Improving Performance of F-4 Aircraft UHF Communication Antennas by Antenna Placement

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Abstract—**In this study, electromagnetic analysis of two UHF communication antennas integrated on F-4 aircraft is performed to improve the operational performance of these antennas by arranging their placements [1]. In parallel with this, in order to see the influence of main structures (such as fuselage, nose, wings and tail) composing the F-4 aircraft on the electromagnetic coupling between two UHF antennas, analysis is carried out on three different F-4 models each of which is modified such that main structures composing the aircraft are removed one by one. Finally, for the optimal antenna placement, far-field radiation pattern performance of the lower UHF antenna is analyzed in terms of directivity and coverage to see whether that antenna has sufficient directivity and coverage values. Aircraft and antennas are modeled based on their real electrical and physical properties in Computer Simulation Technology – Microwave Studio (CST-MWS) simulation tool.**

Keywords— Antenna-to-antenna electromagnetic coupling, far field radiation pattern, antenna placement.

I. INTRODUCTION

Due to the electromagnetic coupling between the antennas of communication systems, EMI may occur between these systems in forms of adjacent channel interference and harmonic interference. Furthermore, due to the high electromagnetic coupling, these systems' RF input circuitry may be damaged. In order to ensure intra system EMC, the operational performance of these antennas shall be improved by arranging their placements for desired coupling levels. Moreover, for the optimal antenna placement, far-field radiation pattern performance of the antennas shall be analyzed in terms of directivity and coverage to see whether they are sufficient.

Electromagnetic analysis is performed by using transient solver of CST MWS so that the whole broadband frequency behavior of the antennas can be observed from only one simulation run [2].

II. ANALYSIS OF UHF ANTENNAS ON THE F-4 AIRCRAFT

In the analysis, the location of the upper UHF antenna is already fixed (antenna #1 in Fig.1), based on the conventional placement of upper UHF antennas mounted on F-4 aircrafts worldwide [3]. On the other hand, for the lower UHF antenna, four different locations (antenna #2, #3, #4 and #5 in Fig.1) are specified on the lower side of the fuselage of the aircraft, considering the physical and operational constraints of the aircraft.

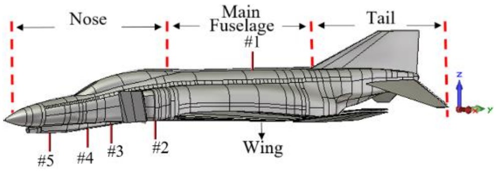

Fig.1 Locations of upper and lower UHF antennas on F-4 aircraft

A. Analysis of Antennas on Different F-4 Models

Two criteria are followed in determining the optimal location of the lower UHF antenna among four different locations

1. Electromagnetic coupling between the lower and upper UHF antennas shall be minimum.
2. Far field radiation pattern of lower UHF antenna shall have sufficient directivity values in its frequency band of operation at its optimal placement.

In parallel, to gain insight about effect of the structural components such as fuselage, nose, wings and tail (Fig.1) composing F-4 aircraft, on the coupling between UHF antennas, three modified F-4 models are created each of which is modified such that main structures composing the aircraft are removed one by one as in Fig.2, 3 & 4 and analyses are performed on these modified models (MODEL I, II and III).

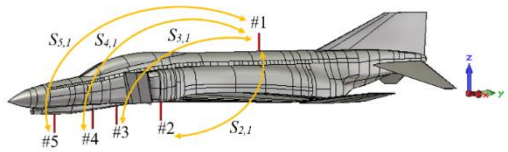

Fig.2 MODEL I: F-4 aircraft (Original Model)

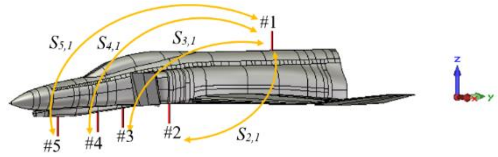

Fig.3 MODEL II: F-4 aircraft without Tail

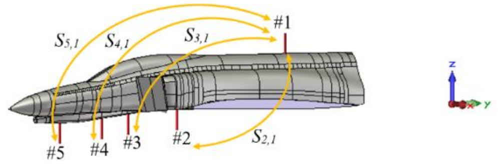

Fig.4 MODEL III: F-4 aircraft without Wings and Tail

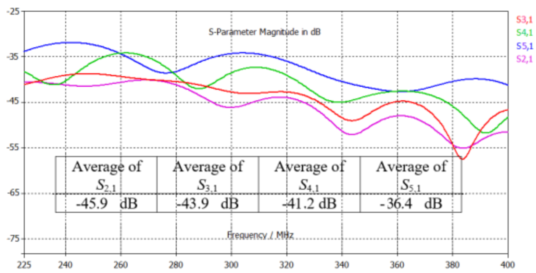

Fig.5 Coupling levels for four different locations of the lower UHF antenna on MODEL III: F-4 aircraft without Wings and Tail

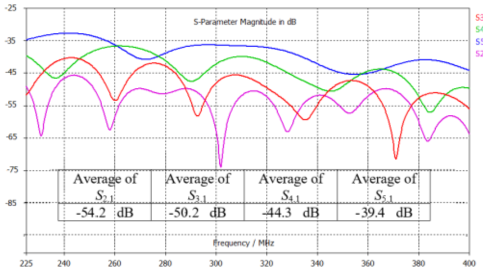

Fig.6 Coupling levels for four different locations of the lower UHF antenna on MODEL II: F-4 aircraft without Tail

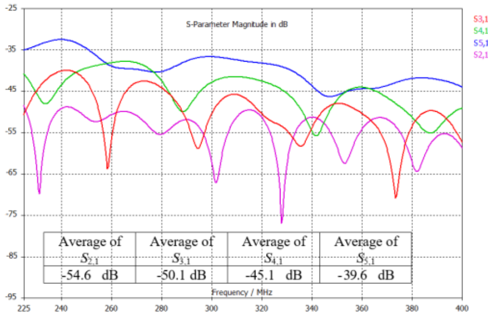

Fig.7 Coupling levels for four different locations of the lower UHF antenna on MODEL I: F-4 aircraft (Original Model)

To sum up:

- Average values of coupling levels between the lower and upper antennas increases gradually as the location of the lower UHF antenna changes from the location of antenna #2 to antenna #5. This is because; the effectiveness of the electromagnetic blockage caused by the F-4 aircraft against the radiation of the lower and upper UHF antennas towards each other is lower at the location of antenna #5 when compared with that of antenna #2.
- Average values of coupling levels between the lower and upper antennas obtained for MODEL I is considerably lower than that of MODEL III. Namely, electromagnetic blockage caused by large wings and long tail of aircraft provide a considerable decrease in the average values of coupling levels between the lower and upper antennas.
- Consequently, location of antenna #2 is determined as the optimal location for the lower UHF antenna among these four different locations.

B. *Far-field radiation pattern performance of the lower UHF antenna at its optimal placement*

For the optimal antenna placement (antenna #2), far-field radiation pattern performance of the lower UHF antenna is analyzed (Fig.8). in terms of directivity and coverage to see whether that antenna has sufficient directivity and coverage values.

In accordance with this purpose, at 300 MHz, the 3D far field radiation pattern of the lower UHF antenna (antenna #2) is compared with the 3D far field radiation pattern of a monopole antenna on an infinite ground plane (Fig.9) having the same electrical and physical properties with lower UHF antenna, in the angular region $90° \leq \theta \leq 120°$ (the region where the lower UHF antenna has to operate efficiently) as follows:

- At least 90 % of the directivity values of the far field radiation pattern of the lower UHF antenna in the angular region $90° \leq \theta \leq 120°$, shall be greater than those of the monopole antenna above infinite ground plane minus 10 dB.
- At least 70 % of the directivity values of the far field radiation pattern of the lower UHF antenna, in the angular region $90° \leq \theta \leq 120°$, shall be greater than those of the monopole antenna above infinite ground plane minus 6 dB.

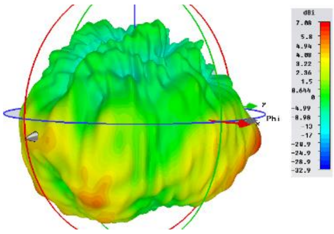

Fig.8 3D far field radiation pattern of antenna #2 lower UHF antenna

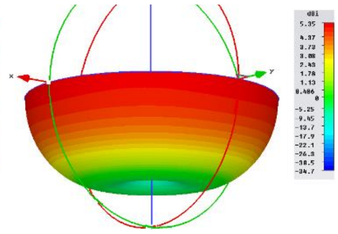

Fig.9 3D far field radiation pattern of a monopole antenna on an infinite ground plane at 300 MHz

- After the comparison, it is seen that 100 % of the directivity values of the far field radiation pattern of the lower UHF antenna in the angular region $90° \leq \theta \leq 120°$, is greater than those of the monopole antenna above infinite ground plane minus 10 dB.
- After the comparison, it is seen that 96,7 % of the directivity values of the far field radiation pattern of the lower UHF antenna in the angular region $90° \leq \theta \leq 120°$, is greater than those of the monopole antenna above infinite ground plane minus 6 dB.

III. Conclusion

In conclusion, among four different antenna placements, location of antenna #2 is determined as the optimal location for the lower UHF antenna.

In section *A*, analysis is carried out on three different F-4 models each of which is modified such that main structures composing the aircraft are removed one by one, in order to see the influence of main structures (such as fuselage, nose, wings and tail) composing the F-4 aircraft on the electromagnetic coupling between two UHF antennas.

For the optimal antenna placement, far-field radiation pattern performance of the lower UHF antenna is analyzed in terms of directivity and coverage. It has been concluded that, antenna #2 has sufficient directivity and coverage values when compared with a monopole antenna on an infinite ground plane having the same electrical and physical properties.

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