Emission of Electromagnetic Disturbances from Coupling Paths of Avionics Unmanned Aerial Vehicles

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Abstract—In paper an approach for the investigation of the emission of electromagnetic interference from coupling path avionics UAV is discussed. In work the unmanned aerial vehicle which made of composite material is discussed. A practical example study emission of electromagnetic disturbances from the coupling path of supply mains and of interfaces of control system is discussed.

Index Terms—Emission of electromagnetic disturbances; electromagnetic compatibility; unmanned aerial vehicle; composite fuselage

I. INTRODUCTION

The current stage by development of the aircrafts is characterized by the widespread introduction of automated technical systems. Most high-level of automation achieved an unmanned aerial vehicle (UAVs), which is caused by the wide use of remote and automatic control systems. The main attribute which largely determines the quality, reliability, functional safety and radio electronic protection of the UAV is electromagnetic compatibility (EMC). Violation EMC of avionics that is included into UAV, can lead to lower quality of functioning or irreversible failure. Under the EMC of avionics is meant, how it operates in accordance with the required specifications in the real electromagnetic environment (caused by electromagnetic interaction or by impacts), without creating inadmissible electromagnetic disturbances in other equipment of UAV.

The high level of automation of UAVs is achieved by the massive use of electronics to control actuators and the introduction of automated command and control systems on the basis of modern element base which have low signal levels and supply voltages. This making an automated system is more susceptible to electromagnetic interactions. The composition an avionics UAV characterized by the simultaneous use of analog, digital and RF devices operating over a wide frequency range (up to several gigahertz) voltages and currents that leads in expansion of paths electromagnetic interactions. All this obviously leads to deterioration in the electromagnetic environment and to difficulties in ensuring EMC.

Along with increasing the level of automation in the aeronautical engineering there is a steady tendency to reduce the weight and increase the strength of the aircraft fuselage. These characteristics of aircrafts was being achieved by using the of composite (carbon fiber and fiberglass) materials. However, the improvement of some characteristics of the aircraft obviously leads to a deterioration of other. The use of the aircraft fuselage on composites based (completely or partially) obviously complicates the ability to ensure EMC of avionics. The parameters of composite material characterized by low electrical conductivity, by low shielding effectiveness, high anisotropy, etc.

The problem of research EMC is acquired the greatest urgency for the UAV. This fact is due to the need for reliable operation in the limited space of the composite fuselage of a large number of electrical, electronic and radio-electronic systems. To study the EMC is first necessary a determine level of the electromagnetic environment near the UAV and in the space of fuselage which is caused by the operation of avionics. One of the main sources of electromagnetic disturbance in space of fuselage UAV is the emission of electromagnetic disturbance that characterized by radiation of coupling path under operation of avionics. Coupling paths like antennas emit electromagnetic fields is created a bad of electromagnetic environments.

Great contribution to the solution of problems related to research of the emission of electromagnetic disturbance from coupling path and the blocks electronic equipment was made by Russian scientists [4, 5]. Among the foreign authors in the first place it should be noted in [6, 7, and 8]. In those papers describes the theoretical and experimental methods for studying emission of electromagnetic disturbance by the operation of technical systems. The basis of the, as a rule, make up the experimental and analytical research methods. To investigate the emissions of electromagnetic disturbance also apply electrodynamic modeling techniques with a significant simplification of the research object. In this papers a recommendations for reduced emission of electromagnetic disturbance on the basis applications of basic approaches ensuring of electromagnetic compatibility are being discussed. A wide range of work is of a purely practical nature describing
the experience of research EMC under emission of electromagnetic disturbance from devices or systems of a particular type. The problems of study emission of electromagnetic disturbance from avionics UAV were not adequately reflected in the scientific and technical literature.

The aim of this work is to study of emission of electromagnetic disturbance from communication lines and their impact on the operation of avionics UAVs. Examples are considered interfaces forming the control system and the power network of UAV.

We can distinguish two aspects of the problem of the effect of the emission of electromagnetic disturbance on avionics UAVs. The first is founded on study of the electromagnetic environment from radiation of the coupling path of supply mains and of interfaces. This information can be useful in determining optimal locations placement of avionics. The second aspect is related to the impact of radiations on a radio link of control system UAV from emission the coupling paths of supply mains and of interfaces.

II. METHODS AND MODELS FOR RESEARCH

A. Research Methods

Research of emission of electromagnetic disturbance from avionics UAV can be carried out by methods based on analytical calculations, experimental studies and electromagnetic simulation. Analytical methods do not allow taking into account a number of factors affecting the prediction accuracy. Experimental studies are applicable only in the later stages of the UAVs design, which essentially does not give the opportunity to predict the EMC. To predict of emission of electromagnetic disturbance from avionics UAV we propose to use the software implementation of numerical methods based on the simulation models development. As a predicting tool we proposed to use the electromagnetic field simulation program: Microwave Studio, FEKO etc. These programs mainly use grid methods: the finite element method, the finite difference method in the time and frequency domain, the TLM method, the finite integrals method [9]. Last research, performed by the authors [10, 11, and 12], and a comparison of the forecasting results of EMC with the use of an electromagnetic simulation-based approach for similar problems with the experimental data show differences not more than 15%, with full and correct description of research objects.

B. Research Models

In work the study conducted UAV at which fuselage and empennage are made of composite material. In work considered the UAV with the following parameters: length - 3100 mm, wingspan - 3180 mm; width and height of the fuselage - 380 mm, material thickness 5 mm, the type of material are layered composite (CFRP). The parameters of the material can describe by the Debye formula (settings on the frequency of 1000 MHz: dielectric loss tangent - 3; electric conductivity - 1.5 S/m, the dielectric constant of - 7.5). The antenna of radio modem: quarter-wave vibrator located in the aft section of fuselage (Fig. 1). Radio modem parameters: frequency of 2.4 GHz, the receiver sensitivity of -90 dBm.

The structure of the UAV control system is based on the RS-485 interface is discussed. By means of converters and pulse-width modulation from interface RS-485 control signals is received to the actuators (Fig. 2). Interface RS-232 is used for communication of control unit with the radio modem.

a) Interface RS-485: The total length of 9354 mm coupling path of interface (cable FTP 4-cat5E). In modeling of the interface RS-485 coupling path on ends equivalent load 120 ohm is connecting. In each location the transducer connection (peripheral interface controller RS-485) is connected source signals corresponding to the passport characteristics of the interface. In this paper we investigate the worst case of simultaneous transmission by the interface information so that is activated all controllers. Also at the of coupling path of to the second pair of the cable is connected power supply the peripheral controllers.

b) Interface RS-232: Length 1863 mm lines to connect radio modem (cable FTP  4-cat5E). In the case of the RS-232 interface to one end of the coupling path is connected the signal source in accordance with specifications of the interface, and to other end of the coupling path - a equivalent load 120 ohm.
c) *Pulse width modulation (PWM)* is used to control the actuators via a converter of interface RS-485 (three wires diameter 0.12 mm). The each set of wires connects the converter and actuator, to one end of a set of wires is connected the voltage source in accordance with the instructions (5V; TTL) by another equivalent load of 50 ohms.

d) *Avionics power supply:* At the physical level is presented by of two wires of diameter 0.14. The supply voltage of avionics is 12 V.

e) *Chain of power supply engines:* At the physical layer is presented by two wires AWG 8. Supplied voltage engines of 60 V.

The paper the distribution of the electric field from emission of electromagnetic disturbance of the coupling paths of supply mains and of interfaces is calculated. The intensity of the electromagnetic field which produced by emission of electromagnetic disturbance of the coupling paths in space fuselage UAV are calculated at the points presented in the Fig. 3

![Diagram of UAV](image)

**Fig. 3.** Points calculation of the electromagnetic field in the space within the fuselage of UAVs

In work the simulation model UAV for research emission of electromagnetic disturbance from coupling paths avionics are developed. The model takes into account the geometric and electrical parameters of the UAV, namely the location of the avionics units in the UAV; parameters of material fuselage and empennage UAV; location of antenna systems; geometric and electrical parameters of coupling paths and their geometry of pads on UAVs; time and amplitude parameters of interface signals and the level of devices supply voltage.

**III. RESULTS**

**A. Research results of electromagnetic environment**

The distribution of the electric field in the space of UAV at emission of electromagnetic disturbance from coupling paths of supply mains and of interfaces is being shown in Fig. 4.

![Distribution of the electric field at the UAV](image)

**Fig. 4.** Distribution of the electric field at the UAV

At emission of electromagnetic interference from coupling paths in space of fuselage UAV is observed a complex electromagnetic environment. The maximum values of the electric field are observed at the points with the greatest number of communication lines in the center and in the wing UAV. The highest value of the electric field is observed in point’s №4, №8 and №14. In these points the electric field strength exceeds the minimum levels set by regulations. It should be noted that the maximum electric field is observed in the compartments with a compact arrangement of coupling paths of pulse-width modulation that connect a peripheral controller and an actuators.

The maximum value of the electric field is observed at point №14, and reaches 161 V / m (Fig. 6).

![Distribution of the electric field strength at the UAV](image)

**Fig. 5.** Distribution of the electric field strength at the UAV

The electromagnetic wave is formed in the space fuselage UAV has a complex shape due to the influence of emissions at the same time a few coupling paths. Major fluctuations in the electromagnetic waves correspond to 1.5 GHz.
IV. RESEARCH RESULTS AND DISCUSSION

A comparison of the requirements of normative - technical documents [13] with the calculated values of the electric field shows that the levels of the electric field in space of fuselage UAV is achieved high values at the emission of electromagnetic disturbance. This can lead to a breach of the quality of functioning of UAV avionics at not complying with the requirements of special regulations developers’ equipment.

To improve the electromagnetic environment in space of fuselage UAVs is need to provide shielding lines pulse width modulation at level at least 60 dB. The cable channels can be used for this purpose. In addition, electromagnetic interference can be reduced by using filters and modal decomposition of signals [14, 15].

The levels of electromagnetic interference in the antenna path radio modem reach values in the amplitude of 0.06 V, the fundamental frequency of the oscillation corresponds to a frequency of 0.4 GHz. The level of electromagnetic interference at the frequency of operation is -164 dBm. The level of sensitivity of the radio modem -90Dbm respectively breach of the functioning of the quality of the radio link as a result of the emission of electromagnetic interference will not occur. Also the radio modem will operate at a frequency of electromagnetic noise (-135 dBm). However, this electromagnetic interference must be taken into account in the study of the emergence of cumulative effects.

V. CONCLUSION

According to the results of the work can be done the following conclusions:

a) An approach for the investigation of the emission of electromagnetic interference from coupling path avionics UAV is discussed.

b) A simulation model of UAV and its elements which allow predicting the electromagnetic environments in the space of fuselage and electromagnetic interference in the antenna-feeder paths at the emission of electromagnetic disturbance from coupling path of avionics. At the same time model takes into account the parameters geometric detail, structural and electrical parameters of the UAV (the location of the electronic equipment units in UAVs, material parameters UAV, geometry parameters of cables and their installation).

c) Research in the electromagnetic environment in space of fuselage UAV at the emission of electromagnetic disturbance is show that the predicted calculated levels of electromagnetic field strength are reach 161 V/m. Comparison of these levels with the requirements of regulatory documents is shows that the EMC of avionics UAV will not be d. In this connection, you must use the engineering methods provide EMC.

d) The levels of electromagnetic disturbance in the antenna path radio modem reach values in the amplitude of 0.06 V, the fundamental frequency of the oscillation corresponds to a frequency of 0.4 GHz. The values obtained of electromagnetic disturbance in the antenna path shows the lack of influence.
REFERENCES


