A coplanar waveguide tapered slot antenna with beam switching capabilities

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ABSTRACT

A wideband tapered slot antenna (TSA) with three radiating elements for beam switching purpose is presented in this paper. The integrated radiating taper slots in assistance with metal strips acting as switches provided the proposed design with the capability of switching its beam into three different directions while maintaining the antenna performance stable. To verify the accuracy of the presented design, the prototype was fabricated and measurements were conducted in terms of scattering parameter (S11), radiation pattern and realized gain towards the three different operating modes. By sequentially, activating the switches, the antenna main beam rotated 90° in the XY coordinates. A realized gain ranging from 4.3 to 6.4 dBi and a wide operating bandwidth (|S11| ≤ -10 dB) from 3.3GHz to 5GHz were observed throughout the antenna performance in simulation as well as in experiment. With the covered bands, the proposed antenna is suitable for sub-6GHz communications systems.

Keywords:
Beam switching
Pattern reconfigurability
Radiating elements
Tapered slot antenna
Wireless communication

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1. INTRODUCTION

Whilst the advancement of wireless communication systems increases tremendously, diverse steps are required to tackle the exponential growth in broadband demands. Fixed antennas are limited in performance and unable to cope in a dynamic environment. Reconfigurable antennas were introduced to allocate the antenna beam on the target thus, increase the overall data rate and reduce the interference. Reconfigurable antennas are described as antennas that support multiple functions within a single structure. This reconfiguration comes in different form such as frequency reconfiguration, polarization reconfiguration and pattern reconfiguration depending on the required applications [1-7].

In a dynamic environment, avoiding interferences in a wireless system is crucial, such that directive antenna with switched beam ability are required in such situation to improve the communication linkage by ensuring the signal reaches the intended users. This enables effective and consistent communication for fast-moving information transmitting in both base stations and user terminals of wireless systems [8-11]. Towards achieving beam switching, various approaches have been studied, namely digital beam forming [12-15]. However, this approach is limited to narrow operating band and quite complex. The current approaches are parasitic tuning and multiple radiators, which are widely employed due to the ease of integration [16-22]. In this work, switched radiators approach is proposed to provide a wide tilt angle of ±90° over a wide operating band and a portion of common area is overlapped for miniaturized profile. The beams are configured by channelling the current flows to the radiating slot. The proposed structure conquered the limitation of ±40° in the tilt angle as reported in [23-25]. The existing studies shows that with a wide operating bandwidth, the beam switching directions are limited to two states at the highest gain of 6 dBi [26, 27].

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Contrary to the previous works, the proposed structure presents a trade-off between bandwidth coverage and beam switching states with three directive beams at the peak gain of 6.4dBi. An exception is exhibited in [28] with 16 states, every 22.5° covering a narrow bandwidth at the peak gain of 6.2dBi. Nevertheless, the design proposed in this work is a good candidate for wide-beam steering applications. The merits of the proposed structure over previous reported works is the fact that different modes can be combined to boost the reconfigurable states (from 3 states to 7 states without additional switches) and improve the directivity. However, this will be examined in the next study.

2. DESIGN AND EXPERIMENT

The proposed TSA is built from an original TSA with one radiating element. The design is optimized with additional taper slots to increase the reconfigurable states. The proposed design and its parameters is displayed in Figure 1 and Table 1. The top layer engraves three taper slots radiators whereas the lower patch of the antenna grooves of a cpw feed and delay slot-line for wideband matching purpose. An FR4 with 0.8mm of substrate thickness board is used with a relative permittivity of 4.3 and a tangent loss of 0.025. The characteristic impedance was selected to be 50 Ω. Initially, the energy is conveyed from CPW to radiating- slot by a delay slot-line with a basic role of upholding the electric field in phase with the other slot-line. Towards the end of the delay slot-line, the two electric fields stayed in phase for wide transmission capacity to be acquired. Secondly, the wave propagations are directed by the taper slot respecting the orientation of the switched radiator.

![Figure 1. Proposed antenna design structure](image)

In order to achieve the three different modes, the metals strips acted as switches, ideally, for radiator 1 to operate, $S_1$ is open whereas $S_2$ and $S_3$ are short-circuited meaning that metal strips are added on to prevent the current to flow in to the radiator 2 and 3. On the other hand, $S_1$ and $S_3$ are short-circuited blocking the current in the left and right modes and allowing the up mode to radiate. Whereas for right mode to be functional, $S_1$ and $S_2$ should be short-circuited.

![Figure 2. Fabricated prototype with metal strips in up, left and right mode](image)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Dimension (mm)</th>
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<tbody>
<tr>
<td>$W_1$</td>
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</tr>
<tr>
<td>$W_2$</td>
<td>63.8</td>
</tr>
<tr>
<td>$W_3$</td>
<td>5.39</td>
</tr>
<tr>
<td>$L_1$</td>
<td>102</td>
</tr>
<tr>
<td>$l_1$</td>
<td>13.39</td>
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</tr>
<tr>
<td>$l_3$</td>
<td>13.95</td>
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<tr>
<td>$G$</td>
<td>4.84</td>
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<tr>
<td>$g$</td>
<td>0.56</td>
</tr>
<tr>
<td>$S_{1,2,3}$</td>
<td>5.39</td>
</tr>
</tbody>
</table>

Table 1. Optimized parameters of the designed antenna
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Figure 4. E-phi component co and cross (sim vs meas)-up mode (a) 3.4GHz, (b)3.6GHz, (c) 3.8GHz

Figure 5. E-phi component co and cross (sim vs meas)- left mode (a) 3.4GHz, (b)3.6GHz, (c) 3.8GHz

Figure 6. E-phi component co and cross (sim vs meas)-right mode (a) 3.4GHz, (b)3.6GHz, (c) 3.8GHz

4. CONCLUSION

A wideband tapered slot antenna with beam switching capabilities is presented in this monograph. The viability of switching the main beam with respect to the intended directions not affecting its operating bandwidth was evaluated. The proposed design achieved three different directions with a realized gain ranging from 4.3 to 6.4dBi. The total efficiency varies from 92% in simulation to 60% in experiments. Furthermore, it is suggested to explore the performance of the design in active mode without the increment in size and the disturbance in the pattern.
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A coplanar waveguide tapered slot antenna with beam switching capabilities (D. Abijuru)


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