Direction Finding Antenna (DFA)

Introduction

Magnetic antenna system [1], patent by G. Wennerberg, is efficiently used as direction finding antenna (DFA). This invention relates to magnetic systems, and more particularly to an improved magnetic antenna, suitable for mounting on an aircraft (the antenna employs no moving parts).

WIPL-D Pro is well-known **full wave 3D EM solver**, based on method of moments (MoM) and empowered with quadrilateral mesh and high-order basis function (HOBFs). Also, WIPL-D offers very **efficient CPU and GPU simulation** on inexpensive hardware platforms.

MoM codes are often challenged when the simulated device is electrically moderate or small. For such simulation, other simulation methods (such as FEM, FDTD) are also used. In this particular application note, we demonstrate that WIPL-D, the state-of-the-art MoM code **can be used for electrically small structure efficiently**, with extremely accurate and fast simulation.

WIPL-D Model of DFA

The antenna structure (WIPL-D model) is shown in Figure 1. The DFA antenna consists of relatively fat wires covering the square magnetic element. The most relevant parameters are given in Table 1. The distance between the wires is approximately $\mathrm{d} = 6\ mm$.

Parameter	Value
L	118 mm
H	4 mm
μ_r	900
σ	0.1 S/m

Table 1. The most relevant parameters of the DFA.

Feeding area of the DFA is displayed in Figure 2. The feeding area shows that the DFA actually consist of 2 **coils wrapped around the magnetic material** (the coils are winded in the orthogonal direction). In order to reduce the coupling between the two coils, the feeding area is also orthogonal. Thus, the model has 2 ports with identical input impedance, and with low coupling between the two ports (low S_{21}).

WIPL-D Simulation and Results

Radius if the wire modeled in this challenging EM simulation is 0.25 mm. In order to efficiently include all the EM effects, the wires are modelled using WIPL-D Pro built-in object - *Body of Revolution* (BoR). The smallest dimension of the mesh element is directly proportional to the wire radius. Since we use 8 segments to model wire radius, the smallest mesh detail is only around 0.2 mm large.

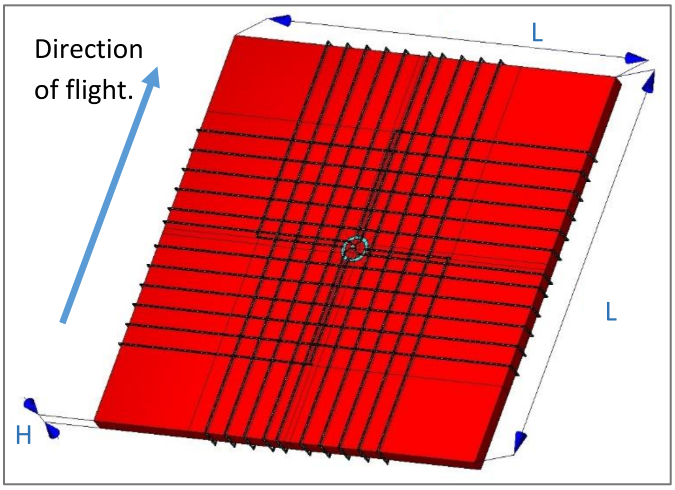

Figure 1. WIPL-D model of the DFA.

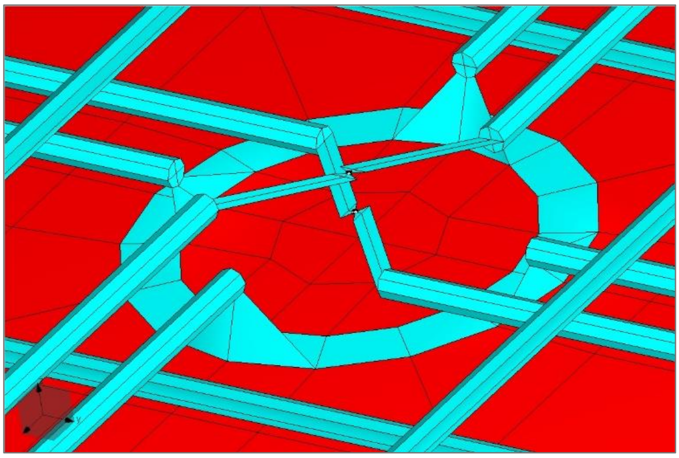

Figure 2. DFA feeding area.

The model is simulated from 190 kHz to 535kHz. At 190 kHz, the wavelength in air is 1,580,000 mm or 1.58 km. The mesh element which is 0.2 mm large represents approximately 1/8,000,000 fraction of lambda. Typically, this is **very challenging problem for the MoM codes**. Owing to **special techniques for increased numerical stability** introduced in WIPL-D Pro v12 and later, for the very low frequency problems is mostly enough to use the double precision. This leads to sufficiently accurate results. As a convergence test, it is enough to test the parameter Integral accuracy and to test whether increasing this parameter to *Enhanced 1* or higher levels has any influence. In this particular simulation, the default Integral accuracy value parameter (*normal*) yields accurate results.

All the parts of the wire coil are quite near the surface of the **magnetic material with rather high permeability**. The only requirement for such a simulation is to implement the **imaging technique**, where the mesh of the dielectric surface (magnetic material surface) is the same (very similar) as the mesh of the coil contours.

Simulation results of interests are imaginary part of Z_{11} and magnitude of S_{21} in decibels. Due to **powerful built-in algorithm for interpolation** of S-parameters, it is sufficient to simulate very low number of frequency points (in this example 5 frequency points is enough).

Number of unknowns is equal to 10,756. EM simulations were performed on used a regular desktop computer with 4 cores (8 threads) Intel Core i7-7700 at 3.60 GHz. Simulation time per simulated frequency is 312 sec. Simulation results are shown in Figures 3-4.

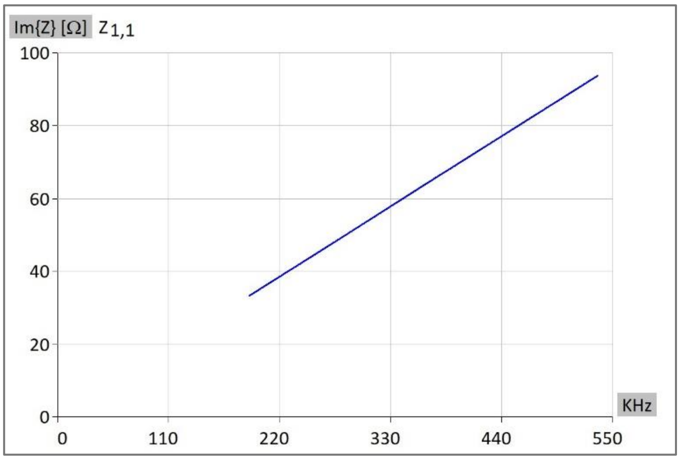

Figure 3. Imaginary part of Z_{11}.

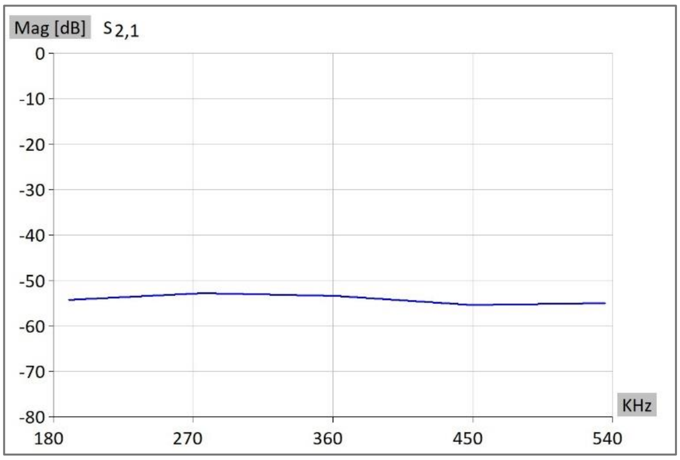

Figure 4. Magnitude of S_{21} in decibels.

Conclusion

The application note demonstrated that **WIPL-D Pro can be efficiently used for extremely low frequency simulations which are not the default application of MoM**. The special techniques for treatment of low frequency problems allow the **accurate simulations to be performed** in WIPL-D software with the default settings and the double precision for storing the MoM system matrix.

No expensive hardware is needed; the simulation can be carried out at regular desktop PC or laptop. The simulation accuracy is extraordinary, showing the -60 dB levels for coupling between the two antenna ports.

References

[1] G. Wennerberg, “Magnetic Antenna Systems” U.S. Patent 3,031,663, issued April 24, 1962

https://patents.google.com/patent/US3031663