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Technical Papers

Micro QR Code as the Basis of Patch Antenna Topologies

Vadym Slyusar
Central Research Institute of Armaments and Military Equipment of Armed Forces of Ukraine
Kyiv, Ukraine
swadim@ukr.net

Ihor Sliusar
Department of information systems and technologies Poltava State Agrarian Academy
Poltava, Ukraine
islyusar2007@ukr.net

***Abstract*— The paper proposes a new type of broadband patch antennas based on MicroQR codes. To synthesize them, the word "antenna" was used. In this research, several design options were considered that used the variation of the antenna's feeder parameters. For their analysis, the Numerical modeling methods were used due to the complexity of describing the interaction of antennas of non-Euclidean geometry with radio waves. Evaluation and comparison of proposed antennas held by the following characteristics: amplitude-frequency response and voltage standing wave ratio. To expand the frequency band of the synthesized antenna was implemented the split square marker that is the element of MicroQR.**

Keywords — MicroQR, patch antenna, amplitude-frequency response, voltage standing wave ratio, VSWR

I. INTRODUCTION

In the process of working on the 6th generation cellular communication systems, among the developers of communication standards, an opinion was formed about the advisability of introducing a transitional standard [1] on the way from 5G [2] to 6G [3–6]. This approach involves the use of millimeter and submillimeter wavelengths in addition to existing 5G systems [3–6]. In this regard, there is a need to develop appropriate radio equipment, including antennas, that would combine operation in one or more traditional frequency bands [7–10] with frequencies above 30 GHz.

II. ANALYSIS OF RECENT STUDIES AND PUBLICATIONS, WHICH DISCUSS THE PROBLEM

As one of the possible options for solving this problem, it is proposed to use patch antennas with the topology synthesized based on the use of MicroQR codes.

The web service [11] was used to generate various MicroQR codes. The main resulting code containing the word "antenna" is shown in Fig. 1. It is formed on the basis of square pixels within a 15 × 15 matrix.

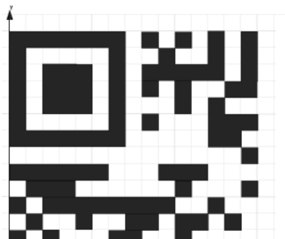

Fig. 1. MicroQR code with the word "antenna".

For antenna modeling, it is recommended to use Ansoft EMT 2020, which is the next generation of Ansys HFSS [12].

The web service [11] generated a gif-format graphic file that was not directly supported by the electromagnetic simulators Ansoft HFSS EMT [12] and Ansoft Electromagnetic Suite. Therefore, it was necessary to pre-convert this file to the .dxf format with the manual drawing of each pixel of the MicroQR code. More convenient in this respect is the qrcode2stl resource [13], which allows you to create an STL file compatible directly with Ansoft EM Suite without a background when used in the setting in the "Separate parts" formation option. However, it is possible to generate only a MicroQR code.

The pixel side length was set equal to 1 mm, thickness (height) Elemenets_thickness = 0.6 mm. The ground screen has been modified in the work by introducing symmetric angular cuts similar to [1]. The external view of the corresponding patch antenna with a feeder line is shown in Fig. 2.

To assess the properties of such antennas, one can use the results of calculating the voltage standing wave ratio (VSWR) and return loss (RL) [14, 15], as traditional indicators in analyzing the characteristics of antennas.

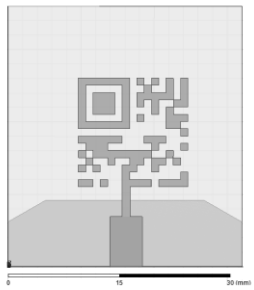

Fig. 2. The proposed patch antenna.

III. THE AIM OF RESEARCH

Thus, the purpose of the work is to create conditions for expanding the functionality of mobile communication systems through the use of patch antennas based on structures in the form of MicroQR code.

IV. THE MAIN RESULTS OF THE STUDY

It is known that the frequency dependences of VSWR and return loss are formed during the simulation with Ansoft HFSS based on S-parameters [12]. The results of such calculations for the patch antenna on the Fig. 2 are shown in Fig. 3 and 4.

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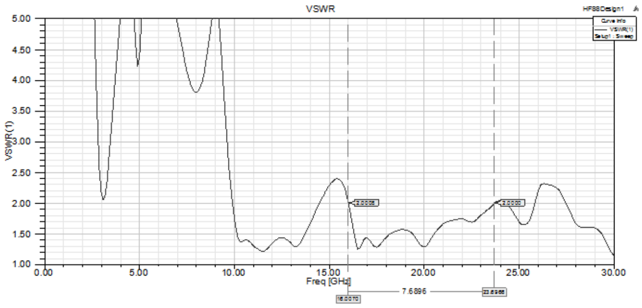

Fig. 3. VSWR frequency dependence for antenna (Fig. 2).

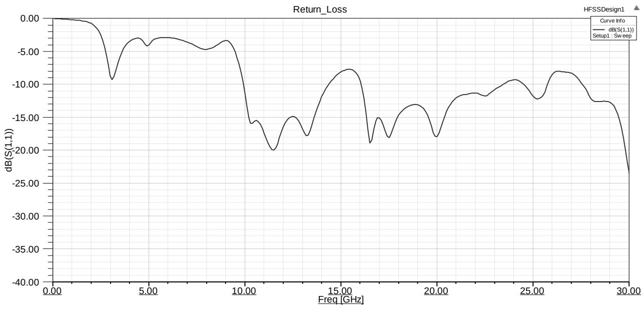

Fig. 4. RL frequency dependence for antenna (Fig. 2).

For the comparison, calculations were carried out for a separate feeder line on the same substrate in the absence of an antenna element (Fig. 5).

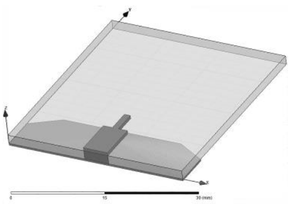

Fig. 5. The separate feeder line.

The comparison of corresponding results presented in Fig. 6 and 7, with fig. 3, 4 allows seeing the effect of the antenna element on the resulting frequency response. It is important that the patch antenna can be interpreted as a capacitive load of the feeder line monopole.

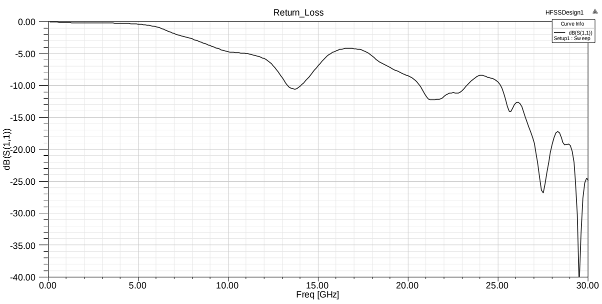

Fig. 6. Frequency dependence of RL of a separate feeder line.

In the course of further research, it was necessary to preserve the possibility of comparison with previously obtained results, for an example, [1]. Therefore, the model with MicroQR code (the word "antenna") was used for the calculation with a scale factor of × 1.28, that corresponded to the size of the template for a chaotic antenna [1]. In this case, the size of the side of one cell in the topology of the corresponding antenna shown in Fig. 8 is 1.28 mm. It is important to note that such a scaling process of the patch antenna did not affect the reading of information from its MicroQR code in any way, since for reading it was enough to increase the distance between the surface of the code and the lens of the smartphone camera. Equally uncritical for decoding an information is the presence of a feed line, which, due to the presence of a special square marker in the code structure, is easily cut off by the scanning algorithm.

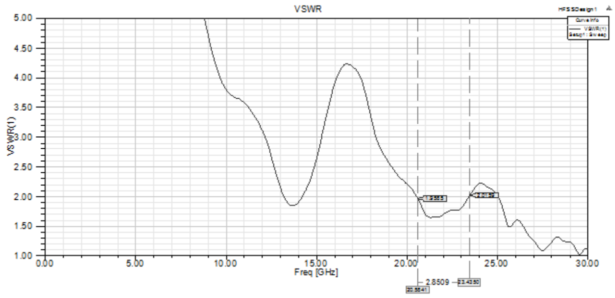

Fig. 7. Frequency dependence of VSWR of a separate feeder line.

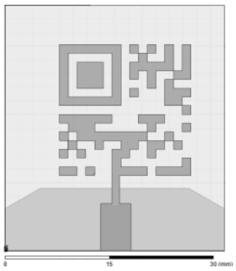

Fig. 8. Model of a patch antenna with MicroQR (the word "antenna") at a scale of × 1.28.

The characteristics of the scaled antenna are shown in Fig. 9, 10. The corresponding graphs allow us to judge the predictable effect of changing the dimensions of the patch antenna on the position of its resonant frequencies.

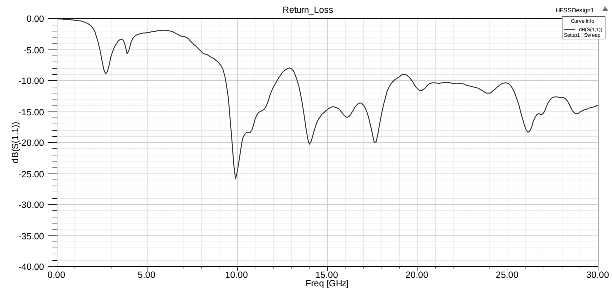

Fig. 9. RL frequency dependence of the patch antenna (Fig. 8).

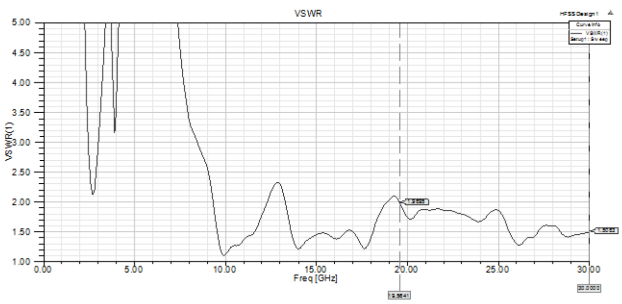

Fig. 10. VSWR frequency dependence of the patch antenna (Fig. 8).

In general, speaking of the applicability of this antenna design for operation in the extended millimeter wavelength range, it would be desirable to eliminate the overshoot in the frequency response curves around 19 GHz. At the same time, the need to preserve the ability to decode information recorded in the MicroQR code significantly limits the ability to change the antenna topology. When looking for possible solutions of this kind, a hypothesis was put forward about the possibility of making a cut in the square frame of the reference (marker) element in the upper left corner of the code.

To study such a modification of the reference frame, bordering the square in the upper left corner of the code, a 0.617 mm wide incision was made in the center of the lower side of the frame (Fig. 11). Verification of the code in the MicroQR scanner confirmed that such cut does not affect the decoding quality of the modified picture. Therefore, the appropriate approach is taken as the basis for optimizing the antenna topology. The corresponding VSWR estimated for such antenna is shown in Fig. 12.

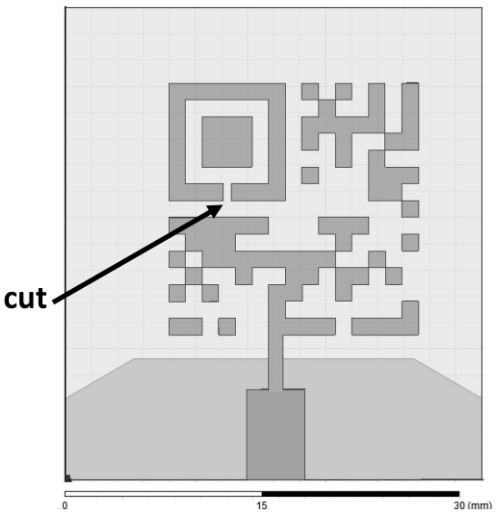

Fig. 11. Modification of the antenna model with a cutout in the reference (marker) element.

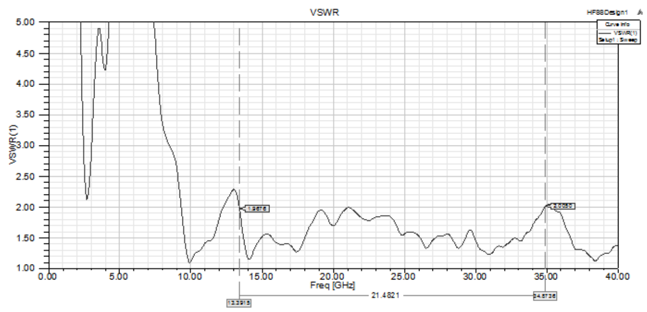

Fig. 12. VSWR frequency dependence for the modified antenna (Fig. 11).

As follows from Fig. 12, the presence of the specified cut in the reference element made it possible to remove the surge in the VSWR graph in the 19 GHz region, that provided a continuous antenna bandwidth from 13.4 GHz to 35 GHz. The relative bandwidth, calculated by the formula [16]:

$$\delta F = \frac{2|f_1 - f_2|}{f_1 + f_2}, \quad (1)$$

where f_1 and f_2 are the values of the frequencies at which the VSWR $\leq$ 2.0, in this section is 21.482/24.2 = = 0.887686.

Further, the influence of the orientation of the cutout in the square frame of the reference (marker) element on the radio-technical properties of the antenna was investigated. It turned out that the turn of the section to the right by 90 degrees worsens the result in the region of 19 GHz. This antenna performs best in the 19 GHz frequency range when the cut is parallel to the feed line (see Fig. 11). At the same time, in the 3 GHz region, a dip below the VSWR = 2.0 level with a width of 190 MHz was achieved. Similarly, in the range 2.593 - 2.753 GHz, a 160 MHz working band arose (Fig. 13).

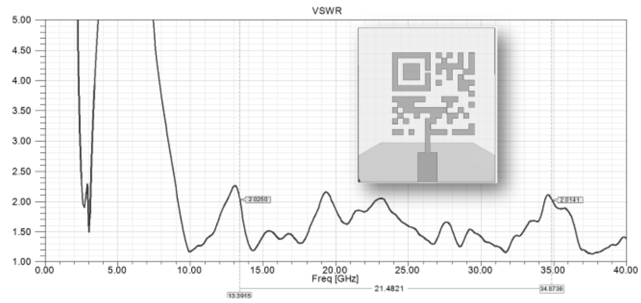

Fig. 13. VSWR frequency dependence for a modified antenna with a cut to the right by 90 degrees.

The variant of the considered patch antenna with a cut at the top of the square frame of the reference element has better characteristics in the region of 20 GHz (Fig. 14) than when the cut-out is turned to the right (Fig. 13), however, according to this indicator, it loses to the antenna with a down cut in the reference element (Fig. 11, 12). In addition, the dip in the 3 GHz region still has not reached the VSWR = 2.0 level.

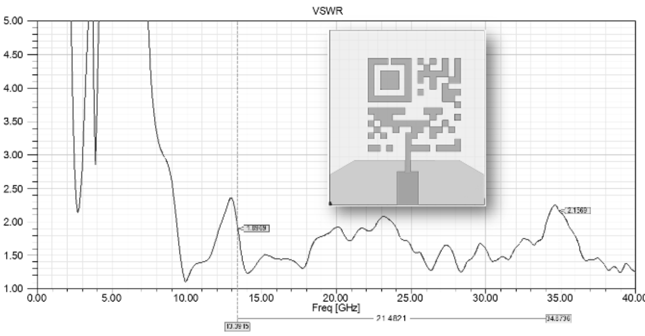

Fig. 14. VSWR frequency dependence of a modified antenna with a cut directed upward.

When the cut section is turned to the left, a small spike is observed at 19 GHz, but a 354 MHz band appears in the section from 2.5493 GHz to 2.9 GHz (Fig. 15).

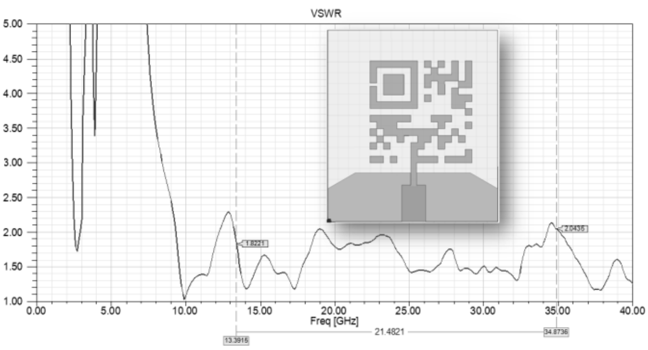

Fig. 15. VSWR frequency dependence for a modified antenna with a cut to the left by 90 degrees.

Along with the orientation of the split section, the influence of its width was studied, to which the properties of the antenna also showed sensitivity. For example, with a split zone width of 0.35 mm, oriented to the left (Fig. 16), it was possible to achieve VSWR <2.0 in the range from 13.25 GHz to 33.92 GHz, and to reduce the return loss at a frequency from 10 GHz to level below -35 dB. On the other hand, also in the frequency band from 2.5 GHz to 2.8 GHz, an operating frequency band with a width of more than 297 MHz was obtained (Fig. 17).

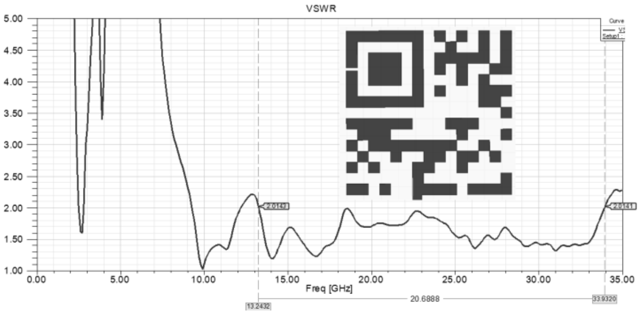

Fig. 16. VSWR frequency dependence when changing the width of the cut.

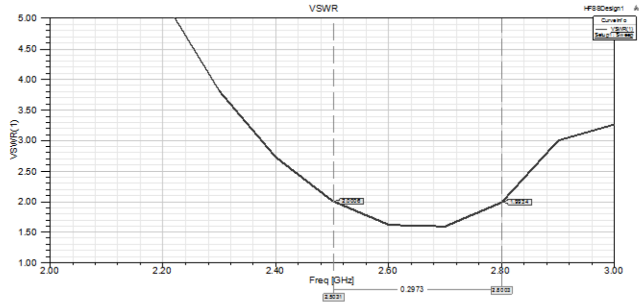

Fig. 17. Fragment of Figure 16.

The closeness of the shape of the split outer frame of the reference frame in the patch antenna design to the SRR element used in metamaterials [17, 18] makes it possible to hypothesize about the possibility of using such a cell of the metamaterial as an element of the MicroQR code. The corresponding modification of the MicroQR code picture was successfully tested on a smartphone scanner, however, provided that the color of the printed element was changed to black. In this case, the word "antenna" was decoded even with some turns of the smartphone plane relative to the display surface.

V. Perspectives of further reseach

It is advisable to direct further research to the analysis of the properties of patch antennas obtained as a result of integrating an SRR element into the topology of a square reference marker of MicroQR codes. In addition, consideration of other topologies of this type of antenna, taking into account the encoding of various phrases in the MicroQR code, deserves attention. In this case, codes with a symmetrically distributed graphical structure with respect to the feeder are preferred. It is also important to optimize the location of the feeder connection point.

VI. Conclusions

The proposed topology can be scaled up to frequencies above 1 THz. However, when simulating such nanoantennas, it will be necessary to take into account the quantum capacitance, kinetic inductance, plasmons, quantum conductivity, and other effects specific for small sizes of antenna elements [19].

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