# Planar Inverted-F Antennas in Free Space and Cell Phone

**Planar Inverted-F Antenna (PIFA)** represents the antenna which is widely used in cell phones and tablet computers. When implemented in microstrip technology it takes a more compact form then its microstrip patch counterpart which makes it a favorable **choice between mobile antenna designers**.

This application note demonstrates simulation of two scenarios describing typical PIFAs operation, the first one where the antenna is located in a free space and the second one where antenna is mounted on the cell phone boards. The rectangular and the curved PIFAs are considered, as presented in Fig. 1. The PIFAs are designed to have dual band properties, about 0.9 GHz (*lower band*) and 1.8 GHz (*higher band*).

**WIPL-D** software, a full wave 3D EM **Method-of-Moments (MoM)** based solver, will be used for modelling and simulating the PIFA application scenarios. It will be shown that the simulations are efficient (executed in a relatively **short time using non-expensive hardware**).

## PIFAs in Free Space

The CAD models of the PIFAs in free space were created from the scratch using **WIPL-D Pro CAD** – the solid modeler and importer (Fig. 1). The next, the PIFAs were meshed and converted to **WIPL-D Pro** native format. The meshed models are displayed in Fig. 2.

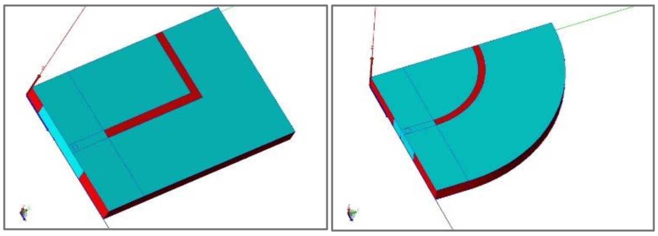

**Fig. 1. WIPL-D Pro CAD models of the rectangular and curved PIFA.**

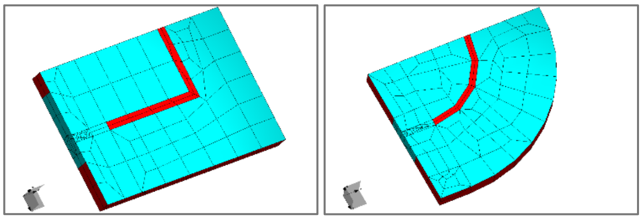

**Fig. 2. Meshed models of the rectangular and curved PIFA in WIPL-D Pro.**

As the first step, the PIFAs were simulated in the free space. S-parameters in the lower band are shown in Fig. 3 while S-parameters in the upper band are shown in Fig. 4.

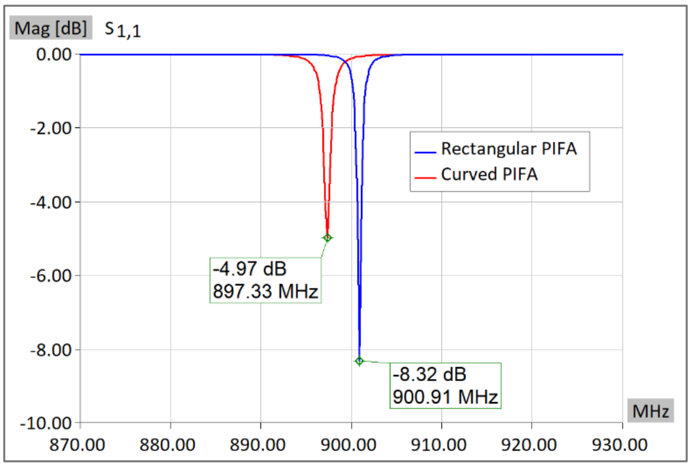


**Fig. 3. S-parameters in lower band - PIFAs in free space.**

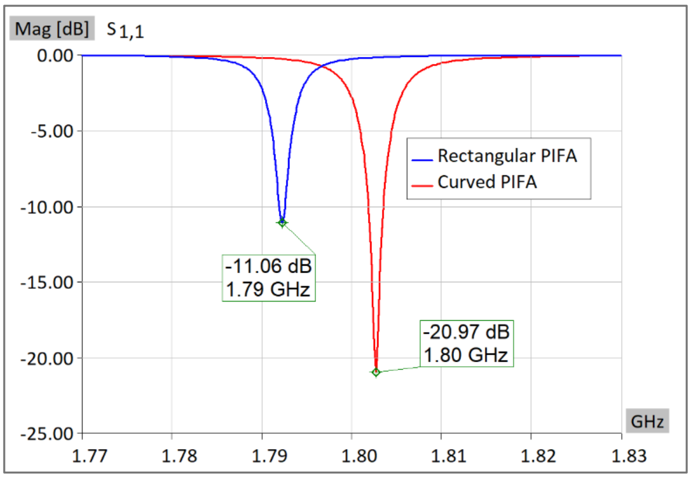


**Fig. 4. S-parameters in upper band - PIFAs in free space.**

## PIFAs in Cell Phone

The CAD model of a cell phone has been imported into WIPL-D Pro CAD and converted to WIPL-D Pro native format (Fig. 5).

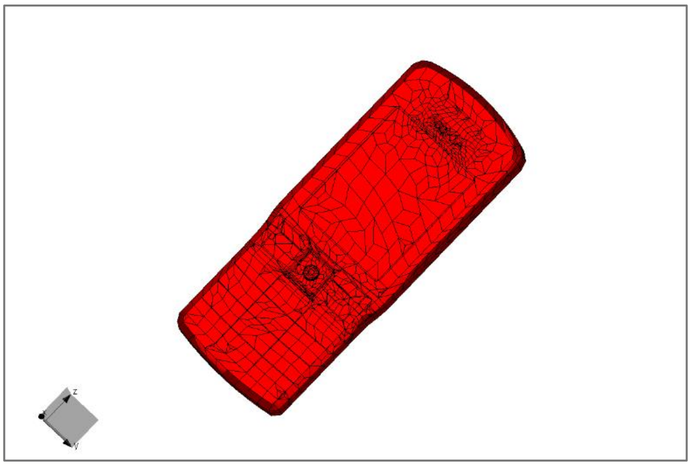

**Fig. 5. Meshed cell phone in WIPL-D Pro.**

PIFAs were imported in WIPL-D Pro model and adequately located with respect to the imported cell phone (Fig. 6 and Fig. 7). Ground plane and electronic devices within the phone were modeled using various metallic shapes (Fig. 6 and Fig. 7).

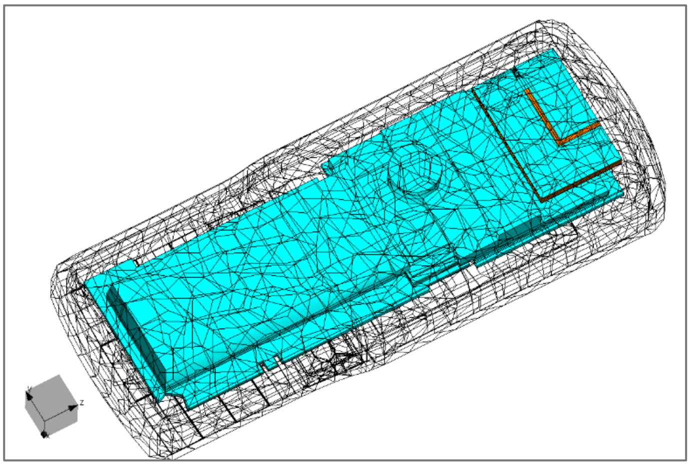

**Fig. 6. Rectangular PIFA in cell phone with ground plane and modeled electronic devices within the phone.**

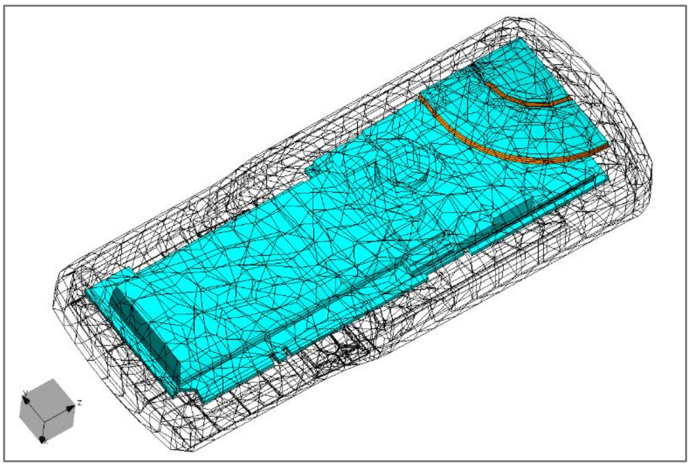

**Fig. 7. Curved PIFA in cell phone with ground plane and modeled electronic devices within the phone.**

The S-parameters obtained by simulations are presented in Fig. 8 and Fig. 9 and compared with the free space results in the same figures.

## Radiation Patterns at Resonant Frequencies

Resonant frequencies of PIFAs in lower and upper frequency bands, in free space and within the cell phone can be deduced from Fig. 8 and Fig. 9.

Radiation patterns for circular and rectangular PIFAs, in free space and within the cell phone are presented in Figs 10-17. The frequencies where radiation pattern has been calculated for free space radiating antennas were selected to coincide with the resonant frequencies of PIFAs when placed inside the cell phone. For example, radiation pattern for rectangular PIFA in free space, in lower band is calculated at 910.53 MHz. The radiation patterns are calculated at 73x73=5,329 points in 3D space (73 points along theta angle from -90 to 90 degrees and 73 points along phi angle from 0 to 360 degrees).

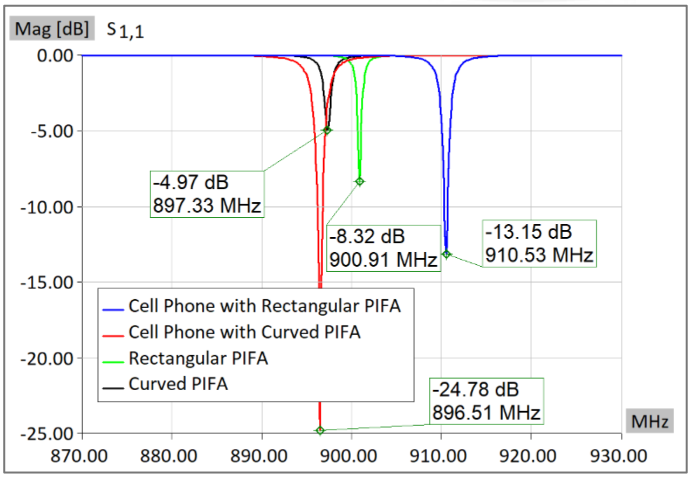


**Fig. 8. PIFAs within the cell phone and in free space. S-parameters in the lower band.**

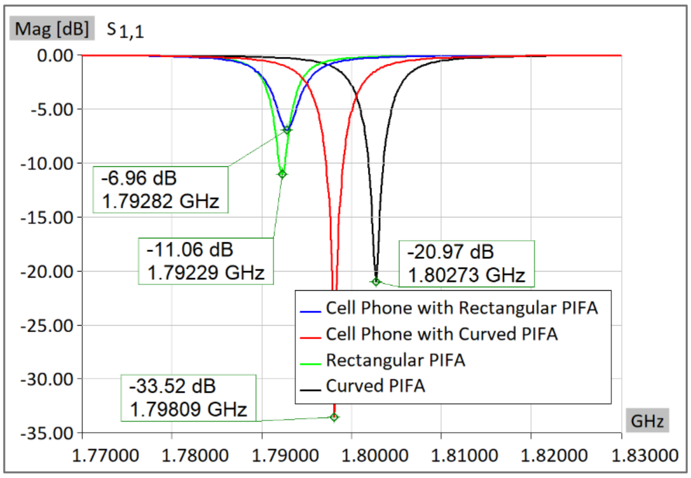


**Fig. 9. PIFAs within the cell phone and in free space. S-parameters in the upper band.**

## Simulations

Computer used for these simulations is presented in Table 1.

**Table 1. Computer used for the simulations.**

| Hardware | Description |
|---|---|
| CPU | Intel® Core™ i7-7700 CPU@3.60 GHz |
| RAM | 64 GB |
| GPU | One card: NVIDIA GeForce GTX 1080 |

Computations are accelerated by using a GPU card. The acceleration has been applied for matrix inversion only. The other operations are performed on CPU. Number of unknowns and simulation time per frequency (without radiation pattern calculation) are given in the Table 2.

It can be noticed that appropriate models in the different frequency bands require the same number of unknowns (e.g. rectangular PIFA within the cell phone in the lower band and rectangular PIFA within the cell phone in the upper band). This is, actually, the result of convergence checking. After the process of convergence check was performed, it was decided that output results are convergent with the kernel parameter reference frequency which is equal to 2 GHz. The same kernel parameter was used in each simulated model.

**Table 2. Number of unknowns and simulation time per frequency.**

| Model | Number of unknowns | Simulation time per frequency [sec] |
|---|---|---|
| Rectangular PIFA in free space (lower band) | 8,556 | 6.2 |
| Rectangular PIFA within the cell phone (lower band) | 29,299 | 112.9 |
| Rectangular PIFA in free space (upper band) | 8,556 | 6.4 |
| Rectangular PIFA within the cell phone (upper band) | 29,299 | 111.7 |
| Curved PIFA in free space (lower band) | 9,044 | 6.7 |
| Curved PIFA within the cell phone (lower band) | 29,787 | 114.5 |
| Curved PIFA in free space (upper band) | 9,044 | 6.8 |
| Curved PIFA within the cell phone (upper band) | 29,787 | 114.4 |

## Conclusion

In this paper we demonstrated **successful computer simulation** of one of a real-life (PIFA) antenna placement scenario. The antenna placement scenario was simulated using WIPL-D software exploiting WIPL-D products: **WIPL-D Pro** and **WIPL-D Pro CAD**. Calculated results are S-parameters and radiation pattern in two frequency bands representing bands used in cell phone communication.

The results are showing that in the case of the particular mobile phone, the antenna designed to operate in the free space can be used inside the phone without significant degradation of the performance.

It was shown that CAD model of the cell phone can be successfully imported and converted to WIPL-D Pro native format and **all of the models simulated in a reasonable time**. The simulation duration, the resources engaged for the simulation and the obtained results demonstrate that WIPL-D software is suitable for complex modelling and efficient simulation of various antenna-cell phone scenarios.

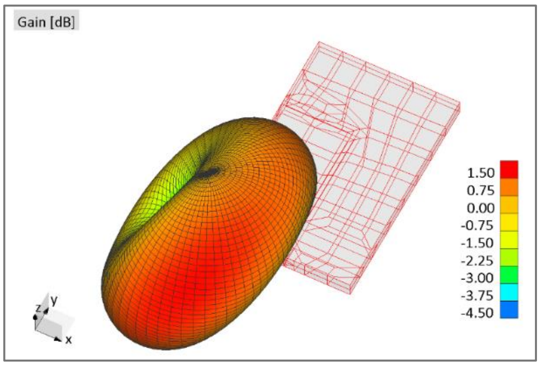


Fig. 10. Rectangular PIFA in free space – radiation pattern at 910.53 MHz.

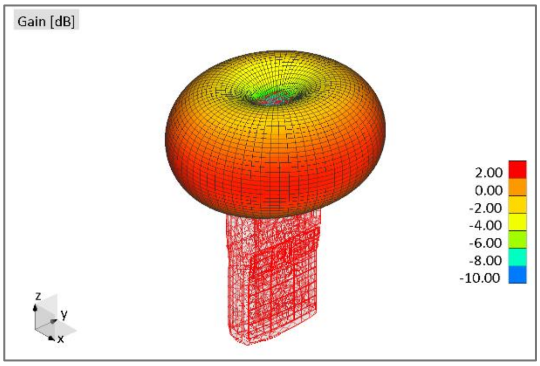


Fig. 11. Rectangular PIFA within the cell phone – radiation pattern at 910.53 MHz.

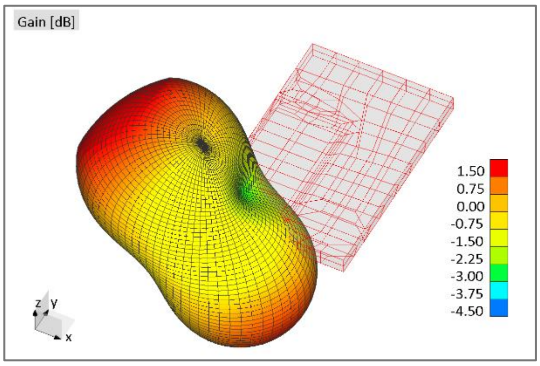


Fig. 12. Rectangular PIFA in free space – radiation pattern at 1.79282 GHz.

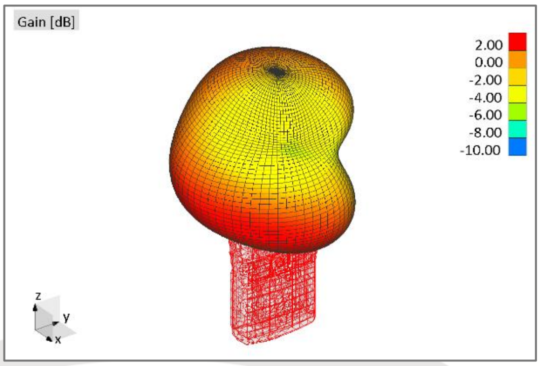


Fig. 13. Rectangular PIFA within the cell phone – radiation pattern at 1.79282 GHz.

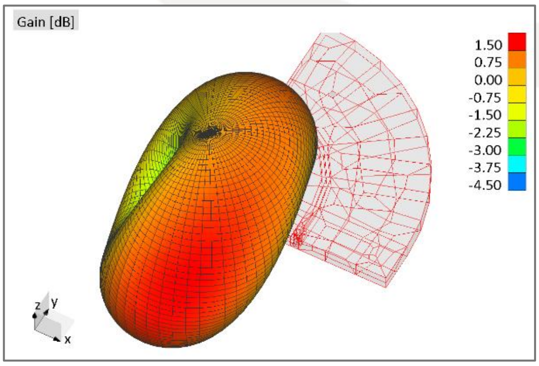


Fig. 14. Circular PIFA in free space – radiation pattern at 896.51 MHz.

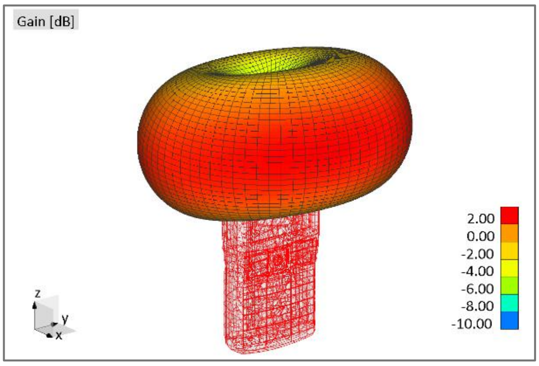


Fig. 15. Circular PIFA within the cell phone – radiation pattern at 896.51 MHz.

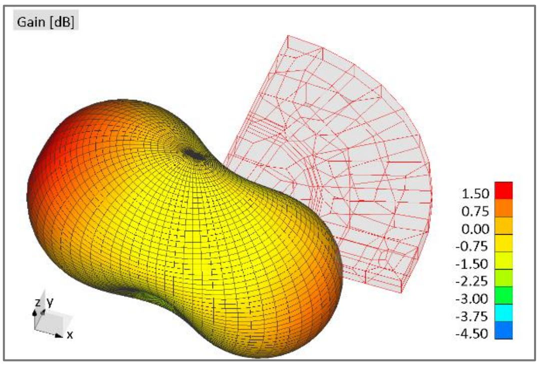


Fig. 16. Circular PIFA in free space – radiation pattern at 1.79809 GHz.

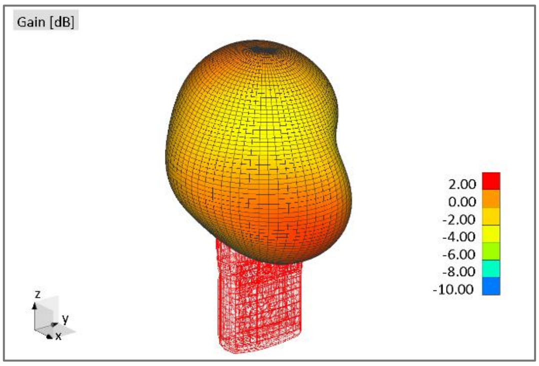


Fig. 17. Circular PIFA within the cell phone – radiation pattern at 1.79809 GHz.