# Slot Antenna Design for 5G Mobile Networks

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***Abstract*—This paper presents the design of broadband microstrip antenna for wireless communication applications. The antenna structure is based on the microstrip line combined with a slot technique and a modified geometry antenna in order to enlarge the bandwidth and adapting the impedance thus minimizing distortion in order to avoid high crosstalk and radiation. The proposed antennas have been successfully designed, optimized, miniaturized and simulated by using Momentum software integrated into ADS "Advanced Design System" and CADFEKO. The final broadband antennas are operating in 8.5GHz on ADS and 8.9 GHz on FEKO respectively with a return loss less than -10dB.**

***Keywords— Component; Microstrip Antennas ,Rectangular patch ,Millimeter Wave ,Slot Antenna***

## I. INTRODUCTION

The emerging 5G technology is demanding antennas with features previously unseen on a user terminal, such as the beamforming capability of the radiation pattern to perform spatial scanning [1-2]. This requirement raises numerous design challenges to achieve a reasonable trade-off between technological design issues and commercial criteria – low cost, small size, radiation efficiency , antenna gain, broadband performance, and so on – mainly at millimetric wave bands [1-3].

On the other hand, with huge bandwidth in the millimeter wave (mmWave) band from 6 GHz to 100 GHz, millimeter wave (mmWave) communications have been proposed to be an important part of the 5G mobile network to provide multi-gigabit communication services such as high definition television (HDTV) and ultra-high definition video (UHDV) [4-5].

Many research studies have come up with techniques to achieve wideband operation for printed antennas [6-7] and microstrip antennas are extremely compatible to other radio frequency microwave integrated circuit in manufacturing and low coupling affect in installation [8-9].

Combination of the microstrip line, antenna geometry, and a variety of slot shapes is a solution to improve, enlarge the antenna operating bandwidth and adapting the input impedance [10-11]. In this paper, a new low cost broadband microstrip antenna is designed by using slot techniques and it is simulated by using FEKO Simulator and ADS to obtain the expected frequency band with suitable technical specifications.

## II. ANTENNA CONCEPTION

### A. *Design Procedures*

Using a procedure for designing a rectangular patch antenna given by [Luxey] [12]. This can be used for a first sizing. The optimization can then be carried out using an electromagnetic simulator.

The input data are: the substrate (electrical permittivity, tangent of losses, thickness), the frequency of operation. Consider a plane of perfect and infinite mass we have the following equations:

$$W = \frac{\delta}{2}\sqrt{\frac{2}{1+\varepsilon_r}} \qquad (1)$$

With:

$$\delta = \frac{c}{f_r}$$

$c$ : Speed of light

$f_r$ : Resonant frequency

$W$ : Patch Width

$\varepsilon_r$ : Relative permittivity

$$h \le \frac{0.3 * c}{2\pi * f_r * \sqrt{\varepsilon_r + 1}} \qquad (2)$$

With:

$h$ : Maximum height

$$\Delta L = h * 0.412 * \frac{(\varepsilon_{ref} + 0.3) * \left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{ref} - 0.258) * \left(\frac{W}{h} + 0.8\right)} \qquad (3)$$

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With:

$\Delta L$ : Extending the Patch Length

$$\varepsilon_{ref} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} . \left[ 1 + 12 . \frac{h}{W} \right]^{-\frac{1}{2}} \quad (4)$$

$$L_{eff} = \frac{\delta}{2\sqrt{\varepsilon_{eff}}} = \frac{c}{2.f_r.\sqrt{\varepsilon_{eff}}} \quad (5)$$

With:

$L_{eff}$ : Effective patch length

$\varepsilon_{ref}$ : Reference permittivity

$\varepsilon_{eff}$ : Effective permittivity

$$L = L_{eff} - 2\Delta L \quad (6)$$

With:
$L$ : Physical Patch Length

$$L_g = L + \frac{c}{20.f_r} \; , \quad W_g = W + \frac{c}{20.f_r} \quad (7)$$

With:

$L_g$ : Ground length

$W_g$ : Ground width

The position of the power is given by the equation (8)

$$X_F = \frac{L}{2\sqrt{\varepsilon_{ref}}} \; , \quad Y_F = \frac{W}{2} \quad (8)$$

The antenna structure designed is based on a microstrip line, with the use of slot techniques, taken into consideration the gain and directivity. The purpose of the slot was to control the radiation pattern in order to obtain an increased bandwidth.
The geometry of the proposed antenna is shown in "Fig. 1". It is simulated by using FR4 epoxy substrate with relative permittivity $\varepsilon_r$ =4.4, thickness of h=1.6 mm, and total area of 4x26 $mm^2$. The microstrip antenna is excited with 50Ω characteristic impedance.

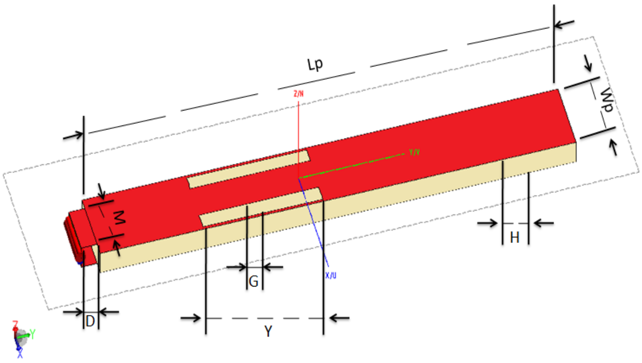



Fig.1 The Geometry of the proposed antenna

*B. Simulation and Comparison*

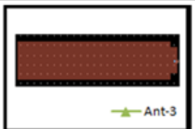
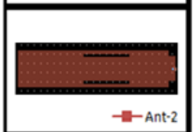
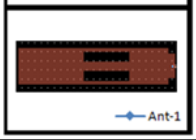
The dimensions of the antenna are optimized and miniaturized by using ADS" Advanced Design System" and FEKO. Based on the theoretical parameters and after many optimizations, the dimensions of the final structure are shown in "Table.I".

Table.I: Antenna dimensions in (mm)

| Variables | Value |
|---|---|
| Lp | 26 |
| Wp | 4 |
| G | 1 |
| H | 1.6 |
| Y | 7.5 |
| M | 2.7 |
| D | 1 |

The return loss and bandwith improvement for successive slots geometry "Table.II" by using the optimization and miniaturization techniques integrated into ADS are presented in "Fig. 2". The final circuit is operating in a large frequency band between 5.7 GHz and 10.7 GHz

Table.II: Slot dimensions in (mm)

| Antenna | Slot Value "G" |
|---|---|
|   | 0 mm |
|   | 0.3 mm |
|   | 1 mm |

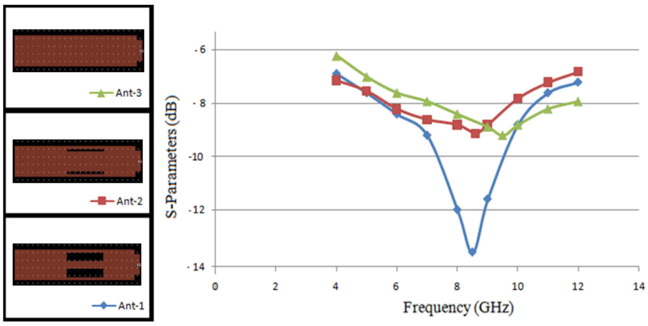



Fig.2 The Return loss Vs frequency"ADS results"

As shown in "Fig. 3" the antenna validated into ADS simulation has a bandwidth from 5.7 GHz to 10.7 GHz and $f_r$ =8.5 GHz .for the comparison of these results we kept the same antenna geometry and we have conducted another simulation by FEKO ,we found that the bandwidth is from 8.85 GHz to 8.98 GHz and $f_r$ =8.9 GHz.

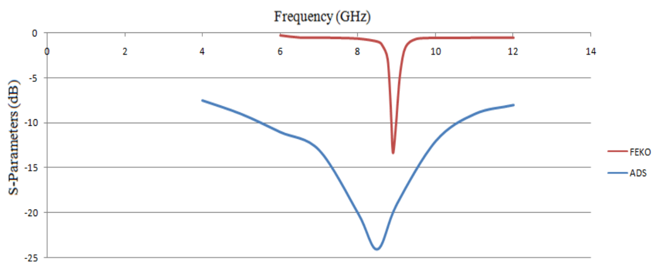



Fig.3 The return loss versus frequency.

The behavior of the phase of reflection coefficient S11 versus frequency is also studied and shown in "Fig. 4". It can be noticed that the phase seems to be linear across the UB frequency range.

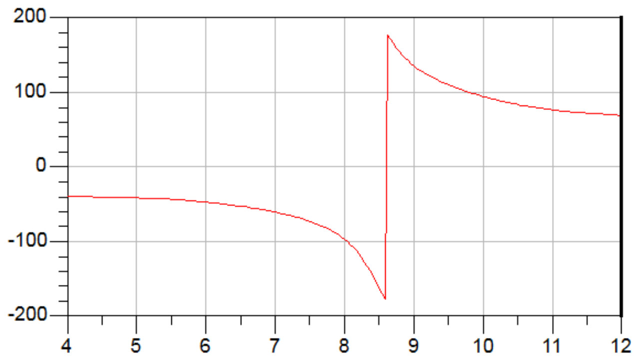


Fig.4 The phase versus frequency in GHz.

The simulated radiation pattern of the antenna at 8.9GH is illustrated in "Fig. 5".

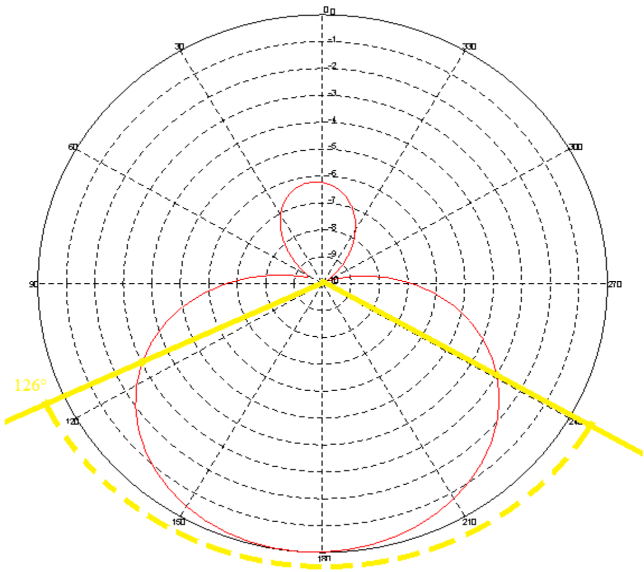



Fig.5 The Radiation pattern at 8.9 GHz

According to the representation of the radiation pattern, the angle of opening of this antenna is 126 °, which is beneficial for a base station for maximum coverage during the mobility of the subscriber. In our case, we took the rear lobe as a reference which means that the rear / front ratio is 6.14 dB therefore good power transmission.

Based on the simulations results presented above we conclude that for a same antenna geometry we have nearly the same results as resonate frequency using ADS and FEKO with acceptable and reasonable bandwidth 130MHZ.

## III. CONCLUSION

In this study, we have performed the conception and the simulation of a new low cost rectangular planar antenna based on the theoretical equations and by using two high electromagnetic simulators FEKO and ADS to obtain the suitable 5G Antenna Geometry operating in 8.5GHz with a return loss less than -10dB. The simulation results obtained by the two simulators are in agreement which validate the proposed antenna structure.

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