TECHNICAL DOCUMENT

RADAR AND RADIO SYSTEMS COVERAGE AND PLANNING

For radar and radio systems coverage analysis and planning, Altair offers Altair® WRAP™ and Altair® WinProp™, two components of Altair® Feko®. WRAP simplifies the technical and administrative tasks required for radio and radar coverage planning over large regions, including spectrum management, interference analysis, frequency administration, and network monitoring. WRAP's optimization tools help users achieve network performance goals without the hassle and cost of large planning teams.

When it comes to planning radar and radio systems, the possible scenarios for coverage analysis and optimization are practically endless.

For **radio** applications, these scenarios range in scale from building interiors—as in the case of wireless coverage within an office—to local urban and rural environments, to nationwide, and even into space. Some examples include ground-to-ground coverage of combat net radios, ground control station coverage to aircraft, and coastal station ground wave coverage.

Common radio coverage and planning applications in the aerospace and defense sector include:

- Spectrum management and automation to minimize interference among stations
- Radio and radar planning for military operations
- Radio planning in airports, ships, and large passenger aircraft
- Analysis of satellite coverage
- Jamming of cellular and satellite signals
- Analysis of communication with ground vehicles (virtual test drives)
- Analysis of communication with aircraft in flight (virtual flight tests)
- Cost and coverage optimization to achieve optimum coverage within a given budget

Radar scenarios vary as well. These can be parsed according to target altitude, the target's radar cross section (RCS), and the presence of jammers or other sources of interference.

Common radar coverage and planning applications in the aerospace and defense sector include:

- Target visibility at a given altitude regardless of RCS
- Target detection depending on RCS at a given altitude
- Target detection depending on altitude for a given RCS
- Impact of jammers on visibility and detection
- Effect of windmills or similar sources of passive radar interference
- Cost and coverage optimization to achieve optimum coverage within a given budget

ALTAIR'S RADIO AND RADAR COVERAGE ANALYSIS SOLUTION

For radio coverage applications, Altair's solution for radar and radio systems coverage analysis and planning simplifies the technical and administrative tasks required for this type of planning, allowing users to optimize network performance with minimized inputs and costs.

Additionally, the solution offers a comprehensive set of propagation models for nationwide, rural, urban, and indoor scenarios, ranging from empirical to semi-empirical to deterministic. These include a broad collection of International Telecommunications Union (ITU) models as well.

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WRAP also provides air interfaces for all major military and civilian radio systems, including interfaces for HF, 5G, radar, and microwave links. Air interface files provide the necessary parameters to calculate data rates and throughput.

SPECTRUM MANAGEMENT

WRAP streamlines the complex task of allocating frequencies among stations to avoid interference. Key spectrum management applications of WRAP include:

- Coordination of frequency utilization by civilian and military entities at both the national and international level
- Central management and coordinated distribution of frequency allocations, allotments and assignments for national defense forces
- Long-term planning of frequency utilization within geographical regions or service branches
- Short-term planning of frequency utilization for missions, maneuvers, and large exercises

WRAP supports any level of implementation, from single-user and client-server configurations (with a capacity to handle several station databases), through local and regional (military unit and service-wide) levels, all the way up to national and international (defense department/coalition) levels.

The tool allows users to design communication, electronic warfare, and radar networks. It facilitates the achievement of coverage, performance, and electromagnetic protection requirements.

PREDICTING RADIO FREQUENCY INTERFERENCE

The ability to calculate radio coverage forms the basis for predicting radio frequency interference. Interference between different systems—between Wi-Fi and cellular networks, for example—can be difficult to resolve. Figure 1 shows an example of a resulting signal-to-noise-and-interference ratio when both Wi-Fi and LTE networks are present simulated with WinProp.

Another example of interference between systems is when FM radio broadcast stations, which tend to be powerful, are present in an area where aeronautical communications are essential. Figure 2 maps predicted interference between local FM broadcasting stations (87 – 108 MHz) and the ILS localizer, VOR and VHF communications equipment (in the 108 – 137 MHz frequency band) of a local airport.

Finally, a site with multiple transmitters and receivers may have collocation interference problems. WRAP provides a tool for the analysis and mitigation of the levels of collocation interference among systems (Figure 3).

With WRAP's extensive spectrum regulation toolkit, users can efficiently perform technical coverage administration, interference management, and spectrum optimization with a flexible, robust solution. WRAP ensures compatibility with spectrum regulations while quickly identifying and resolving interference issues in remote and densely collocated scenarios.

RADAR COVERAGE ANALYSIS

As mentioned previously, the ability to simulate electromagnetic propagation forms the basis for many applications. Radio coverage analysis calculates the received signal, among other parameters. That is, the result of a propagation simulation is the field strength of the received signal in a large area around the transmitter.

Radar analysis, however, seeks a different result. Radar coverage calculations determine if a target can be detected.

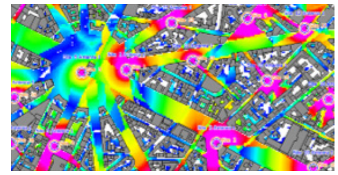

Figure 1: An analysis of interference between Wi-Fi and LTE technologies in an urban environment

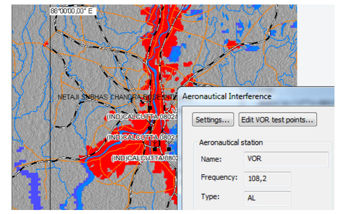

Figure 2: Mapping of local FM interference with airport navigation and communication equipment

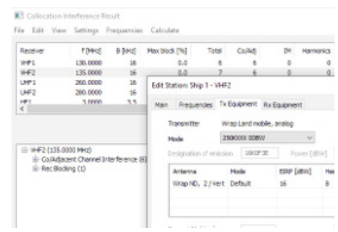

Figure 3: Collocation interference calculation in Altair WRAP

In radar coverage calculations, the important parameters are radar cross section (RCS), range, and target altitude. In general, one of the two is held constant and coverage is calculated as a function of the other.

For example, for a radar station located within a hilly landscape, three types of calculations are possible:

- Target visibility at a given altitude
- Detection of targets at a given altitude
- Detection of targets of a given RCS

In addition, the effects of jammers and sources of passive interference, like wind farms, can also be examined.

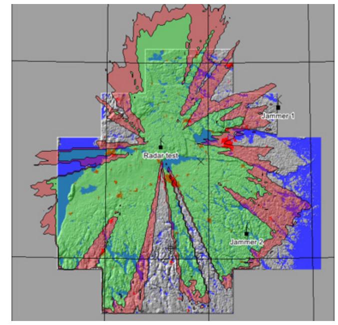

Figure 4: Target visibility at a given altitude

Target Visibility at a Given Altitude

This first type of calculation determines where the radar station has a clear line of sight to a target at a given altitude. RCS does not factor into this calculation, because we are determining visibility, not target detection.

In the example in Figure 4, a target altitude of 300 meters above ground level (AGL) has been selected. For every location, the plot reveals whether the visibility to the target is unobstructed, partially obstructed, or fully obstructed.

The green areas indicate regions where the first Fresnel zone is unobstructed (visibility is good) for targets at 300 meters AGL. Those colored in red indicate regions where the bottom half of the first Fresnel zone is obstructed (target visibility is mediocre).

Simulations like these, performed before taking RCS into account, are instrumental in choosing good locations for radar stations.

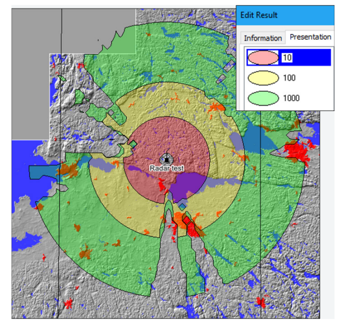

Figure 5: Radar target detection as a function of RCS at a fixed altitude

Target Detection at a Given Altitude

Once we've located a good position for our radar station, we can then calculate what targets that station can detect. One way to do that is to hold the target altitude fixed and calculate target detection capability as a function of RCS.

Figure 5 shows the minimum RCS that can be detected at a given target flight altitude (300 meters AGL in this case) for every position relative to the radar antenna.

Within the red area, the radar can detect targets with an RCS of 10 square meters (m2) or more. In the yellow areas, targets with an RCS of 100 m2 or greater will be detected, but smaller targets may be missed depending on the distance to the target. Within the green regions, the radar will detect very large targets of RCS > 1000 m2, but may miss smaller targets.

As in the simulation for visibility (Fig. 4), this plot also shows that in some directions, hills or other obstacles prevent the detection of objects flying at 300 meters AGL.

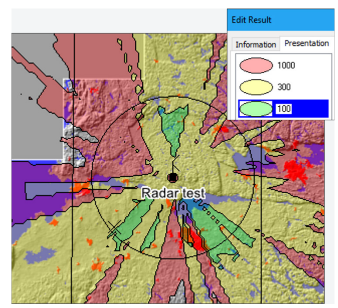

Figure 6: Radar target detection as a function of altitude for a given RCS

Detection of Targets of a Given RCS

Another way to calculate target detection is as a function of altitude for targets of a given RCS.

In Figure 6, we have an example of this type of calculation for a target with an RCS of 100 m2.

The plot shows for every location the minimum altitude at which a target with an RCS of 100 m2 can be detected. In the green areas, a low-flying target can be detected down to 100 meters AGL (or MSL, as selected). In the yellow areas, the target can be detected down to 300 meters. And in the red areas, the radar can detect the target if it is flying at 1,000 meters AGL or higher.

Jammer Effects

The effect of jammers can be included in the calculations. Since radar detection depends on a two-way path (radar detection ~ 1/R4), while jammer interference depends on a one-way path (jammer power ~ 1/R2), a jammer has a disproportionate impact on radar detection. This impact is shown in Figure 7, where we can see how coverage is nulled in the direction of each jammer. WRAP can also display these results as a three-dimensional plot (Figure 8).

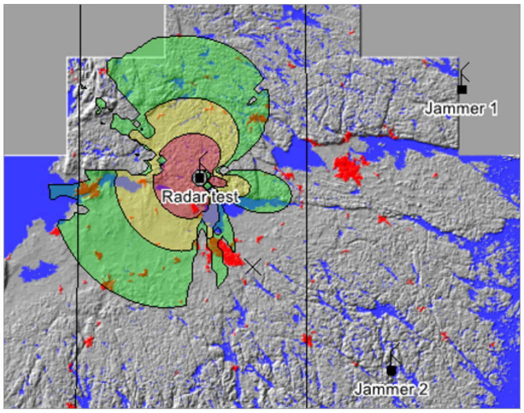

Figure 7: Jammer impact on radar detection (2D)

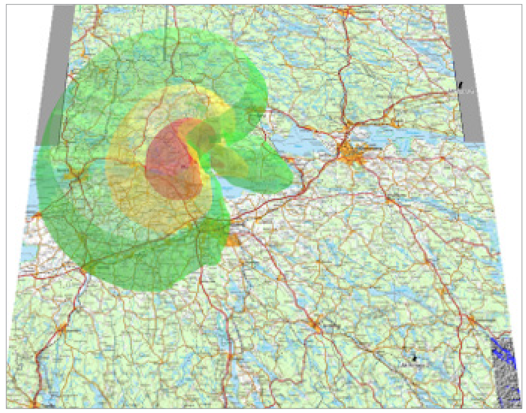

Figure 8: Jammer impact on radar detection (3D)

Effects of Windmills

A wind farm in the vicinity of a radar antenna will have a visible impact on target detection by causing ghost targets as well as multi-path null bands where targets cannot be detected. WRAP can account for these effects by specifying a handful of parameters to describe the wind farm, such as mast diameter, mast height, mast separation, blade size, and the farm's location.

In the example illustrated by Figures 9 and 10, the target RCS (3 m2) and the target altitude (100 meters AGL) have been specified. The windmills shown were generated automatically based on the user's specifications. Their masts are spaced 500 meters apart. In the 3D images, their size has been exaggerated; the wind farm appears far more crowded than it really is.

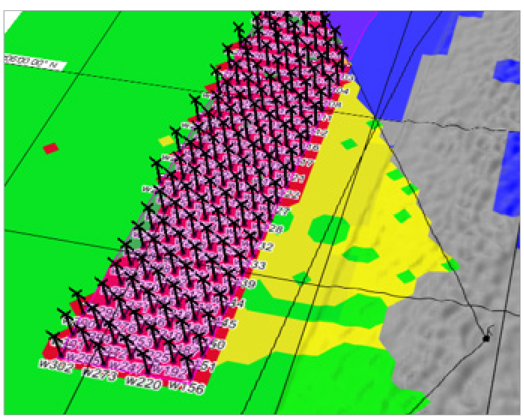

Figure 9: Simulated windmills in a wind farm

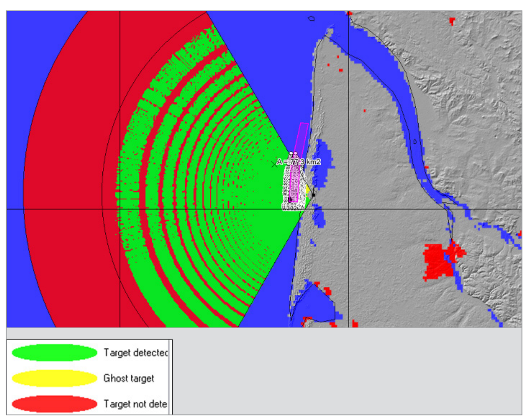

Figure 10: Impact of a wind farm on radar target detection

For all locations within the radar's range, WRAP determines whether a target will be detected or go undetected, or if a ghost image will appear due to the wind farm. In the close-up shot of the windmills in Figure 9, we see that the radar will not detect any targets flying over the wind farm (the area in red) at 100 meters AGL, while ghost images will appear in much of the region (in yellow) between the radar and the wind farm

Meanwhile, the high-altitude view of Figure 10 shows that beyond the windmills the radar will be able to detect targets flying at 100 meters of altitude up to a certain range, but there will also be null bands where it cannot detect targets due to multi-path interference caused by the windmills.

COST AND COVERAGE OPTIMIZER

The examples shown make it clear that multiple radar stations will often be needed to achieve good coverage. This begs the question, "Where should those stations be placed to optimize coverage?"

Answering that question becomes much more complicated when your budget for procurement and maintenance is limited.

Fortunately, WRAP's Cost and Coverage Analyzer does the work for you. It helps you achieve optimum coverage with a given budget.

In the Cost and Coverage optimizer (Figure 11), you simply specify values for several parameters, including:

- Area of interest
- Coverage goale
- Types of stations
- Antenna heights available
- Various budget factors

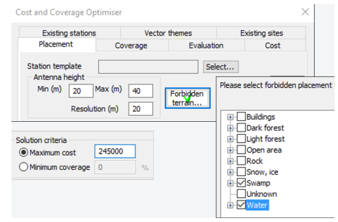

Figure 11: Altair WRAP's Cost and Coverage Optimizer

You can then specify how costs depend on various factors, like tower height, distance to power, and distance to roads. In addition, you can forbid the placement of stations on terrain where they're likely to prove too problematic and costly, such as swamps, bodies of water, forests, or steep slopes.

In the example in Figure 12, the area to be covered was the polygon colored in green, yellow and red. Those colors indicate the minimum target detection altitudes at areas within the coverage region.

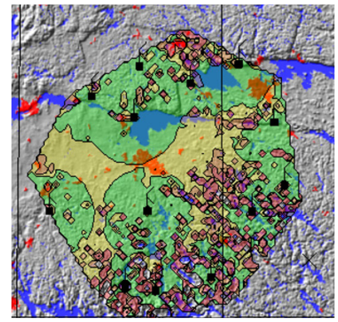

Figure 12: Results of a Cost and Coverage Optimizer analysis

The budget for this installation was limited, limiting the number of stations that could be built. The southern area is hilly, so achieving reasonable coverage there within the budget is a challenge. In the flatter areas to the northwest, achieving good coverage is much easier. The station placements shown constitute the best solution that can be obtained for the available budget.

WINPROP SOLUTION

While WRAP offers a complete solution for radio and radar coverage over large areas, some scenarios, like indoor and urban environments, present additional challenges. For those applications, Altair offers WinProp. Like WRAP, WinProp resides within Feko.

WinProp's advanced communication capabilities facilitate propagation analysis and visualization, air interface simulation, and network planning for any wireless technology standard in any local environment, be it indoor, urban, or rural. In addition, WinProp can provide virtual test drive and virtual flight test simulations for analysis of communication with ground vehicles or aircraft within specified environments.

If you'd like to see a demonstration of WinProp's virtual flight test capability, be sure to view our webinar on radar and radio systems coverage analysis.

CONCLUSIONS

Radar and radio coverage and planning comprise an important and growing list of applications in defense, aerospace, and wireless communications that includes:

- Spectrum management
- Radio planning in airports and ships
- Military radio planning
- Jamming analysis of cellular and satellite signals
- In-vehicle radio coverage
- Satellite radio coverage
- Virtual test drives and flight tests for communication analysis
- Radar coverage and detection capabilities
- Radar jamming analysis

Altair provides a complete and customizable solution for accurate radar and radio coverage analysis and planning used across several industries. Altair tools put a wide assortment of computational methods at your disposal, from empirical to accurate ray tracing, and they can handle any type of radar and radio coverage scenario, be it indoor, urban, rural, or in space.

What's more, built-in optimizers enable highly automated analysis and innovation. Along with the Cost and Coverage Optimizer, there's also Spectrum Management Optimizer. Given a large number of stations and a set of allowed frequencies, the Spectrum Management Optimizer will assign frequencies for you such that interference is minimized or avoided. This automation saves users time and makes their jobs much easier.

For a demonstration of how easy it is to set up and run calculations and simulations in WRAP and WinProp, please be sure to view our on-demand webinar, "Radar and Radio Systems Coverage Analysis" at altair.com/resource/radar-and-radio-systems-coverage-optimization.

For access to our full webinar series on electronic system design for aerospace and defense, please visit altair.com/esd-webinar-series-aerodefense.