Underground Intelligence

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Application Note
AN03.3

Integrated Tunnel Communications

Introduction

This application note describes an integrated communications system that provides seamless coverage inside of a roadway tunnel for police, fire and emergency service. The application note also describes how two-way voice, data, as well as services such as TETRA and FM broadcast, can be carried by the same system to extend coverage inside the tunnel.

Mine Radio Systems has a long established history of providing communications systems for confined spaces in the toughest and most arduous of all environments – underground mining. With decades of combined experience in the design and installation of two-way VHF and UHF communications systems, data and video, Mine Radio Systems can provide a wide variety of communications services in all types of tunnels. Mine Radio Systems also provides other types of tunnel communications services (e.g. for Tunnel Boring Machines) during the tunnel construction phase, which are described in other application notes.

Typical Application

Many major cities have embarked on tunnel construction projects as a way to ease congestion in areas carrying large volumes of traffic. Often these tunnels traverse rivers and port areas where it would be prohibitively expensive or impossible to fill in roadways or construct new bridges. The plan of a typical dual roadway tunnel, consisting of side-by-side tunnels, with a total length of 4,500 metres is shown in Figure 1 below. This tunnel incorporates a toll-way plaza (right hand side) and connects between two major arterial road systems.

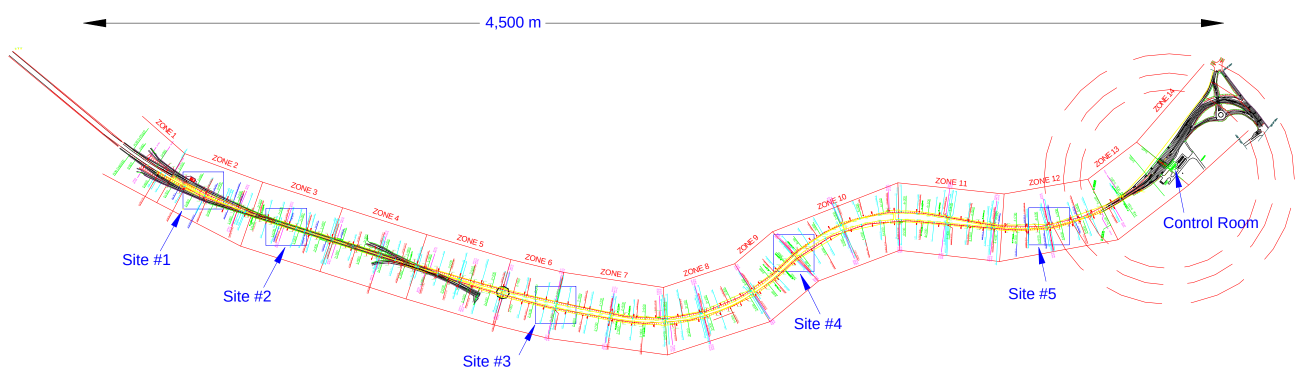

Figure 1: Overview of Integrated Tunnel Communications Systems

The requirements for this project include the provision of an integrated tunnel communications system that allows police, fire and ambulance services to seamlessly maintain communications in the area leading up to the tunnel entrances and inside the entire length of the tunnel. These services are allocated to specific frequencies in the low-band VHF (68–88 MHz), high-band VHF (155–174 MHz) and UHF (460–467 MHz) as well as an option for TETRA (380–395 MHz) for future expansion.

To provide these services it is necessary to design a system that allows for on-frequency repeating of the off-air signals (i.e. transmissions originating outside the tunnel) into the tunnel itself and for on-frequency repeating of signals originating inside the tunnel to outside.

The project requirements also include the rebroadcast of commercial FM radio station signals for commercial and passenger vehicles inside the tunnel and a provision for these signals to be interrupted and overridden with a public address message in the event of an emergency.

Fibre Optic Distribution

The use of fibre optic cables is now the most favoured way to distribute RF signals in tunnels that exceed more than a few km in length. The inherent isolation offered by the fibre optic distribution system provides a high degree of flexibility when it comes to optimising the system for best performance.

The devices that make it possible to use fibre optic cables in this way are optical (“light-wave”) to RF converter pairs. These devices have an essentially flat response from 50 MHz to in excess of 1 GHz and provide a communications link that takes an RF input and provides an RF output at the other end. The technique works equally well for signals originating off-air and transported into the tunnel (“downlink”) as for signals originating inside the tunnel and being transmitted outside (“uplink”).

Leaky Feeder Distribution

A radiating cable is used to provide the required coverage inside the roadways that run in each direction in the dual tunnel.

To simplify the design of the system a separate radiating cable (“leaky feeder”) is used for transmit and receive. Separate cables are also used in each tunnel making a total of four (4) runs of radiating cable totalling 18,000 m along the entire length of the tunnel.

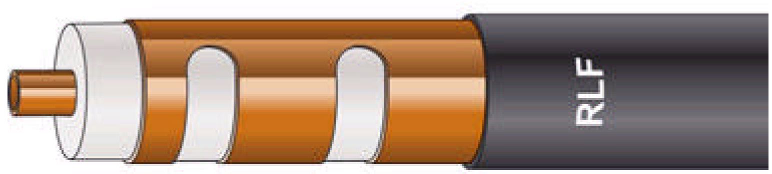

Figure 2: Radiating cable (“leaky feeder”)

The radiating cable is characterised by its attenuation (in dB/100m) and by its coupling loss at each frequency of operation. At a frequency of 450 MHz a typical radiating cable of diameter 7/8” (22.2 mm) has an attenuation of 2.8 dB/100m and a coupling loss of –65 dB.

For the transmit path (i.e. *“downlink”*) it is necessary that the RF signal injected into the cable is high enough to compensate for the cable attenuation (for the longest intended length of cable) and still reach a mobile receiver with enough signal level taking into account the coupling loss.

For the receive path (i.e. “*uplink*”) the coupling loss is experienced before the signal reaches the cable and the length of cable between the mobile transmitter and the point where the signal is taken off serves to attenuate the level further.

The determination of signal levels must be chosen carefully to obtain the optimum dynamic range for the system.

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Tunnel Downlink

The purpose of the tunnel downlink is to carry the RF signals arriving from transmitters in the vicinity of the tunnel entrances and distribute these signals in as uniform a manner as possible inside the entire length of the tunnel.

Frequency MHz	Field strength dBµV/m
450	35
150	25
88	30
75	18

Table 1: Minimum signal strength for downlink

The requirements for the minimum signal strength of each communications channel will vary from one tunnel to another. The values shown in Table 1 are typical for emergency services and broadcast FM radio.

An outline view of a typical tunnel downlink is shown in Figure 3.

This configuration shows a dual redundant system with separate fibre optic distribution cables in each of the two tunnels. Optical splitters are used to reduce the number of fibre optic cables used in the cable bundles with three (3) of the sites sharing a common optical feed and the remaining two (2) sites served by a separate feed. In this system it is not possible to use a single fibre optic cable for the downlink in each tunnel since the optical losses would become excessive.

At each site an Optical to Electrical converter (light-wave to RF) is used to convert the optical signal to RF for input into the Down Link Amplifier (DLA).

Each DLA is connected to the radiating leaky feeder cable that runs down the length of the tunnel. Separate radiating cables are used in each tunnel. There are no active components (such as bi-directional amplifiers) used in the tunnel itself.

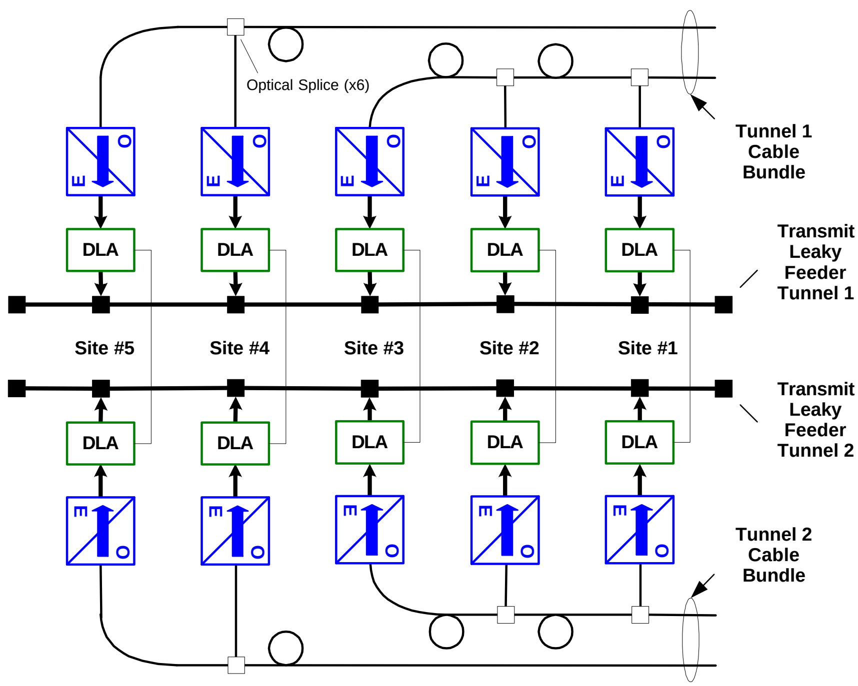

Figure 3: Tunnel Downlink

In the event of loss of optical signal to a light-wave to RF converter the RF signal from the light-wave to RF converter located in the other tunnel (at the same site) is routed into the DLA to maintain operation of the system. The typical power output at each DLA is equalised to 1 Watt per carrier (+30 dBm). At this level, the signal radiated from the leaky feeder cable exceeds the minimum required field strength for a distance of 1,100 m in either direction from the DLA. The maximum distance between adjacent sites in the tunnel is selected to be less than 1,100 m to provide fault tolerance in the event of damage to the cable or the failure of a DLA. A total of five (5) sites along the 4,500 m length of the tunnel are needed to meet this requirement.

This configuration allows the downlink to continue to operate when subjected to any one of the following fault conditions:

- A break in one or more of the fibres to one of the tunnels
- Failure of any one DLA in either tunnel
- A break in the transmitter radiating cable in either tunnel.

Each of these conditions may be detected by monitoring equipment to signal the operator that a specific fault has occurred.

Tunnel Uplink

The purpose of the tunnel uplink is to collect the RF signals transmissions originating inside the tunnel and to boost these signals to a level that is suitable for retransmission to receivers located outside the tunnel.

Frequency MHz	Minimum Receive Signal dBm
450	-94.2
150	-94.5
75	-95.0

Table 2: Minimum detectable signal strength for uplink

In a similar way to the downlink the requirements for the minimum detectable signal for each communications channel in the uplink may vary from one tunnel to another. The values shown in Table 2 are typical for emergency services.

An outline view of a typical tunnel uplink is shown in Figure 4.

The uplink configuration shows separate fibre optic distribution cables in each of the two tunnels. At each site an Electrical to Optical converter (RF to light-wave) is used to convert the received RF from the Up Link Amplifier (ULA) to an optical signal that can be coupled directly into the fibre optic cable.

Each ULA is connected to the radiating leaky feeder cable that runs down the length of the tunnel. Separate radiating cables are used in each tunnel for receiving RF signals. Note that these cables are separate from the leaky feeder cables used in the downlink. There are no active components (such as bi-directional amplifiers) used in the tunnel itself.

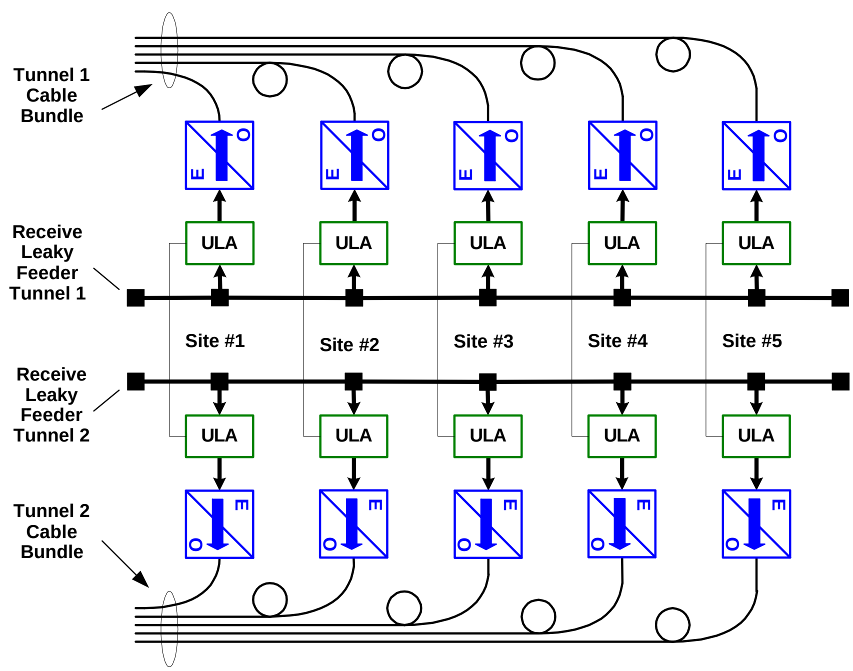

Figure 4: Tunnel Uplink

In the event of loss of optical output from a RF to a light-wave converter the RF signal from the ULA is routed into the ULA in the opposite tunnel (at the same site) to maintain operation of the system. The typical signal output at each ULA is equalised to not exceed +0 dBm per carrier. The dynamic range of the ULA is specified to allow signals that originate at distances of up to 1,100 m in either direction to be received at a level that exceeds the values shown in Table 2. The maximum distance between adjacent sites in the tunnel is selected to be less than 1,100 m to provide fault tolerance in the event of damage to the cable or the failure of a ULA.

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This configuration allows the uplink to continue to operate when subjected to any one of the following fault conditions:

- A break in one or more of the fibres to one of the tunnels
- Failure of any one ULA in either tunnel
- A break in the receiver radiating cable in either tunnel.

Each of these conditions may be detected by monitoring equipment to signal the operator that a specific fault has occurred.

Typical System Layout

The complete layout of the integrated tunnel communications system is shown in Figure 5 below.

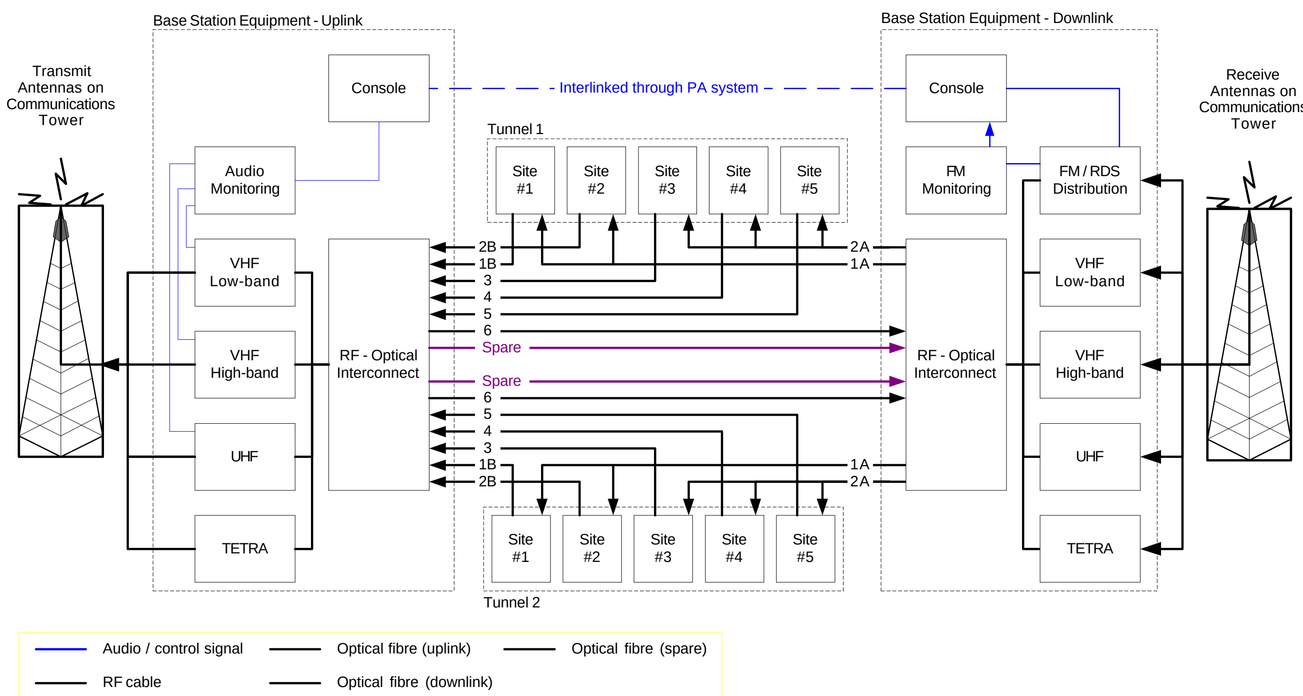

Figure 5: Overview of Integrated Tunnel Communications Systems

The positions of the five (5) sites that are required to provide sufficient coverage along the entire length of the tunnel are shown. A total of six (6) fibre optic cables, including spares, are needed to provide communications services in the VHF low & high-bands, UHF, TETRA and FM rebroadcast. The modules required for monitoring audio from selected two-way channels and the FM rebroadcast stations are shown.

For Further Information

If you require clarification of any of the above notes of have any comments or suggestions relating to this or other application notes from Mine Radio Systems please call your nearest Mine Radio Systems distributor or agent.