Optimized 4-Port MIMO Antenna Operation in Communication Technology

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***Abstract* - In communications data transition is accomplished by using antennas which are in much demand now a days with their wide spread applications in this experiment a MIMO antenna is introduced with 4-ports specific for 5G technology where MIMO stands for Multiple Input and Multiple Output its compact in size with 11mm × 31 mm with exemption of feed lines. There is diversity in pattern of antenna which is observed by the radiation patterns in the azimuthal plane, and by assigning cells of metamaterial unit array an gain can be obtained of about 10dBi.we have less than λ0/5.5 separation between edge to edge and isolation antenna elements in 38 GHz frequency range and is enhanced by ground stub in the antennas and by trimming the high refractive index rectangular metamaterial corners. The loss in the antenna which is return loss will be in every antenna is about Snn < −10 dB with isolation, Snm > 28 dB which is proposed antenna operation in the range of frequency 28 GHz to 38 GHz, that shows this MIMO antenna is best efficient for 5G communication with high potential for many applications. For simulating the results for efficient operation we use CST Microwave tool in this experiment.**

***keywords* - metamaterial, decibals, MIMO, 5G, Azimuthal plane.**

INTRODUCTION

4G frequency bands is limited to few GHz ranges in which traffic is very heavy due to increased usage of smart electronic devices. Whereas this 5G has much high frequency range of 24 to 90 GHz which if we utilize efficiently then signal trafficking problem will be reduced which can provide high bandwidth. 5G has emerged for next communication generation which has low rate of absorption of oxygen. [1] Antennas may have better radiation performance due to these technologies which we observe in this experiment. Antennas which we use are MIMO antennas that have Multiple Input and Multiple Output capability due to which signal loss can be reduced. For transferring data of high rates this MIMO mmWave technology is required promisingly that gives virtual reality services. By fixing one range we find the issues like interference and high path loss, here we proposed a capability of beam forming antennas with high gain [2]. Different 5G application antennas are presented in this experiment. [3–9]. In [10], with a good ability of isolation of about 20dB a MIMO antenna named as Ka-band antenna is presented which has a gain of 9.5–11 dBi in the range of frequency from 28 to 38 GHz in between the ports, in the border this antennas space of occupation is quite heavy of about 33.4mm × 39.8 mm) [11], by having 2 antennas only per area of 41 mm × 85 mm on substrate of 20 mil Rogers substrate by having range of 28-38 GHz using corrugation of metasurface for getting isolation between 2 antipodal antennas of tapered slot which is Fermi-based that is more than 38dB obtained by author and antenna of MIMO type of four-port at 34 GHz range is presented in [12]. We use 4 resonant antennas of dielectric type also said as dielectric resonant antennas (DRA) for have 10dBi gain by micro strip lines feeding to DRA that gives losses at frequencies of mmWave in results.

The major structure of MIMO antenna structure has mutual coupling due to which network performance can be determined as enhanced. For reducing the effect of coupling between antennas we presented a band-gap structure which is of electromagnetic type [13], [14], for suppressing the 2 monopole antennas coupling a metamaterial of single-negative magnetic is introduced. Anyhow for end-fire antennas the techniques we are using are not suitable. However this has overcome by using capacitive loaded loops in array then we have 10 dB isolation between monopole antennas. An MIMO antenna of optimized range in mmWave is introduced and array of CLL with high refractive index is loaded to every dipole antenna 2 purposes are served by array of CLL unit cell loading:

- The CCL array works as region of high refractive index. So, about 10 dBi gain is enhanced by array of CCL unit cell integration with the dipole antennas.
- Mutual coupling among dipole antennas of spaced closely gives defects (trimming) in array of metamaterial cells with high refractive index of about 11 dB at 38 GHz. There is feasibility in antennas having the low mutual coupling with introducing good gain in applications of MIMO antennas of mmWave range.

MIMO ANTENNA

In this section we discuss about the MIMO antenna mmwave design for two and four elements application. For the mmwave range signal we have 2 main design processes to address:

- For high attenuating signal gain is enhanced.
- It is essential to have enhancement of antenna elements isolation for spatial multiplexing.

In this section better throughput is obtained for network of communication by having dipole antenna of 2 elements configuration for enhanced isolation, later forming MIMO antenna of 4 elements translation. With dielectric constant we design a substrate to have a configuration of 2 element antenna. And the parameters of this antenna are height is of 10 mille meters, loss tangent is of 0.0009 with $\varepsilon_r = 2.2$. we feed this design of half wave dipole antenna to line of microstrip of width is equal to 0.77 and a gain of 6dB at 38 GHz frequency range in CST microwave tool, which is not essential for mmwave range frequency band communication. Obtaining a maximum gain through antenna we design is very typical, but it's very easy from Yagi-uda antennas to obtain high gain because of they are popular end-fire antennas. It's obvious that size increases if we want high gain that requires 6-7 dipoles to be placed in dipole antenna. So, for enhancing the dipole antenna gain without size increase, we use CLLs in array. As given in figure .1 we extract the cells of CLL unit from S-parameter when [17] Perfect Magnetic Conductor and Perfect electric Conductor extracted from X and z directions of boundary conditions. CLL cells array goes on increasing the substrates refractive index of about 42 percent, and then we observe the electric field focusing. For fulfilling the loss at 38 GHz frequency range we increase the gain of every dipole antenna to 10 dBi. By loading the metamaterial in the antenna we enhance the gain operation which reaches to 12 dBi for dipole antenna.

As shown in figure 2 the array of metamaterial unit cells carrying by our proposed antenna with configuration of MIMO antenna we feed 2 element dipole antennas to the metamaterial unit cell. Each antenna is placed at equidian distance of 1.9mm, due to surface waves we have mutual coupling of ports which is affected by including the resonance in ground plane by having 2 antennas addition with stub, then current across the stub is obtained [19], which gives the isolation of ports enhancement. As shown in figure.3 for different length values of stub in antennas we isolate them with a length of stub $l_{sb} = 1.8$ mm, which is $\lambda/4$ at 28 GHz,

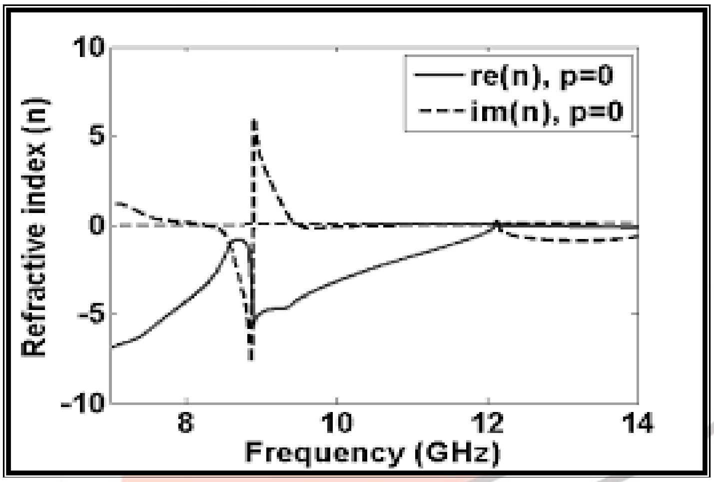


Figure.1: Refractive Index

As we obtain these different refraction of above figure both positive and negative due to metamaterial we used. Extracted real part (re) and imaginary part (im) of refractive index (N), effective permittivity (eps) and permeability (mu) from S-parameters.

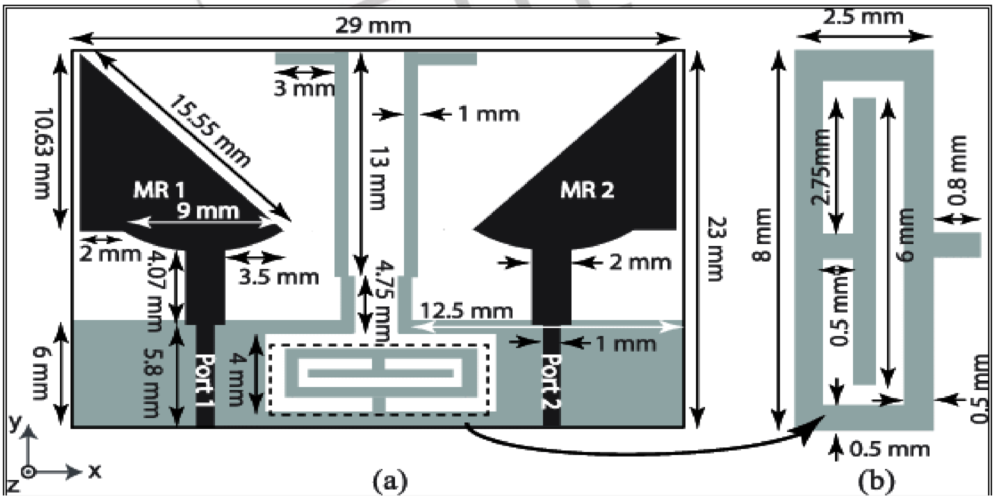
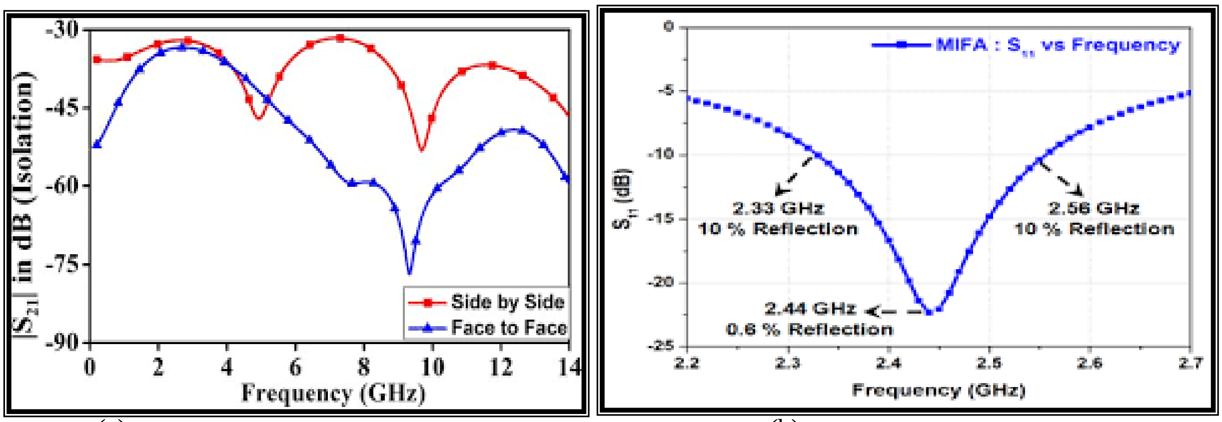


Figure.2: MIMO antenna

This figure resembles the Geometry of two element MIMO antenna with array of unit cells. Zoomed view of dipole and unit cell along with Case-I: without trimming as in figure. a and Case-II: with trimming of corners as in figure. b. Where the dimensions of this antenna varies as $S_{cc} = 5.8$, $S_{dd} = 1.9$, $w_i = 0.77$, $h_e = 10.7$, $l_d = 4.7$, $w_d = 0.5$, $w_{sb} = 0.2$, $l_{sb} = 1.8$, $u_t = 0.2$, $s_{du} = 1.2$, $u_x = 1.4$, $u_y = 0.8$, all dimensions in millimeters.



(a) (b)

Figure. 3: Isolation between dipole antennas (a) as a function of stub length (l_{sb}), (b) without corner trimming

As per the cases given above case I, II which is for with and without corner trimming by removing the cells of CLL unit individually. By adding a stub to the ground we can increase the isolation at 38GHz frequency range from 18dB to 24dB. Using CLL array we propagate mutual coupling operation to adjacent antennas due to spatial field's components. Depending on the H-field coupling ports are coupled to get high region of refraction for exiting the right array by left refraction only when first port is fed then through the antenna CLL array it propagates back towards dipole antenna. By removing the CLL cell we investigate the effectiveness and parametric analysis is done of trimming the CLL array. As shown in above figure the antenna isolation is given in 2 cases as case I, II which says about with and without trimming operation and with CLL-1,2 & 3 removal as given in figure-3 (b), that shows 5 dB improvement in 38 GHz frequency range WITH 18-24dB isolation and the total isolation is more than 30 dB in band of frequency as for second case. Whereas the Figure.4 gives by chopping or trimming off the corners of current displacement on left and right of regions with high refractive index the isolation is basically improved. When there is no trimming of corners then current coupling is done from array of CLL if port one is fed in case-I.

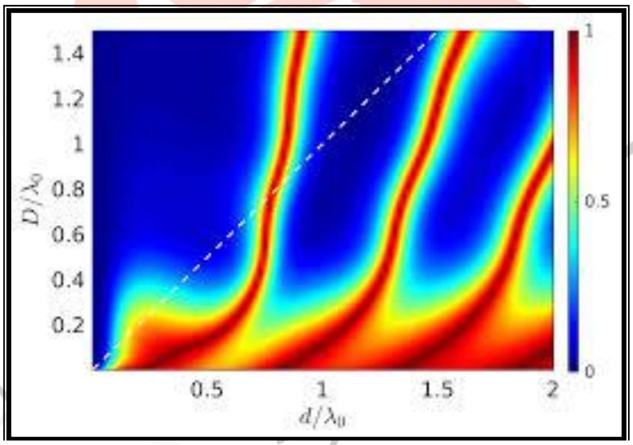


Figure. 4: H-field in X-Y plane

The mutual coupling when antennas port 1 directly fed to 38 GHz frequency range in both the cases as case-I, II. The snapshot of X-Y depicted plane field-H.

MIMO 4- ELEMENT ANTENNA

In figure shown below the four ports configarated MIMO antenna is given where these antennas are fabricated on Neltec substrate of 10 millimeters. In both the directions we separate these dipole antennas with distance of 6mm on X and 2.2 mm on Y- direction. For covering a space of $1.05\lambda_{0@28\,GHz}\times2.9\lambda_{0@28\,GHz}$ the gain is enhanced by loading metamaterial of all the four antennas without feeding to the substrate, for accommodating the end-launch connectors we extend the feed lines. Along the Y-direction the dipole antenna radiates by feeding micro strip line of 50 ohms to every antenna element. Our antenna is fed depending on the array of metamaterial cells in various directions which is focused by Electric field.

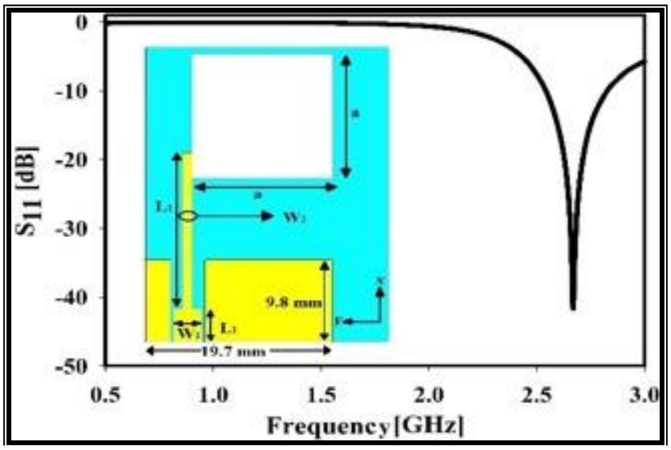
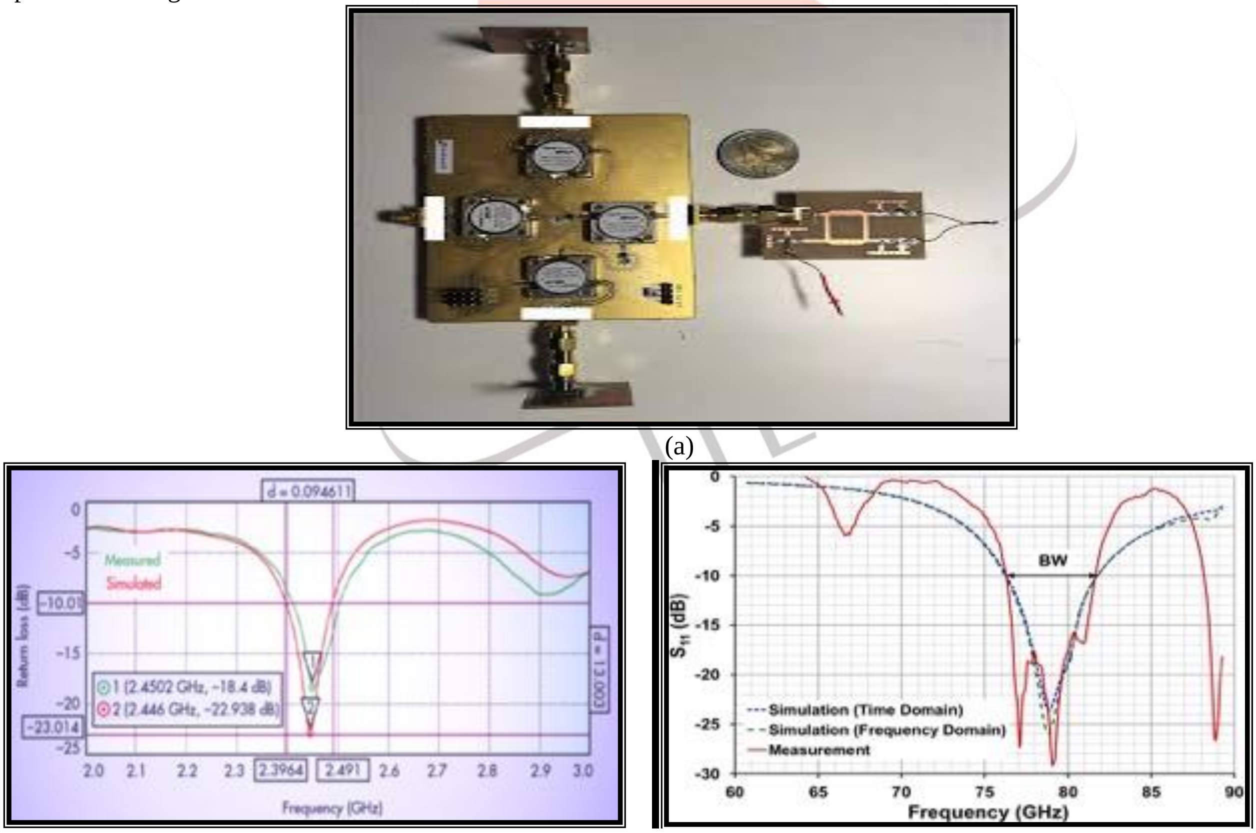


Figure. 5: Proposed antenna

The above figure gives the geometrical configuration of MIMO antenna with four port elements MIMO. With different parameters as illustrated with dimensions W = 31, L = 48, w_l = 10.4, h_e = 10.7, h_g = 6.2, S_{hd} = 2.2.

RESULTS

Using the lithography process of fabrication in-house we have an antenna of 4 port applications in 38 GHz frequency range. As shown in figure-6 below to which we measure the prototype antennas port performance from S-W Microwave, Inc. with 2.92 mm End Launch Connectors by utilizing Key sight PNA in the lab. In the setup given below that we have a facility in our centre for characterizing the antennas radiation performance in a anechoic chamber of far-field type. So, we analyze the spectral performance of both measured and predicted values. For every port of antenna with 28 to 38 GHz frequency range the return loss is less of about -10dB which can be compensated which is shown in figure below. Figure 6 (c) gives the isolation operation among antenna elements.



(a)

(b) (c)

Figure. 6: antenna performance (a) setup of antenna (b) loss measurement (c) Isolation

Efficiency of every individual element is enhanced which is resulting by greater isolation among the ports of MIMO antenna of 38 GHz frequency range which is an important parameter, and because of coupling we have a reduction in power loss of antennas. High diversity in these antennas is main advantage because of high isolation of independence between antennas. For MIMO antenna applications obtained isolation of more than 25dB is enough for 38 GHz frequency range with in short space. For 4 port antenna of MIMO type using the frequency range of 38 GHz for which the pattern of radiation when we terminate other ports in both X-plane and Y-plane with 50 ohm is given in figure-7.

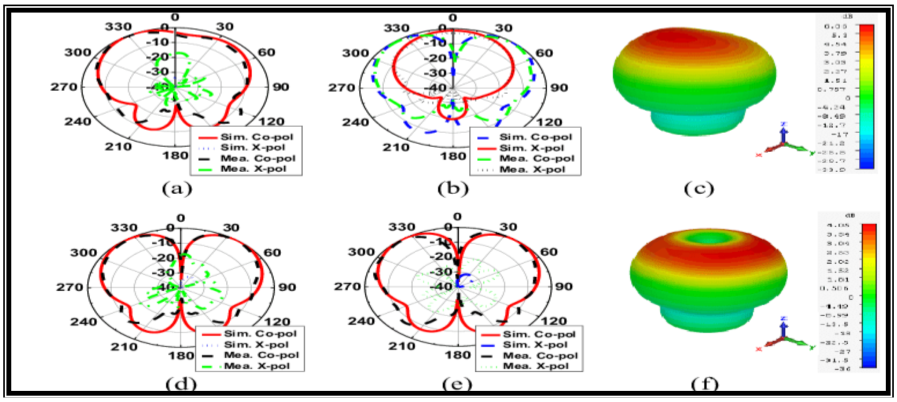


Figure.7: simulated radiation pattern

Above figure shows the gain pattern of simulation in X, Y-planes with 38GHz frequency range of 4- port antenna when we excite at 4 different ports of MIMO antenna type with 38 GHz frequency range shows gain of pattern diversity and we have stable patterns surrounding the band. Only one measured antenna gain is plotted in figure.8 shown below because all the four antennas are having the same gain for that band of frequency. So, 10dB gain from the array of CLL dipole antenna is true in the frequency band as shown in figure.

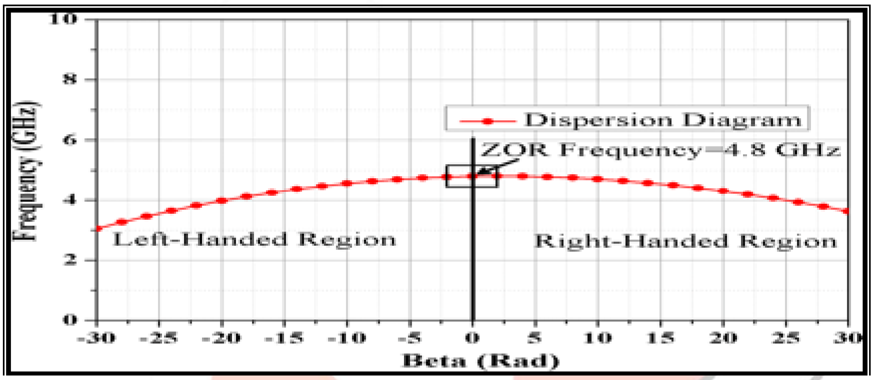


Figure.8: antenna gain plot

By using the envelop coefficient correlation parameter we evaluate the antenna performance such as its isolation, gain etc. in MIMO type antennas represented by ECC or ρ_e, that shows the multi antenna diversity gain system [20] and that values of diversity gain obtained are high even if values of ρ_e, are less that enhances the system performance. As shown in figure.7 the plot is drawn between 1 and 2 (ρ_{e12}) elements and 1 and 4 (ρ_{e14}) elements of antenna for plotting ECC. For calculating the values of ECC by utilizing the results of far-field in CST Micro Wave environment which is less than 15×10^{-4} within the whole band of frequency we characterize the proposed antenna. As shown in table.1 given below we compare the obtained output performance with previous and existing techniques. The distance is very small between edge to edge distance and antenna elements range of ($\lambda_0/6$) which is genuine and acceptable isolation of ports. As per the technology we countered our proposed antenna with 4-ports and without feed lines are smaller than any other MIMO type antenna at 38 GHz frequency band.

Table.1: different works comparison

λ_0 = wavelength of free space

Ref.	Dielectric resonator based MIMO antenna	quasi Yagi-Uda antennas	2 –port antenna	4- port antenna
Total size (mm^2)	48×21	NA	42×85	48×31
Operating band (GHz)	29.7–31.5	31–40.3	27–32	28-38
Min Isolation (dB)	25	21	37.1	21
Peak gain (dBi)	8.6	11	17.9	10
Edge to edge spacing (λ_0)	λ_0/3.6	λ_0/1.27	N/A	λ_0/6
Number of ports	2	4	2	4

CONCLUSION

At 38 GHz frequency range which is of millimeter-wave radiation antenna range that having four elements is introduced for MIMO dipole antenna based application. Pattern diversity is observed in both X-direction and Y-directions. Diversity in pattern of the four port antenna in both planes of X, Y where every antenna is individually offering the same amount of gain that is equal to 10dBi. Sizes of these 4 antennas are also same of about $3\lambda_{20}$, where λ_0 is wavelength of free space in 38 GHz frequency range in fabrication of lithography process on substrate for having a efficient isolation among antennas without feeds. So, these integrated size antennas are very suitable for 5G technology in a compact handheld device communication with some MIMO antenna applications.

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