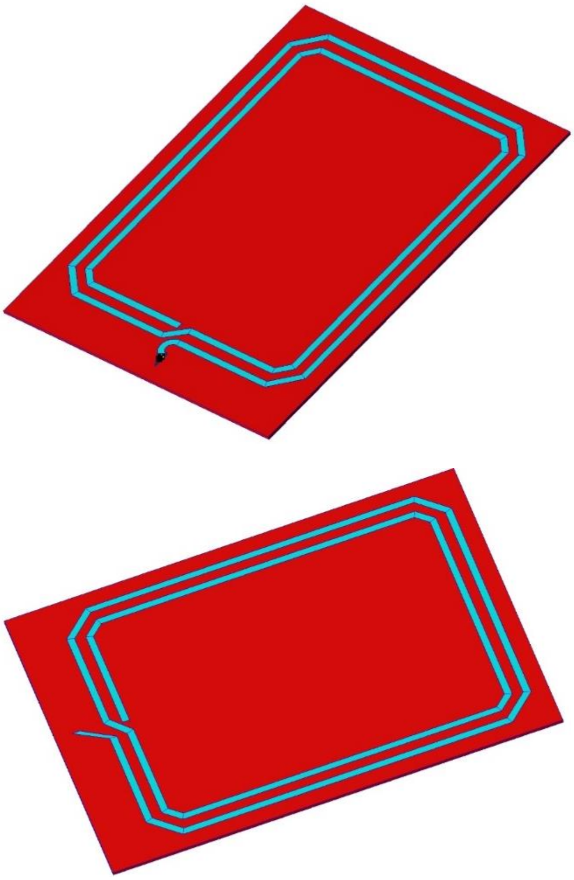
RFID Applications Part 2

Introduction

In the application note RFID Applications we have shown several RFID designs. Here we extend the work by showing some typical reader/tag design, observations on flexible substrates and miniaturization, as well as a realistic RFID scenario.

RFID Reader Design

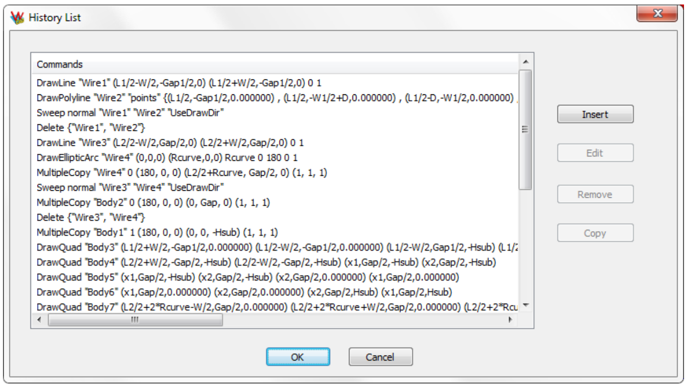
RFID can be used in various frequency ranges. Here we show typical design for most common bands. A typical reader geometry is shown below.



Typical RFID reader

This is a simple design, with a conductor pattern printed on both sides of a substrate and interconnections going through the dielectric. RFID reader model was **built in WIPL-D Pro CAD** by using a dozen commands and several **symbols for parametric definition**.

WIPL-D Pro CAD features easy model creation with straightforward and intuitive user interface. For the project in hand and for similar ones, very useful features are **Sweep command** and **Boolean operations**.



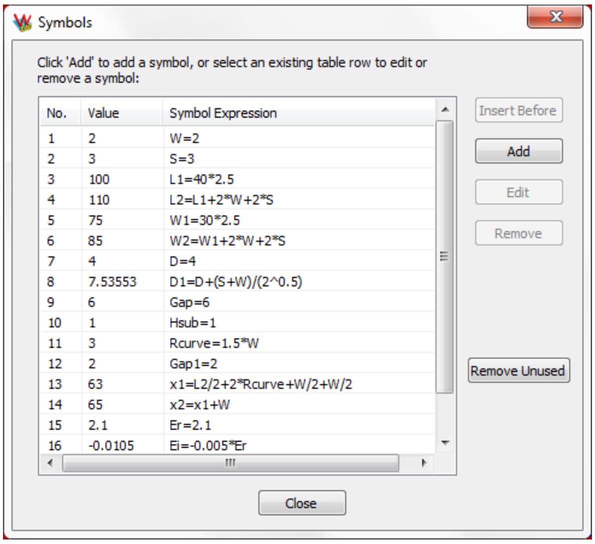
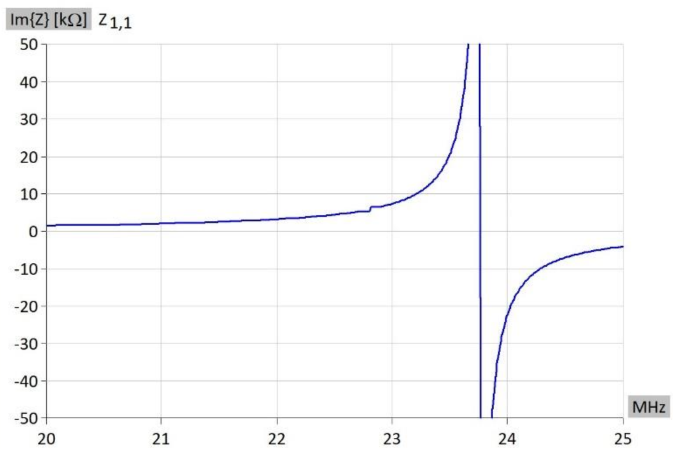
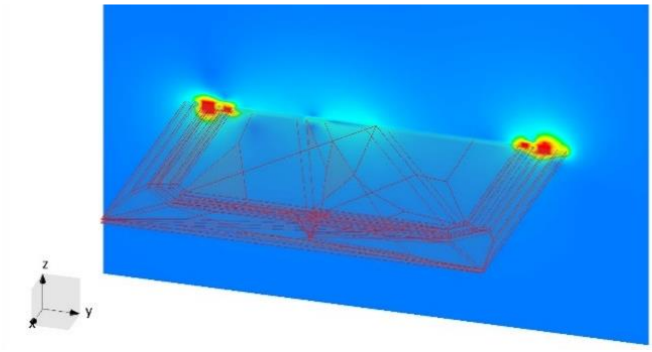


Illustration how the model is built in WIPL-D Pro CAD

The model has been **meshed automatically**. Simulation requires **under 1,000 unknowns and 30 seconds** at regular desktop PC or laptop.

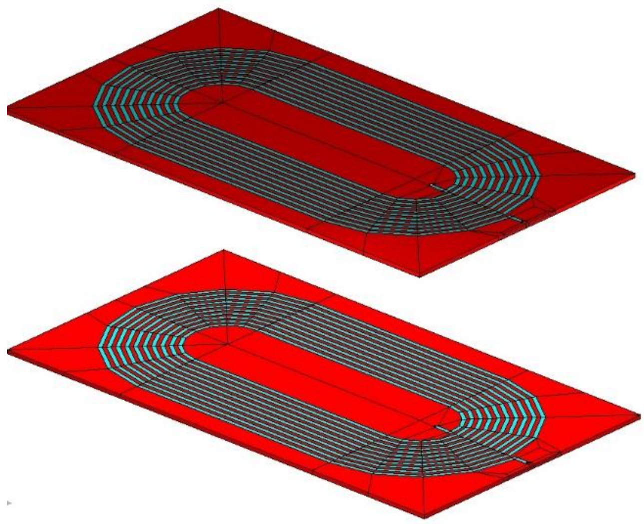
The results of interest for the particular reader are: impedance, near field, far field, current distribution, SAR. Some of them are presented in the following figures.



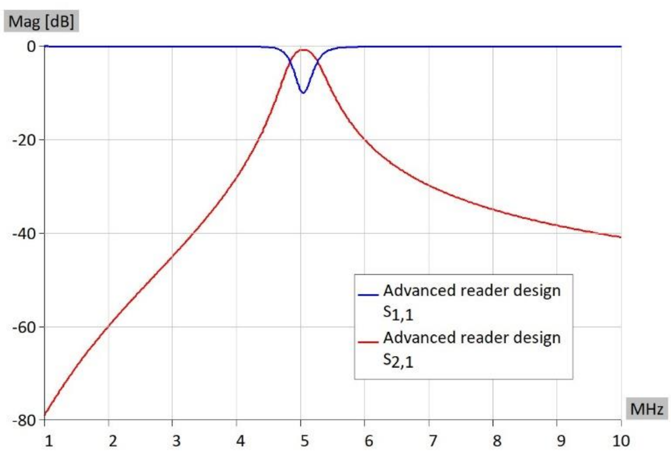


Selected output results for RFID reader

A more advanced design is based on rectangular spiral (conductor pattern is double-sided, each side comprising several turns). Here we also **test the RFID operation scenario**, i.e. coupling between two similar antennas, but the port impedances are different. Thus, as result we show here matching quality of a single antenna and coupling between two antennas.



More complex RFID scenario

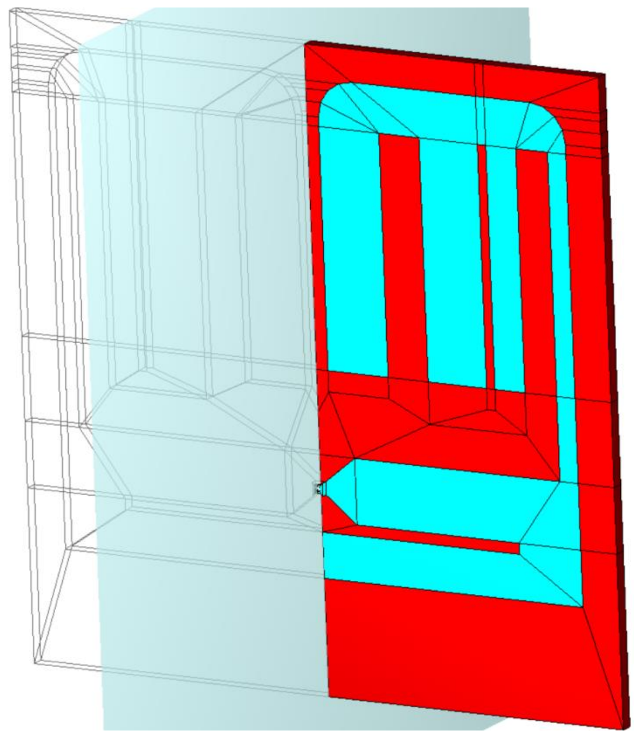


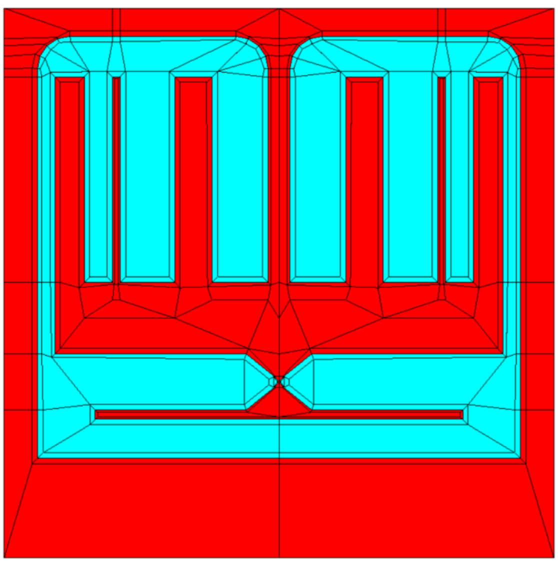
Return loss and coupling between RFID antennas

The simulation requirements do not depend on distance between antennas, as this is the basic property of WIPL-D kernel: <u>**no bounding box is required**</u> **and** <u>**the space between antennas is not meshed**</u>. Antennas can be placed arbitrarily: 10, 100 or 1000 lambdas with a computational burden remaining unchanged. The coupling scenario requires under **10,000 HOBF unknowns**. **Simulation time is a couple of minutes** at any regular desktop PC or laptop.

RFID Tag Design

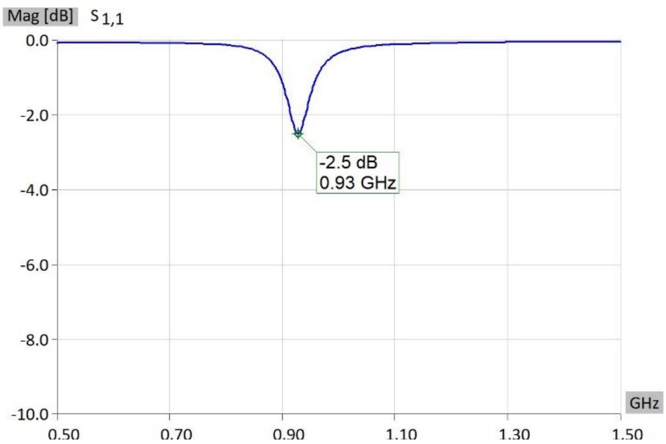
As a next example, a simple **RFID tag model was built in WIPL-D Pro with full parametric definition**. Symmetry of the tag can be exploited to halve the number of unknowns. **Accurate result is obtained with the default project settings** and automatic option set for **edging** of metallization and dielectric.





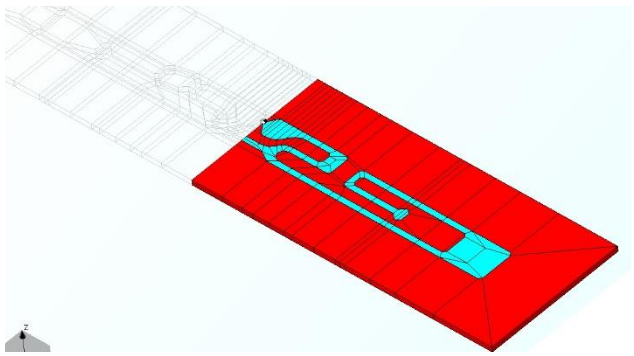
Simple RFID tag, edging improving accuracy

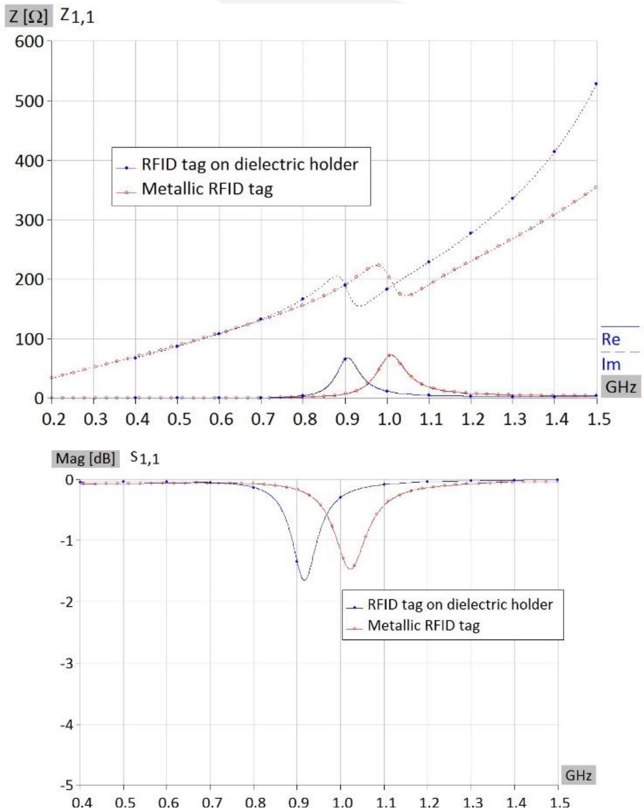
The simulation requires **under 1,000 unknowns** and lasts **a couple of seconds per frequency, less than one minute in total** for the entire frequency range.



Return loss of the tag

An advanced design example shown here is a more complex RFID tag with meandered radiator. Again, it is printed on single layer dielectric substrate. For this kind of problem WIPL-D has excellent efficiency. **Metallic model requires a couple of hundred unknowns and under a second per frequency, while the dielectric one requires under 2,000 and a few seconds per frequency** point. A **powerful interpolation algorithm** can be used for wider bands. When the symmetry of the structure is introduced only a half of the model can be simulated which reduces simulation requirements, as explained earlier. The simulation can be carried out at regular desktop PC or laptop.


Meandered RFID tag printed at dielectric substrate

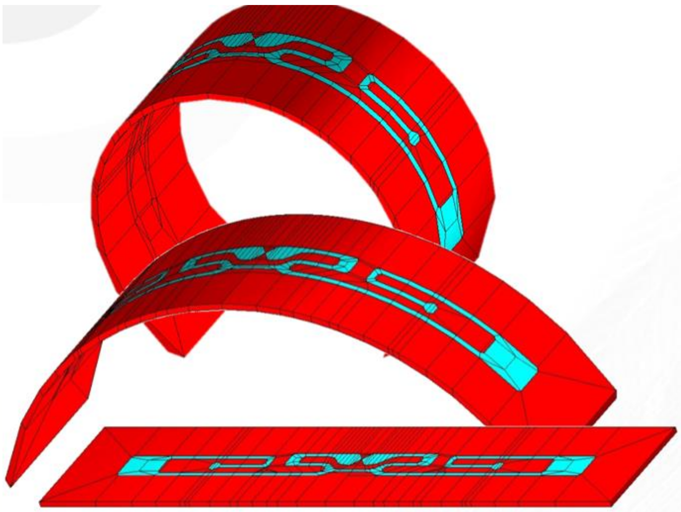


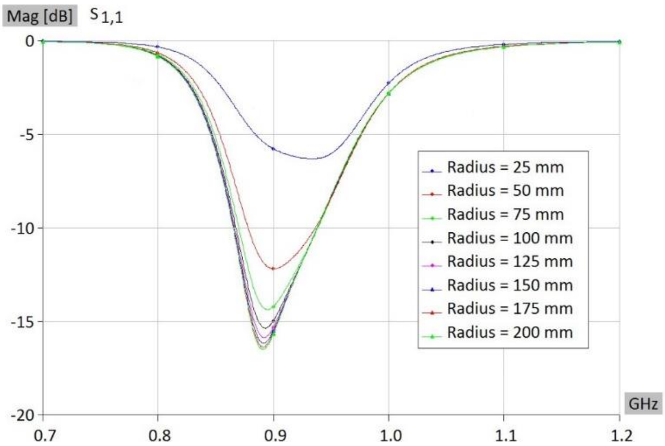
Meandered tag in free space and printed on substrate

Realistic RFID scenarios

In the first scenario, **a tag on a flexible substrate has been investigated**. The effect of bending the previously presented tag is examined, a situation that occurs with RFID systems in hospitals where similar tags are installed by wrapping them around patient's wrist.

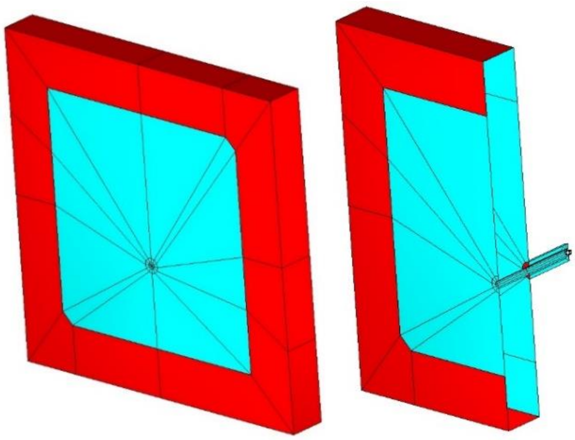
The simulation of a bent tag 3D EM model requires **practically the same number of unknowns as for the straight one**, and the **simulation time is also identical**.


The bent RFID tag emulating wrapping around wrist

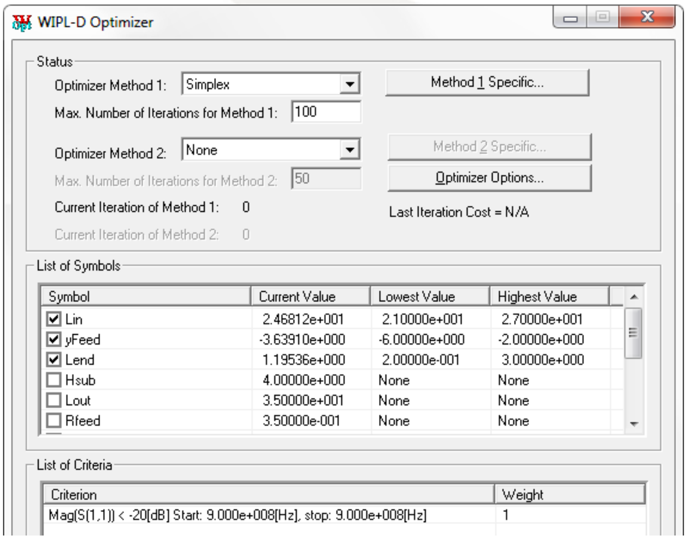


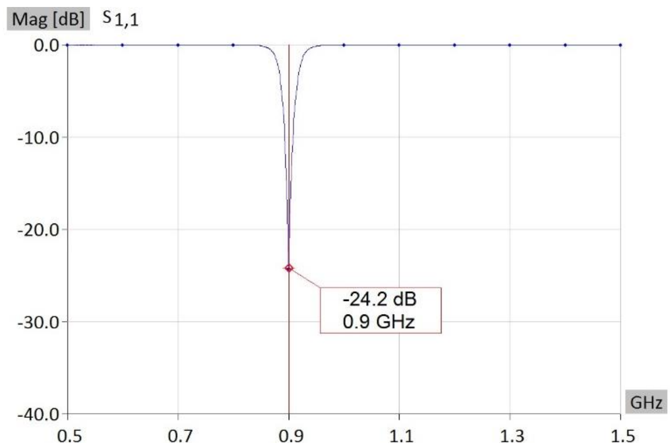
Return loss of the tag when wrapped around wrist

The next scenario shows how a **miniaturized tag** can be made. The solution is based on using a high ε_r substrate. Simple design is made in WIPL-D Pro. **High ε_r** (ε_r=40) results in small size. Model without the symmetry applied requires **around 1,000 unknowns and simulation time is only a few seconds per frequency**.


Simple miniaturized RFID tag based on high ε_r substrate

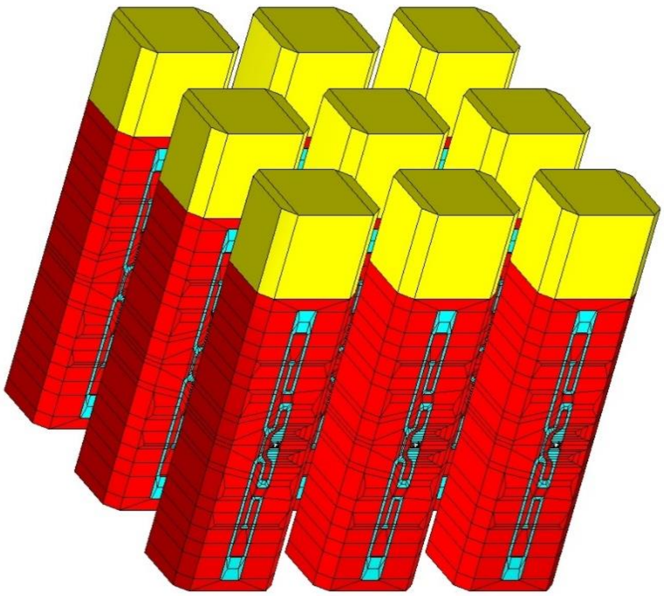
Simple optimization was run in the **WIPL-D Optimizer**: Very fast optimization with less than 100 iterations lasts a few minutes.



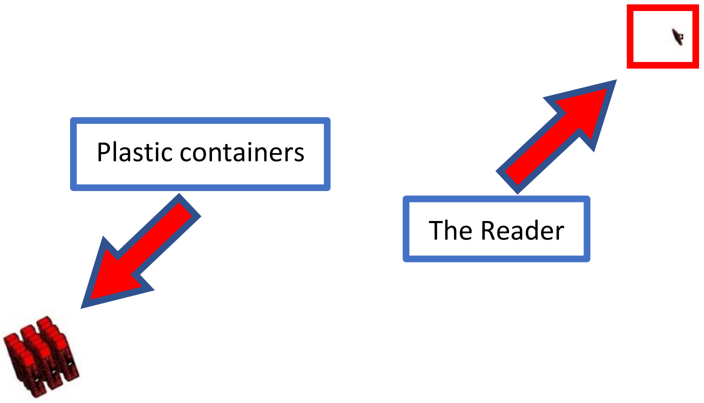


WIPL-D Optimizer and the optimized result

Finally, we present the most complex scenario which involves **tags mounted to plastic containers and RFID reader located at some realistic distance.**

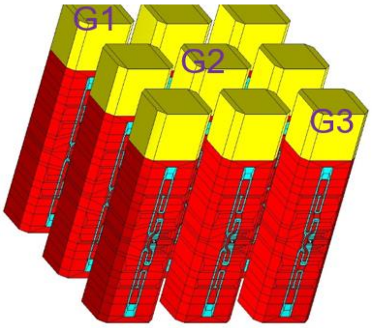

RFID tags on plastic containers

WIPL-D Pro tag is placed on large plastic container (4 x 4 x 14 cm]. The container is made of typical plastic (dielectric constant ε_r=3) and the thickness of 1 mm. Reader is placed at a distance of approximately 2 m. Again, **simulation requirements do not depend on distance, since there is no bounding box**.



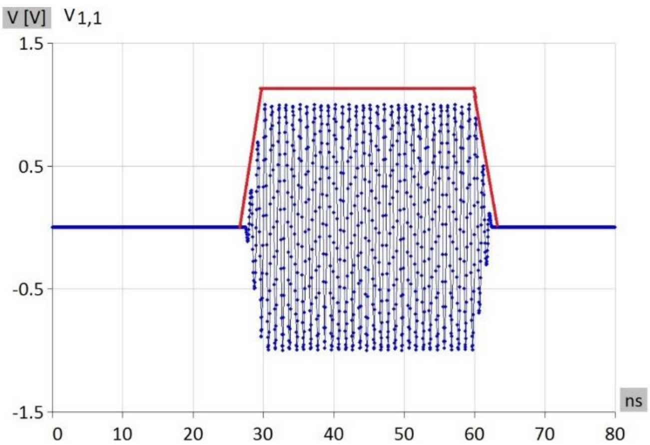
Plastic containers away from the reader

We focus on the transmission between the reader and three tags presented in the following figure.



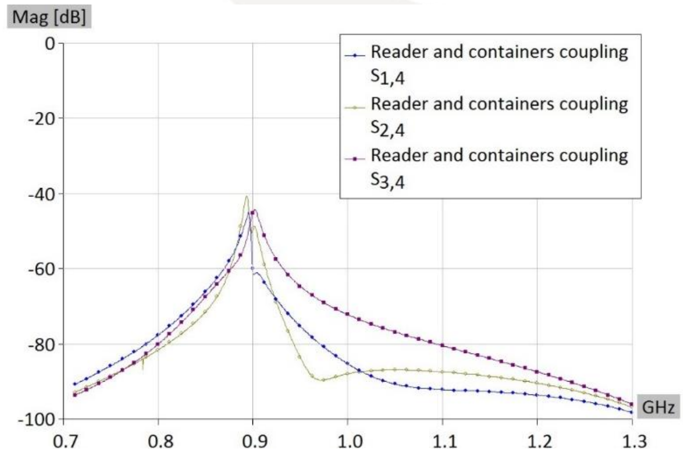
Three active tags: G1, G2, and G3

The radiated impulse is a simple trapezoidal modulated signal.



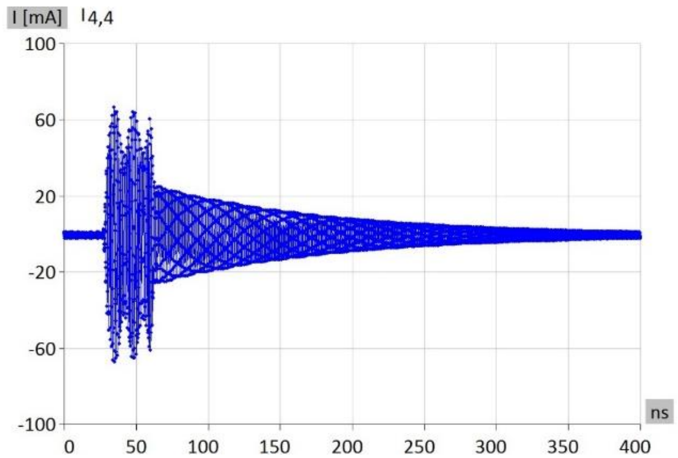
Excitation signal in time domain

The required results involve coupling matrix in frequency domain, but also the received pulses in time domain.



Coupling between reader and tags

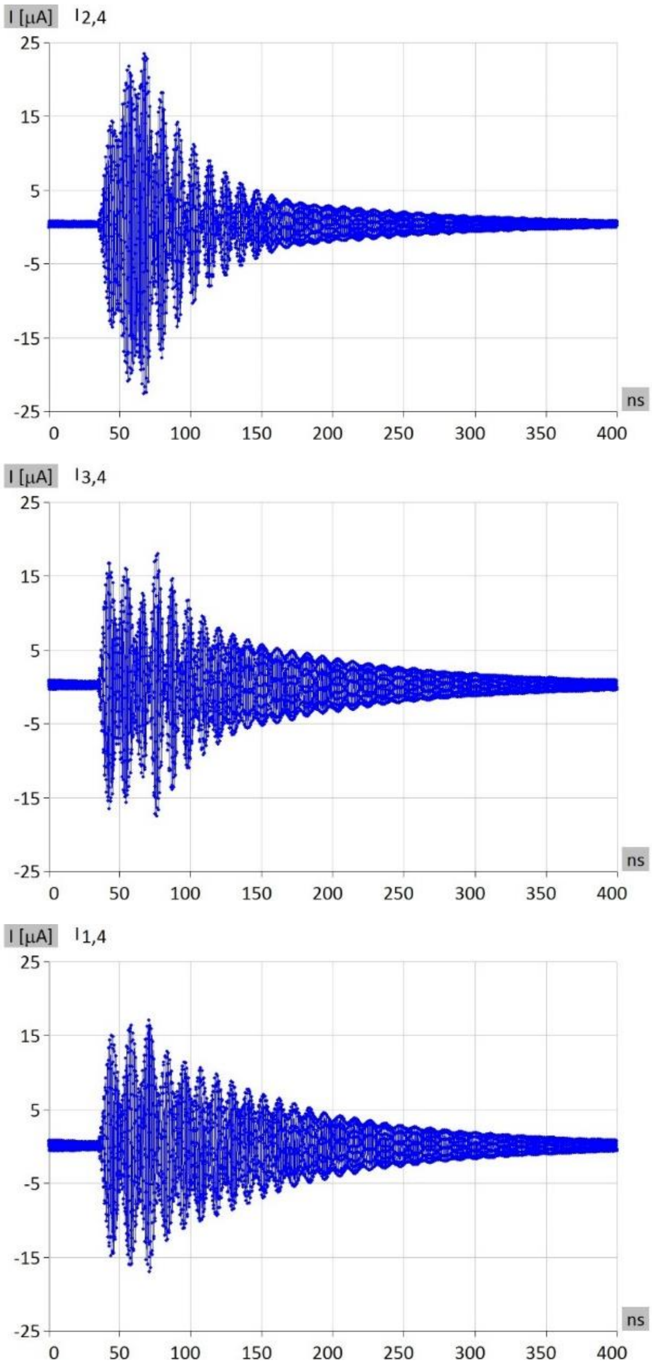
The trapezoidal pulse is modulated with 1 GHz carrier, determining the frequency of the simulation. **The entire scenario requires under 50,000 unknown coefficients**. Such simulation can be carried out in a **couple of minutes per frequency point**. The required hardware is a **desktop PC equipped with moderate CUDA enabled GPU card**.



Radiated impulse

First, we show the time domain of the radiated impulse. This is basically the input current at the Tx port. Narrowband antenna yields long “tail” of the excitation impulse (see above figure).

Next is shown induced currents on Rx ports. Current is in µA, while the Tx power is mA. Signal is delayed for ~6 ns, again with a long tail cause of narrowband antennas.



The received signals

Conclusion

In the application note “RFID Applications” we have shown several RFID designs. Here we extend the work by showing some typical reader/tag design, observations on flexible substrates and miniaturization, as well as realistic RFIF scenario.

Relatively simple, **most common, RFID reader designs are solved instantly with very low number of unknowns at regular desktop/laptop PC**. Even a **more advanced scenario** with complex devices, involving coupling between two antennas, is **solved in minutes**. Well known RFID tag designs are even less complex for simulations. Advanced scenarios show wrapping elongated meandered tag around human wrist and study of the performance. Another scenario shows **accurate simulation and optimization** of simple RFID tag with ε_r=40 to minimize the dimensions.

The most complex simulation shows RFID tags mounted on plastic containers, RFID reader spaced 2 m apart. the results of interest are coupling between antennas and time domain responses of these narrow-band antennas. **the simulation requirements do not depend on distance between antennas since there is no bounding box. The space between antennas is not meshed** and does not contribute to solution complexity.