Enhanced Franklin Antenna for the Future 5G Communication Applications

Ch. Vanaja, N. Pavithra, N. Sravya, M.Manoj, Yuvraj B. Dhanade

Abstract*: A compact antenna which can operate in the 5G communication is presented in this paper. The antenna has been designed by doing the geometrical modifications in the concept of collinear arrays at millimeter wave (MMW) band. This antenna is an extension of the standard narrowband Franklin antenna in a compact 2-D model. The proposed antenna resonates at 25.2 GHz and achieves the bandwidth of approximately 5.5 GHz over the band of 22-27.5 GHz which is one of the bands used in 5G wireless networks recommended by US Federal Communications Commission. In order to achieve the desired band the DGS ground plane has been used. This antenna provides a uniform gain over the bandwidth and achieves a highest gain of 13.3 dB. The performance of an antenna has been examined by simulation of various results like reflection coefficient, VSWR, gain, BW, radiation pattern; impedance plot etc. This antenna can be used in the future 5G communication applications.

***Index Terms*: Bandwidth, Collinear, fifth generation (5G), Franklin, gain,.**

I. INTRODUCTION

Mobile communications has undergone many successful technological innovations over the several generations. As the technology grows the new applications are produced with more capacity and higher speeds of data needed to be transferred, this also paved way to increase in the number of users. As the number of users have increased the most of the bandwidth is being used up due to this the problem of bandwidth scarcity arises. 5G (Fifth generation) in communication through mobile networks provides a solution for the bandwidth scarcity as the number of wireless devices has been increased to meet the demands of the increasing mobile applications [1], [2].

There should be another choice as it is important to introduce other bands of frequency to continue the ongoing upgrades in the wireless mobile communications. The unused millimetre-wave (MMW) range has attracted enormous consideration understanding the previously mentioned 5G vision, and is fit for encouraging the advancements in wireless mobile communications. The MMW structure will support 5G channels for higher data speeds, lower structural cost, higher capacity and many more as the bandwidth is increased [3]. There is another advantage of the MMW's shorter wavelengths is that the reduced size helps us in installation of many number of patches in a smaller (compact) handset to increase the overall gain performance [4]. These MMWs can be installed for short-range steps, but there are a number of limitations and challenges which are a trouble for the long-ranged outdoor setups [5]. Limitations such as propagation losses, rain fades, high attenuation levels, and much atmospheric absorption should be considered while using MMWs. To overcome these difficulties, many innovative models are proposed after a thorough research recommending the usage of high-gain antennas in denser cells to reduce the propagation losses and frequency reuse [6].The licensed bands such as 24, 28, 37 and 39 GHz and an unlicensed range of bands from 64-71 GHz have been allocated for the 5G networks by the U.S. Federal Communications Commission (FCC) [7]. The 5G wireless systems should work efficiently by having a high gain with capability to serve much number of users and should have low energy consumption. Franklin CoA principle is also one among the innovative models which propagate high gain and larger bandwidth. In this principle in the stubs the current is in out of phase and get cancelled and there is only one major radiating beam [8]. This principle is also used in the antenna models having large length of radiating wires which were folded in the form of pulses by using this Franklin CoA principle so that the dimensions of the antenna can be reduced. The main advantages of this model are high gain with the properties of antenna array, single feeding point is maintained [9].In this work, in order to achieve desired frequency band the current patch length must be increased to acquire resonating frequency of 25.2GHz as we have achieved a frequency band of 33-36 GHz with full ground. In order to achieve a desired band, modifications were done in the ground plane by partitioning the ground with spaces less than the thickness of the substrate and can be termed as DGS (Defected Ground Structure)[10].

Thus the ground plane acts like parasitic patches and radiates. Thus the frequency bands are shifted to the lower frequencies.

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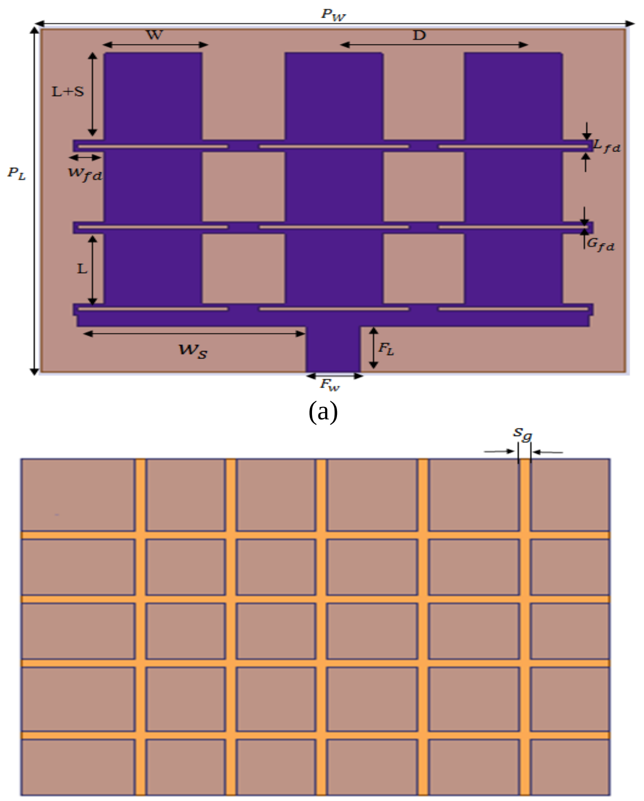
II. ANTENNA DESIGN



(b)

Fig 1:Proposed Franklin 5G antenna (a) Simulated prototype with the optimized dimensions (b) DGS of Simulated prototype

In this work a MMW array antenna which is based on enhanced Franklin array concept is presented. Antenna feeding is done from a single point through micro strip line along with the stub of optimized dimensions. HFSS software is used for antenna modeling and numerical evaluations.

The antenna is designed on the substrate of 21×26 mm^2 consisting FR4 material ($\boldsymbol{\varepsilon}_r$=4.4, loss tangent=0.02, thickness=0.8mm) has been used as a substrate material provided with metallic ground at the bottom K-connector with 50Ω matched impedance.

TABLE I
OPTIMIZED DIMENSIONS OF THE PROPOSED MMW ANTENNA ARRAY

Symbol	Parameters	(mm)
L	Length of patch	4.3
W	Width of patch	4.34
S	Extended length of terminating patches	1
D	Distance between centers of 2 parallel patches	8
L_{fd}	folded Length of dipole	1.4
W_{fd}	Width of folded dipole	0.7
W_S	Width of matching stub	10.15
F_L	Length of feed	2.8
G_{fd}	Gap of folded dipole	0.26
P_W	Length of array prototype	21
P_L	Width of array prototype	26
S_g	Spaces in the ground	0.5
F_w	Width of the feed	2.4

The design of the antenna is initiated by the basic model (i.e without DGS implementation). This basic model containing array of three units each unit is a combination of stub and patch this antenna radiates at 33GHz-36GHz and has a gain of 5.5dB by the use of FR-4 substrate. In order to reduce the resonating frequency band and to increase the gain the parametric analysis is done and from that it is observed that by increasing length of the patch the bandwidth and gain can be increased and frequency can be reduced but even by increasing length of patch by increasing S value the resonating frequency is not shifted to the desired band for 5G networking. So, in order to achieve the resonating frequency of 25.2 GHz modifications were done in the ground by using DGS method.

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In this method the ground is partitioned into small squares these squares act as parasitic patches and radiates along with the original patch by receiving the power from fringing fields from the top of the substrate. In this method the spaces in between ground must be less than the thickness of substrate in order to acquire proper coupling between the parametric patches.So as the thickness of the substrate is 0.8mm the spaces in between the ground are 0.5mm.

III. RESULTS AND DISCUSSION

The performance of this design is verified by the measurement of the reflection coefficient, radiation pattern and realized gain, Voltage Standard Wave Ratio (VSWR), Impedance Matching, Current distribution. In order to simulate the properties of the proposed antenna model ANSOFT High Frequency Structure Simulator (HFSS) has been used. The simulated results are well matched with desired results. The proposed antenna design has achieved a good bandwidth and gain, as explained below.

A. Reflection Coefficient

Simulated result for reflection coefficient is shown in fig2. It can be observed from the plot that the proposed antenna is resonating at 25.2GHz with good reflection coefficient magnitude of -45.14dB which indicates very less reflection losses. From the fig.2 it can be also observed that the minimum reflection coefficient (i.e. -10dB) is observed between a frequency band of 22GHz to 27.4GHz. Thus the bandwidth of approximately 5.4 GHz has been achieved.

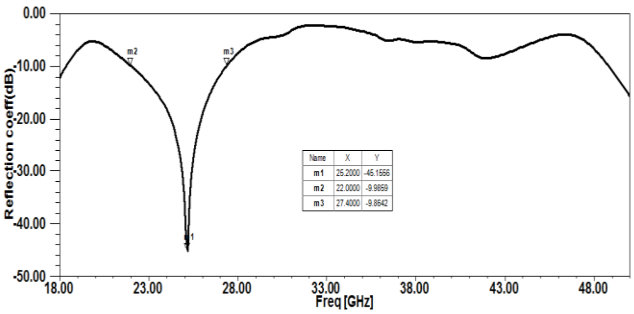

Fig 2: Plot for the Reflection coefficient of the proposed antenna

B. Voltage Standing Wave Ratio

VSWR describes the voltage standing wave ratio of the antenna. The simulated result of VSWR is shown in Fig 3. VSWR less than 2 (i.e. Γ=1/3) has been observed over the frequency band of 22 to 27.4 GHz, which is the same range of frequencies observed by the reflection coefficient plot. Thus over this range the proposed antenna is providing a good impedance matching and very less impedance mismatch losses .

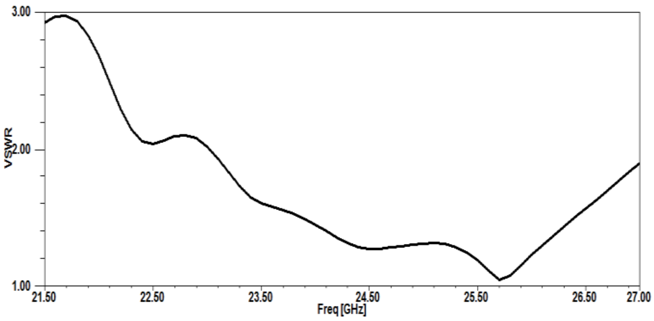

Fig 3: Simulated result for VSWR

C. Impedance Matching

The simulated result for the impedance matching with the feed for maximum power transfer can be observed by using z parameter is shown in Fig 4. At the required bandwidth (22GHz -27.4GHz) the impedance is approximately equal to 50Ω as observed in fig.4. Thus the impedance of an antenna is perfectly matched with feed used.

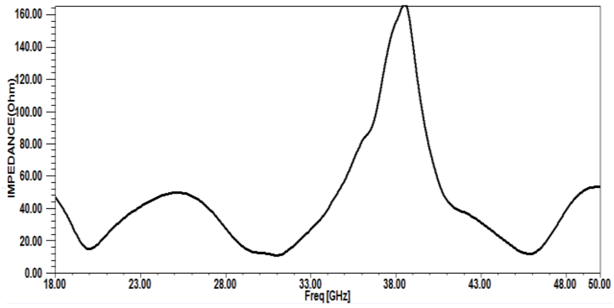

Fig 4: Simulated result for impedance matching Z parameter

D. Radiation pattern

The simulated radiation pattern at the resonant frequency 25.2GHz of this proposed antenna is shown in Fig 5.The co-polarization and cross-polarization for both realized gain Theta and Phi are shown in the Fig 5. It is observed that the co-polarisation is slightly greater than the cross-polarization. Hence we can conclude that the antenna is having better transmission and reception efficiency.

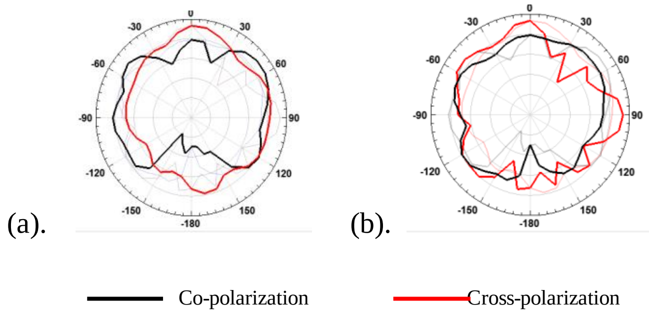

Fig 5: Simulated radiation pattern at 25.2 GHz (a) Realized gain Phi (b) Realized gain Theta

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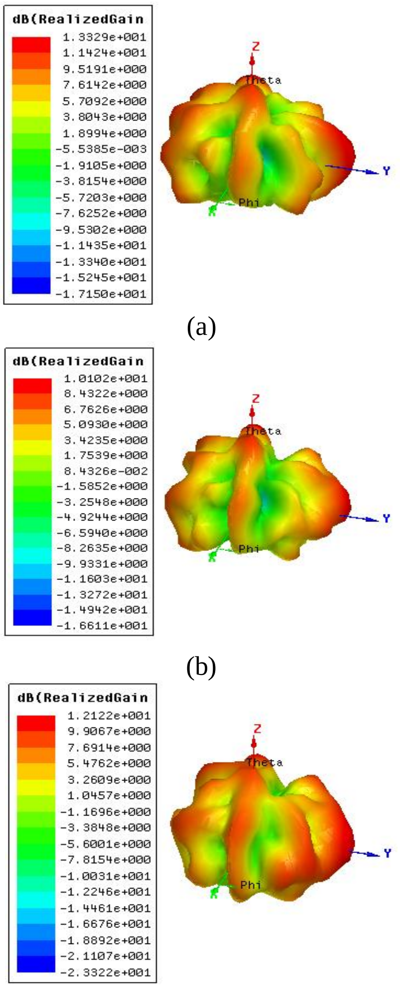
E.Gain of Antenna

The simulated result for the realized Gain at 22 GHz, 25.2GHz and 27.4GHz frequencies is shown in Fig 6. Uniform gain over the bandwidth is observed. Maximum Gain of 13.3dB is observed at the frequency of 22GHz. The gain of 10.1dB and 12.1dB is observed at the frequencies of 25.2GHz and 27.4GHz respectively. The gain can be further increased by increasing the number of antenna elements (i.e. array).



(a)

(b)

(c)

Fig 6: Realized gain pattern at (a) at 22 GHz (b) at 25.2 GHz(c) at 27.4 GHz

F. Surface Current Distribution

The simulated result for the current distribution on patch and ground at frequencies 22 GHz, 25.2GHz and 27.4GHz is shown in fig 7. It is observed that with increase in the frequency there is a decrease in surface current path on patch and ground.

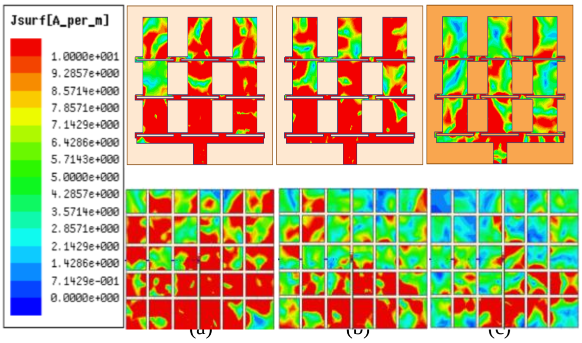


Fig 7: Surface Current distribution on patch and ground (a)at 22GHz (b)at 25.2GHz (c)at 27.4GHz

IV. CONCLUSION AND FUTURE SCOPE

In this article, a novel and compact antenna using Franklin CoA method has been presented and investigated aiming to operate at 22GHz – 27.4GHz MMW frequency band. As Franklin antenna standard theory suggests a high gain this proposed antenna model also provides maximum gain of 13.3dB and bandwidth of 5.4GHz. It is also observed that the antenna is having a uniform gain over the bandwidth. The proposed antenna is designed by using a low cost FR-4 substrate, which reduces the cost of an antenna. The designed antenna is compact in size and thus can be easily mounted in the desired circuit. The antenna can be used in the future MMW 5G wireless communication.

The gain of the antenna can be further increased by making an array in order to use it for the comparatively long distance communication. In order to make the antenna mounting process easy the antenna can be made conformal. In order to increase BW further, the antenna can be designed by using a substrate having less ε_r or (ε_r=1).

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