EFFECT OF CIRCULAR FINITE GROUND PLANE ON THE RADIATION PATTERN OF A MONOPOLE ANTENNA

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The paper discusses the variation of monopole antenna's radiation pattern due to change of its circular ground plane's electrical size. This variation is evaluated in vertical plane by comparing simulated and measured radiation patterns. Emphasis is placed on the angular dependence of the radiation pattern's maximum value on the electrical radius of the circular ground plane.

K e y w o r d s: monopole antenna, ground plane, radiation pattern

1 INTRODUCTION

During measurements of the radiation pattern of a monopole antenna placed on the surface of an aircraft model [1], a phenomenon of radiation pattern's lift from the aircraft surface was observed. As this lift ultimately changes the quality of a radio connection of an aircraft, it is desirable to examine this phenomenon. In order to evaluate it, the measurements described in this article were made.

2 THEORETICAL BACKGROUND

A typical simple monopole antenna consists of a single straight conductor mounted perpendicularly over a conductive surface, the ground plane. The ground plane acts like a mirror and so it creates an image of the straight conductor, resulting in a dipole-like antenna, see Figure 1.

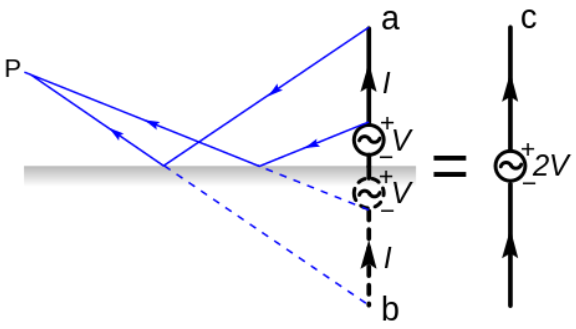


Fig 1 Monopole antenna over a ground plane [2]

As you can see from the Figure 1, the resulting electrical field in point „P" is created by summing individual wave reflections from the ground plane, together with direct waves, which aren't illustrated in the figure. Combination of all direct waves and of all reflected waves by infinite ground plane creates a radiation pattern identical to of a dipole antenna. However, in case of finite ground plane, some of the reflections are not present and resulting radiation pattern is, in comparison to the ideal pattern created by monopole antenna with infinite ground plane, deformed. This deformation usually manifests itself as an angular lift of the radiation maximum [3] [4] [5].

3 MEASUREMENT DESCRIPTION

In aim to have the results of measurement symmetrical and therefore easily readable, a circular shape of the ground plane was chosen.

To have the results of measurement relevant, which in this case means to have them approximately correspond to real aircraft, the circular ground plane was defined to have electrical radius ranging from 1/4 wavelength to 2 wavelengths.

The radius of the ground plane was 10cm, therefore the frequencies of measurement were ranging from 750MHz to 6GHz. Totally 8 measurements were made. Radiation pattern was measured in vertical plane, with angle being varied from 0 to 90 degrees by 1 degree.

To cover the whole frequency spectrum needed for the measurement, multiple monopole antennas were used, all in shape of a rod with radius 4mm and of a suitable length for given measurement frequency.

Constructed circular ground plane, together with mounted monopole antenna, is displayed in Figure 2. The slightly atypical design is due to material availability at the time of measurement. Negative effect of this design on measurement is described later in the paper.

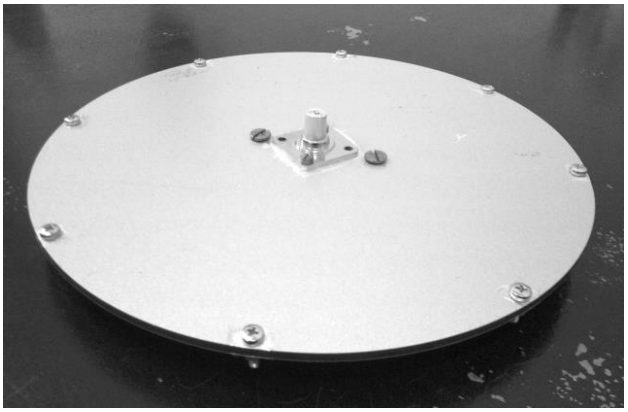


Fig 2 Circular ground plane with monopole antenna

According to the constructed ground plane, a simplified simulation model was created. Results of simulations are later in this paper compared to the measured results in common diagrams. The computer simulation was performed in FEKO software, the numerical method being the method of moments.

4 RESULTS OF MEASUREMENT

In this section of paper, results of made measurements and simulations are presented. Resulting radiation patterns are plotted in common diagrams for the same frequency, that meaning simple comparison between measured and simulated pattern. Used frequency, as in term of electrical radius of the circular ground plane and also as in absolute frequency, is specified in description of the diagrams. For better understanding of plotted radiation patterns in polar diagrams, there is three dimensional version of simulated radiation pattern for radius of 2 wavelengths (6GHz) in Figure 3.

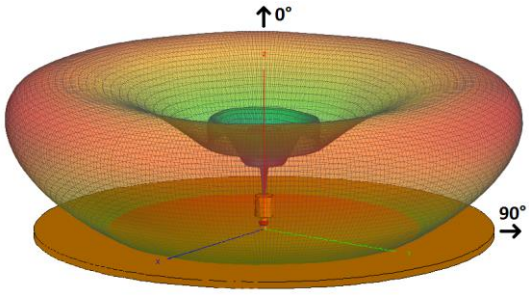


Fig 3 Simulated radiation pattern in 3D for 6GHz

The results of measurement and simulation are presented in polar diagrams, orange colour (lighter) being simulated result, blue colour (darker) measured result.

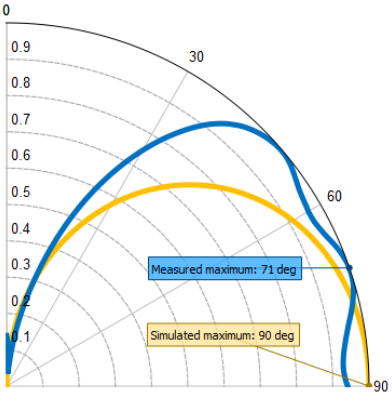
Resulting diagrams show quite good match between measured and simulated results. There is observable rippling of the measured results, with the increasing frequency the rippling being more obvious. This is caused by design of the used ground plane, which has several screws protruding from the ground plane, affecting the reflected electromagnetic waves. The possible capacitive coupling between the two parallel disks, which create the ground plane, didn't manifest at the measured frequencies.

Comparison of the measured and simulated results in term of angle of radiation pattern's maximum is in Table 1, with respect to frequency of measurement.

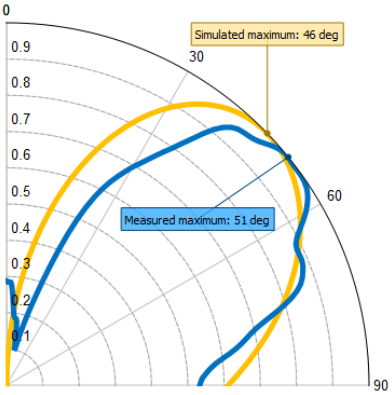
Tab 1 Measurement results

f [GHz]	angle of radiation pattern's maximum [°]	
	measured	simulated
0,75	71	90
1,50	51	46
2,25	38	37
3,00	58	57
3,75	46	50
4,50	64	61
5,25	60	59
6,00	59	63

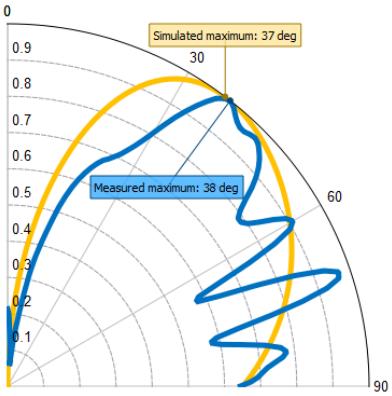
Difference between the measured and the simulated results is in all cases (except for 0,75GHz – see Diagram 1) in 5° range, which shows good match between the results and verifies the simulated results.



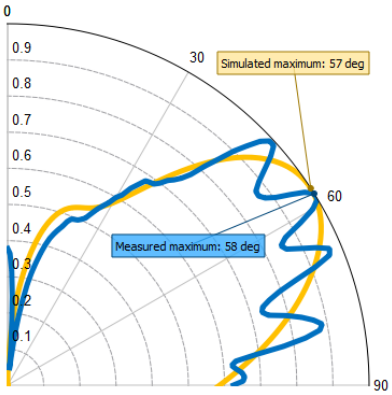
Diag 1 r=1/4 λ (0,75GHz)



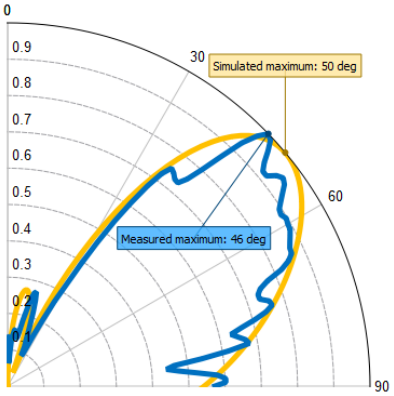
Diag 2 r=2/4 λ (1,50GHz)



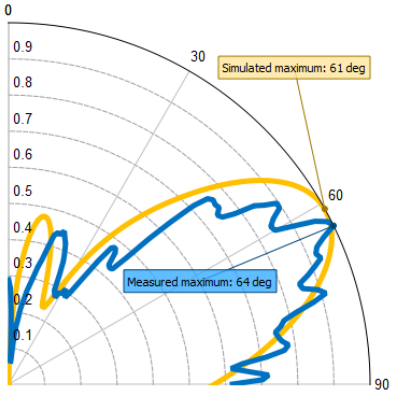
Diag 3 r=3/4 λ (2,25GHz)



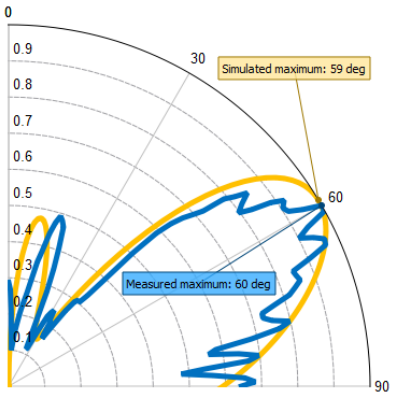
Diag 4 r=4/4 λ (3,00GHz)



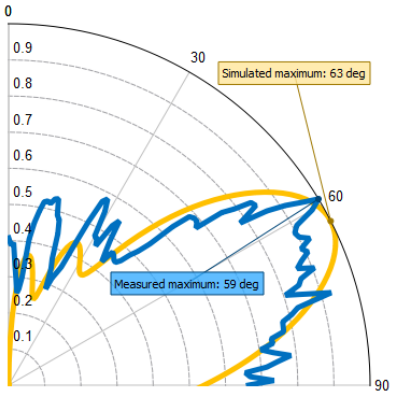
Diag 5 r=5/4 λ (3,75GHz)



Diag 6 r=6/4 λ (4,50GHz)



Diag 7 r=7/4 λ (5,25GHz)



Diag 8 r=8/4 λ (6,00GHz)

5 CONCLUSION

It can be concluded, based on the results presented in this paper, that the finite size of the ground plane has lifting effect on the angular direction of the radiation pattern's maximum. When the radius of the circular ground plane is equal to 1/4 wavelength of the desired frequency, then the radiation pattern is very similar to the radiation pattern of the infinite ground plane, with the radiation maximum in plane with the ground plane. Increasing dimensions of the ground plane somewhat above 1/4 of the wavelength causes rapid lift of the radiation pattern. Further dimensions increasing of the ground plane causes the radiation pattern's maximum to decline closer to the plane of the ground plane.

This resulting knowledge can be used in fast determination of the radiation pattern lift by the rule of thumb, and can be helpful in precise analysis of radiation pattern behaviour of mounted aircraft monopole antennas.

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