BLE Ring Antenna Concept Simulations

Revision 1

March 19th 2024

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Simulation Caveats

- Simulation results do not provide a guarantee of real-world performance – Variations in material dielectric, geometry etc between model and actual product will result in inaccuracies.

- The return loss, smith plots provided are useful in assessing frequency tuning, however, they do not necessarily offer a good indication of radiated performance. A lossy antenna could have a good return loss but exhibit a poor efficiency. Radiated efficiency should therefore be used as the primary comparison criteria.

- For simplicity, simulations use a simplified models of the finger

- Connection ports are modelled as perfect 50 Ohms sources

Materials

The following materials were used in the simulations:

Ring:

Ring metal - Brass (91%) - Lossy metal
Ring Insulator – PTFE (Lossy) – Epsilon 2.1
Gap Insulator – Vacuum
LDS Antenna - Copper- Lossy metal

Finger (Simplified model):

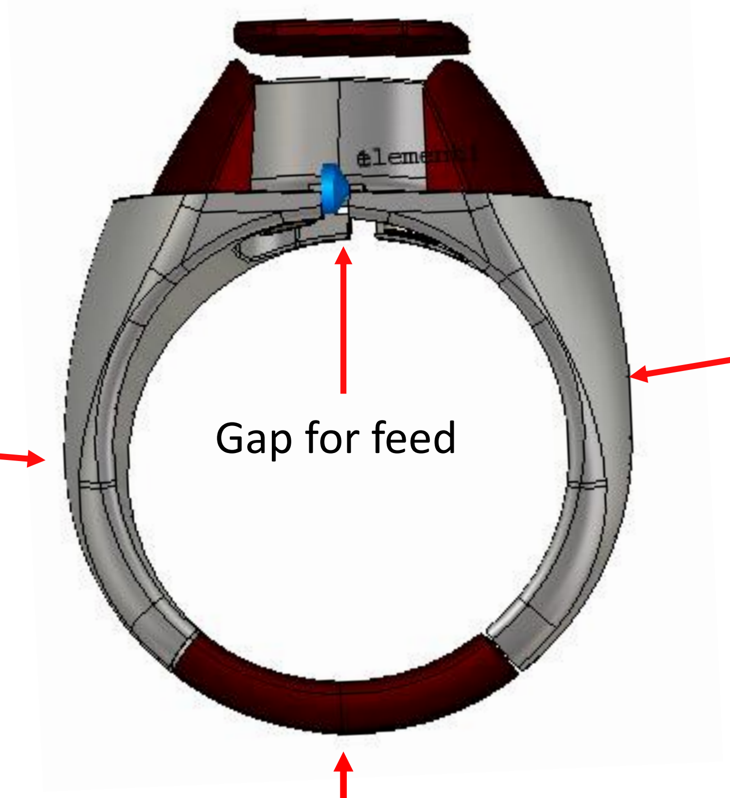
Epidermis - Epsilon 31.3 Tand 0.25
Dermis – Epsilon 31.3 Tand 0.25
Bone – Epsilon 12.6 Tand 0.25

Performance Targets

- Minimum Target efficiency for both the on-finger and free space condition is > 10%.

- 10% efficiency is typical for small wearables such as earbuds.

Concept 1 - Split Ring metal antenna



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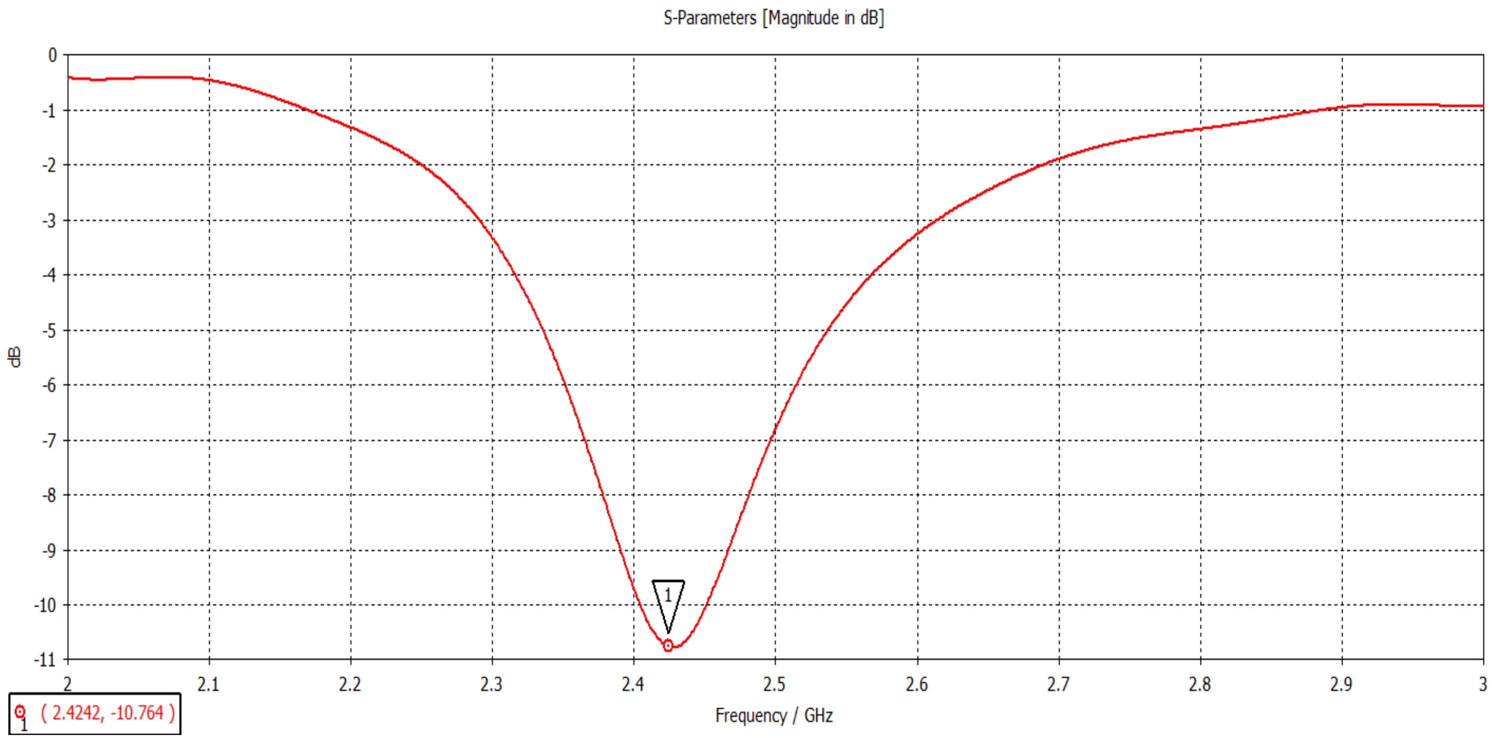
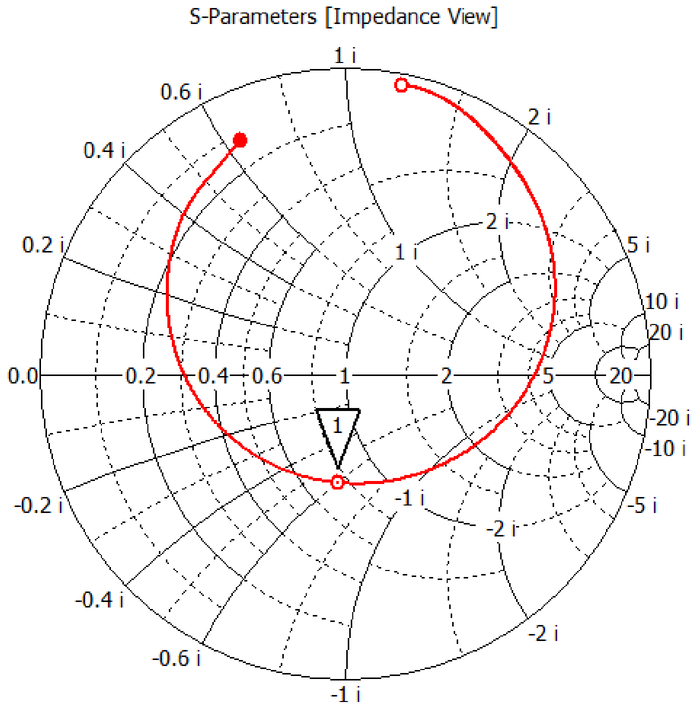
Concept 1 – Free space results





2n2 Shunt Match

Gain: 1.6dBi Radiated Efficiency 90%

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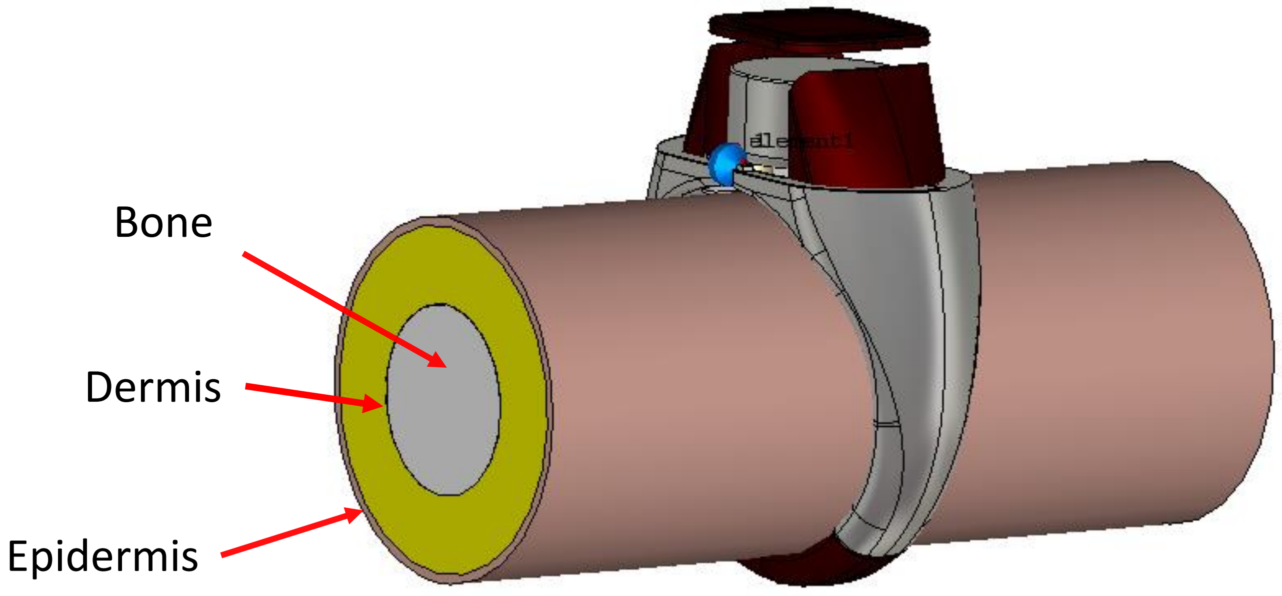
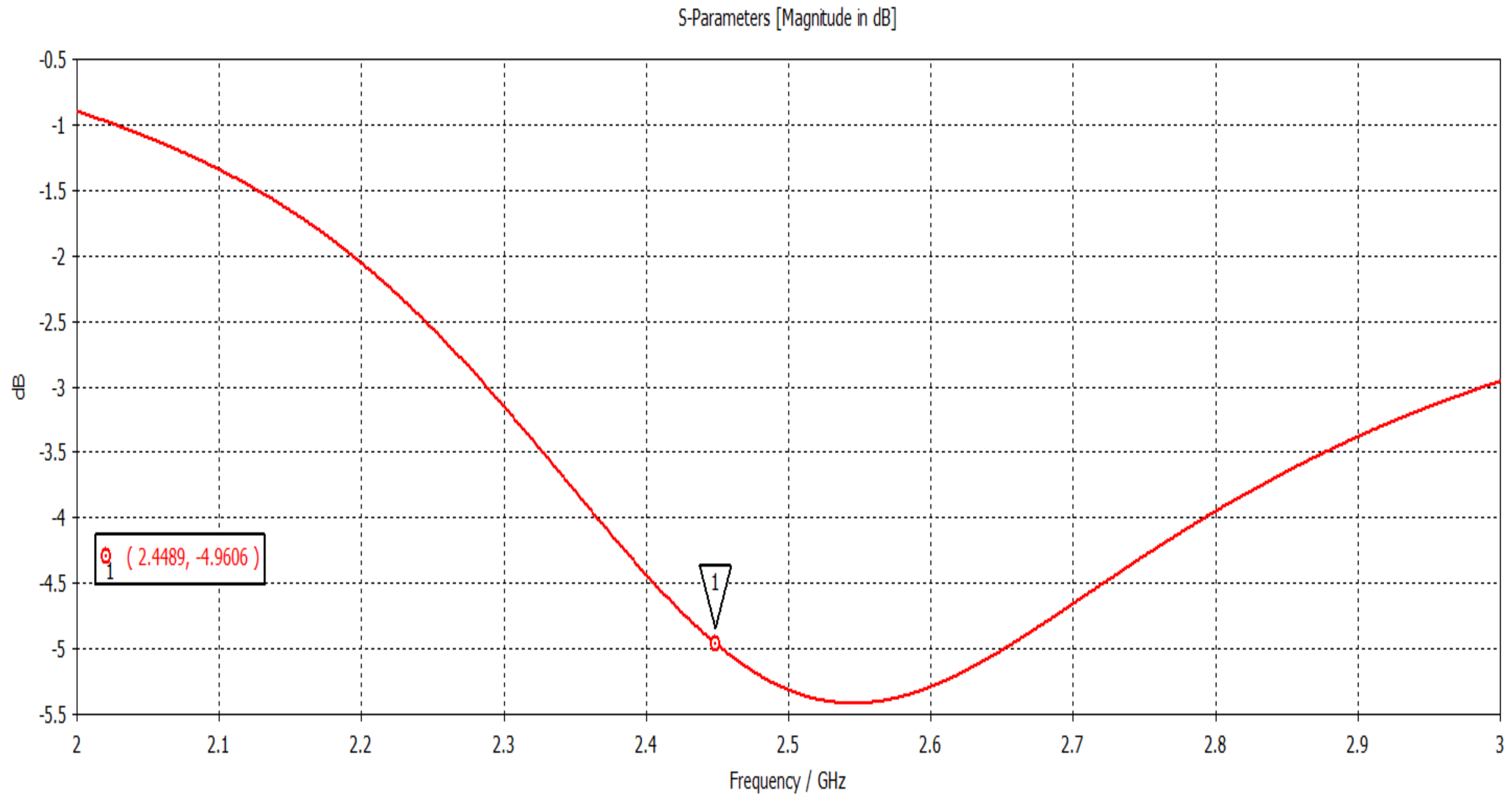
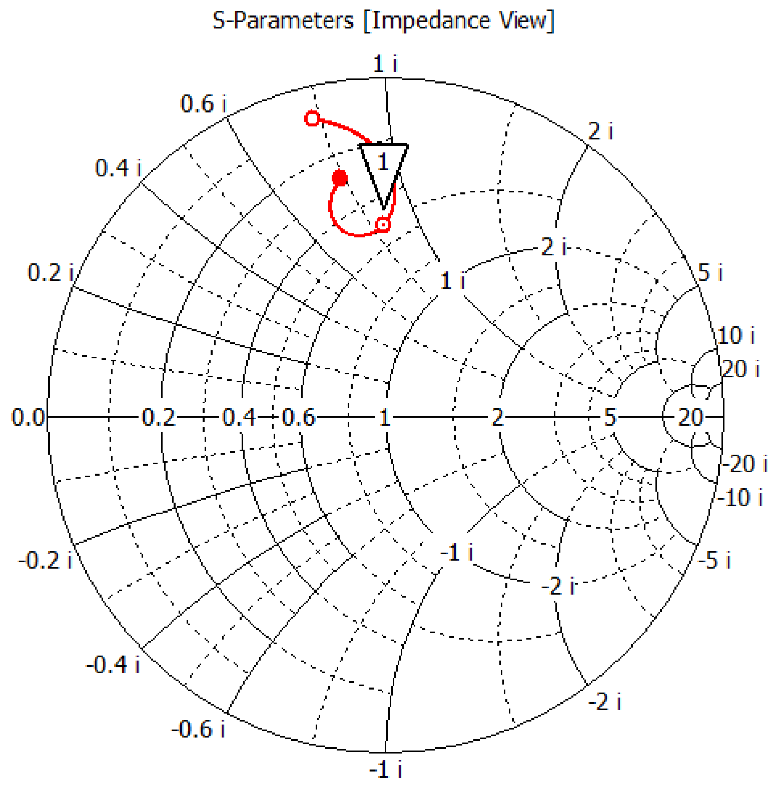
Concept 1 – On finger



Concept 1 – On finger results





2n2 Shunt Match

Gain: -10 dBi, Radiated Efficiency 6.3%

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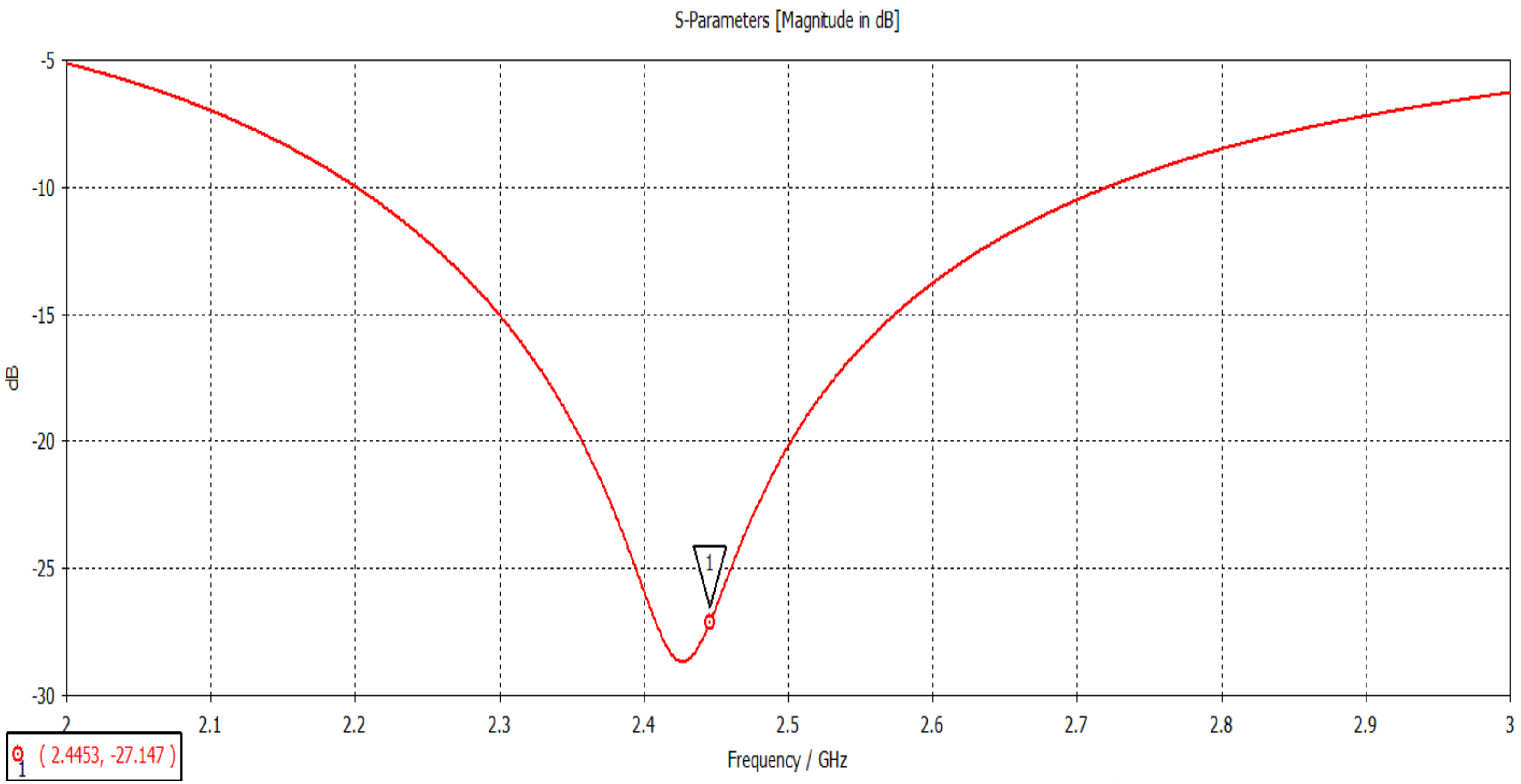
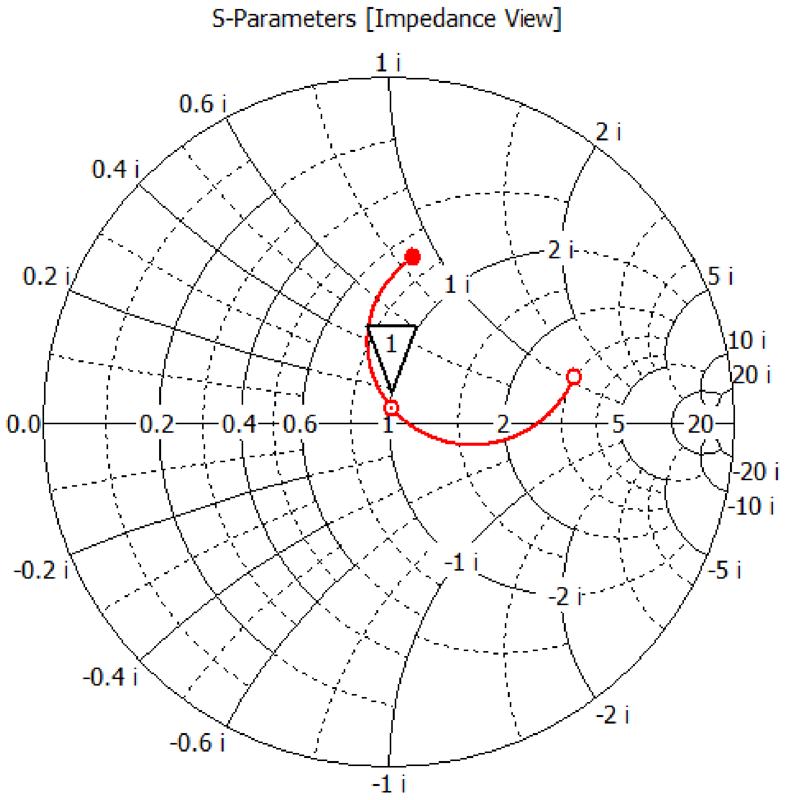
Concept 1 – On finger (No Matching) Results





No Matching network

Gain: -9 dBi, Radiated Efficiency 7.5.%

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Concept 1 Results commentary

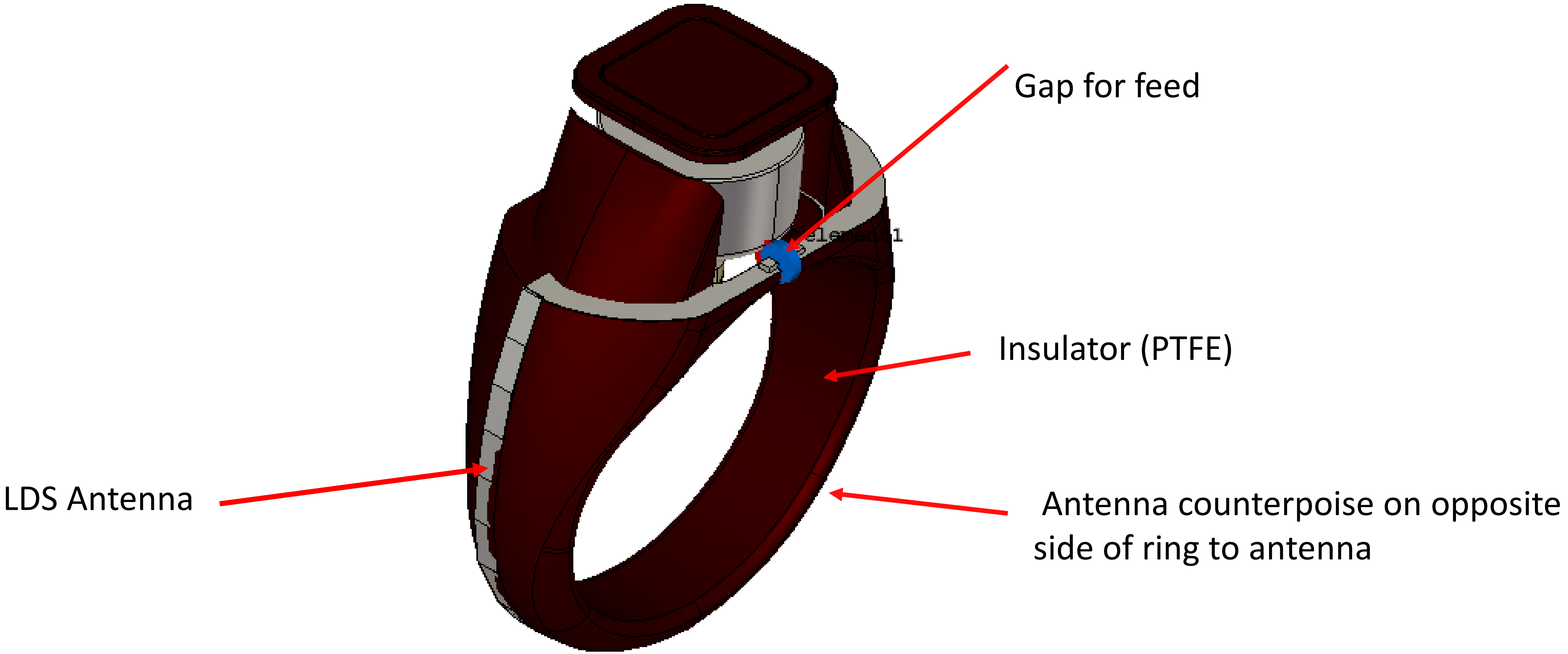
- The simulation results show that when operating in free space (off the finger) the Split Ring antenna preforms very well, with a radiated efficiency of ~ 90%

- However, when on the finger, radiated performance degrades significantly and the radiated efficiency drops to ~6.3%.

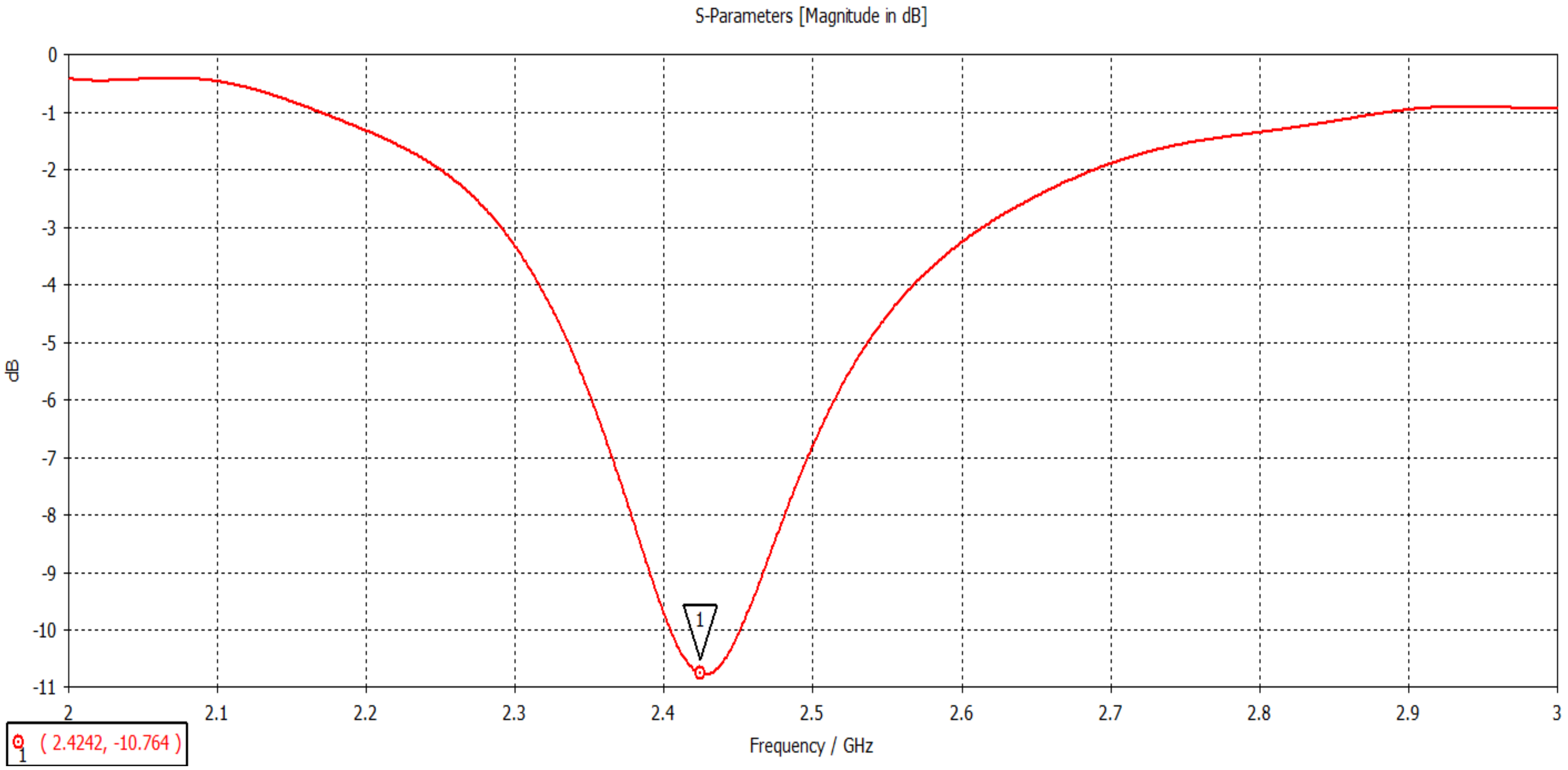
- Although, it's possible to retune for the on-finger condition, this does not provide a notable improvement in radiated performance.

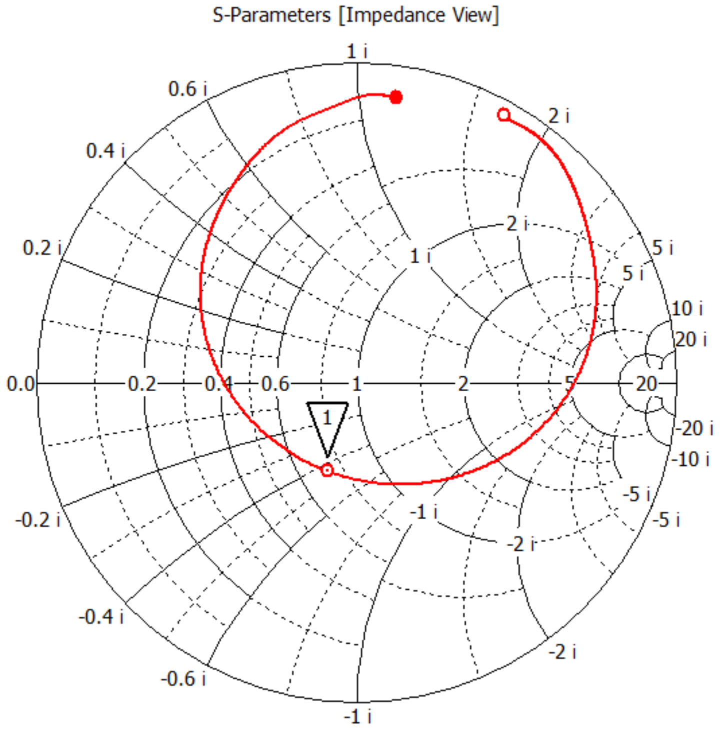
- It's clear that this concept is very sensitive to the presence of the finger and given that primary use case is with the ring on the finger, this concept is not recommended.

Concept 2 - LDS antenna on outside of non-conductive ring



Concept 2 – Free space results





3n3 Shunt Match

Gain: 1.5dBi

Radiated Efficiency 88%

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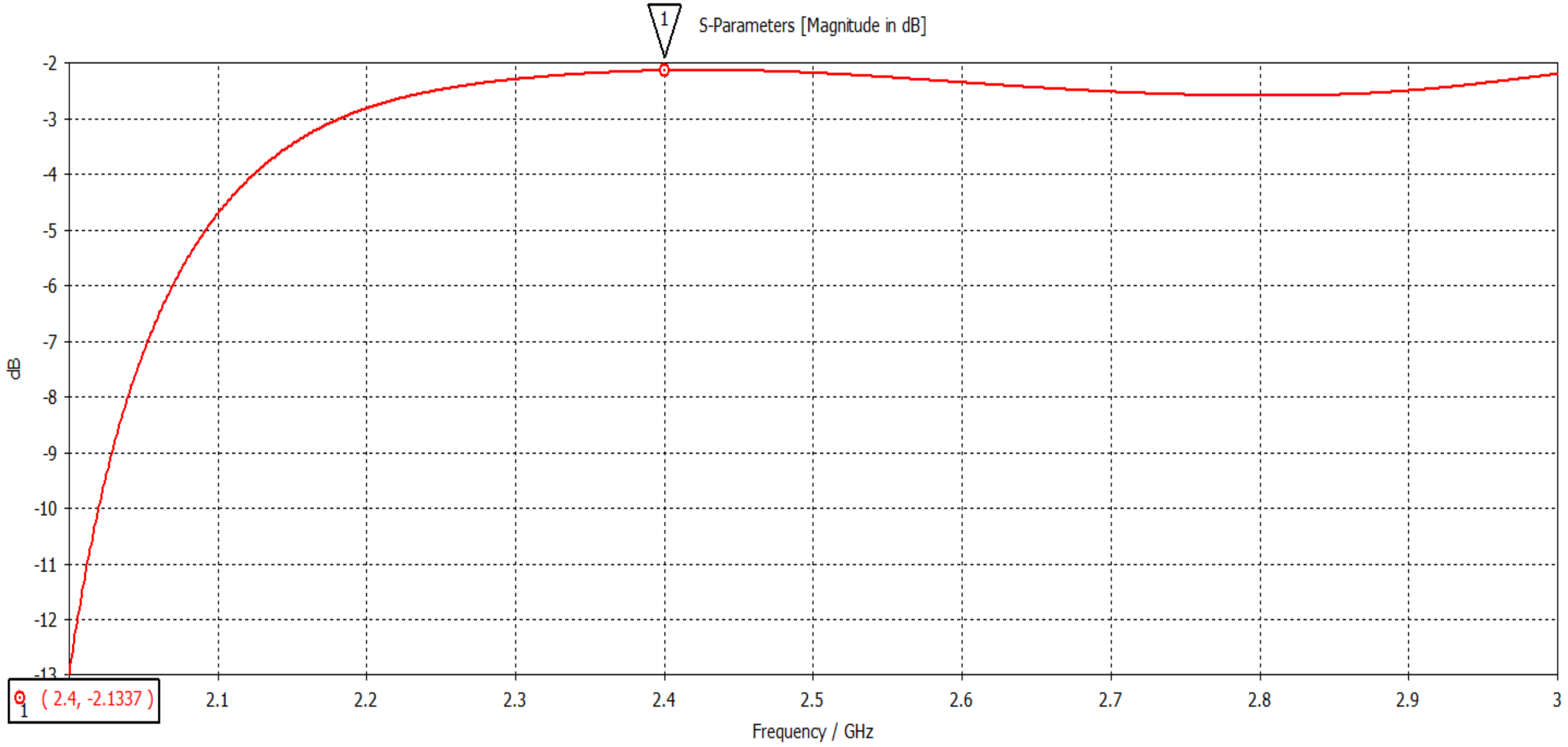
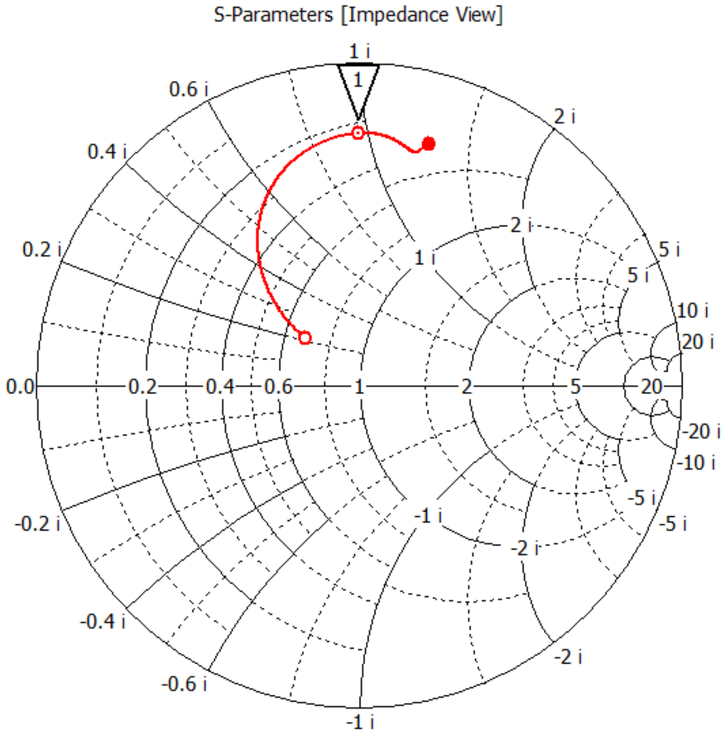
Concept 2 – On finger results





3n3 Shunt Match

Gain: -10 dBi

Radiated Efficiency 7%

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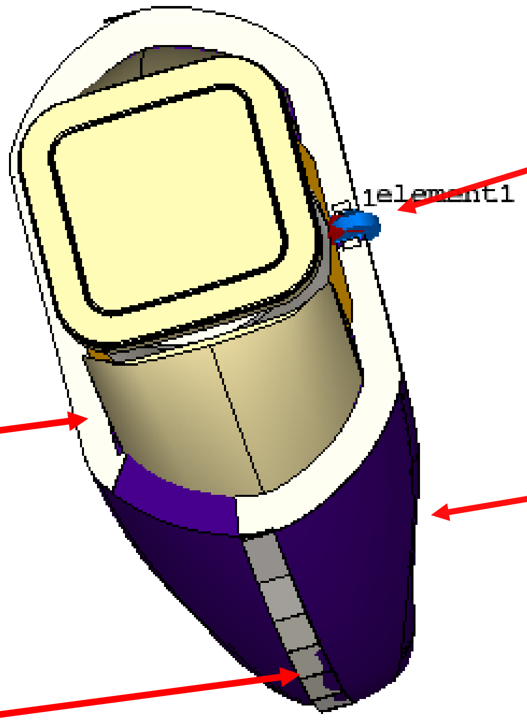
Concept 2 Results commentary.

- The results are similar to those obtained for concept 1,
- This concept is not recommended.

Concept 3 - LDS antenna on top of non-conductive ring



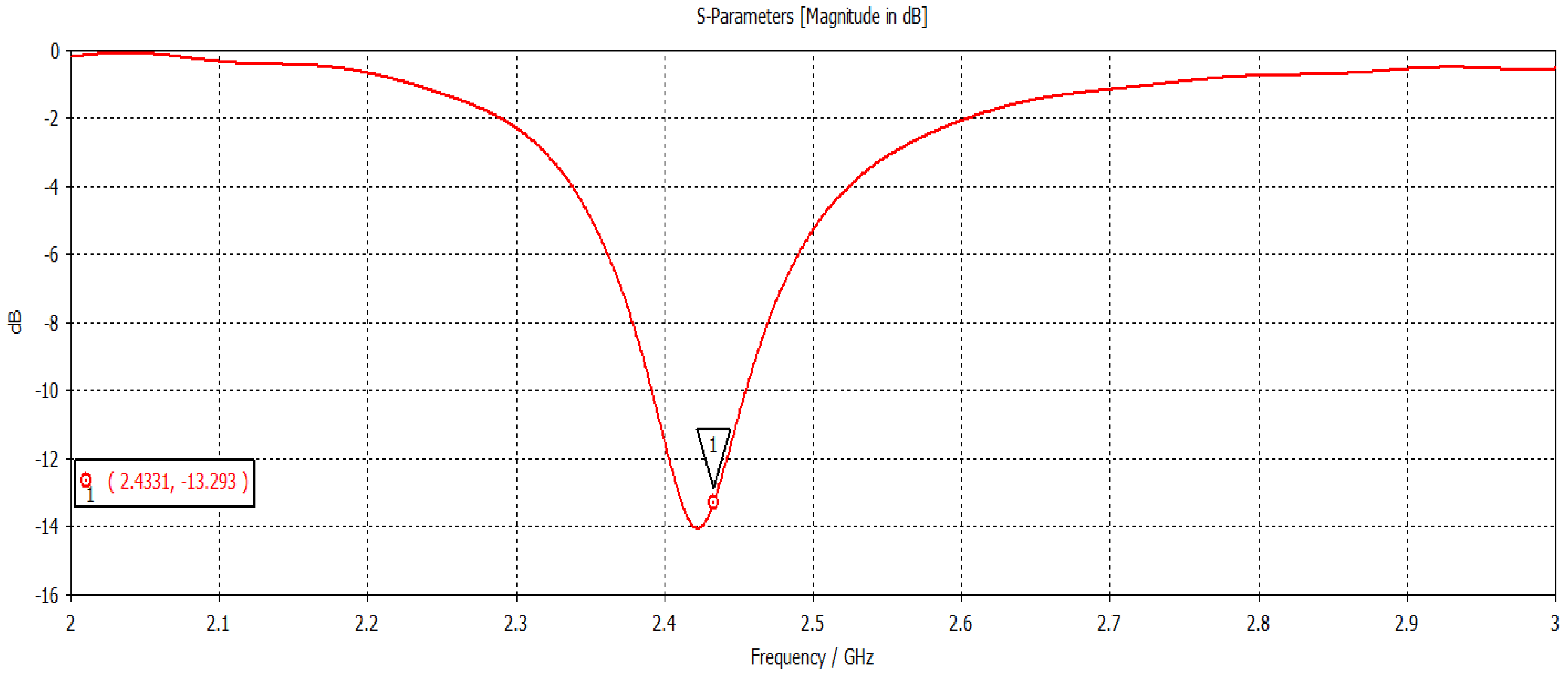
Gap for feed

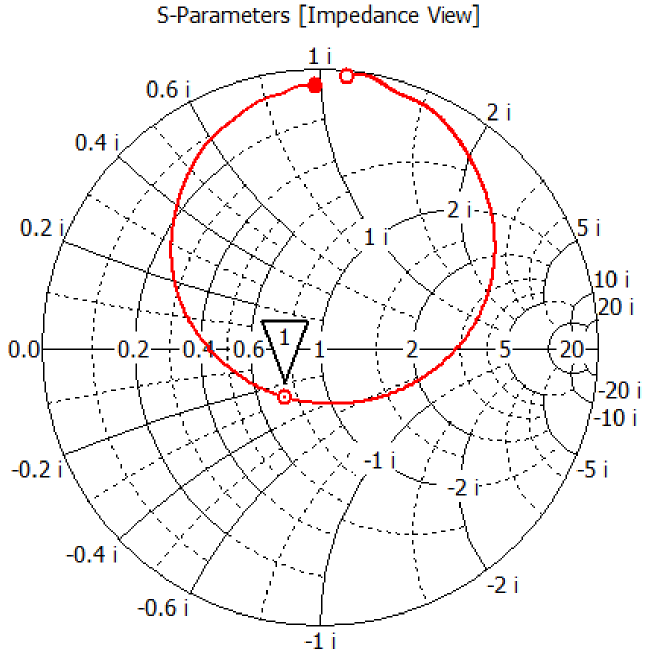
LDS Antenna

Insulator (PTFE)

LDS Antenna counterpoise

Concept 3 – Results

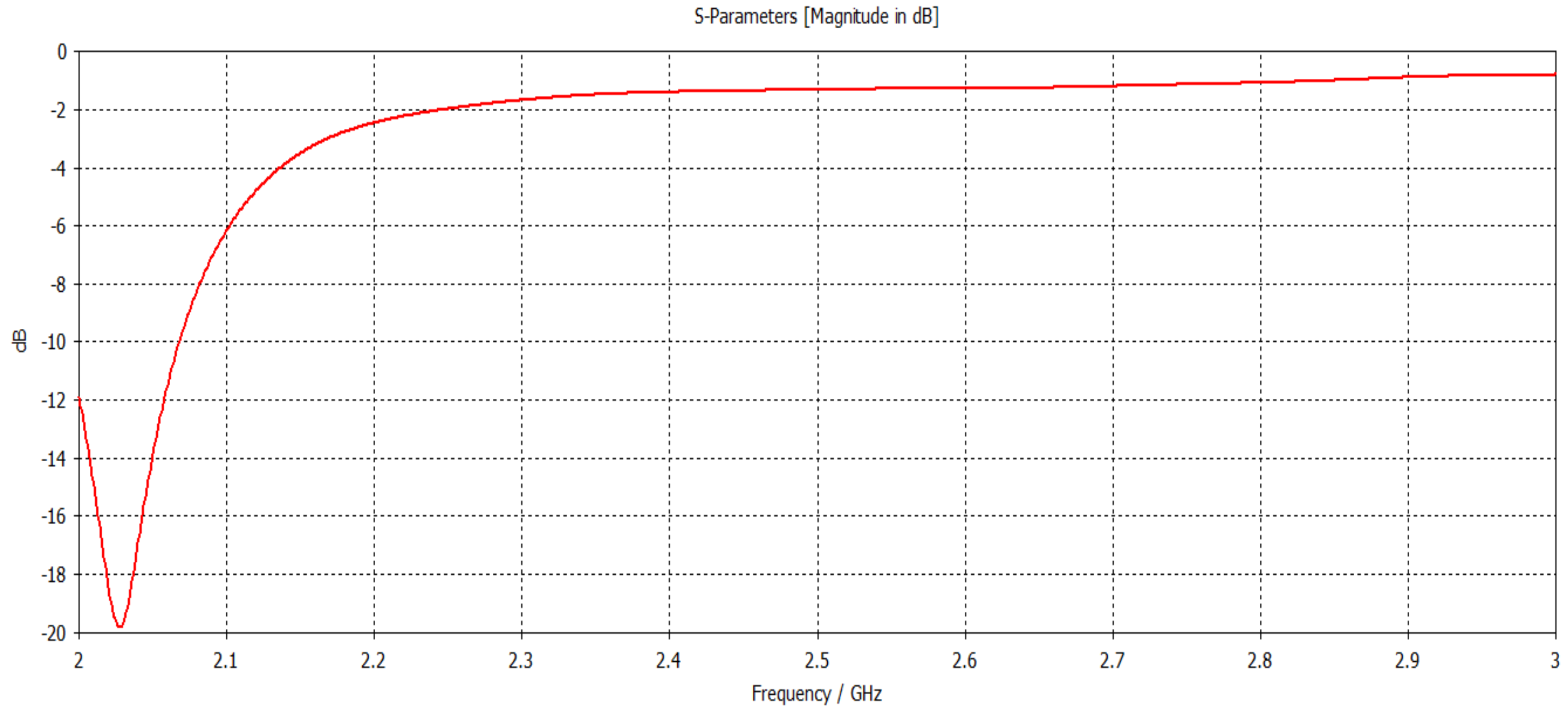


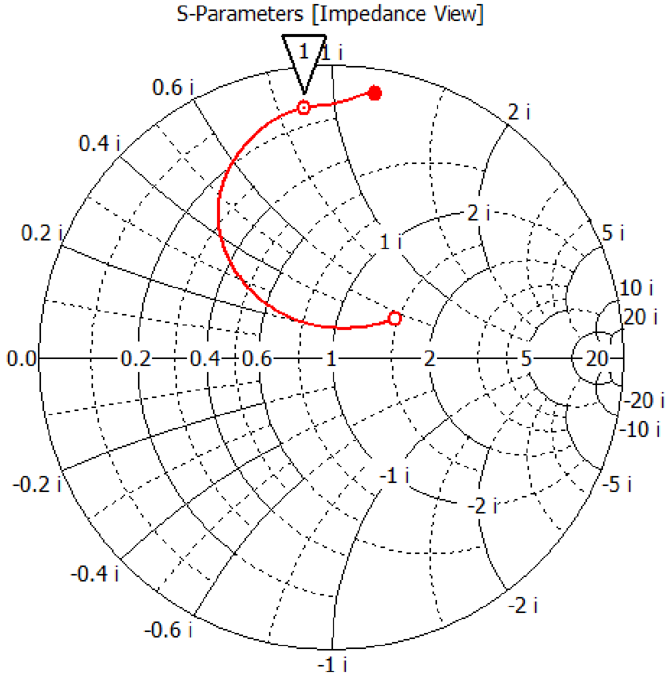


2n2 Shunt Match

Gain: 1.7dBi
Radiated Efficiency 92%

Concept 3 – On finger - Results





2n2 Shunt Match

Gain: -12 dBi
Radiated Efficiency 4.4%

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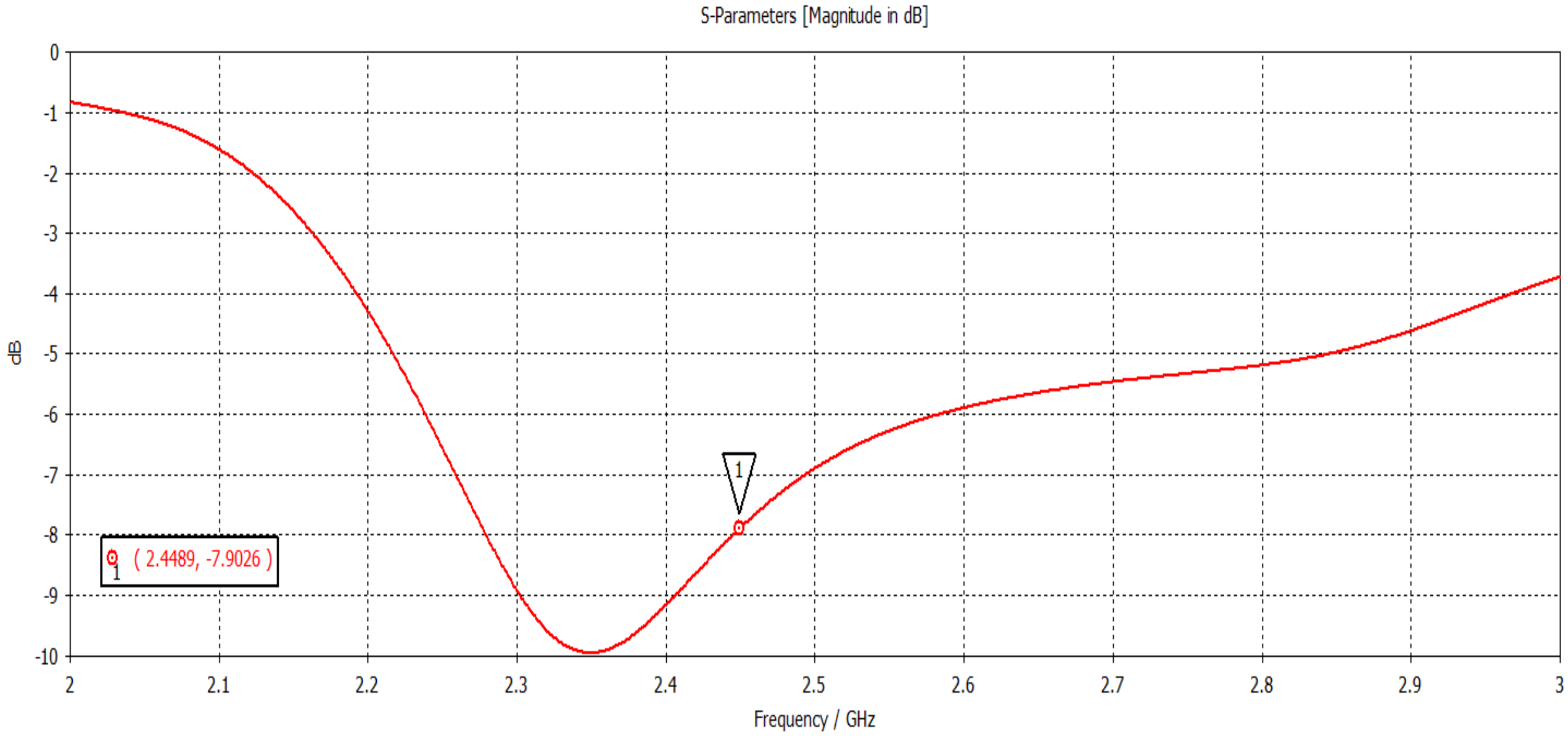
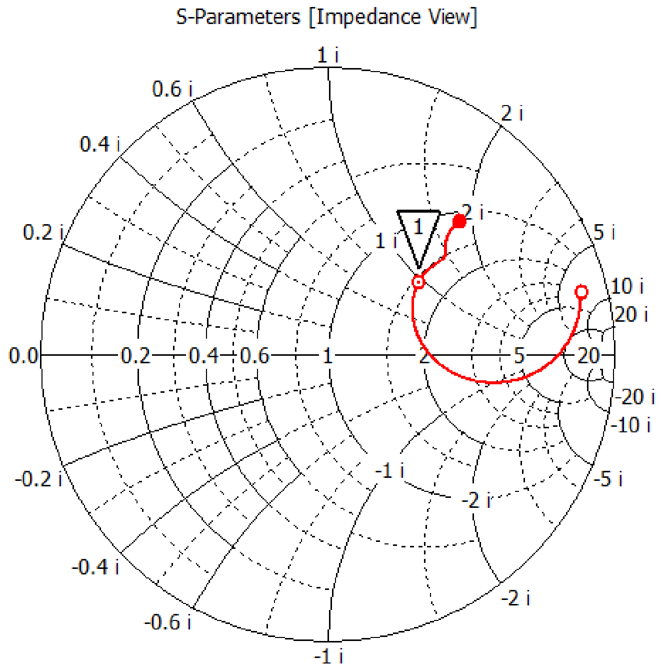
Concept 3 – retuned for On finger - Results





8n2 Shunt Match

Gain: -5 dBi

Radiated Efficiency 18%

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Concept 3 Results commentary

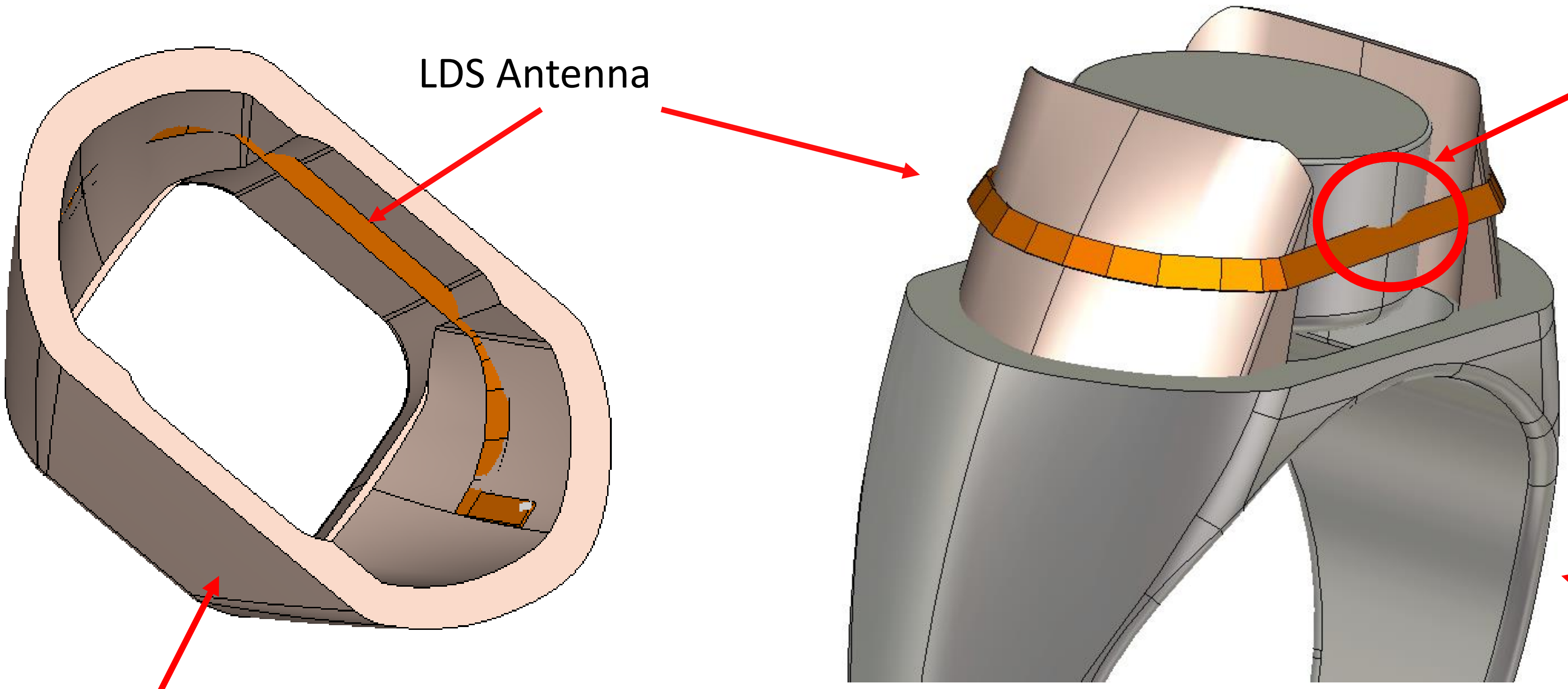
- Again, the results are broadly similar to those obtained in concept 1 and 2, with a very good on-finger efficiency of ~ 92% dropping to jut 4.4 when placed on the finger.

- However, in this case there is greater separation between the antenna element and the finger, which makes tuning specifically for the on-finger condition more viable.

- When retuned for the on-finger condition, an efficiency of 18% was achieved.

- The primary disadvantage of this concept is that it requires the ring to be constructed from a low loss non-metalic material, so brass is not an option.

Concept 4 - LDS antenna on inside of non-conductive top



Antenna too close/touching battery – Concept aborted

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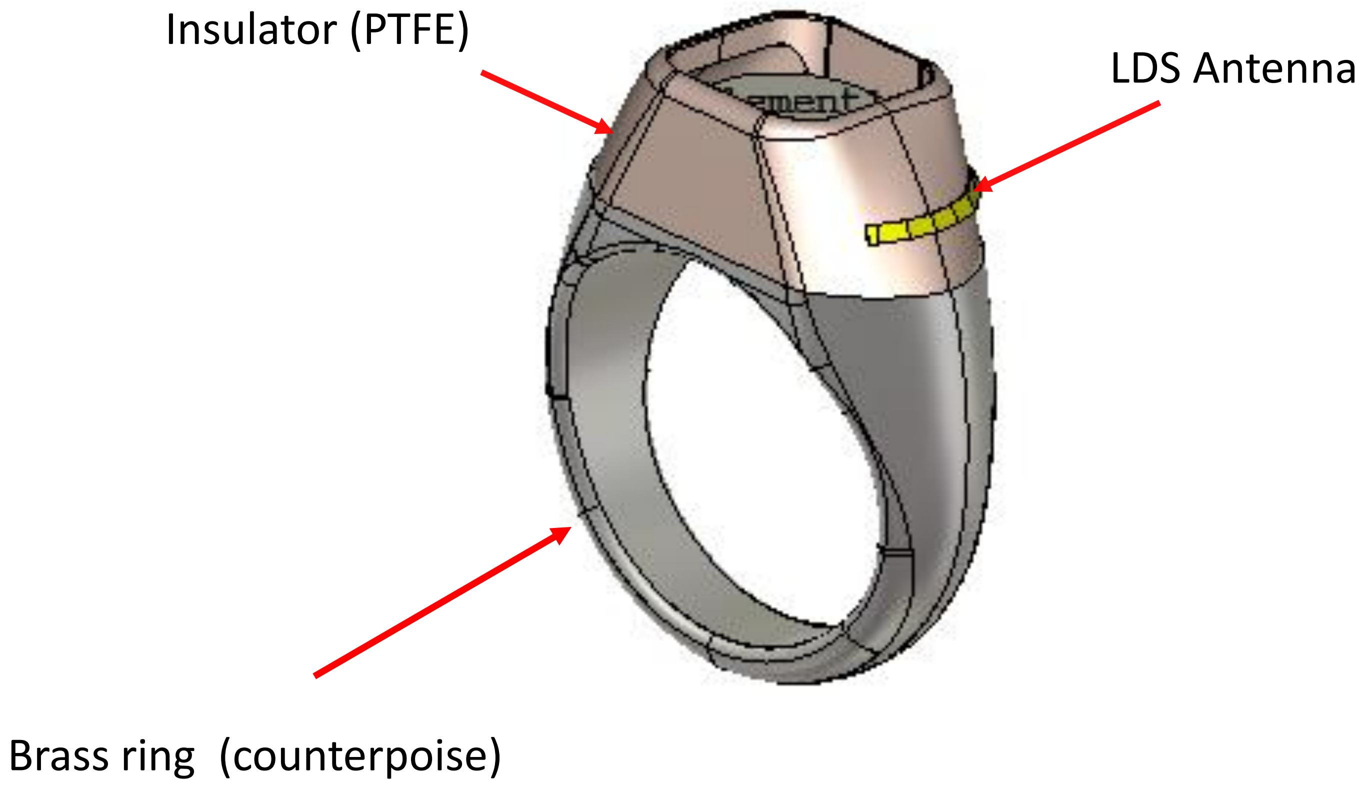
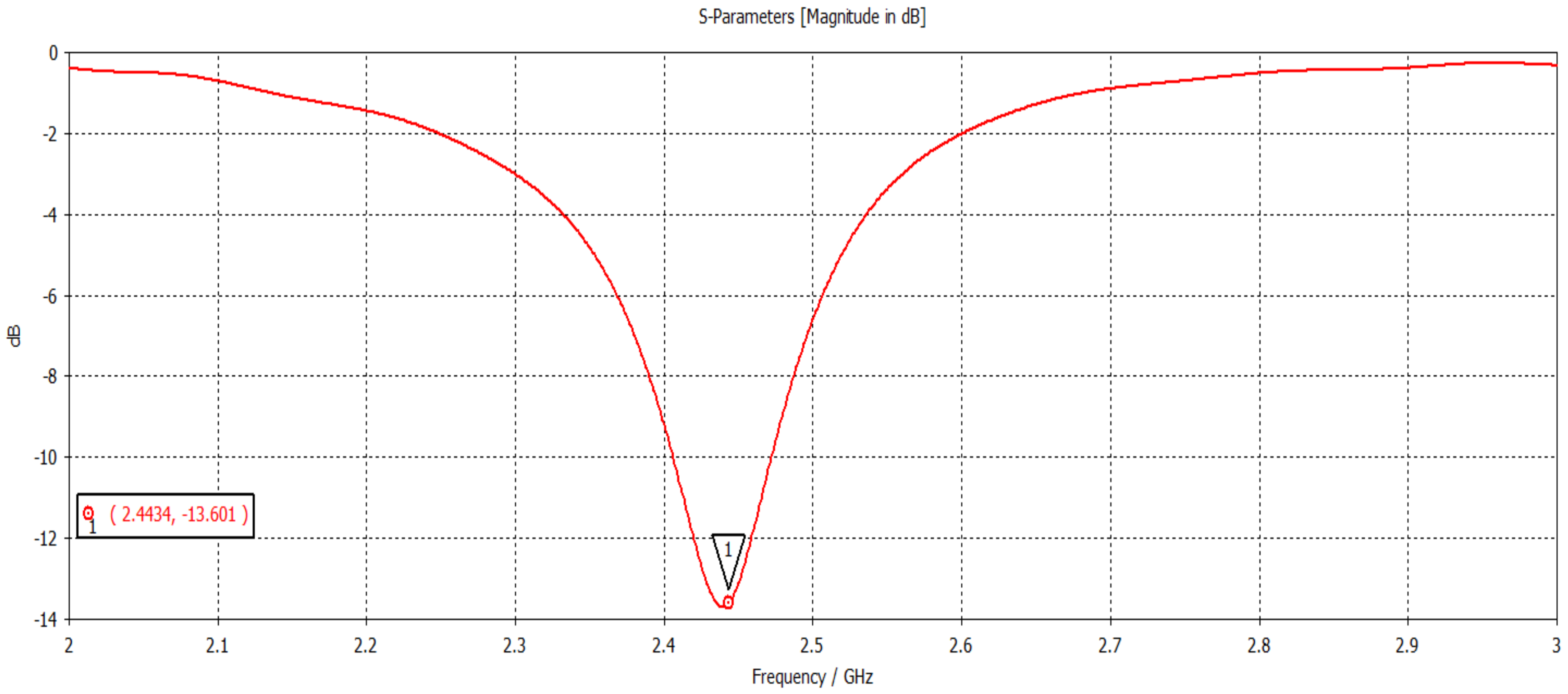
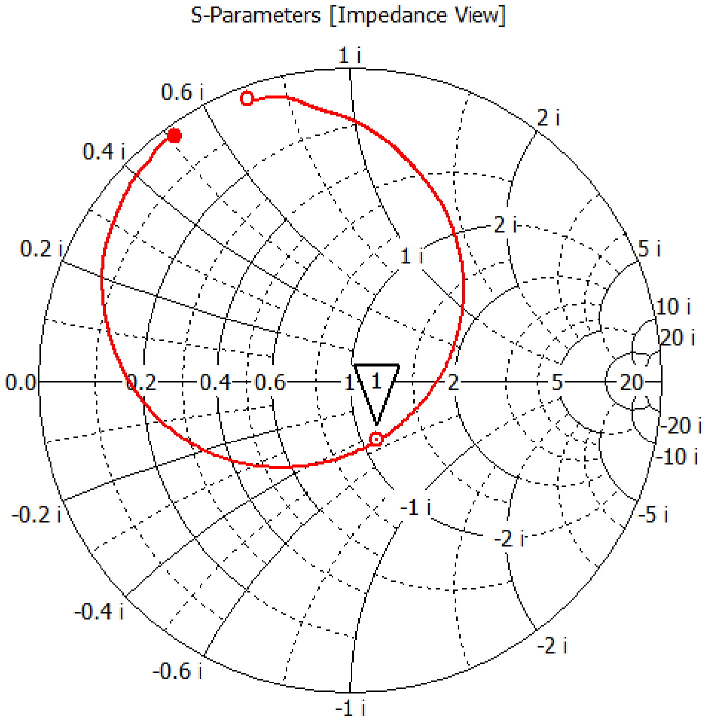
Concept 5 - LDS antenna on outside of non-conductive ring



Concept 5 – On finger - Results





0n8 Shunt Match (Tuned for on-finger)

Gain: -5.5 dBi

Radiated Efficiency 17%

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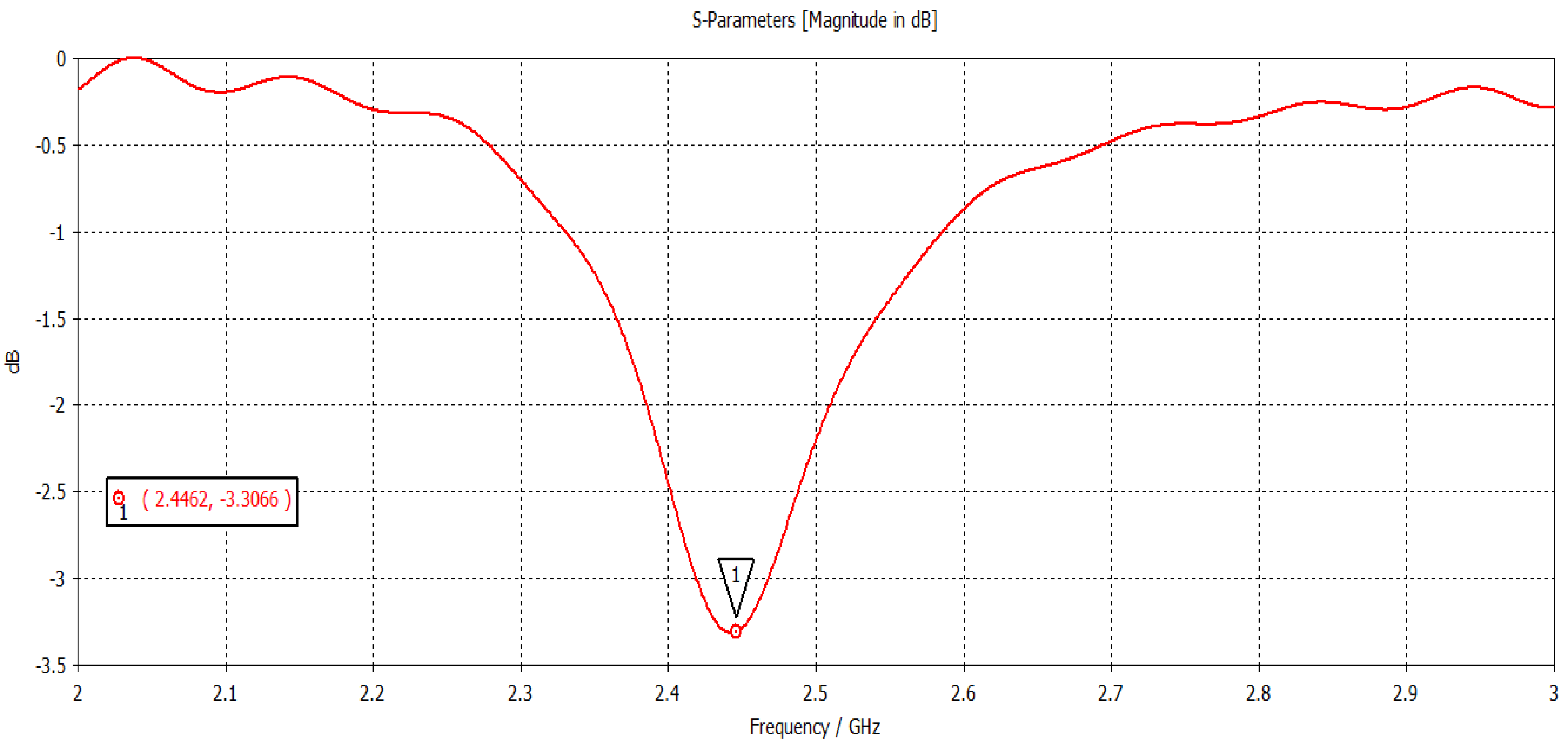
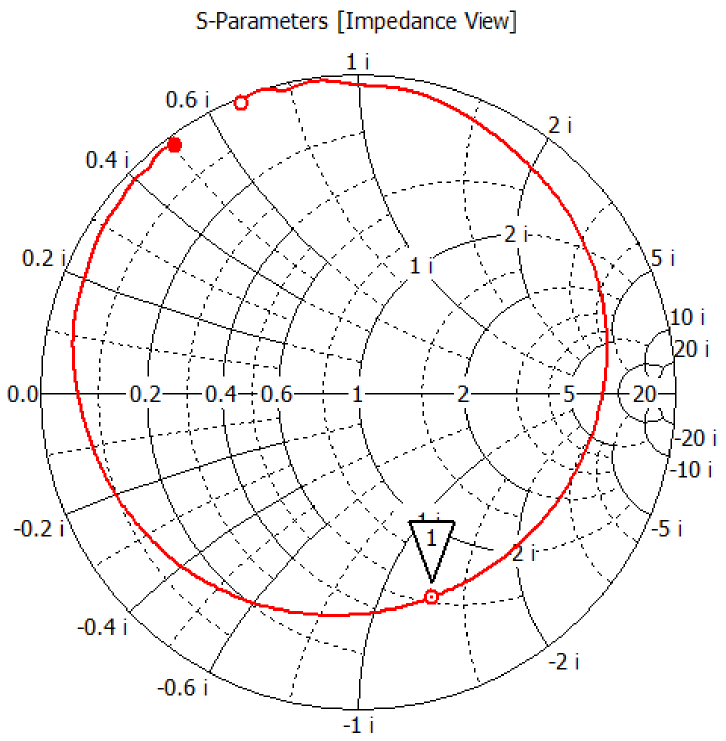
Concept 5 – Results





0n8 Shunt Match (Tuned for on-finger)

Gain: -1.6dBi

Radiated Efficiency 44%

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Concept 5 Results commentary

- For this concept, there is a reasonable distance between the antenna element and the finger, which makes tuning for the on-finger condition viable.

- At 17% the on-finger efficiency is good and meets the target spec of >10%

- This concept also requires the ring section to be constructed from a metallic material, so the use of brass is not a problem.

Conclusions

- Overall, concept 5 offers the best combination of on-finger radiated efficiency and performance stability. It also benefits from the use of brass as the ring section material.

- The main disadvantage of concept 5 is that it requires DLMS (Direct Laser Metal Sintering) or equivalent technology the print the antenna element onto the non-metallic substrate, which will then require some form of aesthetic finishing. However, this is now a relatively mature process and is regularly used on mobile and wearable devices to implement antennas.

- It may be possible to further improve antenna performance with careful routing of the antenna trace and by ensuring maximum separation between the trace and metallic structures.