobile Voice Service. The officer uses a dedicated mobile phone that equipped with the APP, after the identity authentication the voice information can be directly released into the tunnel by using the mobile phone, and through the cabled and FM broadcasting system in the tunnel at the same time.

5. Yan-Chong Expressway Application

5.1. Yan-Chong Expressway Equipment Deployment
The starting point of Hebei section of the Yan-Chong Expressway connects with Beijing section of the Yan-Chong Expressway, and the ending point connects with Zhangjiakou section of the Zhang-Cheng Expressway. It is an important connection line for the Beijing Winter Olympics in 2022. There are 8 tunnels on the main line, including 5 long tunnels, 1 medium tunnel, 2 short tunnels and 3 tunnel management offices.
The tunnel full-band FM broadcasting system is deployed in these 8 tunnels. The broadcasting front-end receiver is located in the tunnel management office. Each tunnel full-band broadcasting base station is installed approximately every 200 meters inside the tunnel, and the co-located FM transmitting antenna, in addition, share the Public IP network for signal transmission with the tunnel emergency telephone system.

5.2. Test Result
Testing the receiving effect and technical indicators inside the tunnel with national standard. The vehicle radio is test for actual monitoring. From the perspective of inside and outside vehicle, the sound of FM broadcasting inside the tunnels of Yan-Chong Expressway was clear, smooth, with good quality, and there was no obvious noise or distortion. According to the national standard GB / T16463-1996 "Subjective Evaluation Method and Technical Index Requirements for Sound Quality of Broadcasting Programs", the listening effect in more than 95% of the area reaches above 4 points, which achieves the technical requirements for uniform signal distribution inside the tunnel.

The coverage field strength test was carried out by a spectrum analyzer with a portable directional antenna; compare with the test results before and after the tunnel FM coverage project finished, the level value was basically around 22dBμV before this project start, and the level value is above 40dBμV after this project finished. It is basically consistent with the theoretical value and meets the requirements of the coverage technology, the tunnel FM broadcasting coverage effect reaches the expectations.

6. Conclusion
This paper proposes adopting the full-band FM broadcasting tunnel system, providing FM signals in daily situations, in case of emergency by using the full-band emergency interruption function to implement emergency information, and proposes a system construction plan. The system is constructing and application inside the Yan-Chong Expressway tunnels. After testing, the FM signal in the tunnel meets the requirements of FM signal coverage. At the same time, it can link with cabled broadcasting for information insertion and broadcast, and has achieved good results. Therefore, the use of FM radio to release emergency information is an effective supplement and improvement of existing tunnel information broadcast system, and effectively reduces the occurrence of traffic accidents inside tunnels.

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