# The Effects of the Physical Properties of the Slot Antenna to the Resonant Frequency and Bandwidth

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***Abstract*—This document discusses slot antennas and how their electromagnetic properties are impacted by their physical characteristics. It is intended to operate the antenna at the required resonant frequency (which is 2.45 GHz) by parametrically examining the antenna's physical characteristics.**

***Index Terms*—slot antenna, simulation, slot length, feed offset, properties**

## I. Introduction

A slot antenna is a form of antenna created by cutting a slot into a metal surface, usually a flat sheet of a conductive material such as metal. The properties of the antenna, including its frequency range and radiation pattern, are determined by the form, size, and material of the slot. Slot antennas are frequently used in radar systems, microwave communication systems, as well as several other applications. The geometry of a slot antenna can be seen in Fig. 1. 2.45 GHz is the targeted resonant frequency for this slot antenna because it is convenient for many applications and also used by the 802.11b and 802.11g versions of the IEEE 802.11 standard for WiFi networks.

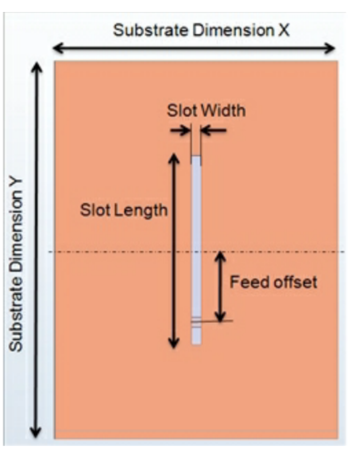



Fig. 1: The geometry and dimensions of a slot antenna

## II. Slot Antenna

### A. Antenna Geometry

A slot antenna is a radiating device that is normally created by cutting an opening in a ground plane. Typically, this opening is referred to as a slot rather than an aperture because the length (L) should be significantly more than the width (W). [1] Fig. 1 shows the dimensions of a slot antenna. The slot antenna was designed using the ANSYS HFSS Antenna Toolkit. The substrate was made of FR4 epoxy and the targeted resonant frequency is 2.45 GHz. Calculated dimensions for the 2.45 GHz slot antenna are given in Table 1. Even though the slot antenna's targeted resonance frequency is 2.45 GHz, after doing simulations with the first constructed antenna, the appropriate resonance frequency could not be found. The resonant frequency value is calculated as 2.16 GHz and the return loss value at the peak is -13.47 dB as can be seen from Fig. 2. Thus, parametric analyses were performed to determine the best parameters for operating the slot antenna at 2.45 GHz.

TABLE I: Calculated dimensions of the slot antenna

| Dimension | Value (cm) |
|---|---|
| Slot length | 6.13 |
| Slot width | 0.31 |
| Substrate height | 0.1575 |
| Substrate length | 12.3 |
| Substrate width | 9.2 |
| Feed Offset | 1.7 |

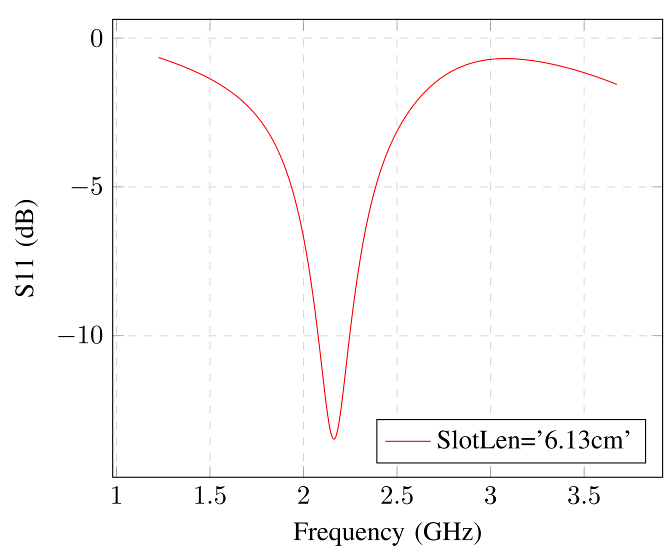



Fig. 2: Return loss with calculated dimensions

*B. Radiation Pattern*

Fig. 3 shows the slot antenna's 3D gain plot of the first synthesized slot antenna which operates at 2.16 GHz frequency. As shown in the figure, the slot antenna's radiation is directed in every direction, making its radiation pattern omnidirectional. The maximum gain of the antenna was calculated as 4.5 dB.

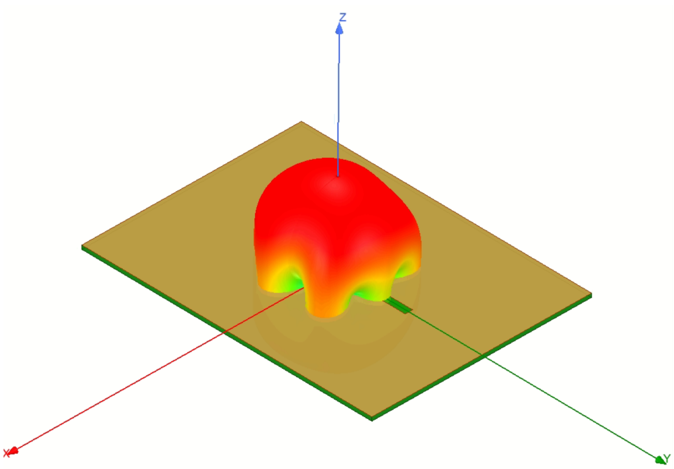



Fig. 3: 3D gain plot (dB)

## III. Parametric Analysis

In order to examine the effects of the physical properties of the antenna on the resonant frequency and the bandwidth such as slot length, substrate height and feed offset; parametric analyzes are applied to each of the physical properties individually i.e. one physical property was altered whilst the other two were left unchanged after each parametric analysis. The next subsections explain the simulation results in further detail.

*A. Slot Length*

Simulations for slot length swept from 5 cm to 6.13 cm, which was the nominal value for the length of the slot, whilst substrate height and feed offset were kept constant at 0.1575 cm and 1.7 cm respectively. As can be observed from Fig. 4, resonant frequency decreases as the length of the slot increases. This relation also can be examined in Fig. 5(a). Bandwidth of the slot antenna is calculated from the graph in Fig. 4 with corresponding frequency values to the -10 dB return loss. It can be observed from Fig. 5(b), as the length of the slot is increased, the bandwidth of the antenna is increased as well. All of the corresponding results for resonant frequency, bandwidth and return loss values at peak for different slot lengths can be examined in Table 2.

*B. Substrate Height*

Simulations for substrate height swept from 0.03 cm to 0.1575 cm, which was the nominal value for the substrate height, whilst slot length and feed offset were kept constant at 6.13 cm and 1.7 cm respectively. As can be seen from Fig. 6, resonant frequency decreases as the substrate height increased.

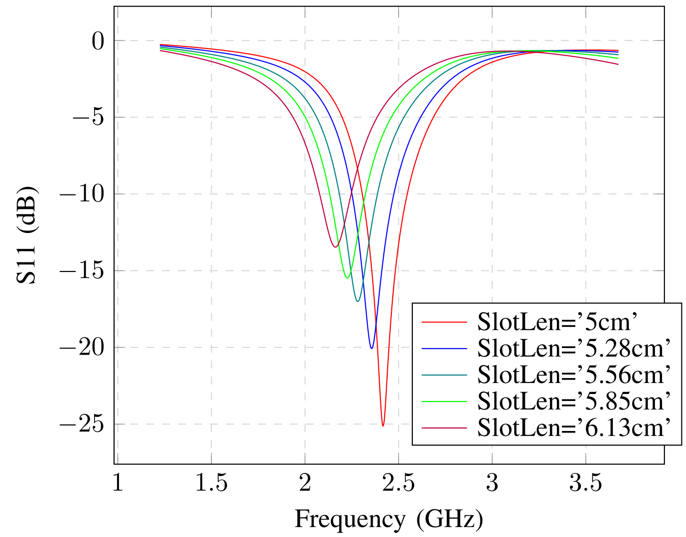
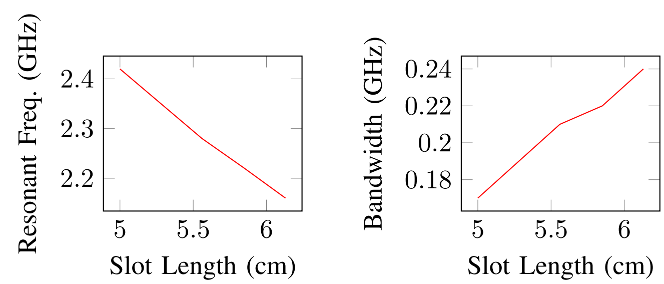



Fig. 4: Return loss graph of the different slot lengths




(a) The correlation between slot length and resonant frequency

(b) The correlation between slot length and bandwidth

Fig. 5: Changes in resonant frequency and bandwidth with changing slot length

This relation also can be observed in Fig. 7(a). The bandwidth of the slot antenna is calculated from the graph in Fig. 6 with corresponding values to the -10 dB return loss. It can be observed from Fig. 7(b), as the value of the substrate height is increased, the bandwidth of the antenna is decreased. All of the corresponding results for resonant frequency, bandwidth and return loss values at peak for different substrate heights can be examined in Table 3.

TABLE II: Effects of slot length to the resonant frequency, bandwidth and return loss

| Slot Length (cm) | Resonant Frequency (GHz) | Bandwidth (GHz) | Retrun Loss (dB) |
|---|---|---|---|
| 5 | 2.42 | 0.17 | -25.11 |
| 5.28 | 2.35 | 0.19 | -20.05 |
| 5.56 | 2.28 | 0.21 | -16.99 |
| 5.85 | 2.22 | 0.22 | -15.47 |
| 6.13 | 2.16 | 0.24 | -13.46 |

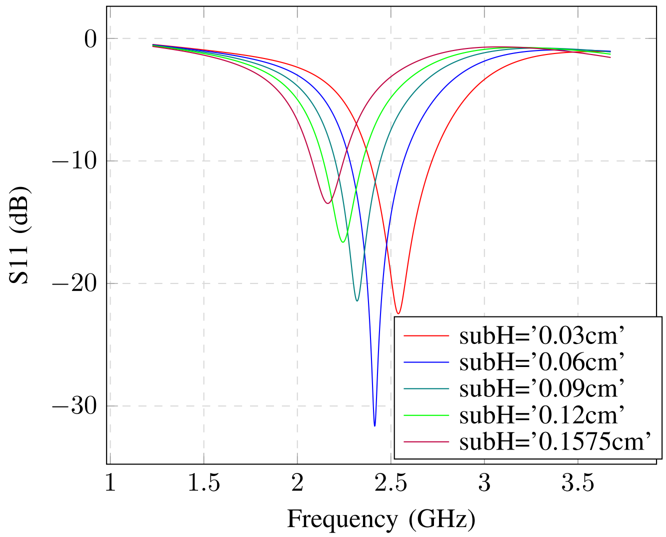
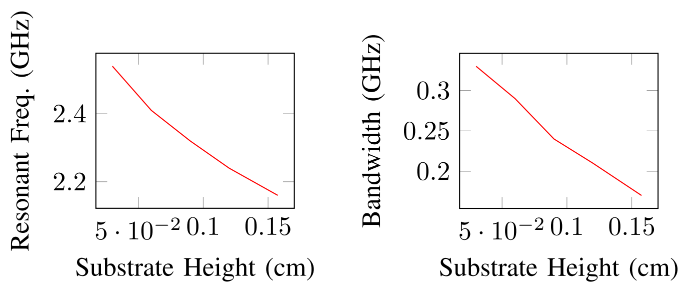



Fig. 6: Return loss graph of the different substrate heights




(a) The correlation between substrate height and resonant frequency

(b) The correlation between substrate height and bandwidth

Fig. 7: Changes in resonant frequency and bandwidth with changing substrate height

### C. Feed Offset

Simulations for feed offset swept from 1.1 cm to 1.7 cm, which was the nominal value for the feed offset, whilst slot length and substrate height were kept constant at 6.13 cm and 0.1575 cm respectively. As can be seen from Fig. 8, resonant frequency decreases as the length of the feed offset value are increased. This relation also can be observed in Fig. 9(a). The bandwidth of the slot antenna is calculated from the graph in Fig. 8 with corresponding values to the -10 dB return loss. It can be observed from Fig. 9(b), as the value of the feed offset is increased, the bandwidth of the antenna is decreased. All of the corresponding results for resonant frequency, bandwidth and return loss values at peak for different feed offset values can be examined in Table 4.

TABLE III: Effects of substrate height to the resonant frequency, bandwidth and return loss

| Substrate Height (cm) | Resonant Frequency (GHz) | Bandwidth (GHz) | Retrun Loss (dB) |
|---|---|---|---|
| 0.03 | 2.54 | 0.33 | -14.45 |
| 0.06 | 2.41 | 0.29 | -16.63 |
| 0.09 | 2.32 | 0.24 | -21.42 |
| 0.12 | 2.24 | 0.21 | -31.64 |
| 0.1575 | 2.16 | 0.17 | -13.44 |

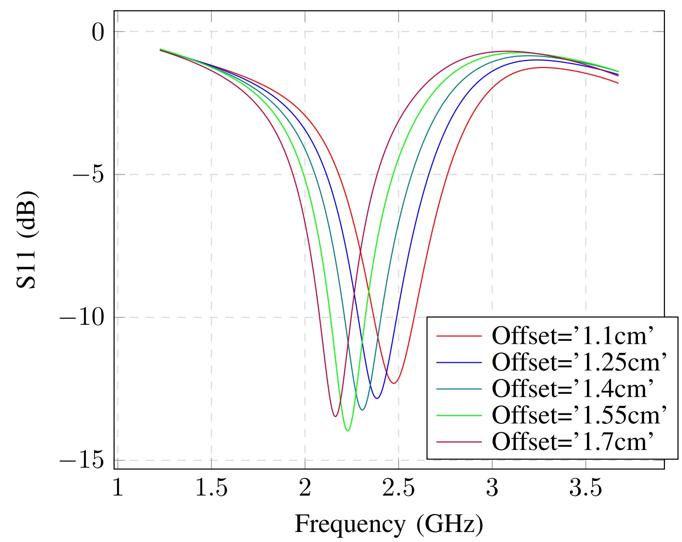
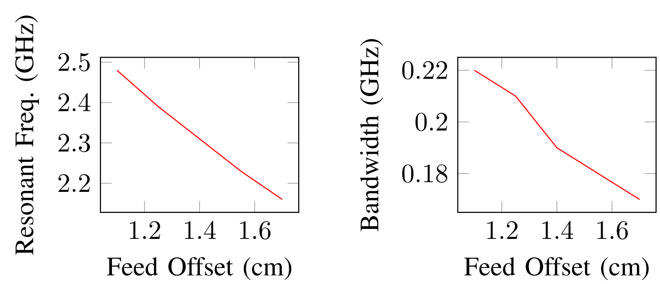



Fig. 8: Return loss graph of the different feed offsets




(a) The correlation between feed offset and resonant frequency

(b) The correlation between feed offset and bandwidth

Fig. 9: Changes in resonant frequency and bandwidth with changing feed offset

TABLE IV: Effects of feed offset length to the resonant frequency, bandwidth and return loss

| Feed Offset Length (cm) | Resonant Frequency (GHz) | Bandwidth (GHz) | Retrun Loss (dB) |
|---|---|---|---|
| 1.1 | 2.48 | 0.22 | -12.30 |
| 1.25 | 2.39 | 0.21 | -12.83 |
| 1.4 | 2.31 | 0.19 | -13.22 |
| 1.55 | 2.23 | 0.18 | -13.96 |
| 1.7 | 2.16 | 0.17 | -13.47 |

## IV. Conclusion

Slot antennas have a straightforward design and these antennas are used in a variety of applications because of easy integrability. Three physical parameters must be considered throughout the slot antenna design process in order to attain the desired resonant frequency and bandwidth which are slot length, substrate height, and feed offset. The simulation results, which include the resonant frequency and bandwidth, demonstrate the relationship between the physical properties and the electromagnetic properties. All three physical properties of the slot antenna are inversely correlated to the resonant frequency. For the bandwidth of the antenna however, a positive correlation is observed with slot length. The substrate height and length of the feed offset are inversely related to the bandwidth of the antenna.

## References

[1] Constantine A. Balanis Antenna Theory: Analysis and Design, 4th ed. pp. 841-842, Hoboken, NJ: John Wiley, 2016.