# AEPI - AZIMUTHAL ELECTRICAL PERIMETER INVESTIGATION FOR THE EXPLORATION OF GEOLOGICAL CONDITIONS AROUND UNDERGROUND CONSTRUCTION

Thomas Kopp

*QuMon GmbH, Lohra, Am langen Loh 13, D-35102, Germany*

**KEYWORDS**
Azimuthal Electrical Perimeter Investigation, Radially Oriented Resistivity/IP Surveys via Perimeters, Azimuthal Electrical Perimeter Sounding (AEPS), Ambient Electrical Resistivity Tomography (AERT).

## INTRODUCTION

AEPI methods (pat.pend.) are designed to investigate geological and urban underground peripheries of tunnels, galleries and boreholes by means of innovative geoelectrical measurement concepts for radially oriented Resistivity(→R/ρ) and IP surveys via perimeters.
The technique of Azimuthal Electrical Perimeter Sounding (AEPS) enables to explore geological and anthropogenic settings encircling underground constructions by usage of selective axial perimeter locations for reconnaissance. By long term tracing of AEPI parameters, hydrogeological conditions e.g. beyond tunnels can be monitored. Ambient Electrical Resistivity Tomography (AERT) through multi-electrode arrays provides an insight into spacious ground by 3D-synopses.
Targets of detection for AEPI methods are layer succession, groundwater level, fault or karstified zones, cavities, flow paths, foundation structures and obstacles, which are of significant volume in relation to distance and sufficient electrical contrast compared with the R/IP properties of an enclosing geological background.

## AZIMUTHAL ELECTRICAL PERIMETER INVESTIGATION METHODS

AEPI methods generate oriented flow of electrical charge in circumjacent settings of underground constructions. Homogeneous environments and construction features are hereby characterized by homogeneous electrical field distributions (s. Fig.1), recorded along circular perimeters accordingly (Fig.1a).

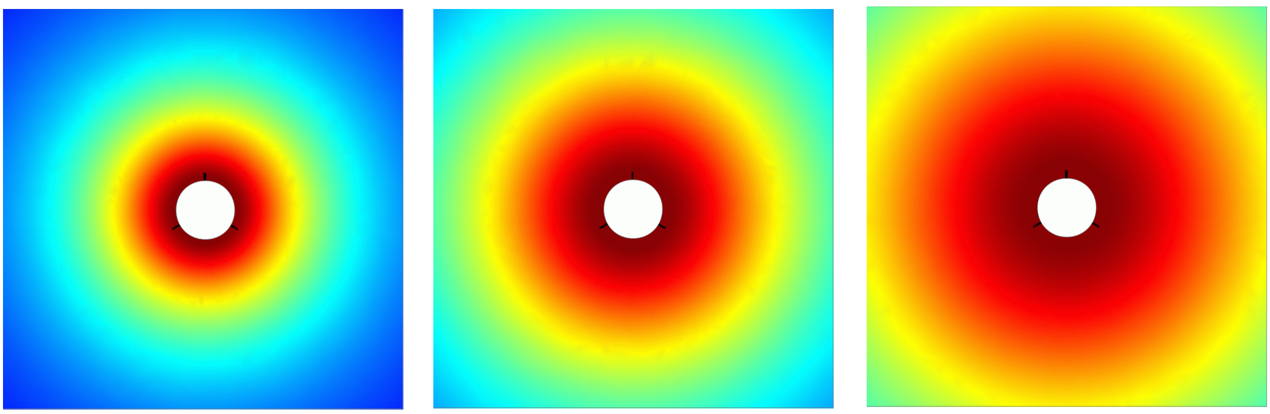

*Fig. 1: AEPI - Principle of Radial Development of Electrical Field by Increasing Distance from Current Feed (Electrodes A, B1), Three Cases for Homogeneous Ground in Analogy with Positions $CR_3$, $CR_2$, $CR_1$ (s. Fig. 3), Left: Close to A-, Right: Far from A-, Middle: Mean Distance from A-Electrode (e.g. TBM).*

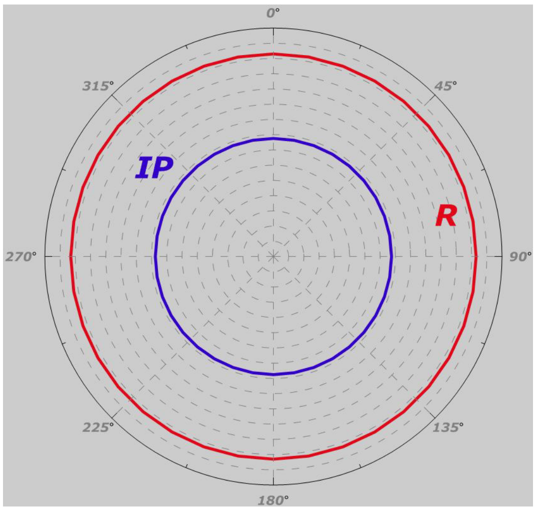


*Fig. 1a: Isotropic Azimuthal R-/IP-Distribution for a Circular Section in Homogeneous Circumjacent Underground; Data Acquisition by Multi-Electrode Array (C-Ring) for one Transmitter Configuration, i.e. one Depth (Radius) of Investigation (s. Fig. 3: A, B1 and B2).*

In case of homogeneous ground and a circular construction contour, isotropic azimuthal R-/IP-distribution is recognized by selective AEPI potential (→R/ρ) and phase shift (IP) measurements (s. Fig. 1a). Non-circular perimeter areas and heterogeneous construction features modify the R/IP parameter distribution, e.g. due to asymmetrical geometric shapes.
Moreover heterogeneous geological or anthropogenic ground settings characterized by different R and/ or IP properties cause axial and azimuthal gradients of electrical potentials and/or IP, which build up as a result of concentration or thinning of current densities and/or phase shifts (s. Fig. 2, 4).

*Principle of Azimuthal Electrical Investigations of Geological or Anthropogenic Tunnel Environments via Perimeters*

Geological and anthropogenic tunnel environments characterized by heterogeneous or anisotropic settings regarding R-/IP-properties cause deforma-tion of electrical AEPI-fields as shown in principle by example of Fig. 2, with two adjoined formations separated by a vertical Resistivity boundary. The AEPI current is hereby fed parallel to the tunnel axis of circular shape through connections into the resistive rock by electrodes denominated A and B1 (s. e.g. Fig.3).
Due to the adjacent conductive rock mass in a distance from the tunnel, a significant zonular distribution of electrical potential is induced, building up maximum gradients along perimeter slices, which are oriented transversal to the current flow (Fig. 2).

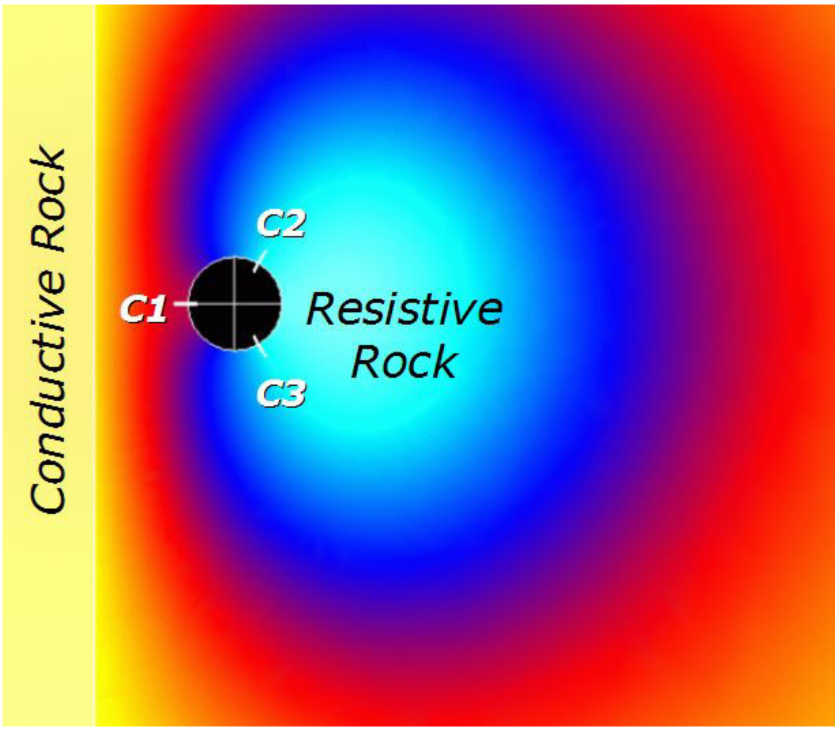


*Fig. 2: 3D-Model Slice Perpendicular to Tunnel Axis with Distribution of AEPI-Potential Due to a Vertical Conductive Boundary.*

According to the modelled geological situation in Fig.2, a small fractional array of three C-electrodes in regular spacing (C-ring/CR) can be used during induction of flow of electrical charge to image existence and direction of the rock boundary beyond the tunnel. Since the C-ring-array in example is directed towards the parallel conductive formation, the levels of potential amplitudes at e.g. C2 and C3 positions are equal but differ both from the potential at C1. Hence the vertical boundary contrasting regarding its R-property is clearly mirrored through the given polarization between left-sided minimum of zonular potential determined at C1 compared with the opposite maximal potential.

*Electrical Layouts for AEPS and AERT*

Layouts for Azimuthal Electrical Perimeter Sounding and Ambient Electrical Resistivity Tomography on site are realized by multiple transmitter-/receiver electrode-arrays, connected e.g. to rock through segment lining of the tunnel. During AEPS or AERT operation, the use of electrodes A, B1, B2 and C is varied (s. Fig.3), e.g. for the modification of the radial investigation range in regard to individual C- or CR-locations or for selective axial/azimuthal geological monitoring. The radial detection range at C- or CR-positions is hereby basically enhanced through increase of the distance between A- and/or B1-electrode. Furthermore Ambient Electrical Resistivity Tomography provides the option to deliver insight into spacious ground by 3D-synopses.

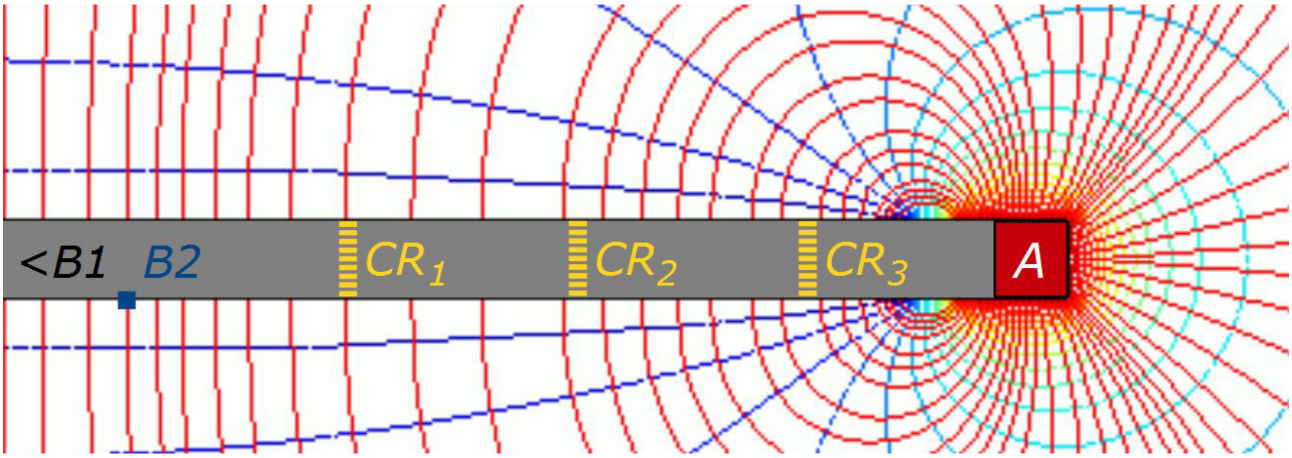


*Fig. 3: Schematic Principle of AERT with three AEPS Positions Using TBM as Electrode A; Ring-Arrays of C-Electrodes (CR) Marked by Dotted Yellow Lines, Usable for Selective Perimeter Monitoring.*

AEPS and AERT can be carried out in conjunction with BEAM4 Integral or BEAM4 Scan applications (s. Fig. 3), whereat the variation of the distance between electrodes A and B1 for current feed happens continuously during TBM advance.
Long-term monitoring of hydrogeological conditions beyond underground construction or leakage control can be carried out through permanent automated real-time measurements (s. Fig. 4).

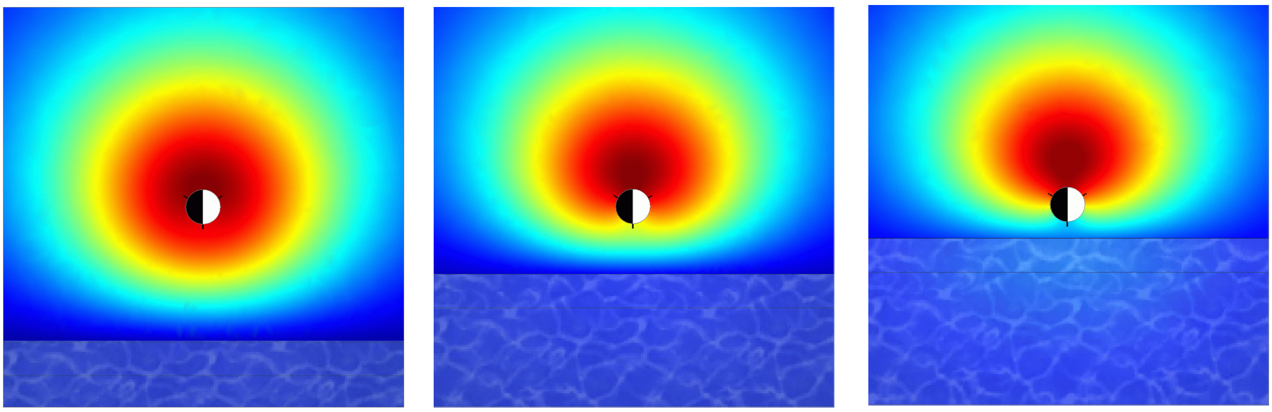

*Fig. 4: Principle of AEPI Using Static Electrode-Arrays for Monitoring of the Distance of Groundwater-Table beneath Tunnel – Rise or Decline of Groundwater Results in Increase or Decrease of Electrical Perimeter Potentials Induced by the Oriented Flow of Electrical Charge; the Vertical Symbol in the Tunnel Contour Indicates the Direction of Electrical Polarization Perpendicular to the Current Flow.*

## CONCLUSIONS

AEPI methods (pat.pend.) enable to investigate ambient geological or anthropogenic settings using electrical connections to perimeter areas of tunnels, galleries or boreholes for radially oriented Resistivity and IP surveys.

The technique of Azimuthal Electrical Perimeter Sounding AEPS is carried out to explore the periphery of underground constructions by usage of selective axial perimeter locations for reconnaissance. Ambient Electrical Resistivity Tomography AERT provides the option to deliver insight into spacious ground by 3D-synopses.

While radial width and depth resolution of AEPI methods are basically controlled by the distance between A- and B1-electrodes for current feed, the azimuthal resolution at selective axial positions is essentially scaled by the number of C-electrodes used for the recognition of AEPI potentials.

Long-term tracing of AEPI parameters by static arrays allows continuous automatic monitoring of hydrogeological conditions beyond perimeters and leakage control of sealing in the range of perimeter areas.

AEPS and AERT can be carried out during tunnelling, e.g. in conjunction with BEAM4 Integral or BEAM4 Scan applications.

Investigation targets for radially oriented AEPI surveys are circumjacent settings of underground constructions and sections in the range of perimeters, which are of contrasting R-/IP-properties compared with the geological or anthropogenic surrounding and which have significant sizes in relation to their displacement from points of potential measurements:

- Groundwater-table
- Faults or fault zones
- Karstified zones, cavities
- Layer successions
- Foundation structures, pillars
- General water- or contamination flow paths
- Leakage control
- Metal objects, UXO

## REFERENCES


Kopp, Th. (2012), "Real-Time Monitoring of Geological Conditions during Mechanized Tunnelling by Means of BEAM4 Methods.", *1st Eastern European Tunnelling Conference*, Budapest/Hungary.

Kopp, Th. (2010), "Elektrisches Verfahren zur zerstörungsfreien Erkundung und Überwachung unterirdischen Raums, Vorrichtung und Verwendung dazu.", Deutsches Patentamt, Munich/Germany.