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Design and Analysis of Wideband Microstrip Patch Antenna for Wireless Communication

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ABSTRACT: A design of rectangular microstrip patch antenna is presented in this paper for wideband applications. The antenna operates in a wide bandwidth covering the frequencies of 2.83-5.67 GHz and the resonating frequency is 4 GHz. The overall dimension of the proposed antenna is 38 x 40 x 1.57 mm^3. length, width and height respectively. FR-4 material has been used for substrate, with the thickness of 1.5 mm. To obtain the wide bandwidth, partial ground plane is designed. The patch and ground layer is made of copper material having a thickness of 1.5 mm. The simulation of the proposed antenna is done with CST Microwave Studio Software Tool. In this design, various antenna performance characteristics like return loss, bandwidth, radiation pattern, directivity, gain and VSWR were analysed.

KEYWORDS: Microstrip patch antenna, Wideband applications, FR-4, partial ground plane.

I. INTRODUCTION

Antenna is a basic building block for any type of wireless communication system. They are design to transmits and receives the electromagnetic waves at specific frequencies. Microstrip patch antenna is widely used because its offers a light weight, compact size, low cost with better performance and it supports various frequency range. An analysis of different designs of microstrip patch antenna have shown that they have some limitations i.e. having a narrow bandwidth and low gain. The wideband antenna with high gain are in need to maintain high speed transmission and reception of signals in order to have a reliable wireless communication [1]. In the designing of microstrip patch antenna, the partial ground plane provide the bandwidth enhancement of antenna, because it radiates in both directions [3].

The objective here is to design an antenna, which provides a broad bandwidth and high gain with less return loss. The proposed antenna is a rectangular microstrip patch antenna with partial ground plane. FR-4 material is used for substrate and thin layer of copper is applied for patch and ground portion. This is a wideband antenna having a frequency range of 2.83 GHz to 5.67 GHz, with the resonating frequency is 4GHz. A designed antenna is significantly used in radio communication, remoting sensing, satellite communication system, radar and other wireless communication applications [2].

This paper is organized as follows. Section II describes the previous work done on the microstrip patch antenna for wideband applications. The designing procedure of the proposed antenna is given in Section III. Section IV presents simulation results showing results of the antenna. Finally, Section V presents conclusion.

II. RELATED WORK

Many research works have been already for the wide band microstrip patch antenna. Some of the selected design work have studied for observation the simulation work. In 2021, [1] the proposed antenna is a L-slot wideband 5G antenna for 5G bandwidth applications, resonating at 39 GHz frequency band. The FR-4 substrate with 0.5 mm. thickness is used for design. The antenna is simulated with the value of S11 is -29.057 dB and 4.142 dB realized gain for 39 GHz. In [2], design of wideband microstrip antenna is analysed with wide bandwidth covering frequency of 6-21 GHz and the center frequency is 9.75 GHz. A 15 GHz bandwidth and 5.3 dB of maximum gain is obtained. In 2020, [3] the design and analysis of a microstrip monopole antenna for ultra wideband applications is presented. The antenna operates in a frequency band 4.3 GHz to 11.6 GHz, which covers the C-band and X-band. The dual resonance of antenna with a return loss of 35 dB at 5.4 GHz and 34 dB at 9.4 GHz with maximum gain of 1.3 dB is observed. In 2018, [4] a microstrip feed square patch antenna for wideband application is presented, which is operated at 3 GHz.

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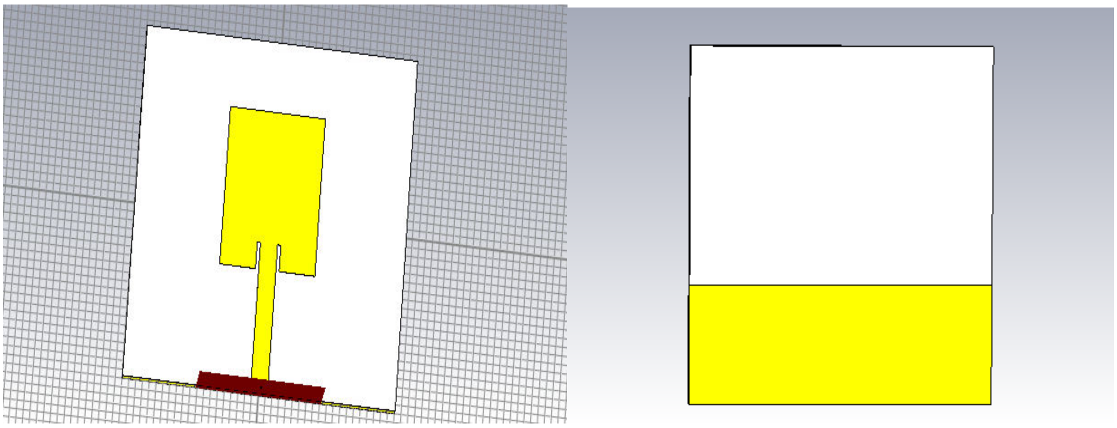
Fractional bandwidth enhancement of 229 % is achieved by introducing defected ground structure (DGS), offset feed and modified patch technique with gain of 2.36 dB. In [5], a circular shaped microstrip patch antenna is investigated with single band notch characteristics for different wireless applications. The return loss of -44 dB and 96% of maximum antenna efficiency is obtained at 4 GHz.

III. ANTENNA DESIGN

A microstrip patch antenna consists of a radiating patch on one side of a dielectric substrate which has ground plane on the other side [11]. For the designing of microstrip patch antenna, the resonating frequency is 4 GHz. The substrate material is FR-4 (lossy), which has a dielectric constant (ε_r) of 4.3. The thickness of substrate is 1.5 mm. The ground plane is partially designed, because the partial ground structure have been optimised for maximum bandwidth. The size of substrate and ground is 38 x 40 mm. and 13.3 x 40 mm. respectively.

For the patch and ground layer of antenna, copper material has been used with the thickness of 0.035 mm. in both cases. The microstrip inset feedline is connected with the patch for excitation to the antenna. The overall dimension of the proposed antenna is 38 x 40 x 1.57 mm^3. length, width and height respectively. The 3-D view of the proposed antenna is shown in fig. 1 (a), depicts that the metallic patch layer, substrate portion along with the microstrip feedline. The red portion shown in the bottom of the proposed antenna represents the port of the power supply.



(a) (b)

Fig. 1. (a) 3-D view and (b) back view of the proposed antenna

In fig. 1 (b), back view of the proposed antenna is shown as a partial ground plane structure to provide the wide bandwidth to the antenna. All dimensions of the antenna is calculated by the design equation.

1. The frequency of operation of the antenna is determine by the length L.

$$f_c = \frac{1}{2L\sqrt{\varepsilon_r \varepsilon_o \mu_o}} \qquad (1)$$

where, f_c = operating frequency,
ε_r = relative permittivity,
ε_o = vacuum permittivity,
μ_o= permeability

2. Calculation of width of the patch (W)

$$W = \frac{c_o}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}} \qquad (2)$$

where, c_o = speed of light in free space.

3. Calculation of effective dielectric constant (ε_{reff})

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

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4. Calculation of extension length (ΔL)

$$\frac{\Delta L}{h} = 0.412\,\frac{(\varepsilon_{reff}+0.3)\,(\frac{W}{h}+0.264)}{(\varepsilon_{reff}-0.258)\,(\frac{W}{h}+0.8)} \qquad (4)$$

5. Calculation of actual Length of Patch (L)

$$L = \frac{c_o}{2f_r\sqrt{\varepsilon_{reff}}} - 2\Delta L \qquad (5)$$

All dimensions of the proposed antenna are mentioned in the table I.

Table I :- Dimensional value of the antenna

Parameter	**Dimensional Size (mm.)**		
	Length (L)	**Width (W)**	**Height (H)**
Ground	13.3	40	0.035
Substrate	38	40	1.5
Patch	18	14	0.035
Cut Depth	3	0.5	0.035
Feed Line	14	2.5	0.035

IV. SIMULATION RESULTS

The performance of the proposed antenna is examined with the help of various parameter of the antenna.

1. Return Loss :- To measure the antenna's power to be transmitted and reflected back is performed by the antenna return loss S1,1 plot. The return loss (S- parameter) of the designed antenna shown in fig. 2 with the value of -42.36 dB at the frequency of 3.704 GHz. So the good return loss characteristics is obtained by the antenna.

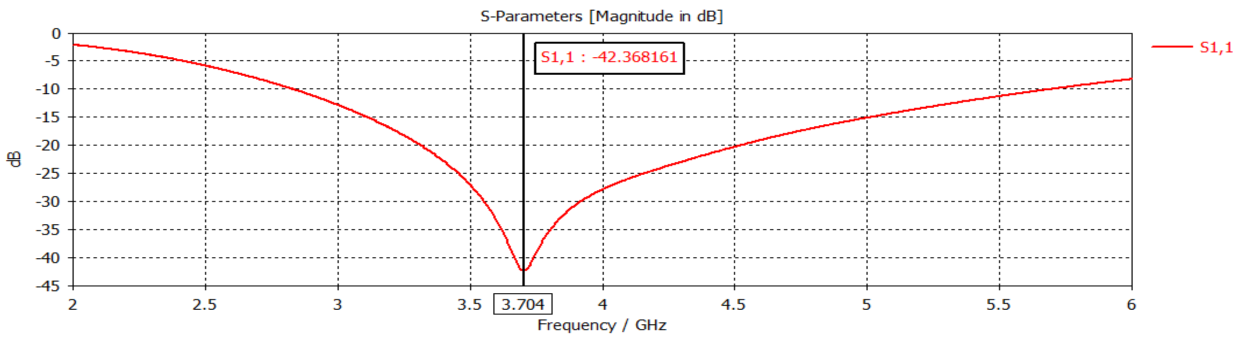

Fig. 2. Return loss of the antenna.

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2. Bandwidth :- The design of antenna is mainly intended for enlarge the frequency bandwidth. The wideband antenna are able to capture a large number of frequencies providing better signal strength. The proposed antenna has a bandwidth of 66.82% over a frequency spectrum of 2.83 GHz to 5.67 GHz, which provide the best bandwidth of the antenna. The formula used for calculating the percentage bandwidth is mentioned in equation 6.

$$\text{Bandwidth} = \left[\frac{F2 - F1}{\left(\frac{F2 + F1}{2}\right)}\right] \times 100 \qquad (6)$$

Frequency 1 = 2.83 GHz, Frequency 2 = 5.67 GHz, put the values of these frequencies in above equation.

$$\text{Bandwidth} = \left[\frac{5.67 - 2.83}{\left(\frac{5.67 + 2.83}{2}\right)}\right] \times 100$$

Percentage Bandwidth = 66.82

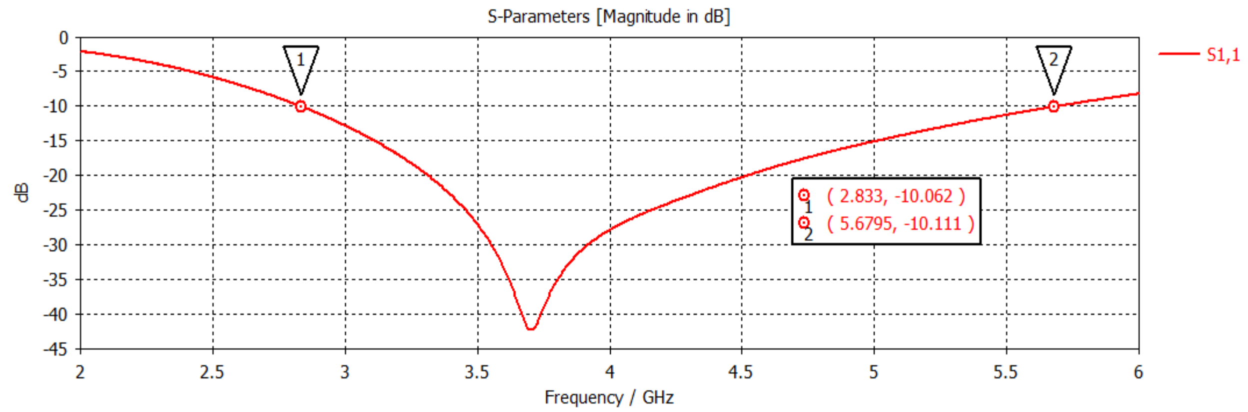

Fig. 3. Wideband of frequency range covering by the antenna.

3. Radiation Pattern: - The energy radiated by the antenna is presented by the radiation far-field pattern. 3D-radiation pattern is shown in fig. 4, describe that the radiation efficiency and total efficiency of the proposed antenna is -0.6475 dB and -0.6498 dB respectively. The effective radiation performance make antenna suitable for proper transmission of signal.

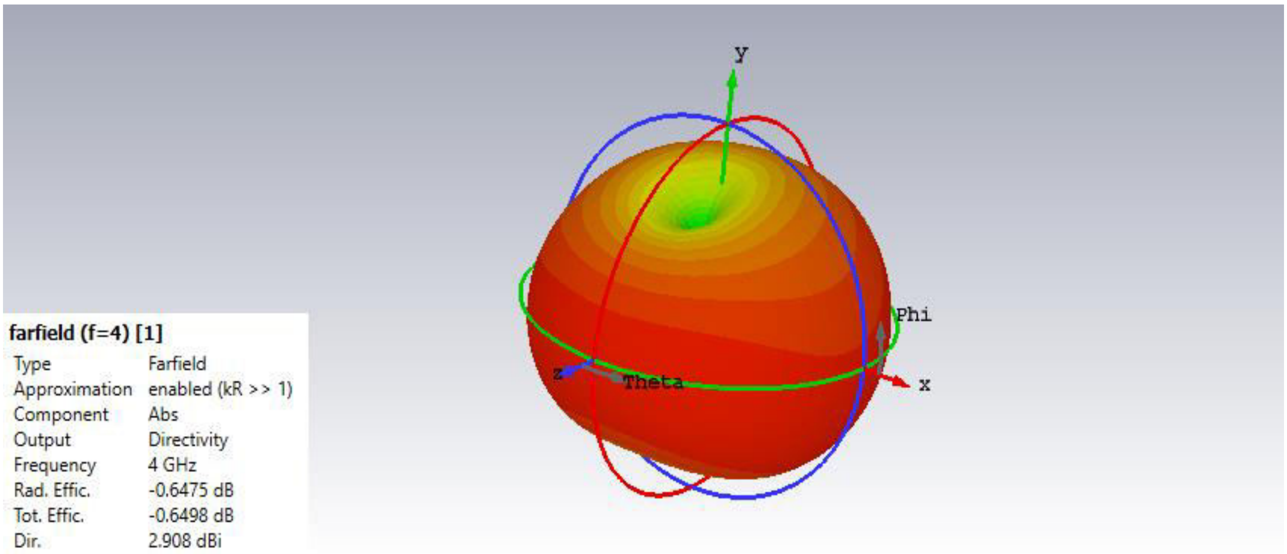

Fig. 4. 3D far-field pattern of the antenna.

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4. Directivity :- The density of the power in a particular direction is measured by the directivity. The antenna radiates in the direction of the strongest emissions versus the power density radiated by an ideal isotropic radiator radiating the same total power. A polar far field pattern of the proposed antenna at 4 GHz is shown in fig. 5. The figure depicts that the main lobe magnitude of the radiation beam is 2.92 dBi, which is situated at 173°, having an angular width of 88.7°. The antenna directivity is obtain the value of 2.908 dBi. So the antenna is highly directional.

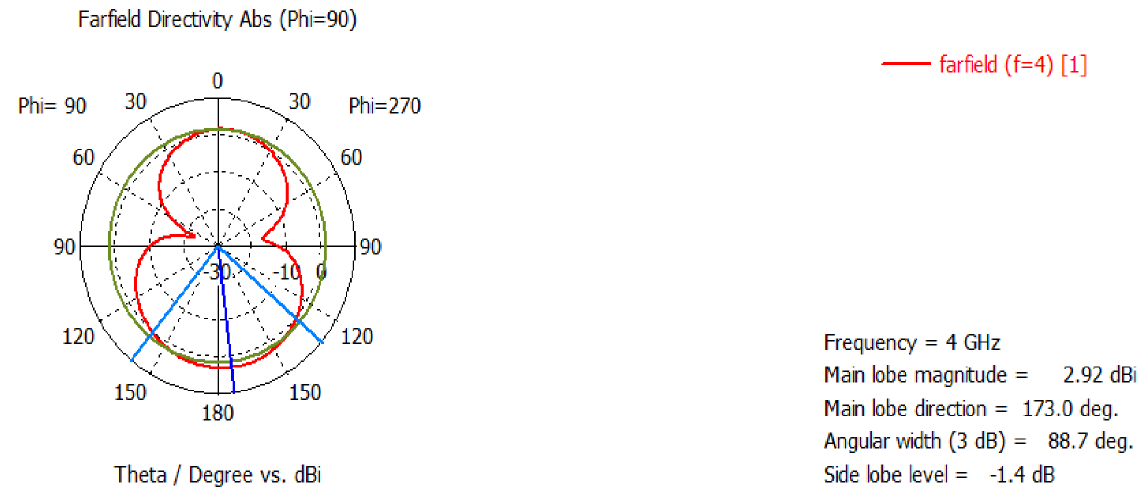

Fig. 5. Polar far-field pattern of the antenna.

5. Gain: - The ability of the antenna to direct the input power into radiation in a particular direction, also measured at the peak radiation intensity with the help of gain. Fig. 6 represents the gain of the proposed antenna. The simulated gain of 2.261 dBi is achieved for 4 GHz frequency. This implies that the proposed antenna is capable to radiate i the specified direction.

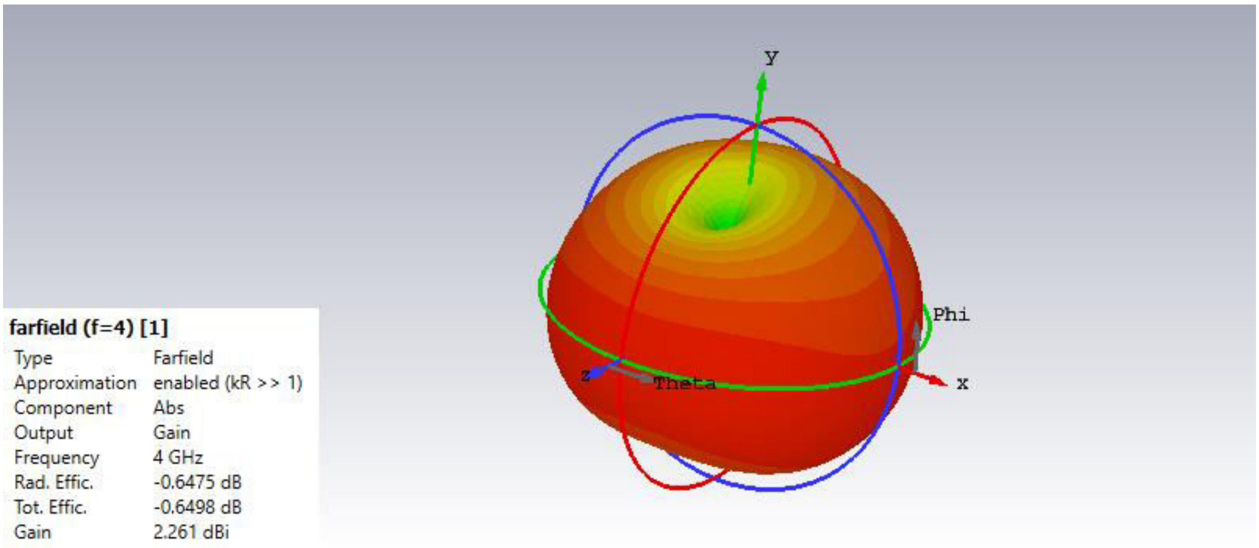

Fig. 6. Gain of the antenna.

6. VSWR :- The voltage standing wave ratio, is a function of reflection coefficient, which gives the information about the power reflected from the antenna. Basically, the acceptable value of VSWR is under 2. From fig. 7, shows the VSWR of the proposed antenna. The value of VSWR is 1.0153. It means that maximum power is delivered by an antenna with minimum reflection.

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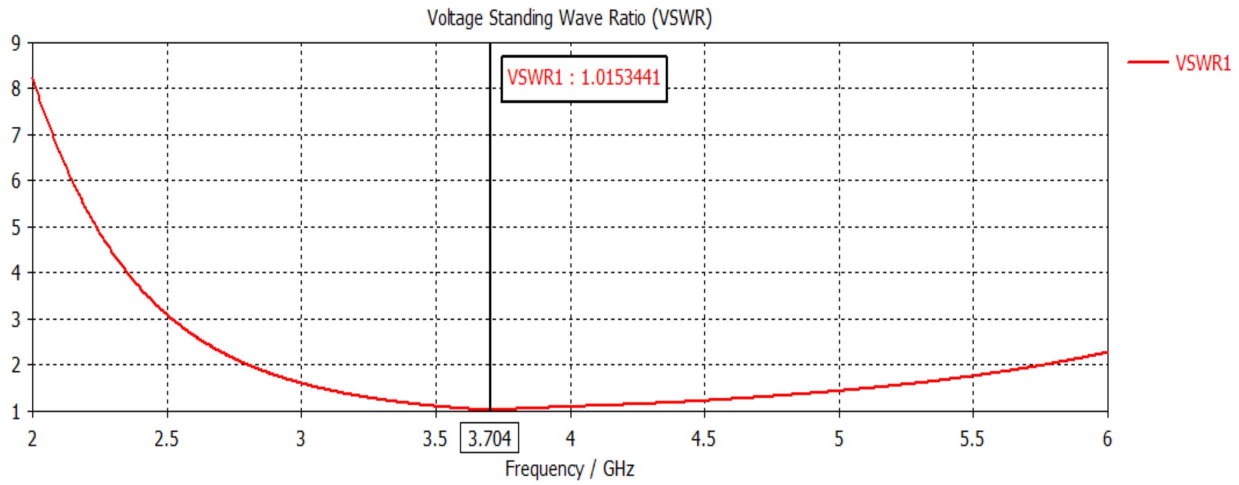

Fig. 7. VSWR of the antenna.

V. CONCLUSION

A rectangular microstrip patch antenna having a wide bandwidth and compact size has been designed for wireless applications. The resonating frequency of the proposed antenna is 4 GHz and it covers a range of 2.83 GHz to 5.67 GHz frequency. The obtained bandwidth is 2.83 GHz and 66.82% of bandwidth of operating frequency range. This proposed antenna has a return loss of -42.36 dB and good radiation pattern is achieved with the maximum gain obtained at 4 GHz is 2.261 dBi. The wide operational bandwidth with omnidirectional radiation pattern emphasis the antenna applicable for WLAN, S-band, C-band, and various wireless communication applications under super high frequency band.

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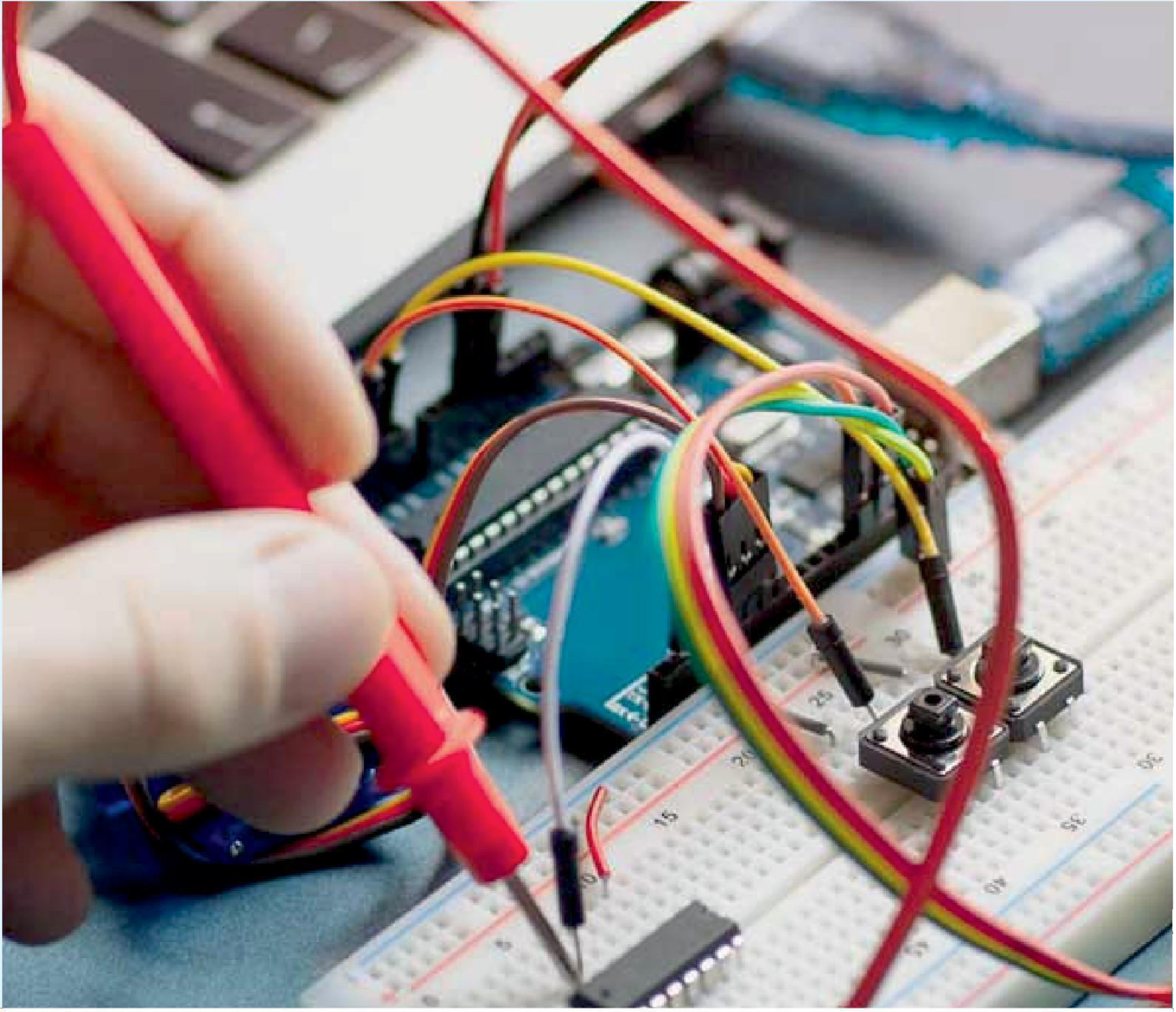

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