INSTALLED PERFORMANCE OF COMMUNICATION ANTENNA ARRAYS
WHITEPAPER

The presence of multiple communication antennas on a tower means that antennas may have to be installed in sub-optimal positions. Electromagnetic simulation can be used to design the antennas themselves, and also to optimize the positioning of the antennas on the tower. This article will describe how multiple solvers in CST Studio Suite®[1] can be combined to predict where to install an omnidirectional stacked bicone antenna array in order to minimize loss of omnidirectionality.

The favoured location for any omnidirectional antenna when installed on a tower is at the very top of the structure. In that way, the omnidirectional performance of the antenna can be realized when it is deployed. Unfortunately, it is often not practically possible to mount the antenna in this location. Generally a mast will have multiple antennas located on the same structure, and several of these antennas will be omnidirectional in characteristic. Consequently, a compromise must often be reached where an omnidirectional antenna is mounted on a boom. The boom is intended to be long enough to prevent the neighboring tower structure from disrupting the natural antenna omnidirectional pattern. Many systems utilize multiple antenna techniques, to enhance the robustness of the system. Such systems will inevitably lead to the requirement to install omnidirectional antennas in a position on a tower where interaction between the tower structure and the antenna is inevitable.

Within such an overall deployment scheme, it is possible for the individual antennas to have a variety of beam shapes. Often a small degree of electrical downtilt will be provided in the antenna structure, such that the majority of the radiation occurs below the horizon. In this manner, the majority of the radiated signal will be in the region where the subscribers to the system are located. The gain profi le of the antenna will also be tailored such that the maximum gain occurs in the region where the maximum range is required. This will be on, or very close to, the horizon. The elevation pattern is also often profiled such that the natural nulls that occur in the radiation pattern are filled in to prevent dropouts in signal at certain elevation angles. These parameters will all need to be taken into account in addition to the disruption to the radiation pattern caused by the presence of the tower. The simulation will be optimized for these requirements before the performance of the combination of antenna and tower can be considered.

It is difficult to use conventional methods to test or simulate such an antenna configuration in order to determine its effective radiation pattern. Testing the assembly of antenna and tower is often not practical in any one of the standard antenna test ranges, as the total structure formed by the combination of antenna and tower is often too large and cumbersome to fit into any one of these ranges. Simulation of the entire structure by volumetric discretization of the model is also difficult, as the fine detail of the antenna structure leads to a meshing of the entire structure that results in huge numbers of cells. This in turn then means that simulation times are prohibitively long, if the problem can be run at all.

The CST Studio Suite integral equation solver is ideal for analyzing the performance of a relatively small and fine-detailed structure (the antenna) alongside a much larger structure (the tower). The surface meshing characteristics of this solver keep the computation time manageable, whilst achieving the required accuracy. The example given here enables decisions to be made on how to deploy an omnidirectional antenna in the proximity of an additional tower structure. Figure 1 shows the arrangement of antenna and tower which has been considered in this analysis.

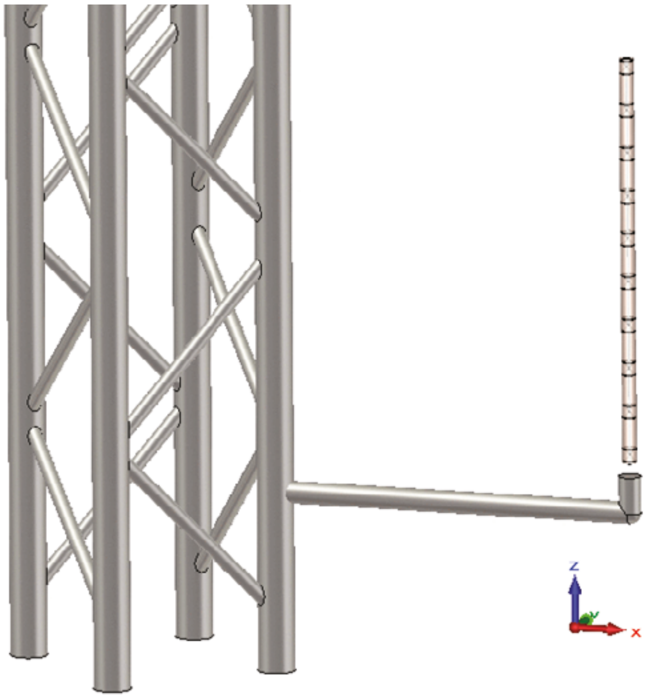

Figure 1: Antenna on tower.

ANTENNA PERFORMANCE

The type of antenna selected for this analysis is a high gain stacked bicone omnidirectional antenna, operating at 3.5 GHz. Such an antenna will produce a very even radiation pattern around the horizon when mounted well away from other structures. The particular design used here has a nominal gain of 10 dBi on the horizon. Figure 2 shows the antenna structure on its own.

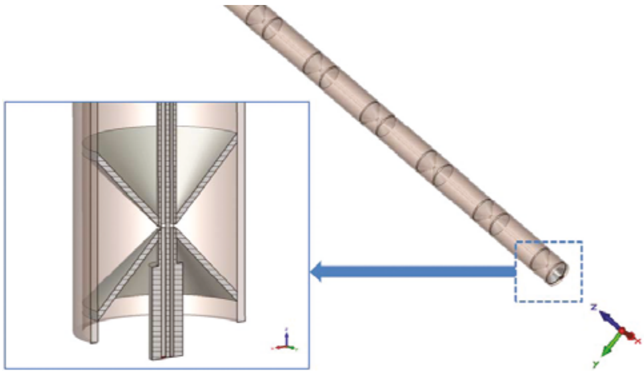

Figure 2: Basic antenna structure.

This antenna was first simulated in isolation using the transient solver. This particular assembly has been designed in CST Studio Suite following an initial optimization of an individual radiating element. The individual element was simulated first, and the parameters of cone diameter, cone angle, and spacing between the top and bottom cone elements were all allowed to vary to produce an individual cone that had optimum characteristics for return loss and radiation pattern. Once this was optimized, an array of these individual cones mounted co-axially, attached to a single cable, was simulated. The gain on the horizon and return loss at the design frequency of 3.5 GHz were then optimized. This was accomplished by setting up a parameterized model, in which the key parameters were allowed to vary, while template-based post processing was used to optimize return loss and gain on the horizon. This is therefore a full electromagnetic simulation of the antenna structure, as opposed to a construction of an individual radiating element placed in an array structure. As such, all effects from mutual coupling are taken into account.

The results obtained are shown in figures 3, 4 and 5. These results relate to measurements that would be obtained for this antenna structure in a test range if it was tested in a conventional manner as a stand-alone item. The tendency of such an antenna to concentrate the radiated energy about the horizon can be seen. The azimuthal pattern on the horizon is seen in figure 4, and is even in all directions, whilst the elevation pattern in figure 5 shows the sidelobe structure with the main beam on the horizon. Such a structure has two planes of symmetry and, when these are used, a transient solver is capable of analyzing this structure in no more than a few minutes.The result that was obtained for this antenna was then saved as a far field source for use with the integral equation solver when the tower was added to the model.

ANALYSIS OF ANTENNA MOUNTED ON TOWER

The same model that was created with the antenna described above was then extended through the addition of the tower structure. It can be seen in figure 1 that the structure modelled was a typical tower structure, having 4 vertical poles connected by bracing struts between them. This structure was then connected to the antenna with a boom. The length of this boom was then varied as the antenna and tower structures were held constant.

In order to be able to quantify the performance of the antenna when deployed on the tower, template-based post processing was used. A 1D result for the peak gain in a cut on the horizon was obtained, from which 0D results for the

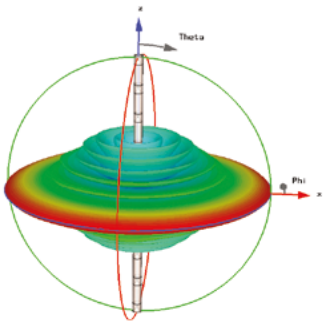

Figure 3: 3D radiation pattern of basic antenna.

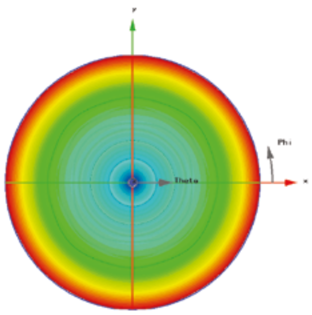

Figure 4: Azimuthal radiation pattern of basic antenna.

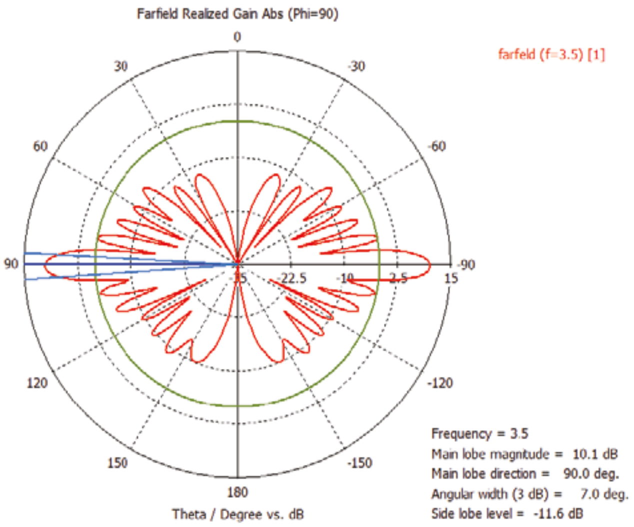

Figure 5: Elevation radiation pattern of basic antenna.

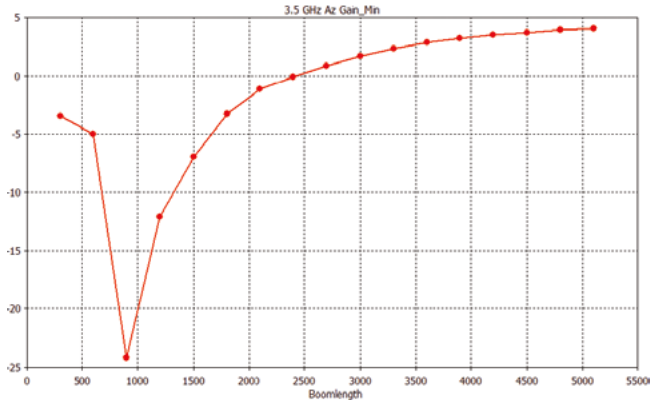

Figure 6: Variation in minimum gain of antenna on tower with parameter "Boomlength".

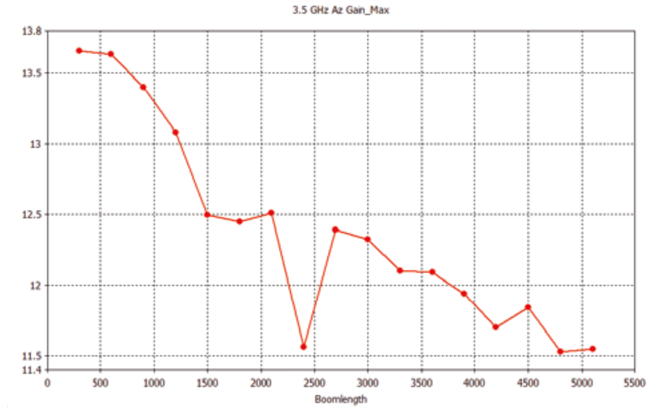

Figure 7: Variation in maximum gain of antenna on tower with parameter "Boomlength".

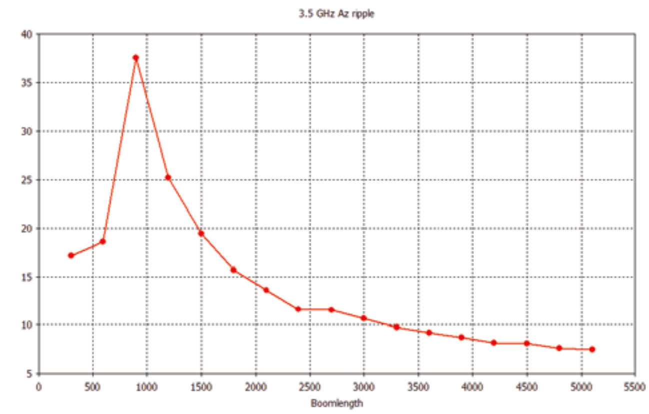

Figure 8: Variation in gain ripple of antenna on tower with parameter "Boomlength".

maximum gain, the minimum gain, and the ripple (expressed as the maximum minus the minimum gain) were extracted. These values were then plotted as the length of the boom, designated as parameter "Boomlength", was varied. The antenna was removed from the model by hiding the steps that created the antenna in the model, and the far field source was maintained in a constant position at the center of the coordinate system, whilst the position of the tower was varied with respect to this position by varying the parameter "Boomlength". The antenna had originally been created with its center at the origin of the coordinate system to make the use of the far field source simpler, so that no mechanical transformation of the far field source was required. Figures 6, 7 and 8 show the variation in the peak gain parameters defined by the post processing 0D result templates, whilst figure 9 shows the azimuth radiation patterns overlaid as the length of the boom was varied from 300 mm to 5100 mm. A quick visual inspection shows that 300 mm is clearly too close to the structure, and it would not be expected that the antenna would exhibit suitable omnidirectional performance in such a position. Nevertheless, as the antenna is increased in distance in increments of 300 mm, the degree of ripple in the azimuth pattern would have been expected to decrease, and it can be seen that this is the case here. Additionally the full 1D results for the azimuth plots for each value used in the simulation are shown overlaid in figure 10.

For additional clarity, the azimuth pattern at 5100 mm (the maximum length of the simulated boom) is shown in figure 10.

As the length of the boom was increased, the number of surfaces for the entire assembly did increase slightly, as did the simulation time. However, even for the longest simulated boom length (5100 mm), the number of surfaces was still only 13,130, and the total solver time for this iteration was 1 minute, 53 seconds. The model was then altered by unhiding the steps in the model that had created the antenna, thereby replacing the antenna, removing the far field source and reverting to the transient solver applied to the antenna input port. This model had 65,767,152 mesh cells, and took 7 hours, 59 minutes and 57 seconds to solve in this mode, with no significant difference to the results. These simulations were performed on a Dell Precision Westmere computer, having dual Intel Xeon E5620 processors, and 24 GB of RAM.

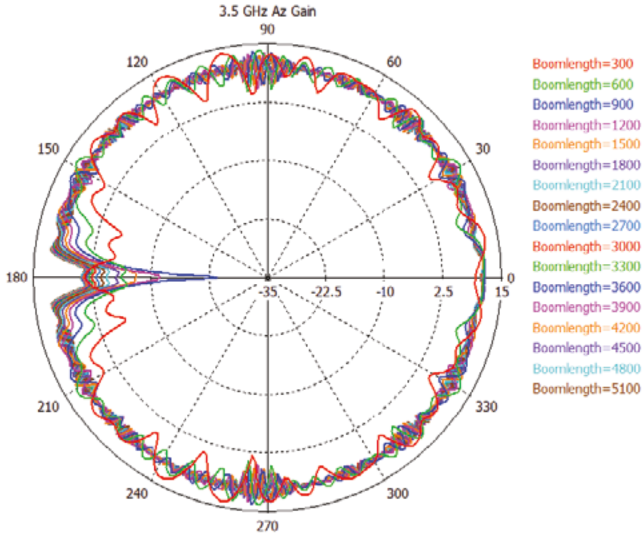

Figure 9: Azimuth radiation patterns for each value of parameter "Boomlength" overlaid.

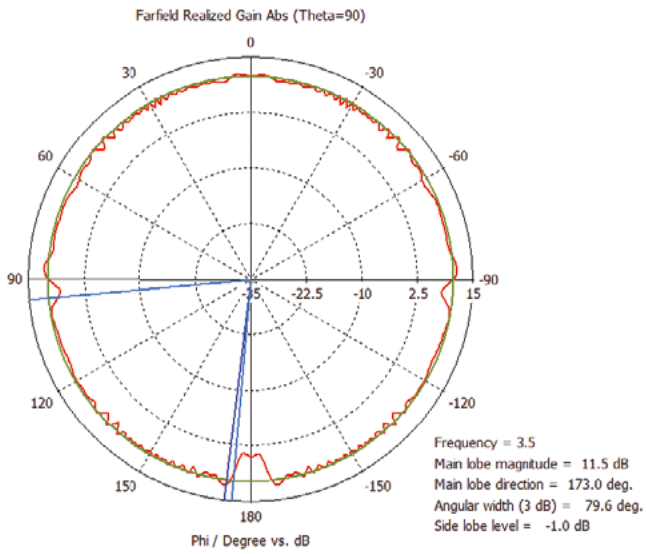

Figure 10: Azimuth radiation pattern for antenna on tower with 5100 mm length of boom.

CONCLUSIONS

In this particular case of an omnidirectional antenna mounted near to a tower, it can be seen that the tower exerts considerable influence on the radiation pattern of the antenna. In order to keep variations to an acceptable level, such antennas do need to be positioned quite a large distance away from the structure, perhaps further than may be expected from a cursory examination. The drop-outs in signal level are over a fairly small range of angles so, if the variations in the patterns are understood, it may be possible to align this region with one requiring less signal strength. An omnidirectional antenna mounted on a tower does very much represent a worst-case condition. If a sector antenna is mounted on a tower directed away from the tower, the interaction with the tower will be far less. This can be seen by inspection of the patterns produced in this simulation, where the signal in directions away from the tower is perturbed far less than in the direction of the tower.

The integral equation solver in CST Studio Suite has enabled the efficient and accurate modeling of a large electrical structure with fine detail within the structure. As the structure was increased in size, the benefit of using the integral equation solver over the transient solver became larger. In this particular case with the maximum boom length, the speed-up factor between the 2 solver methods is 255:1. The analysis of an antenna structure deployed on a tower is one that is particularly suited to this solver. Larger structures would require prohibitively large amounts of memory and solver time using transient solvers but, with the integral equation solver, structures considerably larger than the one simulated here could still be simulated. The integral equation solver does permit the analysis of this particular set of real world problems using practical computers such as would be generally available for use as individual workstations.

REFERENCE

[1] CST Studio Suite, https://www.3ds.com/products-services/simulia/products/cst-studio-suite/

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