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Investigation of LTCC-based patch antenna for Wireless Applications

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Abstract

This work reports the design, development and demonstration of a low-loss rectangular micro-strip patch antenna for WLAN applications using a low-temperature co-fired ceramic (LTCC) substrate. The proposed antenna was simulated in CST Microwave Studio. The patch is printed on a Dupont-LTCC substrate with a dielectric constant of 7.8 and has a 1 mm thickness. The developed antenna with a centre frequency of 5.95 GHz has been demonstrated for video transmission. The S11 obtained experimentally is -29.34 dB with a VSWR of 1.17, which is close to the simulated results.

1. Introduction

Evidently, with the development of several wireless applications, low-loss antenna designs with better antenna performance have become necessary for the evolution of an efficient system. Microstrip patch antennas have the primacy of low profile, easy production and play a significant role in wireless communications. One of the applications is Wireless Local Area Network (WLAN: 2.4-2.484, 5.15-5.25, 5.25-5.35, 5.47-5.725 and 5.725-5.850 GHz)[1]. The paper focuses on 5.725- 5.850 band utilizing LTCC substrate for a rectangular patch antenna and its usage in audio/video transmission applications.

2. Design

As depicted in Fig.1, a microstrip patch antenna with a radiating patch on one side of the substrate and a ground plane on the other was designed for WLAN applications. A rectangular patch dimension was initially calculated through the equations Eq1-4. The inset feeding mechanism was used for the RF input. ~5.79 GHz was the targeted frequency for applications in IEEE 802.11a WLAN band (5.725-5.850 GHz). Eq.1-3 was used for the initial parameter calculations for the patch, and Eq. 4 was used for calculating the width of 50 Ω microstrip line, w_0, where f_0 is the resonant frequency, h is the height of the substrate, c is the speed of light, ε_{eff} the effective permittivity, W_P , L_p is the width and length of the patch, respectively, Z_{cm} is the characteristic impedance of the feed line. After obtaining the initial dimensional parameters, the structure was optimized using the CST FEM simulation tool, and the dimensions are mentioned in table 1. Fig. 2 delineates the S11 obtained by simulation as -40.2 dB.

$$W_p = \frac{c}{2 f_0 \sqrt{\frac{(\varepsilon_r+1)}{2}}} \quad (1).$$

$$L_e = L_p + 2\Delta L = \frac{c}{2 f_0 \sqrt{\varepsilon_e}} \quad (2).$$

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1 + \frac{12\, h}{W}\right]^{-1/2} \quad (3).$$

$$Z_{cm} = \frac{120\, \pi}{\sqrt{\varepsilon_{eff}}\left[\frac{W_0}{h}+0.139+0.667\ \ln\left(\frac{W_0}{h}+1.444\right)\right]} \quad (4).$$

Table 1. Optimized dimension of the antenna

Parameter	Value
Substrate thickness	1.06 mm
Patch length	8.9 mm
Patch width	12.35 mm
Substrate length	24 mm
Substrate width	25 mm
Inset length	3.6 mm
Inset width	0.33 mm

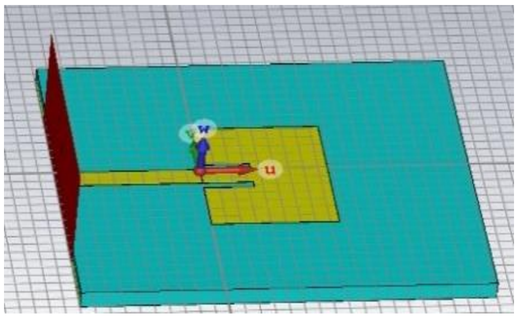

Figure 1. Patch antenna

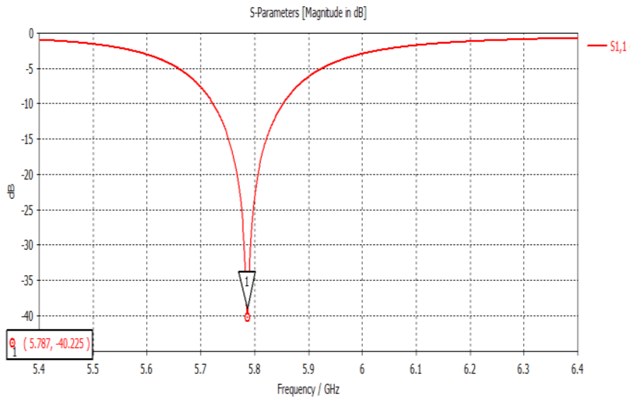

Figure 2. S11 plot (CST)

3. Fabrication and Testing

The antenna was fabricated using LTCC substrate DUPONT 951, having a dielectric constant of 7.8 and a loss tangent of 0.006. DUPONT AgPd paste was used to pattern the antenna and ground. Fig. 3 shows the flowchart for the steps of fabrication. RF signal was directed towards the microstrip feed line through the SMA connector soldered to the ground. The antenna with the SMA connector was tested using VNA (Agilent Technologies). Fig 4. And 5. depicts the S11 and VSWR values, respectively. The fabricated antenna's observed centre frequency was 5.9 GHz, close to the simulated one of ~5.8 GHz. The S11 obtained is -29.3 dB. The soldered connecter losses may have also contributed to the increased losses wrt the simulated one. Fig. 6 shows the smith chart where a line impedance of 54 Ω is obtained after fabrication.

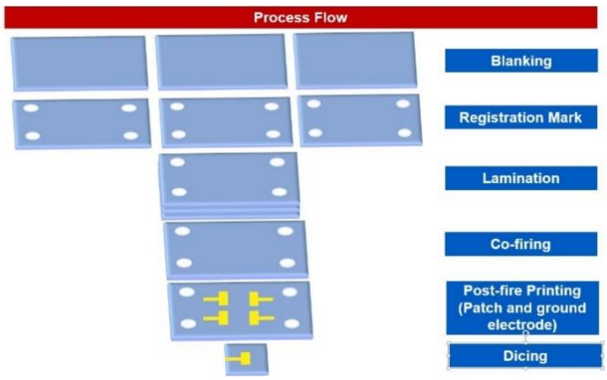

Figure 3. Flowchart for the fabrication process

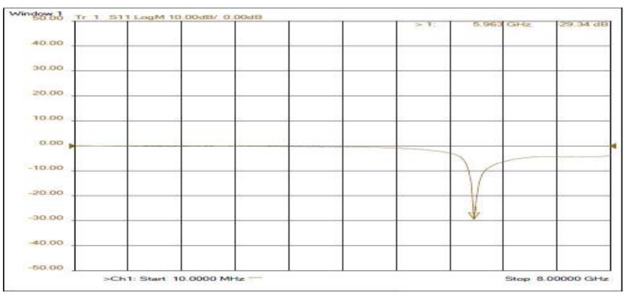

Figure 4. S11 experimentally calculated (-29.34 dB)

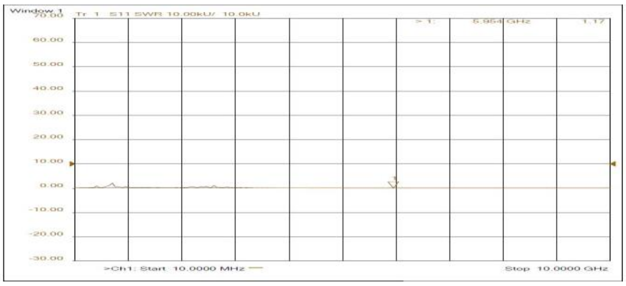

Figure 5. VSWR experimentally calculated (1.17)

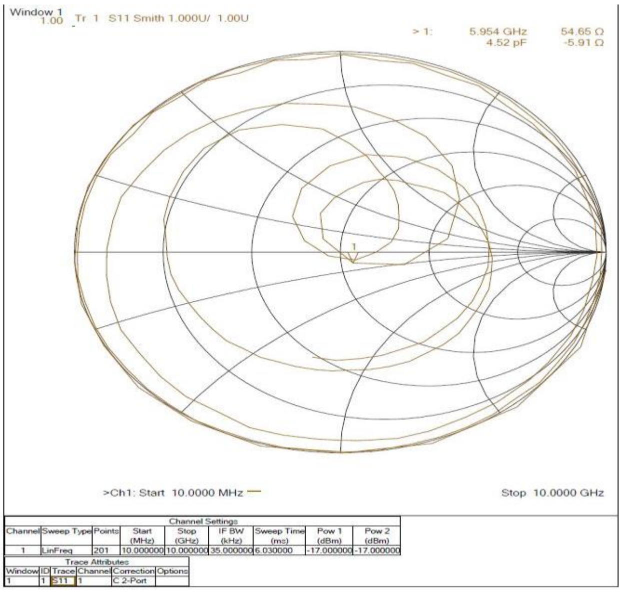

Figure 5. Smith Chart showing the impedance

4. Results and Discussion

The fabricated antenna shows a low loss response with S11 of -29.3 dB. The parameters like S11, VSWR, and respective dimensions of the present work are compared with a few other works of literature, as given in table 2. The gain can be increased by forming an array or other enhancement techniques like a coplanar parasitic patch.

The work reports a low-loss antenna for wireless applications. To verify the working of the antenna for the targeted application, a commercial transmitter and receiver were utilized, as shown in Fig.6. The commercial antenna of the transmitter and receiver was replaced by an in-house developed antenna using LTCC-Technology on both the transmitter and receiver end. Both the transmitting and receiving antenna design and dimensions are the same. The transmitter, antenna, and camera were mounted in a box with a battery. The receiver was connected to the mobile phone with an application for video reception. As the battery is connected to the transmitter, the video taken from the camera's sight is displayed on the phone in real-time. Hence the video transmission was successfully demonstrated. The range is presently tested for approx. 100 m in the open lawn. As the battery was disconnected from the transmitter, the video was not displayed on the phone, and a noise signal was on the channel instead.

Table 2. Comparison of single patch antenna

Work	**Substrate**	**S11**	**VSWR**	**Gain**	**Dimension**
Antonio Carvalho et.al[2]	Rogers(RO3006) ε_r =6.15 tanδ =0.002	-21 dB (sim)	-	7dBi(sim)	P_L= 9.8 mm P_W=13.3 mm T=1.27 mm I_L = 0.034 mm
O.ouazzani et.al[3]	RT/duroid-5880 ε_r =2.2 tanδ =0.0009	-30.58 dB (sim)	1.01 (sim)	7.67 dB (sim)	P_L= 16.54mm P_W=22.44 mm h=1.56mm I_L = 5 mm
Shambhavi S. Salelkar et.al [4]	FR4 ε_r =4.4 tanδ =0.0009	-16 dB (sim)	1.02 (sim)	5.4 dB (sim)	P_L= 15.72 mm P_W=11.73 mm h= 1.6 mm
This work	LTCC-DUPONT ε_r =7.8 tanδ =0.006	-29.3dB (exp)	1.17 (exp)	4.17 dB (sim)	P_L = 8.9 mm P_W = 12.35 mm h = 1 mm I_L = 3.6 mm

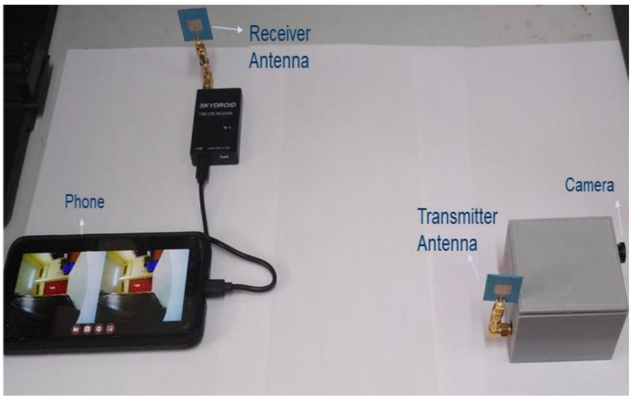

Figure 6. Demonstration of LTCC-based antenna for video transmission.

5. Conclusion and Future work

The proposed LTCC-based antenna showed low loss response experimentally, and video transmission was verified using the testing setup. The scale of VSWR is also less than 2 in the frequency range. Antennae in this frequency band can be tested for their range using the transmitter and receiver in real time for WLAN applications. In future work, a wideband and high gain antenna would be designed and developed such that it covers a broad range of communication bands for other applications, including satellite communication.

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7. References

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