Size Reduction of Octa-Band WWAN/LTE Antenna using Slotted Spirals with Non Uniform Width for Tablets

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ABSTRACT
The effect of slotted spiral technique on an antenna that covers octal bands of WWAN/LTE has been studied and discussed in this paper. The Slotted Spiral consists of strips arranged together forming a spiral of different vertical and horizontal width. The antenna has been initially designed without employing the slotted structure to cover the frequency bands GPS l2 band-1227.60/l3 band 1381.05, DCS1800 /PCS1900/ UMTS2100 LTE2300/2500/2600 (1710–2690 MHz).The size of the antenna was initially 15 x 40 mm^2.Then the structure has been designed employing the slotted spiral technique which provides a size reduction from 15 x 40 mm^2 to 15 x 38 mm^2 which is small enough to be incorporated in a tablet computer. Furthermore the use of embedded parallel resonant structure aids in implementing slotted spiral technique. The antenna after employing size reduction provided a low return loss and good radiation efficiency and high gain than the antenna without slotted spiral.

Keywords
Resonance, tablet computers, embedded parallel resonant structure, Slotted Spiral Technique.

1. INTRODUCTION
Microstrip patch antennas are used because of several attractive features like low cost, ease of fabrication, small weight etc.[1] The development of communication engineering with integration technology demands size reduction of low frequency antennas as an important design perspective. Present day applications require antennas with smaller sizes capable of operating in wider bandwidths [2]. The microstrip antenna can be fabricated on the same printed circuit board containing the electronic components of the device. This provides efficient use of available space and making the device compact. This shows that, in the case of mobile or other small communicating devices, the size of the antenna plays a vital role. So, by reducing the size of antenna [1-2], the overall size of the device Can be reduced.

2. SLOTTED SPIRAL TECHNIQUE
Effective methods to shrink the size of the antenna includes

- Use of high permittivity substrate
- Meandered ground plane
- Coiling
- Slotted spiral

The last method is applied in this paper in conjugation with embedded parallel resonant structure. Similar antennas has been discussed in [3] wherein the four bended slots has been embedded within a square patch to obtain small size. The proposed method provides a size reduction of around 2 mm from 15 x 40 mm^2 to 15 x 38 mm^2. The figure1 shows the slotted spiral patch which is used in the antenna design.

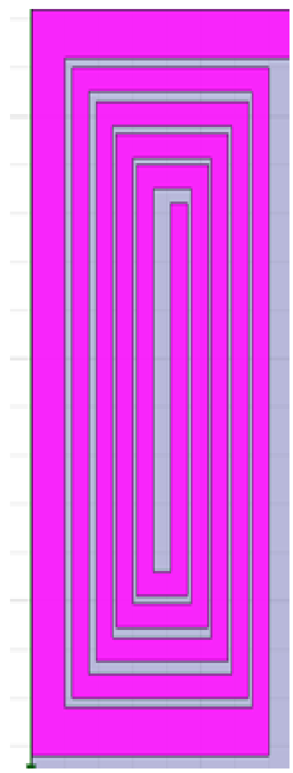

Fig: 1 Slotted spiral patch used in the antenna.

The appreciable bandwidth is achieved with the slotted spiral technique. The vertical and horizontal width of the slotted spiral was varied and with vertical width of 0.25mm and horizontal width of 0.2mm, resonance was good. The reason is that the slotted spiral radiates on sides, the front and back side [5-8]. There will be no need for additional strip to bring about resonance. Without this technique, resonance and impedance matching was poor.With the help of this technique, size of the antenna was reduced from 15 x 40 mm^2 to 15 x 38 mm^2.

3. ANTENNA DESIGN

Fig. 2 shows the architecture of the proposed antenna using a slotted spiral patch along with the parallel resonant structure for size reduction. The slotted spiral patch has been included in the no ground region. The patch is done in a smaller region thereby not interfering the operations of the other strip [9]. The slot has been chosen of unequal width. This forces the surface currents to vary the flow between vertical and horizontal strip thereby reducing the electrical length of the antenna.[10-14].The antenna has a 0.8-mm thick FR4 substrate of size 60 x 120 mm^2 and relative permittivity 4.4 and loss tangent 0.02. On the back side of the FR4 substrate, there are two printed system ground planes, concluding main ground plane of 60 x 105 mm^2 and protruded ground plane of 15 x 22 mm^2, leaving a no-ground region of 15 x 38 mm^2 at the top position of the circuit board to design the proposed antenna[15]. The antenna has been designed without the use of external matching circuits. The parallel resonant structure itself acts as a resonator, thereby reducing the need for additional circuits In the design, the PR (parallel resonant) structure is employed to obtain the desired broadband operating characteristics for GSM/UMTS/LTE/GPS operation.

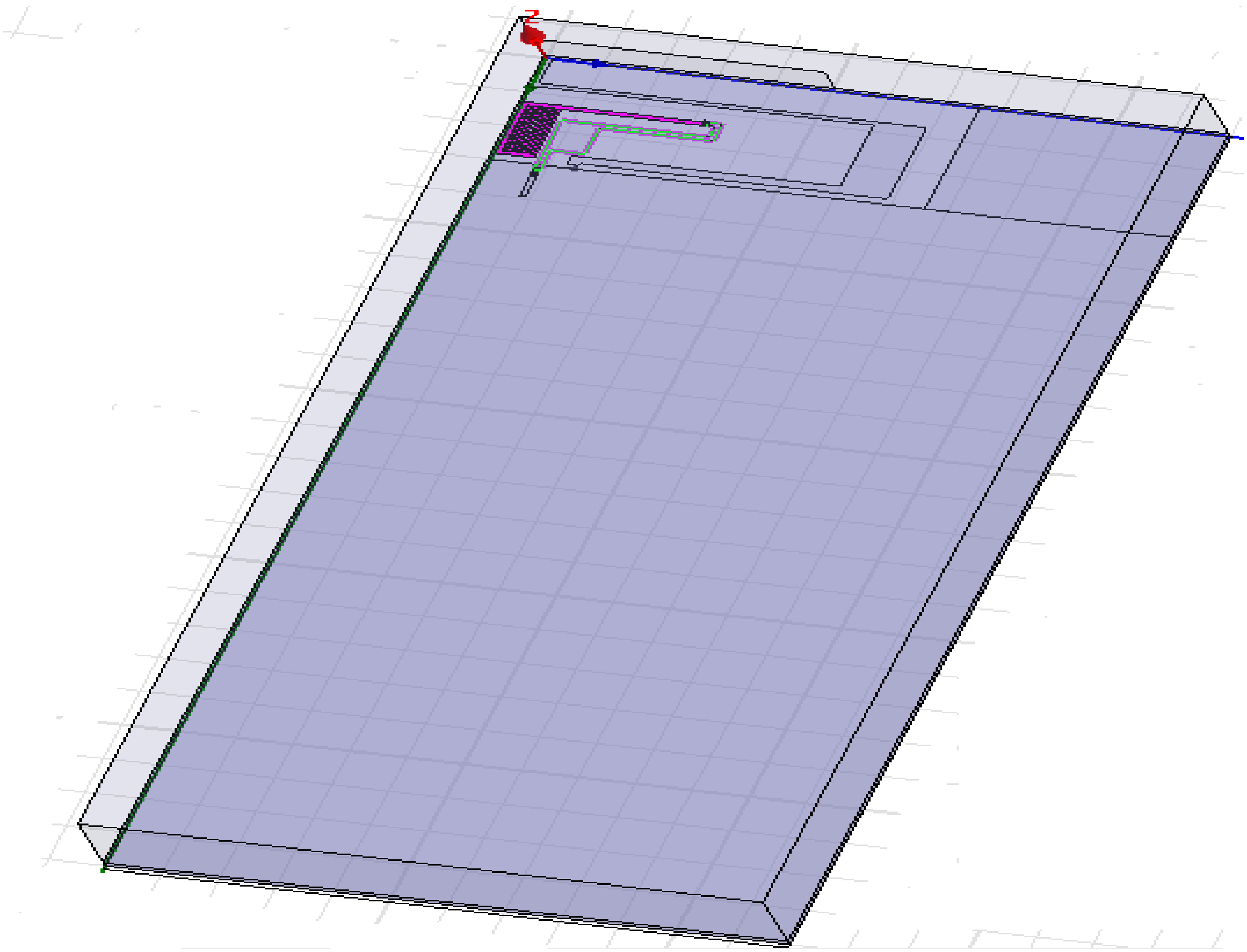

Fig 2: architecture of the proposed antenna

4. PARAMETER STUDY

Size reduction is one major advantage of slotted spiral patch.The return loss obtained for the antenna with slotted spiral patch is shown in the figure 3.the return loss without applying slotted spiral was very less which was around -5 dB to -12 dB for several bands. After employing the size reduction the return loss had a considerable increase which was around -7 dB to -15 dB. The return loss comparison table is shown figure4.

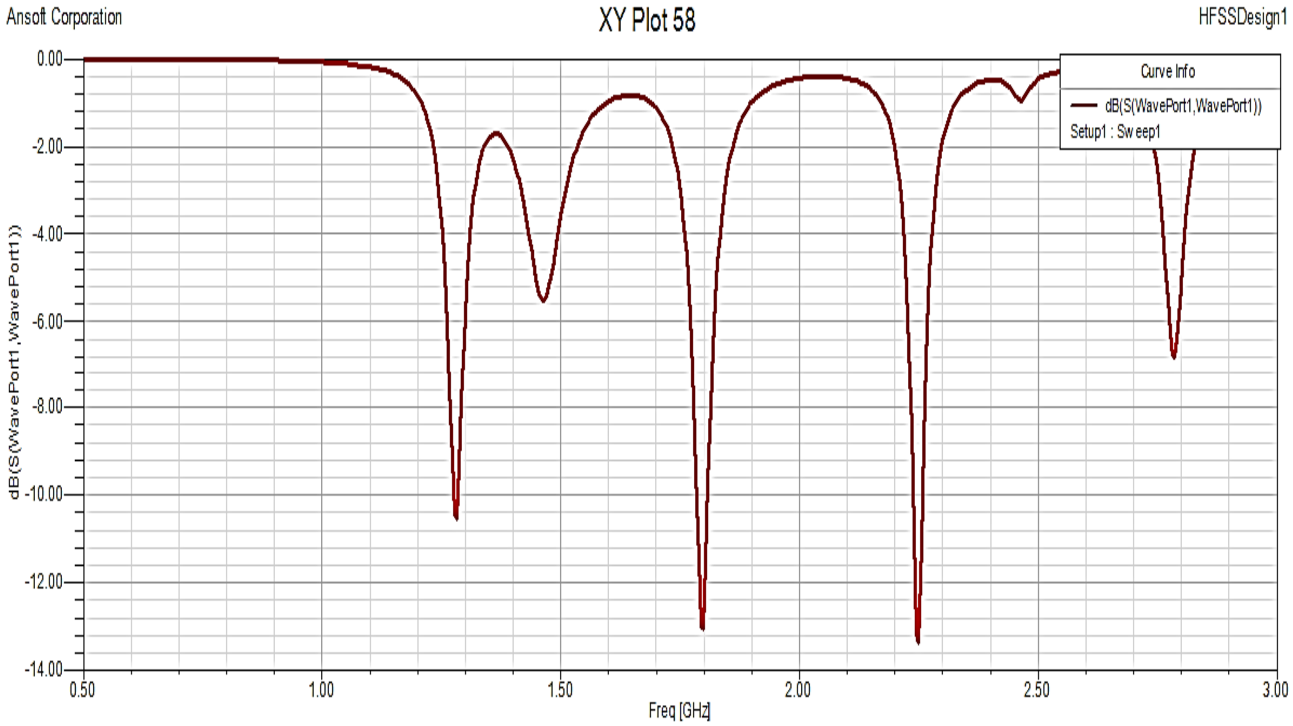

Fig: 3: Return loss for the proposed antenna.

BANDS(MHZ)	RETURN LOSS WITHOUT SIZE REDUCTION	RETURN LOSS WITH SIZE REDUCTION
GPS l2 band(1227.60)	-6	-9.5
GPS l3 band (1381.05)	-7	-5.5
DCS 1800	-12	-14
PCS 1900	-13	-13
UMTS 2100	-9	-13
LTE 2300	-5	-7
LTE 2500	-5	-7
LTE 2600	-5	-7

Fig: 4: Return loss comparison

The figure 5 shows detailed dimensions of the antenna along with the slotted spiral patch. The radiation patterns were obtained with respect to gain for 8 frequencies. These patterns are obtained with XY direction as the reference. Whenever width of the spiral has been increased, there is degradation in impedance bandwidth. With optimum vertical width of 0.25mm and horizontal width of 0.2mm,the impedance bandwidth was considerably good. The gain of the antenna without slotted spiral structure is lower than the gain of the antenna with slotted spiral patch. The antenna achieves a smaller size and a comparable return loss with high gain. The antenna without slotted spiral obtained a gain of around -12 dB to -25 dB whereas antenna with slotted spiral patch obtained a gain of around -10 dB to -22 dB. Figure 7 shows the gain comparison table with and without slotted spiral technique.

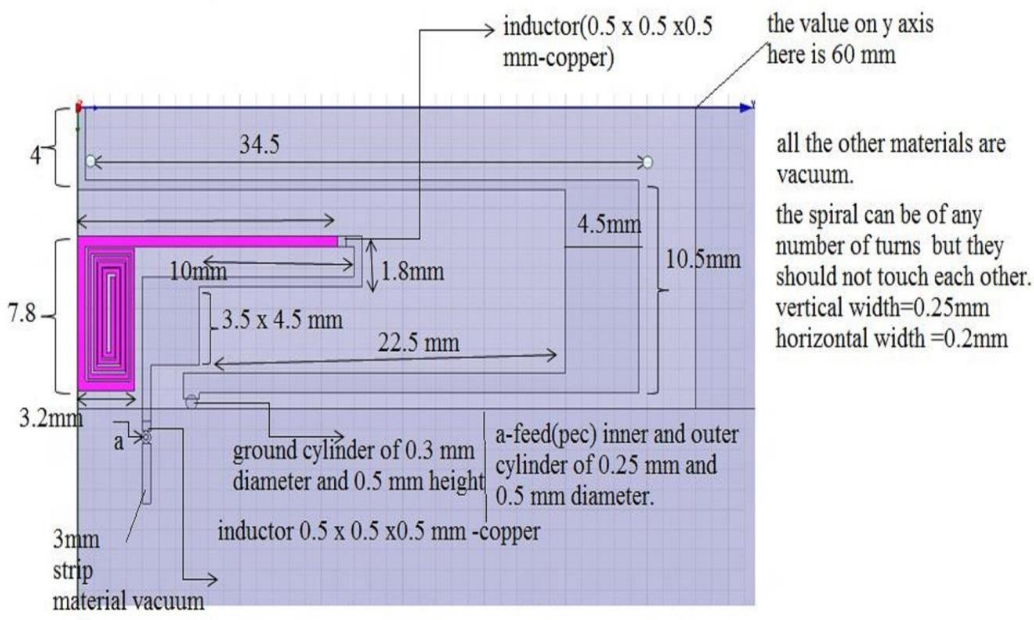

Fig 5: detailed dimensions of the proposed antenna

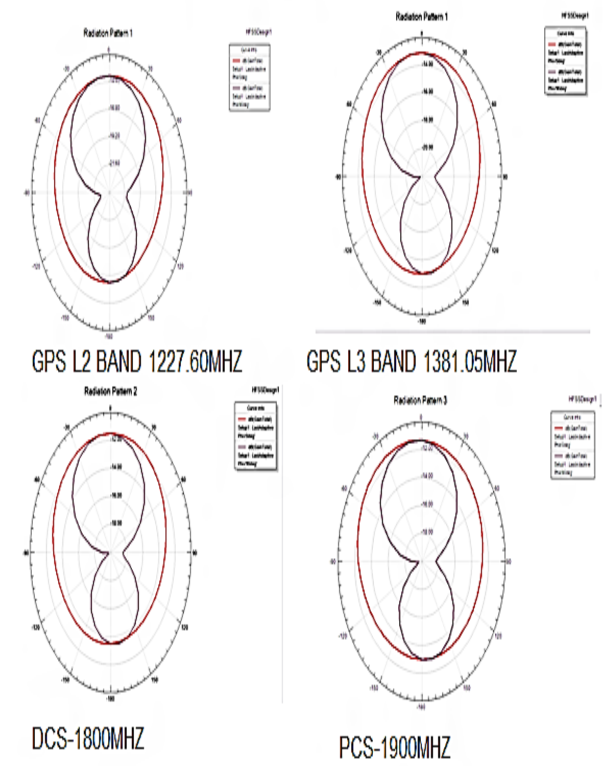

Fig 6: (a) Radiation Pattern for the proposed antenna. (Red indicates E-field and black indicates H-field. These are taken with gain as reference. The values are shown in the figure 7.)

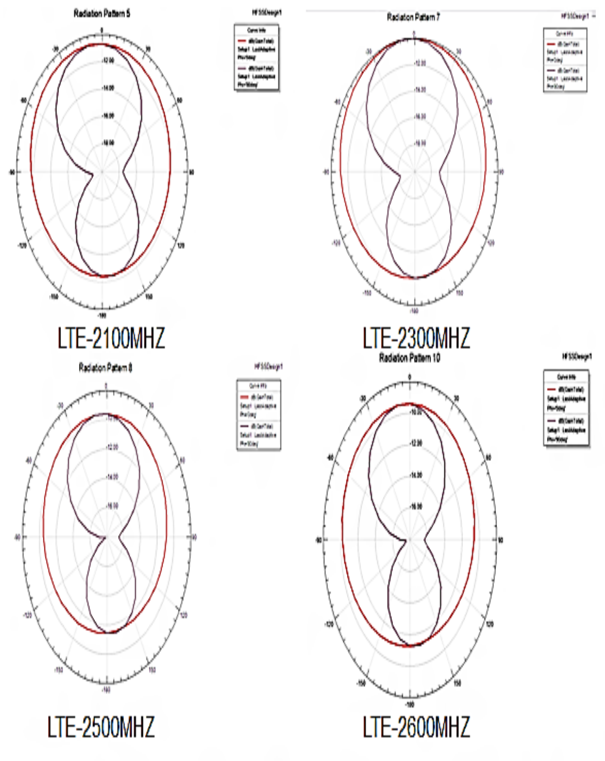

Fig 6: (b) Radiation Pattern for the proposed antenna. (Red indicates E-field and black indicates H-field. These are taken with gain as reference. The values are shown in the figure 7.)

BANDS	GAIN WITH SIZE REDUCTION	GAIN WITHOUT SIZE REDUCTION
GPS L2 BAND (1227.60)	-13.98 to -16.63	-15.78 to -25.58
GPS L3 BAND(1381.05)	-13.16 to -22.21	-15.34 to -25.46
DCS-1800	-11.34 to -19.35	-14.10 to -24.95
PCS-1900	-11.03 to -19.75	-13.72 to -24.75
UMTS-2100	-10.67 to -18.73	-13.09 to -24.19
LTE-2300	-10.08 to -18.25	-12.49 to -23.50
LTE-2500	-9.56 to -17.84	-11.99 to -22.78
LTE-2600	-9.38 to -17.59	-11.63 to -22.57

Fig 7: Gain Comparison

5. RESULTS AND DISCUSSION

With slotted spiral technique the size of the antenna has been reduced from 15 x 40 mm^2 to 15 x 38 mm^2 .The gain of the antenna was -10 dB to -22 dB with size reduction and -12 dB to -25 dB without size reduction. Over the desired GPS l2 band-1227.60/l3 band 1381.05 band of the antenna gain is varied from about -13.98dB to -22.31dB considering size reduction. The gain of the antenna with size reduction is higher than the gain of the antenna without size reduction. For the desired DCS1800 /PCS1900/ UMTS2100 LTE2300/2500/2600 1710–2690 MHz) band, the antenna gain is varied from about -10.34 dB to -22.59 db. The antenna has been designed using HFSS 11.0 and the measured results can be tested by an vector network analyzer. In the design, 3:1 VSWR is used as the impedance matching bandwidth, which is generally acceptable for practical tablet computer antennas. Future work involves optimizing the antenna for better gain and fabricating the antenna and verifying it practically using vector network analyzer. With increasing trend towards slim tablet computers ,reduction in size aids in further slimmer tablet computers.

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