A Slot-loaded Reduced-size CPW-fed Aperture Antenna for UWB Applications

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Abstract— **The paper presents a co-planar wave guide (CPW)–fed slot loaded low return loss planar printed antenna with a small size designed for wireless communication and UWB applications. First, a conventional UWB antenna is modeled to provide a reference point for the modeling and then the shape is modified by a self inverted configuration to achieve higher bandwidth and size reduction. To improve the gain and efficiency, a combination of corner features and loading slots are introduced. The primary aim throughout the modeling was to achieve the minimum possible value of return loss (S_{11}) below -10 dB over the FCC-defined UWB frequency range. The antenna was designed, simulated and modified using Agilent's Advanced Design System (ADS). It was fabricated on FR4 substrate and measured return loss results are presented.**

Keywords—Ultrawide Band, Microstrip Antenna, Size Reduction , CPW-fed aperture antenna.

I. INTRODUCTION

Microstrip patch antennas are appropriate for use in wireless communication systems including ultra wideband (UWB) systems due to their attractive qualities of simple structure and low profile [1-5]. Ultra-wideband communications differs from conventional radio systems because it uses extremely narrow RF pulses and therefore occupies a very wide bandwidth. UWB technology is becoming widely used in radars, high data rate short range wireless communications, and identification/localization applications including UWB-RFID.

The frequency range of operation for such antennas is generally defined as 3.1 GHz to 10.6 GHz (the Federal Communications Commission (FCC) bandwidth). The operational bandwidth of an antenna is usually defined as the frequency range over which the return loss S_{11} is less than 10% (-10dB) [6-10], although some papers present results in terms of VSWR.

In this work we have modeled an existing design [11] using ADS, analyzing the results in terms of S_{11} and then optimized the design stage-by-stage to improve the bandwidth performance whilst reducing the overall patch size relative to the original design.

Our final design exhibits a -10dB S11 frequency range from approximately 2.9 GHz to above 12 GHz with a circuit board area which is 54% of the original. The fabricated antenna band width is shown to extend from 2.56 GHz to above the 9 GHz limit imposed by the available vector network analyzer (VNA).

A key issue in design of antennas intended for UWB use is to match the antenna impedance to produce adequate gain and efficiency over the frequency range. The paper also describes details of the slot loaded CPW feed line.

II. ADS MODELLING

The industry-standard simulation software ADS 2012 based on the momentum method is employed to perform the design and optimization process.

A. Substrate

The antenna modeled here is a microstrip patch antenna implemented on single-sided FR4 circuit board, 1.5mm thick, whose substrate has relative permittivity of 4.1. The feed structure is a 50Ω CPW transmission line, whose end is terminated by a semi-circular tuning stub, similar to that used in [11]. This feed configuration appears similar to a mushroom shape, presenting a simple geometrical structure. The width of microstrip feed line is fixed at 3.6 mm to achieve 50Ω characteristic impedance.

B. Size reduction techniques

Work has previously been undertaken [12] to reduce the size of a patch antenna used for narrow-band applications. It has been found that some of these techniques including corner-cutting and the use of a series of slots to force an increased current path, resulting in an increased effective electrical size of the antenna, can also be applied in modified form to the UWB case.

III. SIMULATION

A. Return loss

Fig. 1 shows the optimized antenna design after approximately 70 iterations. The location and length of asymmetrical slots has been found to be critical in achieving the desired degree of size reduction whilst maintaining the required UWB frequency

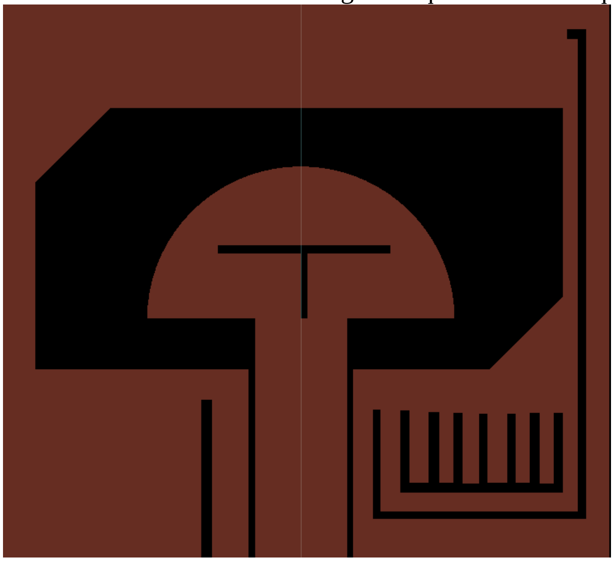

Fig. 1 Layout of Slot loaded CPW-FED Antenna

range. The overall size of the optimized design is 24mm perpendicular to the 9.75 mm length and 3.6 mm feed line width, which attached to a half a circle with radios 6 mm and the other outer dimension 22mm parallel to the feed. The slots width is differ from 0.40 mm to 0.30 mm and the gap between the feed section and the main section is 0.25 mm. the antenna fabricated on a FR4 substrate with dielectric constant ε_r of 4.3, and thickness 1.5mm.

The calculated S_{11} amplitude and phase plots are shown in Fig. 2 and Fig. 3 where it may be seen that the -10dB bandwidth far exceeds the FCC UWB frequency range.

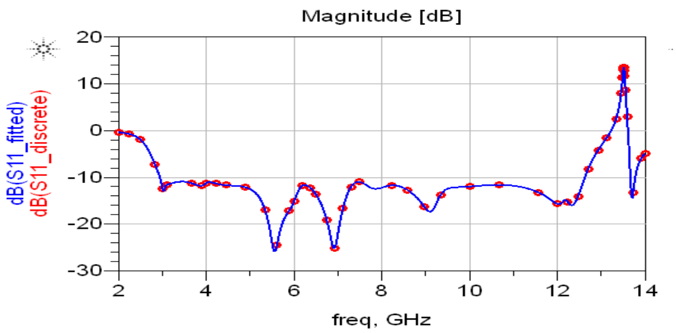

Fig. 2 The calculated S_{11} amplitude.

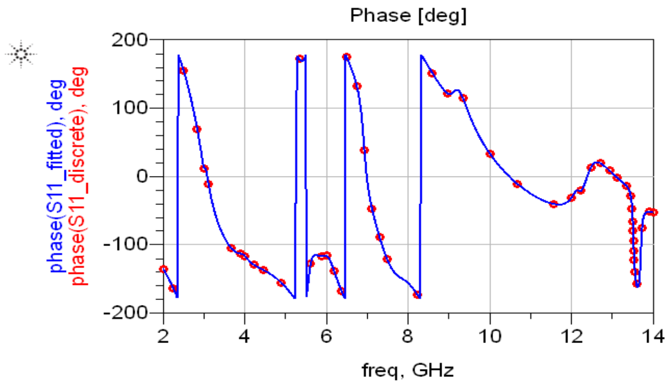

Fig. 3 The calculated S_{11} phase

B. Current Distribution

Fig. 4 and Fig. 5 illustrate examples of the current distribution for the optimised antenna. Frequencies 6.80 GHz and 9.40 GHz have been chosen for illustrative purposes, since it is difficult to show current distribution as a function of frequency over the whole required band. Throughout the optimization process monitoring the current distribution has been the key factor in determination of slot location and length.

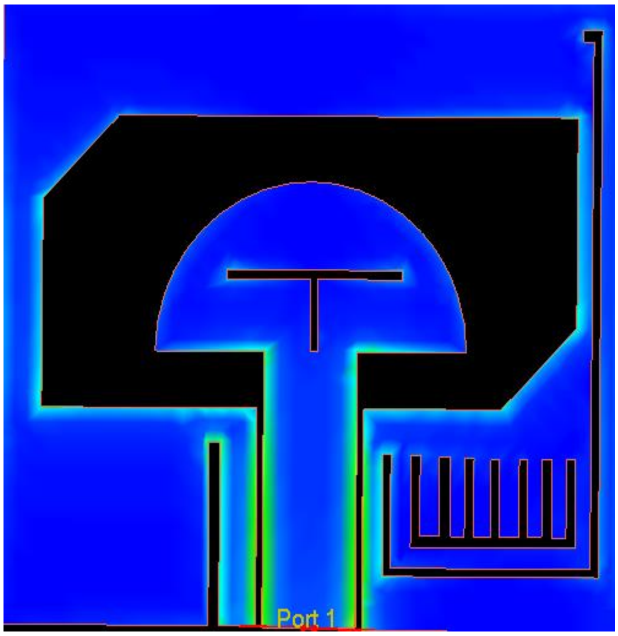

Fig. 4 Current distribution for the frequency 6.80 GHz.

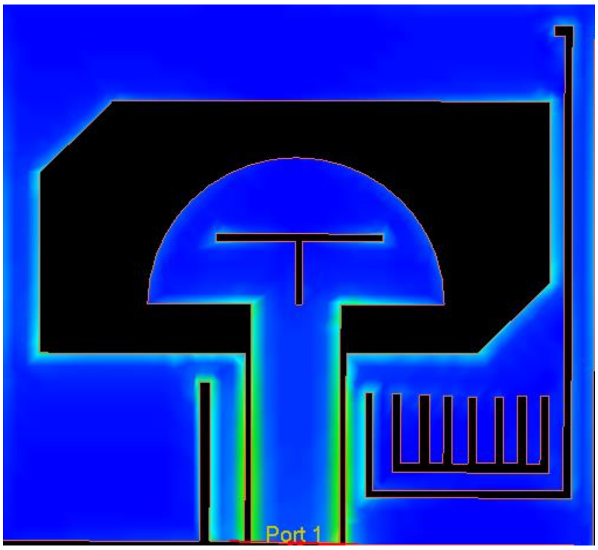

Fig. 5 Current distribution for the 9.40 GHz.

C. Radiation pattern

Fig. 6 and Fig. 7 show three-dimensional plots of the predicted radiated E-field produced using the post processing Far-Field. Again, these have been produced for illustrative frequencies of 6.80 and 9.40 GHz. As expected from an electrically small structure, the radiation pattern is approximately omni-directional with a reduction in field in the plane of the substrate.

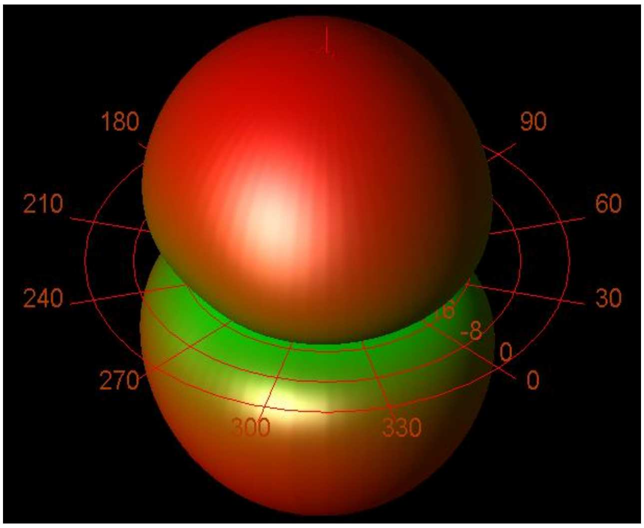

Fig.6 Radiation pattern 6.80 GHz.

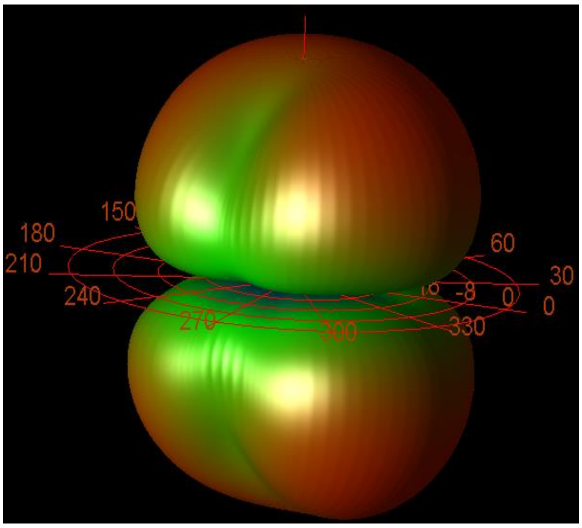

Fig. 7 Radiation pattern for 9.40 GHz.

IV. FABRICATED RESULTS

The fabricated antenna is shown in Fig.8 which includes dimensional information.

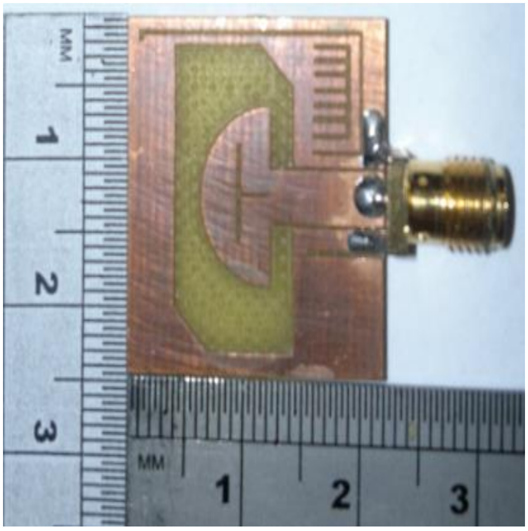

Fig.8 Dimensions of antenna.

The return loss of the fabricated antenna was measured using an Agilent 58358A 300 kHz to 9 GHz vector analyzer (VNA). Results are shown in Fig.9. The results show a wider bandwidth from 2.56 GHz compared to simulated results of 2.8 GHz. Generally good agreement is seen between simulated and measured results, up to the 9GHz limit imposed by the VNA.

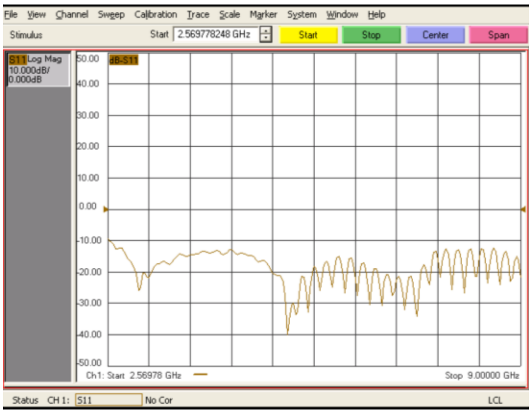

Fig.9 Return loss S_{11} measured by VNA.

V. CONCLUSIONS

We have presented a new design of CPW-fed patch antenna which includes several size-reducing features leading to a structure which is occupies only 54% of the board area of an established design [11]. The design has a bandwidth which exceeds the FCC UWB frequency range and offers potential for operation to frequencies above 12 GHz as shown by simulation (Fig.2) and by measurement (Fig.9). The antenna design presented is critically dependent upon appropriate and accurate positioning of loading slots and combs, which have been determined by consideration of the resulting current distribution. In the narrow-band case [12] the placement of slots can be taken to extreme levels, leading to fractal antenna designs. It has yet to be determined whether or not this approach can be applied in the wideband case.

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