Voice Communication
in tunnel applications

Unified Communication through Public Address /
Voice Alarm and Intercom solution

Stay connected. Stay Safe

Foreword

Tunnels are geotechnical structures enabling roads and railway connections to pass through obstacles such as heavily urbanized areas, rivers, bodies of water, mountains, etc.

PC WORKSTATION
running YELLOW software

3rd party systems:
SCADA, RADIO (RF)

ISE VES
PAVA server

TCP/IP

ABT-ICDG-1
SIP PAGING UNIT

TUNNEL CONTROL CENTER

System visualization & remote management

Paging 2-way conversation

ISE COMM
SIP SERVER

ABT-TNL100
Tunnel horn loudspeaker

smartVES

MAIN TUNNEL

Intercom Management Voice recording System log Integrations

Public Address system

TCP/IP

3rd party systems:
IP-PBX, SCADA, BMS, PSIM

smartVES
Modular system

IP Intercom 2-way conversation Help-call

ICO STRONG
SIP Intercom

ABT-DFMS
Emergency microphone

SAFETY SITE

miniVES

IP intercom for:
- Safety Sites
- Tunnel Portal
- Refuge rooms
- Crosspassages
- Inside of tunnel bore

ICO EMERGENCY
SIP Intercom

miniVES
IP-amplifier

ABT-NSM(B)
Noise sensor

ABT-NSC6
Noise sensor interface

ABT-TNL100-1
Wall mountable tunnel loudspeaker

For this reason, tunnel interiors, including designated safety areas and evacuation routes, are equipped with modern voice communication systems such as: Public Address / Voice Alarm Systems (PA/VA); Intercom two-way Voice Communication Systems. The demanding tunnel environment poses specific challenges for communication systems. While they are used for daily communication between operators and users, their crucial role is ensuring reliable safety procedures and critical communication in emergency situations. The acoustic characteristics of tunnels – particularly the significant increase in reverberation time and high levels of background noise generated by traffic – impede the achievement of required speech intelligibility. To address these challenges and guarantee the intelligibility of both operational messages and priority warning signals or evacuation instructions, it is essential to implement advanced PAVA (Public Address and Voice Alarm) and critical communication systems. Such dedicated systems must be designed and deployed to function effectively in harsh environmental and acoustic conditions, while simultaneously meeting safety standards.

Tunnel Communication Challenges

Tunnels present unique and demanding challenges for communication systems, impacting both Public Address and Voice Alarm (PAVA) and Intercom functionalities. Addressing these requires specialized solutions designed to overcome specific technical hurdles.

CHALLENGE	IMPACT ON THE VOICE SYSTEM	IMPACT ON INTERCOM SYSTEM
HIGH LEVELS OF BACKGROUND NOISE	The need to reproduce speech signal at extreme levels – broadcasts are expected to exceed 100 dB SPL(A) level.	The need to increase the intelligibility of speech while in conversation - using DSP algorithms such as Noise Reduction and Automatic Level Control.
POOR ACOUSTICS	The need to maximize the ratio of direct to reflected sound energy – large format and highly directional loudspeakers shall allow to create a good proportion of direct sound along the main tunnel.	The need to increase the intelligibility of speech while in conversation – using DSP algorithms such as Echo Cancellation, deploying intercoms equipped with handsets to ensure picking up speech at sufficient level.
HARSH WORKING ENVIRONMENT	The need to secure the loudspeakers from corrosion (due to moisture, car exhaust and cleaning) – loudspeakers for the tunnel inside shall be made of corrosion resistant materials such as stainless steel or fiberglass.	The need to secure the intercoms from corrosion and acts of vandalism – interoms housing should provide high level of IP/IK resistance. Intercoms are closed in special wall boxes (openning the box shall cause the intercom to notify the CCTV and SCADA systems).
INSTALLATION CONSTRAINTS	The need to power the loudspeaker system from limited technical space, often with no dedicated rack rooms – the amplification system can consist of a mix of rack mountable modular systems, as well as IP amplifiers to be distributed in nieches along the tunnel path (for example stored within the limited technical space of a safety room).	The need to distribute multiple devices on over large distance - Intercoms shall utilize the redundant tunnel TCP/IP network, for this reason they shall support dual network ports. Communication shall be SIP based with basic device monitoring available via SNMP, directly from the end-point.

Tunnel system management and integration

The extensive length of tunnels (often spanning many kilometers) results in communication and safety systems being based on a distributed architecture. The central integrating element is the Tunnel Management Center (TMC), where the Operator station is located.

The safety systems operator is equipped with dedicated software and tools for individual subsystems, however, his key tool is a common SCADA interface. The SCADA interface is responsible for the comprehensive management of all installations and the execution of integrated action scenarios. Voice communication systems are usually directly integrated as follows: PA/VA Systems (Public Address and Voice Alarm): with the radio communication system and Intercom Systems: with the CCTV system and the tunnel's IP PBX system.

Integration of Voice Communication Systems in the tunnel

Effective integration of voice communication systems with key tunnel safety subsystems is the foundation of efficient crisis management.

CONTROL AND REPORTING	COMMUNICATION AND BROADCASTING	VERIFICATION

SCADA visualization and control systems

Radio communication system RF

IP PBX telephone exchange

Industrial television system with CCTV event analytics

Due to digital integration with systems such as SCADA, radio systems and CCTV, operators in the Tunnel Management Center gain full control and the ability to respond quickly to any incidents. This enables automatic triggering of alarm scenarios and coordination of rescue operations, ensuring maximum safety for tunnel users. It is crucial for efficient information flow and coordinated action of all services during emergency situations.

Voice communication for tunnel safety sites

Tunnels often feature designated locations where users can seek refuge during emergencies, access medical aid or be subjected to triage.

These zones are typically designed as shelters, recesses or technical spaces. For this application Ambient System proposes to utilize a solution based on the miniVES IP-amplifiers. If necessary the solution allows to add a noise tracking feature, provided by ABT-NSM(B) noise sensors connected to ABT-NSC6 type preamplifiers.

MINIVES 4002

The miniVES 4002 is a compact Public Address System specifically designed to provide effective audio coverage for evacuation points and other designated safety zones within tunnels. Its modular construction and IP-based technology enable flexible installation in strategic locations.

ABT-TNL100-1

The ABT-TNL100-1 is a smaller variant of the Ambient System ABT-TNL100, designed for wall instalation. The loudspeaker housing is made of stainless steel and rated at IP66. For rated power of 100W the loudspeaker can provide an output of 128 dB SPL.

- Directional horn speaker
- IP66 rated enclosure
- Stainless steel enclosure
- 100 V line matching transformer
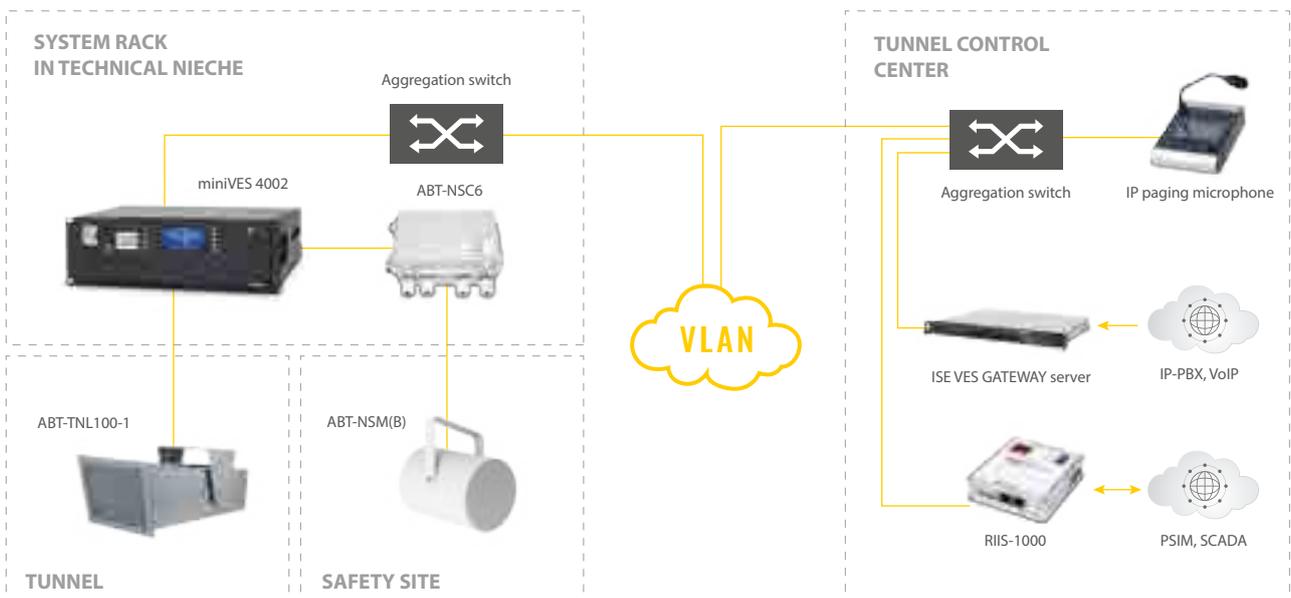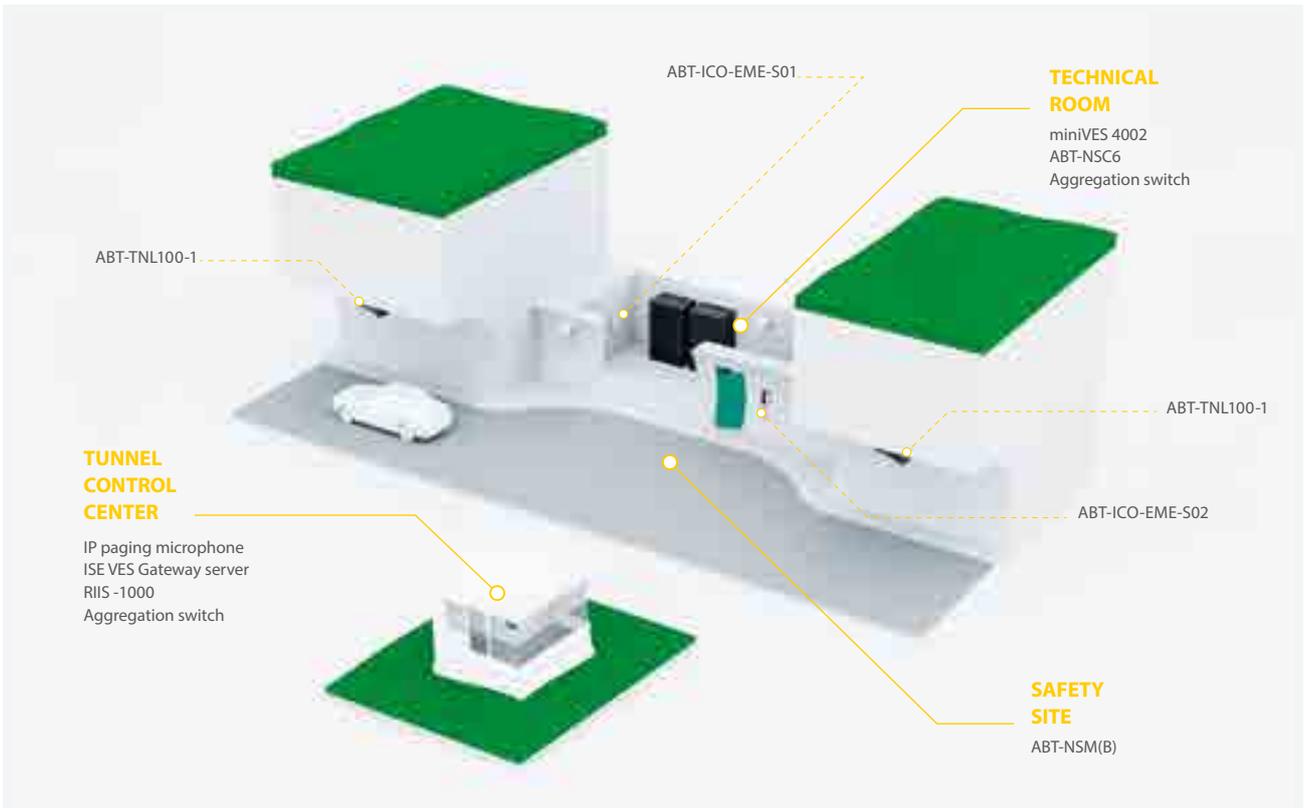- Rated power: 100 W
- Sensitivity – 108 dB SPL (1W/1m)
- Maximum output level – 128 dB SPL
- Frequency response: 250 Hz – 8 kHz

Example of a sound system installation for tunnel safety site

The diagram shows a typical configuration of a Public Address System for an evacuation bay in a tunnel. This solution, based on the miniVES system and ABT-TNL100-1 tunnel speakers, together with noise sensors, ensures optimal speech intelligibility even in challenging acoustic conditions.

ABT-ICO-EME-S01

TECHNICAL ROOM

miniVES 4002
ABT-NSC6
Aggregation switch

ABT-TNL100-1

ABT-TNL100-1

TUNNEL CONTROL CENTER

IP paging microphone
ISE VES Gateway server
RIIS -1000
Aggregation switch

ABT-ICO-EME-S02

SAFETY SITE

ABT-NSM(B)

SYSTEM RACK IN TECHNICAL NIECHE

Aggregation switch

miniVES 4002

ABT-NSC6

TUNNEL CONTROL CENTER

Aggregation switch

IP paging microphone

VLAN

ISE VES GATEWAY server

IP-PBX, VoIP

ABT-TNL100-1

ABT-NSM(B)

RIIS-1000

PSIM, SCADA

TUNNEL

SAFETY SITE

The system covers the safety site and its proximity.

PA/VA System for the entire tunnel

In many countries it has become a standard to equip public transport tunnels with sound systems to be used in emergency situations. While these systems do not usually comply strictly with the EN54 standard for Voice Alarm, they often include many typical Voice Alarm features such as:

✔ Ability to monitor internal elements, including controllers, amplifiers, DSP processors and paging stations

✔ Ability to monitor connected loudspeaker circuits for open-, short-circuit and ground fault

✔ Redundancy of interconnections and critical interfaces

✔ Standby amplifiers with automatic switchover

✔ Ability to interface with other life safety and security systems reliably and digitally.

Ambient System solution for tunnel

For these types of applications Ambient System proposes PAVA system concept including:

SMARTVES

A TCP/IP-based Public Address System, certified to comply with the EN54 standard, featuring a distributed architecture and advanced DSP processing capabilities.

ABT-TNL100 TUNNEL HORN LOUDSPEAKER

EN54 certified, stainless steel loudspeaker, rated power: 100W, sensitivity: 111 dB SPL (@1W/1m), assymetrical opening angle and high directivity.

Diagram of the integrated PAVA in the tunnel.

The presented diagram illustrates the comprehensive architecture of the tunnel PAVA, covering the tunnel interior, evacuation galleries and stairways, as well as the central control center.

*Diagram of the tunnel PAVA (using tunnel speakers and time delays)*

The system uses IP technology (smartVES – IP operator console), providing flexibility and scalability. Integration with the VLAN network enables reliable signal distribution. A key element is the strategic placement of tunnel speakers and sound projectors – combined with properly set time delays – ensuring high speech intelligibility throughout the facility, even in dynamic tunnel conditions.

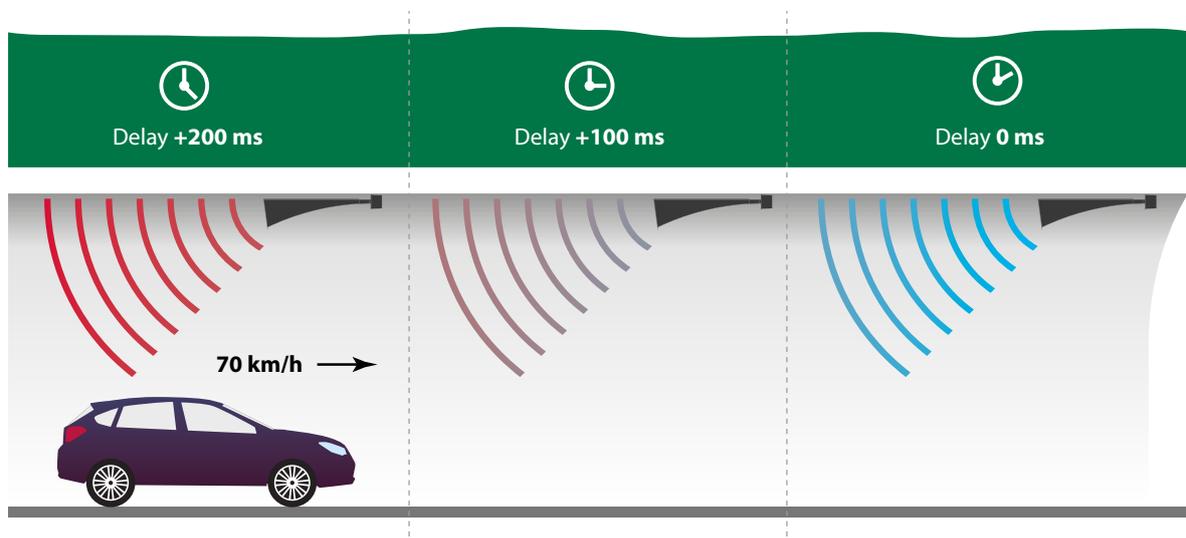# Voice communication in tunnel applications

Optimizing speech intelligibility in tunnels requires precise management of sound propagation.

TUNNEL TUBE
ABT-TNL-100
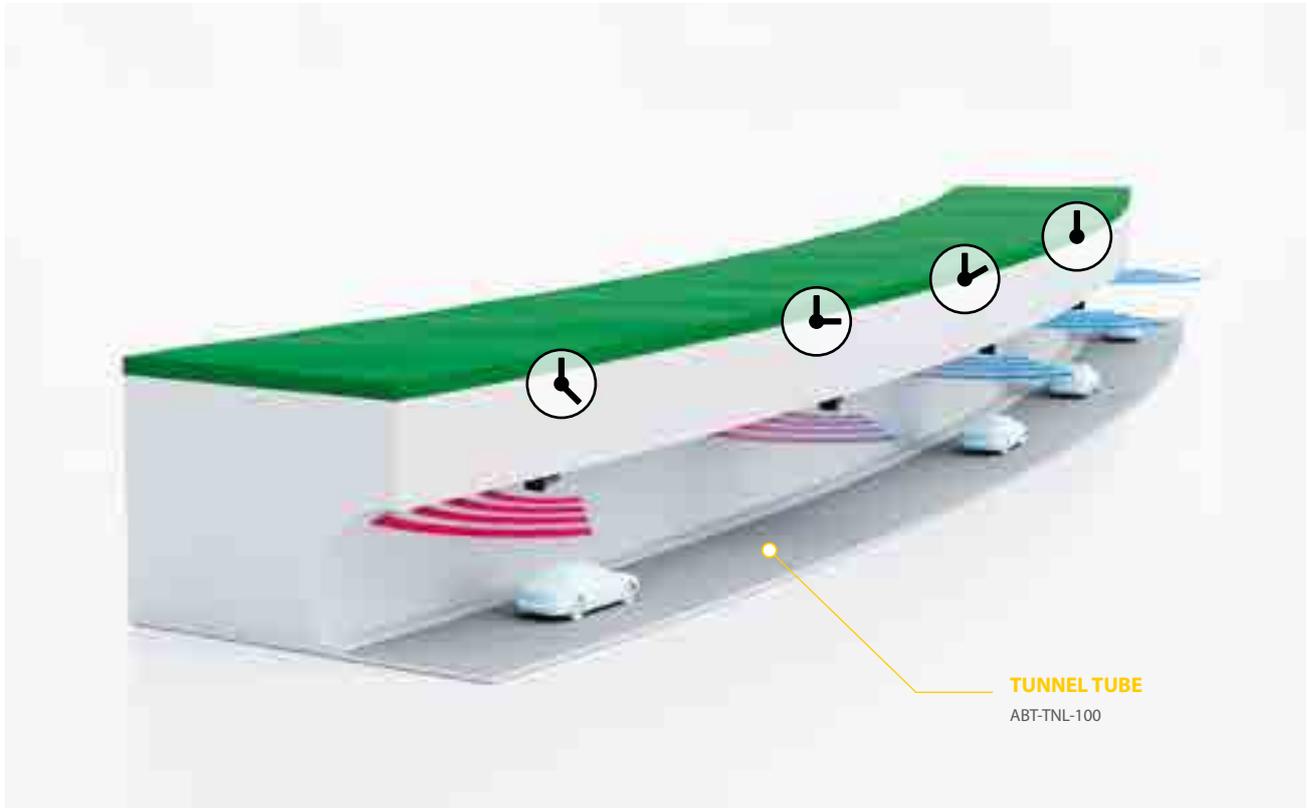
The use of signal time delays, as illustrated in the diagram, allows minimizing the echo effect and improving message clarity, especially with moving vehicles. Thanks to this advanced technique, every tunnel user receives the message at the optimal moment and with appropriate quality, which is fundamental for safety and communication efficiency during operational and emergency situations.

Delay **+200 ms**   Delay **+100 ms**   Delay **0 ms**

70 km/h →

ABT-TNL100 tunnel horn loudspeaker

The ABT-TNL100 large format highly directional horn loudspeaker designed for use in tunnel applications.

A directional tunnel speaker provides a high level of sound energy along the tunnel axis. The direct sound energy in the coverage area significantly exceeds the sound energy that reaches the walls and causes reflections. Consequently, tunnel users receive a favorable ratio of direct to reflected sound, which directly improves speech intelligibility.

✓ Efficiency: 111 dB SPL (@1W/1m)

✓ Rated power: 100 W, allowing the device to achieve an exceptionally high sound pressure level of 131 dB SPL

✓ High front-to-back ratio of 35 dB and narrow beamwidths (24°/42° × 32°/19°) enable precise directional coverage along the tunnel axis while minimizing acoustic reflections from tunnel walls

SOUND RADIATION ANGLE IN THE HORIZONTAL PLANE
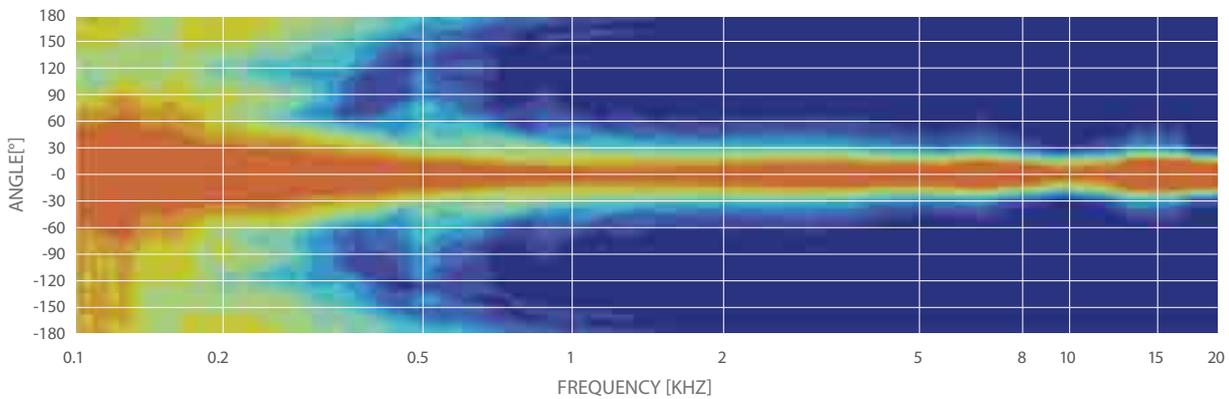
SOUND RADIATION ANGLE IN THE VERTICAL PLANE
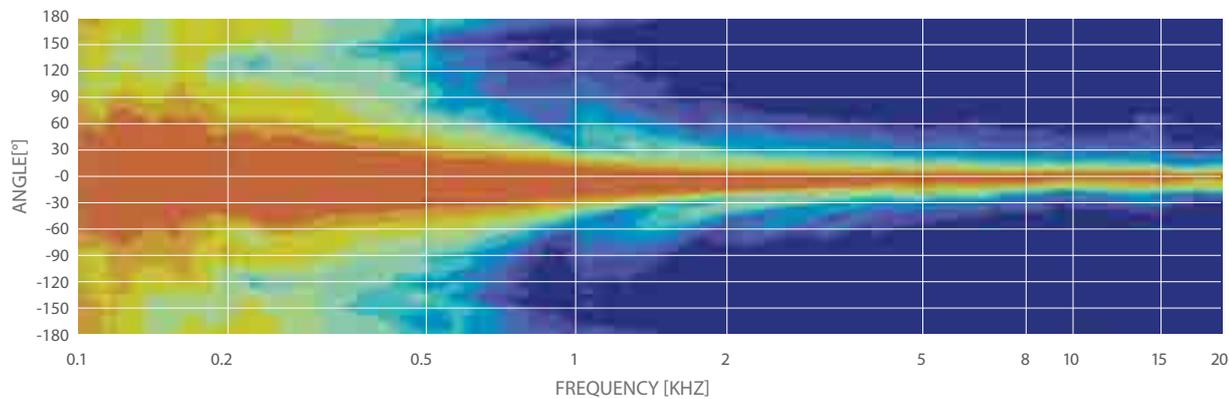
Emergency intercom system for tunnel

Intercom systems (two-way communication) are an essential element of tunnel equipment, providing reliable connectivity between users and operator stations in technical buildings and in the Tunnel Control Center (TCC).

Intercoms are typically located at regular intervals along the tunnel and at safety points, such as shelters, evacuation staircases, etc. They are also located at the aforementioned operator stations. Ambient System proposes a digital IP intercom system based on an ISE COMM server and ICO EMERGENCY series intercoms. The system components utilize as the communication medium a dedicated network or, alternatively, a VLAN isolated within the tunnel's redundant TCP/IP network structure. Key feature of the system is the ability to conduct two-way voice calls in Full Duplex, with conference call capability for multiple intercoms simultaneously. Ability to make voice announcements (using intercoms as loudspeakers) - server-based system architecture, with redundant server configuration option. Monitoring of connected devices: monitoring the operational status of connected intercoms and logging of events occurring in the system. Ability to record audio from voice calls between any intercoms and operator stations; recordings are archived server-side for later analysis. Reporting to external systems – capability to integrate with SCADA servers for visualizing the status of emergency intercoms (distinguishing at least: active status, idle status, and fault status). Integration is implemented using SNMPv3 protocol – possible both on server level and directly from the endpoint - automatic call forwarding: in case of multiple simultaneous calls or when the designated operator does not answer the call within the programmed time, the system automatically forwards the call to another recipient advanced digital audio processing algorithms which maximize communication intelligibility in difficult acoustic conditions in the tunnel.

Visualization of intercom placement in the railway tunnel

The visualization presents the strategic placement of ICO EMERGENCY intercoms in the railway tunnel, covering the tunnel interior, passageways and evacuation rooms.

EVACUATION ROOM
ABT-ICO-EME-S01

TUNNEL INTERIOR
ABT-ICO-EME-S02

EVACUATION PASSAGE
ABT-ICO-EME-S02
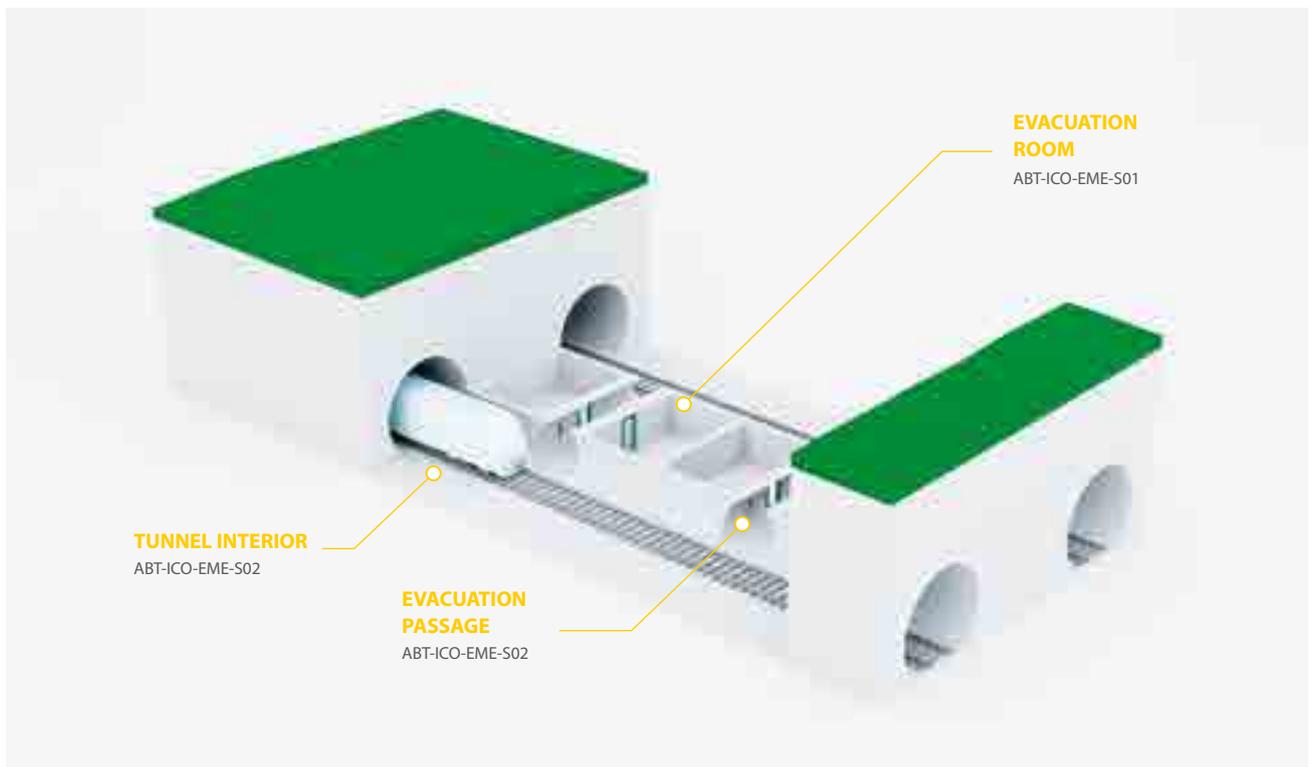
ABT-ICO-EME-S01

Model ABT-ICO-EME-S01 is a wall-mountable intercom, equipped with a single programmable button. Pressing the button initiates a call to the system operator. The housing features a vandal-resistant design, providing IP54/IK08 resistance. Voice communication is conducted via a loudspeaker with a rated power of 5W and a MEMS microphone.

ABT-ICO-EME-S02

Model ABT-ICO-EME-S02 is an intercom dedicated to environments with a very high level of background noise, such as those characterized by ventilation or traffic noise. To maximize speech intelligibility during conversation, the device is equipped with a handset. Lifting the handset automatically initiates a call to the operator. The housing of model ABT-ICO-EME-S01 has a vandal-resistant design and offers IP65/IK09 resistance.

AUTOMATIC VOLUME CONTROL

The system dynamically adjusts the intercom volume levels across frequency bands according to changing ambient noise, ensuring clear speech intelligibility within the tunnel.

ECHO CANCELLATION ALGORITHM

DSP algorithm which effectively reduces echo. This significantly increases speech intelligibility in highly reverberant spaces.

AUTOMATIC GAIN CONTROL (AGC) FUNCTION

IP intercoms automatically adjust microphone gain in real time, ensuring an optimal and consistent speech signal volume regardless of the speaker or distance.

NOISE REDUCTION ALGORITHM

This advanced algorithm intelligently identifies and removes ambient noise from the signal transmission, significantly enhancing the clarity and intelligibility of communication in noisy environments.

Both intercom models discussed above are equipped with 2 relays and 6 GPIO I/O. They enable integration with external devices, such as visual indicators, electronic locks, or buttons. The intercoms are to be mounted in dedicated surface-mount housings in orange, marked with an SOS inscription on the side. Furthermore, Ambient System intercoms feature a mechanism for acoustic monitoring of the microphone-speaker path status. The device status test involves the emission by the intercom of a special test signal, which must be correctly received by the built-in microphone. Audio path faults are automatically reported to the intercom server and the SCADA system.

ISE COMM

The heart of the system is the ISE COMM server, responsible for system management, its maintenance, call handling, and integration with third-party systems. For safety purposes and later analysis of events, the server continuously logs all events (calls, faults, etc.) and enables the recording of voice calls and their archiving for a specified period.

IP Intercom system monitoring

Call management

Integration with 3rd-party systems
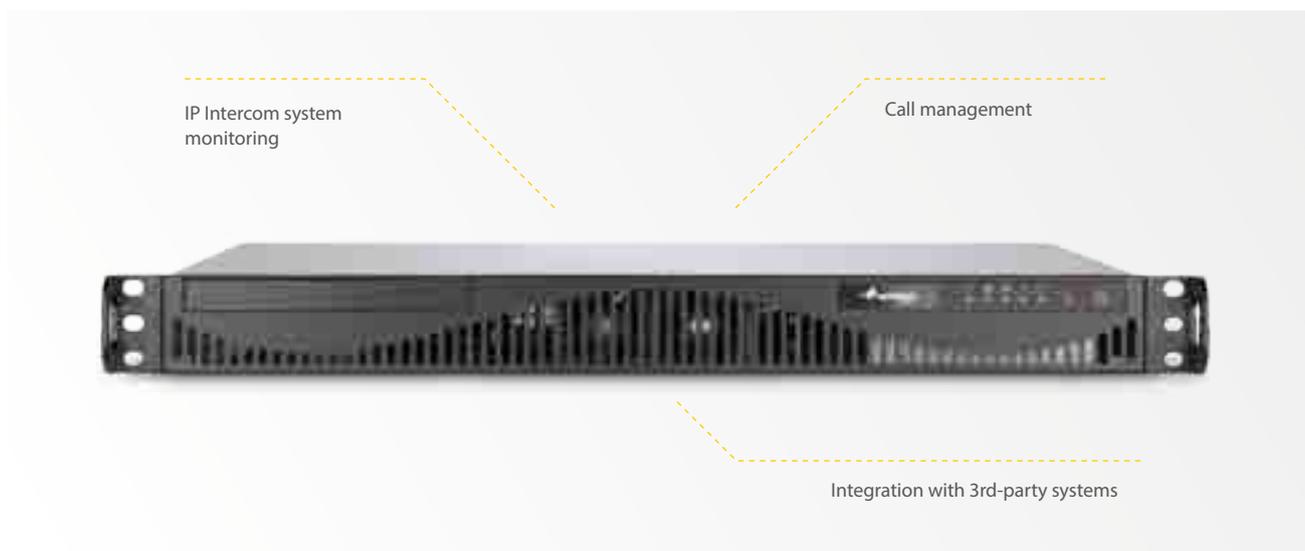
Tunnel safety: A comprehensive approach

Ambient System offers an integrated voice communication system, combining the functionalities of the PAVA system and the intercom system.

TUNNEL A
ABT-P20
ABT-DFMS
ABT-TNL100
ABT-ICO-EME-S01
PAVA rack
ABT-ICO-EME-S02

TUNNEL B
ABT-P20
ABT-DFMS
ABT-TNL100
ABT-ICO-EME-S01
PAVA rack
ABT-ICO-EME-S02

TUNNEL C
ABT-P20
ABT-DFMS
ABT-TNL100
ABT-ICO-EME-S01
PAVA rack
ABT-ICO-EME-S02

VLAN WITHIN REDUNDANT TUNNEL MSN STRUCTURE

PC workstation | SIP paging unit | IP-PBX, VoIP | ISE VES System Gateway | Server ISE COMM | 3rd party integrations: IP-PBX, SCADA, CCTV, RF

CONTROL ROOM

This solution enables the management of both subsystems from one or several central locations using common user interfaces. These are: dedicated PC software (Ambient System YELLOW), a SIP control console (ABT-ICDG-1) and a fireman's microphone (ABT-DFMS). This solution enables the deployment of advanced safety procedures, combining both voice notification and intercom communication, while simultaneously reducing the number of devices and required software. The Ambient System is fully digital – all its key components communicate via Ethernet and protocols

from the TCP/IP family. Integration of the system with external systems, such as SCADA, FAS (Fire Alarm System), or FRC (Fire Radio Communication), is implemented digitally (using open protocols, e.g., SIP or SNMP) or using dedicated hardware interfaces. Due to challenging acoustics and environment ensuring safety in tunnels requires advanced voice communication systems. This document describes Ambient System's integrated PAVA and Intercom solution, designed for these conditions. The system is fully digital, operating over Ethernet and includes key components like smartVES

and ICO EMERGENCY SIP intercoms. The solution features improve intelligibility in high noise (automatic volume, echo cancellation) and ensure system reliability (monitoring, redundancy, acoustic path test). It integrates digitally with external safety systems (SCADA, FAS, FRC) using open protocols or hardware interfaces, managed from central operator stations via dedicated software and consoles.

Ambient System References

ZHELEZNISTSA TUNNEL / BULGARIA

TUNNEL UNDER SWINA / POLAND

TUNNELS ON THE CRACOW BYPASS / POLAND

KARAWANKEN TUNNEL / AUSTRIA

CUSCO TUNNEL / PERU
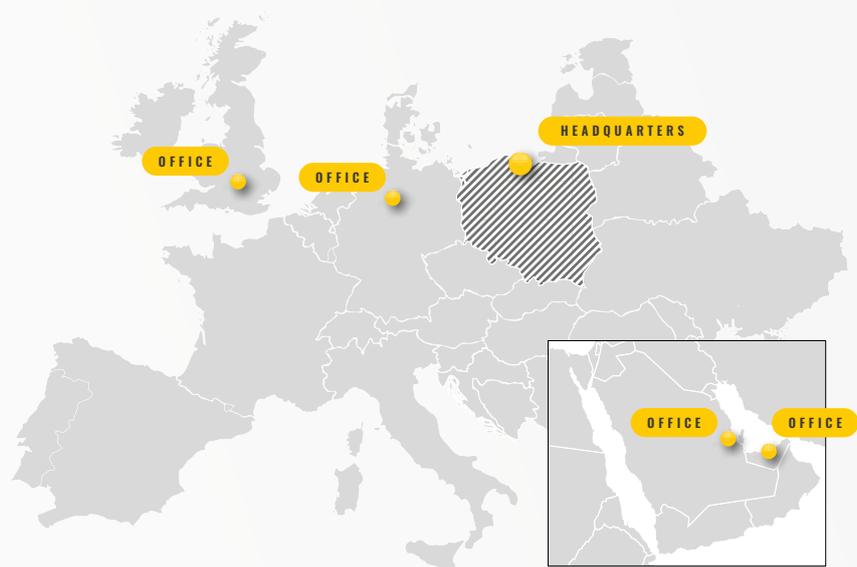

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We make everyday life safer

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