Inside **knowledge**

Recent innovations in radio technology and practice are improving transport tunnel safety and management. By **Richard Lambley**.

Radio coverage in enclosed spaces is increasingly seen as essential – particularly in road and railway tunnels, where reliable systems are needed for smooth operations and to protect travellers.

Sporadic, but alarming, incidents have alerted tunnel operators to the need for reliable communications, not only to prevent mishaps, but also to manage clear-up operations. And, even when lives are not in danger, tunnel incidents can be costly because of the disruption – so a good communications system is an essential tool.

New tunnel projects are including dedicated communications installations from the outset. "While it might have just been fireground and emergency communications, there is now pressure to include 4G and Wi-Fi, which complicates the solution," says Adrian Dain, principal consultant at Mason Advisory. "And a lot of road tunnels have voice breakthrough – [the ability] to make announcements over commercial radio frequencies in the event of an emergency."

To meet coverage needs in this challenging environment, system designers have a variety of technologies at their disposal. Ludovic Rousseaux, a radio network engineer with Airbus Defence and Space, said: "We have to choose between extra base stations or off-air repeaters. We have to choose how we will ensure coverage – for example, antennas or radiating cables. We also choose whether the distribution network is active or passive, with RF cables or fibre optic, and the level of redundancy required. Sometimes, we need a mix of solutions; we can mix base stations, radiating cables, boosters or off-the-air repeaters, plus other systems."

A key requirement is the level of radio coverage expected. Rousseaux says customers typically ask for at least 95% tunnel coverage. "After that, we generally see some redundancy requirements; if equipment is down – because of an accident or non-availability – we have to propose a redundant solution. Often, we have requirements about expandability: if the tunnel is extended or a second bore is to be created, we have to ensure the system will be able to support additional antennas or additional cables."

Reliable, resilient communications are critical in tunnel environments and operators' requirements are changing in response to greater demand for bandwidth-hungry applications.

Active and passive

"A starting point for projects is how much kit we are allowed to put in the tunnel," says Dain. "Particularly with rail, clearance is a big issue. There's very little space inside the bore, so there's a push to put passive equipment in the tunnel and active equipment in places that are little bit more accessible."

At its simplest, a tunnel system can consist of an outside antenna relaying an off-the-air signal into the interior via another antenna or a radiating cable ('leaky feeder'), to provide distributed radio coverage along the length of the tunnel. "There is often a drive to make radiating cable sections as long as they can be," comments Dain. "With lower frequencies, that's usually not too much of a problem – at around

Image: Adobestock

400MHz, you can go up to 1km or so without boosting the signal.

"As frequency increases, the distance you can cover without active equipment gets shorter. We are now looking at Wi-Fi and 2.6GHz, which tend to be the top end of what we will put on radiating cables." Dain says, for 2.6GHz, 500m might be the furthest you can go before active equipment is needed.

More complex installations may support multiple communications and broadcast services (such as TETRA or Tetrapol, analogue private mobile radio, mobile phone services, AM, FM and digital radio) in their various frequency bands, with dedicated base stations serving a system of remote antennas (a distributed antenna system or DAS). These may be backed up by reserve units and standby power supplies in case of failure. Many modern schemes employ an optical fibre distribution network, with an optical master unit (OMU) at its hub. The OMU converts RF signals into modulated light and back again, enabling signals to be exchanged efficiently with remote antenna units throughout the tunnel.

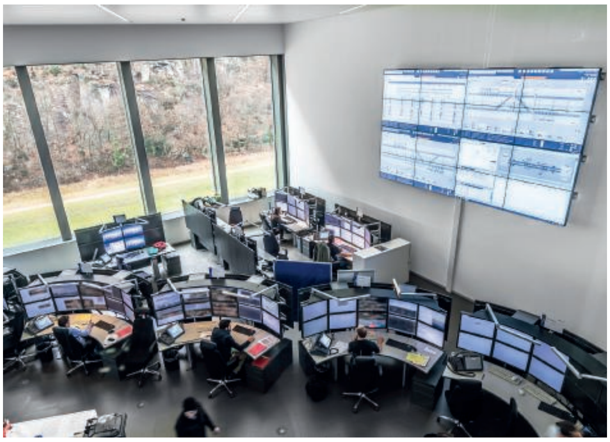
Distributing the signal

"[With] a small tunnel, it's preferable to use off-air repeaters," says Rousseaux. "It will be cheaper and will generally cover the need. But for longer tunnels – more than 10km – we prefer to use OMUs. There is also a need to ensure a certain degree of redundancy and resilience. For example, an accident in one of the tunnels might destroy the base station of the active equipment. So we feed the distributed antenna system from both ends – if we lose one connection, the other will still be available."

Dain says distributed antennas can be a lot cheaper than radiating feeder cables, particularly at higher frequencies, where larger cable is needed to reduce the attenuation per metre. "There's a cut-over point and that point depends on how much space you've got in the tunnel. DAS systems now come with an integrated unit that will take a fibre cable and provide the whole RF stage, so you can run an easy-to-install fibre cable through the tunnel to each DAS point. There, you have a small box that drives your RF stage, and then you have the antennas.

"The cost of DAS has come down, which has moved the break between DAS and radiating feeder cable systems. The cost of RF-over-fibre [looks like it's] about to come down, so you can put in place a kind of neutral hosting system using fibre and distributed antennas that's all quite broadband, then add discrete radio systems at a later stage."

In railway tunnels, signal propagation can be blocked by trains themselves. To deal with this, some DAS installations are designed to work with on-board equipment. For example, a signal could be picked up by an antenna on the train and then re-radiated. "That's popular for things like Wi-Fi backhaul," Dain notes, "but it's sometimes used for other in-train systems, such as condition monitoring and passenger information."



Picture: ATOS

The Gotthard Base Tunnel control room. Radio coverage in the tunnel is part of Switzerland's national Polycom emergency services network, supplied by ATOS Switzerland

Disturbance, interference

Designers have also responded to changes in tunnel construction specifications, such as those resulting from the 1999 Mont Blanc tunnel fire. "Not only do we have to provide redundancy, but we also have to consider fire-retardant feeders," says Rousseaux. "You also need to provide micro and macro redundancy. Micro is inside the equipment – for example, dual redundant power supplies. With macro, for example, we feed the different antenna systems and/or leaky feeders with two radio sources, so two cells are repeated throughout the tunnel."

In multi-band systems, one potential problem is interference. "We have to take care, especially with intermodulation products," Rousseaux continues. "They can happen between different carriers – they may intermodulate and generate interference on the uplink. This is something we have to calculate beforehand. The most difficult thing is to mix FM radio with TETRA signals. The FM radios mix with TETRA carriers and create third-order intermodulation products on the uplink at very high levels. This can desensitise the whole system.

"We have to reduce the feed-in power to mitigate the issue – but we generally recommend avoiding the use of FM."

Meanwhile, a new approach to DAS is being pioneered by Cobham Wireless, whose idDAS architecture for LTE is being extended to public safety applications. "We will launch a product that combines TETRA 400 and LTE in any available band," explains product manager Ingo Flomer. "You can choose up to four bands in total. One could be TETRA, then you could have three LTE bands, or two TETRA and two LTE bands.

The cabinet has a physical limit of four bands, but Flomer says these can be cascaded. "The technology we are using allows us to cascade each unit – we call them idRUs – so remote units can be cascaded at the same location, for example, which is important to create MIMO or to generate more than four bands."

At the heart of the installation – the base station room – capacity is supplied by conventional base station equipment. "RF signals then go into a digitiser," continues Flomer. "We call it MTDI [multiple technology digital interface]. We use the same protocol used by base station manufacturers to connect their remote radio units."

In contrast to conventional DAS systems, where these streams are hardwired to individual antenna units, the idDAS system connects them via a router. "The important thing is that we can steer capacity," Flomer emphasises. "It is a flexible approach; a cloud-run architecture where you can address the sectors to destination points. You can do that on an hourly or a daily basis and this is how you react to events. In a stadium, for example, you don't need capacity when they're idle mode most of the year. You can just bring it there when there is capacity demand. And that is valuable."

Capacity, he adds, is a factor that will increase in significance with the introduction of LTE into public safety communications. "TETRA was pretty straightforward, with time slots and user groups. But LTE is data-centric and it is walking away from the group approach. It means capacity becomes an issue, even in public safety."

Connections from the router to the remote antenna units can be Cat6 copper cable or multimode or single mode fibre. With TETRA, links of up to 40km are possible and up to 60km with LTE.

Though idDAS may sound costly for simpler tunnel installations, Flomer claims the opposite is true. "We have customers doing significant rollouts in Norway for tunnels. Those tunnels need typically one or two remote units. The problem was they needed an off-air repeater to pick up the signal, bring it into the master unit and then feed it to the remote units. With idDAS, we can take a remote unit and change its software to make it a master. Then you have, in one box, the RF front end and the converter to fibre. It's IP65 and lower cost than an analogue DAS in a comparable situation."

Moreover, he adds: "It can be cheaper for a small tunnel to use idDAS because you don't need base stations – you usually pick up the signal from outside."

Nonetheless, he acknowledges an idDAS remote unit is somewhat more expensive than an analogue remote unit. "I'm talking about a 10 to 20% gap," he says. "But it has more functionality. Another good thing about idDAS is that you can daisy-chain or cascade the fibre. So you connect your first link to the first remote unit and then connect from that to the next one ... and, if you are worried about redundancy, you can create a ring – you connect the last remote back to the router."

The picocell option

For underground railways, a further option is picocell coverage. In the past, a picocell system would have been hugely expensive, but the cost of picocells has dropped to the point where they are becoming a good solution for sites such as station platforms – even tunnels. Picocells can be connected using Ethernet cable or gigabyte fibre, without the expense of RF cables or concern over constraints such as bend radius, especially in retrofitting schemes for older tunnels.

Since picocells embody software defined radios, it becomes possible to radiate several services, including 3G and 4G for the connected passenger, as well as emergency communications. Here, much will depend on the commercial model adopted by the system operator. But the public's appetite for mobile communications might drive the provision of emergency communications coverage by creating opportunities for infrastructure sharing.

"Critical radio communications is one of the ways we can keep old tunnels working," declares Dain. "Modern tunnels are designed with things like SOS telephones and safe spaces for people if there is a problem – maybe even places where you can pull over. Those features weren't thought of when they built [older] tunnels. So, often, they are more reliant on special coverage solutions than modern tunnels and use comms to make up for some deficiencies."

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This is creating new issues for installers, who are rising to the challenge with novel techniques and new technology. While it is still relatively early days, the hunger for data will only continue to grow, making in-tunnel connectivity a 'must-have'.

Many tunnels are driven with a round bore: this leaves a culvert beneath the road that offers a safe space to lay radio system cables. In this way, the radio distribution system can be fed from both ends of the tunnel, affording protection from possible fire damage.

Author profile
Richard Lambley is consulting editor with New Electronics' sister publications TETRA Today and Land Mobile.