Series-fed Travelling Wave Patch Array

Introduction

This application note describes simulation of travelling wave patch array in the WIPL-D Software suite. WIPL-D Pro is based on the Method of Moments applied over quadrilateral mesh. The advance implementation of the code involves mesh elements up to 2 wavelengths, which are allowed since the current approximation over them is adjusted based on their size. The current order is set between 1 and 8, corresponding to smallest elements extending to 2 lambda elements. In general, WIPL-D Pro allows minimum requirements for the simulation of electrically large or moderate structures. Most of the common antennas can be simulated at regular desktop machines, without the need for any expensive hardware. The simulation times are usually measured in seconds.

One type of microstrip array antennas ate travelling wave arrays. Here, the array is series-fed. One of the major advantages of microstrip patch arrays is their low profile and light weight. They are used in large number of EM applications including satellite and ground communication. The specific antenna described here has 10 elements. Since they are series-fed and spaced, they have a progressive phase distributed over the array.

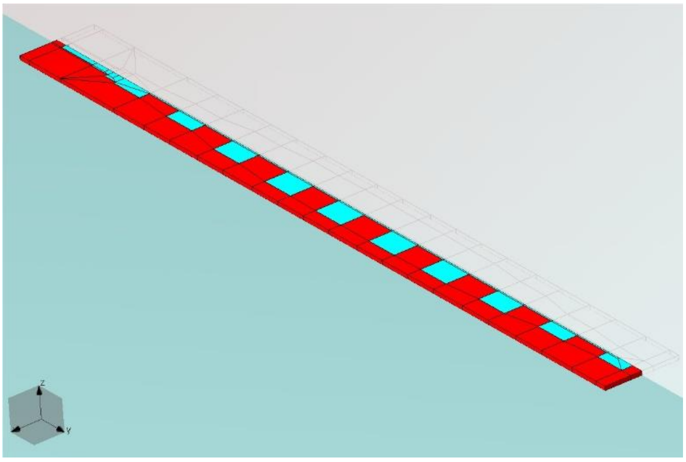

Figure 1. Series-fed travelling wave microstrip patch array

The focus was to investigate the return loss of the array with greatest accuracy. The operating frequency is 77 GHz. One of the most important effects at such high frequency (where the patch size is very small) is the finite thickness metallization (18 um). It was introduced along with the feeding mechanism which emulates the realistic coaxial feeding.

Namely, it can be shown by adding a realistic coaxial feeder, that the feeding mechanism introduced at Figure 3 shows very similar results. It serves as a good approximation of coaxial feeder emerging from the metallic ground.

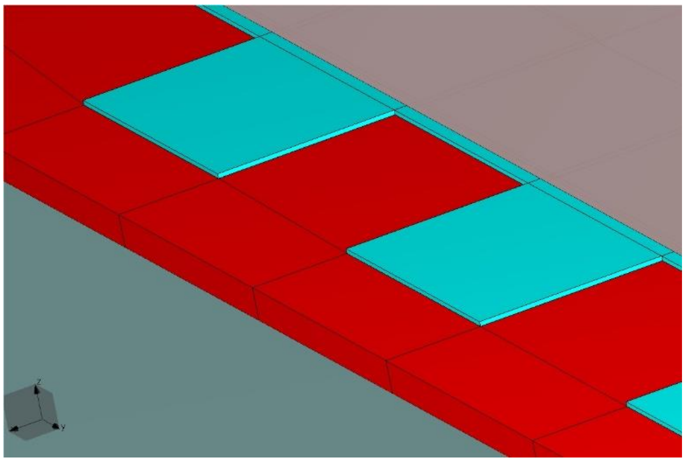

Figure 2. Introducing finite metallization thickness

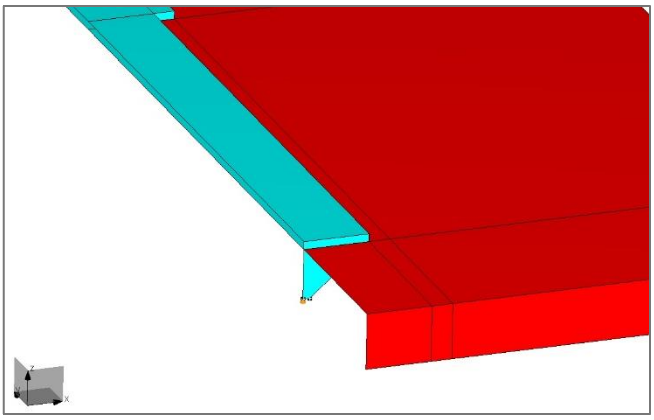

Figure 3. Feeding mechanism emulating coaxial feeding

Simulation Results

The result of model with and without finite thickness is shown in Figure 4.

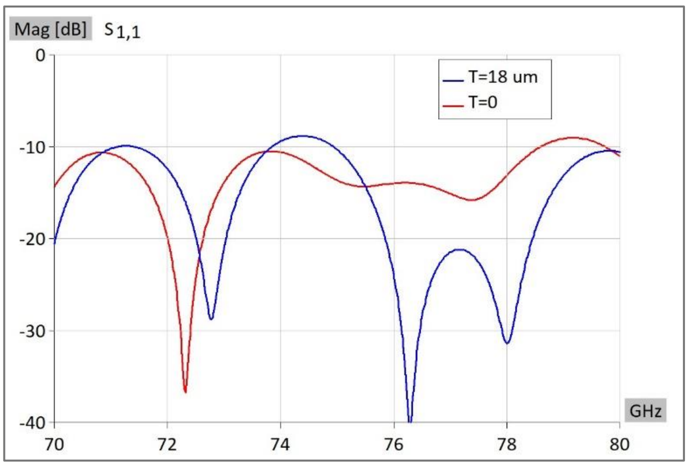

Figure 4. Influence of finite thickness

The simulation requirements for the two models above are very similar. For the result with high accuracy, zero thickness model requires 2,800 unknowns while finite thickness model requires 3,100. Both models run in 10 seconds per frequency point on regular desktop PC with quad core CPU. The results indicate that thickness at such high frequencies (patches are only 1 mm x 1mm large) is a must-have.

Next a series of tests was performed to confirm the validity of results. This is a typical simulation process in WIPL-D. WIPL-D efficiency allows that each simulation can be verified quickly by testing all possible EM effects. The first test includes using a larger substrate area around the printed surface. Standard value used in WIPL-D simulations is 3 times substrate height, and here we tested 5 and 10 times the substrate thickness. There is no significant difference in results so we can proceed with the smallest shoulder width.

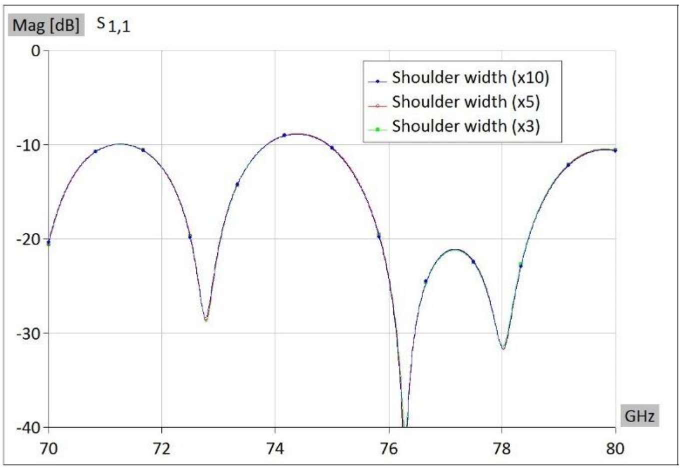

Figure 5. The influence of shoulder width

The next test was to examine the influence of number of unknowns and mesh size. The standard maximum mesh size in WIPL-D Pro is 2 wavelengths, which allows usage of basis functions with order up to 8. These are so called higher order basis functions (HOBF). The convergence test can be performed by meshing the model with 2 lambda elements, but with increased referent frequency (simulation frequency is 80 GHz). This way the number of unknowns is increased. Reference frequency was constantly raised for 20 GHz (25% of the original frequency). The test was continued even when the results converged to confirm stability of results.

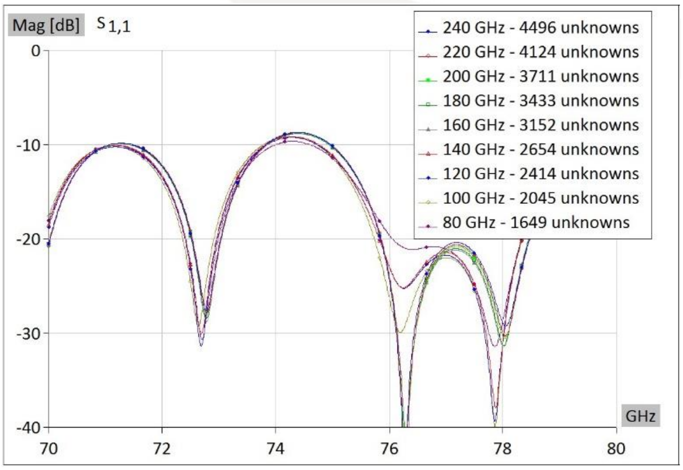

Figure 6. Convergence test – 2 lambda elements

Then the same procedure was performed with maximum mesh size of lambda/3 (which results in much larger number of unknowns). The results converge the same way. The basis functions used are so called roof-tops, basis function of the first order.

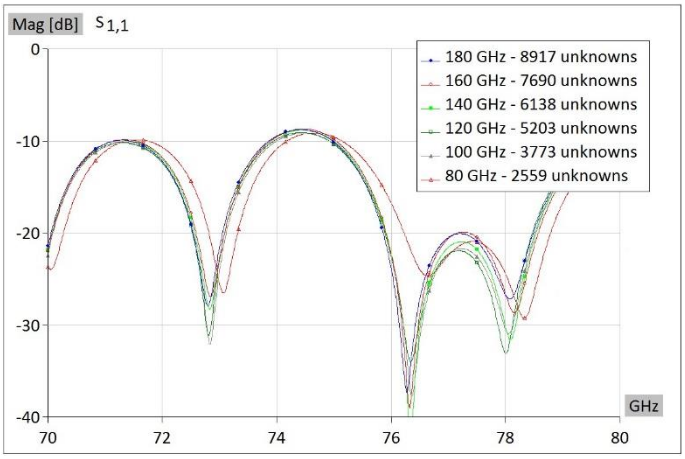

Figure 7. Convergence test – 0.33 lambda elements

A very important aspect of this simulation is the effect of losses in metal. At high frequencies, skin effect is pronounced. Thus, for copper strips we account roughly 3 times larger losses (19 MS/m). When a finite ground is present, the similar current flows on the ground so losses are even higher. We present results with losses set to none, 19 and 4 MS/m.

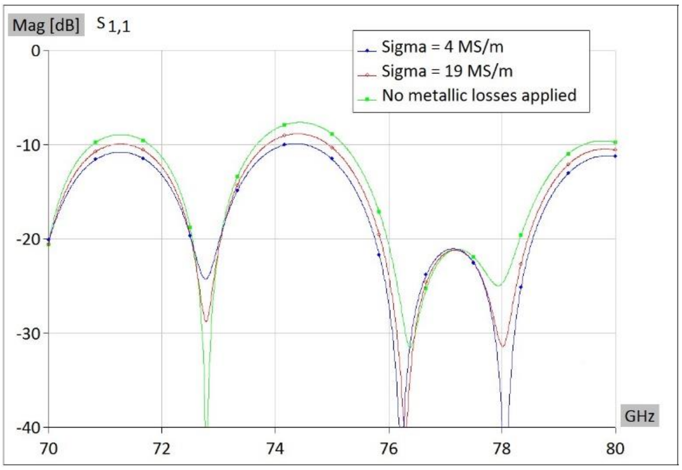

Figure 8. The effect of metallic losses

Finally, one of the most important aspects is the exact position of the coaxial pin. The starting feed location is 1.3 mm away from the first step. If this length is extended for 0.5 mm, 1 mm, 1.5 mm and 2 mm, a significant difference in results occurs.

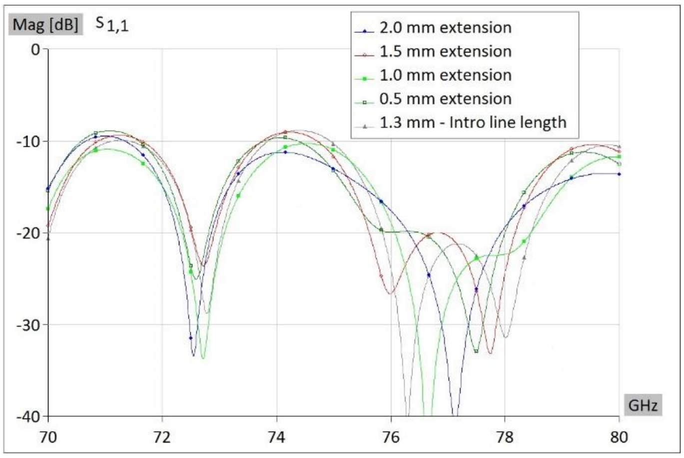

Figure 9. The effect of pin position

At the end, we present the radiation pattern of the array at 76, 78 and 80 GHz. The beam squint effect is clearly seen.

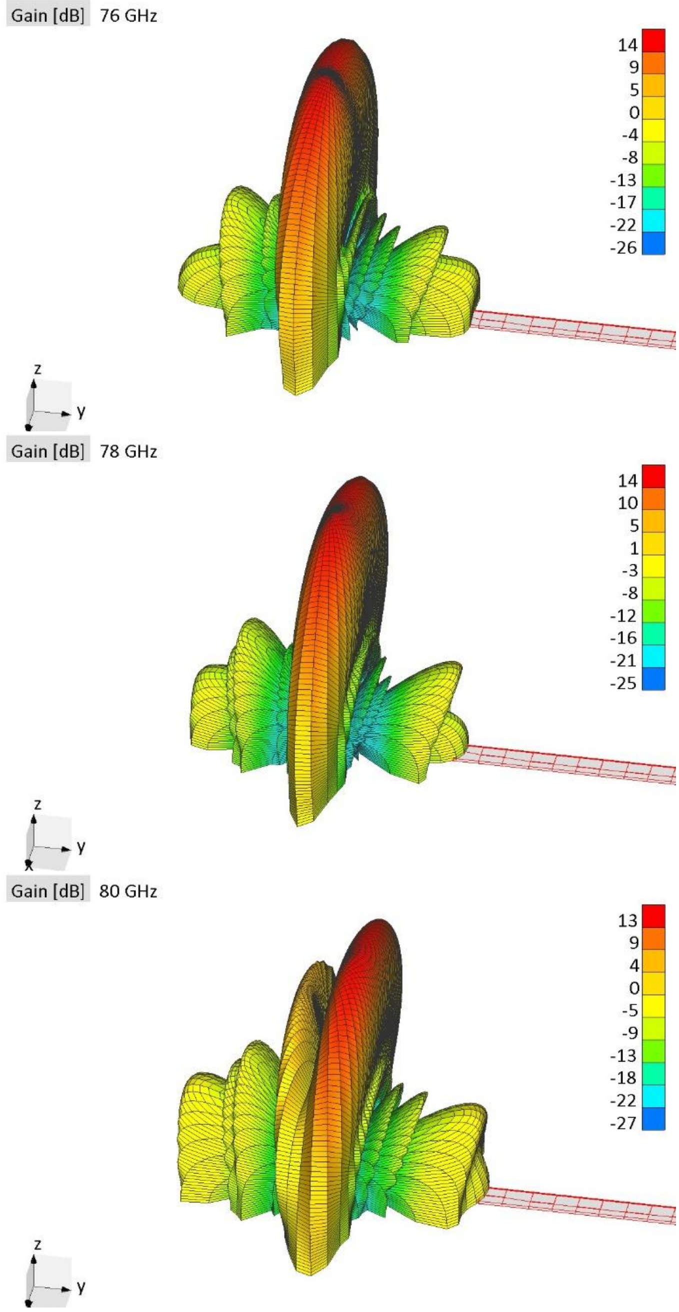

Figure 10. Radiation pattern – beam squint

Conclusion

The application note shows a detailed convergence study of the travelling wave patch array. Owing to the efficient WIPL-D simulations, the entire simulation runs in under 10 seconds at regular desktop PC or laptop. This enables software users to run numerous simulations and investigate all important EM effects. The specific attribute of the array is high frequency (77 GHz). The dramatic influence of the finite metallization thickness, metallic losses and the exact pin position are investigated in details.

At the end, we show the beam squint by displaying the radiation pattern at the 3 selected frequencies.