

# DESIGNING PRINTED SLOT ANTENNAS FOR MULTI-BAND APPLICATIONS

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## ABSTRACT

This paper describes the design of printed slot antennas for multi-band applications. The aim of this design is to develop a single antenna that can be used by all the IEEE 802.11 WLAN network standards collectively known as Wi-Fi. It is required to have a polarisation complementary to that of multi-band printed monopole antennas, to achieve polarisation diversity. Design of a printed slot antenna element operating in the 2.4 and 5 GHz bands is discussed. Parametric studies are presented and different types of feedline configurations are investigated. The theoretical results are promising.

## INTRODUCTION

The popularity of wireless communication systems has increased significantly in the last decade as evident from applications such as mobile phones and wireless networks. As the demand for these systems increases, there is a need for advanced antennas and antenna systems with new capabilities and better performance. A single antenna that can support multiple communication services such as mobile phone, Wi-Fi WLAN, Bluetooth etc. is an example. Such an antenna would allow a wireless device with multiple wireless applications to utilise a single antenna element to transmit and receive signals. By only having a single antenna element, the space required for antennas on the device is reduced significantly. There have been designs of antennas operating in multi-band in order to accommodate this. Some examples of these antennas are fractal antenna [1], printed slot antenna [2], planar monopole [3], and printed inverted-F antenna [4]. These antennas are capable in operating in dual to quad bands.

When transmitting RF signals, multi-path propagation and fading effects can cause signal degradation. A popular method used to combat these effects is the diversity technique. The type of diversity considered here is the polarisation diversity. A printed slot antenna's polarisation is orthogonal to that of a printed monopole antenna. By using a printed slot antenna and a printed monopole antenna together, polarisation diversity technique can be implemented efficiently.

The design of the printed slot antenna element in this paper is focused towards operating in the frequency bands of IEEE 802.11 WLAN standards and providing polarisation diversity for the printed monopole. IEEE 802.11 networks operate in either 2.4 or 5 GHz bands depending on the standard being used. The design and development of an antenna element capable operating in these two bands is discussed in this paper.

## DESIGN OF A PRINTED-SLOT ANTENNA

The antenna element considered in this paper is a printed slot antenna. Design of this antenna is based on a printed monopole multi-band antenna concept [5-6]. The printed monopoles designed in those papers are optimised to operate in the 802.11a, 802.11b, 802.11g, and 802.11j standards frequency bands, which require bandwidths of 2.4-2.5GHz and 5.1-5.8GHz. Although these printed monopole antennas are capable in operating in these frequency bands, there are challenges that impede these printed monopoles from operating to its full capacity, as described below.

Our designs of multi-band printed-slot antennas were inspired by the designs of multi-band printed monopole antennas in [5] and [6]. Fig. 1 shows the generic configuration of the multi-band printed-slot antennas we designed. The antenna is built on a substrate with the ground plane and slot on one side and the feed-line on the other side. There are two separate arms on the antenna. The longer arm with length of  $S_3 + S_2 + S_1$  resonating at the frequency band of 2.4GHz, while the shorter arm of length  $S_4 + S_5$  is resonating at the higher frequency band of 5GHz. These two arms are bent such that their ends are close to each other to enhance the mutual coupling between them. This coupling reduces the



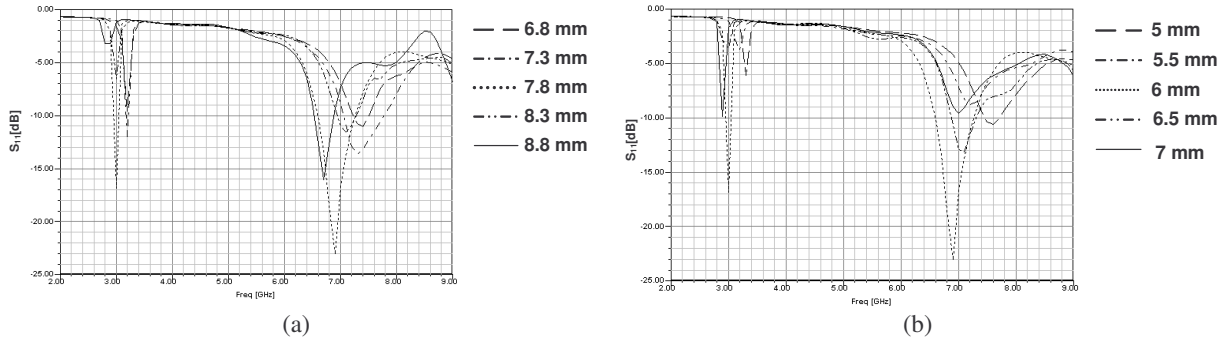


Fig. 2: Return loss when (a)  $S_1$  and (b)  $S_5$  are varied.  $W = 2\text{mm}$

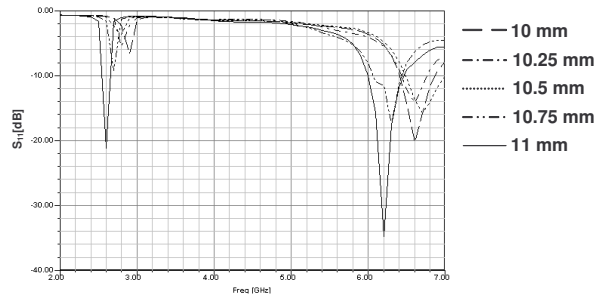


Fig. 3: Return loss of the printed-slot antenna when  $S_2$  is varied.

### Effect of $S_3$

This parameter affects on the mutual coupling between the two arms and the resonance frequencies of the antenna. Fig. 4 shows the return loss of the antenna as  $S_3$  is varied. In this study,  $S_1$  and  $S_5$  have been fixed. As  $S_3$  is increased, in the range of 10mm to 10.5mm, the resonance frequency at the upper band increases. As  $S_3$  is increased, the overlap and hence the coupling between the two arms decreases and therefore the effective length of the shorter arm decreases as well, increasing the resonance frequency. However, this effect is only valid for this parameter range only and when  $S_3$  goes outside this range, there are some unexplained behaviour observed on the return loss characteristics. Parameters used for this study are:  $S_1=7.8\text{mm}$ ,  $S_2=9.5\text{mm}$ ,  $S_3=10$  to  $10.5\text{mm}$ ,  $S_5=6\text{mm}$ ,  $d=0.5\text{mm}$ ,  $L_f=2\text{mm}$ ,  $W_f=2.5\text{mm}$ ,  $W=2\text{mm}$ .

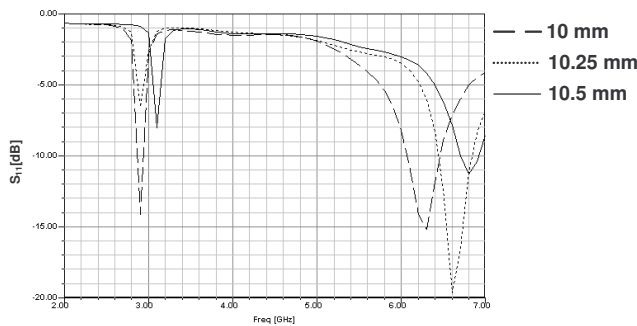


Fig. 4: Return loss parameters as  $S_3$  is being varied.

## RESULTS

Using the first type of feed-line configuration, it was found that excellent results can be obtained with the following parameters:  $S_1=6\text{mm}$ ,  $S_2=13.5\text{mm}$ ,  $S_3=12.5\text{mm}$ ,  $S_5=6\text{mm}$ ,  $S_4=11\text{mm}$ ,  $d=0.5\text{mm}$ ,  $L_f=4\text{mm}$ ,  $W_f=2\text{mm}$ ,  $W=2\text{mm}$ . Fig. 5 shows the return loss versus frequency for an antenna with these parameters.

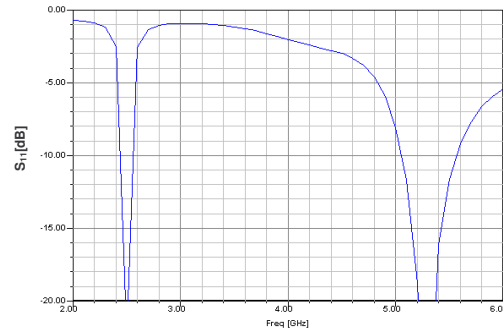


Fig. 5: Return loss versus frequency for one of the best designs.

Using these parameters, at  $-10\text{dB}$  return loss, the bandwidths obtained are around  $2.45\text{-}2.55\text{GHz}$  and  $5.05\text{-}5.6\text{GHz}$ . These results are promising in order to develop a suitable printed slot antenna to cover the 802.11b/g systems operating from  $2.4\text{-}2.4835\text{GHz}$  and 802.11a systems operating from  $5.15\text{-}5.825\text{GHz}$ .

## CONCLUSION

We discussed the design of printed slot antennas operating in the  $2.4\text{GHz}$  and  $5\text{GHz}$  bands to accommodate IEEE 802.11 WLAN standards. Effects of different parameters in the antenna structures on antenna bandwidth have been examined. By varying these parameters, the resonance frequencies of the antenna can be altered to meet the required specifications. This multi-band printed slot antenna appears to be a promising companion to previous multi-band printed monopole antennas in providing polarisation diversity.

## ACKNOWLEDGEMENT

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