Low-Profile and Wideband Dipole Antenna with Unidirectional Radiation Pattern for 5G

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Abstract: A low-profile wideband unidirectional dipole antenna is presented for the 5G operation. Parasitic strips are utilized for broadband impedance matching at a relatively small height of 4.9 mm (0.067λ₀, where λ₀ is the free-space wavelength at the center frequency). The measured results show that an impedance bandwidth of 55.4% is realized, ranged from 2.96 GHz to 5.23 GHz. The proposed antenna is with the merits of stable and symmetric unidirectional radiation patterns, low back-lobes and an average antenna gain of 7 dBi over the operating band, making it very promising for 5G system.

Keywords: Dipole antenna, radiation pattern, wideband, low-profile, 5G

Classification: Microwave and millimeter wave devices, circuits, and systems

References


1 Introduction

Recently, the fifth generation (5G) mobile communication system has attracted great attentions and commercial networks are expected to be deployed in 2020. Compared with 2G and 3G [1], different bands between 3 GHz and 5 GHz have been considered for first trials in many countries [2]. To accommodate the frequency requirements of all the countries, an universal and wideband antenna for 5G base station are desired.

As a good candidate, the dipole has been studied for years due to its favorable features of symmetrical radiation patterns and wideband performance [3, 4, 5, 6, 7]. In order to cover the frequency band from 3 GHz to 5 GHz, the antenna should achieve a relative bandwidth of ~50%. Although there are some wideband designs in literatures [5, 6, 7], they have a relatively large profile of more than 0.1λo. For cost reduction and environmental friendliness, a low-profile antenna is much preferred for 5G. Some wideband antennas with a low-profile structure have been reported [8, 9, 10]. A wideband and low-profile microstrip antenna was presented in [8] based on the high-impedance surface (HIS). The antenna achieved a bandwidth of 55.6% with a relatively large profile of 0.098λo, meanwhile, the radiation pattern had certain deterioration. A dual-polarized patch antenna was presented in [9]. A low profile of 0.08λo has been realized, but the relative bandwidth was only 18.8%. To achieve a wider band, a metasurface antenna was proposed in [10]. The bandwidth has been improved to be 31% and the profile has been reduced to 0.07λo. Although some progress has been made, they still cannot fulfill the frequency demand of 5G system with a low-profile structure. Some novel designs with wider band and lower profile are expected for 5G base station antenna.

In this letter, a low-profile and wide band dipole antenna is presented for 5G...
The proposed antenna can cover an impedance bandwidth of 55.4% while the antenna height is only 0.067\(\lambda_0\) (\(\lambda_0\) is the free-space wavelength at the center frequency). By adopting parasitic strips, the impedance matching can be improved effectively between 3 GHz and 5 GHz. Unidirectional radiation patterns and low back-lobes are realized. The measurement results agree well with the simulations.

### 2 Proposed antenna structure and analysis

The geometry of the low-profile and wideband antenna is shown in Fig. 1. The proposed antenna operates at the center frequency of 4.1 GHz. It consists of a planar dipole, two parasitic strips, a feeding structure and a transmission line. All are printed on FR4 substrates (horizontal and vertical) with relative dielectric constant of 4.4. The antenna is located on a ground plane of 55.5 mm × 51.5 mm, with the total height of 4.9 mm. Detailed dimensions are in Table I.

The planar dipole is a combination of truncated ellipse and rectangle with dimensions of \(W\) and \(L_3\). Two parasitic strips are located at the side of the planar...
dipole and they are printed on both sides of the horizontal substrate with vias. The ground is below the dipole with a separation of $H_1$ (thickness of top FR4 layer) and $H_2$ (thickness of air layer). A microstrip transmission line is located under the ground with a separation of $H_3$ (thickness of bottom FR4 layer). The dipole is excited by a differential feeding structure, as shown in Fig. 1(d). The bottoms of two vertical strips are connected to the ground and transmission line with a characteristic impedance of 50 $\Omega$, respectively. Vertical wall is added near the port to mitigate interferences from the SMA connector and nearby circuits for practical applications.

Usually, the impedance matching would deteriorate when the radiation patch is very close to the ground, that would cause a degraded bandwidth. In this low-profile design, parasitic strips are introduced to alleviate the ground effects for a wideband impedance matching. The influence of parasitic structure on the $Z$-parameter is simulated and illustrated in Fig. 2. By employing parasitic strip, more gentle impedance curves are achieved, especially at the resonant frequency points of 3.75 GHz and 4.7 GHz. The $Z$-parameters with and without parasitic
strip are simulated and plotted in the Smith Chart in Fig. 3 with magenta and green color, respectively. The black and blue traces illuminate the variations of two resonant points. It is observed that the two resonant points are moved from the right side down to the center circle, i.e., with VSWR=1:2, in the Smith Chart, exhibiting the obvious effect of parasitic strip. It can be concluded that the parasitic strip can be equalized as capacitive loading, which can improve the impedance matching effectively over the operation band.

3 Experiment verification

The antenna performance is simulated with a commercial software ‘HFSS’. For the purpose of verification, the antenna is fabricated with PCB technology and the prototype is shown in Fig. 4. The $S_{11}$ is measured by the Agilent N5247A vector network analyzer while the radiation pattern and gain are obtained in an anechoic chamber. Fig. 4 also shows the results of $S_{11}$ and gain, the measured impedance bandwidth ($S_{11} \leq -10 \text{ dB}$) of 55.4% from 2.96 to 5.23 GHz are achieved with an average gain of 7 dBi in the boresight direction. The measured radiation patterns at frequencies of 3.5 and 4.6 GHz are depicted in Fig. 5. The antenna has stable unidirectional radiation patterns and low back-lobe levels at the two principal planes across the entire band. Due to the instability of FR4 substrate, the fabrication and assembly error, certain discrepancies are observed between the simulation and measurement results at higher frequency band.

The proposed antenna is compared with some existing designs in the literature [8, 9, 10]. Though the antenna in [8] realized similar bandwidth, it cannot maintain stable radiation pattern, the profile was also relatively high. The planar dipole design in [9] achieved a low-profile structure of $0.08\lambda_0$ with a bandwidth less than 20%. A wider bandwidth of 31% was realized in [10] based on metasurface structure and the profile was reduced to be $0.07\lambda_0$, but it cannot accommodate the frequency bands for 5G simultaneously. This work achieves a wide impedance bandwidth, low profile and relatively stable gain across the passband. Therefore, the proposed design with a lower profile can offer good performance with low fabrication cost for 5G system.

![Fig. 4. Measured and simulated S-parameter and gain results of the antenna.](image-url)
Conclusion

A low-profile and wideband dipole antenna is presented for unidirectional applications. Parasitic strips are used as capacitive loading for wideband performance in a low-profile structure. Experimental results demonstrate that the antenna has wide impedance bandwidth of 55.4% from 2.96 GHz to 5.23 GHz, it also has stable directional radiation patterns with an average gain of 7 dBi over the passband. Moreover, the antenna profile has been reduced to be 0.067λ0 with FR4 substrate which makes it low cost and very promising for practical applications. Because of these excellent features, the antenna should find wide applications in the 5G wireless communication systems.

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