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Design of Penta-Band Antenna for Concurrent Multiband Single Chain Radio Receiver

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Abstract: In this paper, penta-band antenna is presented for concurrent, multiband, and single chain radio receivers. The antenna is manufactured on a 50 × 100 mm FR4 printed circuit board, and is able to provide five concurrent, operating bands covering a frequency range from 2 to 6 GHz. The antenna bandwidth can be increased up to 280 MHz. Using hexahedral mesh the slot antenna design we can achieve more accurate concurrent bands. These five bands are having larger bandwidth than conventional antennas. Using CM-FARAD

(Concurrent Multiband Frequency Agile Radio) architecture we design the antenna for achieving concurrent multiband and single chain radio receiver. Using five slots we achieve our five concurrent bands that operate over wide bands which operate at 2.4,3.0,3,7,4.5,5.6 GHz respectively.

Keywords : Microstrip Feed, slot antenna, hexahedral ,Concurrent, Multiband ,Single Chain.

I. INTRODUCTION

The traffic on radio access systems (RANs) requires the fifth era (5G) of cell versatile radio access advancements (RATs) to have higher zone limits, lower latencies and more Speed [1]. To help such a CM-FARAD framework, the reception apparatus needs to give various recurrence groups at the same time over the ideal recurrence run. One of the restricting elements is the common coupling between transmitting components, which can show itself as an undesirable move in the radio wire thunderous recurrence because of the tuning of another band. This will detrimentally affect the framework execution, as regularly the receiving wires are narrowband over the frequencies of intrigue. We propose a reduced, penta-band receiving wire structure for a recurrence low profile, CM beneficiary. The antenna supports five operating bands covering a frequency range from 2GHz to 6 GHz. Antennas were manufactured on a FR4(Fire resistant) Substrate.

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Printed Loop Antenna With a Perpendicular Feed for Independently tunable Triband antenna has been discussed in [2] which is having only three bands, which are operating concurrently and it needs to be improved. In [3] Tunable multiband handset antenna operating at VHF and UHF bands has been given however this does not include 5G. Penta-Band Mobile Phone Application is discussed in [4],Where the perpendicular feed arise problems to low cost and low profile antennas. Dual band antennas with wide tunability range is also CM(concurrent ,Multiband)-FARAD(Frequency Agile Radio) Receiver which gives the structural architecture of CM-FARAD receivers[5]. In [6] Dual-band reconfigurable antenna with a very wide tunability range having tunability range increased have negative impact on gain performance of antenna. Slot antennas are studied using [7] as reference book for antenna design. The necessary formulae needed to design antennas are taken from[8].

II. ANTENNA DESIGN

The design is compromising of five slots paced coplanar on PCB ground sandwiched with feed on the back side and slots on the front side. The antenna is designed on a FR4 substrate having thickness of 1.6 mm. The antenna consists of 5 slots on a PCB ground plane which are resonant at five concurrent frequency bands. The architecture used to design the antenna is CM-FARAD (Concurrent, Multiband, Frequency Agile Radio) Architecture. The design consists of three main components. Those are slots on plane ,PCB ground and microstrip feed line on the back side of PCB to give Feed to Antenna by Electromagnetic coupling.

The length of first slot is calculated first to keep the wavelength of resonated slot as $\lambda/4$ and the remaining keeps decreasing by order of 4 as $\lambda/8$ for second slot and so on.

As shown in figure two slots are shown parallel to each other. A slot perpendicular is added between two slots. Now to make it to operate for five frequencies we need to add two more slots which should be of same size and orientation. Since we already used open circuited slot to reduce our antenna profile ,we cannot use another open circuit slot. So we add fourth slot by using the same features of second slot and by adding length of 2mm. the fifth slot is added parallel to third slot and distance between them should be more than or equal to slot length.

Table1. Antenna Configuration Parameters

	Slot1	Slot2	Slot3	Slot4	Slot5	Substrate
Length	26	15	15	15	15	50
Width	2	2	2	2	2	100
Thickness	0.4	0.4	0.4	0.4	0.4	1.6
Feed	F1	F2	F3	F4		
Length	47	19.7	26.3	11.4		
Width	3.2	1.7	3.2	1.7		

The above table gives the geometry of antenna which ha five slots numbered from left to right. Four microstrip feed are joined together to support CM FARAD architechture. The feeds are given perpendicular to each slot numbered right to left F1,F2,F3,F4 respectively. This geometry give the antenna to achieve single chain receiver with concurrent and multiband frequencies.

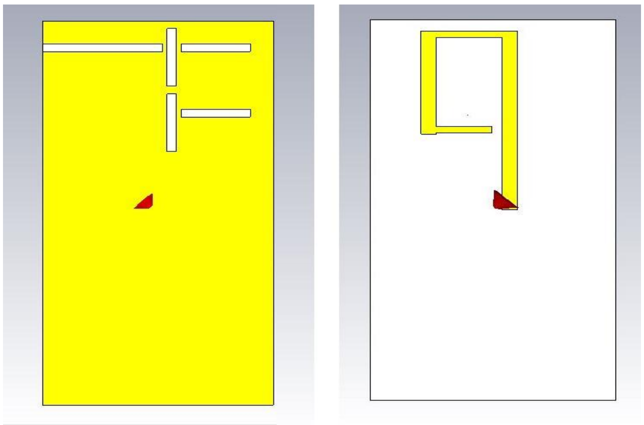

Fig.1 Antenna design in CST front and back structure of antenna

Five slots are placed on the antenna as shown in the figure and a microstrip feed line is given as feedback with open end port. Slot at its first mode can be considered as a λ/2 transmission line short circuited at two closed ends. The space length can be additionally decreased to λ/4 in the event that one finish of the opening is open circuited, which is known as an open-end opening. As per Babinet's rule, the radiation example of the space radio wire will be exactly as same as its integral dipole however with traded E and H fields.

To make geometry of antenna suitable for transient analysis for 5G frequencies we use the same length of slots for the remaining slots after the first slot is given its length 26mm.So the length and width of remaining slots is kept same, which is slot length is 15mm and width is 2mm. To keep the geometry of antenna minimum and sustain at less electromagnetic mutual coupling we keep the distance between two vertical slots is 2mm and two parallel slots horizontally is 4mm and vertically is 15mm. Thickness of feedline and slots are taken same i.e., copper is 0.4mm on the front and back side of substrate.

The feed line is constructed to perpendicular to each of slot and provide the excitation signal to slot via port connected. The geometry of Feed is given as four rectangular strips in a connected shape with a strip starting below 3mm from top the back side of antenna. The length and width of strip which is at top the back side is 1.7mm x19.7 mm. The strip which is perpendicular to open ended slot has 47mm x 3.2mm which is longest of four strips. The strip which is second longest and parallel to first longest has dimensions 26.3mm x 3.2 mm. The last strip which smallest of all strips has 1.7mm x 11.4 mm as shown in figure. The distance between short strip and antenna edge is 10.4mm.

Hexahedral Mesh Refinement

Hexahedral Mesh is used instead of traditional tetrahedral to improve our S11 ratio to get more number of bands operating through antenna Hexahedral mesh improves accuracy. Since we are using simple geometry of structure it is preferable to use hexahedral. One hexahedron is similar to six of tetrahedrons. So computation becomes lengthy and tome consuming for simulation but provides accurate results. In CST Microwave studio 2018, we have option to switch from tetrahedral mesh to hexahedral mesh to improve our results.

To solve hexahedral computations the computer takes more time as much 6x times of tetrahedral and more to represent accurate results. Now the surface current distribution denotes slot current distribution which can observed in CST by adding Field monitors

zAn open port is given to the feedline at bottom side of feed to increase the frequency range and adjacent blockers to each of frequency bands. This type of feed can reduce the errors occurring during manufacturing process of antenna.

III. RESULT AND DISCUSSION

The antenna is simulated using Hexahedral Mesh to get our desired five concurrent bands. Hexahedral Mesh structure is more advantages for simple geometrical structure and can give us our desired results.

A. S-Parameters

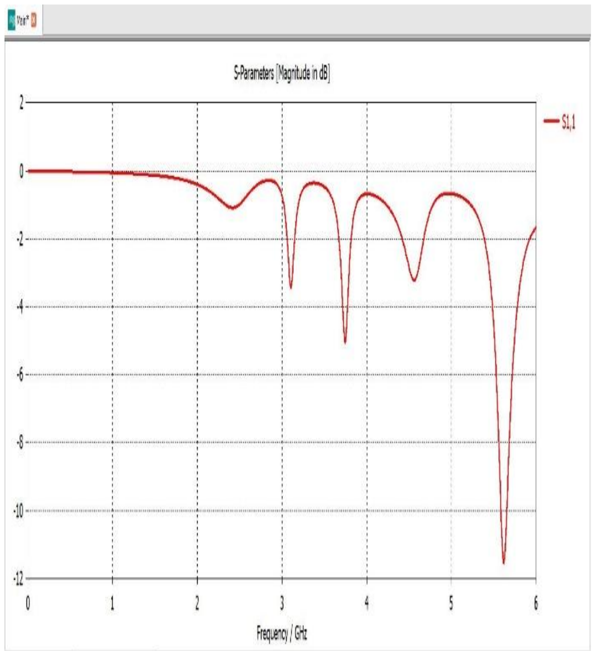

Fig2. S-parameters of simulated antenna

Frequency range covered by our antenna is 2-6 GHz (FR1 range of 5G systems).As we can see from our result the antenna is radiating in five concurrent bands each of them having different bandwidth range. The result is given by the table below.

Table2

Slot NO	Frequency(GHz)	Gain(dB)	Bandwidth (MHz)
1	2.4	1.08	590
2	3.0	3.40	350
3	3.7	5.06	260
4	4.5	3.2	510
5	5.6	11.55	510

As we observe the five bands which are resonating for different frequencies having different bandwidths. This is due to mutual coupling between the slots. To reduce the mutual coupling between two parallel slots we introduce a slot between them vertically and to reduce mutual coupling we keep distance between two parallel slots horizontally with more than slot length. The slots are radiated each at different frequencies producing different frequency ranges. The lowest frequency range is obtained by the first slot which is a open circuited to reduce Slot length by

We have five operating bands covering from range

2 to 6 GHz. The first band operates at 2.0784-2.6705 GHz with gain 0.49dB has over 590 MHz which covers higher bands of spectrum of 4G communications. The second band which covers 2.9392-3.2974 GHz with gain with potential 5G Spectrum lower band having 350 MHz with gain of 0.49dB.The third band covers 3.6158-3.876GHz with gain 1dB having lowest bandwidth of other bands as 260MHz. The fourth band covers 4.275-4.7854 GHz with gain of 0.98dB. The final fifth band which consists of largest gain of 1.9 dB has 510 bandwidth covering 5.3878-5.9095 GHz.

B.Raditation Pattern

The radiation pattern of antenna on five farfield regions is shown in below figures the comparison is theta/Phi relation. The five farfield regions are 2.41,3.09,3.74,4.55,5.61 GHz approximately. The radiation pattern shows the adjacent resilience to each of bands and no interference in radiation Pattern. The radiation pattern gives the antenna output for the frequencies. At 2.41GHz the theta/Phi relation shows that the radiation pattern is has magnitude of 6.22 dB and with wide coverage of bandwidth about 590MHz. At 3.09GHz the theta/Phi relation shows that the radiation pattern is has magnitude of 24.6 dB and with wide coverage of bandwidth about 350MHz. At 3.09GHz the theta/Phi relation shows that the radiation pattern is has magnitude of 24.6 dB and with wide coverage of bandwidth about 350MHz. At 4.5GHz the theta/Phi relation shows that the radiation pattern is has magnitude of 8.2 dB and with wide coverage of bandwidth about 590MHz. At 4.55GHz the theta/Phi relation shows that the radiation pattern is has magnitude of 8.2 dB and with wide coverage of bandwidth about 510MHz. At 5.61GHz the theta/Phi relation shows that the radiation pattern is has magnitude of 23,7 dB and with wide coverage of bandwidth about 510MHz.

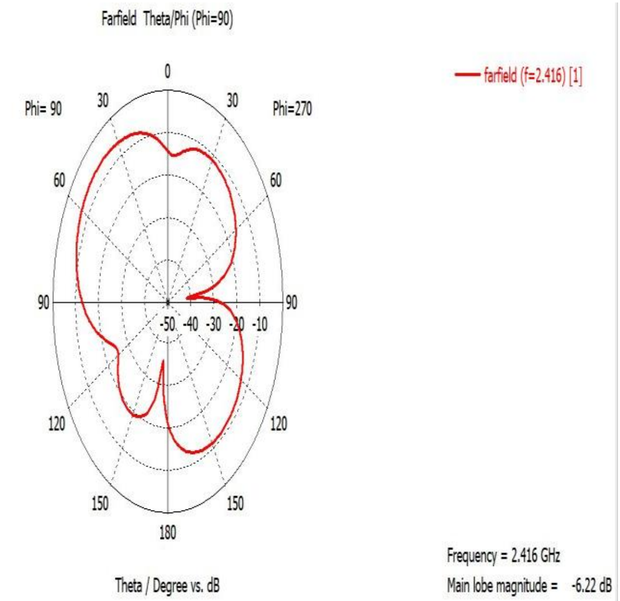

Fig3.Radiation Pattern at 2.41GHz

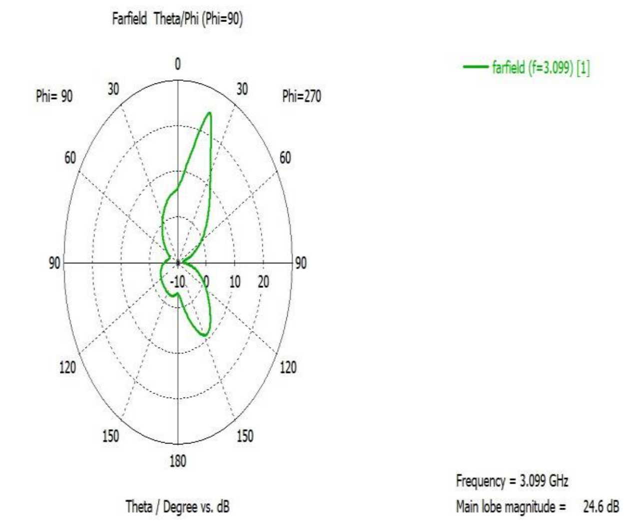

Fig4.Radiation Pattern at 3.09GHz

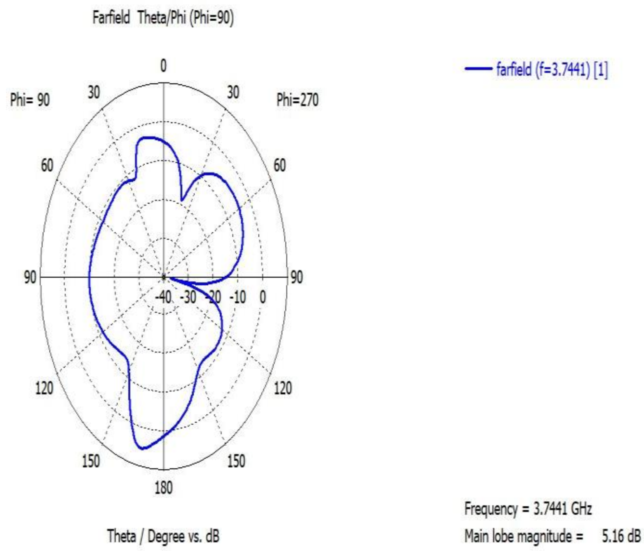

Fig6.Radiation Pattern at 3.74GHz

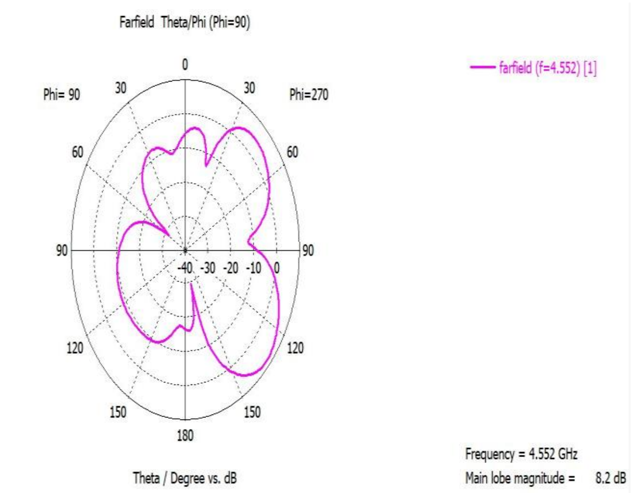

Fig5. Radiation Pattern at 4.55GHz

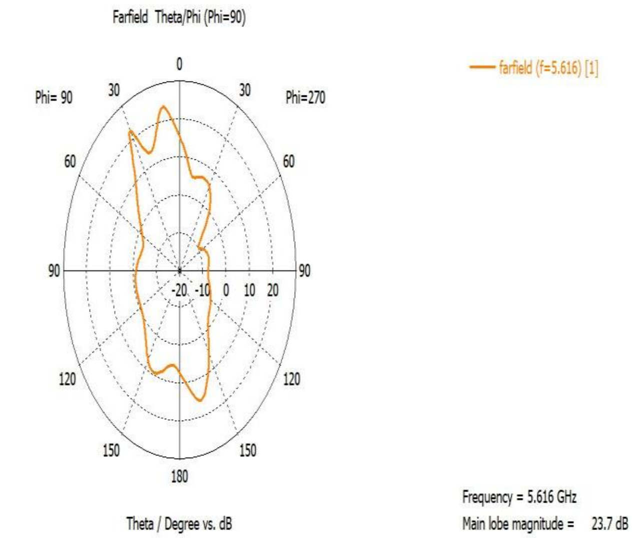

Fig7. Radiation Pattern at 5.61GHz

IV. CONCLUSION AND FUTURE SCOPE

The design and simulation of penta band antenna using microstrip slots antenna is achieved. The antenna is simulated using CST Microwave Studio Suite 2018. The results show that our antenna is radiating at five concurrent bands below sub 6 GHz frequency range covering from 2GHz to 6 GHz each having individual bandwidth above 260 MHz. The antenna is radiated at five different frequencies 2.4,3.0,3,7,4.5,5.6 GHz.

Further Improvements can be tuning for gain improvement , as we have for first four bands have less gain than fifth band and fifth band has more gain than all other band. The Bandwidth of each frequency is more than 260 MHz and adjacent band resilience is 180 MHz.

Tunability can achieved by adding DTC (Digital tunable Capacitors) to the slots, Independent tunability gives more command over the frequency range.

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