Active Patch Antenna for Wi-Fi 5, 6 and Wi-Fi 6E Applications

E A Ischenko¹, Yu G Pasternak¹, V A Pendyurin¹, S M Fedorov¹

¹Department of Radioelectronic Devices and Systems, Voronezh State Technical University, 84 20-letiya Oktyabrya st., Voronezh, 394006, Russia

E-mail: kursk1998@yandex.ru

Abstract. The article discusses a planar patch antenna with a metamaterial integrated into the structure, which allows the antenna to function in the upper Wi-Fi 5, 6 frequency range and the Wi-Fi 6E range. For the study, we built graphs of S-parameters, radiation patterns; on the basis of the resulting structure, we formed a MIMO antenna array for which we determined the main characteristics - the envelope correlation coefficient and the multiplexing efficiency.

1. Introduction

Modern Wi-Fi devices that support Wi-Fi 5 (ac) and Wi-Fi 6 (ax) technologies operate at 2.4 GHz and 5 GHz, however, these frequency bands are no longer enough to provide access to high-speed Internet with low latency. In the frequency range, the most unused and vacant are the frequencies from 5.735 to 5.835 GHz. In order to increase the number of devices that are simultaneously connected to the wireless Internet, and also have low latency and high connection speeds, the Wi-Fi 6E (Extended) standard was developed with frequencies of 5.925-6.425 GHz. Antennas that provide Wi-Fi connection should be omnidirectional, which provides wide coverage and convenient connection for the user. However, installing additional antennas requires more complexity in the design of devices, as well as the allocation of additional space.

This article proposes a patch antenna design with an active metamaterial integrated into the design, which allows switching the operating frequency ranges, providing broadband access to Wi-Fi 6 (5.735-5.835 GHz) and Wi-Fi 6E (5.925-6.425 GHz). Also, to ensure the operation of devices based on Wi-Fi 6 and 6E, it is required to form a MIMO antenna array, which can improve the network performance.

2. Antenna design

To accomplish this task, we propose to use a planar patch antenna with a microstrip power line, around the emitter of which an active metamaterial is formed (Figure 1).

The dielectric substrate is Rogers RO3203, the thickness of the copper conductor is 35 microns. A microstrip line acts as a power line, which provides a high level of matching between the emitter and the power line.
In the process of activation of the metamaterial layers, the dimensions of the emitter increase, which leads to a restructuring of the frequency range, while a low level of return loss stays stable, which ensures stable operation of the emitter in a wide frequency range. The rectangular patch antenna, however, has a narrow operating frequency band; to expand the operating range, we propose to use a design with a shortened grounding plate (Figure 2) [1-4].
The use of this design allows us to achieve an expansion of the antenna bandwidth, as well as lower return losses (Figure 3).

![Figure 3. S11 antenna parameters for different grounding designs.](image)

As can be seen from the results obtained, the use of the proposed grounding design leads to an expansion of the operating frequency range of the antenna, which is usually determined by the level of $S11 = -10$ dB. Thanks to such an extension of the operating range, it is possible to provide operation in wider frequency ranges, which is required for antennas that provide Wi-Fi operation.

3. **The use of active metamaterial to control the characteristics of the antenna**

The active metamaterial is activated due to the use of MEMS switches, which provide high isolation of the metamaterial and the basic structure of the antenna, and the use of active devices in the design of antennas to control the characteristics is quite popular [5]. By increasing the radiating area of the plate, the operating frequency range of the antenna changes, and due to the design features, the connection of the metamaterial increases the frequency of the antenna. In order to track how the pattern of flowing currents in the antenna changes, we built patterns of surface currents (Figure 4).

![Figure 4. Pictures of surface currents: a) - the metamaterial is active; b) - metamaterial is disabled.](image)

As can be seen from the obtained patterns, currents flow through the formed structure of the metamaterial. The use of the resulting design allows us to get a picture of return losses, which is shown in Figure 5.
The results show that the active metamaterial allows the antenna to be used in a wide frequency range, so in the range from 5.735 GHz to 5.964 GHz, the antenna can provide the proper characteristics without activating the metamaterial (the frequency range 5.735-5.835 GHz corresponds to high-frequency Wi-Fi 5 and 6 channels); activation of the metamaterial allows for low return loss in the range from 5.964 to 6.364 GHz, after which disabling the metamaterial allows operation in the remaining frequency range of Wi-Fi 6E. Typical radiation patterns are shown in Figure 6.

As can be seen from the results obtained, the antenna provides all-round radiation, which is one of the requirements for Wi-Fi antennas. The use of metamaterial keeps the all-round radiation of the antenna while reducing the directivity by 1 dBi. For the implementation of Wi-Fi 5, 6 and Wi-Fi 6E technology, MIMO technology is used.

4. Formation of a MIMO antenna array based on the developed antenna
The view of the formed MIMO antenna array is shown in Figure 7.
Figure 7. Formed MIMO antenna array 2x2.

For any MIMO antenna array, it is important to ensure a low envelope correlation coefficient [6]:

\[
\rho_e = \sqrt{\frac{\iiint \left| \tilde{F}_n(\theta,\phi) \ast \tilde{F}_n(\theta,\phi) \right| d\Omega}{\iiint \left| \tilde{F}_n(\theta,\phi) \right|^2 d\Omega \iiint \left| \tilde{F}_n(\theta,\phi) \right|^2 d\Omega}}
\]  

(1)

where \( \tilde{F}_n(\theta,\phi) \) – the radiation pattern of the n-th antenna;

* – denotes the Hermitian transformation.

This parameter should be minimal for the designed antenna array. The resulting graph of the envelope correlation coefficient is shown in Figure 8.

Figure 8. Envelope correlation coefficient in the MIMO antenna array.

As can be seen from the results obtained, when the metamaterial is activated, an increase in the coefficient is observed but the value is much less than 0.1, which means high efficiency of the MIMO antenna array.

Another important parameter is the efficiency of multiplexing in a system of two antenna elements [7]:

[Image 146x535 to 450x729]
[Image 103x182 to 494x339]
The results are shown in Figure 9.

\[ ME = \sqrt{\eta_1 \eta_2 (1 - \rho_r)} \text{(in dB)} \]  

Figure 9. Efficiency of multiplexing for the designed MIMO antenna array.

As can be seen from the obtained dependence, when the metamaterial is activated, there is a slight decrease in the multiplexing efficiency since there was a slight decrease in the efficiency.

5. Conclusion
In the considered work, we proposed a planar antenna with an integrated metamaterial, which allows the antenna to be used for Wi-Fi 5, 6 and 6E technologies. Based on the proposed design, we developed a MIMO antenna array, which has all the required characteristics for a MIMO system. The proposed design is promising since it has small dimensions and provides the required characteristics for Wi-Fi antennas.

6. References
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