



COLLINEAR ANTENNA FOR ADS-B SYSTEM: SIMULATION AND FIELD TESTS

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Abstract – The paper a detailed investigation of collinear antennas for Automatic Dependent Surveillance - Broadcast (ADS-B) reception at 1090 MHz. Both four-element and twelve-element designs were analyzed using electromagnetic simulation and validated in field experiments. Performance metrics such as gain, standing wave ratio (SWR) and reception range were measured and compared. Results indicate that increasing the number of elements improves their parameters but may create many side lobes which create blind spots in antennas' vertical plots.

Key words – ADS-B, antennas, electromagnetic compatibility, RF engineering, radio navigation

INTRODUCTION

Automatic Dependent Surveillance–Broadcast (ADS-B), a next-generation surveillance technology endorsed by the International Civil Aviation Organization (ICAO), seamlessly integrates surveillance and communication capabilities. Aircraft equipped with this system automatically transmits flight numbers, positions, and other information. Aircraft and base stations with receivers process transmitted messages to support the global Air Traffic Management (ATM) system [1,2]. ADS-B is a system which allows surveillance aircraft traffic and receives a lot of other data. The system works on 1090 MHz frequency. Collinear antennas, consisting of multiple half-wave dipoles aligned on the same axis, offer potential for improved gain without requiring complex directional arrays. That is the reason why a collinear antenna seems to be the best option. The range of the antenna is strictly connected with gain and farfield directivity in vertical position. The more elements, the better the performance antenna has. Therefore the first chapter states design and simulation - according to radio frequencies theory, a four element antenna's vertical plot should be similar to a simple dipole and have low gain and bigger SWR. Twelve element antenna's vertical plot should be extended, have much more gain and less SWR. The second chapter includes the next step after simulation. It consists of checking the performance in field tests, which were conducted on the roof of the 5 - storey block, for 4 and 12 - element antennas. The third chapter summarizes all the research related to antennas and outlines potential directions for future research.

1. DESIGN AND SIMULATION

The collinear antenna is most commonly found these days as a vertical antenna with several elements stacked above each other. The basic idea is that several antenna elements that are arranged along the same axis are fed with the signal. A collinear array consists of two or more half-wave dipoles, which are placed end to end. These antennas are placed on a common line or axis, being parallel or collinear. The antenna structure recalls the use of Franklin's principle in linking several radiating dipoles, to sum up, all radiations' intensities. The feed of the antenna is located on the lateral face of one of its ends; the other end is an open circuit [3,4]. Both prototypes were constructed using RF-10 coaxial cable for inter-element phasing. First part of calculations states wave length:

$$\lambda = \frac{c}{f} = \frac{3 * 10^8 \text{ m/s}}{1090 \text{ MHz}} = 275.22 \text{ mm} \quad (1)$$

For 275.22 mm wave length and RF-10 cable's velocity factor, the length of the one dipole is:

$$L = 0.5 * 275.22 * 0.84 = 115.59 \text{ mm} \approx 11.6 \text{ cm} \quad (2)$$

Using above calculations model of the four and twelve element collinear antenna and its plots are shown below, simulation was conducted in CST Studio Suite:

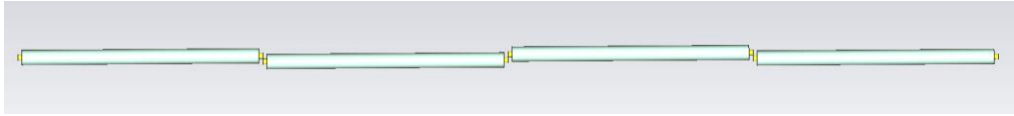


Fig. 1. Four element collinear antenna model

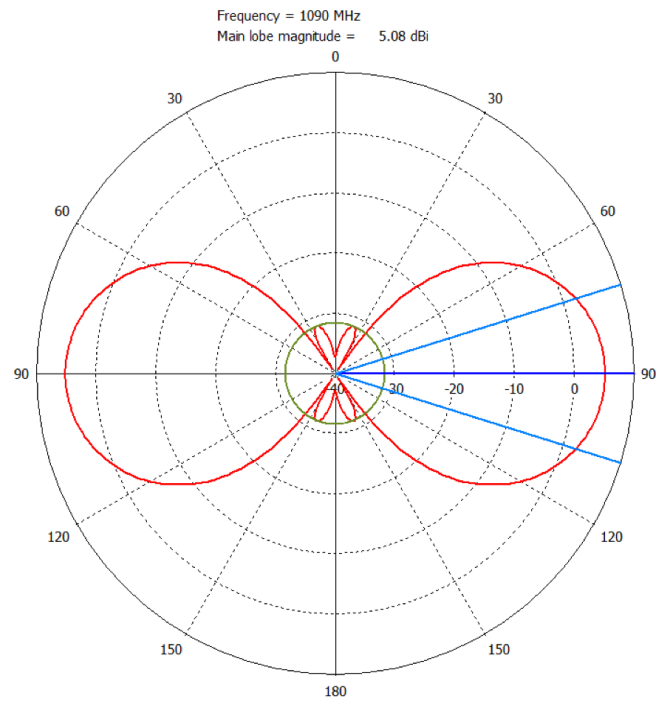


Fig. 2. Four element collinear antenna vertical plot

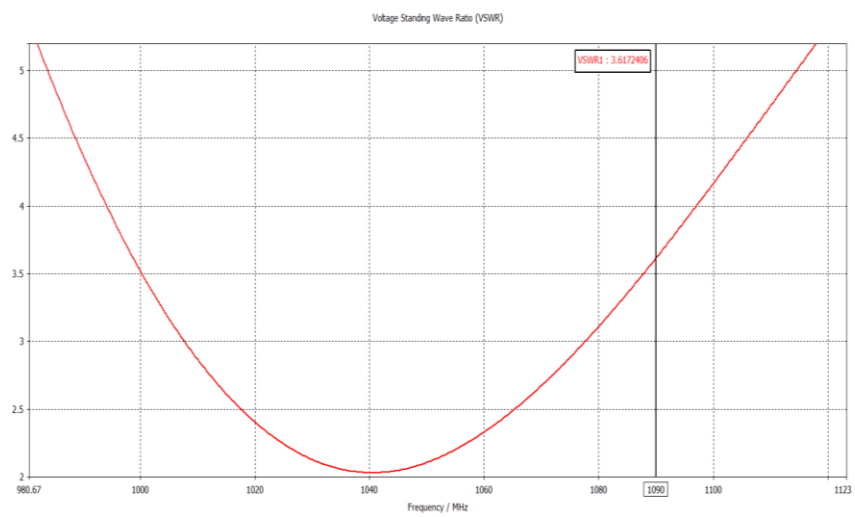


Fig. 3. Four element collinear antenna - Standing Wave Ratio

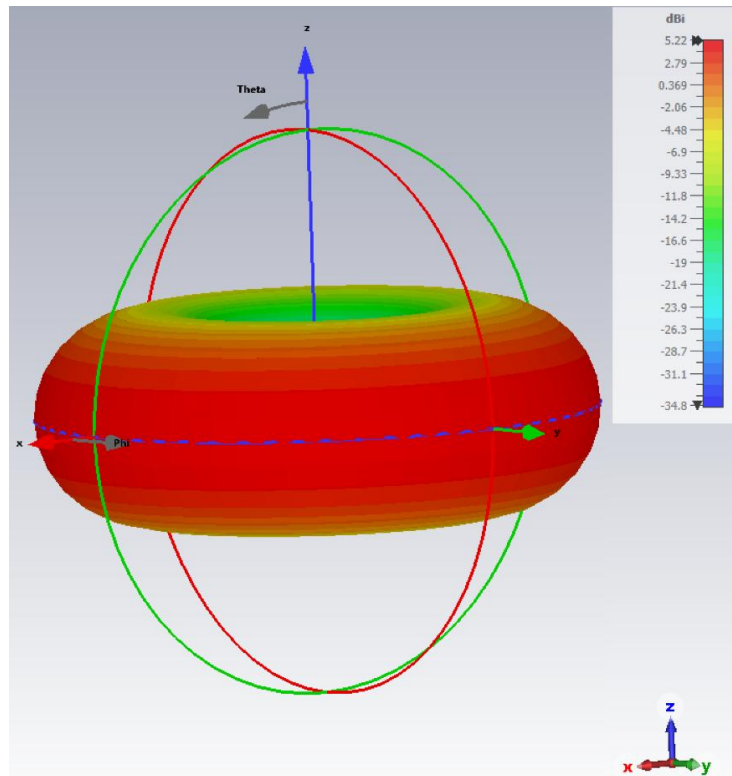


Fig. 4. Four element collinear antenna 3D plot

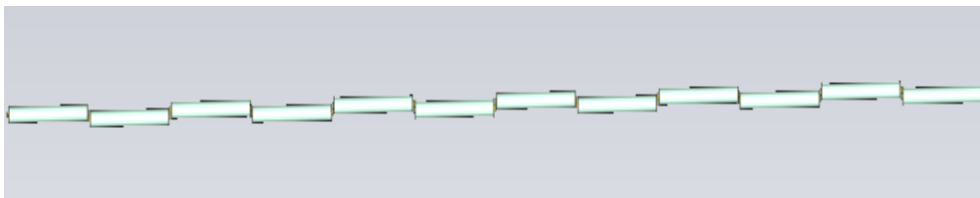


Fig. 5. Twelve element collinear antenna model

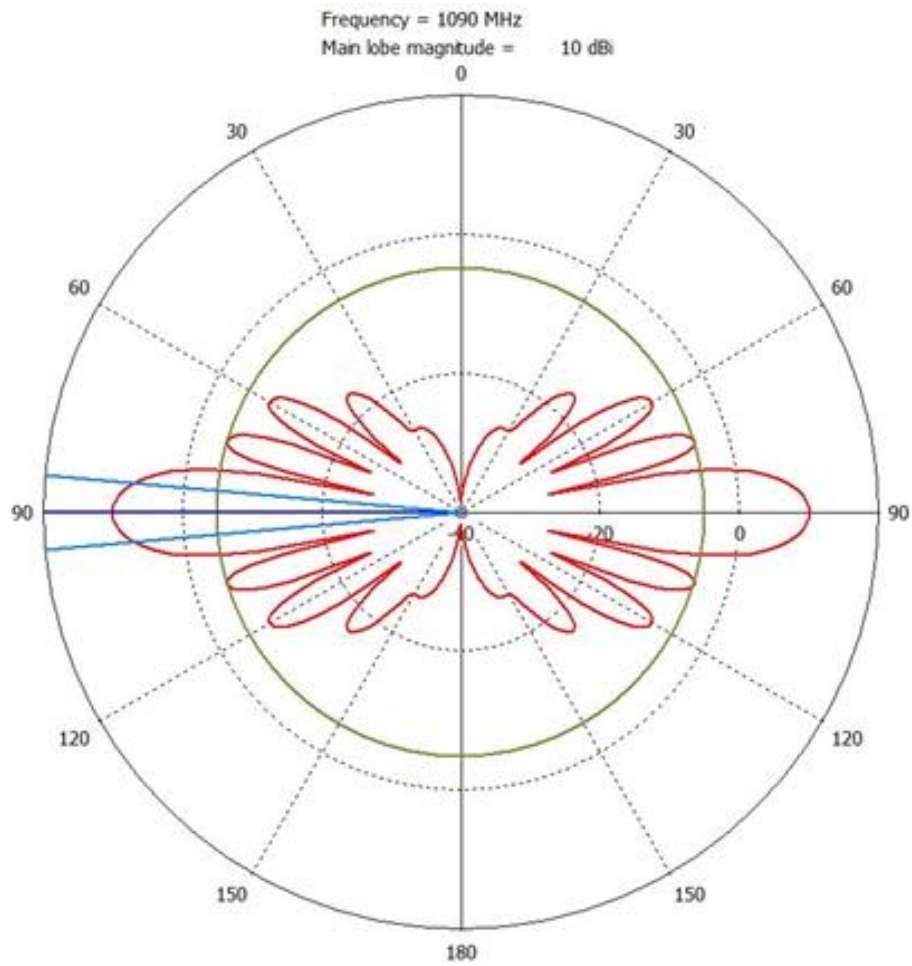


Fig. 6. Twelve element collinear antenna vertical plot

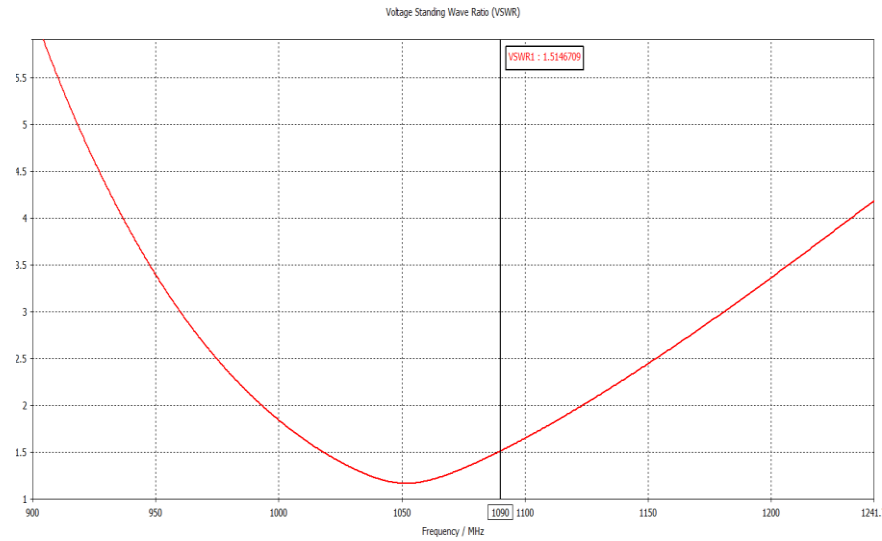


Fig. 7. Twelve element collinear antenna - Standing Wave Ratio

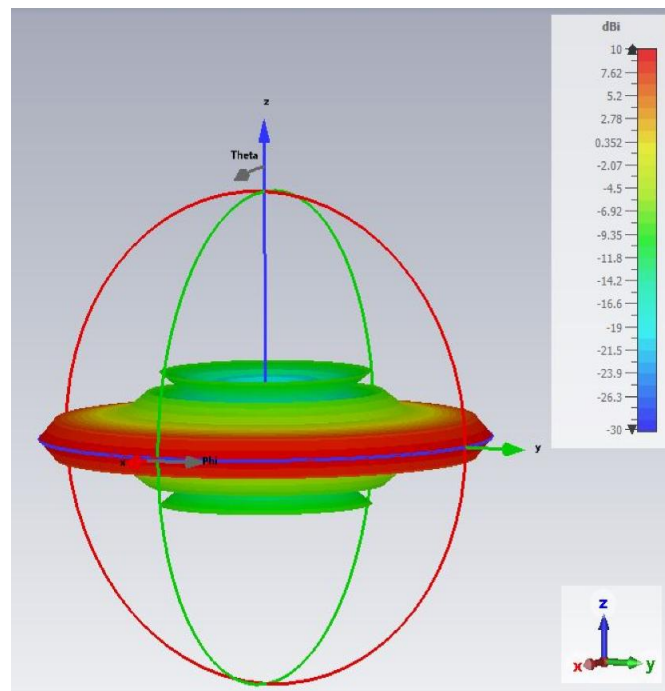


Fig. 8. Twelve element collinear antenna 3D plot

2. ANTENNA TESTS

Field tests of antennas were conducted on the roof of the 5 - storey block in Dęblin, Poland. The aim of the antennas tests is to illustrate the real range of the antennas which is directly connected with gain and standing wave ratio. These antennas are easily connected with a low - cost, commercial receiving device RTL-SDR V3, plugged into a laptop. Programs used to receive ADS-B system are: dump1090 (to decoding signals) and Virtual Radar Server (for range visualisation). The signals are received and decoded to show the locations of other planes [5]. Plots are created in Virtual Radar Server which marks the aircraft position and makes the line which then creates the range plot [6].

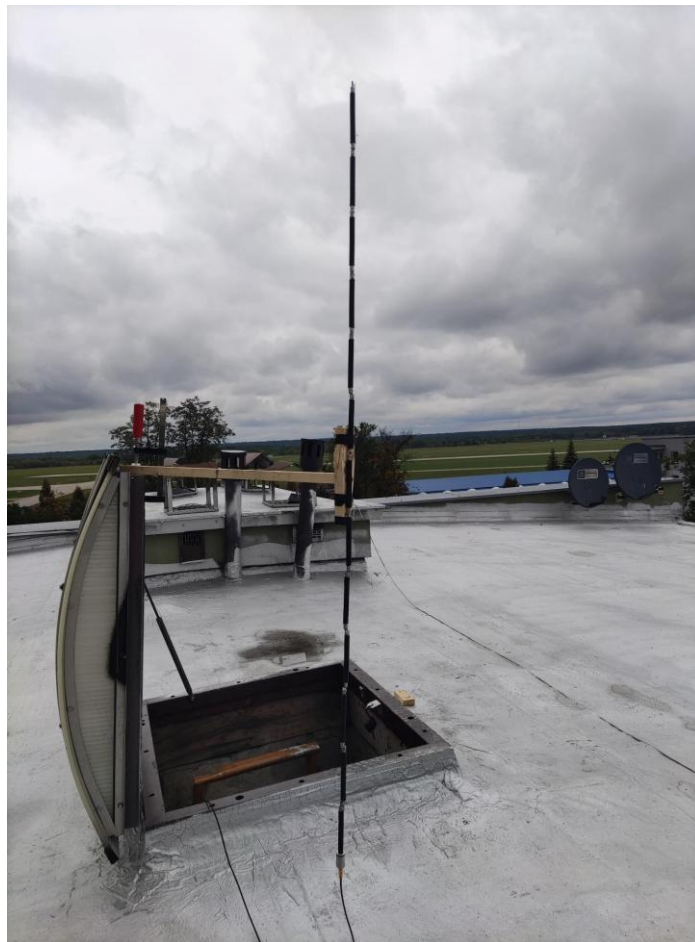


Fig. 9. Measurement stand for collinear ADS-B antennas

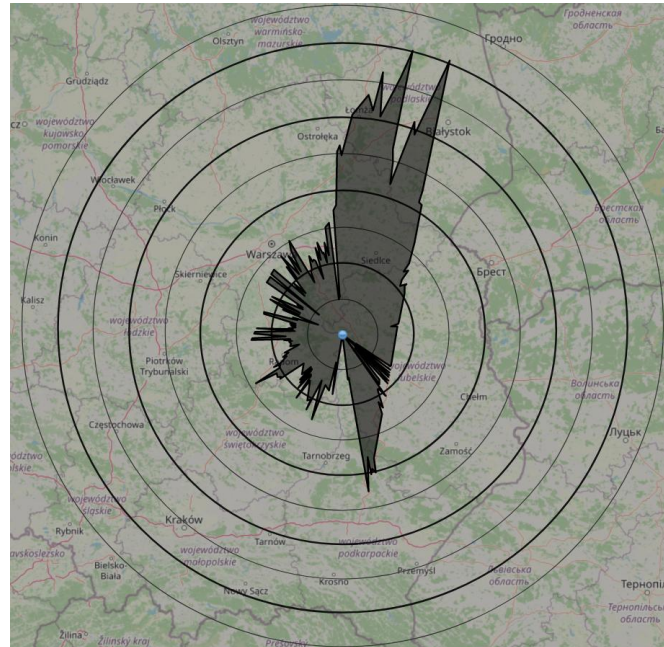


Fig. 10. Four element collinear antenna range



Fig. 11. Twelve element collinear antenna range

3. RESULTS AND CONCLUSIONS

The tests of the antennas confirm that they were projected properly. According to the radio waves theory four element antenna's plot should be similar to the dipole. Also gain is not good enough for receiving ADS-B system. Due to the high SWR, the 1090 MHz frequency matching is poor. Adding more elements causes higher antenna gain and better fitting to center frequency. It increases the power radiated and provides a highly directional beam according to the radio waves theory. But it also creates many side lobes, which creates blind spots where signal is not received. To sum up, the most suitable antenna for the ADS-B receiving should have high gain, low standing wave ratio and significant directivity in horizontal plot. A collinear antenna with many elements seems to be the best option for this system, which confirms the conducted research. The next stage of the ongoing work will be to create a microstrip collinear antenna to compare coaxial and microstrip constructions and performance.

Table 1. Antenna's performance comparison

Number of elements	Gain [dBi]	SWR	Maximal range [km]	Average range [km]
4	5.08	3.62	210	90
12	10	1.52	360	240

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