Dielectric Resonator Filter [Verified by Measurements]

The aim of this white paper is to present the possibilities for modeling, simulation and adjusting of a dielectric resonator filter in WIPL-D software environment. Using a variety of WIPL-D features, rather complex model of the DRF can be easily designed and efficiently simulated.

This paper describes the realization of a 2.3 GHz band filter using dual-mode dielectric resonators for cellular communications. These filters are a new and exciting technology in the microwave filter industry. The filters capitalize on the inherent property of dual-mode dielectric resonators to exhibit two resonances. Dual-mode DR filters are superior to single-mode DR filters, but they are more complex and harder to simulate, design and implement.

The property of having two modes can be exploited to develop filters that have the same advantages of single-mode dielectric filters while also exhibit better performances, as well as small size and mass with fewer components and, therefore, they are less expensive to manufacture.

The simulations repeat the simulations and measurements reported in [1], starting from the simplest cavity models, them progressing to models with puck and numerous required additions.

Dielectric resonator inside single cavity

At the resonant frequency most of the electromagnetic energy is stored within the dielectric resonator. The support is used to ensure that there is no contact between the puck and the enclosure. The enclosure acts as a shield to prevent radiation and due to the puck's remoteness the resonant frequency is controlled by its cross sectional area and permittivity constant. The shape of puck used in this example is shown in Figure 1.

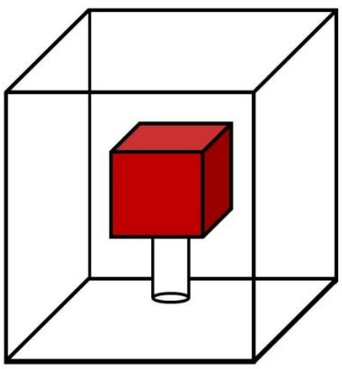

Figure 1. Shape of dielectric puck.

Figure 2 shows the first and basic simulation of the dielectric puck inside of the metallic cavity. The model is fed by coaxial cable whose "hot" end is curved to form a loop exciting the cavity.

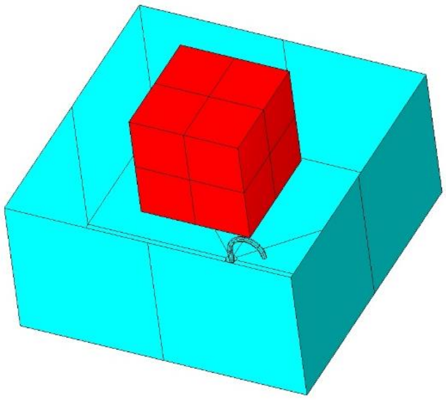

Figure 2. Basic model in WIPL-D Pro

The resonance is simulated at 2.04 GHz, identical value as the measured resonance.

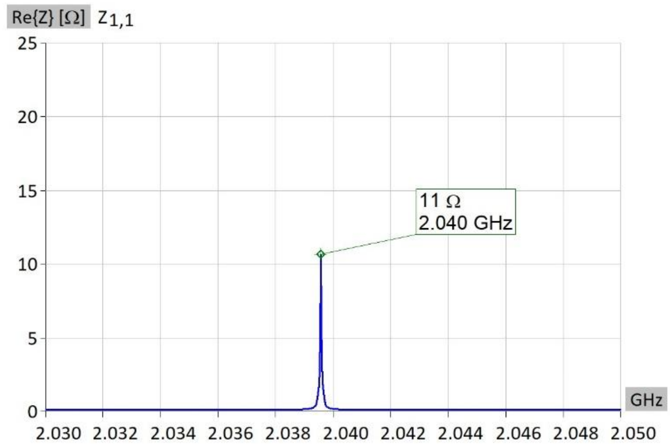

Figure 3. Resonance of single cavity with simple dielectric puck, predicted exactly as the measurements

The model is simulated as symmetrical and requires only 425 unknowns. Simulation is carried out at split of the second at any given standard desktop or laptop PC.

In the next step, the dielectric puck is hollow, a cylindrical hole is cut of it as in Figure 4.

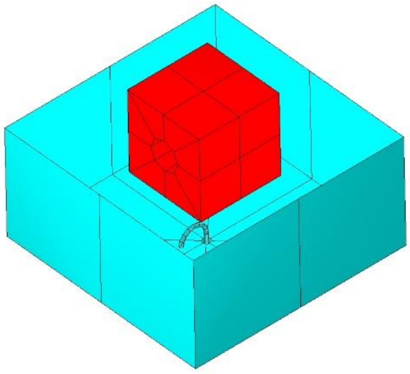

Figure 4. Single cavity with dielectric puck, the hole is drilled in the middle of the puck

The resonance shifts to 2.23 GHz, while measurements predict 2.22 GHz. Number of unknowns is increased to 545 only, simulations remain instantaneous. Simply to show the variety of WIPL-D outputs, this time we present return loss instead of real part of impedance.

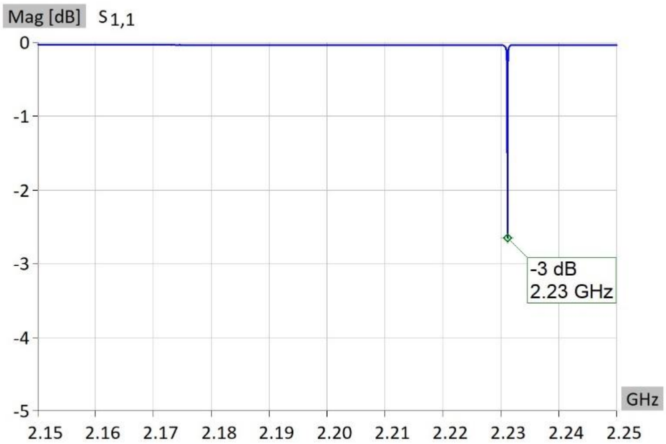

Figure 5. Resonance of single cavity with hollow dielectric puck, predicted almost exactly as the measurements

As a final test to confirm the validity of simulation, we use the fact that the WIPL-D model is fully parametrized. WIPL-D Sweeper can be used for sweep of puck length. The simulations are so short that we get the resonance for each puck length and we demonstrate how the puck controls the cavity filter.

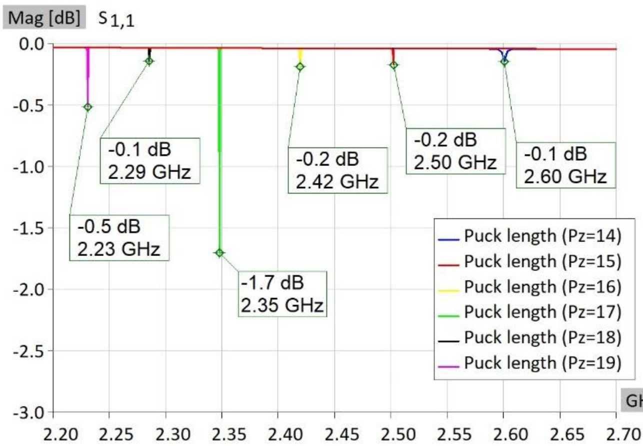

Figure 6. Resonance of single cavity with hollow dielectric puck, controlled by puck length

Single Cavity Filter

The next step is to model single cavity filter with the goal post, dielectric puck and tuning screws.

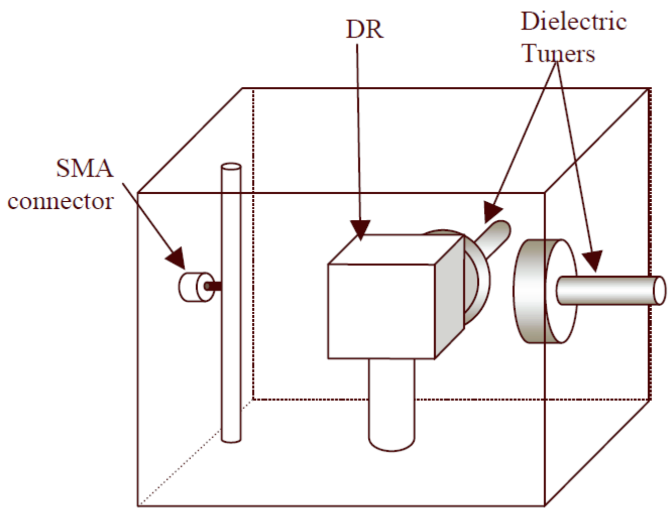

Figure 7. Single cavity filter sketch [1].

The filter prototype is shown in the following image.

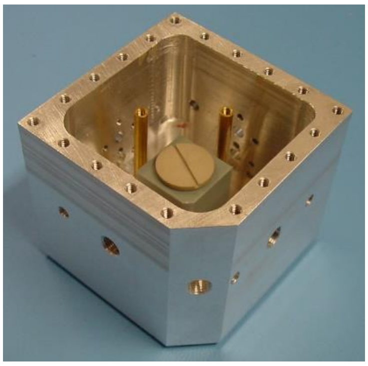

Figure 8. Single cavity filter photo [1].

The interior of the WIPL-D model is shown next.

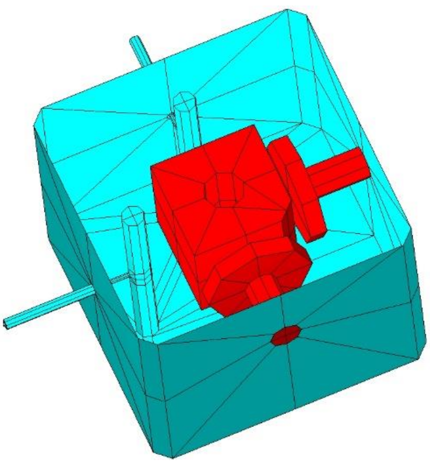

Figure 9. Interior of single cavity dielectric resonator filter.

The dimensions of the cavity are 50 mm x 50 mm x 40 mm. The resonating frequency should be roughly between 2 and 3 GHz.

Transformer is used to replace the wire probe. The transformer is a rod made of metal, smaller than the length of the cavity, with a hole at the bottom to enable fixing to the cavity. It is placed vertically in cavities to couple to the electric field of the dual-mode resonance. The details of the feeding are presented in Figure 10.

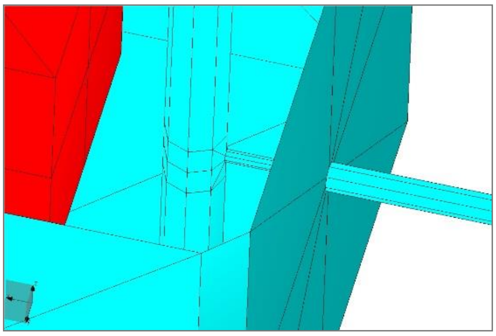

Figure 10. Transformer used for feeding of the structure.

Two dielectric tuners are used in each cavity to control the resonant frequency. They are cubes (19 mm x 19 mm x 19 mm) made on high quality ceramics with Er = 44 and TgD = 10^{-5}. Support for the dielectric tuners is made from alumina (Er = 9.8 and TgD = 10^{-4}).

The return loss at both ports (identical) and transmission is shown in the following image.

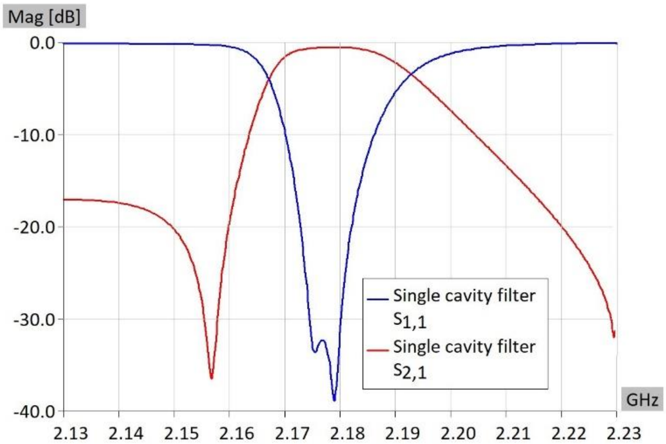

Figure 11. S11 and S21 of single cavity filter, predicted exactly as the measurements.

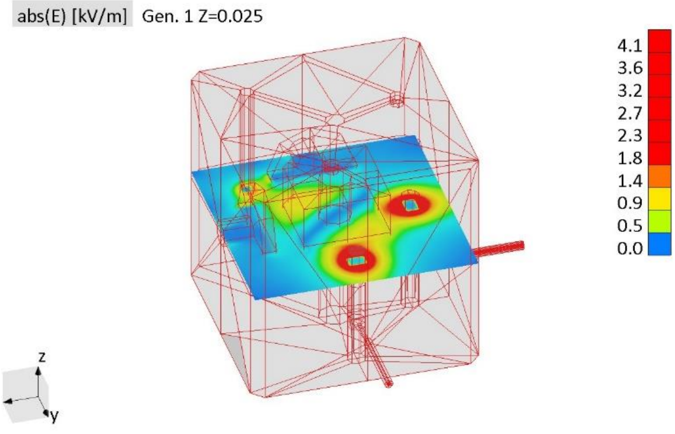

Figure 12. Near field inside of single cavity filter.

The model requires 2,601 unknowns and lasts 3 seconds per frequency point at regular desktop PC Intel i7 7700 3.60 GHz. It is enough to simulate 11 frequency points owing to powerful built in interpolation.

Dual Cavity Filter

An example used to fully expose the wide variety of WIPL-D unique features is a dielectric resonator filter with 2 separate cavities, which are coupled in a rather specific way. Thus, this filter is a four-section, two-cavity filter. Filter layout is presented in Figure 13.

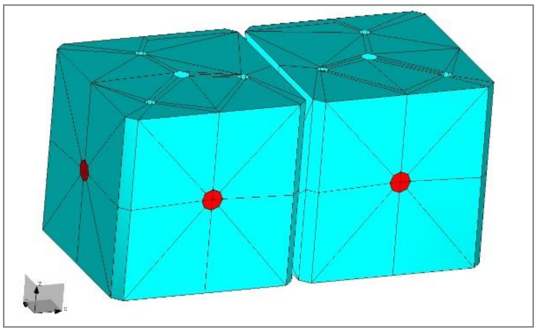

Figure 13. Layout of two cavity dielectric resonator filter.

The interior of the filter is presented in Figure 14.

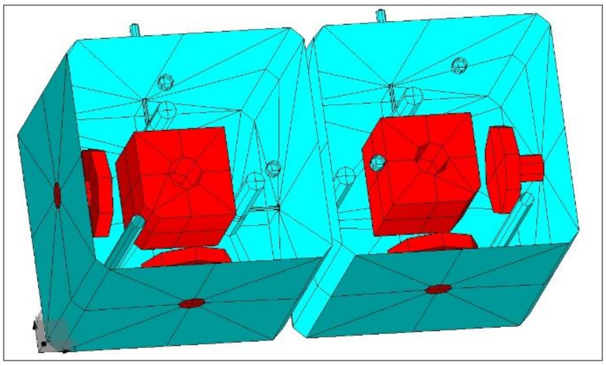

Figure 14. Interior of dielectric resonator filter.

The filter is modeled as symmetrical and the distance between dielectric tuner and the dielectric puck is the main factor used to control the filter response (Figure 15).

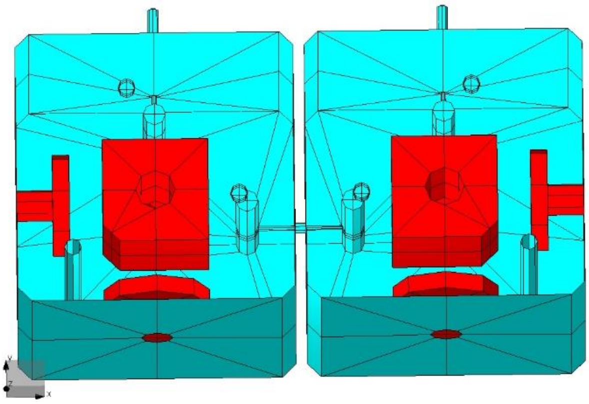

Figure 15. Coupling distance between dielectric objects.

The actual model (prototype) of the filter that was designed in WIPL-D is presented in Figure 16.

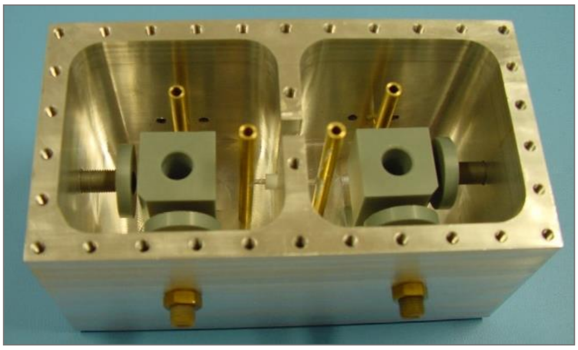

Figure 16. Prototype of the filter.

“Goal-post” inter-cavity coupling design was implemented below (Figure 17). A piece of wire was inserted into a tube of Teflon and set up across the two transformers in the different cavities.

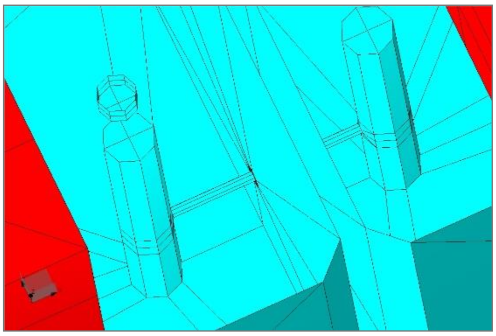

Figure 17. “Goal-post” coupling between the cavities.

The complete filter arrangement has two identical mirrored cavities joined by a narrow, short iris with the “goal-post” transformers (Figures 14-17). The model was created using WIPL-D objects:

- *BoR*s and *Circle*s for transformers, pucks and transformers
- *BoCG*s for the walls of the cavities.

The complete model is parameterized. Hence, the power of WIPL-D Optimizer can be used to tune the filter.

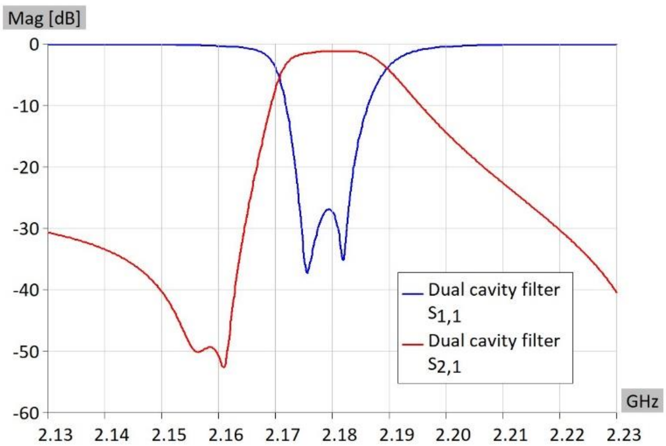

Figure 18. Return loss and transmission.

Near field and return loss calculation are presented in Figures 18-19. The model requires approximately 4,000 unknowns and around 3 minutes per frequency to be simulated.

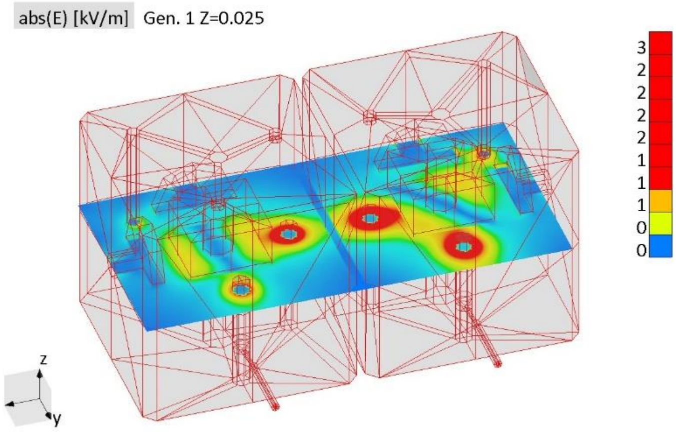

Figure 19. The strength of the electric field.

The model requires 5,044 unknowns and lasts 7 seconds per frequency at Intel i7 7700 3.60 GHz.

Conclusion

The application note deals with complex dielectric resonator filters with numerous tuning elements. Careful comparison to measured results is carried out in each step. The story unfolds from a simple single cavity with the loop made of coax cable. The cubic dielectric puck is inserted at the middle to modify the resonance.

In the next step, the puck is hollow, which changes the resonance again. WIPL-D sweeper is used to demonstrate how the resonance shifts by merely changing puck length. Such models are simple and the simulation is carried out in seconds in the entire frequency band.

Single cavity with solid puck is the most important model. It is tuned to achieve a wide and deep resonance, which coincide with the measured results. A single cavity model is very fast and lasts only a couple of seconds per frequency point, where powerful built-in interpolation allows using only 11 frequency points.

In the last step, a single cavity is mirrored and connected to the second cavity with goal post. The simulation is still carried out in seconds per frequency point at regular desktop or laptop PC.

References

[1]
http://innovexpo.itee.uq.edu.au/2001/projects/s369481/thesis.pdf

Dual Mode Dielectric Resonator Filters by Samantha Kerr

Thesis submitted for the degree of Bachelor of Engineering (Honours), Department of ITEE, In the Division of Electrical Engineering (Biomedical Minor), The University of Queensland