



EMI Resilient Drone Navigation System

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Abstract. Unmanned Aerial Vehicles (UAVs) or specifically drones are commonly used in monitoring and delivery applications. Due to their versatile characteristics in many sectors, they are also used in all environments, which also include EMI prone zones. Zones which are surrounding transmission / power lines are considered as an EMI prone zone. EMI interferes with the switching logics and communication links thereby tampering with the stability of the drone. EMI can tamper with drone components like flight controller (FC), inertial measurement unit (IMU) and GPS module, causing unstable flight, navigation errors, and thereby loss of control. To navigate these issues, a system based on sensor-based EMI resilient navigation is proposed which can detect EMI from various directions and navigate the drone towards the path with least EMI, therefore allowing the drone to operate near EMI prone zones safely and autonomously. The system utilizes various sensors to continuously monitor the amplitude and direction of EMI during flight. When the detected EMI level exceeds a threshold, the sensor feedback allows the FC to designate a path with the least EMI and changes the drone's trajectory thereby moving the drone away from interference prone zones. A simulation is developed using SIMULINK to model the harmonics caused by the EMI, drone's navigation behavior with respect to the EMI levels and navigation planning.

Keywords: UAVs, EMI, IMU, FC and GPS.

1. INTRODUCTION

Unmanned Aerial Vehicles (UAVs) have become adaptable to various industrial applications like inspection and monitoring. Despite their advantages, one of the challenges faced during flight operations near high voltage transmission lines is the presence of strong electromagnetic fields (EMF) which induces strong electromagnetic interference (EMI) [4] [5]. These interferences are generated from the high power and switching operations of power lines, which can have significant impact on the onboard electronics of the drone [4] [5].

The FC acts as the logical processor of the drone, responsible for interpreting sensor data, navigating the drone to maintain stability and controlling the output power of the motor. It processes real time data from components such as gyroscopes, accelerometers and magnetometers to maintain the UAV's altitude and position. However, EMI can destabilize the drone by either inducing unwanted voltage and noise into the FC circuitry potentially leading to false triggers or leading to faulty operation of the micro electromechanical systems (MEMS) present in the IMU leading to incorrect positioning. Prolonged exposure to strong electromagnetic fields can also result in communication dropouts between the FC and the Human Machine Interface (HMI).

Our objective is to integrate EMI / EMF detection sensors within the UAV to navigate these challenges. The sensors collect real time data regarding the nature and amplitude of the surrounding electromagnetic field and trigger a safe navigation path command when the EMI exceeds a threshold value. The path chosen is declared based on the surrounding environment with the least EMI. By implementing the proposed solution, navigation around high power transmission lines in substations and other infrastructures can be safer and more reliable by reducing risk of control failure, equipment and infrastructure damage.

2. LITERATURE SURVEY

- A. [1] [Shervin Salehi Rad, Zilong Zheng, Reza Kheirollahi, Amr Mostafa; Shuvan Zhao; Yao Wang](#)
- Researchers conducted a case study on a 500kV transmission line to verify its impact on the IMU of an Unmanned Aerial Vehicle.

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R. Vasanth Kumar Mehta et al. (eds.), *Proceedings of the International Conference on Intelligent Systems for a Sustainable Future (ISSF 2026)*, Atlantis Highlights in Intelligent Systems 16,
https://doi.org/10.2991/978-94-6239-693-7_47

- The transmission line was modelled with the help of a 2.2 kA planar coil and a 7.5 kA solenoid coil and the study validated that except for the magnetometer; the other sensors were immune to both electric and magnetic fields [10].
- B.** [2] [Marcos Quílez; Marc Aragón; Andreu Atienza; Mireya Fernández-Chimeno; Pere J. Riu; Ferran Silva](#)
- The paper establishes the fact that near field probe detection is a better way to analyze complex EMI situations in industrial applications.
 - The probe is a loop built using a PCB trace with a diameter of 10cm and the signal transmission occurs with the help of optical fiber cables.
 - The model was able to identify and distinguish various EMI generated from various parts of the machine and create a spatial map out of it [11].
- C.** [3] [Zhao Zhang, Yang Zhao, Yang Zhang and Baoliang Qian](#)
- The researchers aim to introduce the potential strong electromagnetic interference that UAVs may encounter during flight.
 - They concentrate on three of the most important subsystems of a UAV, namely, the datalink system, FC & IMU and the power system [12].
- D.** [4] [Zeinab Jalali, Seveb Mohamad Hashemi, Alireza Sadeqi and Javad Ghalibafan](#)
- The sensitivity of a DJI Phantom 4 UAV to EMI is analyzed with the help of Characteristics Mode Analysis.
 - By extending the analysis over a wide frequency range, it identifies components with high induced currents and demonstrates that UAVs are more susceptible to interference at higher frequencies [16].
- E.** [5] [Rashid A. Saeed, Mohamed Omri, S. Abdel-Khalek, Elmustafa Sayed Ali & Maged Faihan Alotaibi](#)
- The paper clearly elaborates on drone navigation that relates to obstacle avoidance and path planning when multiple paths are at play.
 - Looking at the various algorithms discussed in this paper, the ISPO is the most efficient in finding a path that stays outside the EMI saturation radius [15].
- F.** [6] [Marius Pastorcici, Ana-Maria Ursea, Razvan D. Tamas](#)
- The paper highlights that the drone's frame and metallic components significantly distort the electromagnetic fields.
 - Implementation of a calibration factor to subtract the drone's own electromagnetic field from the environmental EMI is crucial [14].
- G.** [7] [Lorenzo Ciorba; Fabio Paonessa; Marco Righero; Giorgio Giordanengo; Giuseppe Addamo; Giuseppe Vecchi](#)
- The paper proves that the drone doesn't need to scan an entire area to understand the EMF. By using the electrical size of an antenna, the drone can calculate a minimal set of waypoints to visit.
 - This ensures that the drone does not stay in EMI prone zones for vast amounts of time [13].

3. METHODOLOGY

3.1 Background

UAV, commonly referred to as drone, is an aircraft without an onboard pilot. They are either remotely controlled by a ground operator or operate autonomously using sensors like GPS, IMUs, cameras & LiDAR, control algorithms, and navigation systems. The position of a drone in the 3-dimensional space is detected with the help of the Inertial Measurement Unit which contains various position sensors like accelerometer, gyroscope, barometer etc. The IMU provides real-time data on pitch, roll, yaw, and velocity of the drone, which the flight controller uses to stabilize the UAV.

The EMI generated by the transmission lines can be classified into Conducted EMI and Radiated EMI. Conducted EMI is electrical noise that travels alongside the transmission lines, disrupting the drone's stability by coupling with its circuitry which causes IMU issues, GPS errors, communication loss etc. leading to instability. Radiated EMI travels through air (due to high frequency) interfering wirelessly with the GPS compass and communication leading to navigation errors. While IEC and CISPR standards focus on design to provide electromagnetic shielding and electromagnetic compatibility (EMC), achieving reliable operation against strong EMI sources requires autonomous and sensor-based approach.

3.2 Proposed methodology

The methodology for this project is divided into various phases involving system study, sensor integration, simulation, navigation algorithm development and validation. The first phase involves determining the impacts of EMI on drone components like the flight controller, inertial measurement unit (IMU) and the GPS module. This includes reviewing the result EMI effects on the drones near high-voltage transmission lines.

In the second phase, electric-field and magnetic-field sensing modules namely the E-Field and H-Field probes are modelled to detect EMI in real time. The onboard control system (FC) receives data from the sensors and process it to determine the intensity. The intensity is then used to identify safe and unsafe zones based on the measured EMI levels.

The third phase talks on simulating the recognition of EMI levels. When the sensed EMI exceeds the defined threshold, the navigation system triggers a flight path deviation mechanism to steer the drone towards the path with the least EMI. A simulation environment is created with the help of SIMULINK to test the detection and avoidance strategy. The simulation includes a UAV model to measure its amplitude of EMI. The drone's trajectory is monitored to verify that the system successfully identifies EMI zones and alters its path to maintain safe operation.

3.3 Software Used

SIMULINK / MATLAB:

SIMULINK is a graphical environment for designing, simulating and analysing dynamic systems to allow users to model complex systems with the help of block diagrams. It allows users to design, simulate and test systems before hardware implementation, therefore reducing costs and errors [1].

Simscape Electrical:

Simscape Electrical is a MathWorks library for modelling electrical systems involving electronics, power electronics and electrical power systems. Due to Simscape's multi domain capabilities, high fidelity modelling can be achieved ensuring detailed electronic systems with control over thermal, mechanical and other parameters [1].

3.4 Circuits and Schematic

The simulations are performed in SIMULINK to showcase a realistic approach to the EMI prone difficulties of the drone [1].

Drone:

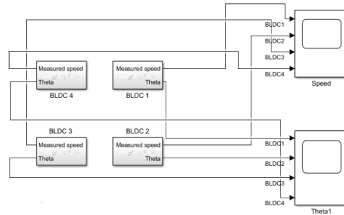


Fig.1. Schematic of a Quadcopter with 4 BLDC motors

The circuit of the quadcopter is shown in Fig.1 which shows four drones and different motions based on the input fed to it [1]. If the drones are at the same speed, the drone is climbing or hovering based on the speed. If diagonal pairs have a higher speed, yaw motion takes place. If the front pairs are at higher speed, pitch takes place. Similarly, these motions can be induced with trigger signals programmed into the Flight controller.

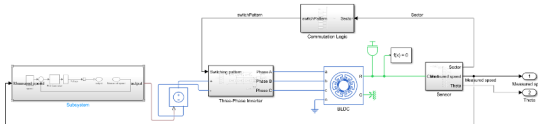


Fig.2. Schematic of a BLDC motor

The picture shown in Fig.2 is a representation of the various components present inside each motor. The BLDC motor is electronically commutated with the help of the Commutation logic block. The Three-Phase Voltage Source Inverter supplies the required power to the motor. The speed and position of the motor is measured with the help of an RPS. The position of the rotor is fed back for commutation, and the speed of the motor is fed to a controller to achieve speed control.

Schematic:

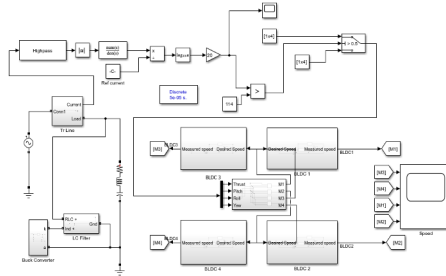


Fig.3. Schematic of the proposed solution

The source of the EMI is a buck converter (shown in Fig.3) which switches at a frequency of 10kHz, constantly introducing harmonics and ripples into the transmission line [2][8]. This causes high and low order harmonics to be introduced into the transmission line.

The LC filter is used to introduce a delay into the harmonics fed [3]. If the capacity of the LC filter is high, so is the time delay to diminish the harmonics. This concept is mainly used to simulate the activity of the drone during safe and unsafe EMI limits.

The harmonics of the transmission line are filtered with the help of a High Pass Filter. The noise is now isolated from the AC supply. The noise is now fed to a low pass filter to derive a constant value of the amplitude of EMI. If the harmonics are high, the amplitude of EMI exceeds the threshold which is shown in Fig.4. Vice versa, and the EMI remains under the safety threshold which is shown in Fig.5. The amplitude of the EMI is converted into dB with the help of mathematical modelling. The measured value of EMI is compared to the threshold amplitude to either navigate the drone towards the path with least EMI or continue its original trajectory.

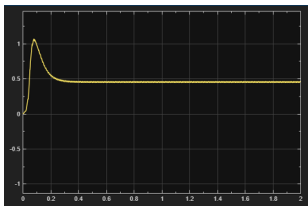


Fig.4. EMI greater than threshold

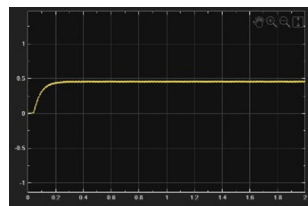


Fig.5. EMI less than threshold

4. RESULTS AND FINDINGS

4.1 Scope:

The scope shown in Fig.4 can be interpreted when split into 2 zones. Zone A shows the intensity of EMI before 0.3 seconds, and Zone B shows the intensity of EMI after 0.3 seconds. In Zone A, the simulation results show, that the speed of BLDC 2 and 4 are higher than that of BLDC 1 and 3. This causes a pitch motion allowing the drone to navigate away from the EMI prone zone.

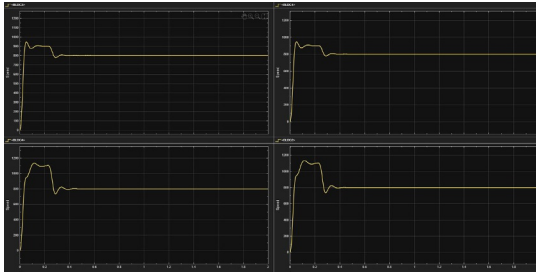


Fig.6. Speed vs Time Characteristics of all motors

Once the drone navigates away from the EMI prone zone (which is after 0.3 seconds according to the simulation), the model enters Zone B where the speed of all the motors returns to the same causing a hovering motion.

4.2 Future Scope and Overhauls:

- Utilizing a PID controller to diminish the initial spikes, reduce steady state error and improve the response time.
- Storing the data of EMI prone zones to create an EMI depth map can lead to prevention of entering the EMI prone zones. For the successful implementation of the above model, multiple drones with the same algorithmic and autonomous approach are necessary.

4.3 Conclusion:

The proposed EMI resilient UAV navigation system successfully demonstrated the ability to detect electromagnetic interference zones and autonomously alter its flight path to ensure safe operation [7]. The sensor-based approach effectively identified high interference regions, triggering the deviation algorithm when the measured electric-field value crossed the defined safety threshold. As a result, the drone navigated away from the EMI prone zones, thereby maintaining a stable safe and reliable navigation.

In the SIMULINK simulation, the UAV initially followed the predefined path toward its destination. However, upon entering an EMI prone zone, the system detected the shoot up in intensity and determined the directional EMI used to achieve the navigation change maneuver. The motor speed plot clearly showed a smooth deviation away from the EMI zone, followed by returning to the original trajectory once the EMI intensity levels dropped. Therefore, the simulation confirmed the path deviation towards the path of least EMI without jeopardizing mission completion.

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