Impact of Dielectric Constant and Frequency Variation on the Conductance of A Rectangular Microstrip Patch Antenna

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***Abstract*—A micrsotrip patch antenna occurs is various shapes such as rectangular, square, circular etc, and is widely used in many portable communication devices today mainly because of its light weight and smaller size. But despite its use in many communication devices like cell phones, laptop computers, aircraft communication systems, there is further need to investigate how the conductance of this antenna varies with varying parameters of the antenna such as its frequency of operation and dielectric constant. This is the aim this work wants to achieve. The work employs transmission line model, and the various parameters of the antenna were gotten in two ways; one at constant frequency and changing dielectric constant values, and the other at constant dielectric value and changing frequency of operation. It was observed that the conductance of a rectangular microstrip patch antenna is higher at lower frequency and lower dielectric constant value, and vice versa. It was concluded that a rectangular microstrip patch antenna with lower values of frequency and dielectric constant conducts better than that with higher values of frequency and dielectric constant.**

***Index Terms*—conductance, frequency, dielectric constant, micrsotrip patch antenna**

I. Introduction

Microstrip patch antenna is an antenna that consists of a dielectric substrate, with a ground plane and a metallic patch placed on the substrate. A substrate is a semi-conducting material that is mainly used as a base.

Microstrip antennas are becoming very widespread within the mobile phone market. Patch antennas are low cost, have a low profile and are easily fabricated. Micro strip antennas find many applications as they are low profile, light weight, conformable to surface and inexpensive to manufacture using printed-circuit technology (Mohamed *et al,. 2015*). It can used in cell phones, laptop computers, feed for dish antenna, aircraft communication system, wearable communication gadgets, etc.

In addition, there is an increase in demand for microstrip antennas with improved performance for wireless communication applications are widely used for this purpose because of their planar structure, low profile, light weight, moderate efficiency and ease of integration with active devices (Amit *et al.,* 2013).

Several works on microstrip patch antenna have been done by many researchers, scientists and engineers, and some are still ongoing with a view to finding out something new information or to confirm the already obtained result. This work is aimed at assessing the relationship between the conductance of a microstrip patch antenna and its operating frequency as well as the dielectric constant of the dielectric substrate such as the common RT DUROID 5888 which is used in this work.

Microstrip patch antenna has the advantages of simple to manufacture or fabricate, low cost, easy to form a large array and has light weight. However, it has some setbacks such as low gain and low bandwidth, but can be compensated using a thick substrate with low dielectric constants.

II. Definition of Related Terms

A. Conductance

Conductance of a component or material is a measurement of how easily an electric current can flow through it. It is the degree at which a material or component conducts electricity. It is the reciprocal of the resistance of a material, which means that a material with higher conductance has lower resistance. It is given by the symbol, G, and has the unit of Siemens (S).

B. Conductivity

Conductivity is the ability of a material to conduct electricity. Conductivity is given by the symbol, **σ**, and has the unit of Siemens-metre (**Sm**) It is the reciprocal of resistivity. Conductivity is related to the conductance of a material with formula given in equation 2.1.

$$G = \frac{\sigma l}{A} \tag{2.1}$$

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where G, is the conductance, A, is the cross sectional area, l, is the length of the conductor, and σ , is the conductivity of the material

C. Resistance

It is the opposition to the flow of electric current in a material. Its unit is ohm (**Ω**), and is represented by the symbol, R.

D. Resistivity

Resistivity is the ability of a material to oppose the flow of electric current through it. It is also the reciprocal or inverse of conductivity. It is given by the symbol, **ρ**, and has the unit of ohm-meter (**Ωm**). The mathematical relationship between resistivity and conductivity as well as resistance are shown in equations 2.2 and 2.3 respectively.

$$\rho = \frac{1}{\sigma} \quad (2.2)$$

$$R = \frac{\rho l}{A} \quad (2.3)$$

where ρ , is resistivity, R is the resistance, A is the cross sectional area, *l* is the length of the conductor, and σ , is the conductivity of the material.

III. Design Analysis A Rectangular Microstrip Patch Antenna

A. Determination of the Height (h) of the Patch

The height of the patch is calculated using the formula represented as;

$$h = \frac{0.3C}{2\Pi f_o \sqrt{\varepsilon_r}} \quad (3.1)$$

where C = Speed of light, given as 3.0 x 10^8m/s,

ε_r = The dielectric substrate.

The height, h is in millimetre (mm)

B. Determination of the Width (w) of the Patch

The width of the patch is calculated using the formula represented as;

$$W = \frac{C}{2 f_o \sqrt{\frac{(\varepsilon_r + 1)}{2}}} \quad (3.2)$$

The width, W is in millimetre (mm)

C. Determination of the Effective Dielectric Constant (ε_{eff})

It is calculated using the mathematical relation represented as;

$$\varepsilon_{eff} = \frac{(\varepsilon_r + 1)}{2} + \frac{(\varepsilon_r - 1)}{2}\left(1 + \frac{1}{\sqrt{1 + 12\left(\frac{h}{W}\right)}}\right) \quad (3.4)$$

h and W are the height and the width of the patch in that other.

D. Determination of the Effective Length of the Patch (L_{eff}*)*

The effective length of the patch is given by the formula represented as;

$$L_{eff} = \frac{C}{2 f_o \sqrt{\varepsilon_{eff}}} \quad (3.5)$$

E. Determination of the Length Extension (Δ *L)*

Length extension is the additional length at the end of the patch as a result of the fringing field along its width. It is calculated using the formula represented as;

$$\Delta L = 0.412h\left[\frac{(\varepsilon_{eff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{eff} - 0.258)\left(\frac{W}{h} + 0.8\right)}\right] \quad (3.6)$$

where ΔL is the patch length extension in millimetre, *h* and *W* are the height and width of the patch respectively, and ε_{eff} is the effective dielectric constant of the substrate, and is dimensionless.

F. Determination of the Actual Length (L) of the Patch

The actual length of the patch, *L* is the difference between the effective length and twice of the length extension of the patch. It is calculated using the mathematical representation given as;

$$L = L_{eff} - 2\Delta L \quad (3.7)$$

G. Determination of the Conductance (G)

The conductance of a microstrip patch antenna is calculated using the formula represented as;

$$G = \frac{W}{120\lambda}\left(1 - \frac{1}{24}\left[\frac{2\pi h}{\lambda}\right]^2\right) \quad (3.8)$$

IV. Results and Discussion

The computations for various parameters were done using Microsoft excel package worksheet.

Dielectric constant (ε_0) = 3.0

Table I shows the calculated parameters using the dielectric constant value of 3.0 (unvaried) and the frequencies of 1.0, 1.5, 2.0, 2.5 and 3.0 GHz in that order.

From the result, it was observed that the conductance of a rectangular microstrip patch antenna is inversely proportional to the frequency of operation of the antenna. In other words, the conductance of a rectangular microstrip patch antenna increases with decrease in operating frequency and vice versa. For instance; at the frequency of 1.0 GHz, the conductance was 4.404 milliSiemens (mS) and at the higher frequency of 3.0GHz, the conductance of the antenna became was 1.472 milliSiemens (mS). This is as shown graphically in Fig. 1. Thus in a device in which higher conductivity (and low resistivity) is required, the operating frequency should be low.

TABLE I. DESIGN PARAMETERS AT CONSTANT DIELECTRIC CONSTANT VALUE AND VARYING FREQUENCY

S/N	f (GHz)	h (mm)	L (mm)	W (mm)	G (mS)
1	1.0	8.27	82.9	106.0	4.404
2	1.5	5.51	55.3	70.7	2.942
3	2.0	4.13	41.4	53.0	2.207
4	2.5	3.31	33.2	42.4	1.766
5	3.0	2.76	27.6	35.3	1.472

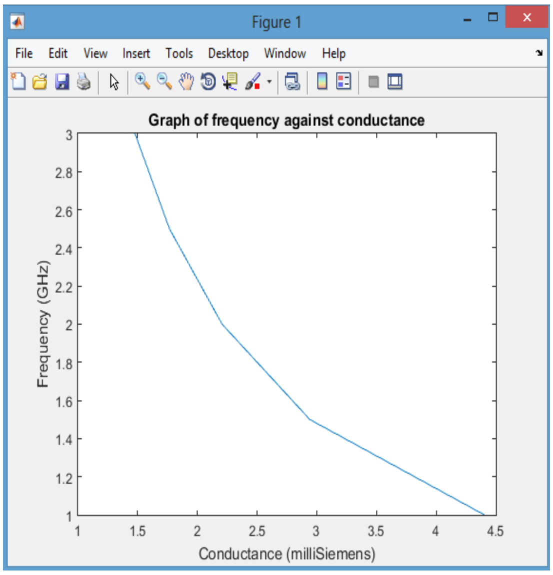

Figure 1. Graph of frequency against frequency

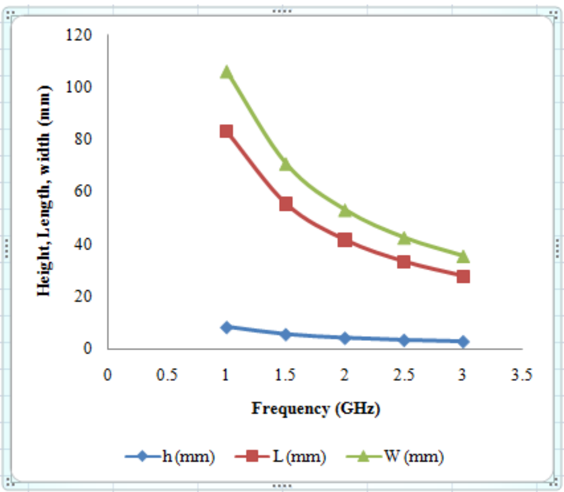

Figure 2. Graph of height, length and width against frequency

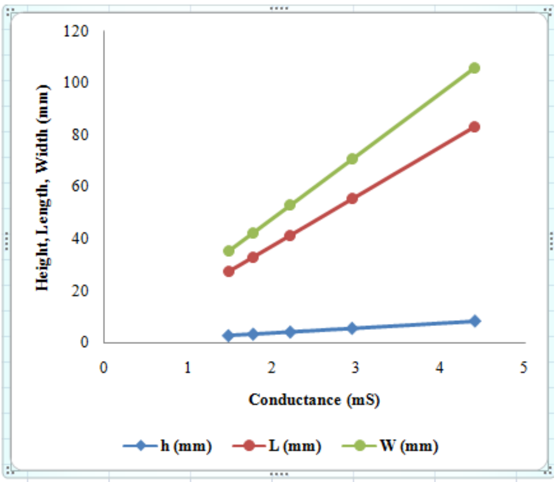

Figure 3. Graph of height, length and width against conductance

However, it can also be seen that at lower frequency, the size of the antenna designed will be greater than that at higher frequency. This is also shown in Table I, in which the height, length and width of the antenna decrease with increase in frequency. This implies that there is also an inverse relationship between the frequency of the operation of a rectangular microstrip patch antenna and the height, length and width of the antenna [Fig. 2]. Furthermore, it can be observed that the height, length and width of a rectangular microstrip patch antenna increase with increase in conductance of the antenna. That is; larger size rectangular microstrip patch antenna conducts more than smaller size rectangular microstrip patch antenna. The graphical relationship between them is shown in Fig. 3.

TABLE II. DESIGN PARAMETERS AT CONSTANT FREQUENCY AND VARYING DIELECTRIC CONSTANT VALUE

Frequency = 1.5GHz (constant)

S/N	ε_r	h (mm)	L (mm)	W (mm)	G (mS)
1	2.0	6.75	66.2	81.6	3.394
2	2.5	6.04	60.1	75.6	3.145
3	3.0	5.51	55.3	70.7	2.917
4	3.5	5.10	51.5	66.6	2.772
5	4.0	4.77	48.4	63.2	2.631

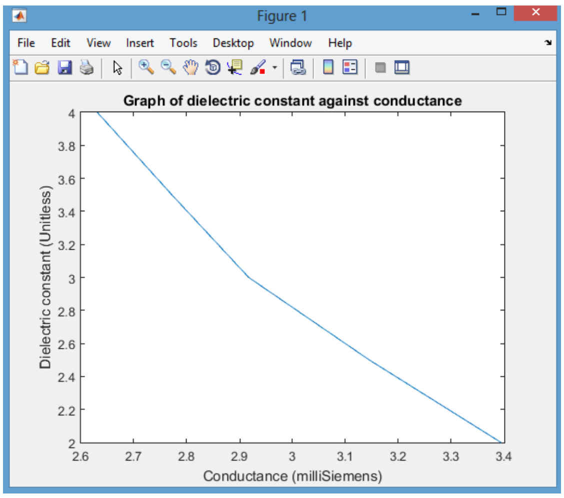

Figure 4. Graph of dielectric constant against conductance

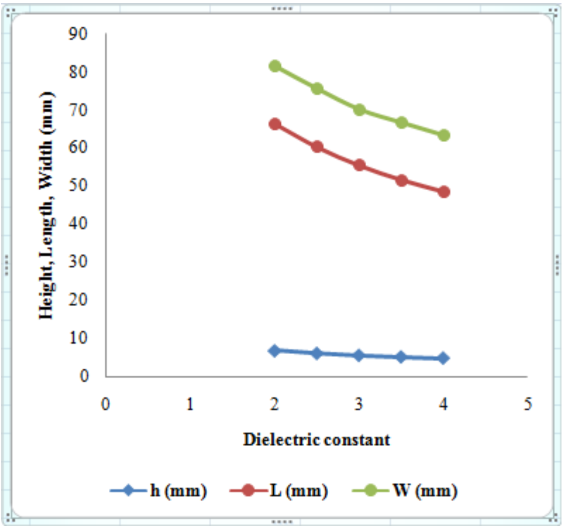

Figure 5. Graph of height, length and width against dielectric constant

Table II shows the calculated parameters at the frequency of 1.5GHz (unvaried) and the dielectric constant values of 2.0, 2.5, 3.0, 3.5 and 4.0 in that order. It was observed that at constant frequency, the conductance of the rectangular microstrip patch antenna decreases as the dielectric constant value was increasing. That is, the conductance of the rectangular microstrip patch antenna will be higher at lower values of dielectric constant and vice versa. For example, when dielectric constant has the value of 2.0, the conductance was 3.394 mS, and when dielectric constant increased to 4.0, the conductance reduced to 2.631 mS. This is shown graphically in Fig. 4.

However, as seen in the case of varying frequency and constant dielectric constant value, the dielectric constant increase with reduction in the size of the antenna in terms of the height, width, and length. In other words, the conductance of a rectangular microstrip patch antenna is inversely proportional to the height, width, and length of the antenna. This is shown in Fig. 5.

V. Conclusion

The assessment of how a change in the frequency of operation of a rectangular microstrip patch antenna as well as it dielectric constant affect the conductance of the antenna has been carried out. Conductance of a component or material is a measurement of how easily an electric current can flow through it. This means that a material with higher conductance allows electric current flow through it easily than the one with lower conductance.

From the results and the analysis, it was seen that the conductance of a rectangular microstrip patch antenna increases with decrease in frequency and increase in dielectric constant. That is; conductance of a rectangular microstrip patch antenna is inversely proportional to the frequency and dielectric constant [Fig. 1 and Fig. 2]. It can therefore be concluded that a rectangular microstrip patch antenna with lower values of frequency and dielectric constant conducts better than that with higher values of frequency and dielectric constant.

Recommendation

The assessment of the relationship between the conductance a microstrip patch antenna and its operating frequency, and dielectric constant was done on rectangular type in this work, the case of circular, triangular, etc should be looked into as future work.

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