Radiofrequency bidirectional decoupler for the electrical insulation of coaxial cables in railway's tunnel

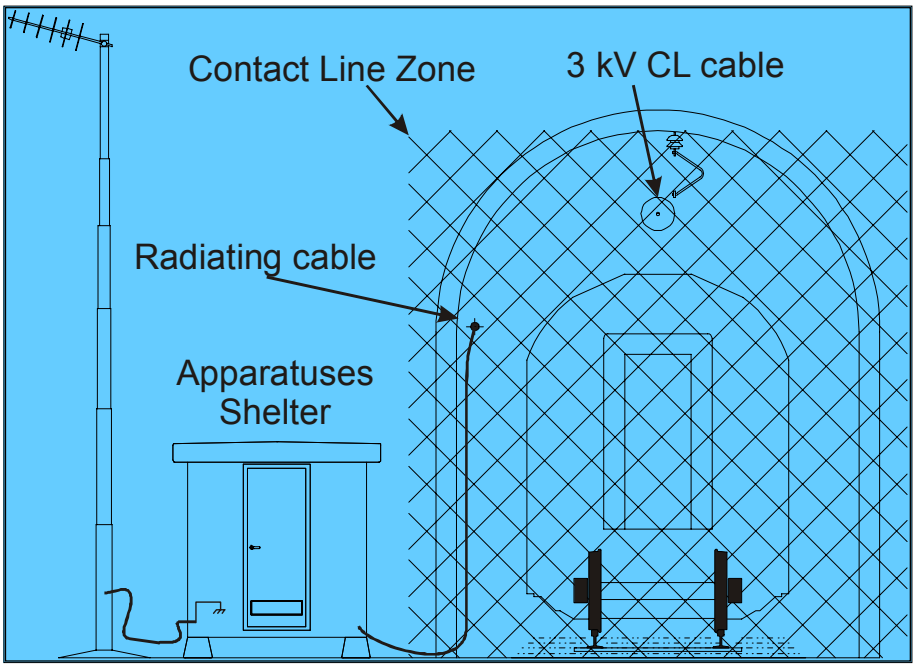
DBS and DBA Series (IInd generation)

Telecommunications inside tunnels

During the last years, the use of radiofrequency apparatuses for audio and data communications inside railways and underground tunnels was increasing in a very important manner.
Is more frequent to see coaxial and radiating cables installed in phisical areas defined, from the electrical safety point of view, to be second category (II) or higher voltages: in other words, in these systems are used electrical circuits supplied with alternate currents higher than 1.000 V or direct currents higher than 1.500 V. In case that these elements are not provided with proper insulation (like the railway overhead Contact Line) a surrounding area has to be defined (Contact Line Zone) where must be taken particular cautions for the installation of conductors, apparatuse and metallic structures that may become in accidental contact with category II systems.
For example, in case of accidental contact between a coaxial or radiating cable, installed along the tunnel's vault, and the overhead 3 kVdc contact line, the lack of insulation of the cable jacket determines the transfer of the 3 kVdc voltage to the radiofrequency apparatuses, with consequent destruction of the same and electrical-shock danger for the operators working on them.
Due to the high short-circuit currents, the earthing connection is never sufficient in order to guarantee safe touch and step voltages (less than 50V).

CL 3 kV cable mechanical fault

The following figure represents the typical configuration of a railway tunnel illuminated by a radiating cable placed about 4 m higher than the track plan: the outlined area puts in evidence the "Contact Line Zone" with a dimension of about 6 x 6 metres. The radiating cable is completely placed inside the CLZ while the shelter is generally outside
The antenna to the Base Station, the radio apparatuses , the external conductor of the radiating cable and the 48/60 power supply systems are bound to the local equipotential node placed inside the shelter.
In case that, for an accident, the CL 3 kV cable (that uses the track as return conductor) had to be cut and to be gone in contact with the external conductor of the radiating cable, the high available short circuit current (>10 kA) and the indetermination of the plant's earthing resistance value allow the allocation of the total voltage on the apparatuses' structures placed inside the shelter. In this case a very dangerous situation is created for the persons that are in place. In the worst case that the CL cable had to be also gone in contact with central conductor of the radiating cable there would be also fire risks for the apparatuses, cause the arcs generated, without the possibility to break them with protection circuits.



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The protection from the 3 kV CL fault

The protection against CL cable's mechanical fault, that send high voltage on the radiating cable, **IS NOT POSSIBLE** using the following components.

Surge arrester or voltage valves

The very high fault energies (2.500 kWs) bring to destruction of every component of this type available on the market. If a component of this type were available it would be however difficult to characterize the right position to guarantee low touch and step voltage levels.

DC-Block or DC/DC-Block

The construction of these type of components foresee the installation of a low value capacitor (about 200 pF) only in the central conductor and nothing on the external one; not even alternatives of these products (using capacitors on both conductors) permit to guarantee safety on fault as foreseen on recent railway standards (EN 50129 – Failures mode – Inherent Physical Properties).

Transformers

The only possible solutions are those that preview the galvanic separation on both conductors between radiating cable and RF apparatuses through the use of transformers capable to guarantee common mode insulation voltages (primary / secondary) greater or at least equal to 10 kV peak and 4,6 kV 50 Hz alternate current. The operating conditions determined by the RF apparatuses, that foresee transit power greater than 53 dBm (200 W) with frequencies up to 1000 MHz, permit to use both electromagnetic transformers and electrostatic transformers (decouplers).

Electromagnetic transformers

They have small dimensions, extremely economic prices but low reliability to insulation test.

Electrostatics transformers (decouplers)

They have slightly greater dimensions but they guarantee:

- low losses
- good impedance matching
- high capability to withstand high voltage insulation test, both in pulsed direct current and industrial frequency.

In any cases it will be necessary to take into consideration the following operating conditions.

- Installation in external tunnel position not accessible to persons and animals.
- Adverse climatic conditions (exposure to rain, direct sun and the attack of bugs and vegetation).
- Constant insulation capabilities in the time
- Installation of coaxial cables with outside diameter from 10 to 33 mm already terminated with 7/16 connectors.

Bidirectional decoupler DBS series (IInd generation)

For applications in railway's tunnel was particularly developed a radiofrequency insulation transformer (decoupler) obtained with two electrostatic Couple-Balun and designed to obtain the following characteristics.

Insulation	on two conductors
Insulation between ports	great. than 4,6kVca great. than 10kVp
Insulation conformity	EN 50124-1
Characteristic impedance	50 ohm
Maximum transit power	53 dBm
Operating frequency	800 – 1000 MHz
Bidirectional insertion loss	less than 1,5dB
GSM+GSMR Flatness	less than 0,5 dB
Ports return loss	better than 16 dB
Capacity between ports	less than 20 pF

The double transformer is cointained inside a glass-fiber-polyester case where are mounted the RF connectors of the coaxial cable to be insulated. The environmental characteristics of the final product are as follow.

Dimensions	75 x 235 x 75 mm
Protection degree	IP65
Accepted temperature	from –40 to 80 °C
Toxicity	alogen free

Telepowered systems DBA series (IInd generation)

Sometime there are situations where coaxial cable (or radiating cable) are used for the contemporary transport of radiofrequency and electric energy when is necessary to supply some amplifiers, equalizers or repeaters installed inside the tunnel. This type of solution can be valid for the following reasons.

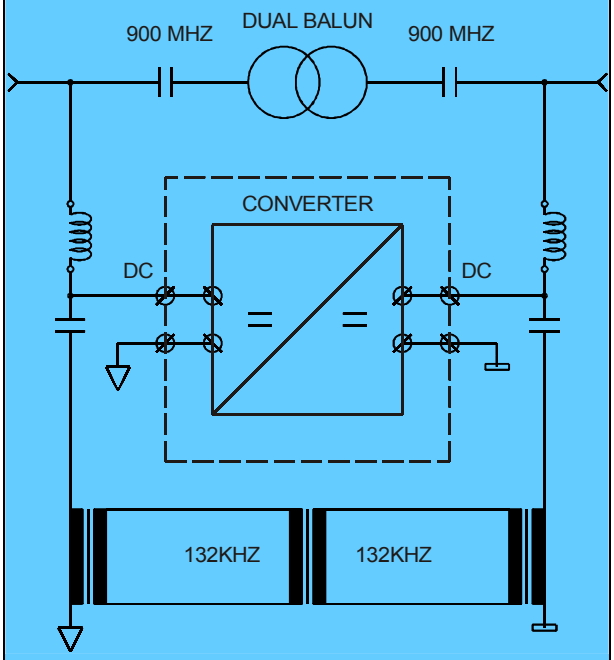
- Inside railways tunnels, above all, those of advanced age up to 20 years, against the highway's one, is not available a distribution network for the ac current.
- The used coax cable is frequently an optimum bipolar conductor with resistance values less than 2 ohm / kilometer
- The used voltages (48/60 Vcc) belong to category 0 and do not require particular cautions against accidental contacts.
- It's also frequent the necessity to transmit low frequency teleoperation signals that may be transported with the same cable to the radiofrequency apparatuses.

Also in these cases is necessary to galvanically insulate the two cable sections on both conductors:

it's possible to do that using the following apparatuses.
- DBS decoupler for radiofrequency
- High insulation DC/DC converter of the ASX series for DC electric energy
- High insulation 132 kHz or 10,7 MHz repeating coil for teleoperations.

The final set is called Active bidirectional decoupler DBA series followed by the converter denomination (i.e. ASX150-2) and telecontrol frequency. The characteristics are as follows.

DC/DC converter section



Insulation type	on two conductors
Output power	50 or 150 Watt
Input voltage	from 36 to 72 V dc
Output voltage	60 V dc
Impulse assigned voltage (input – output)	10 kV (OV1/PD1; in double IP65 case EN 50124-1 par.6.1.5
Dielectric strenght (input – output)	≥ 4,6 kV EN 50124 - 1 par. B2.2

Telecontrol carrier insulation transformer

Insulation type	On two conductors
Frequency range	132 kHz or 10,7 MHz
Insertion loss	≤ 1,5 dB
Dielectric strenght (input – output)	≥ 4,6 kV EN 50124 - 1 par. B2.2

Heavy environment installation

Due to electrical reasons both installed connectors, fixed and removable, the last one coupled with the first, must be made of metallic materials. In particular heavy atmospheric situations, like humidity, fog, bugs, vegetation and soil, can be created, along the insulating container, low electrical resistance paths that permit, in case of high voltages (>1.000 V), arcs firing with successive losses of insulation between the two ports. It becomes necessary, to conform to EN 50124-1 standard, to install the bidirectional decoupler inside a second case that must be able to guarantee the following performances.
- To guarantee that the atmosphere inside is constantly free of humidity (at least IPX5 degree).
- To permit the access of cables not yet headed or headed with 7/16 connectors with external diameters from 10 to 33 mm (½" corrugated coax cable up to 7/8").
- To guarantee that the connectors heading section (generally protected by shrinkable sleeve) will be maintained inside the case.
- To permit the installation in whichever position and to be easy handled.

We have chosen some products able to accept DBS and DBA decoupler and all the possible options, to warrant all the above mentioned requirements. The final characteristics are as follows.

Case dimensions (DBS)	560 x 280 x 130 mm
(DBA or multiple DBS)	560 x 380 x 180 mm
Total dimensions	650 x 280 x 130 mm
(DBA or multiple DBS)	650 x 380 x 180 mm
Total weight	Less than 5 Kg
(DBA or multiple DBS)	Less than 10 Kg
Protection degree	IP65
Accepted temperature	From –40 to 80 °C
(DBA)	From –20 to 55 °C
Toxicity	Alogen free
Accepted RF cables	from ½" to 7/8"
Transit connectors	from N to 7/16
Wall mounting	6 x M6 expansor

Capo Verde Tunnel

Passive decoupler (DBS) in a starting trunk of a 3 Optical Remotizer System and two Head Station Repeater

Terrabianca Tunnel

Passive decoupler (DBS) in a stand-alone system west side even-odd tracks

Mattone Rosso Tunnel

Active decoupler (DBA) in a four amplifier cascade supplied by a Head Station

Mattone Rosso Tunnel

Odd-even tracks radio covering shelter west side entrance

DRTecnologie

Bidirectional decouplers for electrical insulation of coaxial cables in railways tunnels

Some installation examples along railways track of Italian Railways Company (RFI) for cellular extension system in Stand-alone, Cascade and Optical Remotizer configurations. The installation was done after 12 months from the commissioning of radiofrequency apparatuses.