X-band coaxial monopole antenna with an additional metal screen

Maksym Khruslov and Vadym Pazynin

Abstract— The novel coaxial monopole antenna design with an additional metal screen is presented. The radiation characteristics of this antenna are investigated depending on a distance between the ground plane and additional metal screens, as well as on a size of the latter. Measured and calculated radiation patterns are compared within limits of the operative frequency band and their revealed distinctions are discussed. The antennas characteristics allow pronounce that it can be considered as a promising candidate for various practical applications both a single radiator and a composite element of antenna arrays.

Keywords— monopole antenna, near field, radiation pattern, FDTD technique.

1. Introduction

Monopole antennas have found the wide applications in wireless local area network (WLAN) systems [1], subsurface communication, geophysical exploration, biomedical telemetry, for mobile terrestrial and aerospace communication systems, etc. With respect to the class of coaxial monopole antennas there is a possibility to form the different conical radiation patterns by changing the architecture of the separate antenna elements, for example, a geometrical shape [2, 3] and size [4] of the proper monopole. It stimulates a search of new modifications of these antennas to improve their performance, as well as to design both the individual radiator and arrays with new qualities.

The main objective of this research is the establishment of basic regularities of the radiation pattern formation with reference to the proposed novel design of X-band coaxial monopole antenna with an additional metal screen.

2. Theoretical and experimental methods

Numerical modeling has been carried out by the finite-difference in time domain (FDTD) technique, in which the exact "absorbing" conditions are used to solve a problem of the effective restriction of the computation space [5, 6]. The special software package developed allows one to compute all basic space-time and space-frequency characteristics of the axially-symmetrical radiators of both pulse and monochromatic waves.

Experimental investigations have been performed in the anechoic chamber by means of the method and software developed by us earlier [7] which provides a possibility to make signal processing and analyze the radiation pattern characteristics in real time over the entire operative frequency band (7.8–11.1 GHz) with a discrete of 10 MHz in every point of the receiving antenna position (the angular step is 0.5°).

3. Monopole antenna designs under testing

In this paper we present the results of theoretical and experimental investigations of radiation performances of the original monopole antenna consisting of the vertical monopole ($d_{r1} = \lambda/4$) with two screens, namely: ground plane with the radius R and additional metal screen with the radius C. The distance d_r between both screens has been as a variable parameter (Fig. 1). Some antenna prototypes with the parameters depicted in the Table 1 have been investigated to determine the effect of additional screen on the radiation characteristics of monopole antennas under testing.

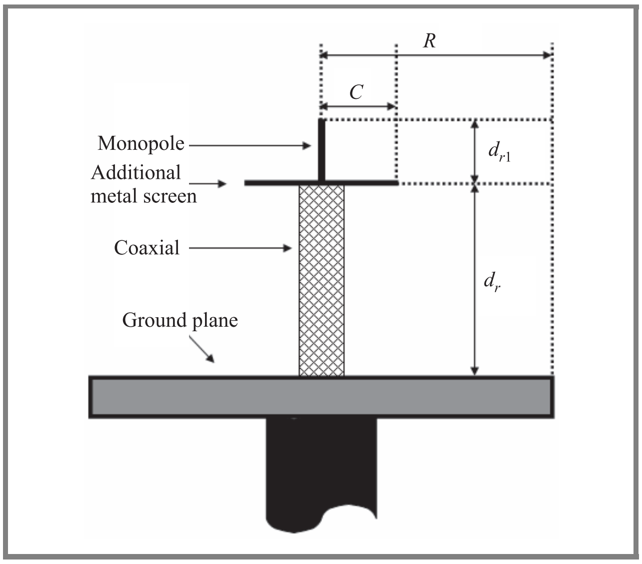

Fig. 1. Side view of the coaxial monopole antenna.

Table 1
Geometric parameters of antenna prototypes

Antenna N	1	2	3	4	5	6	7	8	9	10	11	12
d_r [mm]	19	30	7.5	15	19	22.5	30	7.5	15	19	22.5	30
C [mm]	10	10	10	10	10	10	10	15	15	15	15	15
R [mm]	∞	∞	230	230	230	230	230	230	230	230	230	230

4. Results and discussions

The analysis of calculated radiation patterns of antennas N1 and N2 with different distance between screens (Fig. 2) in the operative frequency band shows the availability of characteristic regions with sharp changing in the elevation angle of peak directivity due to the modes interaction of the open resonator formed by two plane metal screens. For both antenna prototypes we can mainly observe the monobeam radiation patterns with slow changing of the elevation angle of peak directivity with the frequency increase. So, for antenna N1 the elevation angle is changed from $\theta = 38°$ to $\theta = 56°$ in the frequency band $f = 7.80$–8.58 GHz. With the further frequency increase the elevation angle of peak directivity is not virtually changed and remains equal $\theta = 25°$. Under these conditions the radiation pattern shape is not qualitatively changed too, although its beamwidth increases. In contrast to the antenna N1 for the antenna N2 the cut-off frequency between two frequency regions is shifted to the higher frequency ($f = 10.5$ GHz, see Fig. 2b). In this case we can also observe a change in the elevation angle ($\Delta\theta = 30°$), whereas a beamwidth is not virtually changed in the limits of the frequency band under testing.

Thus, as it follows from the analysis of radiation pattern shape of the monopole antenna with an additional metal screen, the power radiation is concentrated in the main beam close to zenith unlike the conventional monopole antenna, and two frequency regions with different elevation angles of peak directivity are observed (Fig. 2). We emphasize that with the additional screen diameter increase the main beam of radiation pattern tends to zenith. The process of radiation pattern formation one may retrace on the near field pictures (Fig. 3). As can be seen from those, the main contribution in the radiation field of antenna gives the EM

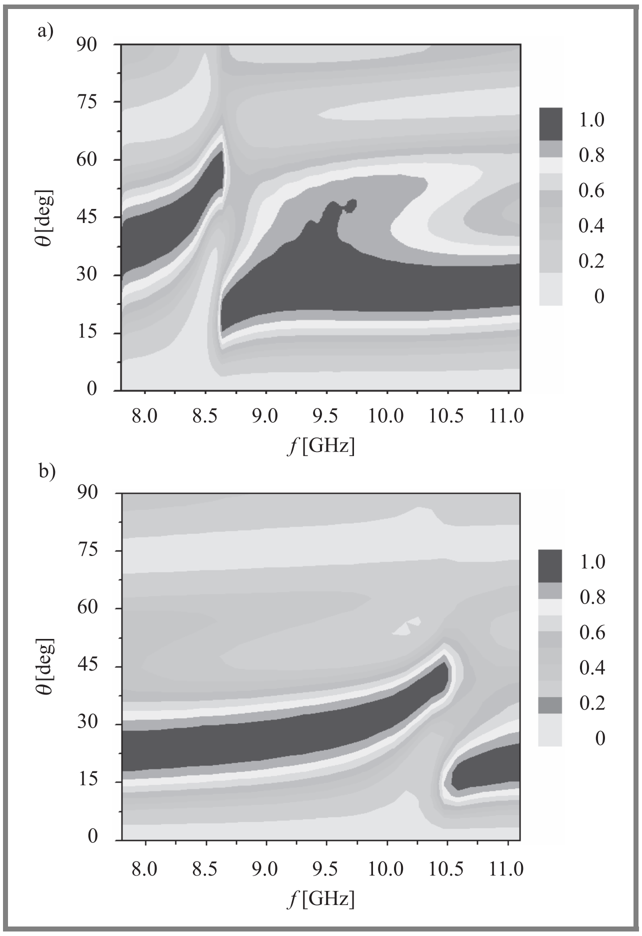

Fig. 2. Calculated radiation patterns normalized at the every fixed frequency: (a) antenna N1; (b) antenna N2.

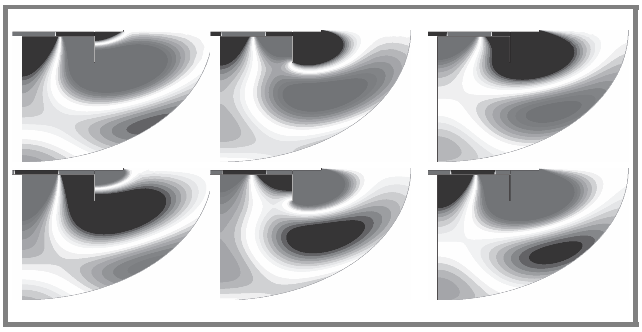

Fig. 3. Calculated near field distributions ($H\varphi$-component) highlighted in the successive time points of the antenna N1 at the frequency $f = 7.9$ GHz.

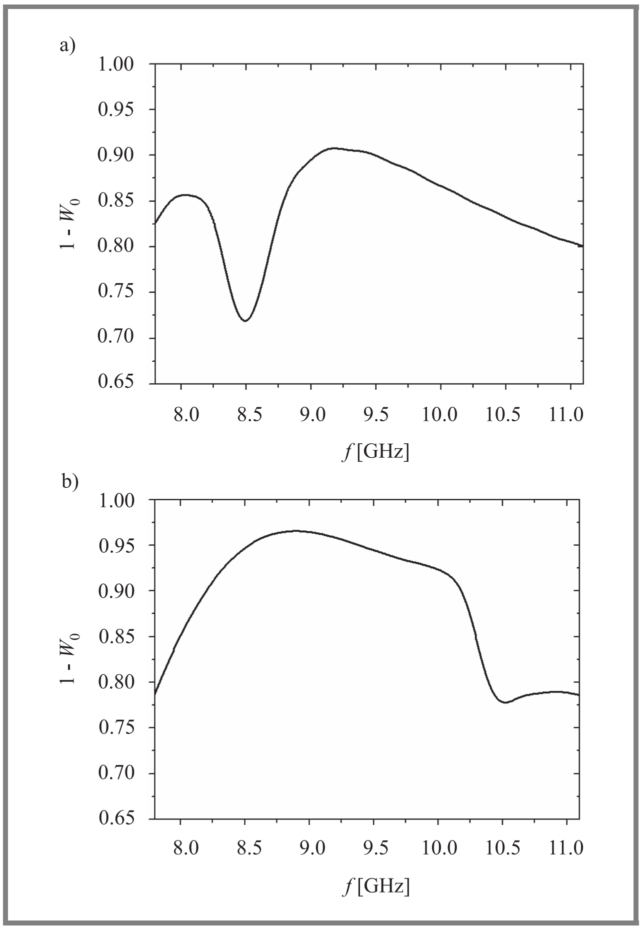

Fig. 4. Calculated antenna efficiency (W_0 is the power reflection coefficient from the antenna aperture): (a) antenna N1; b) antenna N2.

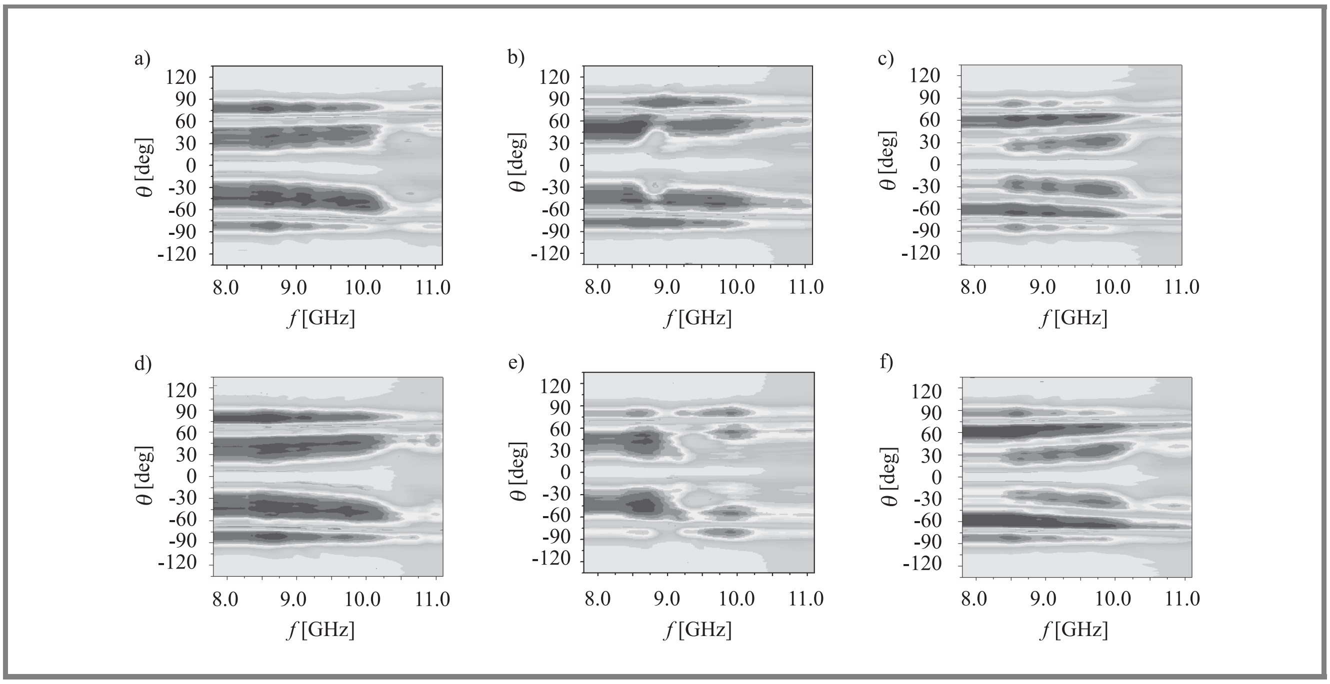

Fig. 5. Experimental radiation patterns of the following antenna prototypes: N4 (a); N5 (b); N7 (c); N9 (d); N10 (e); N12 (f).

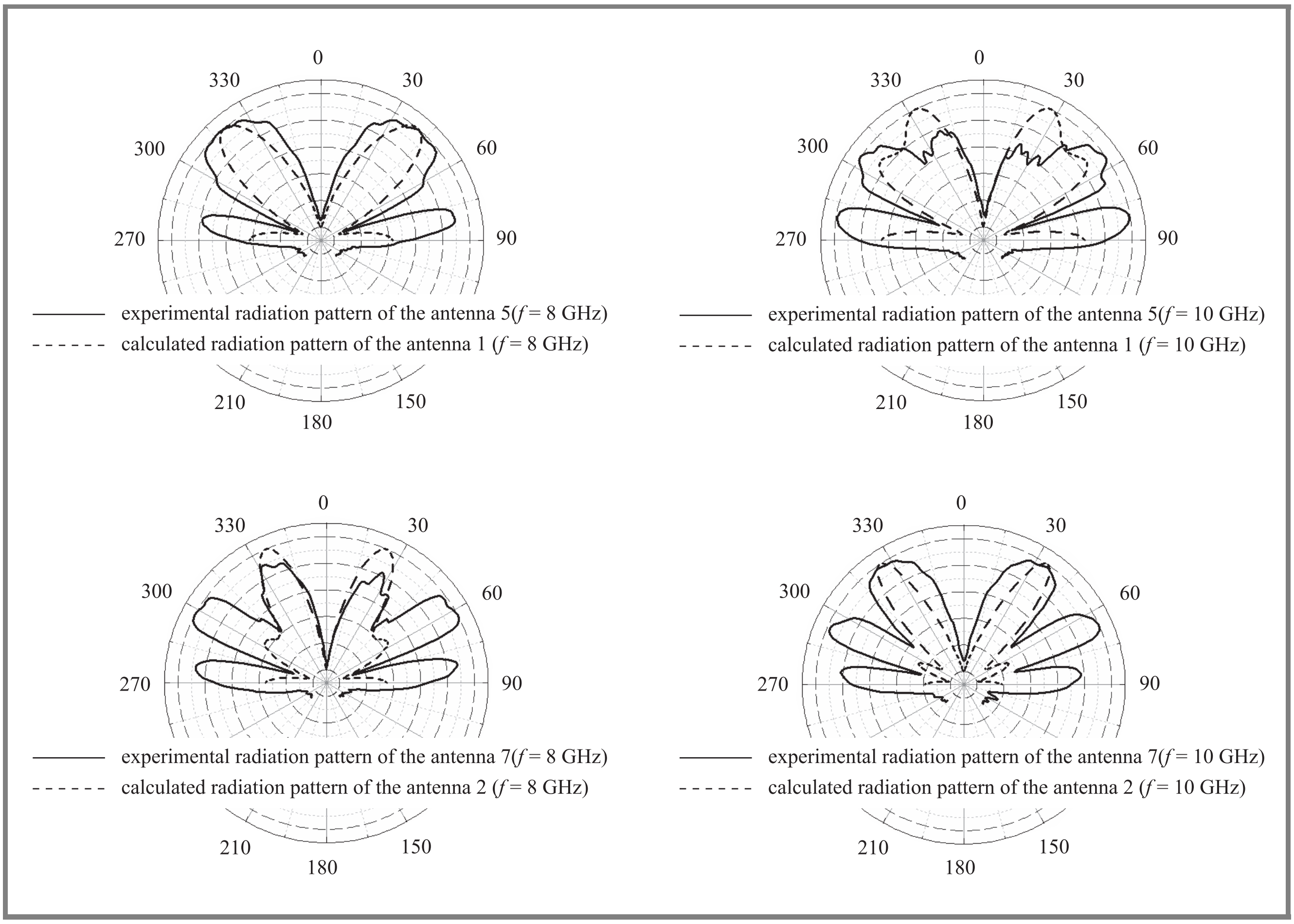

Fig. 6. Radiation patterns of some antenna designs.

field scattered from the additional metal screen and, correspondingly, the change in its diameter leads to the shift of the elevation angle of peak directivity from azimuth.

According to the calculations the antenna efficiency decreases with the additional screen radius reduce (Fig. 4) and maximal efficiency of antenna N2 reaches 97% (Fig. 4b). It is worth noting that the calculated efficiency of these monopole antennas indicates a visible degradation of antenna performance just in the aforementioned cut-off frequencies (Fig. 4).

Unlike the theory, the experimental radiation patterns of antenna prototypes under testing are found to be multi-beam ones and the pronounced cut-off frequency regions also appear but they are weaker (Fig. 5). The most probable reason of the revealed discrepancy is the use of infinite ground plane in theory that does not permit to take into account the effect of its finite dimensions in experiment on the radiation pattern formation. It is quite reasonable to suppose that the finite ground plane availability will give rise to the appreciable contribution of EM field scattered from that in the radiation pattern formation. The comparison of measured and calculated radiation patterns at the fixed frequencies shows that they really differ by the radiation power in beams closer to the azimuth (Fig. 6). By choosing both a radius of the additional metal screen and a distance between this screen and ground plane (for example, antennas N5 and N7) one may obtain two-or three-beam radiation patterns. In this case both antennas demonstrate a good bandwidth (22–24%).

We note also one more feature of the presented antenna, namely the elevation angle change with an additional screen radius increase (Fig. 7). In other words, we can change the elevation angle of peak directivity in the wide limits with increasing a distance between the ground plane and the additional metal screen.

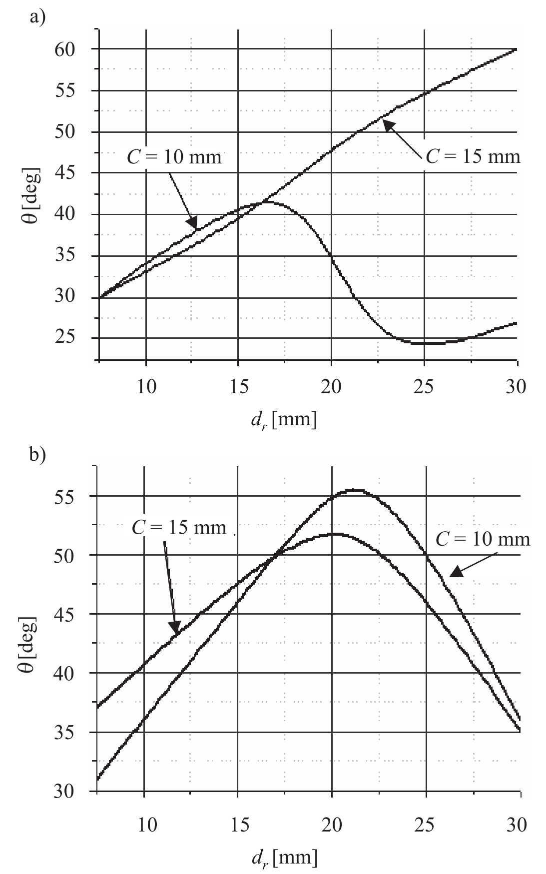

Fig. 7. The elevation angle of peak directivity versus the parameter d_r for antennas with different radius of additional screen C: (a) $f = 8$ GHz; (b) $f = 10$ GHz.

5. Conclusions

The novel broadband monopole antenna design with high efficiency is presented. It was found that the different conical radiation patterns can be formed by variations the distance between this screen and ground plane, as well as the additional screen radius. We note that the multibeam radiation patterns in experiment are formed due to the interference between the waves scattered from the finite ground plane and additional metal screen. A possibility of antenna operation in the dual-band mode has been shown. This original coaxial monopole antenna design can be used as a basic one in manufacturing the compact and effective antenna arrays due to its.

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