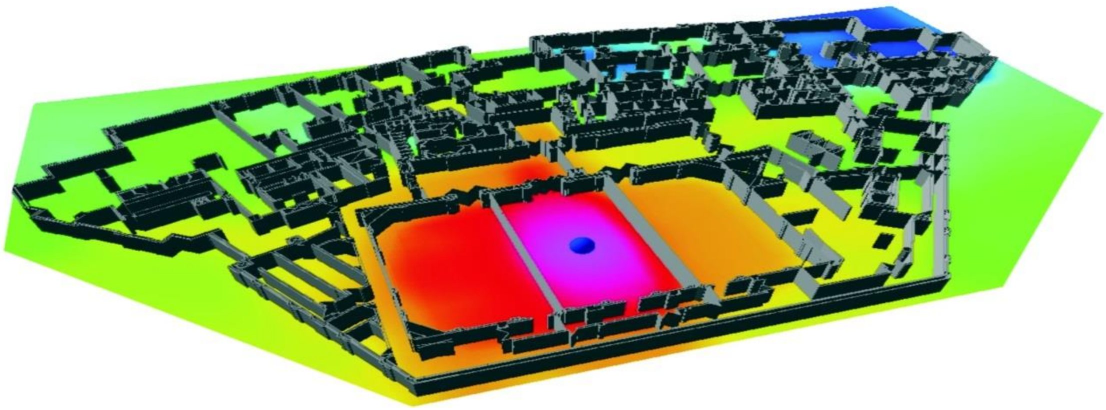
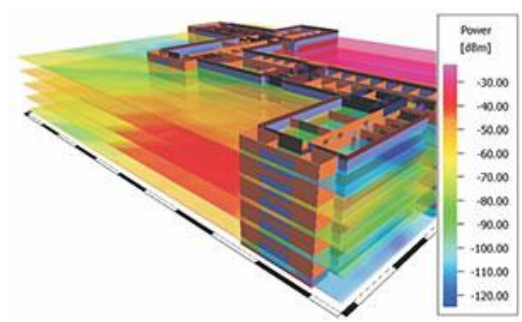
CellTrace™ powered by AWE

Indoor Prediction Tool Based on Ray Tracing



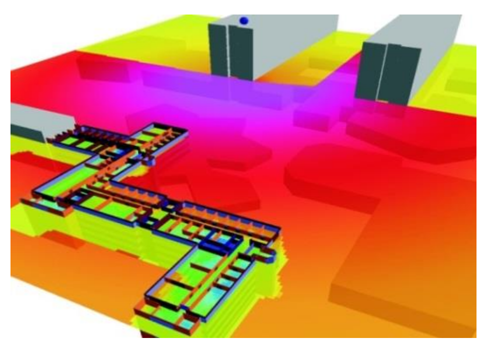
CellTrace™ is a suite of software tools that addresses Radio Frequency (RF) planning, design, modeling, analysis and optimization of wireless communication systems within buildings, tunnels, stadiums and in urban environments.



It supports a wide variety of Air Interfaces, including but not limited to LTE, WiMAX (802.16x), Wi-Fi, CDMA, UMTS, GSM, and TETRA. It also supports MIMO technology, Distributed Antenna Systems (DAS), leaky feeder cables and a number of other transmission modes.

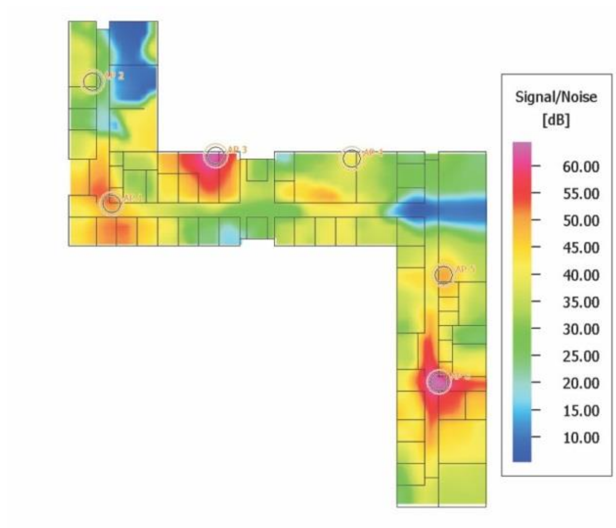
CellTrace™ uses 3D vector databases with planar objects, each with their own individual properties, combined with extremely fast & accurate propagation models to compute path loss and wide-band properties, such as delay and angular spread, LOS/NLOS, directional channel, impulse response, angular profile, and propagation paths, of radio links within buildings.

Depending on the application, **CellTrace™** offers static, Monte-Carlo, and dynamic network simulators. It also allows for the planning of coverage and capacity as well as network simulations.



With regards to coverage, different transmission modes can be defined (bandwidth, MCS, data rate, SNIR target, signal threshold, Tx power,...) and the coverage maps (cell assignment, best server, active set, channel quality, Rx power in DL & UL, SNIR,...) are computed individually for each transmission mode. Link adaptation is considered and depends on the channel quality predicted with the propagation models. Maximum received power as well as maximum achievable data rates are predicted accurately for each location in the coverage area.

CellTrace™ computes the capacity (throughput, max. data rates, packet delays, QoS, etc.) of the different radio links and cells in the network based on the coverage analysis and the traffic assumptions. Capacity limitations and overloaded cells can be detected easily and networks can be optimized to provide both high capacity and throughput.



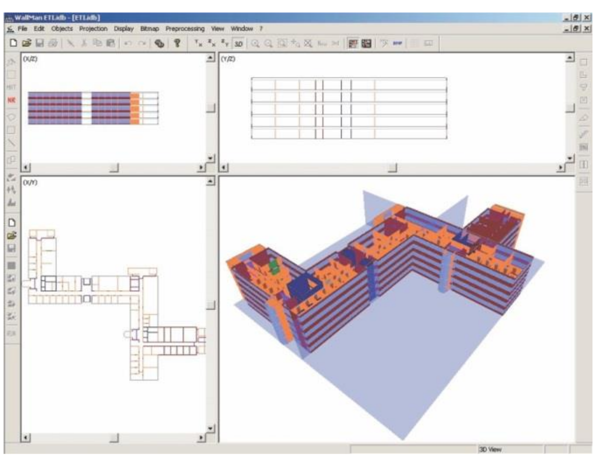
Capacity improvements due to MIMO and/or Beamforming are modeled accurately because of the sophisticated, deterministic propagation models. Arbitrary antenna configurations (linear, circular,...) are possible and their impact on the radio channel - determined during the propagation analysis - is considered in the network planning.

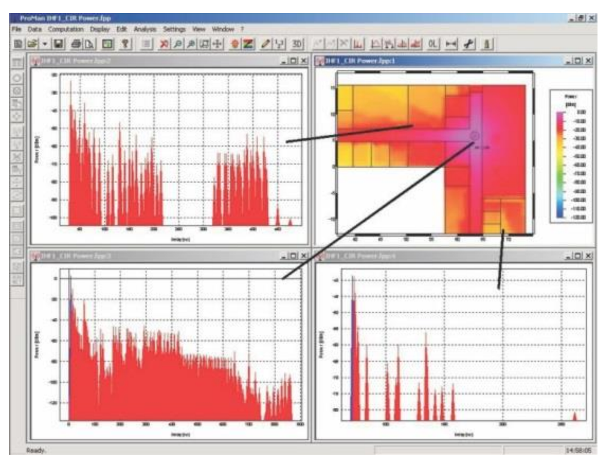
CellTrace™ comes in two versions to address the specific needs of the end-user:

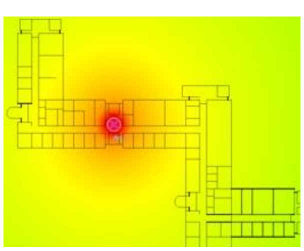
- **CellTrace™ I**: Supports the indoor deployments of all wireless technologies, including tunnel environments
- **CellTrace™ D**: Supports only Wi-Fi network planning in indoor scenarios

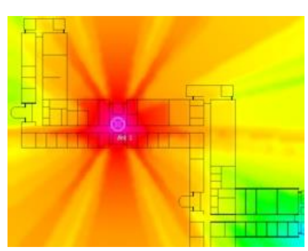
The following add-on modules are also available for **CellTrace™:**

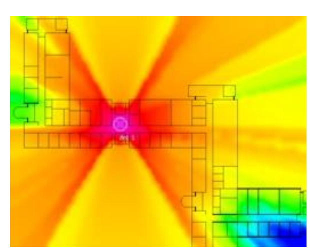
- CellComp, which includes all components for indoor network planning.
- CellAntenna, which offers a convenient facility to generate and edit antenna patterns.











CelPlan Technologies, Inc. ☎ +1 (703) 259-4020 / +1 (703) 476-8964 / sales@celplan.com / www.celplan.com

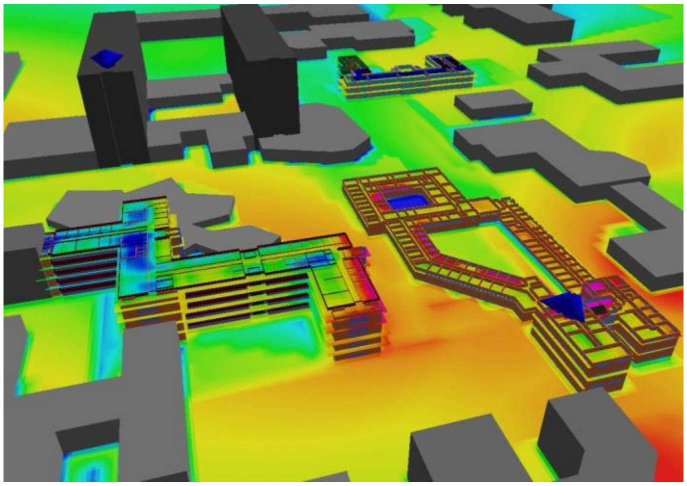
FEATURES

Product	Propagation Module		Description
	CellTrace I	CellTrace D	
Databases			
• Indoor Walls: 3D Vector data	X	X	Arbitrary shaped and oriented planar 3D objects, incl. individual material
Propagation Models			
• Empirical / One Slope Model	X	X	Prediction of signal level (path loss, power, field strength) No obstacles between Transmitter (Tx) and Receiver (Rx) considered.
• Vertical / Direct Ray • COST 231 Multi Wall & Motley-Keenan	X	X	Prediction of signal level (path loss, power, field strength) and LOS/NLOS Obstacles in vertical plane between Tx and Rx considered (attenuation due to diffractions (topography, clutter, buildings) or penetrations (indoor walls).
• 3D Single Path • 3D Dominant Path Model (DPM)	X	X	Prediction of signal level, propagation paths, and LOS/NLOS.
• 3D Multiple Paths • 3D Standard Ray Tracing (SRT) • 3D Intelligent Ray Tracing (IRT)	X	X	Prediction of signal level (path loss, power, field strength), delay and angular spread, delay and angular profile, propagation paths, and LOS/NLOS.
Transmitter Types			
• Isotropic Radiator (without antenna pattern)	X	X	
• Directional Antenna (2x2D or 3D antenna pattern)	X	X	Supported File formats for pattern: 3D CelTrace, 2x2D *.msi or ASCII
• Leaky Feeder Cable	X	X	Specification of coupling loss and attenuation of cable
• Satellite Transmitters	X	X	Either geo-stationary or moving satellites (broadcasting and navigation)
Prediction Modes			
Horizontal prediction plane(s)			
• Relative prediction height(s)	X	X	Relative to ground
• Multiple prediction heights (inside buildings)	X	X	Only in Empirical/Direct Ray/DPM/SRT mode. Not supported in IRT mode.
Arbitrary prediction			
• Arbitrary oriented prediction planes	X	X	Planes oriented arbitrarily in the scenario
• Multiple prediction points	X	X	List with multiple prediction points (individual and arbitrary heights)
Database converters			
Pixel to Vector Data Converters	X	X	Conversion of Bitmaps (*.bmp), JPEG (*.lpg), TIFF (*.tif) to vector data
Vector: Indoor Vector Objects: CAD Set	X	X	AutoCAD *.dwg, *.dxf
Export of network/transmitter data and simulation results			
• Export of transmitter data and settings	X	X	Supported file formats: ASCII Lines
• Export of simulation results	X	X	Supported file formats: ASCII Grid / DXF / Geo Bitmap (*.bmp. *.jpg, *.tiff)
Software Tools			
• CellProp: Propagation and Network Planning Tool	X	X	GUI to edit project parameters, visualize prediction results,….
• CellAntenna: Antenna Editor (without CellAntenna)	X	X	GUI to edit, convert, and visualize antenna patterns
• CellWall: 3D CAD and GIS Editor	X	X	GUI to work with 3D CAD and GIS data (Basic module)
• CellWall: 3D CAD editor for planar objects	X	X	GUI to work with 3D CAD data with planar objects
• CellTunnel: 3D CAD editor for tunnels	X	n/a	GUI to work with tunnel data (cross sections and trajectories)

Product	Network Module		Description
	CellTrace I	CellTrace D	
Air Interfaces			
• GSM / GPRS / EDGE (arbitrary TDMA air interfaces)	X		Can be adapted by the user to any other TDMA air interface
• UMTS-FDD (WCDMA) incl. HSPA	X		A dynamic system simulator is additionally available
• UMTS-TDD / TD-SCDMA	X		
• CDMA-2000 incl. EV-DO	X		
• W-LAN IEEE 802.11 a/b/g/n (WiFi)	X	X	
• WiMAX 802.16-2004 (Fixed) & 802.16e (Mobile)	X		IEEE 802.16-2004 (Fixed WiMAX) and IEEE 802.16 e (Mobile WiMAX)
• LTE	X		
• TETRA	X		
Extensions			
• MIMO Technology	X	X	
• Distributed Antenna Systems (DAS)	X	X	Multiple antennas radiating the same signal => superposition, etc.
• Leaky feeder Cables	X	X	Only if leaky feeder cables are supported in propagation scenario
• Number of transmission modes	Unlimited	Unlimited	Multiple transmission modes with individual parameters
Simulator			
• Static Network Planning	X	X	Interference due to cell load independent from traffic in cells
Consideration of Interference			
• Downlink: Cell Load (Relative Tx power)	X	X	Relative percentage of max. available power used for interference
• Uplink: Noise Rise	X	X	Can be specified for each cell individually
• Consideration of polarization for interference	X	X	Different linear polarizations of signals influence interference
• Adjacent Channel Interference	X	X	
Simulation Modes			
• Simulation of horizontal grids on multiple heights	X	X	One height (all scenarios) or multiple heights (only indoor scenarios)
• CNP simulation (outdoor & multiple indoor heights)	X	X	CNP urban/indoor simulations
• Point to Multi-Point Mode	X	X	Simulations for individual points
Predicted Results			
Cell Assignment and Consideration of downlink transmission			
• Best server / Cell layout	X	X	Results are depending on selected algorithm for cell assignment
• Neighbor cell list	X	X	Neighbor cell list (based on cell assignment)
• Max. received power	X	X	Max. received power in downlink (e.g. used for cell assignment)
• Number received carriers / sites	X	X	Number of received carriers / sites /cells in cell assignment
• Soft / Softer handover regions	X	X	Type of handover (hard, soft, softer) incl. size of active set
Downlink & Uplink trans-mission modes			
• Min. required Tx power	X	X	Min. required MS and BS Tx power required for transmission mode
• Max. received Rx power	X	X	Max. received MS and BS Rx power required for transmission mode
• SNIR (Downlink)	X	X	Max. available SNIR for transmission mode (in downlink)
• Reception probability (DL)	X	X	Percentage for coverage incl. fast fading (Rayleigh fading).
For all trans-mission modes			
• Nr. of MIMO streams (DL, UL)	X	X	Number of received MIMO streams (in MIMO networks)
• Throughput / Bit Rates (DL,UL)	X	X	Highest achievable bit rates available for pixel (downlink, uplink)
Definition of Mobile Stations (MS) / User Equipment (UE) / Subscriber Stations			
• MS properties for each transmission mode	Individual	Individual	
Definition of Base Stations (BS) / Access Points / Satellites / Cells			
• Tx power, antenna pattern, carrier, frequency cell load	1	Unlimited	Nr of carriers influences nr of radio links. No carrier assignment.
• Noise figure / Cable losses / etc.	X	X	Default for all BS in network or individual for each BS

CellProp™ powered by AWE

Prediction of Wave Propagation



Wave propagation models are necessary to determine the propagation characteristics for the installation of mobile radio systems.

Path loss predictions are required for the coverage planning, the determination of multipath effects as well as for interference and cell calculations, which are the basis for the high-level network planning process.

Generally this planning process includes the prediction of the received power in order to determine the parameter sets of the base transceiver stations (or access points). With the introduction of MIMO and wireless broadband services, the wideband properties (e.g. delay spread, angular spread and impulse response) of the mobile radio channel become more and more important for the network planning.

The environments where these systems are intended to be installed are ranging from large rural areas (macrocells) down to indoor environments (femtocells). Hence, wave propagation prediction methods are required covering the whole range of macro-, micro- and femtocells including in-building scenarios and situations in special environments like tunnels or along highways.

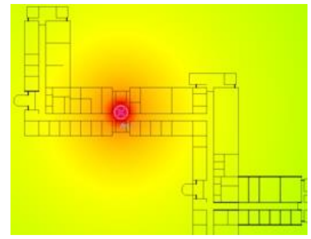
Propagation of electromagnetic waves inside buildings in the frequency range above 600 MHz is influenced mainly by walls and large furniture elements. Diffractions around corners as well as waveguiding in corridors, due to multiple reflections, often dominate the propagation inside buildings.

For frequencies below 600 MHz, simple empirical propagation models can be used. But for higher frequencies deterministic approaches are mandatory, because the multipath propagation is very important and empirical propagation models are therefore not sufficient. The scenario in and around the building must be described either with 3D vector databases or with pixel databases. The materials of the objects should be defined as well to obtain accurate results.

In CelTrace "indoor propagation" is not restricted solely to the interior of buildings. Indoor propagation also includes campus scenarios, tunnels, vehicles or any scenario which can be described with a 3D vector or pixel database.

CelTrace includes all software modules for propagation analysis (including various propagation models, database editors, etc.). All propagation models included in CelTrace can be used for:

- Cellular network planning (e.g. picocells/femtocells) inside buildings (including penetration of cellular networks into buildings)
- Broadcasting (e.g. indoor coverage of terrestrial transmitters or satellites)
- Coverage analysis and network planning inside tunnels or underground stations
- Short range radio link analysis
- LOS analysis



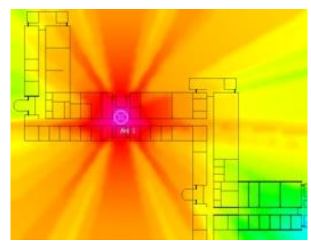
Propagation Models

Phenomena like multi-path propagation, reflection (wave-guiding), diffraction and shadowing have a significant influence on the received power inside buildings. So the corresponding propagation models should consider all these phenomena to obtain accurate results.

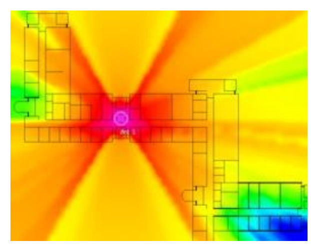
Additionally, the analysis should not be restricted to single floors. Rigorous 3D modeling offers the possibility to predict the radio signals on multiple planes (multi-floor), with each resulting plane having an arbitrary orientation (not limited to horizontal planes).

CelTrace also supports leaky feeder cables and distributed antenna systems (DAS).

CelTrace offers a wide variety of propagation models for indoor scenarios.



- Empirical Models:
  - One Slope Model
  - Motley Keenan Model
  - COST 231 Multi Wall Model
- Dominant Path Prediction Models:
  - Indoor Dominant Path Prediction Model (IDP, 2D and 3D)
- Ray Optical Propagation Models:
  - 3D Standard Ray Tracing (SRT)
  - 3D Intelligent Ray Tracing (IRT)



Features

- Accurate empirical and deterministic propagation models
- Dominant Path Model (either 2D or 3D)
- Rigorous and fast 3D Ray Tracing
- Prediction of path loss and delay spread
- Prediction of channel impulse responses
- Display of propagation paths
- Prediction of all results on multiple polygonal planes - each plane with arbitrary orientation
- Individual material properties of objects possible
- Definition of subdivisions (windows, doors) possible
- Easy handling of the vector building data (support of multi-floor buildings)
- Support of scanned drawings (pixel building data) without conversion to vector data
- Consideration of leaky feeder cables
- Support of distributed antenna systems (DAS)

CellWall™ powered by AWE

Software for the generation and modification of building databases

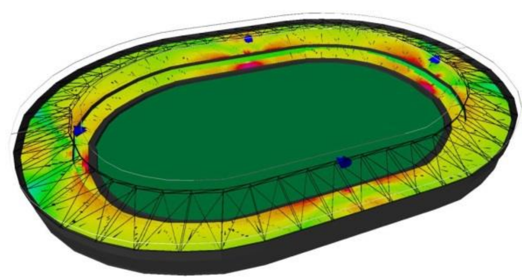
The CellWall software offers a convenient facility to generate and edit urban and indoor building databases. 3D views of building data helps to detect errors in the building database. Several import filters for standard GIS, CAD and pixel formats are available.

Indoor Databases

In indoor scenarios, an accurate description of the walls and objects inside the buildings is very important. CelTrace supports different types of 2D or 3D indoor databases:

- Vector databases
- Pixel databases
- Combined pixel/vector databases

Vector databases lead obviously to more accurate prediction results, but due to the amount of data, they might require a longer time to process and verify the accuracy of the data.

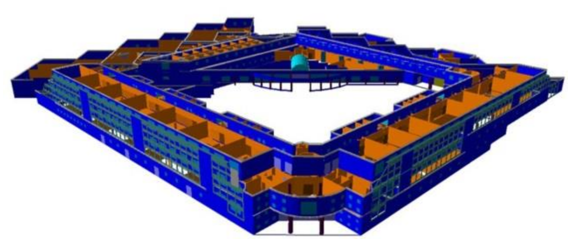


Pixel databases can be used to define a scenario within a shorter time frame. Drawings of the building floors can be scanned and imported within a few minutes leading to a very efficient propagation analysis.

CelTrace also allows usage of a combination of pixel and vector data to provide the most flexible interface to the user. In the combined databases, 3D vector objects can be inserted in pixel databases to model the scenario accurately.

The pixel databases are generated with individual, scanned bitmaps of the drawings of each floor. Different material properties and heights of the objects can be assigned to the various colors in the bitmaps.

CelTrace's indoor vector databases are based on:

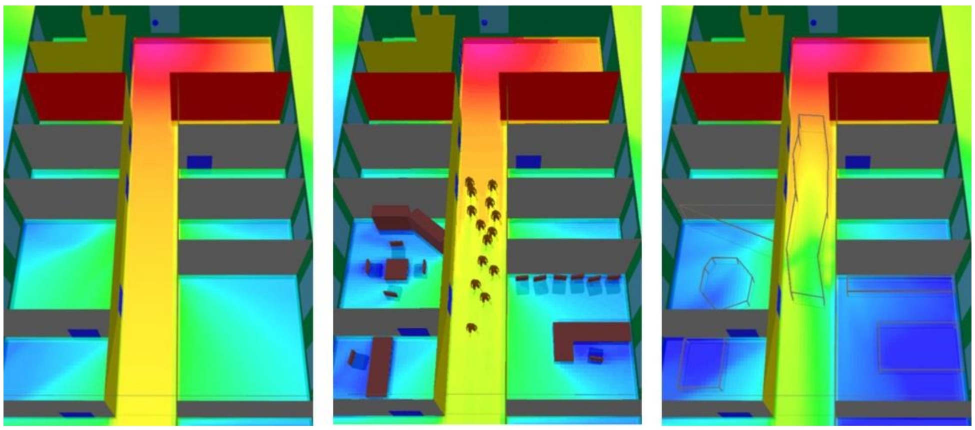


- Planar objects with polygonal shape
- Arbitrary number of corners in polygons
- Individual characterization of material properties for each object
- Multiple subdivisions (e.g. doors, windows, etc.) in objects possible
- Each subdivision with individual material properties

Non-Deterministic Objects

Furniture and persons inside buildings have a significant impact on wave propagation and should therefore be considered in the propagation analysis. However, the locations of these objects are non-deterministic in nature in that the user does not know where exactly they are located (furniture) and/or if they are even non-stationary (persons).

Therefore the effects of furniture, persons, etc. in indoor databases cannot be described with deterministic 3D objects (polygons) in vector and pixel databases.



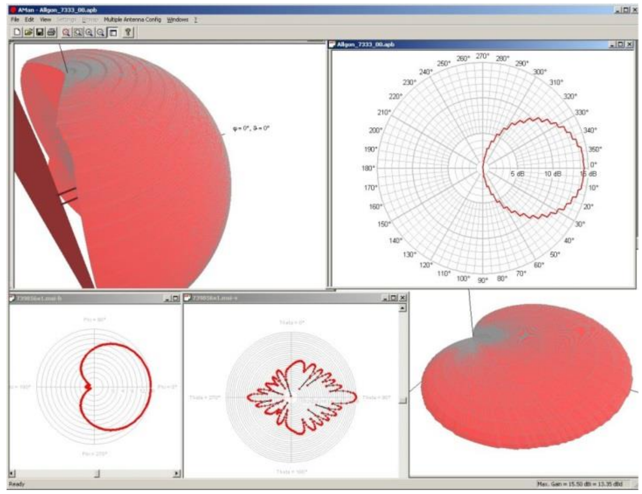
CellWall offers the possibility to define areas with non-deterministic objects in the database. These areas can be defined to describe the shadowing in a statistical sense. The propagation paths inside these areas (polygonal cylinders) get a higher attenuation depending on the length of the path inside the object and the type of object. Depending on the type of object, mobile stations located inside these objects will also get a higher path loss assigned. Accordingly the above mentioned, non-deterministic objects in indoor environments can now be considered in the propagation analysis, thereby leading to a higher level of accuracy.

CellWall offers many features to convert, create and edit databases:

- Vector oriented CAD-tools (move, delete, edit, etc.)
- Dialogs for the settings of the material properties (individual or default values)
- Zoom features for the display
- Converters for a variety of GIS, CAD and pixel data formats:
- MapInfo
- ArcView (Shapefile)
- Data Exchange Format DXF (2D, 3D)
- AutoCAD Format (DWG)
- Stereolithography Format (STL)
- Geb (Pegasos, etc.) and Gen format
- Aircom ASSET/ ENTERPRISE (NSN NetAct)
- Agilent Wizard
- MSI Planet (Siemens Tornado)
- and many more..
- Filters for export of databases in open ASCII file format
- 3D view (with rotation, zoom, etc.)
- Marking and finding of objects
- Detection of errors in the databases
- Dialogs for the settings concerning the preprocessing of databases
- Bitmap image (e.g. scanned map of the city or map of the building) can be put in the background and the vector-defined buildings/walls can be drawn over the bitmap.

CellAntenna™ powered by AWE

Tool for generation and modification of antenna patterns



The CellAntenna software offers a convenient facility to generate and edit antenna patterns. It is relevant for the interaction with other CelTrace software tools, because the antenna patterns can also be stored in *.xml, *.msi or further file formats, which enables usage with other radio network planning tools. Additionally antenna designers can use the software as a tool for the verification of their antenna patterns.

Besides the analysis and modification of single antennas, CellAntenna also includes a Multiple Antenna Scenario Configurator (MASC). This feature takes into account the superposition of multiple antennas radiating the same signal (including phase shifters and power splitters) as well as the consideration of the local environment (masts, arms, walls, sub-arms, etc.) to determine the actual antenna pattern.

Antenna Patterns:

Antenna patterns are very important for accurate propagation modeling. CelTrace is very flexible and supports an open ASCII formats for antenna patterns.

- Description of the far-field of the radiation of the antenna(s)
- At least (measured or computed) vertical and horizontal patterns are available from antenna manufacturers (in most cases also 3D pattern) describing the radiation of the antenna in ideal environments. These patterns are used as input of MASC.
- CellProp can use 2x2D patterns (horizontal and vertical plane) or full 3D patterns for computation of antenna patterns.

Import of Data

CellAntenna offers several import filters to enable conversion of the most popular antenna file formats:

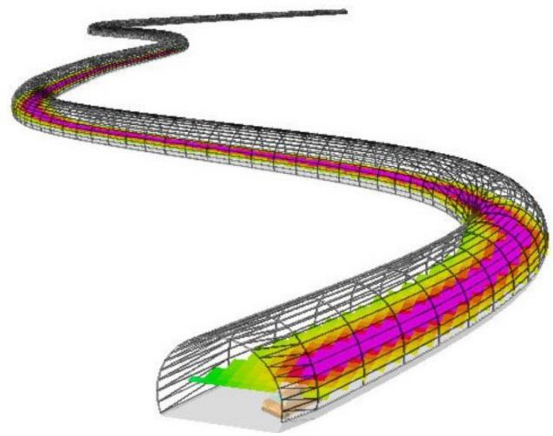
- Antenna Patterns in *.msi or *.pln format - Many antenna manufacturers offer digital patterns of their antennas in the *.msi and/or *.pln data format. These patterns can directly be used with all CelTrace modules.
- Open ASCII pattern format - CelTrace also uses an open ASCII data format for antenna patterns.

Features

- 2D display of vertical and horizontal antenna patterns (with rotation, zoom, etc.)
- 3D display of antenna patterns (with rotation, zoom, etc.)
- Linear interpolation of antenna pattern
- Generation of 2D vertical and horizontal antenna patterns
- Graphical editor for 2D vertical and horizontal antenna patterns (insert, delete, modify individual points (angle and gain))
- Display for 2D and 3D antenna pattern either with linear or with logarithmic scale
- 2D display with scale circles (dB or linear)
- Bitmap (with zoom) of scanned antenna pattern as background in 2D display possible (important if generation of patterns is done manually and only plots of the antenna pattern are available)
- Exact definition of points in antenna pattern (either by mouse clicking or by dialogs)
- Conversion of a horizontal and a vertical antenna pattern to a full 3D antenna pattern (with 4 different conversion algorithms, published in literature)
- Print 2D or 3D antenna pattern
- Converter for simple ASCII file formats of antenna patterns (2D and 3D patterns)
- Converter for *.msi and *.pln antenna files (including interpolation from 2D to 3D)

CellTunnel™ powered by AWE

Editor for Tunnel Scenarios

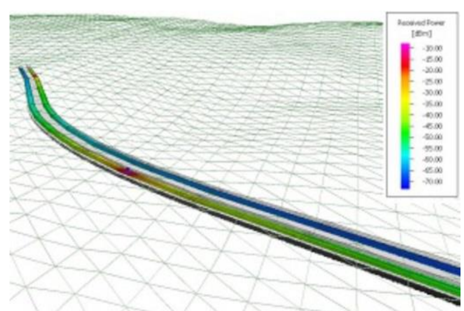


Tunnels have a complex geometrical structure. The cross section of a tunnel can vary along the curved profile and the ground of the tunnel is not always generally flat (i.e. the tunnel has a "terrain profile").

Additionally, a single tunnel can be split into multiple branches or some branches can be merged to a single cross section.

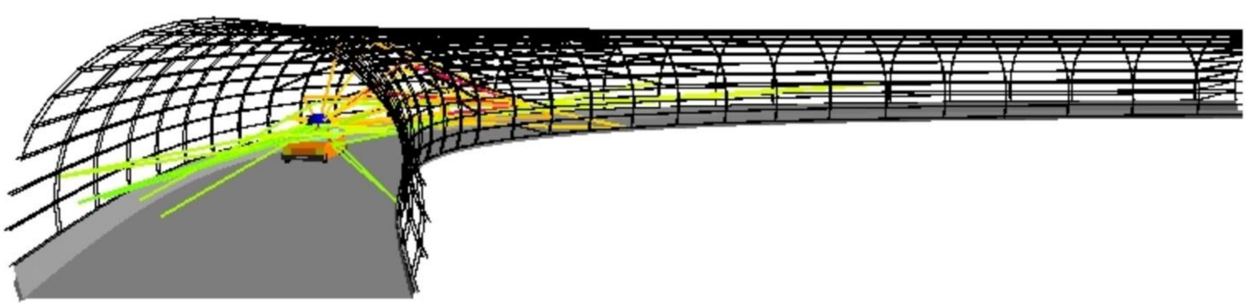
The generation of databases to accurately describe tunnel scenarios is therefore very complicated. To simplify this task, the CelTrace software suite offers the graphical editor, CellTunnel, to generate and modify tunnel scenarios.

CellTunnel allows the definition of different cross sections within one tunnel. Additionally multiple curves with different radii can be defined to model the tunnel and its curved profile accurately. Additionally, the terrain profile inside the tunnel can also be defined in CellTunnel.



The tunnels generated with CellTunnel can be exported into CelTrace's 3D vector data format for further processing with CellWall. The CAD tools of CellWall can be used to insert further objects into the tunnel databases (e.g. cars, trains, signs, etc.) and they can be used to define the time-variant behavior of the objects.

Inside tunnels the time-variant objects (e.g. cars, trucks, trains, etc.) have a significant effect on the wave propagation. Shielding and waveguiding are depending on the obstacles inside the tunnels. If the obstacles are moving, the propagation environment changes significantly.



CelPlan Technologies, Inc. ☎ +1 (703) 259-4020 / +1 (703) 476-8964 / sales@celplan.com / www.celplan.com