MICROWAVE FILTERS

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INTRODUCTION

- Microwave filters are designed to selectively pass certain frequencies of electromagnetic signals while attenuating or blocking others. They help ensure that the desired signal bandwidth is transmitted accurately while minimizing interference from neighboring frequency bands.

- Filters are employed in various applications, including wireless communication systems, satellite communication, radar systems, electronic warfare, and test and measurement equipment.

For our project , we simulated four type of filters for Gigahertz and Terahertz frequencies.

- Capacitively-Coupled Resonators for Terahertz Planar-Goubau-Line Filters
- Dual split resonator lowpass filter with ultrawide stopband and sharp roll-off Rate.
- Improved Frequency Response of Microstrip Lowpass Filter Using Defected Ground Structures.
- Design of THz low pass filter using split-ring resonator

CAPACITIVELY-COUPLED RESONATORS FOR TERAHERTZ PLANAR-GOUBAU-LINE FILTERS

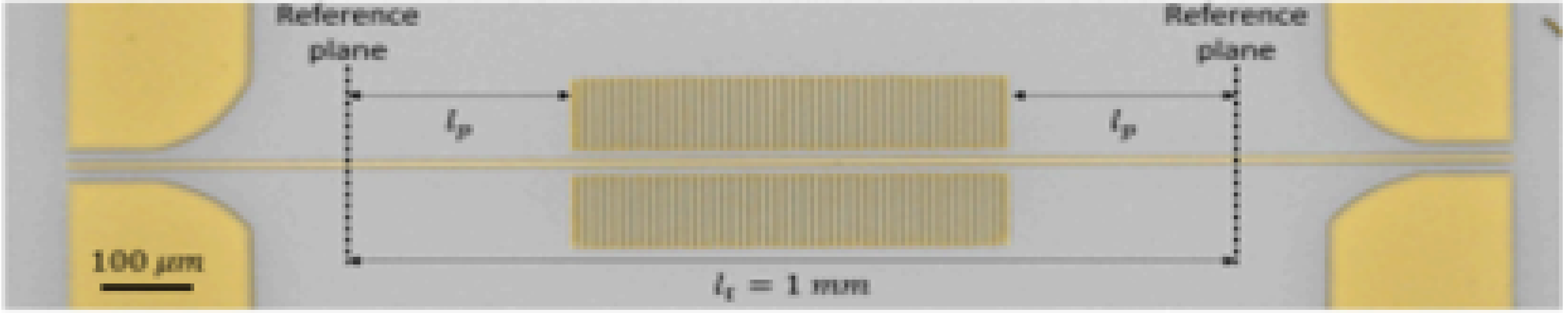
VISION

1. Introduction to THz technology and the interest in planar Goubau lines:
   - THz technology holds promise for various applications.
   - Planar Goubau lines have attracted attention due to their low-loss properties.
2. Challenges posed by single-wire waveguides in component development:
   - Single-wire waveguides limit design flexibility for standardized components.
   - Overcoming these limitations is crucial for practical implementations.
3. Research objective: Design and implement a tailored bandpass/bandstop filter:
   - The study aims to address the need for standardized components in THz technology.
   - Focus is on developing a filter optimized for planar Goubau lines.
4. Definition of Planar Goubau Line Filters (PGLFs) and their structure:
   - PGLFs operate by guiding electromagnetic waves along planar Goubau lines.
   - Structure consists of a conductive strip above a dielectric substrate.

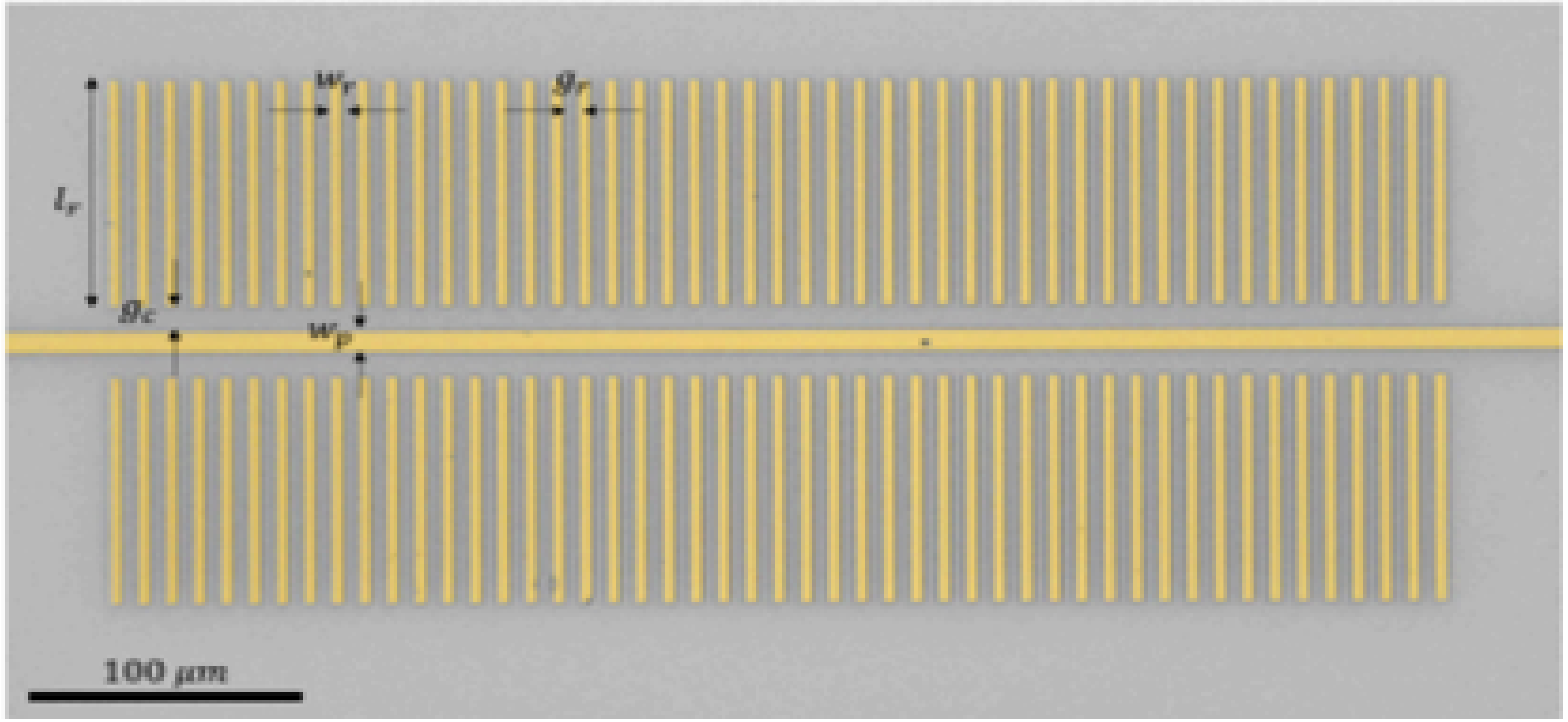
5. Unique propagation characteristics of Goubau waves:
    - Goubau waves exhibit distinct propagation behavior along the interface.
    - Characteristics include low radiation losses and strong field penetration.
6. Innovation: Integration of periodically loaded capacitively-coupled λ/2 resonators:
    - Resonators are strategically incorporated to enhance filter tunability.
    - Electrical length manipulation offers unprecedented flexibility in design.
7. Introduction of a sophisticated transmission-line model:
    - A transmission-line model is introduced to elucidate filter operation.
    - Model reveals the intricate interplay between resonator loading and wave propagation.
8. Significance of the novel approach in filter design optimization:
    - The novel approach overcomes constraints of single-wire waveguides.
    - Transmission-line model enables precise optimization and fine-tuning of filter design.

DESIGN

- Substrate is characterized by a bulk permittivity of εr = 11.7
- Tangent loss tan δ = 1.7 × 10−5
- Gold as a conductor (σ = 4.1 × 107 S/m)
- Large strip width of wp = 10μm --decreases conductor loss
- The resonator width and gap we took wr = 5 μm and gr = 5 μm --o guarantee subwavelength structure and operate well below the Bragg frequency
- Coupling gap of gc = 10 μm


Reference plane
Reference plane
l_p
l_p
100 μm
$l_t = 1\ mm$

(a)


w_r
g_r
l_r
g_c
w_p
100 μm

RESULTS

1. Loss Characteristics: Investigation reveals relatively low attenuation in the fabricated PGL, indicating its potential for THz applications.
2. Filter Performance: Comparison between experimental and simulated S-parameters demonstrates excellent agreement, validating the filter's design and functionality.
3. Band Characteristics: Identification of passband and stopband frequencies, along with their respective bandwidths, provides crucial insights into the filter's frequency response.
4. Insertion Loss: Despite slightly higher insertion loss compared to resonator-free PGLs, the fabricated filter remains competitive for practical THz applications.
5. Challenges and Optimization: Recognition of asymmetrical passband responses and ripple effects highlights the complexity of THz filter design, emphasizing the need for further optimization and refinement.

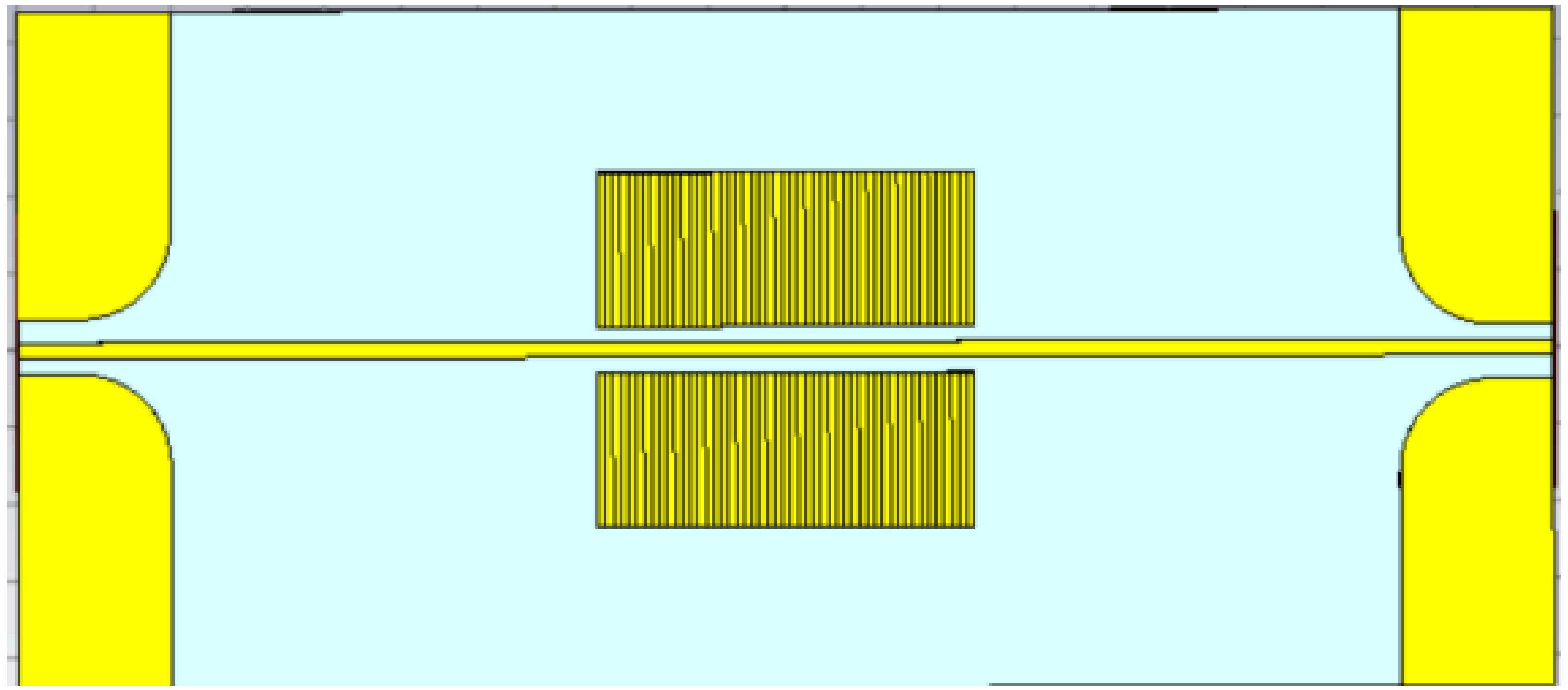
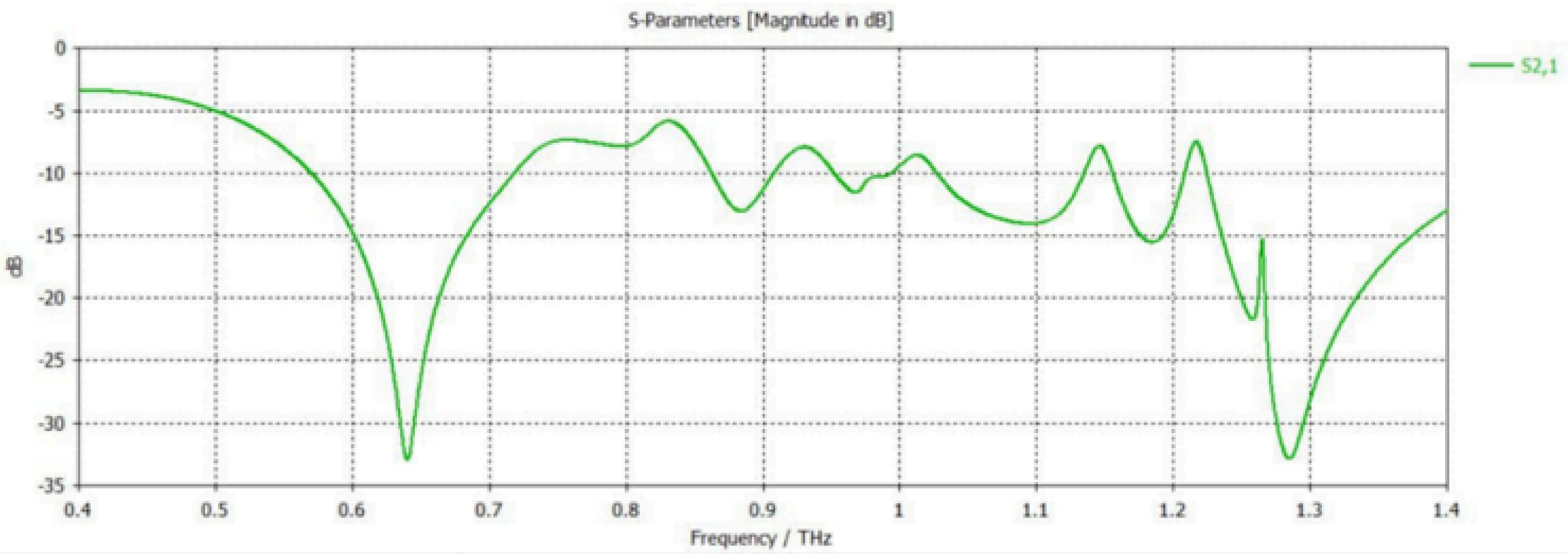


Fig.4.15. Structure of the filter



DUAL SPLIT RESONATOR LOWPASS FILTER WITH ULTRAWIDE STOPBAND AND SHARP ROLL-OFF RATE

- Modern research studies are now searching for novel approaches in the field of filters, as these are the important component for all the circuits which are (narrow or a wide band) frequency-dependent.

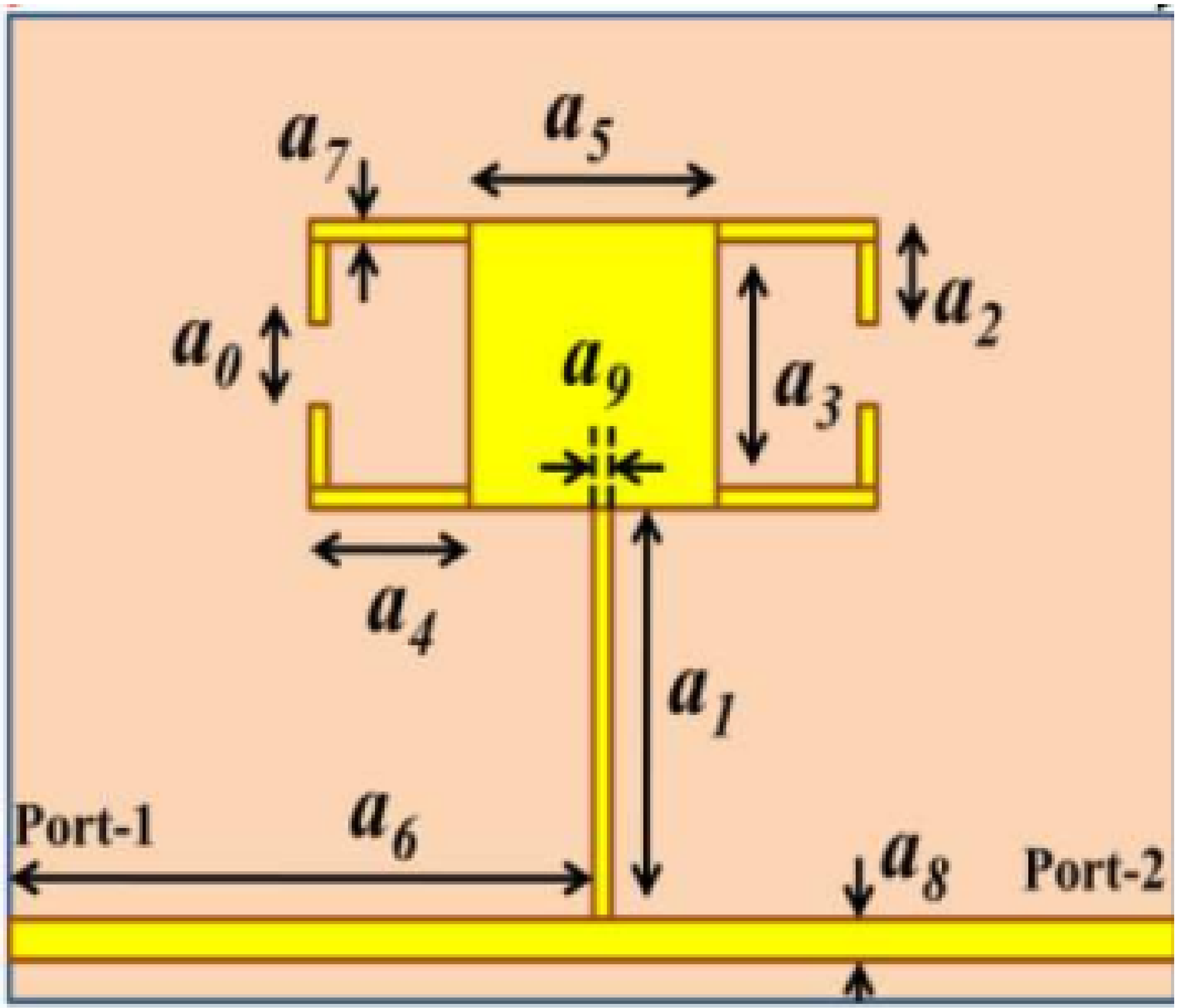
- Split ring resonator (SRR) structures are commonly created with different shapes such as square, circular, and spiral where the frequency response can be improved using such structures. The performance of the conventional lowpass filter can be improved by increasing the number of resonators and lumped elements at the cost of enlarged size and poor passband characteristics

- Usual conventional split-ring resonators show square, circular, or spiral shapes with single split and having high impedance stubs. They show poor performance.
- After the detailed survey of SRR, and other approaches, the design procedures are found to be common by using the SRR with different geometry and etched in the ground plane. The splits in the geometry of resonators can make a difference in the performance characteristics of the filters and the proposed resonators can replace the other SRR for the enhancement in the filter response.

DESIGN

- Conventional constructions of split resonators are by using concentric rectangular loop split rings. Here split resonators (SR-1 and SR-2) with dual splits (DSR-1 and DSR-2) are designed on a substrate with a thickness of 0.79 mm, loss tangent 0.0009 and having a dielectric constant of 2.2 to obtain better coupling and achieve maximum frequency performance

DUAL SPLIT RESONATOR-1 (DSR-1)

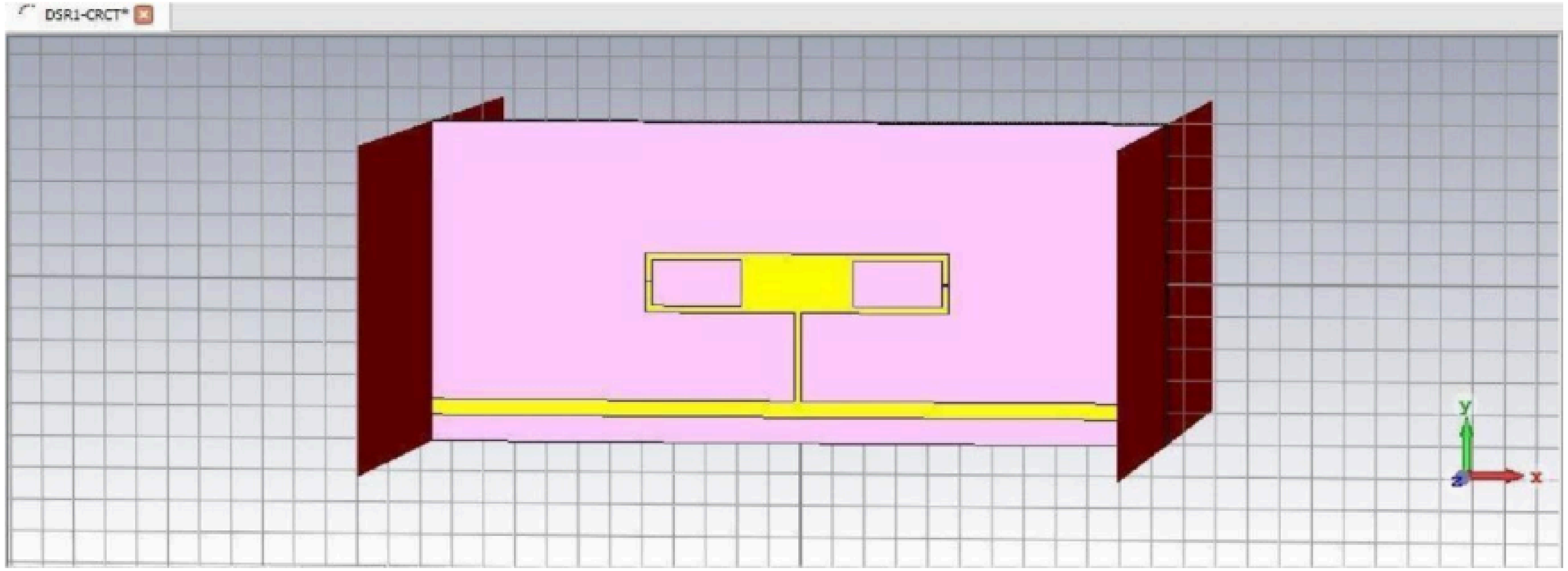


Dimensions of DSR-1

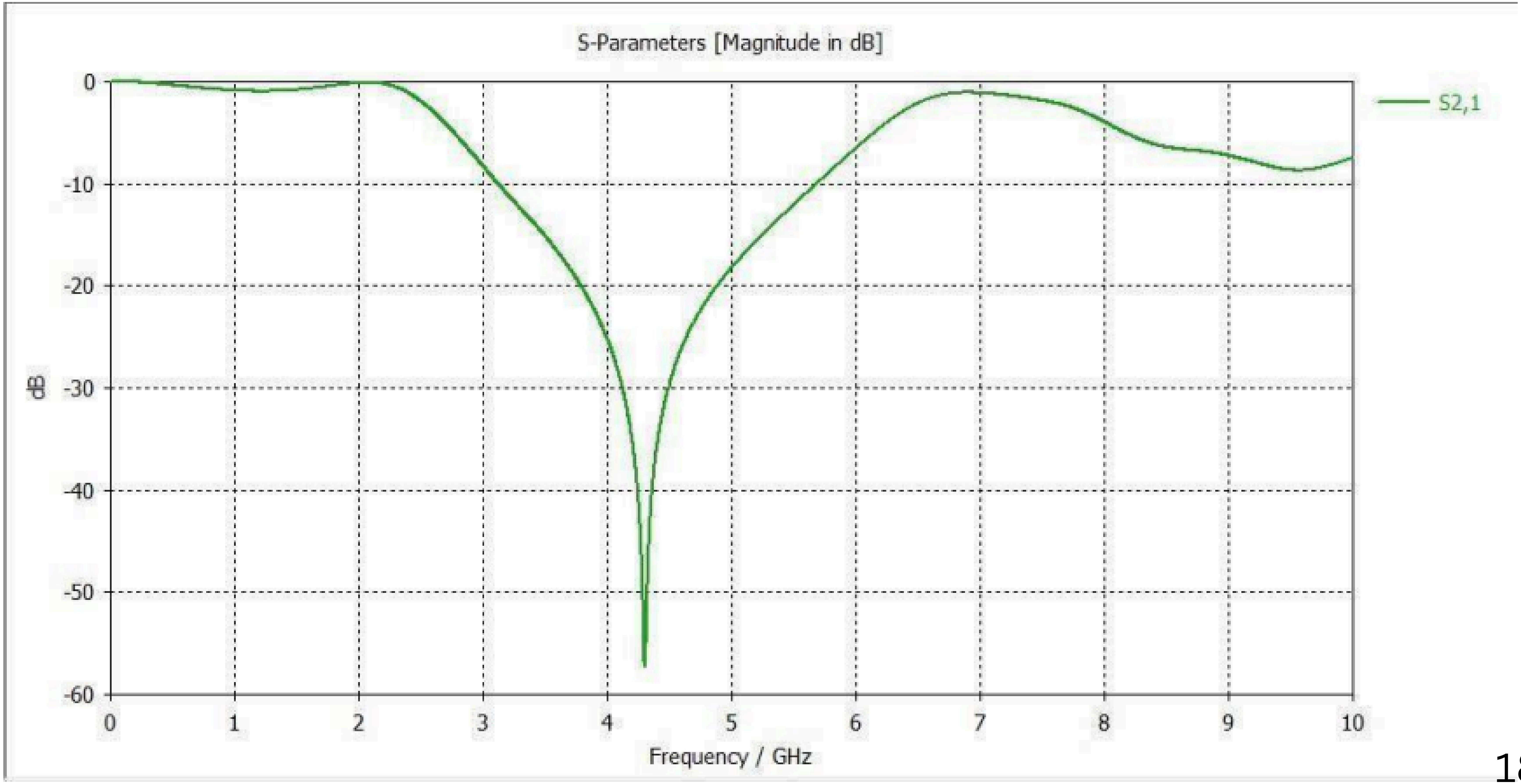
Parameters	Values, mm
a_0	0.75
a_1	2.7
a_2	0.75
a_3	1.85
a_4	3
a_5	3.5
a_6	11.4
a_7	0.2
a_8	0.5
a_9	0.2

- Splits on both sides of a rectangular loop with low impedance patch, which are placed on the high impedance stub constitute DSR-1. Here a0 denotes the splits in the rectangular loop and a5 gives the low impedance patch with ZC1= 38.83 Ω . The loop having splits on both sides are placed on high impedance stub showing a1 and having characteristic impedance of ZL1= 159.03 Ω .

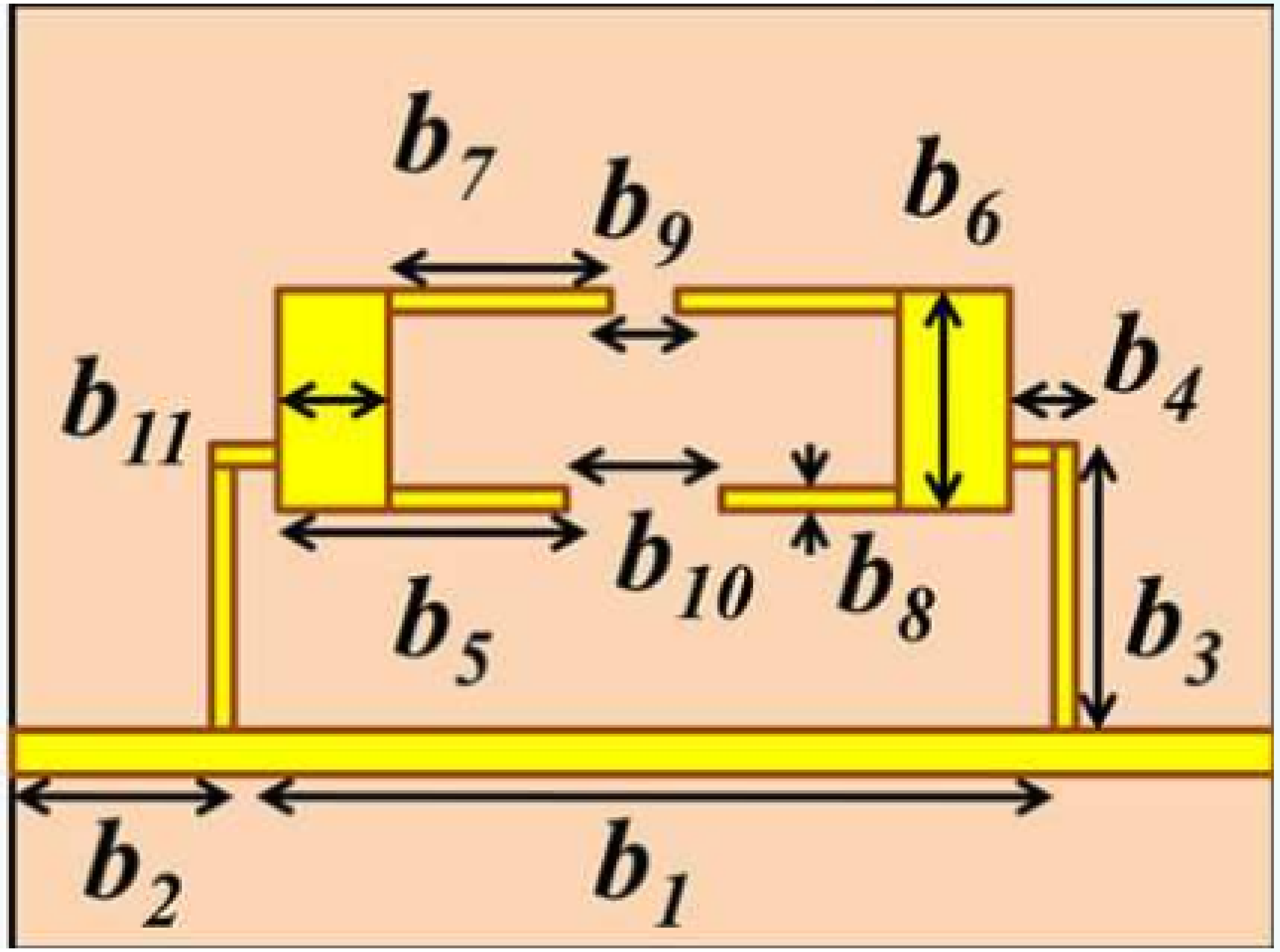
- . DSR-1 resonates at 4.3 GHz.


DSR1-CRCT*
y
z
x

Simulation results of DSR-1 (S21 characteristics)



DUAL SPLIT RESONATOR-2(DSR-2)



Dimensions of DSR-2

Parameters	Values, mm
b_1	10.6
b_2	6
b_3	3.5
b_4	0.5
b_5	4.7
b_6	3.2
b_7	3.15
b_8	0.2
b_9	0.2
b_{10}	0.6
b_{11}	1.75

- The rectangular loop resonator having dual splits on top and bottom form DSR-2. It is placed on a bent high impedance stub shown in Fig.
- The DSR-2 is a rectangular loop with a low-impedance patch on both sides.

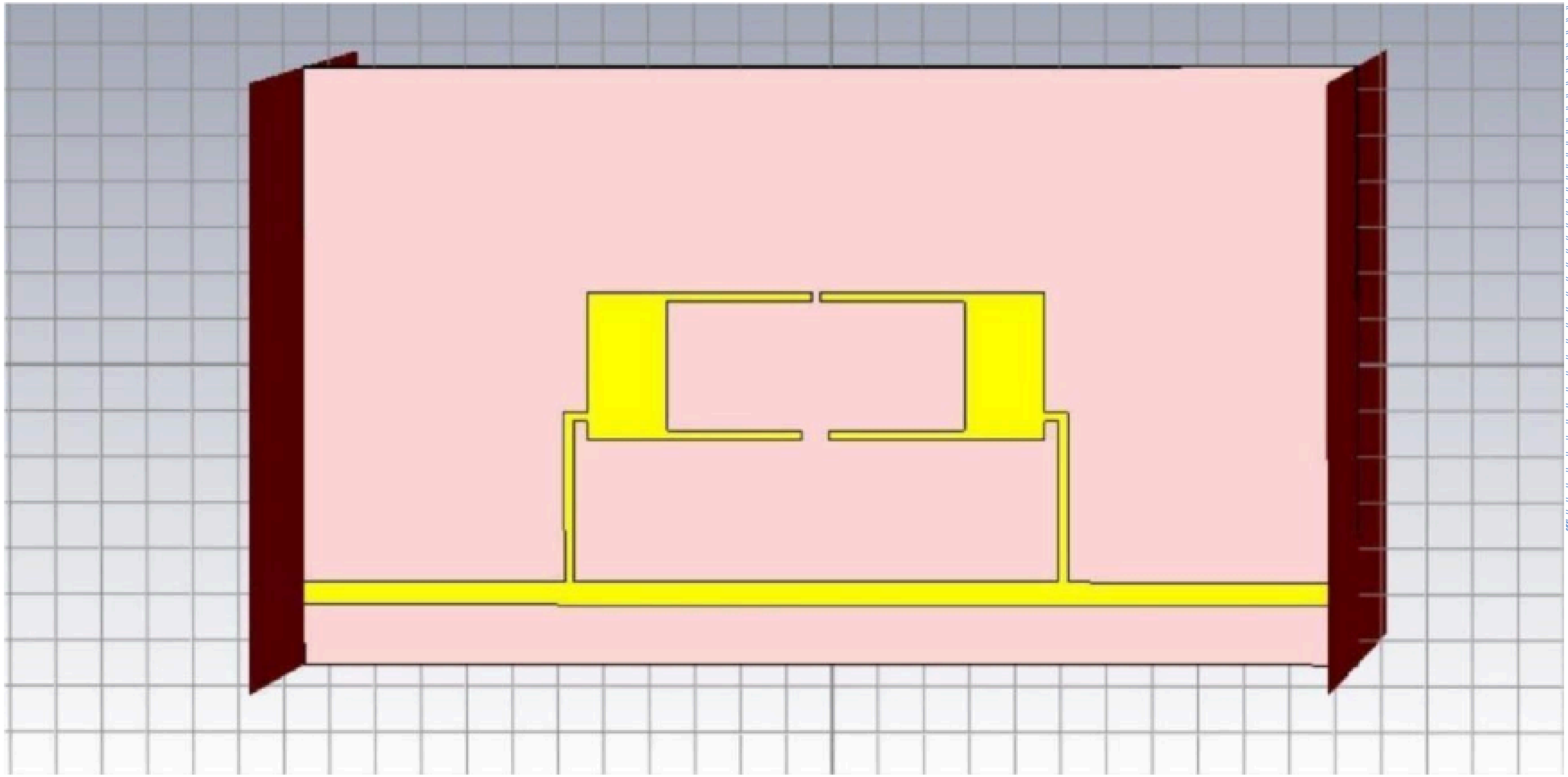
- The proposed DSR-1 and DSR-2 are not regular-shaped structures and EM simulations are encountered with some parasitic effects along with dielectric losses and conductor losses as it comes to the substrate material

- The DSR-2 having resonators designed on both sides achieves two resonances fz1 and fz2 with 35 and 65 dB attenuation, respectively.

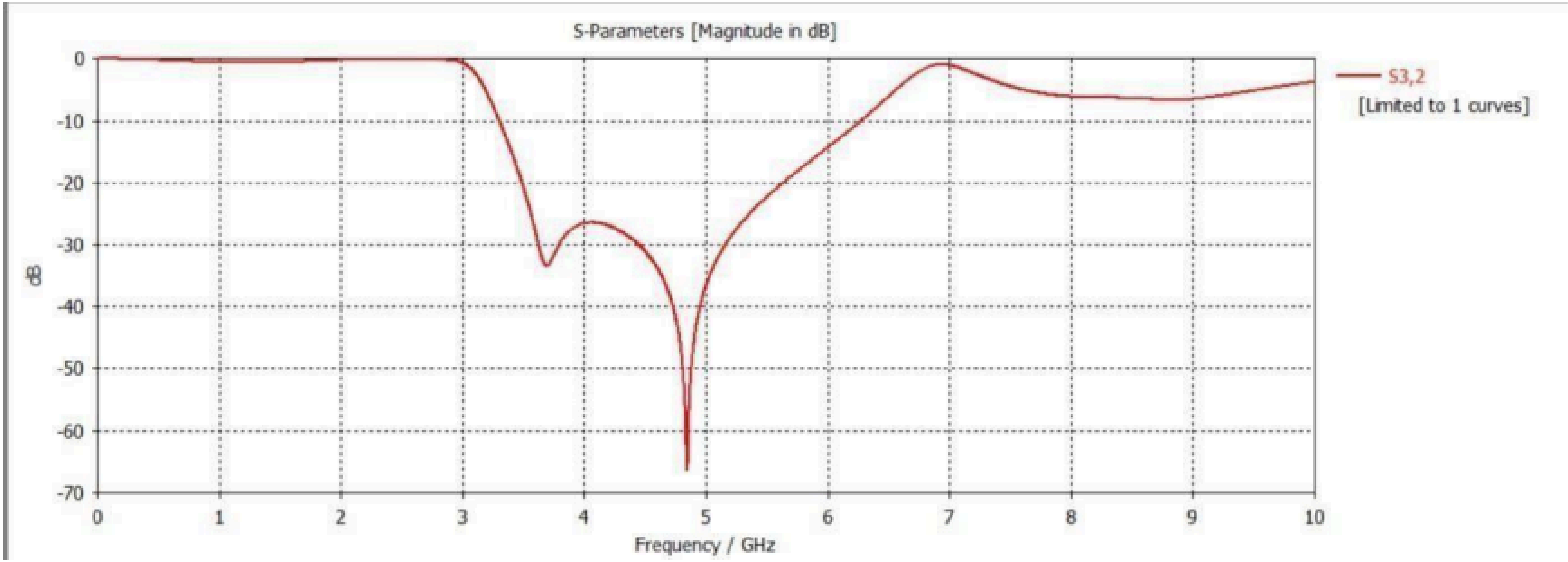
- In this resonator we get two transmission zeros at 4.6GHz and 6 GHz and the output field at 4.6 GHz are found to be higher than 6 GHz.

- It is observed that, according to the dimensions of the loop in the DSR-2, the attenuation level of first and second transmission zero varies.

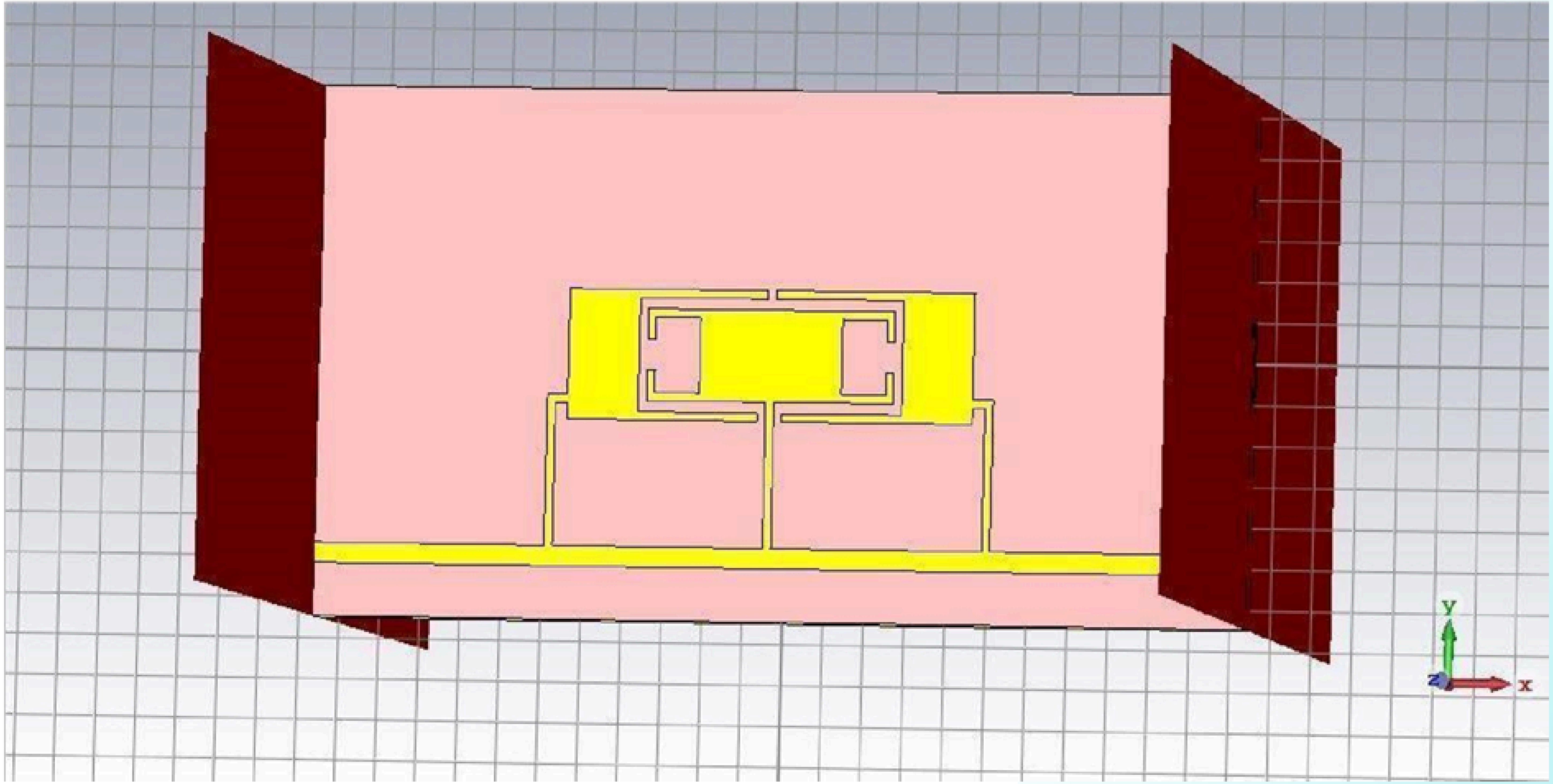
Design of Dual split resonator-2 (DSR-2)



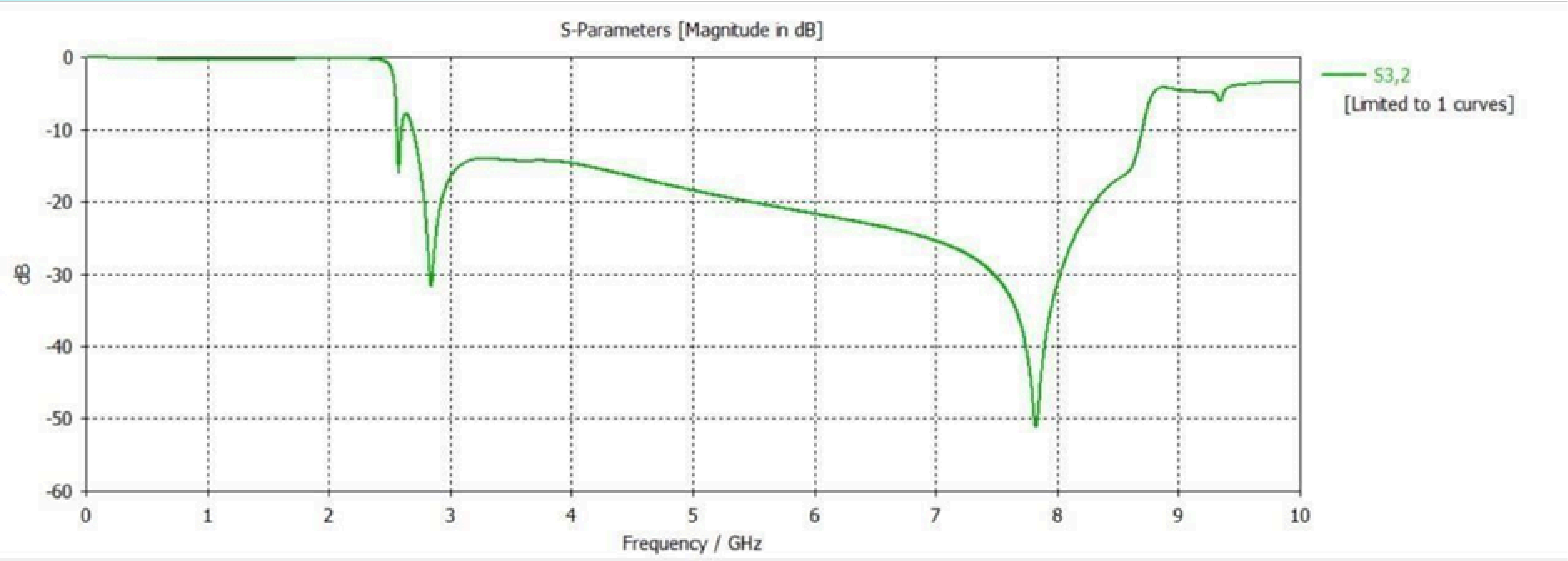
Simulation results of DSR-2 (S21 characteristics)



Analysis of cascaded DSR structure



Cascaded structure of DSR1 and DSR2



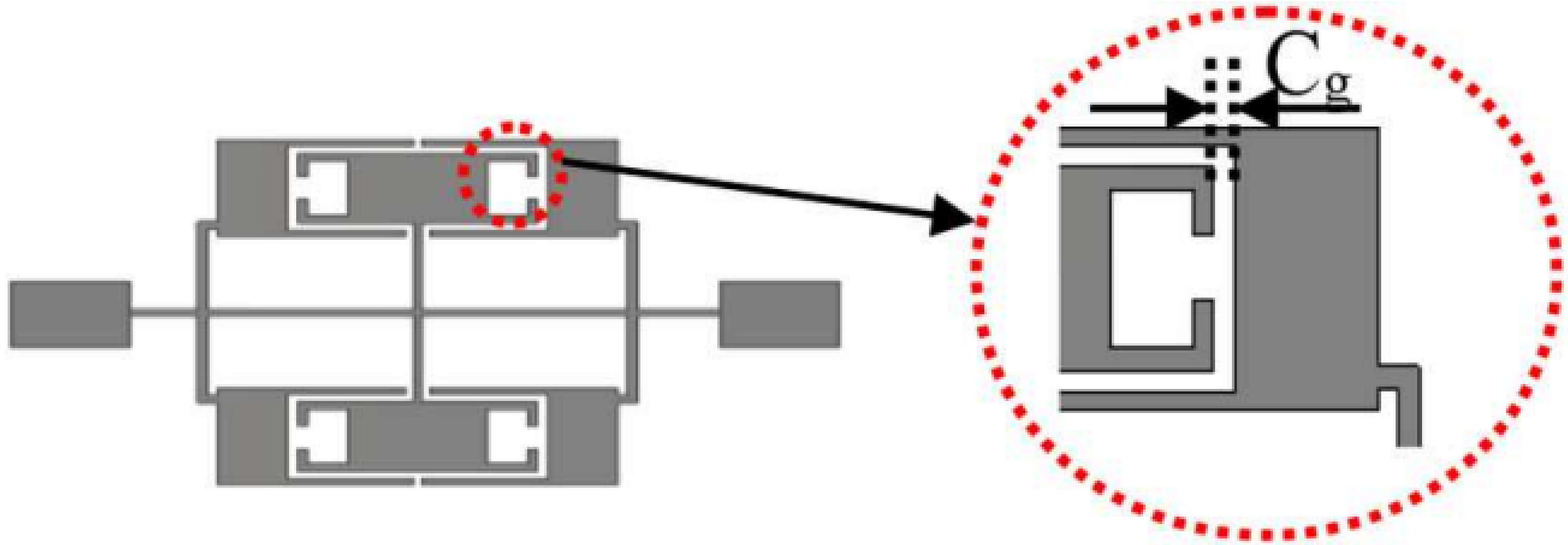
Simulation results of Cascading DSR1 and DSR2

- The DSR structure placed in parallel, on the high impedance transmission line will decrease the effective impedance of the resonator circuit .It also provides further suppression at the stopband and widens the region beyond cut-off frequency.

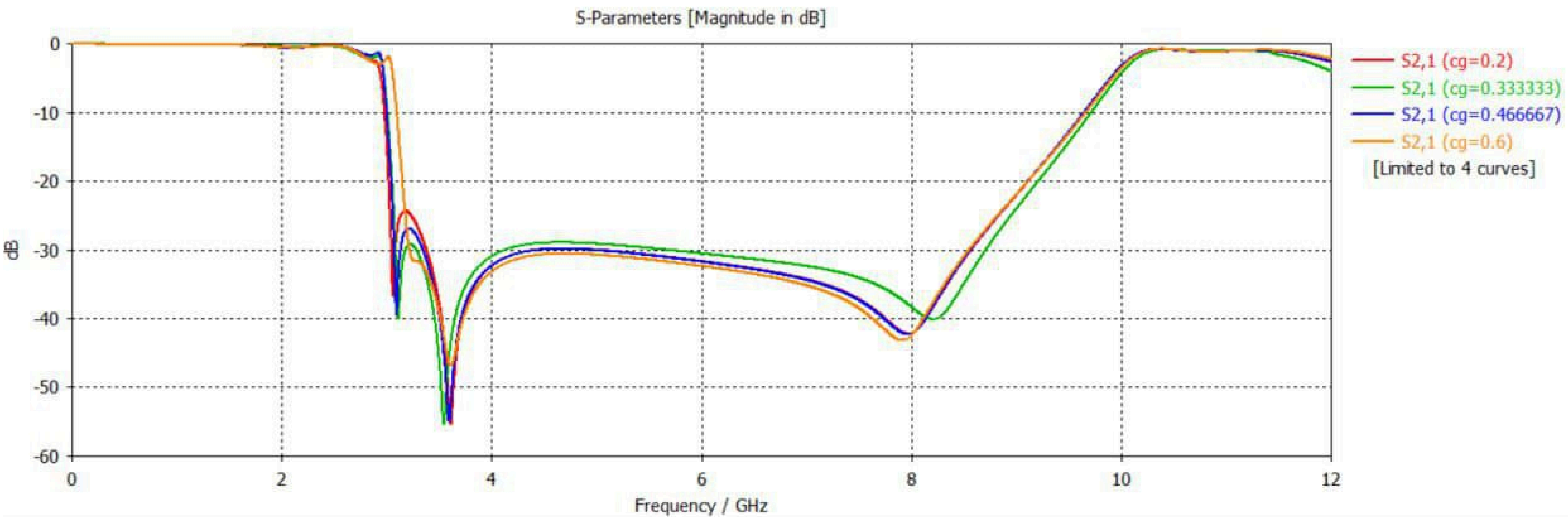
- DSR-1 and DSR-2 are cascaded together after the coupling gap optimization.

- It is observed that the stopband width and the skirt selectivity of the filter are enhanced using the cascaded structure with Cg = 0.2 mm.

- It shifts the first transmission zero from 3.1 to 3.5 GHz on further increase in the coupling gap

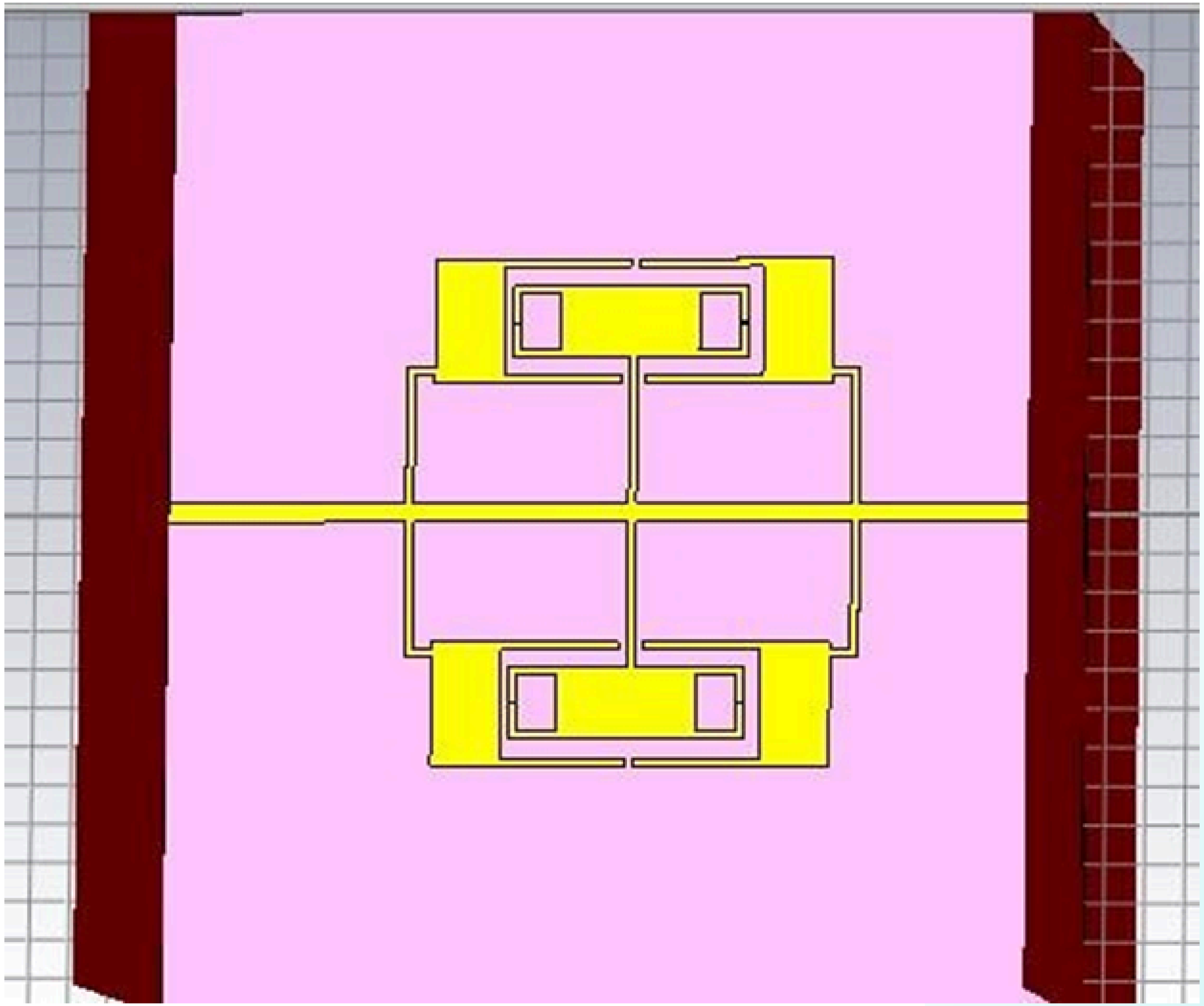


Cg

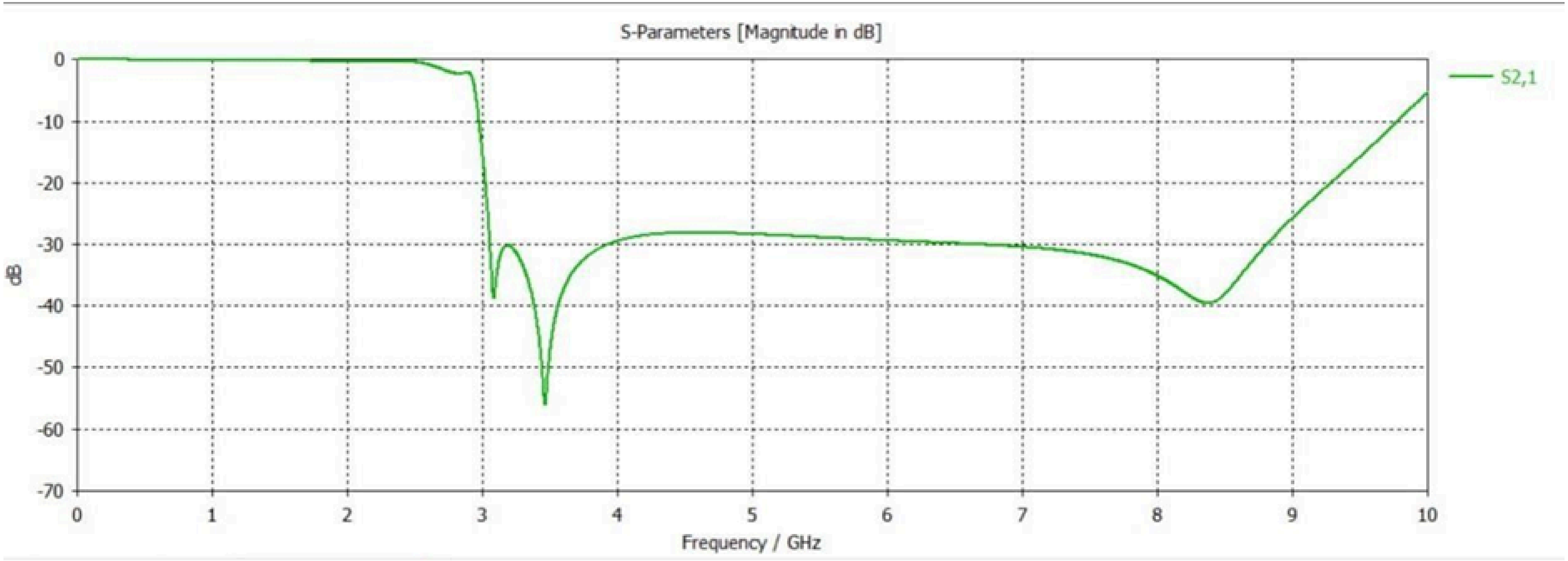


Frequency response of cascaded DSR structure for the variation in Cg

- Shift in first transmission zero from 3.1to 3.5 GHz on further increase from cg=0.2(red curve) to cg=0.6 (orange curve)

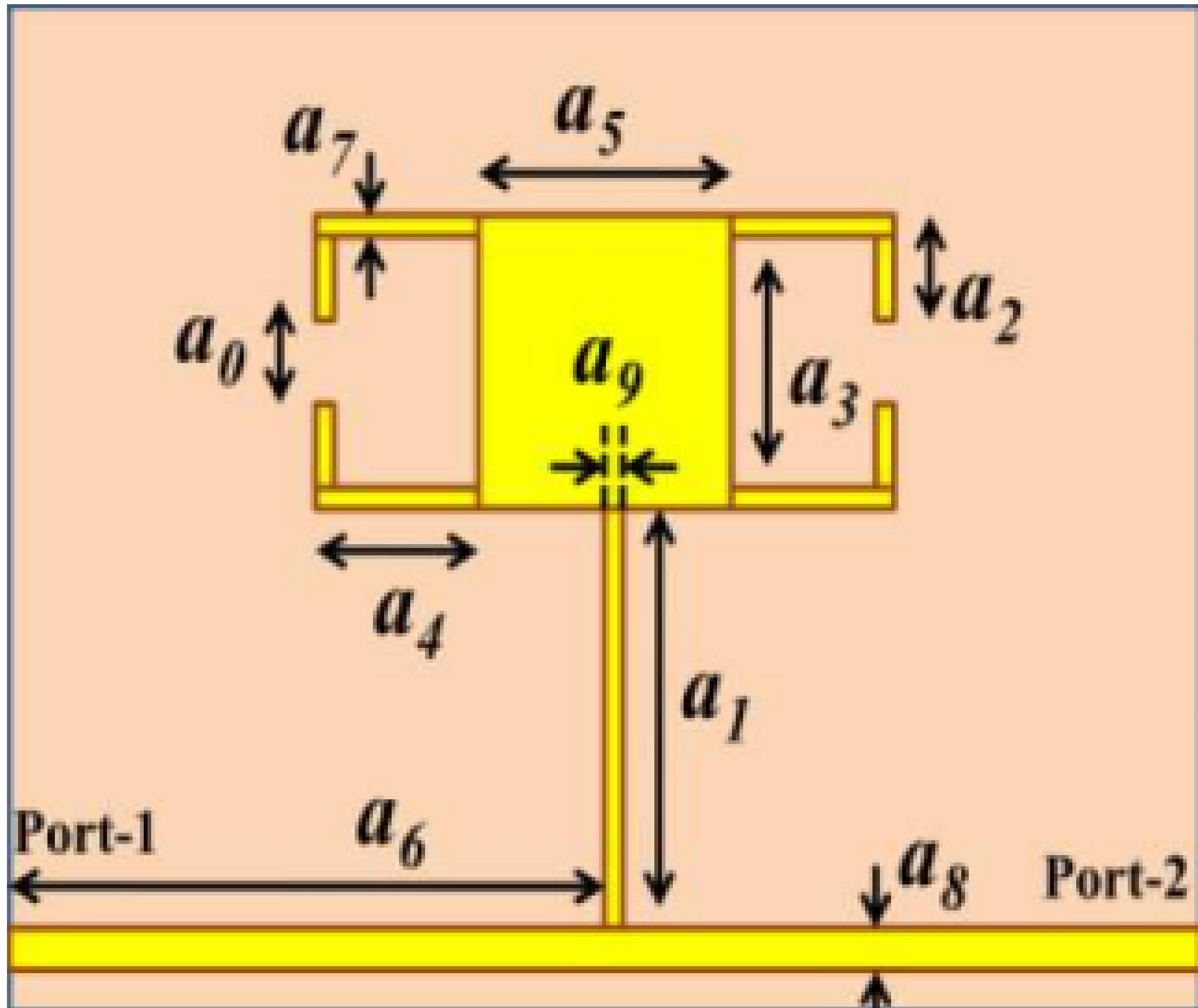


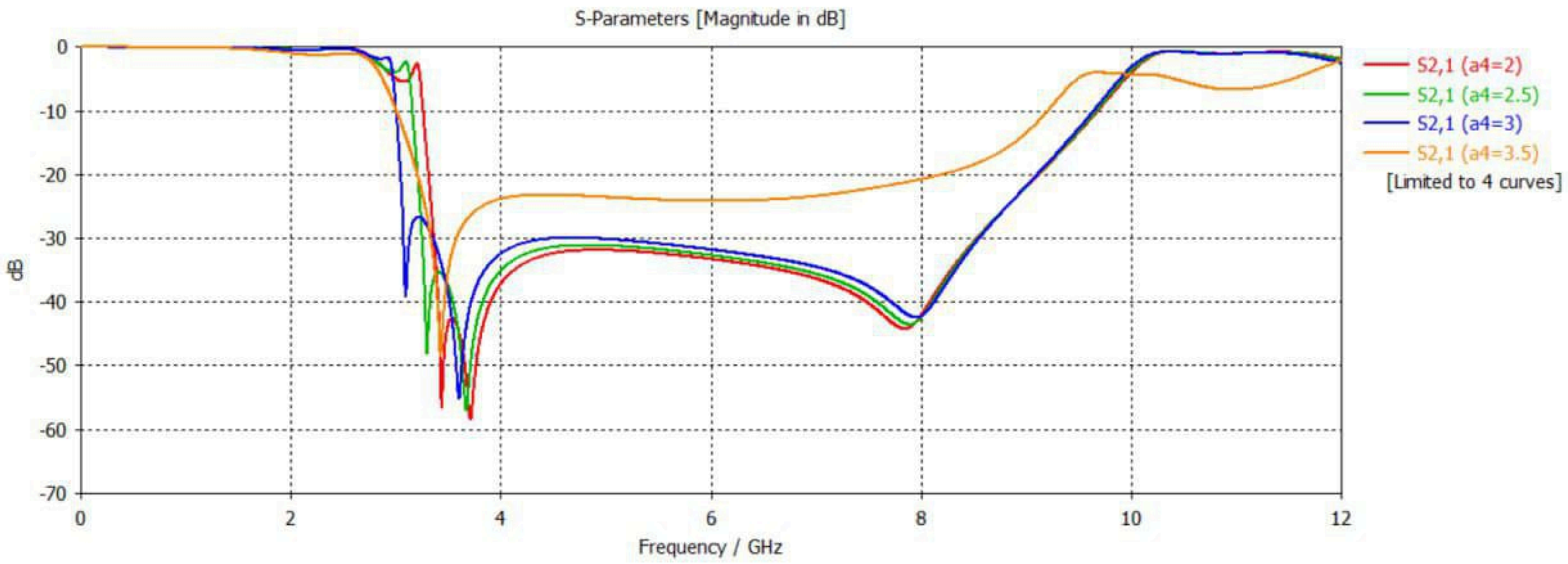
Parallel Cascaded DSR1 and DSR2 in the simulation



Simulation results of Parallel Cascaded DSR1 and DSR2

- The horizontal stub length (a4) and center patch width (a5) of DSR-1 are varied for and observed the frequency response.
- The cut-off frequency of the proposed structure deviates from changing the stub length and a slight variation in the position of the transmission zero is observed.
- The stopband width shifts towards the lower frequencies.
- Hence stub length is taken as 3 mm which is a compromise between stopband width and suppression level and we observed the results.





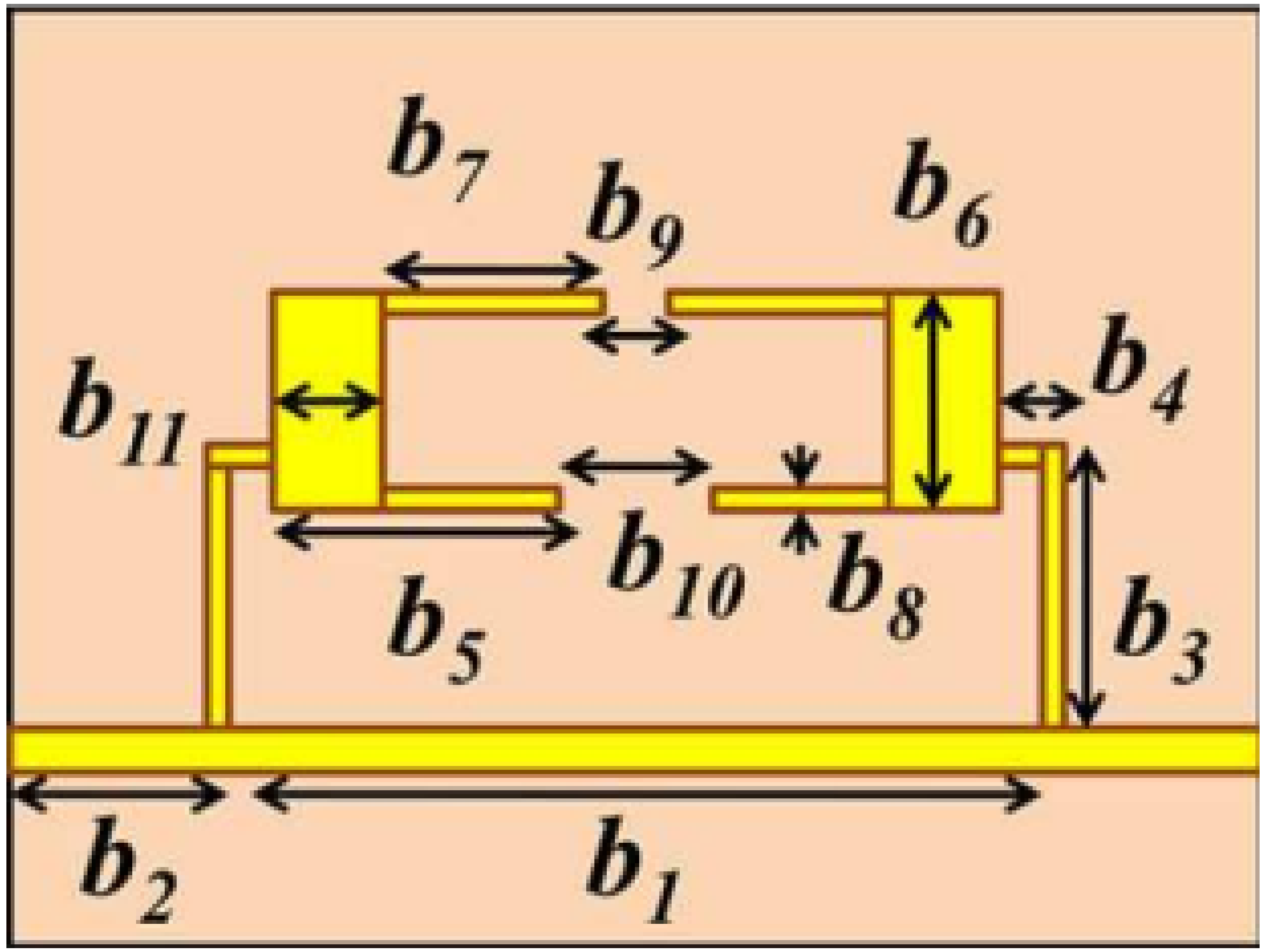
Frequency response of cascaded DSR structure for the variation in a4

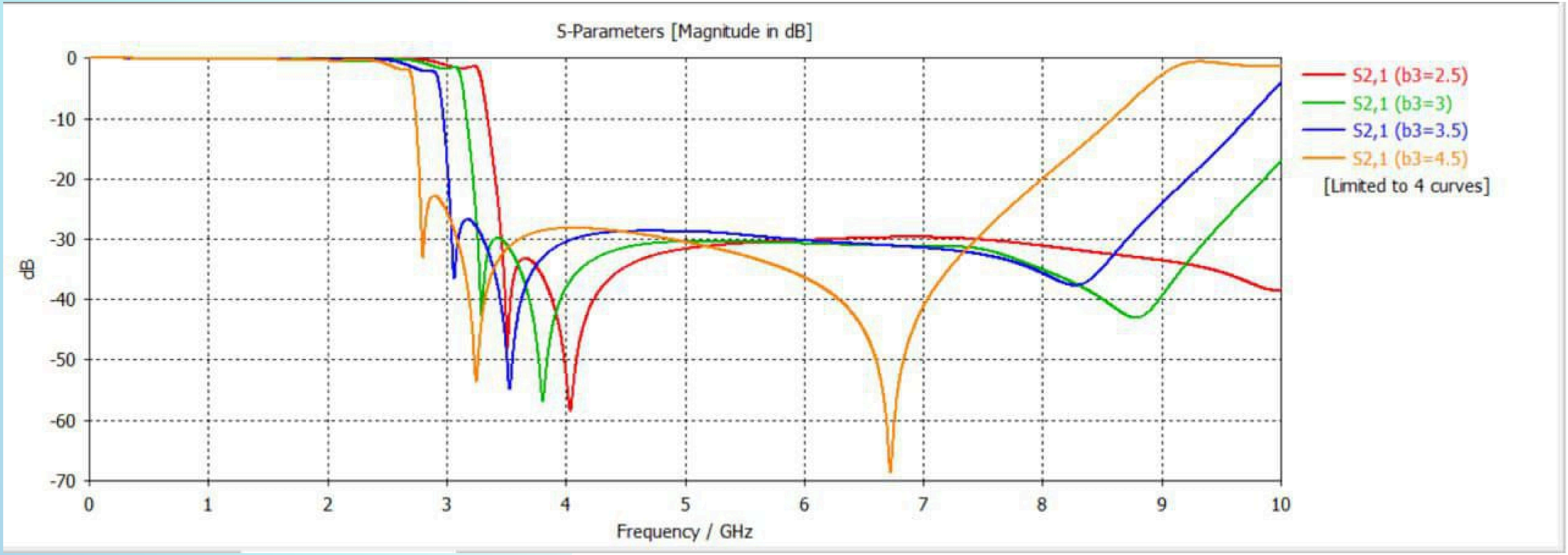
- As the value of a4 increases(orange curve has highest a4 value=3.5)The stopband width shifts towards the lower frequencies.

- The vertical stub length (b3) of DSR-2 shows a drastic effect on the position of transmission zeros in the filter response they shift towards the cut-off frequency for higher values of the vertical stub length

- The stopband region is reduced with poor suppression after the first transmission zero.

- First transmission zero moves towards the cut-off frequency for the higher patch width. Since the filter has size limitations, the patch width is optimised to 1.75 mm after considering the stopband area

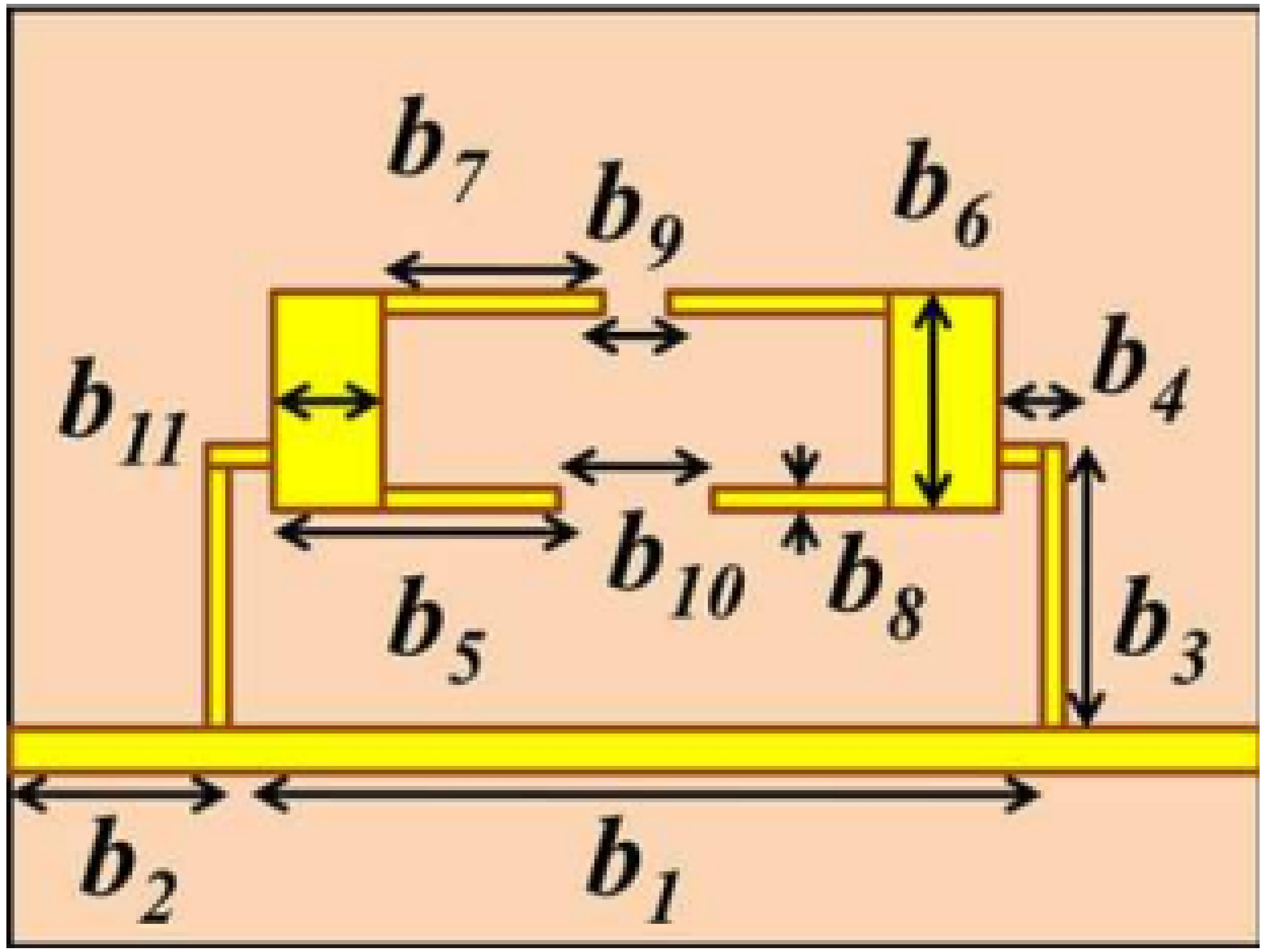


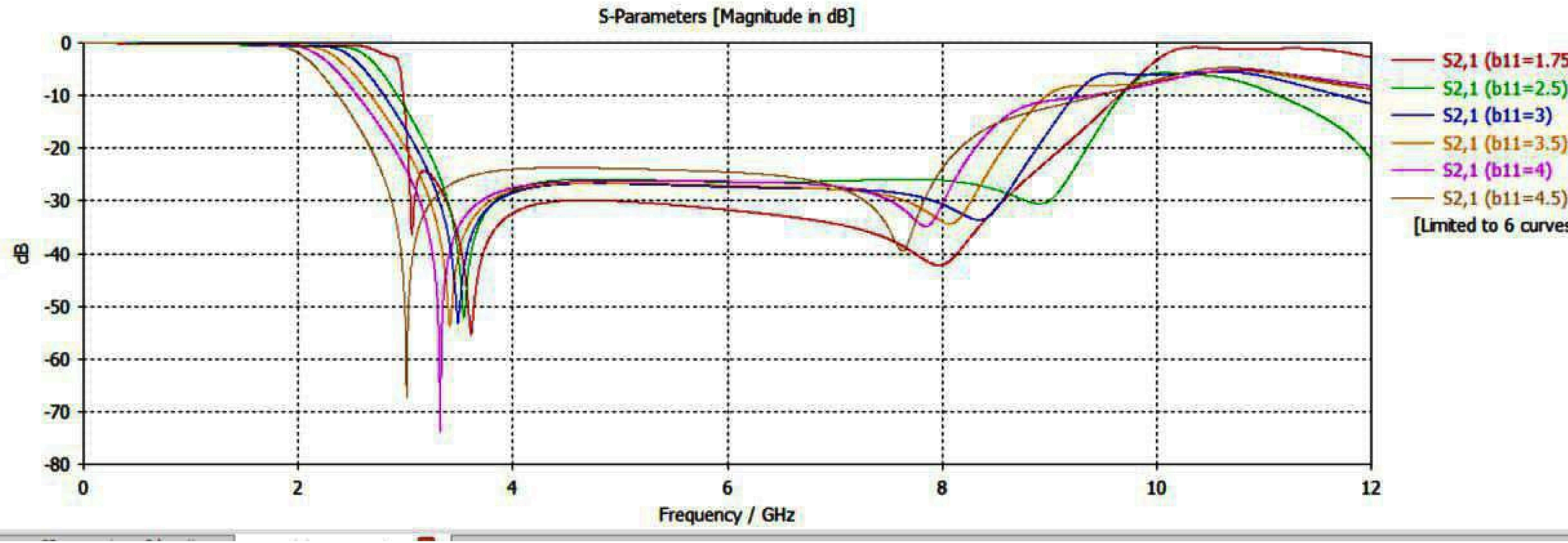


Frequency response of the cascaded DSR structure for the variation in b3

- There is a significant change in the roll-off of the filter and an optimum value of 3.5 mm is selected after considering the attenuation level of the S21 characteristics.

- The selectivity and cutoff frequency of the filter are improved for the slight changes in the patch width (b11) of DSR-2

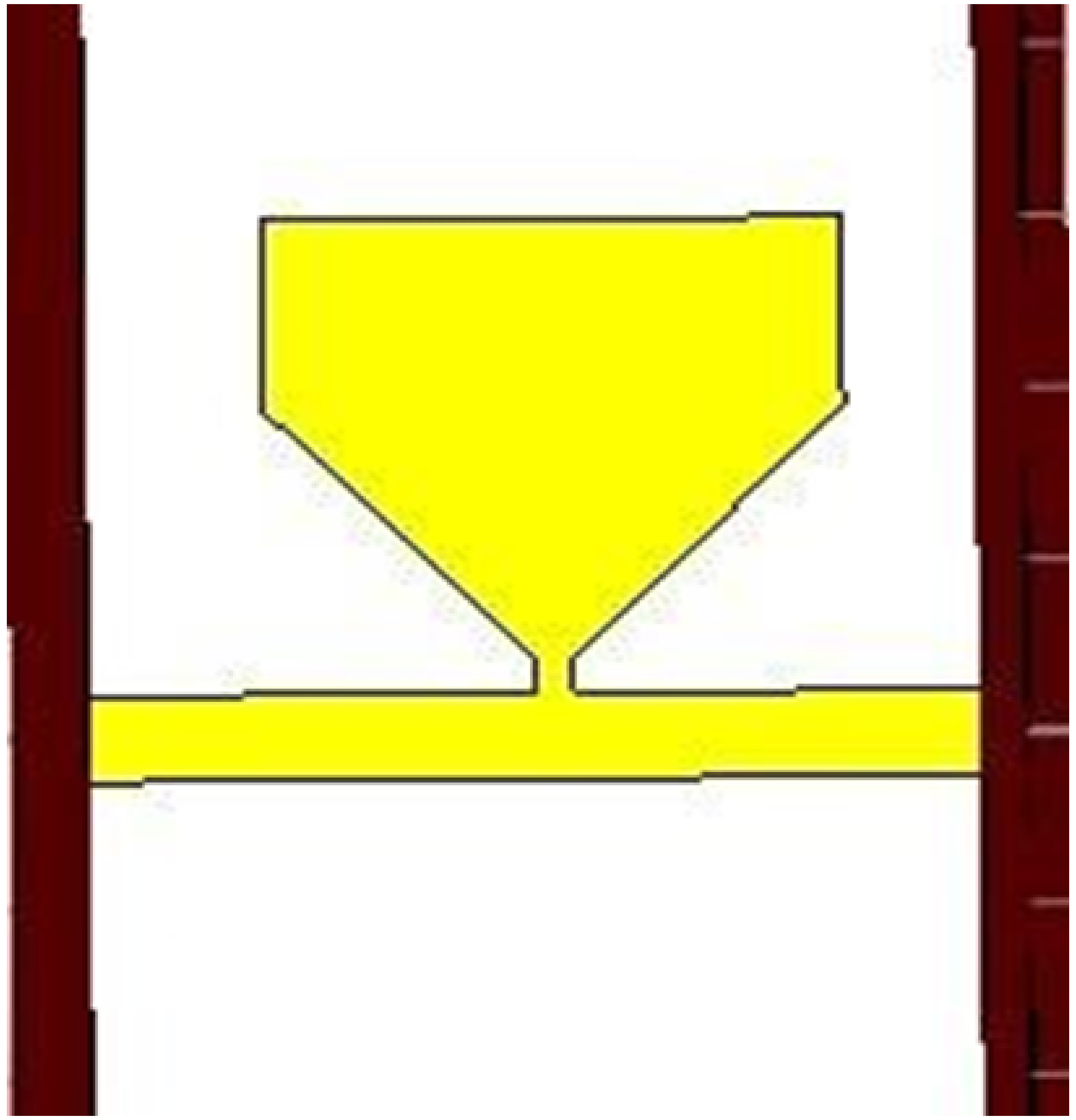




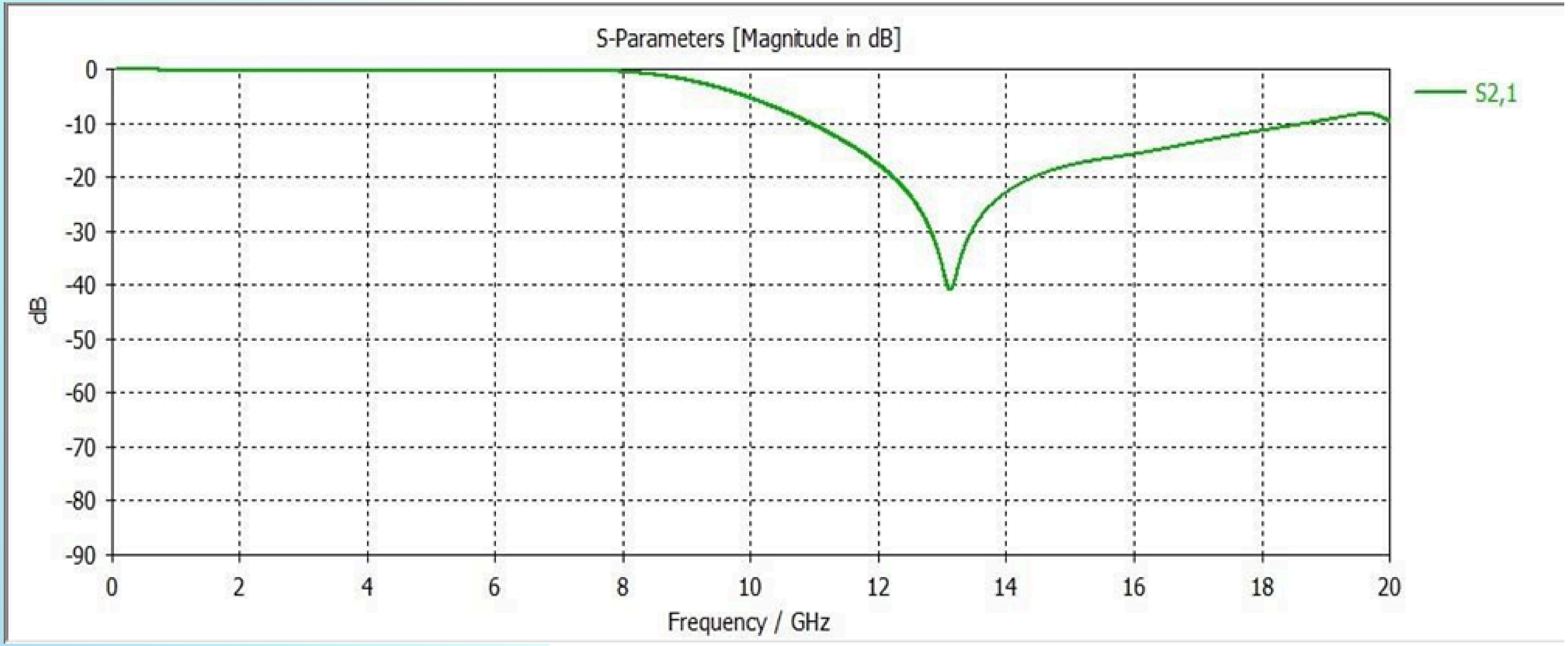
Frequency response of the cascaded DSR structure for the variation in b11

- As we know tuning of the cut-off frequency can be effectively carried out by modifying the proposed DSR structure.
- The increase in the width of the low impedance patch in both DSR-1 and DSR-2 reduces the cut off frequency due to the variation in the lumped equivalent values
- Similarly, the length of the horizontal stub increases, a more stable transition from passband to stopband occurs. Furthermore, horizontal stub length reduces the effect of patch capacitance in the filter response, thereby increases the cut-off frequency.
- The vertical stub length in both resonators will result in the reduction of cut-off frequency due to the increase in the stub inductance value. However, it is not possible to reduce the cut-off frequency beyond a limit due to the size constraint

- Tuning of the cut-off frequency can also be accomplished by changing the split distance without affecting physical circuit size, we now have designed the dimensions of FSSC with C1 = 3.1 mm, C2 = 2.55 mm, C3 = 0.2 mm, C4 = 0.6 mm, C5 = 0.2 mm



Supressed cell

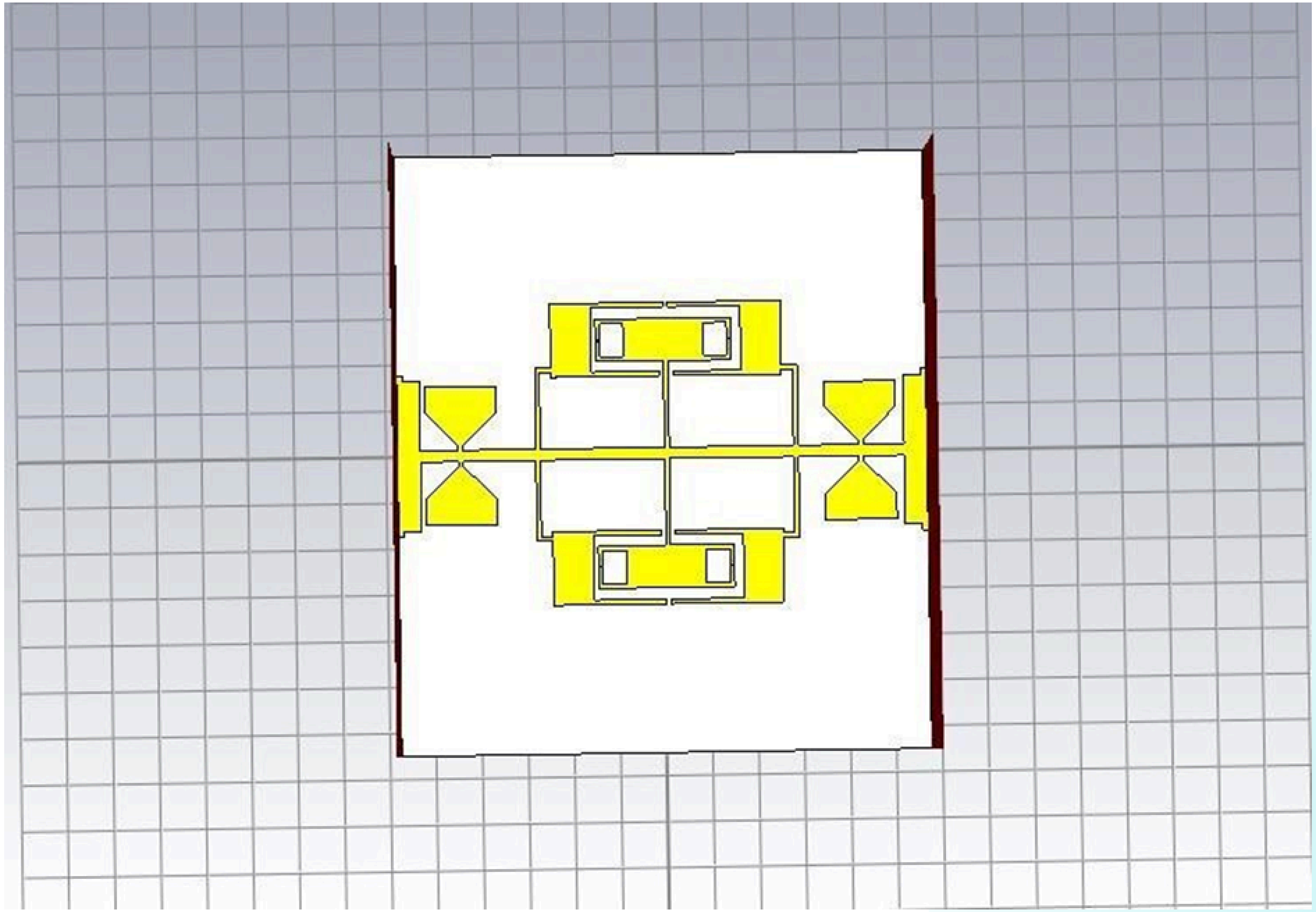


Simulation results of a supressed cell

- The funnel-shaped suppressing cells (FSSC) which was shown previously resonate at a higher frequency of $fz' = 13$ GHz is symmetrically added to the DSR unit.

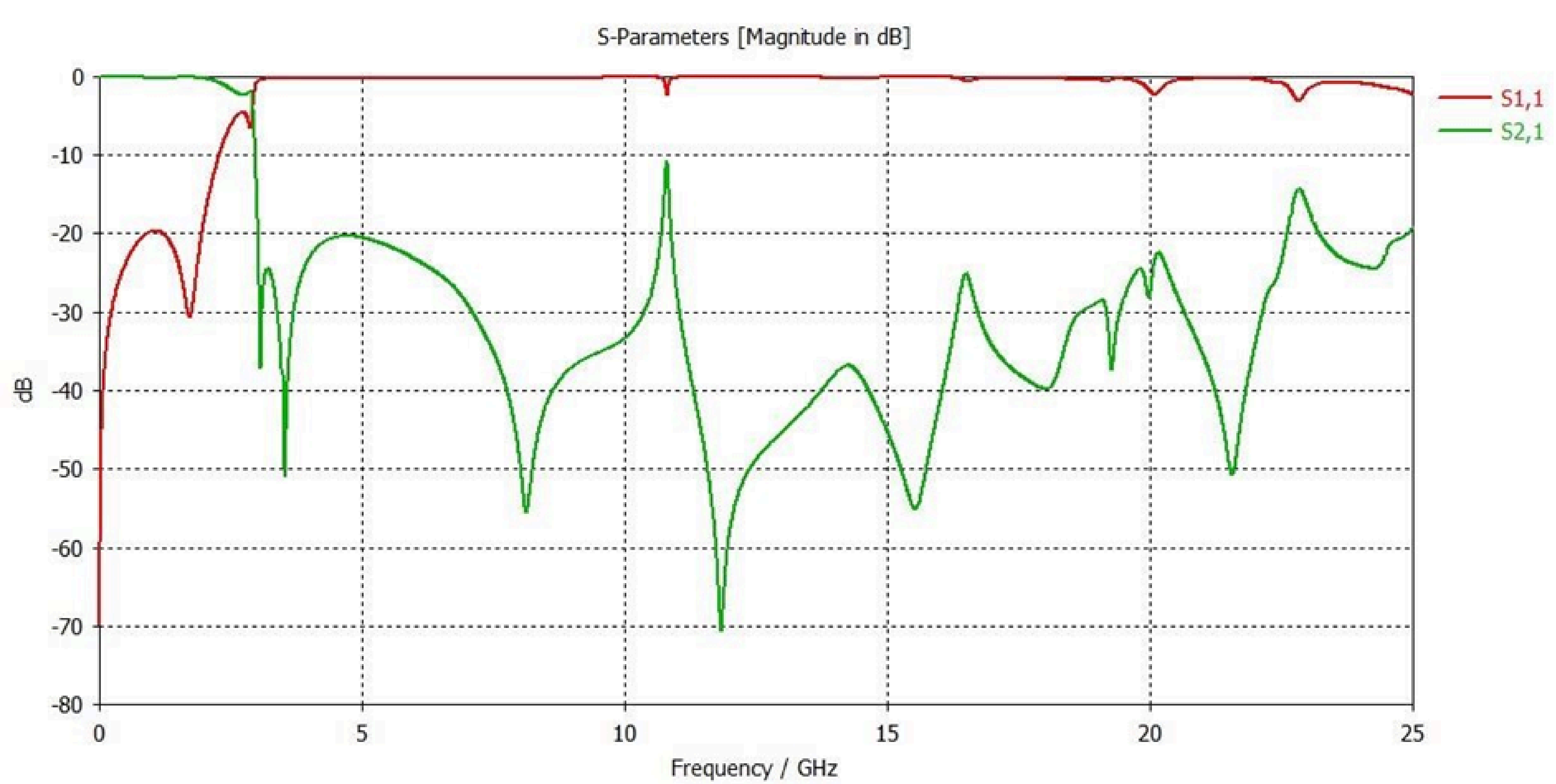
- We designed the final DSR filter with suppressing cells and open stubs, which rejects higher harmonics with suppression of 22 dB beyond second transmission zero and 27 dB at 25 GHz

- Beyond 10 GHz, deep suppression of 30 dB is achieved with minimum losses at the simulation results.



Final proposed DSR filter

- In the final simulation, the control on the transmission zeros and thereby its roll-off factor is configured by changing the stub length of the DSR-1 and DSR-2. Similarly, it is interesting to note that the control on extended stopband beyond 14 GHz depends upon the size of the suppressing cells.

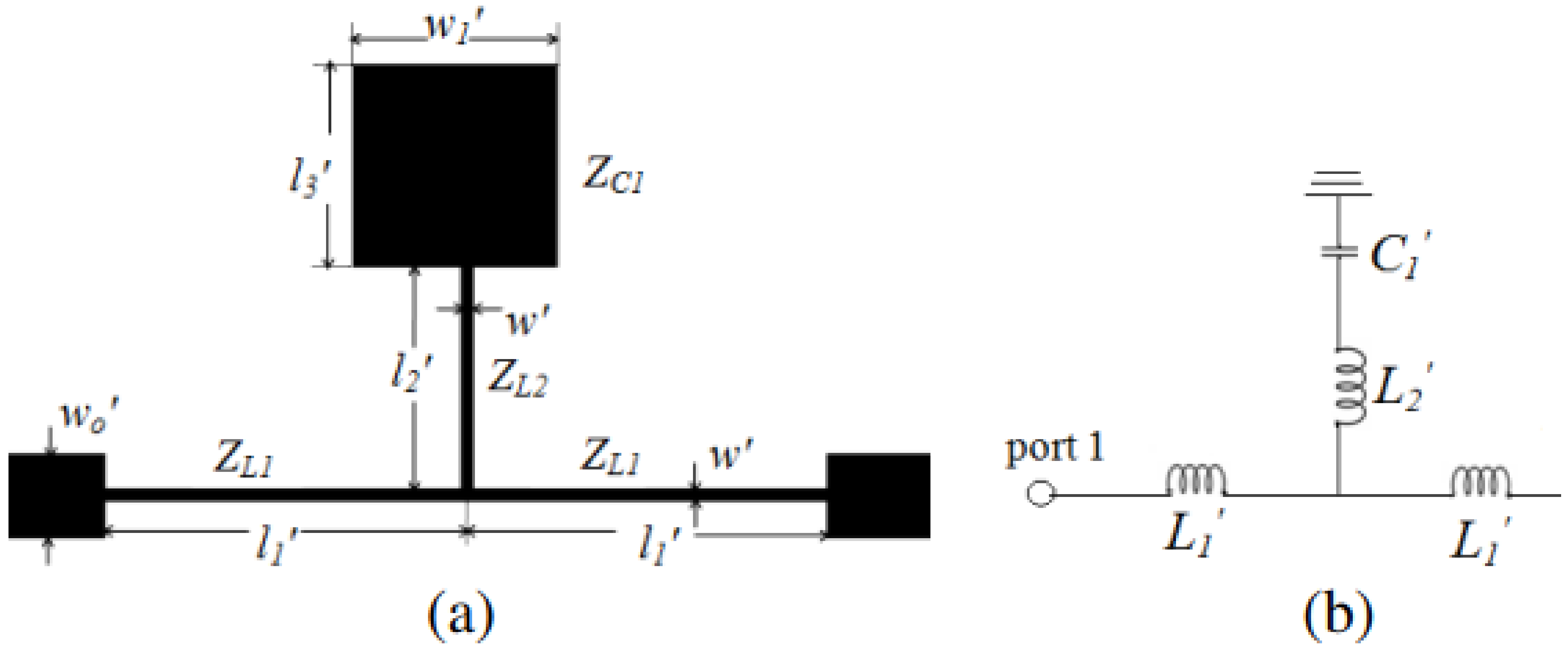


Simulation result of the final proposed DSR filter

Improved Frequency Response of Microstrip Lowpass Filter Using Defected Ground Structures

Primary Resonator

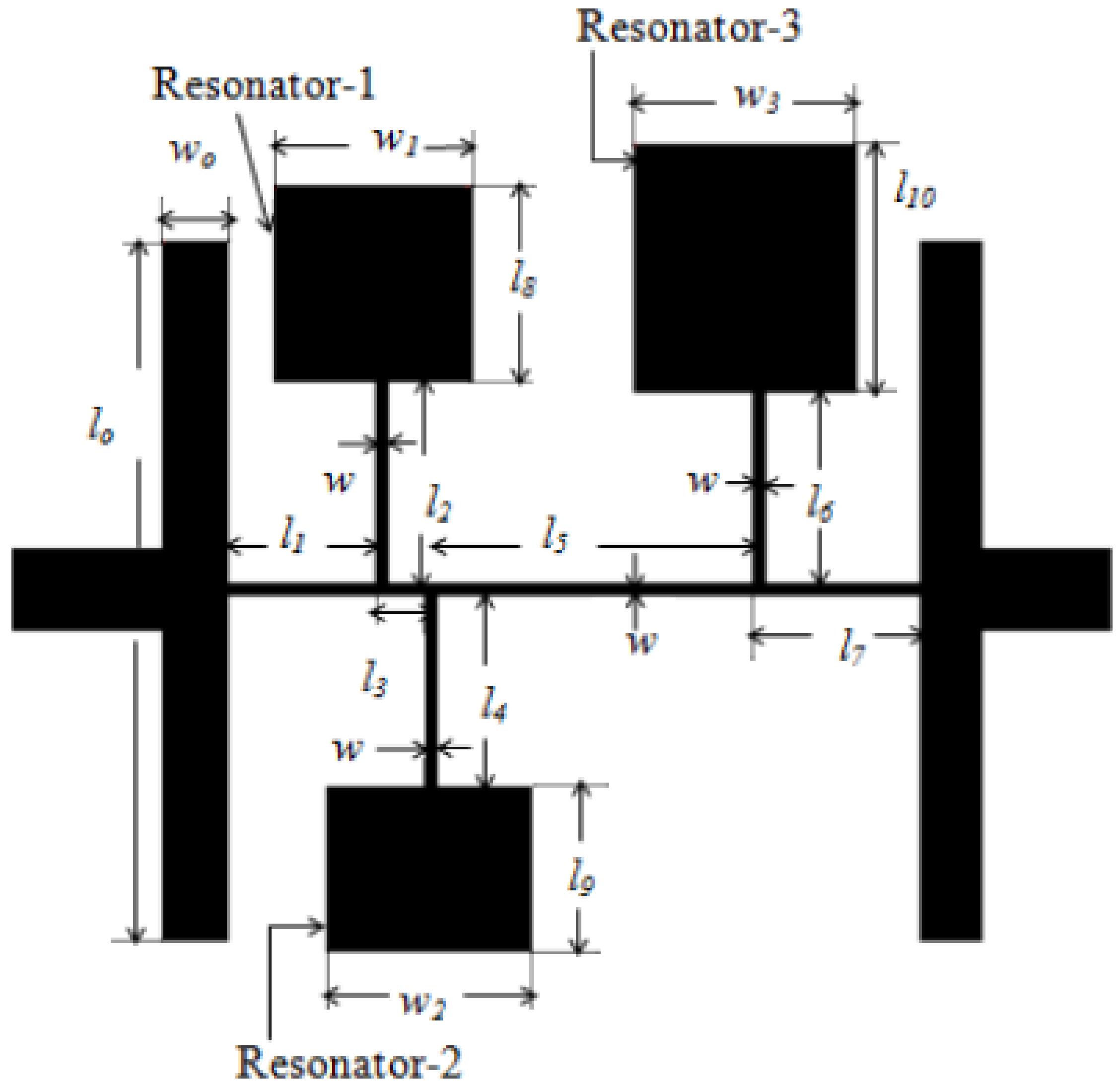
- A series resonant branch having a high impedance stub and a low impedance patch, modeled as inductor and capacitor respectively is connected in shunt with a high impedance main transmission line

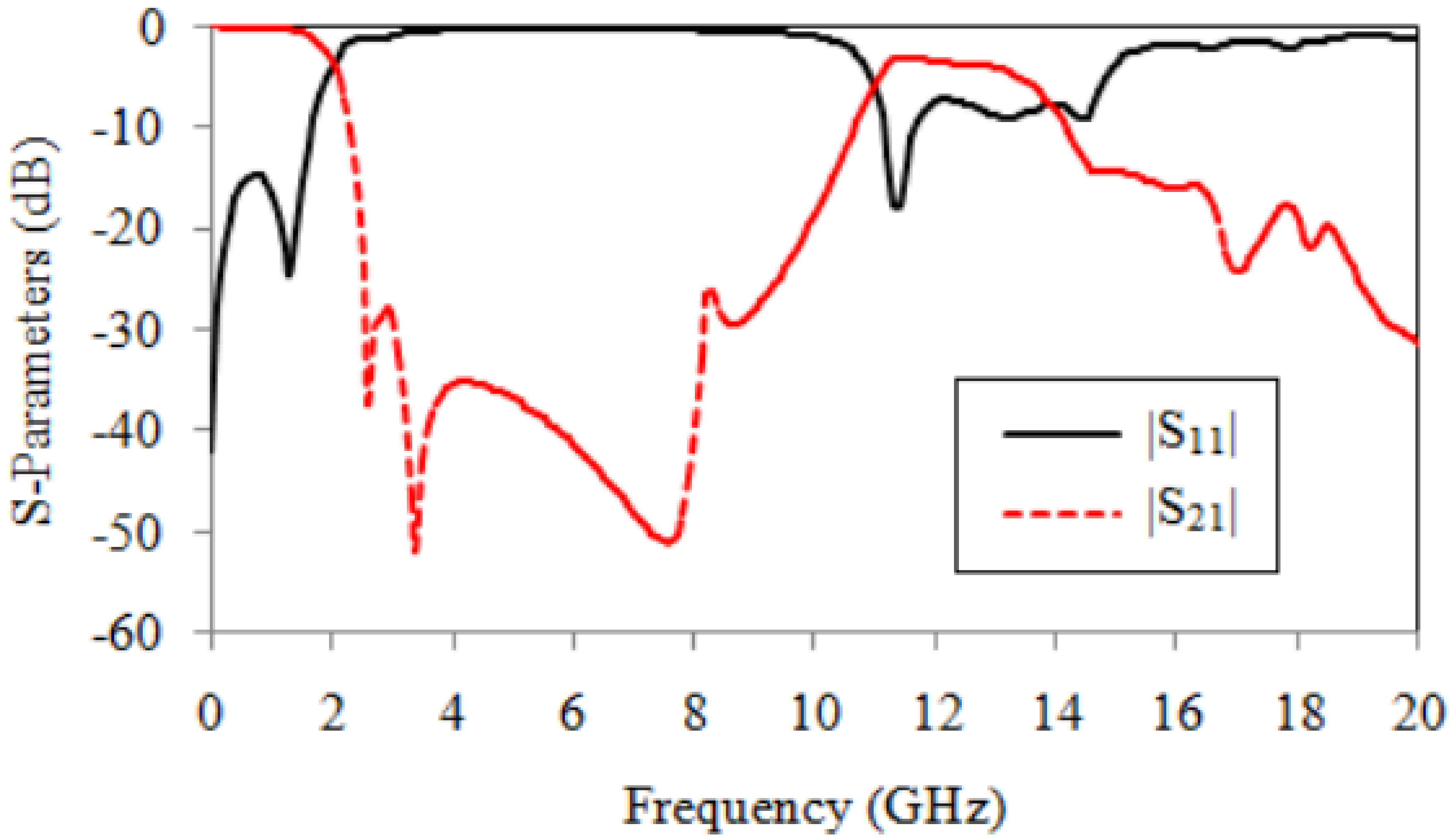


(a) Structure. (b) LC equivalent circuit.

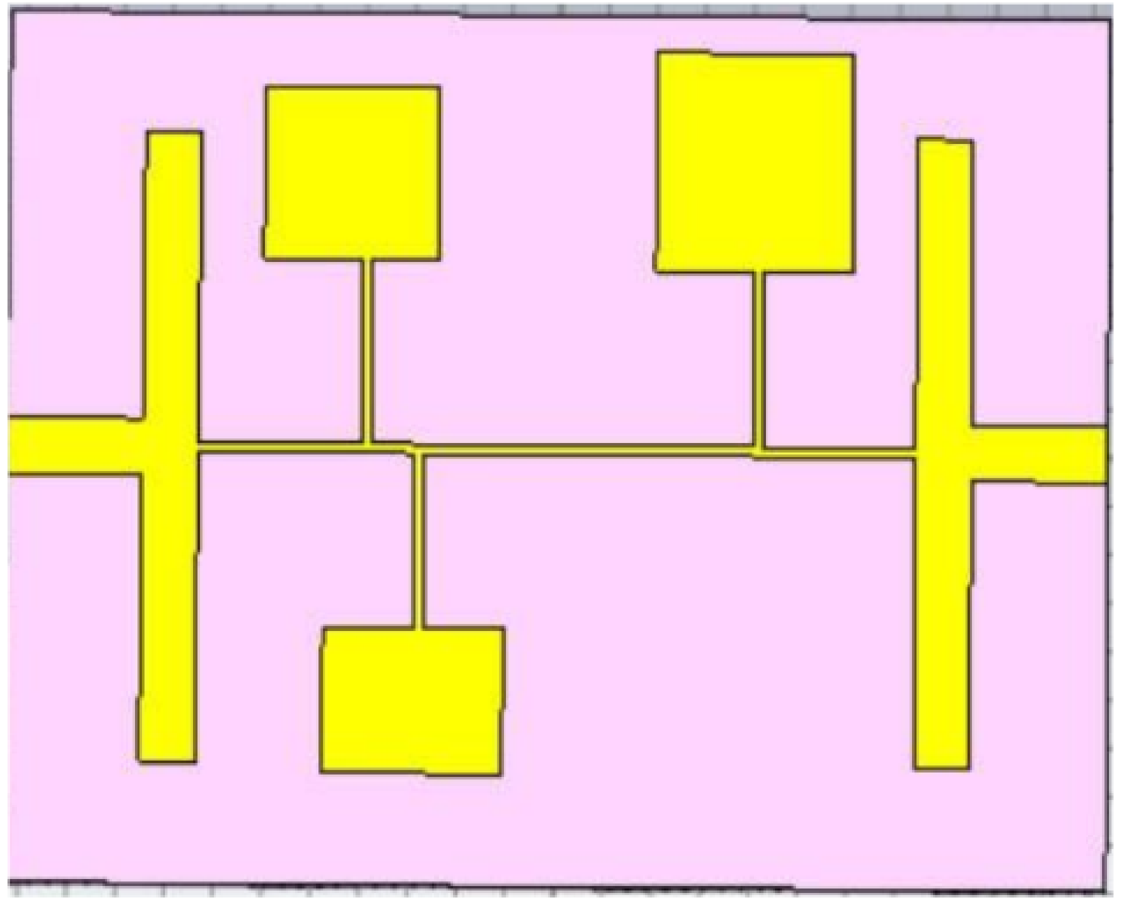
BASIC MICROSTRIP LOWPASS FILTER

- Basic microstrip lowpass filter is designed using stepped impedance resonators and uniform impedance stubs (SIR-UIS)
- The structure consists of two uniformly shaped low impedance stubs and three stepped impedance resonators, Resonator-1, Resonator-2 and Resonator-3 loaded on the high impedance main transmission line.

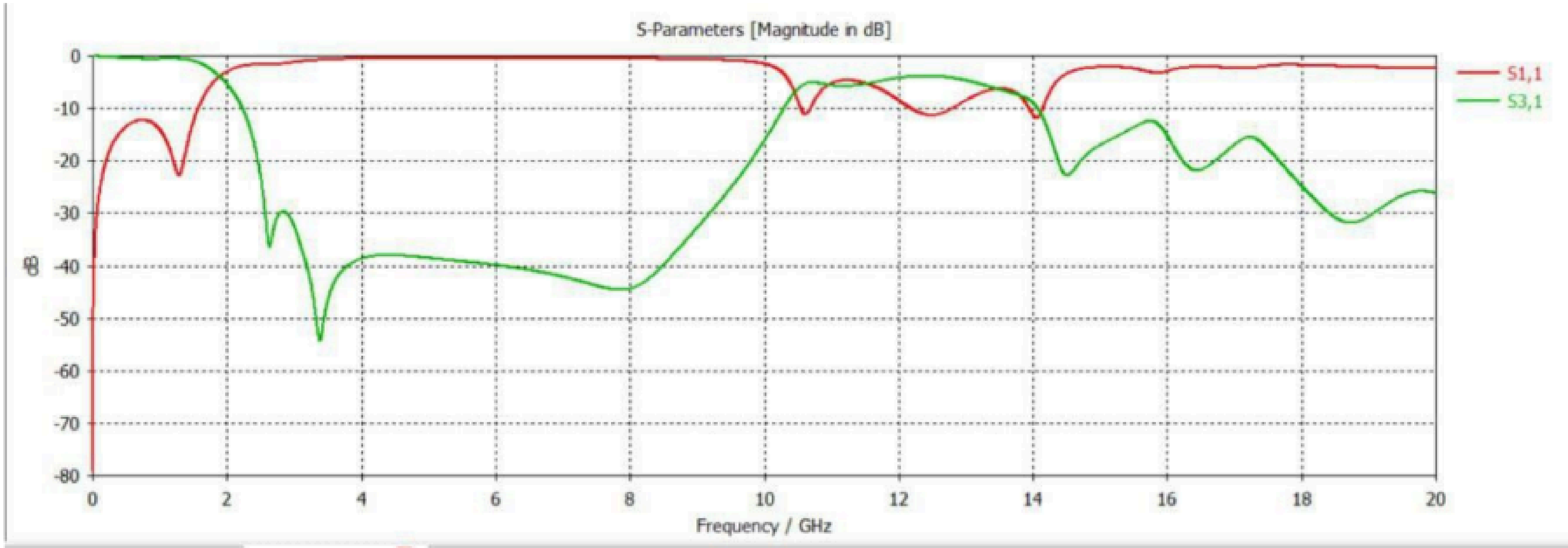




- The **cutoff frequency** of the filter is **1.95 GHz**
- The insertion loss is less than 0.35 dB up to 1.1 GHz of the passband and the return loss in the passband is better than 14.7 dB
- The physical size of the filter is only 15.1 mm × 14.95 mm



Basic lowpass filter



Simulation results of Basic lowpass filter

DEFECTED GROUND STRUCTURE (DGS)

- DGS is a purposefully created defect on the ground plane of a printed microstrip board.
- It is typically created in the form of an etched-out pattern on the ground plane.
- DGS is a simplified form of Electromagnetic Band Gap (EBG) structure.

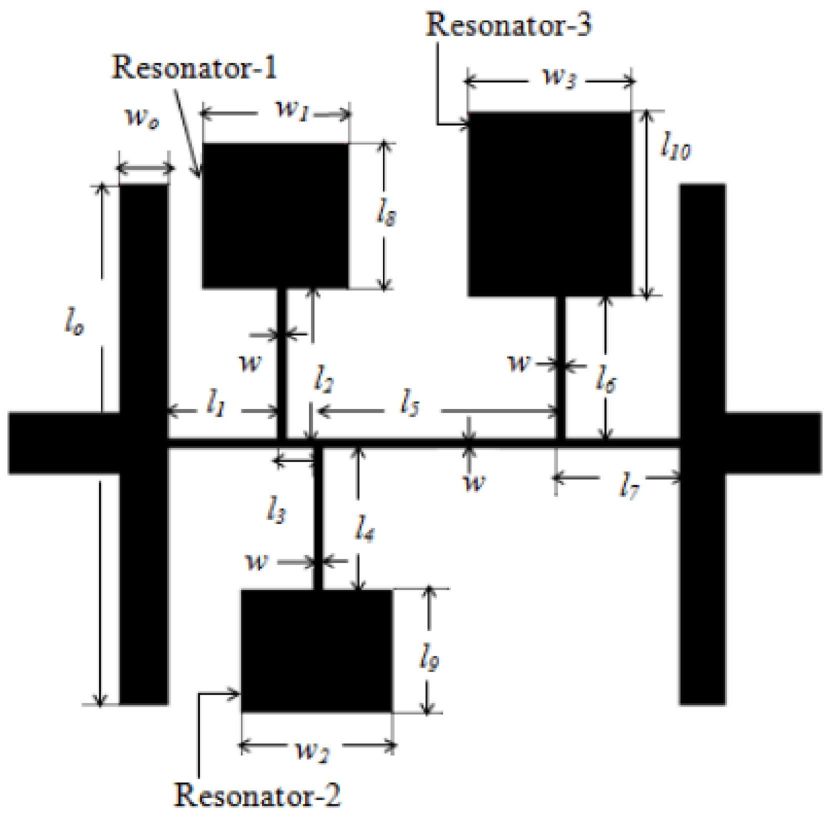
used to enhance the **bandwidth** and **gain** of microstrip antenna

to suppress the **higher mode harmonics, mutual coupling between adjacent element, and cross-polarization**

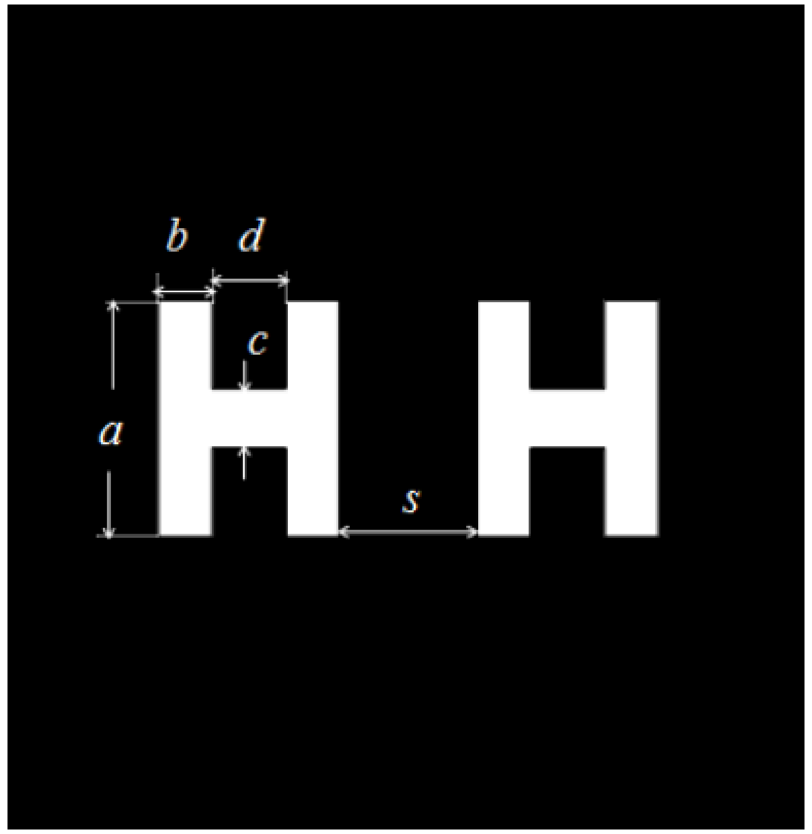
for **improving** the **radiation characteristics** of the microstrip antenna.

proposed Filter-1

- consists of two **symmetric H-shaped** DGSs etched on the ground metallic plane of the basic lowpass filter structure
- The **stopband bandwidth** of the filter is **improved** by the use of etched units in the ground plane without increasing the physical size



(a)



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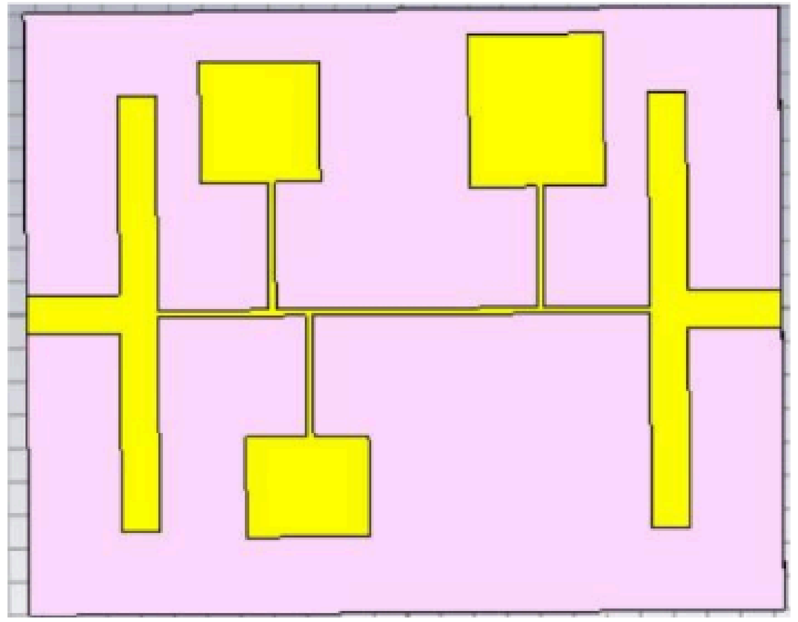
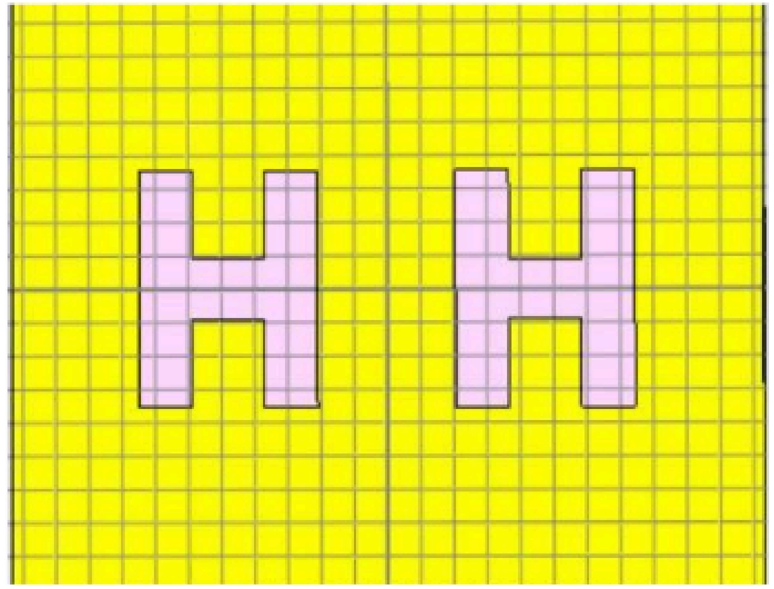
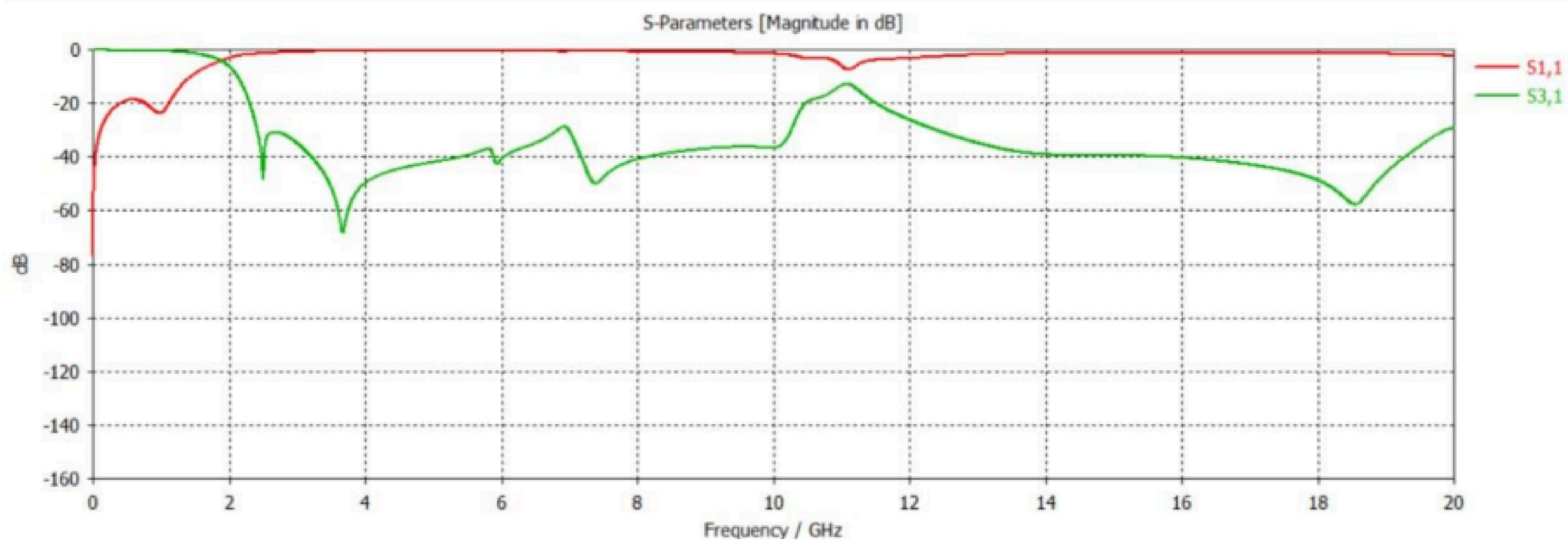




Layout of the proposed Filter-1. (a) Top view. (b) Bottom view

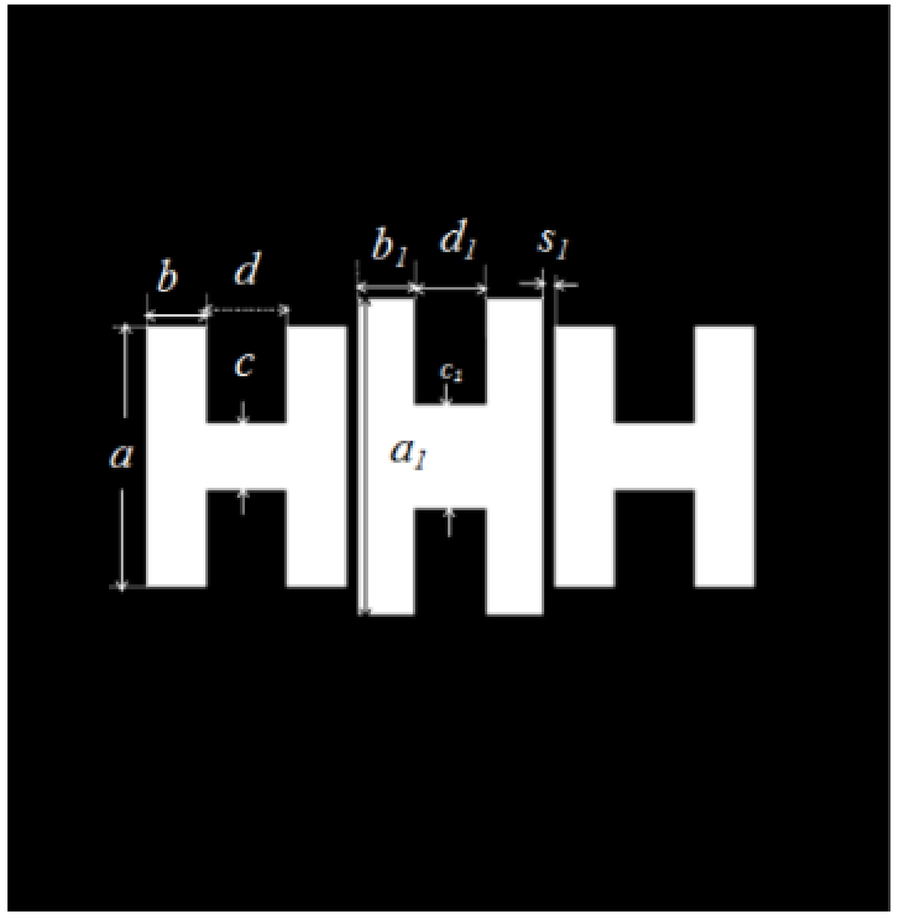
- The simulated 3 dB **cutoff frequency of Filter-1 is 1.945 GHz**, and wide stopband bandwidth from 2.315 GHz to 20 GHz
- The insertion loss is lower than 0.3 dB up to 1.1 GHz of the passband and the return loss is higher than 30.4 dB

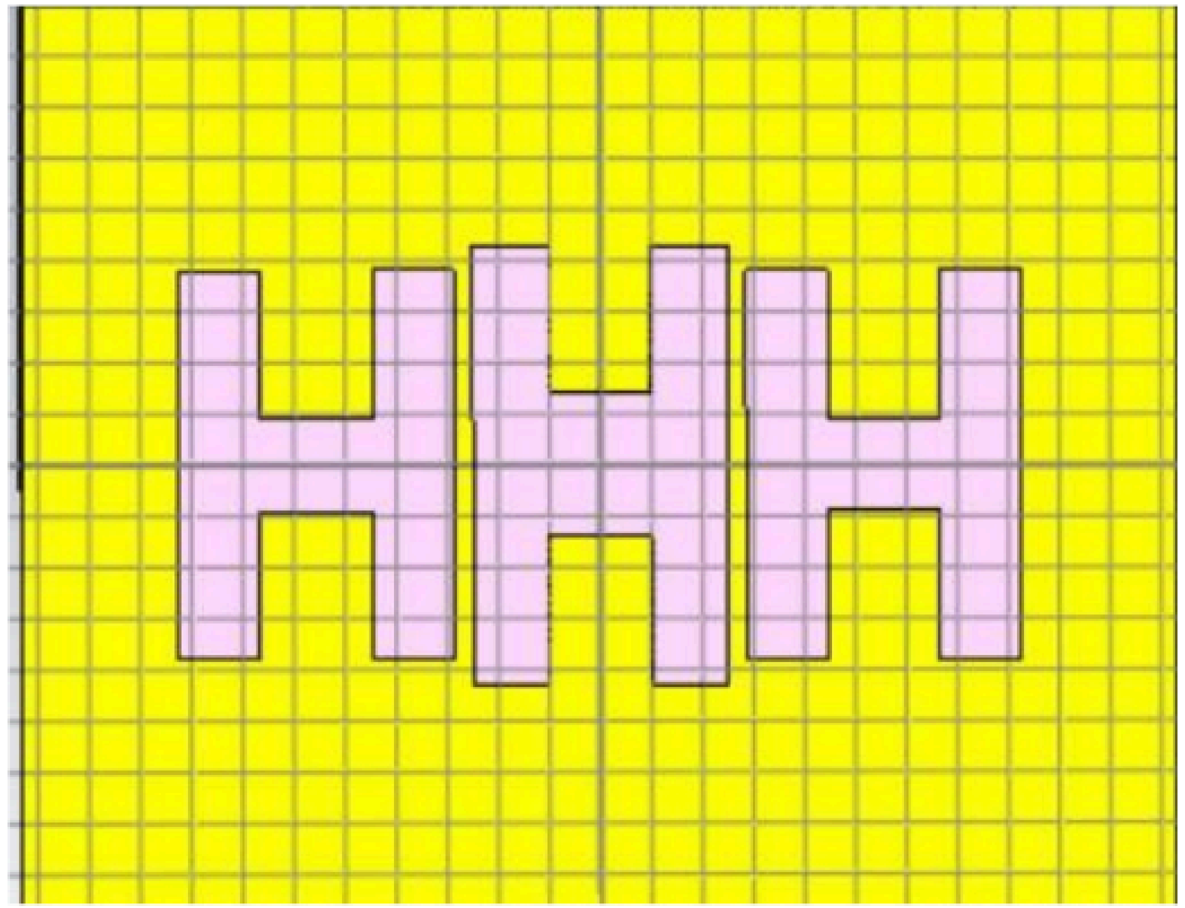


Simulation results of the filter with DGS

proposed Filter-2

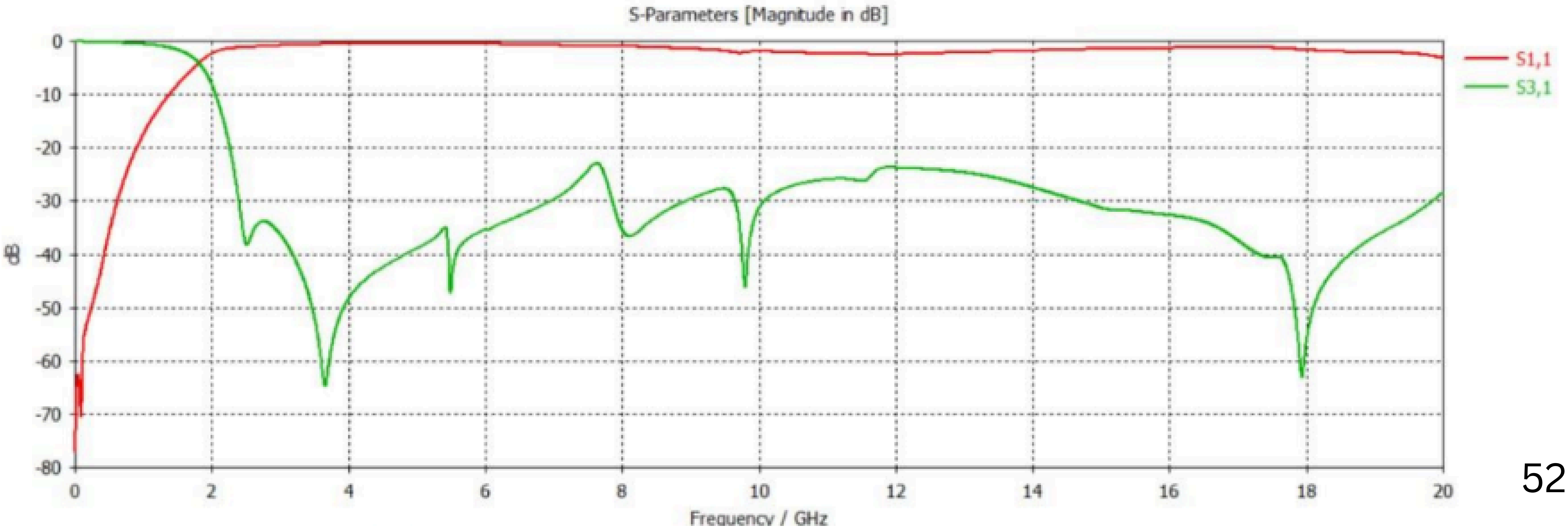
- To improve the characteristics of Filter-1, one more H-shaped slot is added to the ground plane, and the coupling between the DGS resonators is increased





Bottom view of filter with three H-shaped slot on ground plane

- Due to increased etched area in the ground plane, the simulated **3 dB cutoff frequency** of the proposed Filter-2 is reduced to **1.88 GHz.**
- Filter-2 has low insertion loss and high return loss values in the passband together with a wide stopband up to 20 GHz
- The insertion loss in the passband is less than 0.22 dB up to 1.1 GHz, and high return loss



DESIGN OF THZ LOWPASS FILTER USING SPLIT RING RESONATOR

INTRODUCTION

- Terahertz (THz) technology has emerged as a promising field with a wide range of applications.
- One of the critical components in THz systems is the filter
- Design and implementation of a passive low pass filter (LPF) in the THz spectrum using split-ring resonators (SRRs).
- SRRs are a type of metamaterial that exhibits unique electromagnetic properties.
- SRRs consist of two concentric loops with a split in both loops facing opposite to each other

- Split accumulate large capacitance acrosss it.
- Loop store magnetic energy
- Gap between the loops is kept small
- Project is to realize a novel passive LPF with acceptable electrical performance and reduced losses
- No active components

SPLIT RING RESONATOR

- Designed to store electromagnetic energy
- Generated by the loops and split in the structure.
- The dimensions of SRRs are smaller than the resonant wavelength, which increases the overall gain and reduced losses.

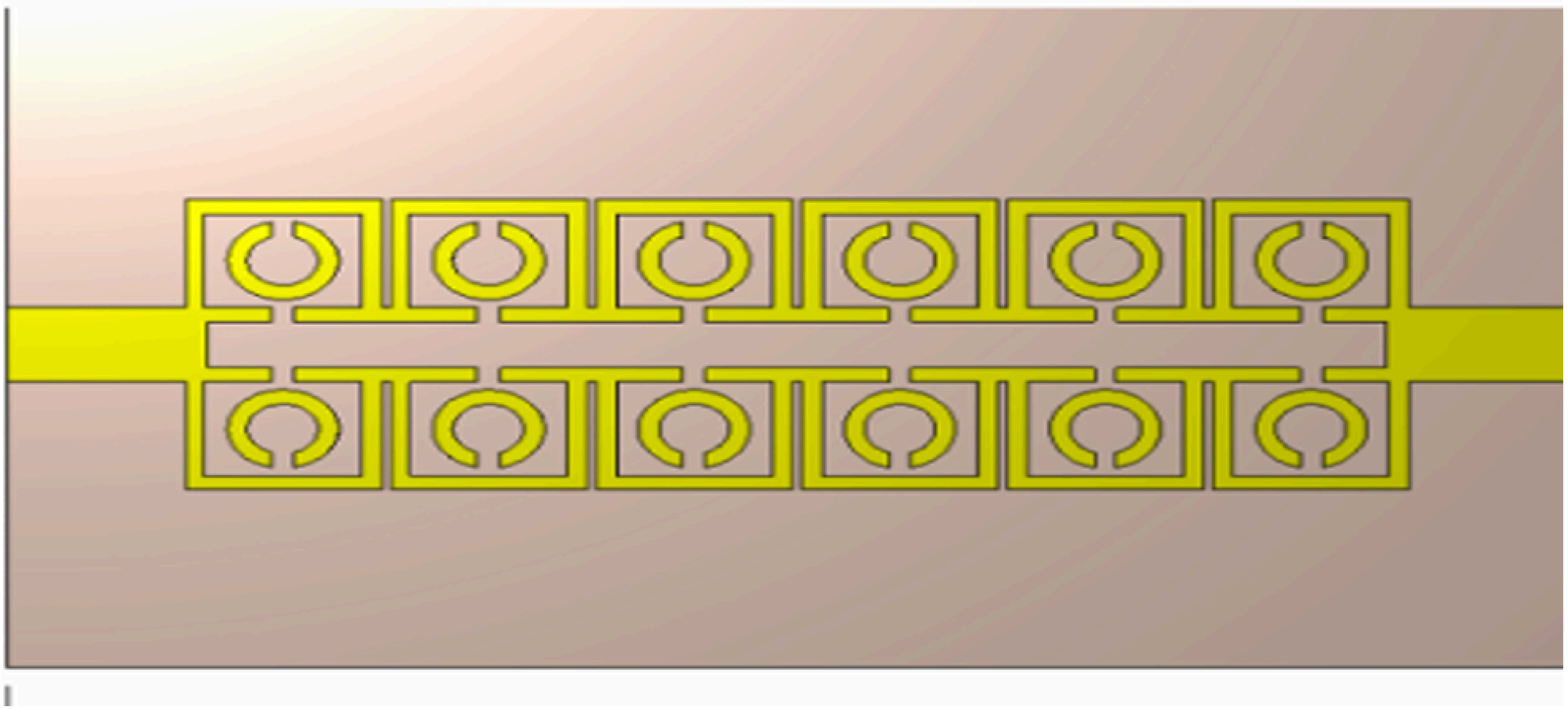
DESIGN AND IMPLEMENTATION

- The SRRs are arranged periodically along the microstrip line, and their dimensions are optimized to achieve the desired cut-off frequency and bandwidth
- At first, the frequency at which the SRR structure resonates is tuned via adjusting various parameters.
- Match the input impedance of LPF to the input signal frequency spectrum

DESIGN AND IMPLEMENTATION

- After that, an array of the basic unit cells (SRR) combined to form the Microstrip transmission line.
- The final structure of the Passive Low Pass Filter has been printed on a Polyimide substrate .
- All the potential power relationships between a microwave junction’s numerous input and output ports are given by a square matrix known as S-parameters.
- The return loss measures the reflected wave to the incident wave. The lower the filter’s return loss, the better is the transmission coefficient.

DESIGN AND IMPLEMENTATION



TESTING AND OBSERVATION

- The LPF is tested for its return loss
- The LPF is designed to have a cut-off frequency at fc=5.8THz and a satisfactory bandwidth with a low insertion loss.
- Also, from the conventional procedure, miniaturization at the nanoscale is required for the same values.
- This is not possible because of various fabrication challenges as the length and width are in nanometers. Hence,metamaterials have been proposed

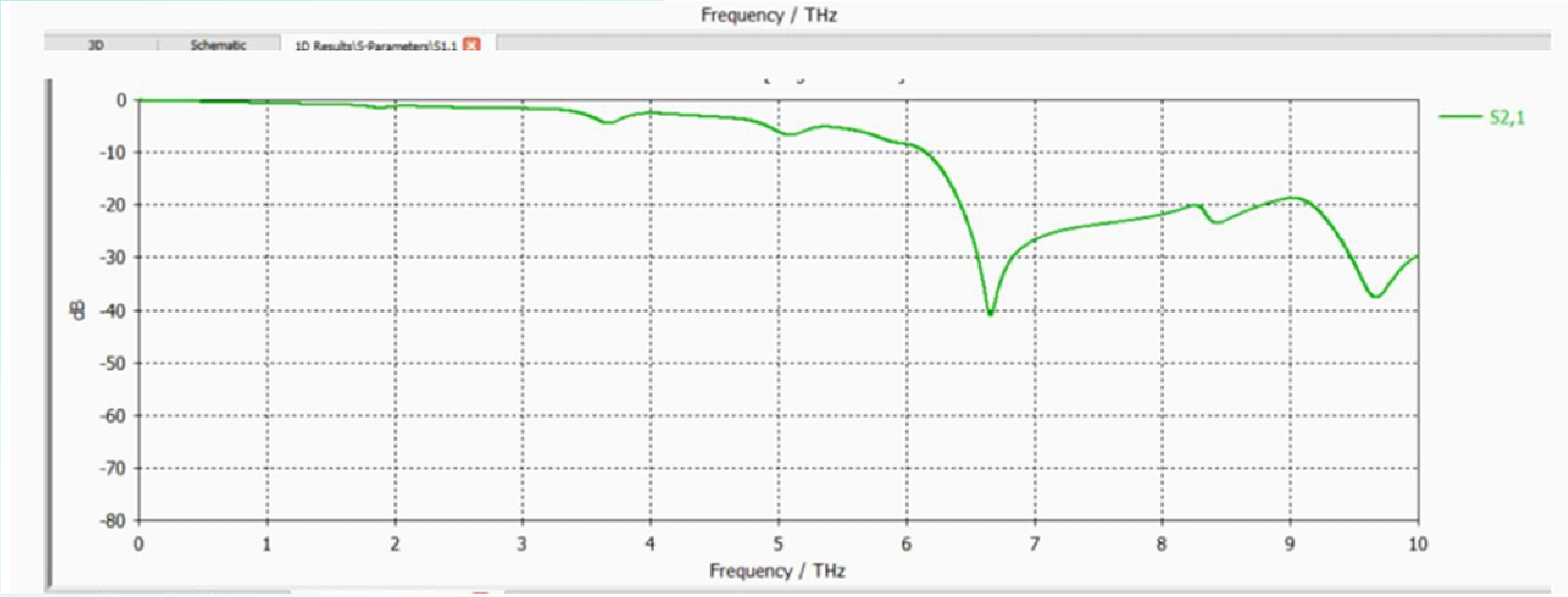
TESTING AND OBSERVATION

- The unit cells of the proposed filter have their electrical dimensions as λ/4 of the waveguide.
- Therefore, in this paper, we propose a THz lowpass filter using a planar circular resonator.

RESULT AND DISSCUSSION

- The computed outcome of the filter shows a cut-off frequency at fc=5.8 THz.
- A good sharpness of the filter response is achieved in the frequency range of 6–7 THz
- There are three resonance points in the filter having six SRR while others have one or at maximum two.

RESULT AND DISSCUSSION



CONCLUSION

In summary, microwave filters in the GHz and THz frequency ranges are indispensable tools for engineers and researchers working in wireless communication, radar, terahertz imaging, and related fields. By understanding the principles and design considerations of microwave filters, we can unlock new possibilities for innovation and technological advancement in the GHz and THz spectrum.Our study was on different type of microwave filters and through this project we were able to get insights into different type of microwave filter designs.

Thankyou