# Thermal Analysis of Metamaterial for High Energy Microwave (HEM) Devices

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**Introduction**: Metamaterial[1,2] is an artificially structured material where it's electrical (ϵ), magnetic (μ) and refraction properties (n) are simultaneously negative in narrow frequency band. Currently, metamaterials are being widely used in microwave and radio frequencies as devices[3,4] like filter, coupler, antenna etc. However, the applicability of metamaterials as High Energy Microwave (HEM) [5,6,7] devices is still developing and is a research speculation. The objective of this poster is to give an overview of metamaterials as a HEM device as to check its material properties and to explore where it exhibits negative (ϵ, μ, n) properties. The work is carried out using COMSOL multiphysics[8] software

**Theory**: The dawn of this century brought about the introduction of new type of artificially structured material known as metamaterials. One of the most familiar metamaterials structure is "Split Ring Resonator". Figure 1(a) illustrates the basic structure of SRR along with its dimension. Figure 1(b) depicts the S parameters. This is artificial magnetic atom at micro-wave regime, and important constituent in meta-material applications.

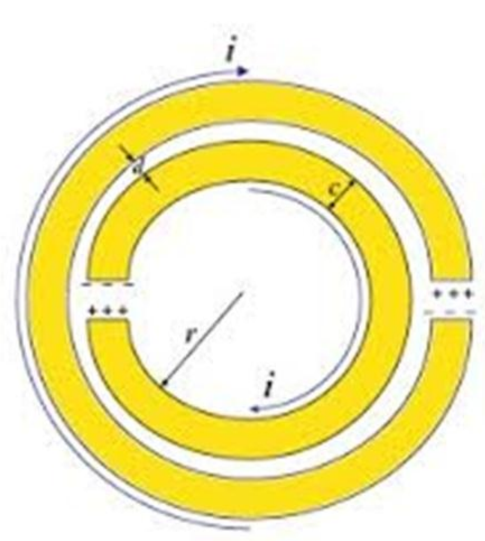

Figure 1. (a)

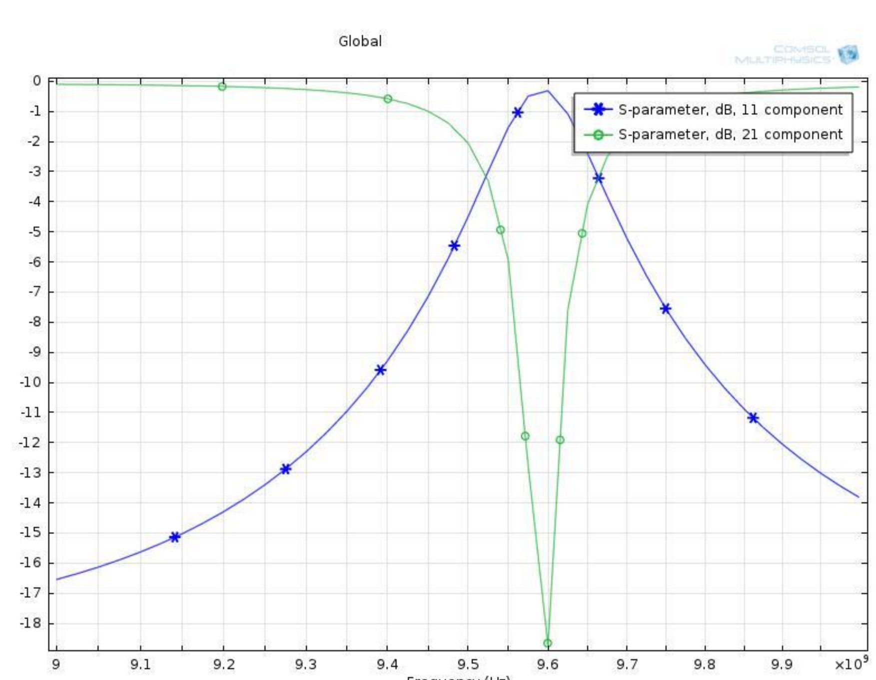

Figure 1. (b)

**Figure 1**. **(a)** Basic SRR structure r=0.9mm,c=0.25mm,d=0.25mm **1(b)** S-parameters of the SRR

**Computational Methods**: We have modeled a Split Ring Resonator (SRR) in an X-band waveguide. The waveguide was assigned aluminum material with copper coated at the inner boundaries. The SRR was made of copper on the substrate with a dielectric constant 2.1 with loss tangent of 0.001. (RT-Duroid)

Using RF module, we simulated and achieved resonance at around 9.6GHz. At this frequency, the transmission will be minimum due to the negative permeability exhibited by SRR. Figure 2(a) and 2(b) displays the E-field and H-field at resonance.

Then using Microwave Heating Module, we subjected the SRR to different power levels. With increase of power, the dielectric and the copper rings gets heated and structure gets deformed. This results in breakdown of the resonance and results in transmission of EM waves in the designed stop-band.

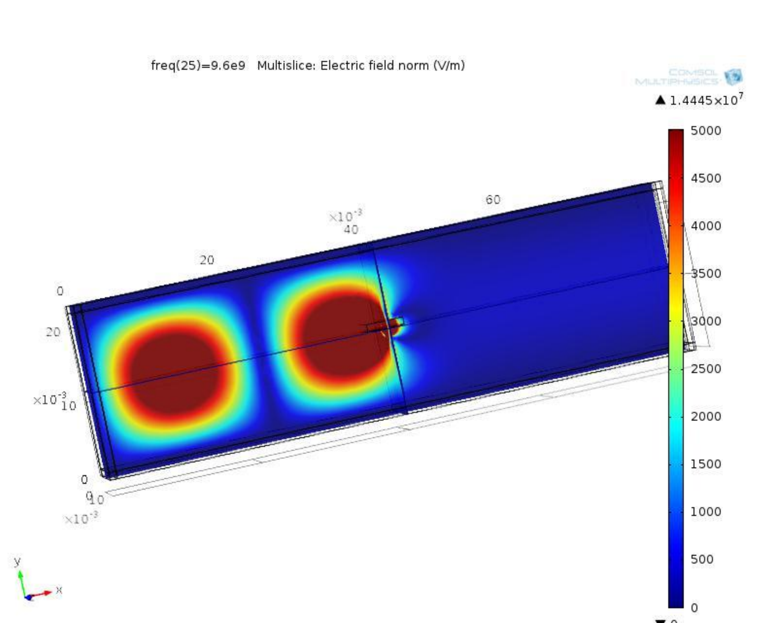

Figure 2. (a)

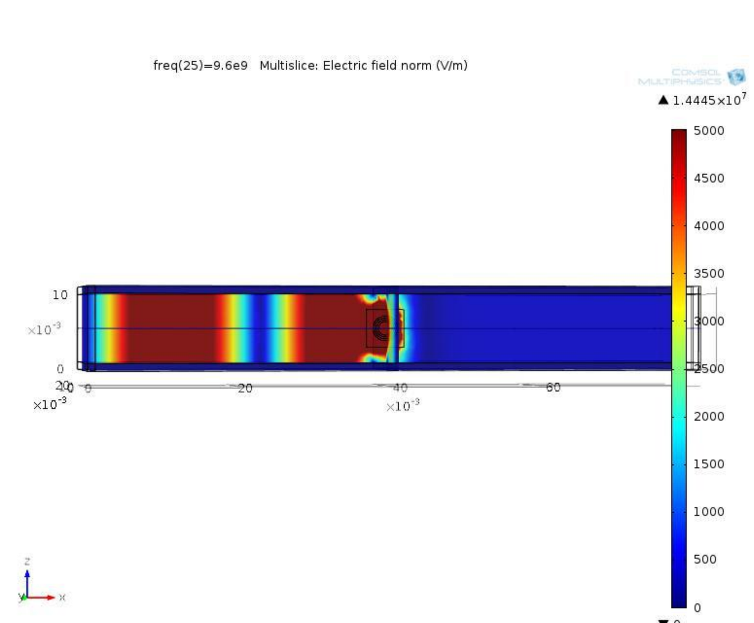

Figure 2. (b)

**Figure 2(a)** Electric field in xy plane **2(b) M**agnetic field in zx plane depicting inhibition of wave propagation at resonance

**Results**: As the power is increased from 1mW to 1W, there was increase in temperature. Table1 provides the numerical details. The temperature is in Degree Celsius (°C).

| Time(sec) / Power | 15 s | 30 s | 45 s | 60 s | 300 s |
|---|---|---|---|---|---|
| 1mW | 20.28 | 20.57 | 20.85 | 21.41 | 25.72 |
| 10mW | 20.97 | 21.95 | 22.93 | 23.90 | 39.53 |
| 100mW | 29.78 | 39.54 | 49.30 | 59.06 | 215.29 |
| 1W | 34.80 | 49.57 | 64.33 | 79.08 | 315.46 |

**Table 1**. Table depicting the change in temperature with increase in input power and time

Further, it was observed that on increasing the input power, the SRR got heated, the magnetic resonance was inhibited and clear transmission was achieved at high powers. This is depicted in the Figure3(a) and 3(b).This work is also carried out in Ansys HFSS software.Figure3(c) and 3(d) shows the intensity of electrical field generated at SRR and dielectric.

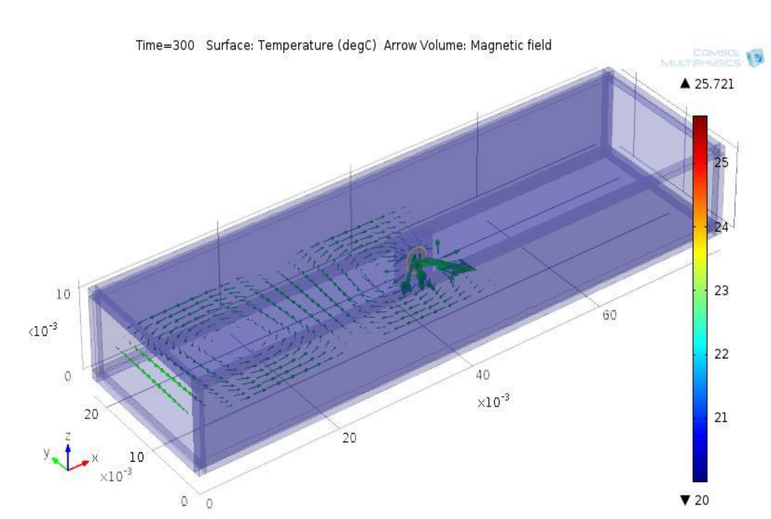

Figure 3(a)

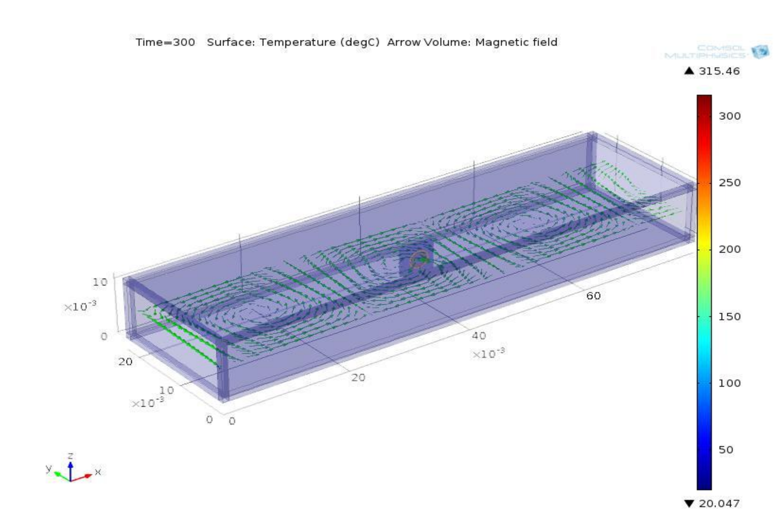

Figure3(b)

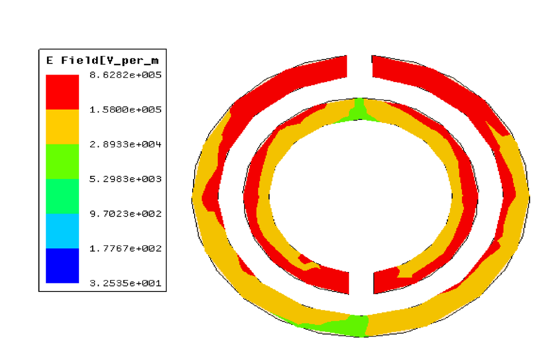

Figure 3(c)

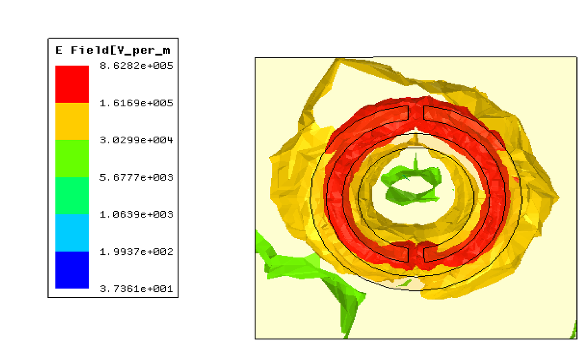

Figure 3(d)

**Figure 3**(a) 3D plot of SRR inside X-band waveguide showing magnetic resonance at 1mW input power. (b) 3D plot showing clear transmission at 1 W. (c) Electrical field at SRR and (d) dielectric with1 W input power

**Conclusions**: We have simulated an SRR model subjecting it to increasing power level. It is observed that PCB printed SRR structure cannot sustain power level beyond 1 W. Therefore, it is useful as HEM devices upto 1 W.

**References:**

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