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Performance Comparison of a W–T-Shaped Microstrip Patch Antenna Loaded with Dgs, Csrr and Fss Using Rogers and Fr-4 Substrates

Kuna Haritha[1], Dr. U. V. Ratna Kumari[2], Prasanthi Badugu[3]
[1]PG Scholar, Dept. of ECE, University College of Engineering Kakinada, JNTUK, Andhra Pradesh, India
[2]Professor, Dept. of ECE, University College of Engineering Kakinada, JNTUK, Andhra Pradesh, India
[3]Assistant professor, Dept. of ECE, University College of Engineering Kakinada, JNTUK, Andhra Pradesh, India
Emails: *kunaharitha23@gmail.com[1], Vinayratna74@jntucek.ac.in[2], Prasanthir52@gmail.com[3]*

Abstract
This paper presents the development of a modified microstrip patch antenna evolved from a U-shaped starting configuration into a W–T-shaped radiating structure. The design incorporates a Defected Ground Structure (DGS), Complementary Split Ring Resonator (CSRR), and Frequency Selective Surface (FSS) to modify the electromagnetic response and improve the overall antenna performance. The proposed structure is modeled and analyzed in ANSYS HFSS using two substrate implementations, namely Rogers and FR-4 epoxy. Based on the supplied HFSS results, the FR-4 implementation gives S11 = −21.8115 dB, VSWR = 1.3, gain = 5.78 dBi, and directivity = 8.51 dBi, whereas the Rogers implementation gives S11 = −15.2693 dB, VSWR = 1.7, gain = 8.59 dBi, and directivity = 8.62 dBi. The comparison indicates that the Rogers case provides higher gain and slightly higher directivity, while the FR-4 case provides the lower VSWR and deeper S11 value in the supplied results.
Keywords: *W–T-shaped patch; U-shaped patch; DGS; CSRR; FSS; Rogers; FR-4; ANSYS HFSS; S11; VSWR; gain; directivity.*

1. Introduction
Microstrip patch antennas are widely used in wireless communication systems because of their low profile, low weight, planar structure and ease of integration. However, conventional microstrip antennas generally suffer from narrow impedance bandwidth and performance trade-offs among matching, gain, efficiency and size. The reference W-shaped antenna study demonstrates the use of a W-shaped radiating patch together with CSRR metamaterial and an FSS layer to improve antenna characteristics. The reference U-shaped antenna study demonstrates that a DGS etched in the ground plane can disturb the surface-current distribution and alter the effective inductive and capacitive behavior, thereby improving impedance characteristics. In the present work, these enhancement concepts are combined with a modified W–T-shaped radiating structure. The design starts from a U-shaped concept, is modified to a double-U/W–T-type geometry, and then incorporates DGS, CSRR and FSS. The final design is evaluated in ANSYS HFSS using Rogers and FR-4 substrates.

2. Literature Review
The supplied W-shaped reference paper reports a W-shaped patch antenna loaded with CSRR metamaterial and an FSS layer. It was simulated in HFSS around the 6 GHz region and fabricated using FR-4. The paper reports 5.9 dBi gain for the metamaterial-loaded antenna and 7.1 dBi after FSS integration, with improved reflection-coefficient characteristics. The same study explains that the CSRR loading is used to enhance gain, bandwidth and antenna performance, while the FSS layer is introduced to improve the reflection coefficient and gain. The supplied U-shaped DGS paper describes a five-stage design evolution and states that a rectangular slot in the ground plane forms the DGS, disturbs current distribution, and improves return-loss behavior. The research gap addressed here is the combination of the U-to-W–T geometry modification with DGS, CSRR and FSS in one HFSS model, followed by a substrate comparison.

3. Proposed Methodology
The proposed design sequence is: U-shaped starting geometry, double-U/W–T-shaped modification, DGS

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in the ground plane, CSRR loading, FSS integration, Rogers and FR-4 substrate comparison. A 50-ohm excitation is used in the HFSS model. The final structure is enclosed by a radiation region and evaluated through S11, VSWR, gain and directivity. As shown in Figure 1 Final modified W–T-shaped (double-U-type), Figure 2 DGS used to ground plane to developed antenna, Figure 3.W-T-Shaped Antenna HFSS model show the DGS, CSRR, FSS arrangement,

3.1.Microstrip Patch Antenna Formulas:

Step 1: Calculation of Width (W)

$$W = \frac{c}{2f_0 \sqrt{(\varepsilon_r + 1)/2}}$$

Step 2: Calculation of the Effective Dielectric Constant

$$\varepsilon\_eff = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} \frac{1}{\sqrt{1 + 12h/W}}$$

Step 3: Calculation of the Effective Length

$$L\_eff = \frac{c}{2f_0 \sqrt{\varepsilon\_eff}}$$

Step 4: Calculation of the length extension ΔL

$$\Delta L = 0.412h \frac{(\varepsilon\_eff + 0.3)(W/h + 0.264)}{(\varepsilon\_eff - 0.258)(W/h + 0.8)}$$

Step 5: Calculation of actual length of the patch

$$L = L\_eff - 2\Delta L$$

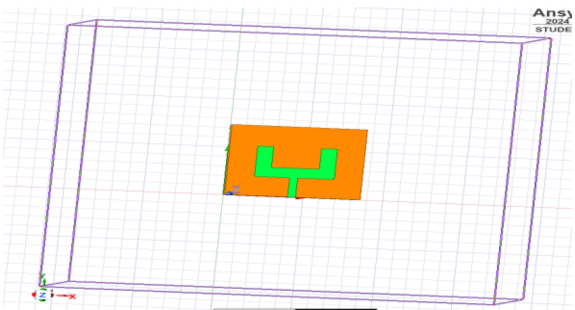

Figure 1 Final modified W–T-shaped (double-U-type)

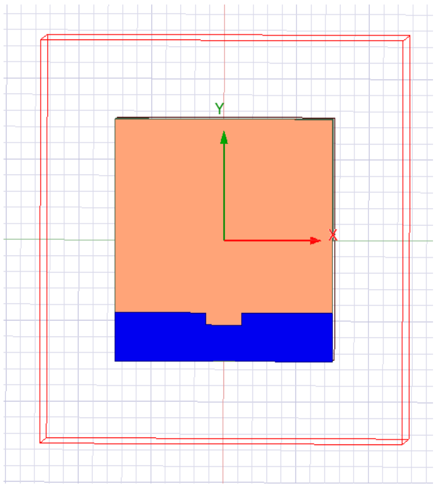

Figure 2 DGS used to ground plane to developed antenna

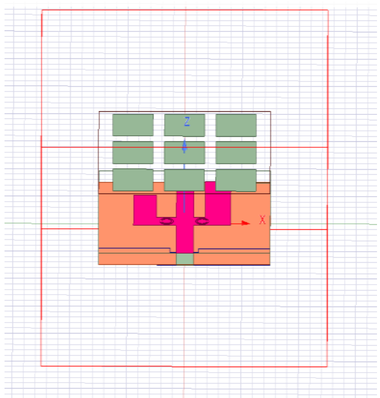

Figure 3 W-T-Shaped Antenna HFSS model show the DGS, CSRR, FSS arrangement

4. Experimental Setup

The antenna is modeled and simulated using ANSYS HFSS. The principal evaluation parameters are the reflection coefficient (S11), voltage standing wave ratio (VSWR), gain and directivity. The supplied HFSS result sheets are used directly for the numerical comparison. The exact Rogers grade, substrate thickness and frequency marker should be retained exactly as specified in the original HFSS project because these details are not completely visible in the supplied result screenshots[1 – 10].

5. Results And Discussion

The results are presented separately for each substrate, as requested. Each HFSS result is inserted as an individual figure and the corresponding numerical value is written immediately below the

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figure. No result image is merged into a single composite photograph, so the figures remain clear and editable in the Word version[11 – 18].

5.1.Fr-4 Substrate Results

The supplied FR-4 result sheet reports S11 = −21.8115 dB, gain = 5.78 dBi, directivity = 8.51 dBi and VSWR = 1.3.As shown in Figure 4 FR-4 HFSS result for S11 = −21.8115 dB, Figure 5 FR-4 HFSS result — Gain = 5.78 dBi, Figure 5 FR-4 HFSS result — Gain = 5.78 dBi, Figure 7 FR-4 HFSS result — VSWR = 1.3, Figure 6 FR-4 HFSS result — Directivity = 8.51 dBi., Figure 7 FR-4 HFSS result — VSWR = 1.3.

S11 parameters= -21.8115
Gain = 5.78

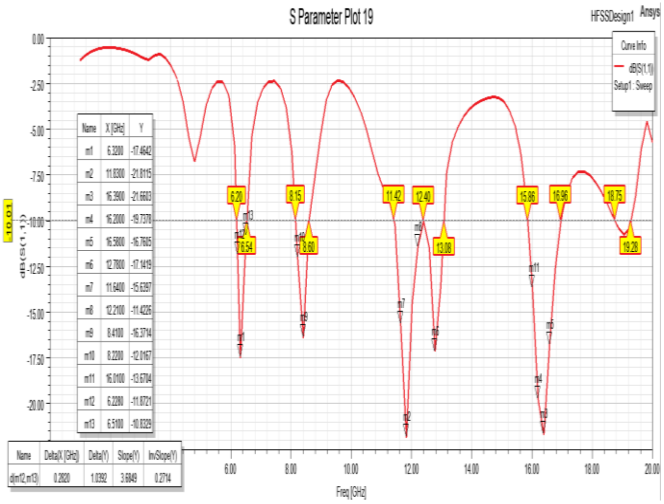

Figure 4 FR-4 HFSS result for S11 = −21.8115 dB

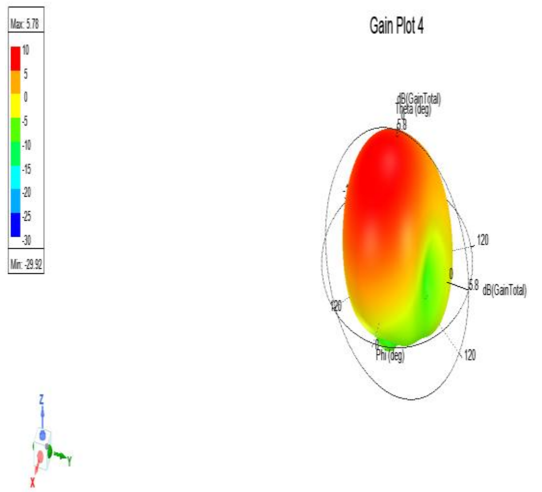

Figure 5 FR-4 HFSS result — Gain = 5.78 dBi

Directivity= 8.51
VSWR= 1.3

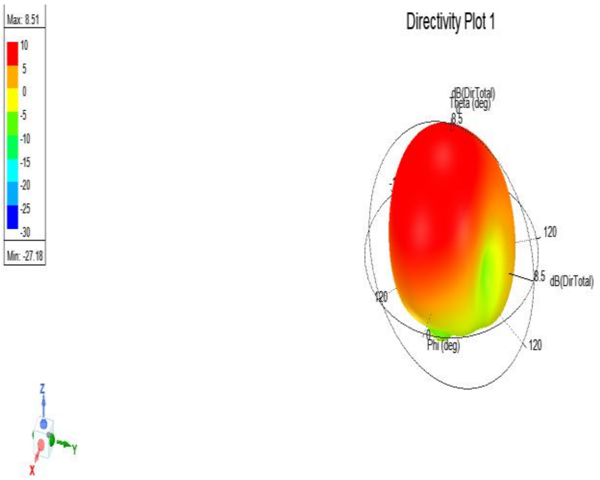

Figure 6 FR-4 HFSS result — Directivity = 8.51 dBi

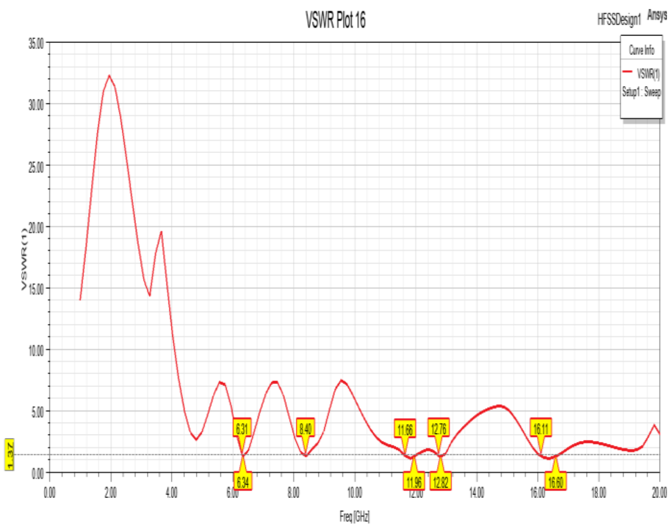

Figure 7 FR-4 HFSS result — VSWR = 1.3

The FR-4 case gives the deeper S11 value and lower VSWR among the two supplied substrate cases. These values indicate stronger input matching at the reported result point

5.2.Rogers Substrate Results

The supplied Rogers result sheet reports S11 = −15.2693 dB, gain = 8.59 dBi, directivity = 8.62 dBi and VSWR = 1.7.As shown in Figure 8 Rogers HFSS result — S11 = −15.2693 dB, Figure 9 Rogers HFSS result — Gain = 8.59 dBi, Figure 10 Rogers HFSS

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result — Directivity = 8.62 dBi

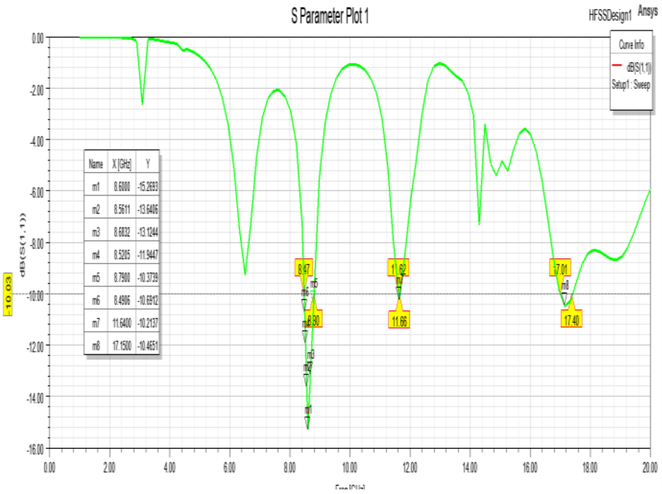

Figure 8 Rogers HFSS result — S11 = −15.2693 dB

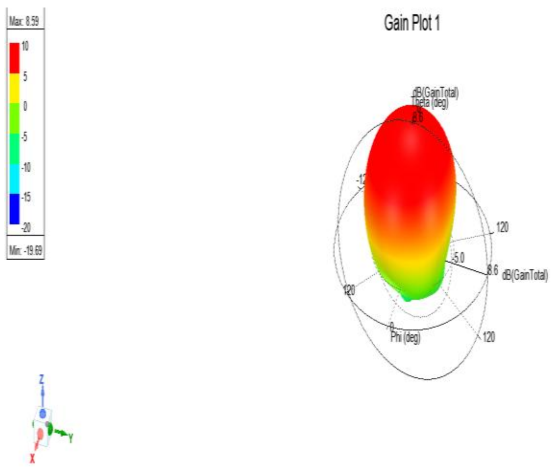

Figure 9 Rogers HFSS result — Gain = 8.59 dBi

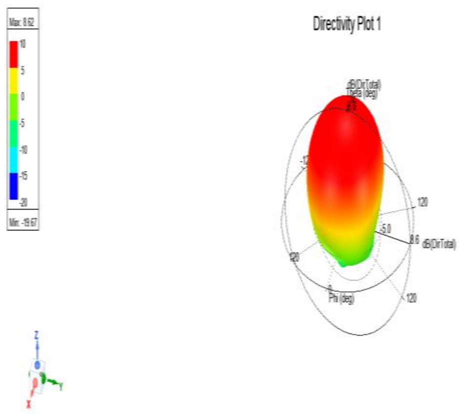

Figure 10 Rogers HFSS result — Directivity = 8.62 dBi

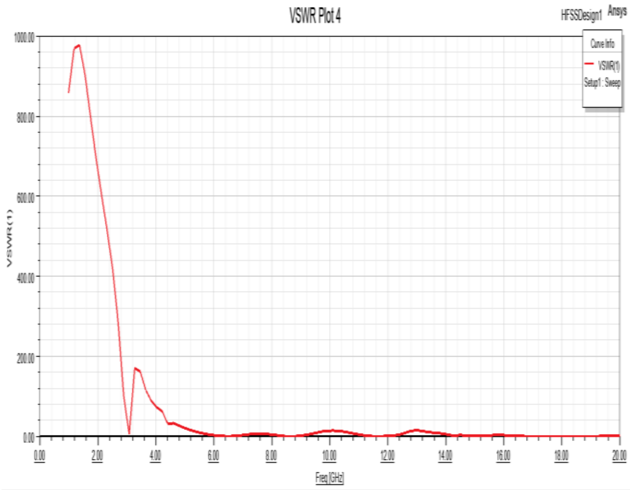

Figure 11 Rogers HFSS result — VSWR = 1.7

The Rogers case gives substantially higher gain and slightly higher directivity than the supplied FR-4 case. However, its S11 and VSWR values are not as low as those of the FR-4 case. Thus, the two substrates show a trade-off between radiation performance and input matching.

5.3.Substrate-Wise Result Comparison

From the supplied values, the Rogers substrate improves gain by 2.81 dB compared with FR-4 (8.59 dBi versus 5.78 dBi). Directivity changes only slightly, from 8.51 dBi to 8.62 dBi. FR-4 provides the lower VSWR and deeper S11, while Rogers provides the higher gain and slightly higher directivity. As shown in Table 1 Substrate-Wise Result Comparison.

Table 1 Substrate-Wise Result Comparison

Parameter	FR-4	Rogers
S11	−21.8115 dB	−15.2693 dB
VSWR	1.3	1.7
Gain	5.78 dBi	8.59 dBi
Directivity	8.51 dBi	8.62 dBi

Conclusion

A W–T-shaped microstrip patch antenna was developed from a U-shaped starting concept by integrating DGS, CSRR and FSS techniques. The final structure was analyzed in ANSYS HFSS using

Rogers and FR-4 substrates. The supplied simulation results show that Rogers provides the highest gain (8.59 dBi) and slightly higher directivity (8.62 dBi), whereas FR-4 provides the lower VSWR (1.3) and deeper S11 (−21.8115 dB). The proposed combination provides a useful basis for further optimization of the patch, DGS, CSRR and FSS dimensions.

Future Scope

Future work can include parametric optimization of the W–T patch dimensions, DGS slot dimensions, CSRR dimensions, FSS periodicity and spacing between the antenna and FSS layer. Fabrication and measurement using a vector network analyzer and anechoic chamber can be performed. Radiation efficiency, impedance bandwidth, surface-current distribution and E/H-plane radiation patterns should also be included in the final validation.

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