

Novel Compact Broadband and Dual-Band Patch Antennas

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Abstract—In this paper, two proposed compact broadband and dual-band microstrip patch antenna configurations have been analyzed, investigated and optimized using the Zeeland-simulator. The presented antennas resonate at 6.0, 12.0 and 13.0 GHz with bandwidth of more than 600MHz (about 10% of center frequency).

Keywords- Compact; Broadband; Dual-band; Patch antennas

two horizontal slots. Two patch antenna configurations have a single slot. The first one is referred to as upper-slot-patch “USP” antenna as shown in Fig.2. The second one is referred to as lower-slot-patch “LSP” antenna as shown in Fig.3. The third configuration is referred to as two-slots-patch “TSP” antenna as shown in Fig.4. The slot dimensions are assumed to be 3.0mm length and 26.0mm width.

I. INTRODUCTION

Microstrip antenna configurations have numerous benefits in wireless communication and radar systems applications. This is due to its small size, low cost, less weight, easy fabrication, and excellent compatibility with the typical manufacturing process of MMIC planar circuits. Two proposed compact broadband and dual-band microstrip patch antennas are analyzed, investigated, optimized and presented in this paper. Section II presents a detailed description of a conventional microstrip patch antenna with single and double horizontal slots. Simulation results of these antenna configurations are presented in section III. To achieve the 4G wireless communication system constrains, the antenna should be a wideband as well as compact in size. In addition, the antenna characteristic must be optimized over the operating frequency range. The basic concept of the proposed antenna compactness and optimization is discussed in details in section IV. A detailed parametric analysis of proposed patch antenna configurations and their simulation results are also presented in section IV. Simulation results of the proposed optimized and compact patch antenna configurations are compared to the conventional patch and presented in section V. Such antennas resonate at single and/or dual frequencies with a symmetric and wide bandwidth about the required resonance frequency. Finally, section VI concludes the presented paper.

II. PATCH ANTENNA COFIGURATION AND DESCRIPTION

A basic conventional patch “BCP” antenna configuration is illustrated in Fig.1. The basic patch dimensions are 15mm length and 30mm width. The patch is mounted on a single FR-4 substrate ($\epsilon_r = 4.6$, 1.6 mm height, and tangential loss of 0.02) and the conductor thickness is assumed to be 0.035mm. These patch dimensions has been selected and designed to resonate about 4.0 GHz with transmission line feed of 50 Ohm. Three antenna configurations are proposed to operate in the 4G frequency band as shown in Fig.2 through Fig.4. These antenna configurations may have either one horizontal slot or

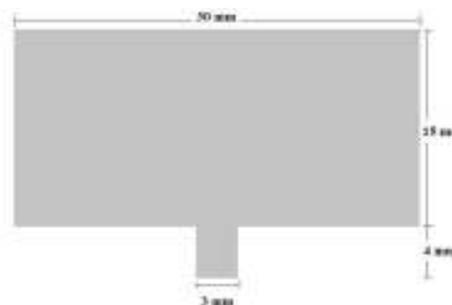


Fig. 1 BCP antenna configuration

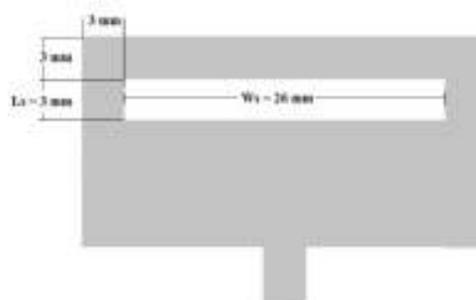


Fig. 2 USP antenna configuration

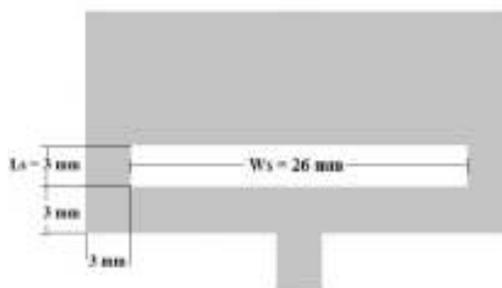


Fig. 3 LSP antenna configuration

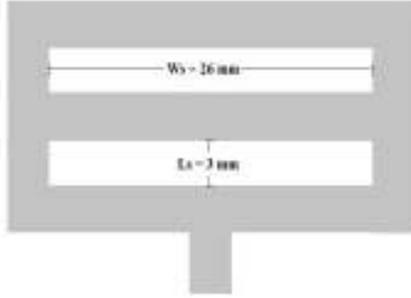


Fig. 4 TSP antenna configuration

III. SIMULATION RESULTS

The three presented antenna configurations are simulated using Zeeland software and the results are compared to the conventional patch and presented in Fig.5 through Fig.7. It is clear from these figures that the conventional patch has multi resonance frequencies due to the mismatch between the patch and the feed line (Inset has not been used). In addition, adding either one slot or two slots has the effect of shifting the resonance frequencies to the higher frequency band.

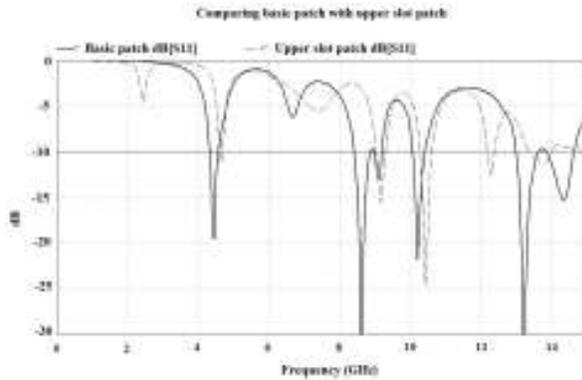


Fig. 5 S_{11} of BCP and USP antennas

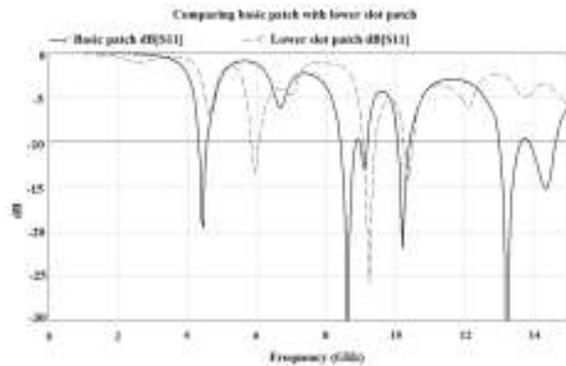


Fig. 6 S_{11} of BCP and LSP antennas

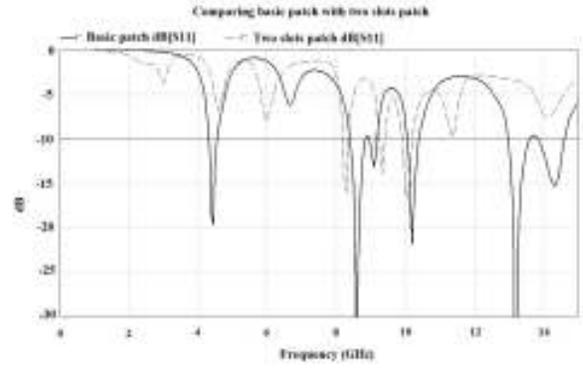


Fig. 7 S_{11} of BCP and TSP antennas

IV. OPTIMIZATION OF THE PATCH ANTENNA DESIGN

A parametric analysis has been performed to study the effects of the patch and the slot dimensions on the antenna characteristic. Many cases of study have been simulated and the obtained results have been investigated to optimize the antenna dimensions. The objective of such optimization process is to end up with an antenna configuration achieves the current challenges of the 4G-wireless communication systems. This includes three important factors. First the operating wideband frequency, second the antenna compactness, and third the antenna duality band. To achieve such goal, the optimization process is based on three main parameters. First reducing all patch antenna dimensions by a factor "K" to make it compact in size. This has the effect to shift the antenna resonance frequency. Second, adding a symmetric planner array of vies has the effect to bring back the antenna resonance, and finally adjusting the feed line width to control the antenna duality band.

A. Scaling the patch antenna dimentions

The first approach to achieve a compact patch antenna design is to reduce its initial dimensions by a "K" factor without reducing the antenna feed line (i.e. 50 ohms matched line). Scaling the patch antenna dimensions leads to a frequency shift of all resonance frequencies to much higher values than without scaling. Consequently, scaling leads to only one resonance frequency depending on the initial patch dimensions. That is to say that the patch antennas resonate at a single higher frequency instead of multi-resonance frequencies. Simulation results of this approach are shown in Fig. 8 through Fig. 10, where, each scaled antenna configuration (USP, LSP & TSP) is compared with the scaled BCP antenna configuration (Scaling the antenna dimensions by factor $K=3$). As it is clear from the presented figures, the scaled BCP antenna has only a poor resonance at 12.25 GHz as compared to unscaled one. The compact patch antenna with a single scaled slot (USP and/or LSP) has the effect to make the antenna resonates at 13.0 GHz with a narrow-bandwidth and poor efficiency. However, adding the other scaled slot (TSP) enhances the antenna efficiency and the bandwidth as well as the resonance by more than 10 dB as illustrated in Fig.10.

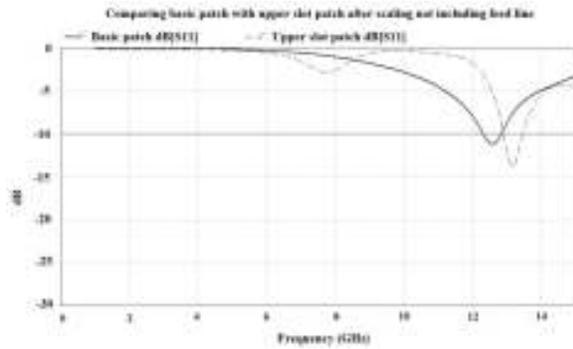


Fig. 8 S_{11} of BCP and USP antennas after scaling dimensions ($K=3$) with feed line 50 Ohm

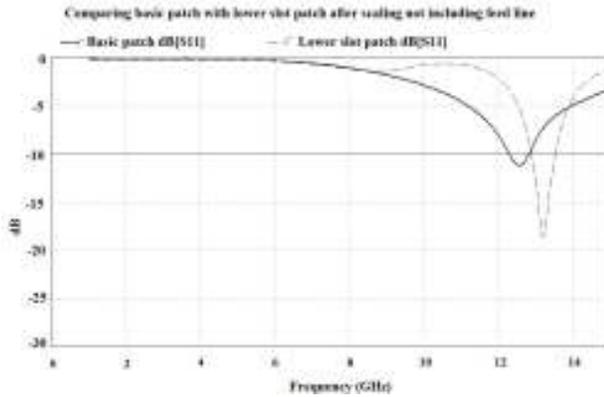


Fig. 9 S_{11} of BCP and LSP antennas after scaling Dimensions ($K=3$) with feed line 50 Ohm

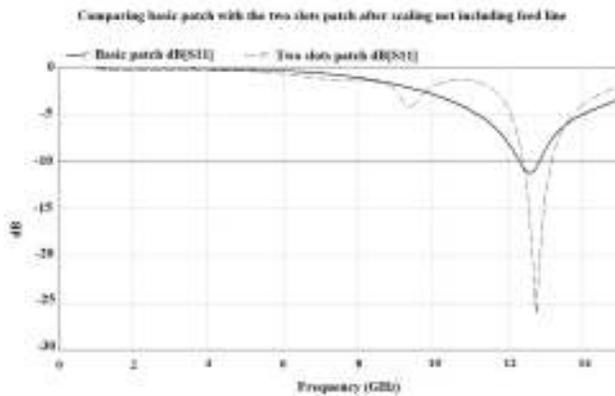


Fig. 10 S_{11} of BCP and TSP antennas after scaling Dimensions ($K=3$) with feed line 50 Ohm

B. Adding a symmetric planner array of vies

The second approach is to add a symmetric planner array of six vies to each of the scaled previously mentioned antenna configurations (BCP, USP, LSP, and TSP). The radius of each via is assumed to be of 0.16mm. The spacing between vies of the planner array have been investigated for the scaled patch

antenna configurations and it is found to be: the horizontal spacing between vies is 1.0mm and the vertical spacing between vies is double the value of the horizontal one (i.e. 2.0mm). Simulation results of this approach are illustrated in Fig. 11 through Fig. 13. As it is clear from figures, each compact antenna configuration is compared with the BCP antenna configuration (without slots) after adding array of six vies. Also, the compact LSP and compact TSP antennas resonate at higher frequencies above 16 GHz.

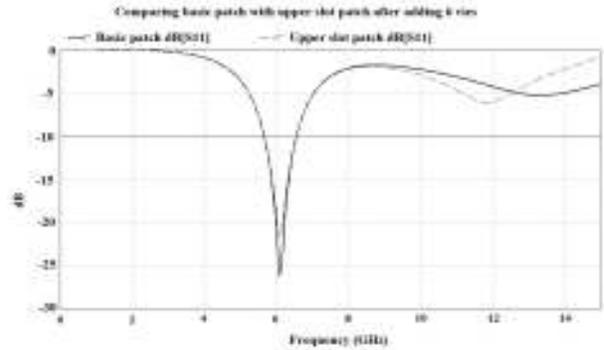


Fig. 11 S_{11} of BCP and USP antennas after adding six vies ($K=3$ and 50 Ohms feed line)

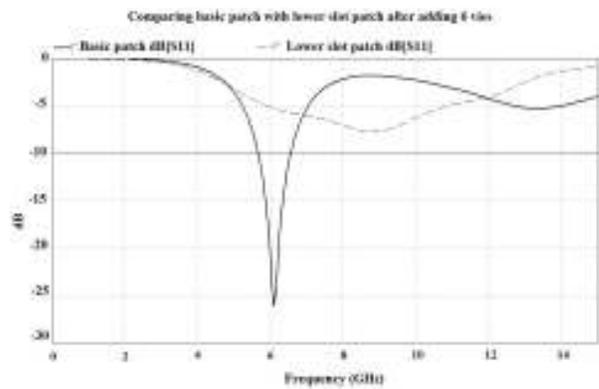


Fig. 12 S_{11} of BCP and LSP antennas after adding six vies ($K=3$ and 50 Ohms feed line)

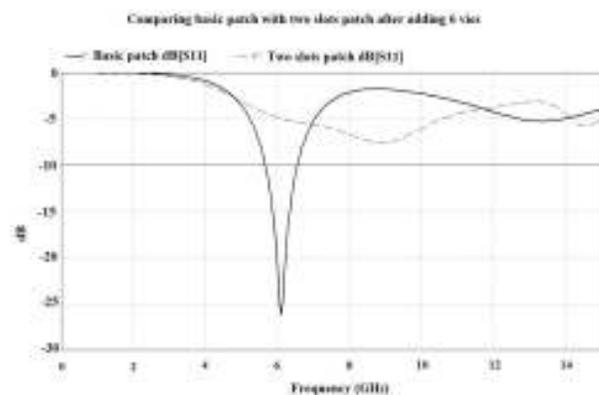


Fig. 13 S_{11} of BCP and TSP antennas after adding six vies ($K=3$ and 50 Ohms feed line)

C. Controlling the antenna feed line

The third approach is to scale the feed line width of the compact patch antenna configurations with array of six vies. The feed line width is reduced by a factor of three i.e. the compact antenna configurations are completely scaled by a factor of three. In this case the feed line has 85.0 ohms ($W=1.0\text{mm}$) instead of 50.0 ohms (the antenna port is not matched). This mismatching has the effect to make compact patch antenna resonates at dual-frequencies instead of only single frequency. The results of simulation are illustrated in Fig. 14. As it is clear from the figure, the compact USP and compact BCP antennas resonate at dual-frequency band at 6.0, 12.0, and 13.0 GHz. In fact, the other compact patch antenna configurations (LSP and TSP) need adding more vies to enhance their resonance at 6.0 and 11.0 GHz as shown in Fig.15 and Fig.16.

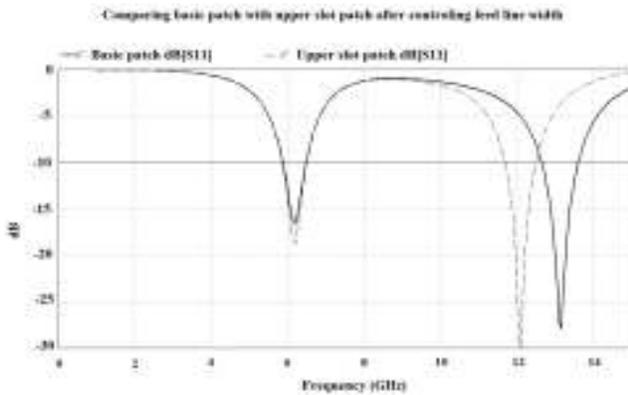


Fig. 14 S_{11} of BCP and USP antennas ($K=3$ and 85.0 Ohms feed line)

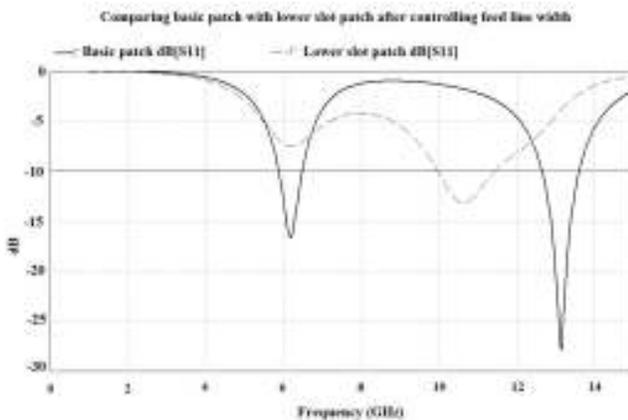


Fig. 15 S_{11} of BCP and LSP antennas ($K=3$ and 85.0 Ohms feed line)

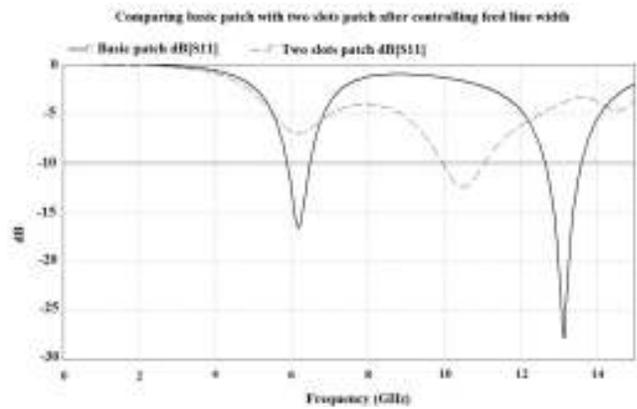


Fig. 16 S_{11} of BCP and TSP antennas ($K=3$ and 85.0 Ohms feed line)

V. SPECIFICATIONS OF THE SELECTED DESIGNS

The above analysis demonstrates in a simple manner how a conventional patch antenna can be designed and optimized with extremely compact dimensions to operate at the desired broadband and/or dual-band frequency range. Based on the simulation results, two patch antenna configurations have been selected and optimized. The first one is a conventional patch with single-upper slot reduced in size by a factor of three and an array of six vies as shown in Fig. 17 (USP). The second antenna configuration is the same as Fig.17 but with no slot (BCP). The feed line of these antenna configurations is either 50 Ohm ($W=3.0\text{mm}$, un-scaled) or 85 Ohm ($W=1.0\text{mm}$, scaled by factor of three). Fig.18 illustrates the s-parameter of the compact BCP antenna for 1mm port (85 ohms) and 3mm port (50 ohms). It is clear that this antenna can operate as broadband or dual-band antenna based on the feed line impedance. In addition, the s-parameter of the compact USP antenna with 1mm port (85 ohms) and 3mm port (50 ohms) is shown in Fig. 19. Again, this antenna can operate as broadband or dual-band based on impedance of feeder. The VSWR of the compact patch Broadband and/or Dual-band antennas is shown in Fig.20. This figure illustrates the acceptable VSWR values within broadband and the dual-band of the proposed compact antenna configurations (BCP and USP). The observed resonance frequencies are about 6.0, 12.0 and 13.0 GHz in each band with bandwidth of 600, 900 and 1000 MHz respectively for maximum VSWR value less than 2. Also, the upper slot has the effect of shifting the higher dual frequency as compared to the compact BCP (compact patch without slot).

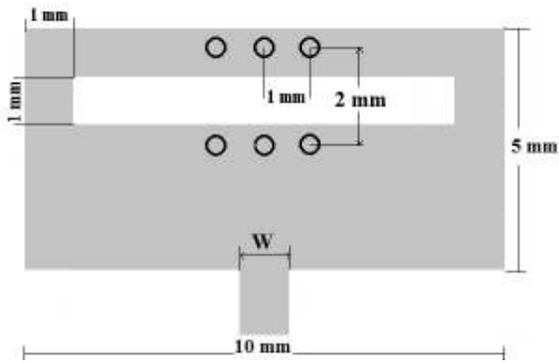


Fig. 17 Dimensions of the compact USP antenna

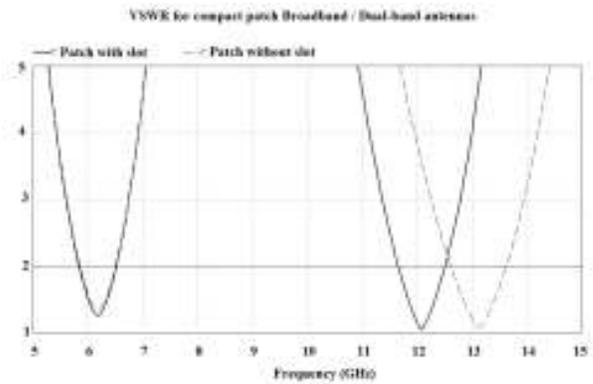


Fig. 20 VSWR for compact patch Broadband (50.Ohm) and Dual-band (85.00hm) antenna configurations (compact BCP, and USP antennas, where, $K=3$ and planner of six vies)

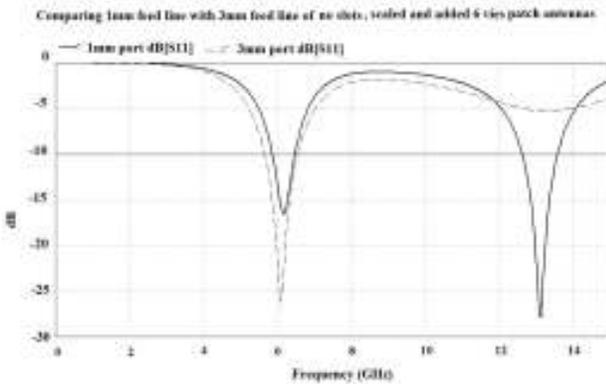


Fig. 18 S_{11} of the compact BCP antenna of 1mm port (85 ohms) and 3mm port (50 ohms)

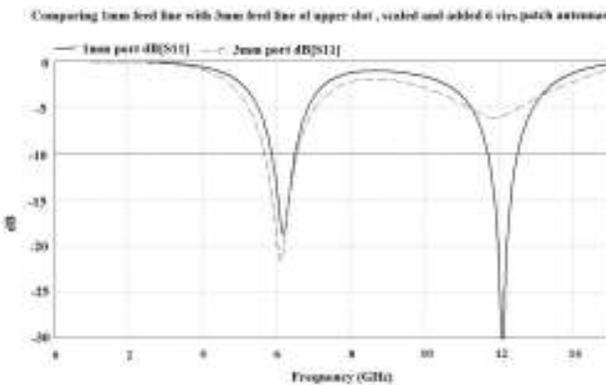


Fig. 19 S_{11} of the compact USP antenna of 1mm port (85 ohms) and 3mm port (50 ohms)

VI. CONCLUSION

A compact broadband/dual-band patch antennas have been analyzed, designed and simulated. To design such antennas, first select a patch antenna to resonate at a specific required frequency in the 4G wireless band. Second, the patch dimensions are scaled by a factor “K” to make it compact in size. This will shift the resonance frequency (frequencies) at a higher frequency band. Finally, a planner array of vies is added to control the antenna resonance frequencies at the desired range. The results of our simulation show that the proposed compact Broadband and/or Dual-band antennas resonate at 6.0, 12.0, and 13.0 GHz with bandwidth at least of 600 MHz and a maximum VSWR value of 2.0. Future work will include analysis and design of a compact patch array antenna to achieve the broadband and dual-band characteristic used in the fourth generation wireless communication systems.

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