IMPACT OF ADDITIONAL ANTENNA ON ANTENNA COUPLING

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This paper deals with impact of additional antenna on mutual coupling of two VHF antennas. All the three antennas are tuned to the same constant frequency, placed on an idealized tail boom of a helicopter. The varied parameters are common distances of antennas and resistance of the additional antenna. It provides mainly the results of simulations, which were made on this subject, accompanied by real-life measures taken on an experimental model of tail boom.

K e y w o r d s: antenna coupling, helicopter tail, s-parameters, simulation, model

1 INTRODUCTION

In modern world aviation, many systems operating in radiofrequency spectrum are used. All these systems need antennas to be functional. Therefore, there are usually also many antennas placed on aircraft. Between every two antennas, there is some mutual coupling. It means that energy radiated from one antenna is received by another antenna. It's desirable in transmitter-receiver networks, but not in situations, where both antennas have to function independently from each other. In considered case, where each antenna belongs to different avionic system, mutual coupling effectively causes power losses. This problem is particularly significant on antennas of same frequency band. It is desired to have as low mutual coupling as possible. To find out how coupling of two antennas is changed with third antenna present, this paper was written. It is oriented on the VHF spectrum, which is widely used in aviation and it belongs to the most crowded spectrum. On long wide-body airplanes there's plenty of space for antenna placement. However, problem of correct antenna placement becomes more delicate on smaller structures. For this reason, a helicopter tail boom was chosen as structure, on which the antennas are mounted.

2 EXPLOITED THEORIES

2.1 Friis' formula

To get the idea how coupling depends on distance between two antennas in free space [1], Friis' formula can be used

$$P_r = P_t \, G_t \, G_r \left(\frac{\lambda}{4\pi R}\right)^2 \qquad (1)$$

As can be seen from the formula, the received power is determined by transmitted power, gain of both antennas and wavelength squared. What's most important in this case is that the received power is also determined by 1/R squared. In other words, the further the antennas are apart, the weaker their mutual coupling will be. Friis' formula can be also written in decibels

$$10log_{10}P_r = 10log_{10}P_t + 10log_{10}G_t + 10log_{10}\,G_r + 20log_{10}\left(\frac{\lambda}{4\pi R}\right) \qquad (2)$$

2.2 S-parameters

Scattering parameters, shortly called S-parameters, are used to describe power relationship between ports. In the considered case of two antennas, port of the transmitting antenna can be presented as port 1 and port of the receiving antenna as port 2. Then power received on port 2 relative to power transmitted on port 1 is called S21 parameter. If we look back to the Friis' formula, we can see it's the P_r/P_t ratio and therefore the S21 parameter will depend on distance between those two antennas. As the S21 parameter talks about how much power is received relative to power transmitted, it is ideal as a parameter for measuring mutual coupling of the antennas.

3 MEASUREMENTS OF COUPLING

3.1 Specifications

All simulations were made in simulation software tool FEKO v6.1. The purpose of this paper is to find out how antennas mounted on helicopter tail boom couple. Hence real dimensions of tail boom were simulated, specifically dimensions of Mi-17 helicopter tail boom. To simulate this tail boom, conductive cylinder of 6,4m in length and 0,8m in diameter was modelled. To simplify simulations, narrowing of the tail section was not taken into consideration. Frequency of 130MHz (wavelength 2,308m) was chosen for simulations, as it falls into aviation VHF communication frequency range. The antennas were chosen to be vertical monopoles with quarter wave length 0,577m. After setting up the simulation model, the S21 parameter between transmitting and receiving antenna was measured.

Similar situation to the simulated one was examined in [2]. A scaled-down model of a Mi-17 helicopter tail boom was used. It was 3,2 times smaller in diameter and in length, resulting into tube of 0,25m diameter and 2m length. This plastic tube was then coated with thin aluminium foil. Antennas were custom made, with SWR under 3:1 in frequency range of 350 – 450 MHz. They were used on frequency of 416MHz

(130MHz x 3,2). To measure coupling, spectral analyzer Arnitsu MS2711D was used.

3.2 Various distances between transmitting and receiving antenna

First type of measurements, let's label them measurements "A", was made with various distances between transmitting and receiving antenna, specifically 1,28m, 1,6m, 1,92m and 2,24m. In 3,2x scaled down dimensions it corresponds to 40cm, 50cm, 60cm, 70cm. Distance between transmitting and additional antenna remained unchanged during these measurements at 0,64m (20cm). This configuration can be seen in Figure 1.

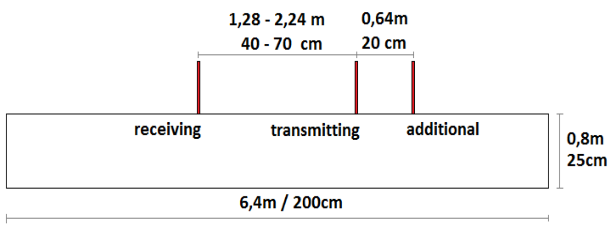


Figure 1: Configuration "A"

First measurement was made without the additional antenna, to provide reference. Then the additional antenna was installed and its load was set to 50Ω, 0Ω and ∞ Ω. Results of these measurements are in Diagram 1 for simulation and in Diagram 2 for real-life measurements.

Diagram 1: Simulation results "A"

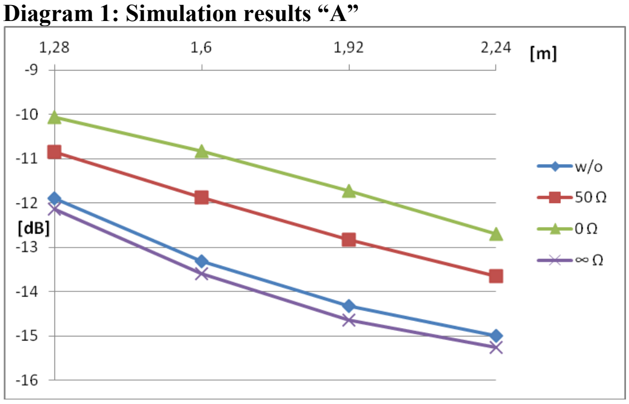
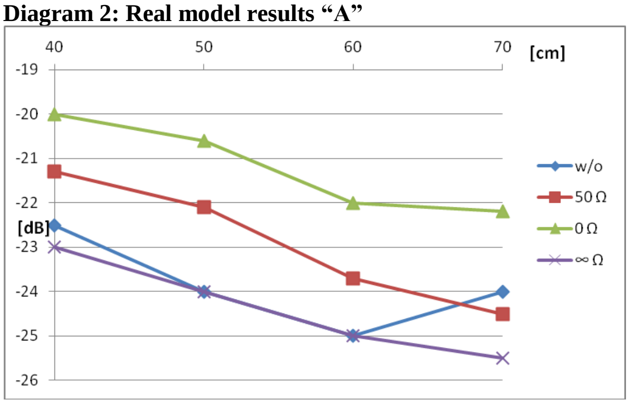


Diagram 2: Real model results "A"



3.3 Various distances between transmitting and additional antenna

Second type of measurements, "B", was made with distance between transmitting and receiving antenna being set to 0,64m (20cm) – in diagrams as "B1", to 0,96m (30cm) – in diagrams as "B2", and to 1,28m (40cm) – in diagrams as "B3". Distance between transmitting and additional antenna was varied from 0,64m to 1,6m with 0,32m step (20cm to 50cm with 10cm step). This configuration can be seen in Figure 2.

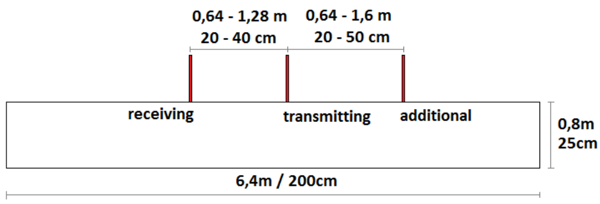


Figure 2: Configuration "B"

Load of additional antenna was chosen to be 50Ω. Results of measurements are in Diagram 3 for simulation and in Diagram 4 for real-life measurements.

Diagram 3: Simulation results "B"

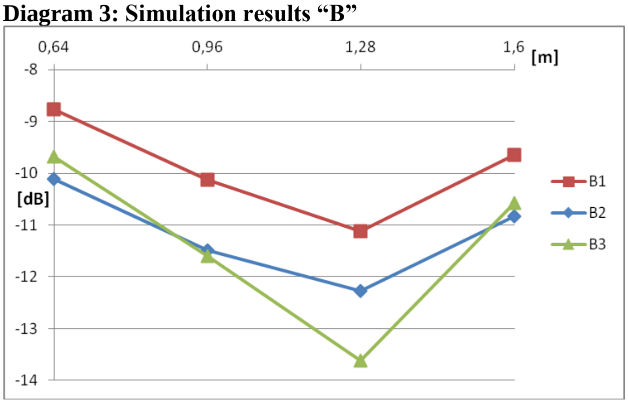
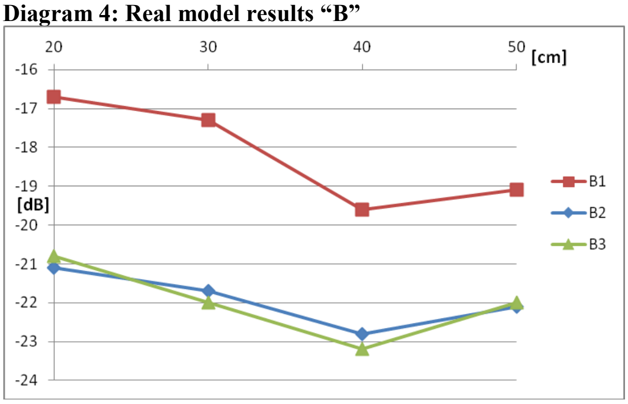


Diagram 4: Real model results "B"



3.4 Additional antenna placed between the transmitting and receiving antenna

Last type of measurements, "C", was made with additional antenna placed between transmitting and receiving antenna, where distance between receiving and additional antenna was 0,32m (10cm), and between receiving and transmitting antenna was 3,04m (95cm). This configuration can be seen in Figure 3.

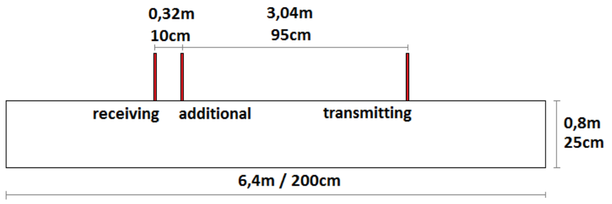
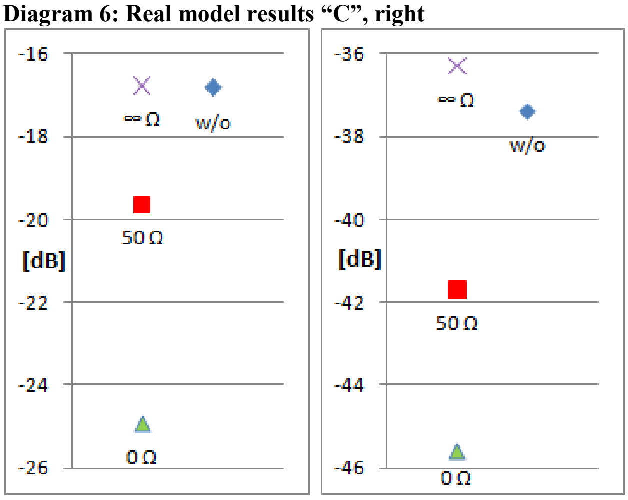


Figure 3: Configuration "C"

Measurements were made firstly without the additional antenna and then with additional antennas load set to 50Ω, 0Ω and ∞ Ω. Results are in Diagram 5 for simulation and in Diagram 6 for real-life measurements.

Diagram 5: Simulation results "C", left
Diagram 6: Real model results "C", right



5 CONCLUSION

From the "A" measurements one can clearly see the impact of the additional antenna. Coupling of transmitting and receiving antenna is about 1 – 1,5 dB stronger in case of the installed 50Ω additional antenna, compared to no additional antenna installed. Increasing transmitting-receiving antenna distance reduces coupling as expected.

From the "B" measurements can be seen impact of additional antenna as of a reflector. Reflector is most effective when it is placed in distance of (λ/4 + k*λ/2) from transmitting antenna, "k" being integer from zero higher, and least effective when placed (λ/2 + k*λ/2). At frequency 130MHz (λ=2,308m) it means that the minimal effect of reflector and hence weakest transmitter-receiver coupling can be expected around mutual distance of 1,154m between transmitting and additional antenna. This assumption is confirmed by Diagram 3.

Measurements "C". Because additional antenna is placed between transmitting and receiving antenna, power sent from transmitter reaches the additional antenna as first. The lower the resistance of this antenna, the more power is absorbed by it and thus making the coupling between transmitting and receiving antenna weaker.

By comparing simulation and real-life results it can be seen that graphs of functions look similarly. Nevertheless, there is an approximate offset of 10dB in measurements "A" and "B" and approximately 20dB in measurement "C". These offsets are probably caused mainly by non-ideal radiation pattern of real antennas and by lower conductance of the model surface.

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