The hexapod robot for aircraft fuel tank and the use of calculation in the analysis of the effectiveness of radio interference

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Abstract: *This paper focuses on the use of calculation for analyzing the effects of radio interference associated with the entry into the aircraft fuel tank of the hexapod robot. The analysis will help to demonstrate how the mobil robot will interact with the work environment. There are number of advantages from this automation to make the job of the human factor easier and to work in a safe environment by protecting both equipment installed on the aircraft and the hexapod robot.*

Key Words: *Hexapod robot, Interaction, Calculatios, Aircraft, Fuel tank, Radio interference*

1. INTRODUCTION

The hexapod robot has been designed to perform inspections inside the aircraft's fuel tank. For a robot that is inspecting an aircraft's fuel tank, the platform was designed for high torque and for low speed applications. The mechanical design is advantageous due to its modular, compact and robust design. The robot has a compartment inside the frame which provides a safe place for cameras and power supply.

In order to perform this inspection, one important thing was to analyze the working environment, not only the interior of the fuel tank but also the equipment installed on the aircraft with which the robot can interact.

Starting with the definition of the radio interference which is: "the effect of unwanted energy due to one or an combination of emissions, radiations or inductions upon reception in a radio-communication system manifested by any performance degradation, misinterpretation or loss of information which could be extracted in the absence of such unwanted energy" [2], a scenario can be drawn that is not good for both the hexapod robot and for the equipment installed on the aircraft.

It must be specified that during the inspection inside the fuel tank the airplane is not connected to an electrical source, in other words, the airplane is closed, but the hexapod robot can interact easily with other elements in the work environment. Due to this situation, the paper focuses on the use of calculations to see what is the effectiveness of the radio interference and to what situations the hexapod robot is exposed.

2. GENERAL DESCRIPTION OF THE HEXAPOD ROBOT – A.F.T.R.H.

The hexapod robot – A.F.T.R.H. (Aircraft Fuel Tank Robot Hexapod) (figure 1) is an extension of the fixed robot in terms of degrees of freedom. The mobile manipulator is a remote-controlled vehicle operated by an operator from a control panel, with the possibility to view and control its movements.

The hexapod robot performs complex operations for which locomotion is indispensable; it has a broad capability in the field of special works that pose a danger to humans. In this case, the hexapod robot AFTRH needs to enter in the aircraft fuel tank because of a large number of inspections and changes that should be done to the aircraft fuel tanks and their adjacent systems. Due to its characteristics, the robot can easily get inside the fuel tank of the aircraft and the operator can guide the robot from outside to facilitate its aircraft maintenance activities.

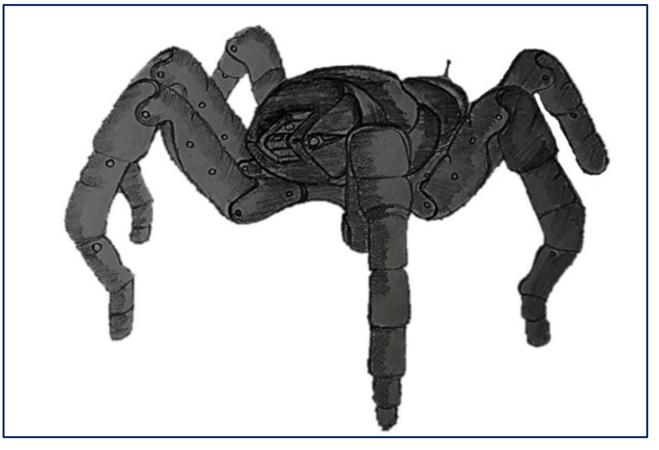

Figure 1. - Hexapod Robot-AFTRH

The hexapod robot - AFTRH has a structure consisting of:
→ mechanical system;
→ localization system;
→ system of environmental perception;
→ information handling and task management system.

The only task of the hexapod robot is to search and track the trajectory for inspecting surfaces inside the aircraft fuel tank. Its operation in the aircraft fuel tank is defined by agility and maneuverability.

Agility is the ability of the hexapod robot to pass obstacles, and maneuverability is defined by the minimum surface required to handle it.

The hexapod robot used in inspections inside the fuel tank has the following characteristics:
→degree of freedom: allows to track various trajectories in terms of shape, length and number of stopping points;
→travel speed: ranges from 1 to 10 m/s, as it works in the surrounding or outside environment;
→autonomy: reffers to the dependence on its own energy sources (accumulators);
→remote command and automation of operations.

The projected hexapod robot - AFTRH is defined as a mobile platform type, platform with legs and multiple sensors, on which video cameras are mounted. The entire assembly composing the hexapod robot is able to move with a certain degree of autonomy in an unfavorable environment to humans, under the control of a multiprocessor hierarchical computing system.

The Subsystem Sensor will allow real-time updating of the current environment configuration information and the identification of internal operating conditions, thus enabling on-line generation and modification of motion trajectories and workflows [3-6]. The tasks that the robot control system must perform are [5]:

→acquisition of information from external sensors;

→providing data from sensors of a different nature, interpreting and processing this information;

→the decision, based on previous training, identifying previous behaviors and combining action responses to construct aggregate behaviors;

→generating motion controls in the "look/ sense - and – move" navigation mode, avoiding collisions with unknown obstacles on the move.

In addition, the control system must in particular cases perform additional functions [5], [6]:

→modeling the environment, based on the merging of different sensory information as nature;

→trajectory corrections to target/ target area;

→immediate response to orders received on higher levels;

→clearing errors and recovering from error mode;

→maintaining an on-line status information communication with the user via a human-machine interface.

This increase in the complexity of tasks involves the need to equip the robot with a control reagent, based on the multimaster type behavior and multitasking operating system (control stand). Figure 2 shows the schematic diagram of the control system, together with the user interfaces and the workspace of the hexapod robot.

User Interface: This module will perform the task specification. For this purpose, the interface will allow to configure the following parameters [3-8]:

→mode of operation of the system: teleoperation, semi-autonomous and autonomous;

→type of motion performed in teleoperation mode: motion in translation and rotation speed increments, motion in increments of distance traveled and orientation of the hexapod robot platform;

→navigational task parameters: initial position (position + orientation) and desired final location;

→trajectory-associated function: minimum distance and minimum change of direction.

The second function of the user interface is to supervise the movement of the robot. For this purpose, the interface must receive and display the following information[3], [5], [6]:

→ all parameters specified and confirmed by the execution of that task;

→ the rotation and current translation speeds, the current position and orientation of the robot relative to a user-defined reference system;

→ data from sensors;

→ the current state of battery loading from the hexapod robot platform .

The control block will contain the following specialized modules:

→ work environment modeller;

→ the planned control unit;

→ communication modules;

→ the supervisor;

→ reactive control unit.

The environmental modeler: progressively divides the workspace into smaller rectangular small cells and at the same time establishes an index associated with each of them. This index is the probability that the cell will be occupied.

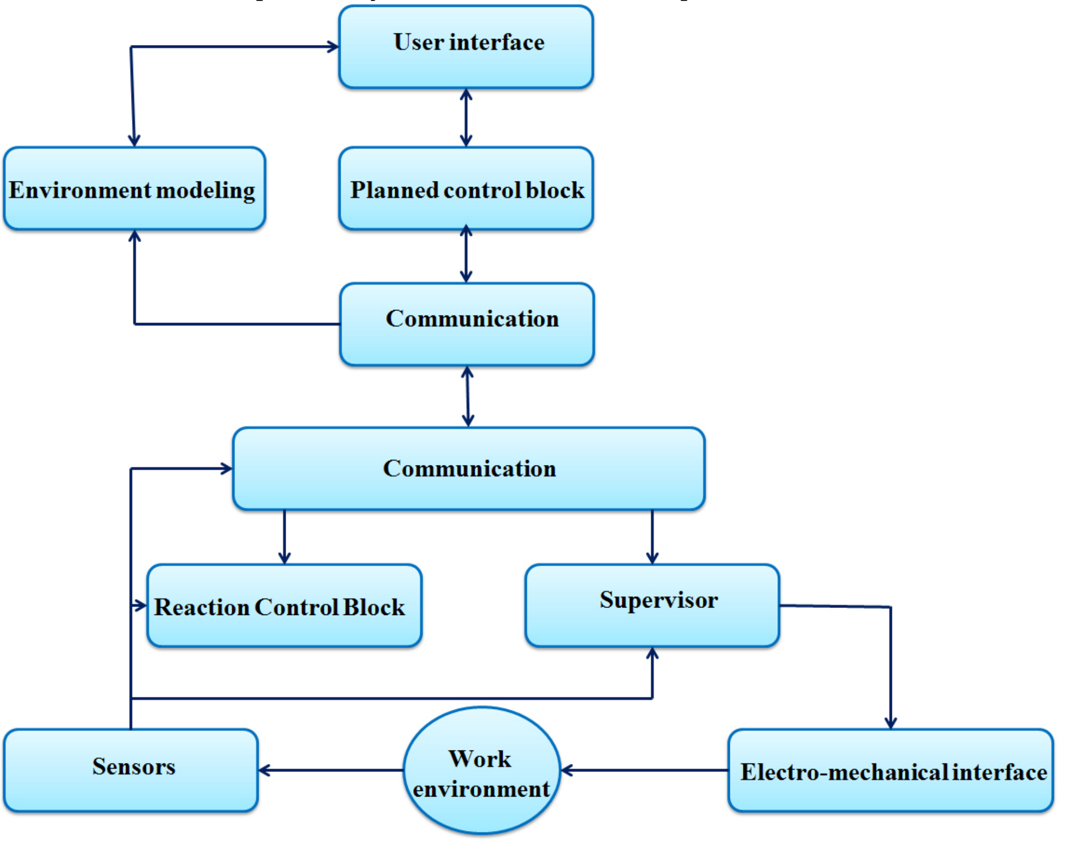

Figure 2. - Structure diagram of the control system, together with the user interface and the workspace of the hexapod robot – AFTRH

3. USE OF THE CALCULATION TECHNIQUE IN THE ANALYSIS OF THE EFFECTIVENESS OF RADIO INTERFERENCE

Many components of an aircraft are possible sources of electrical interference which can deteriorate the performance and reliability of avionics components [9]. Rotating electrical devices, switching devices, ignition systems, propeller control systems, AC power lines, and voltage regulators all produce potential damaging fields [9]. The hexapod robot – AFTRH can easily interact with all of these.

Radio frequency interference (RFI) is defined as: “the effect of unwanted energy due to one or an combination of emissions, radiations or inductions upon reception in a radio-communication system manifested by any performance degradation, misinterpretation or loss of information which could be extracted in the absence of such unwanted energy” [2], [10]. The continuous increase in the number of radio resources that simultaneously participate in a modern action imposed by the diversification to the same extent of the means of counter-action radio-electric. The optimal use of these means can only be made by knowing the parameters governing the effectiveness of the interference and how it is varied during the “scenario” (how the robot will manifest inside the fuel tank of the aircraft is just one of many other questions). This article try to determinate de interference zone between the robot and the aircaft by calculation and to see the relationship between the radio interference and the hexapod robot.

Within a complex interference research system, the interference efficiency calculation program plays the lead role.

This program presents aspects of the analysis of the “efficacy area” of an isotropic interference emitter over a radio link (transmitter-receiver) [1-3].

►Determination of the neutralization zone

The “optimal interference” for each mode of a radio link is that interference is capable of neutralizing the useful signal under a minimum ratio between the signal strength of the interference and the signal strength of the link. For each type of interference transmitter, determine the area where optimal interference that is called the “neutralization zone” may occur [1], [4].

From the possible cases, it is chosen that of a fixed interference which acts on a radio link, made with a fixed emitter and a mobile handset.

The coefficient of necessary interference, for which effective interference takes place, has the value [1]:

$$K_{Bnec} = \left(\frac{P_B}{P_L}\right)_{\min} = \left(\frac{U_B^2}{U_L^2}\right)_{\min} \qquad (1)$$

Determining the points where the coefficient of intereference is at the input (K_{Breal}) of the receiver is equal to the required interference rate; it will be possible to draw out contours of effectiveness for different scenarios of the radio-electric [1]. It is considered the arrangement of the respective means according to figure 3, in which:

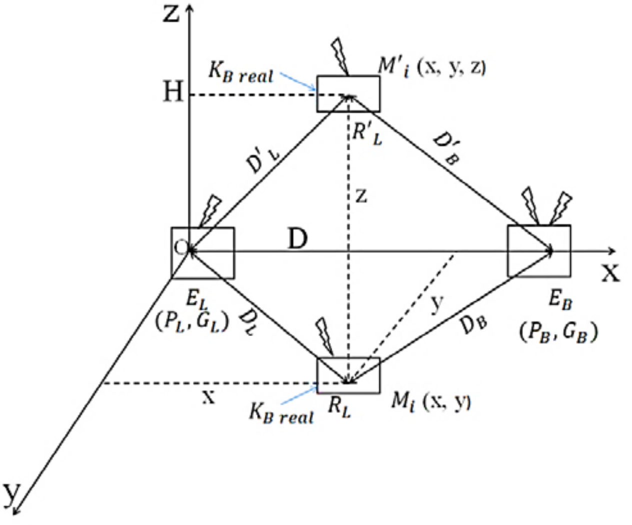

Figure 3. - Determining points [1]

- the receiver may be on the ground, R_L at a point $M_i(x, y)$ or at a certain height $R_L^{'}$ at the point $M^{'}(x, y, z)$;

- the transmitter (E_L) is considered to be the origin of the coordinate axes;
- the interference emitter (E_B) is on the ground;
- D_B, D_L, D - the distances interference, connecting and / between transmitters.

Is consider the situation in that the xOy plane and determine the geometric location of the points K_{Bnec} with [1], [3], [6].

It is supposed that $M_i(x, y)$ to be a point where the parameters of the transmitter E_B can do K_{Bnec}.

Without committing large errors, you can use the formula [1]:

$$K_{Bnec} = \left[\frac{P_B \cdot G_B \cdot G_{RB} \cdot B_L}{P_L \cdot G_L \cdot G_{RL} \cdot B_B}\right] \cdot \frac{D_L^2}{D_B^2} = K \frac{D_L^2}{D_B^2} \tag{2}$$

where: G_B, G_L - the earnings of the transmitters; E_B and E_L; G_{RB}, G_{RL} - earnings receivers R_B and R_L. R_L, $R_B =$ receiver bandwidths of the R_L and R_B. [1]

Because no advantage is anticipated from limiting the ratio to a value below the receiver bandwidth, it is considered [1]:

$$\left.\frac{B_L}{B_B}\right|_{\max} = 1 \tag{3}$$

Therefore

$$\frac{D_L}{D_B} = c \tag{4}$$

Therefor $M_i(x, y)$ represents a general point where it is achieved K_B. The derived condition for the geometric location of the points where it is made K_{Bnec} is that the report $\frac{D_L}{D_B}$ to be constant [1].

Figure 3 shows [1]:

$$D_L = \left(x^2 + y^2\right)^{\frac{1}{2}} \tag{5}$$

and

$$D_B = \left[\left(D - x^2\right) + y^2\right]^{\frac{1}{2}} \tag{6}$$

From (6) it follows [1]:

$$\frac{\left(x^2 + y^2\right)^{\frac{1}{2}}}{\left[\left(D - x^2\right) + y^2\right]^{\frac{1}{2}}} = c \tag{7}$$

which through appropriate transformations becomes [1]:

$$\left(x+\frac{Dc^2}{1-c^2}\right)^2+y^2=\frac{D^2c^2}{\left(1-c^2\right)^2} \tag{8}$$

Equation (8) [1] shows that the locus of points $M_i(x,y)$ in which K_{Bnec} is realized is a circle with the center [1] $\left(-\frac{Dc^2}{1-c^2},0\right)$ and with radius $\left|\frac{Dc}{1-c^2}\right|$.

Similarly, the situation in space is analyzed, resulting in an effective hemisphere of action [1-3]. The interpretation of the result is made by analyzing the three cases in equation (2) [1-5]:

a) $c < 1$, follows:
- the parameters of the interference device: predominate those of the junction device;
- the useful link area is a circle with the center on the left of the link emitter, surrounded by the interference area (see figure 4).

b) $c > 1$, follows:
- the parameters of the emitter link predominate those of the interference;
- the useful link area is outside the circle that limits the effective action of interference.

c) $c = 1$. In this case, the geometric location of the points where $K_{Breal} = K_{Bnec}$ is an equidistant line between the interference and the junction transmitter.

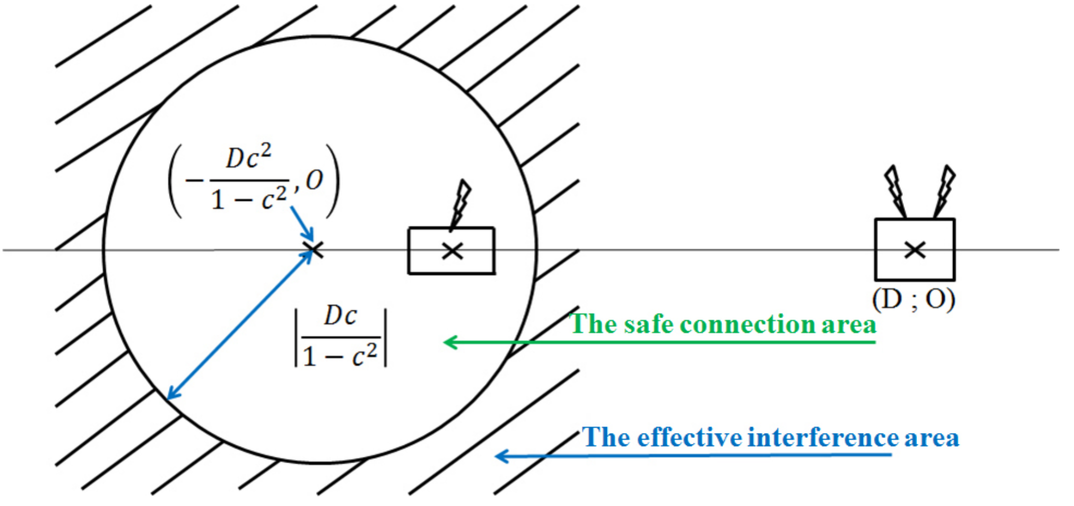

Figure 4. - Hemispheres of action [1]

For the general study of the neutralization zone, [1] the arrangement in fig. 5, where [1]: the binding receptor, R_L, may be located in the points $M_i(x,y)$ and $M_i(x,y,z)$; $r_B=\left|\frac{Dc}{1-c^2}\right|$, and the center O 'of the effective interference area has the following coordinates $O'\left[-\frac{Dc^2}{1-c^2},0,0\right]$, [1-4].

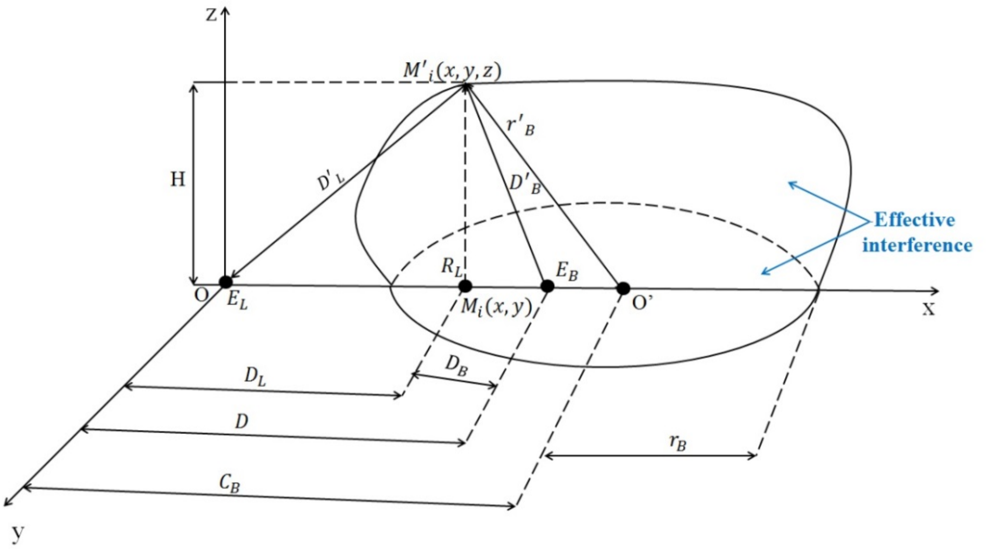

Figure 5. - The neutrality zone [1]

The interference design software optimization is a very complex composition having a number of subroutines [1]. One of them determines the variation of the neutralization zone, according to the relations for the case c = 1, while maintaining the binding distance, D, fixed or variable.

Running the equations obtained with Microsoft Office Excel resulted in Tables 1 and 2.

Table 1. - $D_B = f(D, D_L)$

D_L / **D**	**10**	**15**	**20**	**30**	**40**	**50**
30	**20**	**15**	**10**	**0**	**+10**	**+20**
50	**40**	**35**	**30**	**20**	**10**	**0**
70	**60**	**55**	**50**	**40**	**30**	**20**
90	**80**	**75**	**70**	**60**	**50**	**40**
100	**90**	**85**	**80**	**70**	**60**	**50**
150	**140**	**135**	**130**	**120**	**110**	**100**

Table 2. - Variation of the neutralization zone for D_L = 10m

Dist. [km] / **D [km]**	**c**	D_B	c_B	r'_B
30	0,25	20	-1,98	7,98
	0,50		-9,99	19,98
	0,75		-38,46	51,36
	1		1	1
	1,25		83,34	66,72
	1,50		54	36
	1,75		43,26	25,32

70	0,25 0,50 0,75 1 1,25 1,50 1,75	60	-4,62 -23,31 -89,74 1 194,46 126 100,94	18,62 46,62 119,84 1 155,68 84 59,08
90	0,25 0,50 0,75 1 1,25 1,50 1,75	80	-5,94 -29,97 -115,38 1 250,02 162 129,78	23,94 59,94 153,08 1 200,16 108 75,96
150	0,25 0,50 0,75 1 1,25 1,50 1,75	140	-9,9 -49,95 -192,3 1 416,7 270 216,3	39,9 99,9 256,8 1 112,2 180 126,6

4. CONCLUSIONS

Competitiveness in aircraft construction, as in other economic sectors is strongly influenced by the manufacturer's ability to adapt to technological change and the speed of a new product. In future more human operator will move behind the terminals.intelligently intervening in adapting robots and flexible systems to the degree of organization of production. This is the uniqueness of the product and the manufacturing plan. Flexible automation of processing processes is now the “backbone” of the evolutionary process of integration based on computerized production techniques. It is achieved by associating complex devices and machines with sophisticated computerized systems, integrating in a hierarchical unitary view the functions of control, handling, transport and storage.

The flexible processing system offers flexible automation to the art status through its exceptional performance in the wide range of small and medium-sized production, and its subsequent development will depend on the contribution of new technologies and technical-scientific achievements as it enters contemporary industrial world.

Due to this technological development we can create robots that can become more efficient. Therefore, this paper focuses on the use of calculation for analysis the effectivenes of radio interference assoicated with the entry of the hexapod robot into the aircraft fuel tank.

Entry into the aircraft fuel tank is required for inspections and modifications, but this works may present a risk factor for technical personnel.

Working in the fuel tank can be carried out safely if the technical staff is trained and has the necessary equipment for the work. The hexapod robot can successfully intervene and play a vital role in this area.

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