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Improvement of bandwidth and gain of Yagi Array Microstrip Antenna using series and corporate feeding for 5G application

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Abstract— In this paper we present a new design a simple four-element Microstrip patch array antenna fed with corporate-series technique Feed Rectangular Patch Antenna with yagi element Array operated at 28GHz, for 5G mobile wireless applications have been designed and simulated. The proposed array contains 4-elements excited by one port, through a power divider. The array has a wide bandwidth from 27.29 to 29.30GHz and a high gain of 13.2dB the simulations are based using HFSS (High-Frequency Structure Simulator)

I. INTRODUCTION

As a result of scientific development and the requirements of human life, and due to the development of mobile phone users with applications that require high bandwidth, 5G technology comes. 5G technology achieves much higher data rates than 4G.

The utilization of mm-wave bands is one of the most important solutions in 5G [2]. It will allow the expansion of channel bandwidth and thereby increase data transmission capacity. One of the disadvantages of using millimeter-waves frequencies is the significant free space path loss due to high operating frequency [1], hence the need for an array antenna with high gain and wide bandwidth.

The spectrum available for the 5G, allocated by the Third Generation Partnership Project (3GPP), is separated into two different frequency ranges. Frequency Range 1 that includes frequency bands below 6GHz [5], Range 2 frequency bands above 24GHz and into the millimeter wave range (24GHz, 26GHz, 28GHz and 39GHz) [3].

For the antenna design, the Microstrip patch antenna is the most appreciated antenna in wireless communications because it's unique properties. As it is characterized by light weight and small size, and it can take several different shapes, including (rectangular, square, circular), and it is also economically characterized by its low cost during manufacturing, and it can make a series of antennas out of it, and it is easy to engrave and form on any printed electronic board.[7]

Millimeter waves are the future of wireless communications, but they have a few problems One of them is the significant free-space path loss caused by their high operating frequency [6] Millimeter waves are also susceptible to high propagation loss because of atmospheric absorption. Thus, the factor of

High propagation loss because of atmospheric absorption must be considered in the mm-waves antenna design [9]. However, the band of frequencies below 28 GHz is relatively less affected by atmospheric absorptions and has relatively less attenuations.

II. Array Antenna with Corporate-Series Feed

Among the existing feeding systems, the simplest feeding method for linear antenna arrays is the series feed. Because the feeding design is compact, space utilization can be enhanced and the line losses related to this type of array will be reduced compared to a corporate-fed array. Since the antenna input power must come from an extremity of the array, the principal limit of series fed arrays is the significant variation of the input impedance and the main beam direction. In the parallel or corporate feed, the benefits in this method are simplicity of design, flexible choice of element spacing and wider bandwidth since the antenna elements are powered by a "1 to n" power divider with the same line lengths between the feed point and each element. However, a linear array fed by the corporate method will occupy a much larger area, which will prevent it from being stacked to form a two-dimensional array. To limit the variation of the main beam direction and obtain better efficiency, the combination of parallel and series feeding techniques is used in this work [4].

In this technology, the matrix antenna and the Yagi elements are fed with an equal power of 50 ohms using a network in the form of a power divider T-Junction meaning that this technology combines the feeding of the matrix antenna using the sequential feed and corporate

The design was built on a substrate of Taconic RF-45 that has a dielectric constant (er) of 4.5 and loss tangent of 0.0037. The initial values of the dimensions of patch antennas are obtained by using the following equations [8] [10]:

The width of the antenna:

$$W_p = \frac{c}{2f}\sqrt{\frac{2}{\epsilon_{r+1}}} \qquad (1)$$

The length:

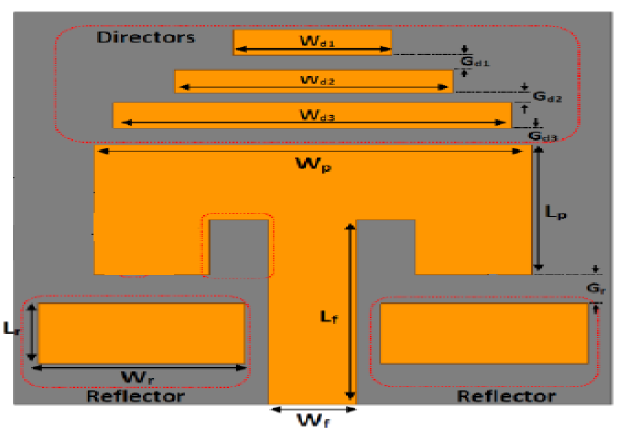
$$L_p = L_{eff} - 2\Delta L = \frac{C}{2F\sqrt{\epsilon_{eff}}} - 2\Delta L \qquad (2)$$

For $\frac{W}{h} > 1$:

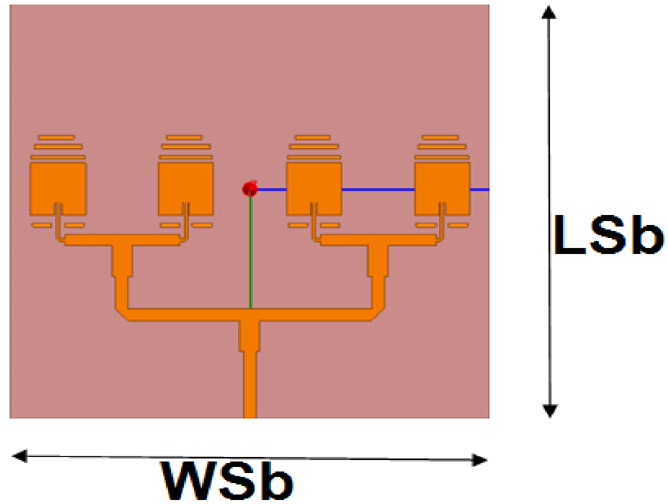
$$\epsilon_{eff} = \frac{\epsilon_r+1}{2} + \frac{\epsilon_r-1}{2}\left(1 + 12\frac{h}{w_p}\right) \qquad (3)$$

$$\frac{\Delta L}{h} = 0.412\frac{(\epsilon_{eff}+0.3)\left(\frac{wp}{h}+0.624\right)}{(\epsilon_{eff}-0.258)\left(\frac{wp}{h}+0.8\right)} \qquad (4)$$

- W_p and L_p: width and length of the patch antenna.
- c: speed of light.
- f: resonant frequency.
- h: thickness of the substrate.
- ϵ_r: dielectric constant of the substrate.
- DL: length extension.
- ϵ_{eff}: effective dielectric constant of the substrate.



(A)



(B)

Fig. 1.(A) (B) The proposed antenna array

TABLE 1 : ARRAY 'S PARAMETERS

component	parameters	mm
Substrate	Ls*Ws	16*15
Patch	Lp*Wp	5.3*11
Ground	Lg*Wg	16*15
Feed Line	Lf*Wf	7.55*2.2
Reflector Element	Lr*Wr	2.5*5.2
	Gr	1.2
Director Elements	Ld	1
	Gd1,Gd2,Gd3	0.6 , 0.4 , 0.7

Array Antenna with Corporate-Series Feed

The proposed corporate power divider is shown in Fig.1 (B). It is designed from Microstrip lines where the different impedance transformations are ensured by tapered lines. Each of the accesses is assumed to have an impedance of 50W. The two output ports (1 and 2) are therefore parallel in terms of the input port. It is, therefore, necessary to transform the impedance of the two outputs so that they have an equivalent impedance of 100W at the node. Indeed, tapered lines offer additional degrees of freedom allowing impedance transformation over a wide bandwidth. The use of the power divider to reduce the distance between patches in order to have a better directivity.[5]

$$Z = 50\Omega = \frac{120\pi}{\sqrt{\varepsilon_{eff}}\left[\frac{W_f}{h} + 1.393 + 0.667\ln\left(\frac{W_f}{h} + 1,444\right)\right]} \quad (5)$$

$$Z = 100\Omega = \frac{60}{\sqrt{\varepsilon_{eff}}}\ln\left[\frac{8h}{W_{100}} + \frac{W_{100}}{4h}\right] \quad (6)$$

Where:
The value of effective dielectric constant of the substrate (ϵ_{eff}) in (5) is the same value in (3). The value of ϵ_{eff} in (6) (W/h < 1) is:

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(\frac{1}{\sqrt{1 + 12\frac{h}{W}}} + 0.04\left(1 - \frac{w}{h}\right)^2\right) \quad (7)$$

III. SIMULATION RESULTS

The antenna array was simulated using the HFSS (High-Frequency Structure Simulator) program to obtain the following results:

A. Return loss

Fig.2 shows the S parameter of the proposed antenna array. The return loss at the resonant frequency 28.01GHz is –18.36 dB with a bandwidth of 2.02GHz taking as criteria S11≤-10dB to define bandwidth.

B.VSWR

The value of VSWR is 1.35 at the 28.01GHz resonant frequency and less than 2 for the rest of our bandwidth, this means that the antenna array presents an acceptable value of VSWR. The result is presented in Fig.3.

C. Gain and Radiation Pattern

The 3D radiation pattern is shown in Figure 4 (a) (b). The figure shows a gain of 13.9 dB for the resonant frequency. This high gain value fulfills the antenna requirements for 5G applications because it will compensate for the large free-space path loss due to millimeter wave propagation.

IV. Conclusion

Four-element patch antenna designs with feed chain and common feed techniques are presented in this paper. Moreover, the feeder technologies were combined to form a corporate chain feeder network, which was applied to the antenna design to propose a wide bandwidth array antenna and fire end radiation patterns. Moreover, Yagi elements have also been added to the designs to improve the overall antenna gain. Overall, the simulation results prove that the proposed Microstrip array antenna with the companies' series feed technology outperforms in terms of gain, size, and bandwidth. The proposed four-element antenna also covers most of the higher frequencies of 5G communications. The maximum achieved antenna gain was 9.49 dB and achieved a wide bandwidth between 25.15 and 30.87 GHz.

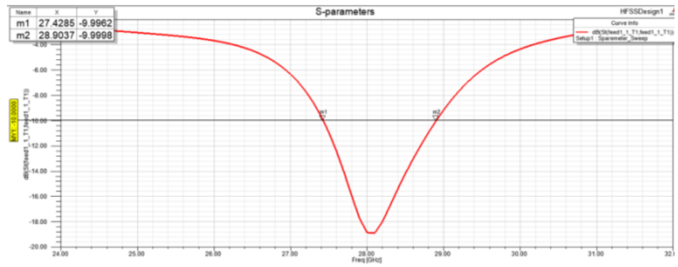
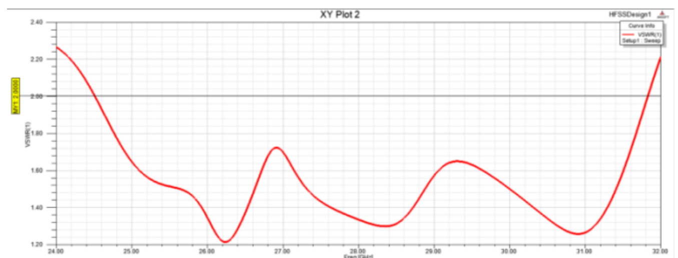
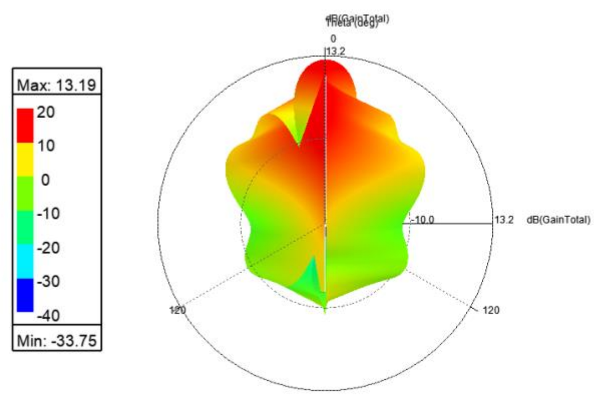


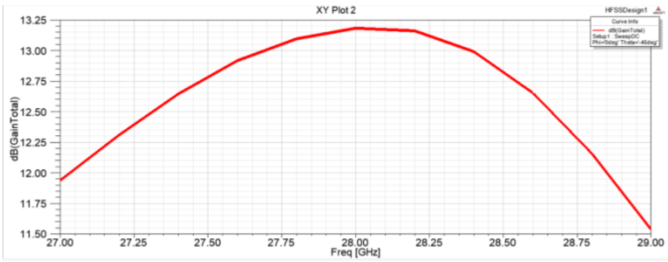
Fig (2) Return Loss



Fig(3) VSWR



a. Radiation pattern 3D



b. Gain VS Frequency

Fig 4 (a).(b) value of gain

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