

# A Wide Band MIMO Slot Antenna for 5G Wi-Fi

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**Abstract**—The bandwidths of the wireless channels have been extended in IEEE 802.11ac compared to 802.11n and is restricted strictly to the 5 GHz ISM band. It also allows MIMO which makes antenna design challenging especially where the space is restricted. Here a wide band slot antenna in the shape of a modified square with dual ports is proposed. The antenna has two asymmetrical orthogonal micro-strip line feeds. One port covers the 802.11ac band with 13% fractional bandwidth while the other port is matched over a greater 26% fractional bandwidth. The slot is modified with protuberances such that the coupling between the feeds are minimized and the excitation of the modes hence the bandwidth of the feeds are controlled by the protuberances. As a result of this modification the slot size is reduced further by 22% compared to the unaltered square slot design.

## I. INTRODUCTION

In IEEE 802.11ac the bandwidths of the wireless channels have been extended and restricted to the 5 GHz ISM band. It also allows MIMO operation which makes antenna design challenging especially in mobile devices where the space is restricted. The radiating element(s) must cover the 5GHz ISM band, be as compact as possible and contend with a variety of propagation environments. A dual polarization wide-slot antenna offers an attractive solution. Located in the ground plane of a device these compact elements offer wide-band two channel MIMO, while the magnetic slot is less effected by its surroundings than electrical elements[1].

Achieving polarisation diversity from a small slot antenna is fundamentally incompatible with obtaining wideband operation since multiple modes will inevitably be excited across the frequency band and, since these modes excited by each feed cannot be orthogonal if the antenna is symmetrical, they will unavoidably couple to each other, resulting in loss of the desired diversity. A number of designs for Dual Polarization Wide-Slot Antennas (DPWSAs) have been proposed [2]–[7] and demonstrate low levels of coupling between the two feeds, in some cases less than -30dB [3]–[5]. However, the electrical size of these antennas, approximately 25mm in most cases, makes them unattractive where space is restricted.

In this paper we present a novel DPWSA targeted for integration with an SD Card with Embedded Wireless LAN. It supports two asymmetric and perpendicular microstrip line feeds where the first feed excites multiple modes thereby gives a large operational bandwidth and the second feed excites an orthogonally polarised and hence uncoupled single mode. The slot is modified by introducing conductive surfaces protruding towards the slot such that the coupling between the two feeds are minimized and the excitation of the modes and

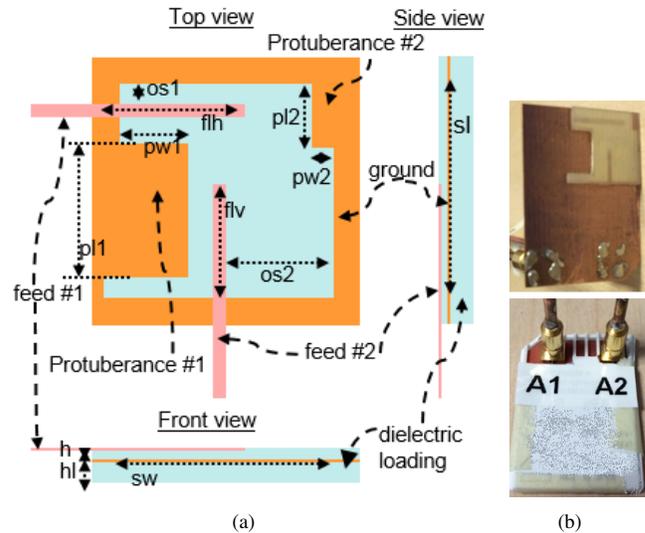


Fig. 1. Modified and loaded square slot with two feeds (a)Antenna model (b)Prototyped antenna located in the casing of an SD card

hence the bandwidth of the feeds are controlled by the size and the location of the protuberances. Furthermore the the protuberances provide space to mount part of the electronics for relevant circuit components. The antenna design steps are outlined in Section II. The results are presented in Section III. The paper concludes in SectionIV.

## II. ANTENNA DESIGN

A square slot of  $0.4\lambda_{guided}$  by  $0.4\lambda_{guided}$  is modelled on 0.4 mm thick FR4 substrate with two micro-strip line feeds and it is optimized with HFSS simulations.

Two orthogonal micro-strip line feeds are inserted on the upper face of the antenna where the slot is on the lower face as seen in Fig. 1. The horizontal feed, Feed #1, is located near the upper edge of the slot with an offset of  $os1$  whereas the vertical feed, Feed #2, is located centrally with an offset of  $os2$ . This is the first step of perturbing the symmetry. Feed #1 excites the upper horizontal edge of the slot at around 5 GHz and the feed line acts as a radiator itself at around 6 GHz. Therefore the slot width ( $sw$ ) and the feed length of Feed #1 ( $flh$ ) control the operating frequency of the 1st feed. The vertical feed excites the slot at around 5.5 GHz. The length of the lower slot edge ( $sw$ ) controls the operating frequency, and the slot length ( $sl$ ) together with the length of Feed #2

(flv) control the coupling between feeds. The parameters: sl, sw, flh, flv, os1 and os2 are optimized to get less than  $-10$  dB reflection over the 5 GHz ISM band (5.180-5.835 GHz) at both ports while maintaining low mutual coupling.

As a second degree of asymmetry, protuberances are added to the structure to improve the coupling between the feeds. By analysing the field distributions in Fig. 2 it has been observed that left edge of the slot is not very active except the lower left corner. So a protuberance is introduced on the left edge as seen in Fig. 1. Since the length of slot's lower edge is critical in determining the resonant frequency of Feed #1, the protuberance has an offset. The protuberance width (pw1) is critical because it affects both feeds' operating frequencies. As it increases, the resonant frequency of Feed #2 decreases as the radiating edge becomes larger in size. The same effect is visible on the lower resonance of Feed#1 however it has the opposite effect on the higher resonance of the same feed. As pw1 increases, Feed #1 matches for a larger frequency band. However pw1 cannot be increased unlimitedly since it increases the coupling by physically making the feeds come closer. On the other hand the length of the extension (pl1) is chosen to be as large as possible as it does not have significant effects on the matching of the ports as long as there is an offset between the ports and the extension.

A second protuberance is inserted at the upper right corner which has a stronger control over the coupling. The size of this protuberance does not affect the frequency response of Feed #2 but it detunes the lower resonance of Feed #1 since the length of the upper slot edge is altered by inserting it. The size is maximized as long as the response is kept under the desired requirements. Protuberances decreased the size of the antenna to  $112 \text{ mm}^2$  (22% less than the non modified version of the dielectrically loaded slot) and resulted in a reduction in maximum coupling in the 802.11ac band from  $-13\text{dB}$  to  $-17\text{dB}$ . The specific example given has the following dimensions: sl = 12 mm, sw = 12.5 mm for the upper edge and 13 mm for the lower edge, os1 = 1.5 mm, os2 = 4.9 mm, flh = 9.7 mm, flv = 5.5 mm, h = 0.2mm, hl = 1.16 mm, pw1 = 4.55 mm, pl1 = 7.8 mm, pl2 = 3 mm, pw1 = 1mm.

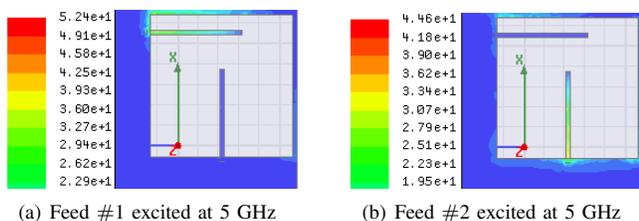


Fig. 2. Surface current distributions

### III. RESULTS AND DISCUSSION

The modified square slot antenna is prototyped on 0.4 mm thick FR4 substrate and the micro-strip line feeds are elongated up to the edge of the SD card itself and finalized with SMP connectors as seen in Fig. 1 (b). Note that the effects of the

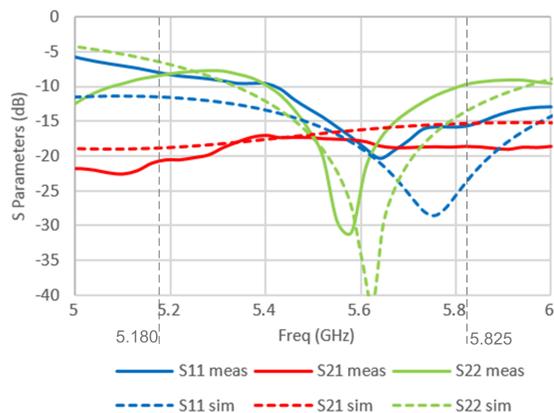


Fig. 3. Measured and simulated S Parameters

packaging was taken into consideration during the design steps with the assumption that it was constructed from polyethylene.

The simulated and measured S parameters are compared in Figure 3 and show good agreement having 26% and 13%  $-10\text{dB}$  fractional bandwidths for Y and X polarizations. The  $-6\text{dB}$  S11 bandwidth of the antennas covers the entire 802.11ac 5GHz band while the  $-10\text{dB}$  S11 bandwidth of both polarizations cover the the upper 75%. Differences between simulation and measured results can be attributed to the exact electrical properties of the case being unknown and the and the effects of the connectors being out of the scope of the simulations.

### IV. CONCLUSION

The modified square slot antenna achieves 2 polarizations with low mutual coupling while having 26% and 13%  $-10\text{dB}$  fractional bandwidths for X and Y polarizations. The  $-6\text{dB}$  S11 bandwidth of the both channels covers the entire 802.11ac 5GHz band. It supports 2 by 2 MIMO and shows 86% efficiency while being a simple and small structure. It has been shown that the antenna is insensitive to components located on its ground plane through simulations.

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