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Imas Tri Setyadewi
Department of Electrical Engineering, Universitas Indonesia

Purnomo Sidi Priambodo
Department of Electrical Engineering, Universitas Indonesia

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Study and Analysis of Crosstalk Reduction in UAV Cabling by Using Various Cable Types

Imas Tri Setyadewi[1], Purnomo Sidi Priambodo[2,*]
[1,2]Department of Electrical Engineering, Universitas Indonesia, Indonesia

*Author to whom correspondence should be addressed:
E-mail: purnomo.sidhi@ui.ac.id

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Abstract: Measuring the amount of crosstalk in the UAV is necessary to ensure that the system and equipment on the onboard UAV can be operated properly without any Electromagnetic Interference (EMI). This paper was conducted to determine the effect of interference in the UAV cabling system by measuring EM crosstalk between the cables. Variations in the type of cables and the distance between the transmitting and receiving cables are carried out to analyze the relationship between the magnitude of the induced voltage on the receiving cable. The results of the experiments that have been measured, it is found that the use of coaxial cable is the best in reducing EMI. In addition, a distance between transmitting and receiver cables of more than 4 cm can suppress EMI by almost 60%.

Keywords: UAV, electromagnetic interference, EM crosstalk, induced voltage, cable

1. Introduction

UAV is currently used widely for both civilian and military needs. The development of UAV applications will be increase in line with the complexity of the payload and the carried electronic systems. When the UAV operates, electromagnetic field environment influence, either from the internal induced voltage between the UAV components or from outside such as electric towers, lightning, thus will affect the performance of the UAV, hence it causes not work optimally[1-3]. EMI (Electromagnetic Interference) is defined as pollution of signal electromagnetic caused by electromagnetic noise either from natural sources (lightning discharges, solar radiation, etc.) or from electronic equipment/circuits at the source frequency by ground segment transmitter for navigation, communication, radar surveillance which can reduce the quality/performance of electronic equipment. While EMC (Electromagnetic Compatibility) is the ability of an electronic system and materials to perform properly against EMI radiation[4-5].

The complexity to achieve a perfect EMC level is caused by the UAV's structural materials that are made of composites or even using ABS plastic materials which has desirable physical properties such as light weight, high specific modulus and strength[6-10]. This makes it more difficult to find solutions to internal EMC problems on the UAV. The electrical system and data link on the UAV are the most vulnerable systems or susceptibility to EMI[11]. For this reason, before operating UAV, it is better to conduct an EMI test on the UAV. Y Wu[12] categorizes EMI testing on UAVs into two steps. First, radiation in the form of an electromagnetic field, and second is a conduction test to investigate the flow of current along the cable. Cable length is the biggest influence on EMI susceptibility generated either from internal or external[13]. From the statistical research, the majority about 60% of EMI interference on aircraft is caused by electromagnetic coupling on the cable UAV

Several studies on the effect of EMI on cables have been discussed, Gainutdinov [2016] divided several methods to estimate crosstalk in the coupling path feeder and interface areas[14] . Davis [2020] researched by making shielding CNTs on coaxial cables and obtained good results in the frequency measurement range of 300 MHz to 18 GHz[15]. Balakrishnan [2018] used elevated guard traces to significantly reduce crosstalk, the higher the wall of the guard traces the better signal isolation is[16]. Ghosh [2018] used three layer PCB with three traces on the top, a midle trace and a ground plane to describe the radiation effect and crosstalk[17]. Crosstalk studies on cables have also been carried out using various types of copper cables and by varying the distance between cables, then the results are compared with the simulations. The result is a 50 times reduction in crosstalk in the aluminum shielded cable[18].

It is critical in the development stage of prototyping UAV to ensure that the aircraft's electronic system has an appropriate function as a powers supply, data transmission and signal transmission between subsystem, and the electronic performance of wires and cables for the UAV onboard system[19]. By using of such electromagnetic simulation tools, or do the EMI chamber test it can be evaluated the effect of EMI for aircraft components[20]. This study aims to complement the previous studies, by comparing the induced voltage of different cable types, and investigate the effect of induced EMI by variated the distance between transmit cable (source) and receive cable. We focus on EMI that occurs on the wiring path rather than on PCB instrumentation in onboard UAV. In addition, we investigate the effect of using copper shielding tape, also with varying the distance between each cable pair of single wire cable. After understanding the effect of induced voltage on various cable types, we can consider the space which is needed to provide cable spacing in the initial design of UAV. As a result, using a coaxial cable can reduce the induced voltage or EMI received by the receiver cable three times less than the use of a single wire cable. Moreover, by varying the distance between transmit and receive cables above 5 cm, it can reduce by 60% EMI induces that occurs between cables

2. Methods

The crosstalk measurement experiment on the cable was obtained by measuring EM induced voltage on the cable using an oscilloscope. Type of conducting single wire copper cable 22 AWG with a length of 50 cm is used. This cable has a conductor diameter of 0.65 mm. The second cable type is a coaxial cable with a length of 1 m and the thickness of the copper conductor is 9.4 mm. The third type of cable is the same as the first cable but characterized using shielding tape with copper foil 0.07 mm thick. The experimental test was conducted by analogizing one cable as a data source namely transmit cable and the other cable being a receive cable or power cable

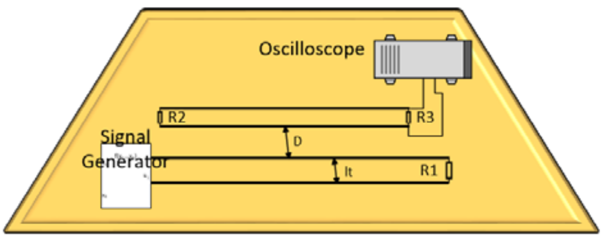

Fig. 1: Experimental Setup

Mostly in practical, signals from the transmitter are received by the receiver, then converted into the PWM (Pulse Width Modulation) to be transmitted to the actuator. To controlling the attitude of UAV, these signals are interpreted by the flight control to specific actions according to the commands. Major electrical components onboard UAV such as servo, flight controller, and sensor are PWM signal[21-22].

The test setup was carried out in four models and the setup configuration can be seen in Fig. 1. EMI induced experiment on cables is divided into 4 test models:

- The first model, the experiment setup consists of 2 pair single wire AWG 22 cables, the first pair of the cables is connected to the signal generator with the other end loaded by resistor R1 of 50 Ohms, this system acts as an EMI source to the other set of cable. In the second pair, both ends are terminated by resistors R2 and R3 of 1 Mohm. The second cable acts as receiving EMI induced signal, where the signal is picked up from the R3 port by oscilloscope. The signal generator is set to a square waveform and at a frequency of 2 MHz and amplitude of 10 V. The square wave signal was chosen because it is identical to the PWM as a data signal. The distance between the cables is then varied from 1 to 10 cm.
- The second model uses the same cable as the first model, however, there is a change, which the condition that both cables are twisted in each pair.
- The third model uses a coaxial cable with an impedance of 50 ohms, and
- The fourth model uses the same cables as in the second model, however, each cable is shielded by copper foil with a 0.07 mm thick, and both cables are located separately.

The method of injecting signal by the signal generator and receiving signal by oscilloscope which is performed on the first model (see Fig.1) is also accomplished throughout all models discussed. In addition to the first model, besides varying the distance between the two cable pairs, we also vary the distance between each cable in a pair represented by variable lt (varied from 1 to 5 cm) as shown in Fig.1.

3. Experimental Result

In this experiment, GW Instek GFG 8129A is used as a signal generator to generate a square wave signal at 2 MHz frequency with an amplitude of 10 V. Textronik TDS 2012c oscilloscope is used to detect induced EMI signal on the receiving cable system as shown in Fig.2. EMI induced signals on the cable are obtained by measuring the induced voltage output from the power cable or receive cable which is observed from the oscilloscope. The measurement results of each model test are described as follows.

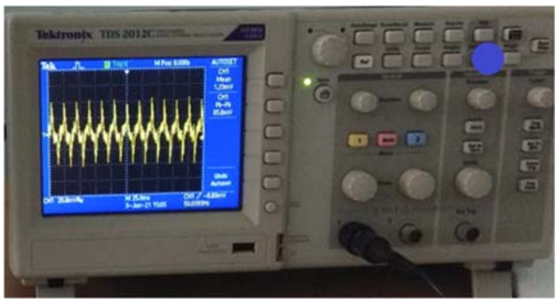

Fig. 2: Monitoring the induced voltage with an oscilloscope

3.1 *First and Second Model Experiments*

The induced voltage measurement is selected based on the peak-to-peak noise instead of rms. Peak to Peak (Vpp) induced voltage is measured from the highest voltage point on the waveform to the lowest voltage point. This measurement is chiefly important for applications where noise spikes could deteriorate accurate measurements on a considered load, such as RF circuitry, while rms does not show the actual DC power supply noise because if there are high output noise spikes in the ripple signal for a short duration it will not be visible and increase the rms value[23].The result measuring crosstalk by using a single wire cable untwisted and twisted are shown in Fig. 3. The first model by using 2 pairs of single wire cables, with one cable connected to the signal generator and the second cable connected to the oscilloscope. The presence of the EM induced voltage is highest when the distance between the two cables is closest, which in this experiment was carried out at a distance of 1 cm. As can be seen in Fig. 3a, the maximum value obtained is 234 mV. Measurements using the second model have been carried out by using twisted wire cable pair. The results of the second model are shown in Fig. 3b with the maximum induced voltage obtained at D = 1 cm is 176 mV.

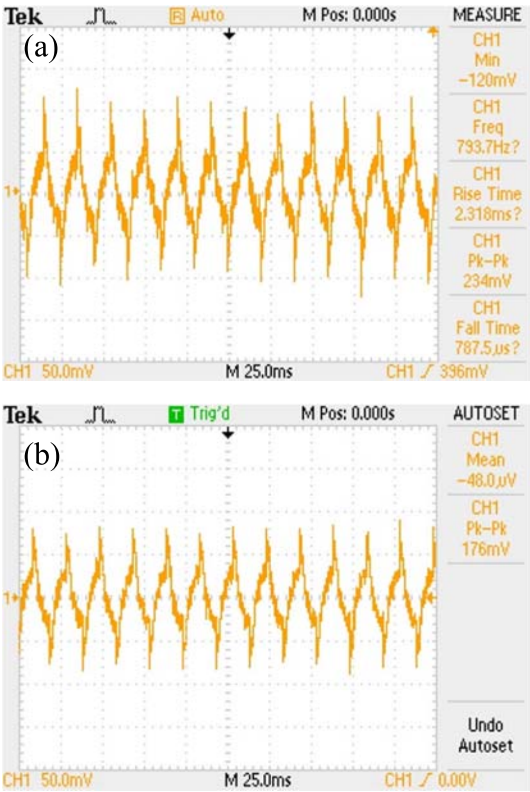

Fig. 3: Monitoring the induced voltage of first model (a) and second model experiments (b)

The measurement results of the induced voltage by using single wire cable pair show a higher value than the induced voltage on the twisted cable pair. Then for the induced voltage generated by the use of coaxial cable is discussed in sub-section 3.2.

3.2 *Third Model Experiments*

The third model is to substitute the single wire cable pair by using a coaxial cable with an impedance of 50 ohms. By using this cable, the variation of distance D does not affect the value of the induced voltage generated. Fig. 4 shows the monitoring of the received signal on the receiving coaxial cable. The maximum induced voltage obtained is 50 mV

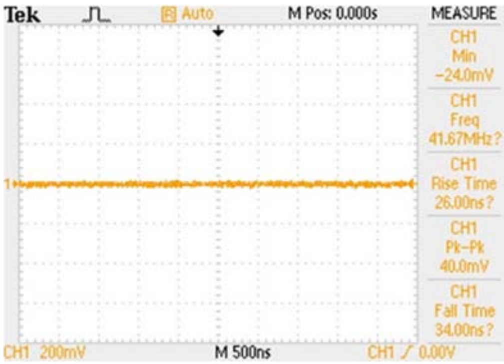

Fig. 4: Monitoring the induced voltage of the third model experiment

3.3 *Fourth Model Experiments*

The fourth model is by using a twisted wire cable with both the transmit and receive cable are shielded by copper foil. The maximum induced voltage Vpp measurement for this cable model obtained is 101 mV at a distance between cables D = 1 cm (see Fig. 5). From the measurement monitoring, it is can be seen that there is a reduction in the value of the induced voltage Vpp received, but it is not better than using the third measurement model. From all experiment models that have been carried out, the use of coaxial cable shows a very significant reduction in EMI induced signal

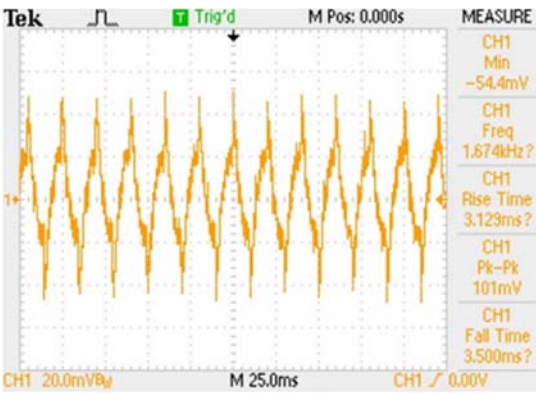

Fig. 5: Monitoring the induced voltage of the fourth model experiment

For comparison of measurement results, Table 1 shows the summary comparison for each value of the induced voltage received at the cable receiver with the effect of distance variated from 1 to 10 cm on the experiment of the four models discussed above.

Table 1. Induced Voltage Measurement Results

Model Type	Vin (mV)									
	D (cm)									
	1	2	3	4	5	6	7	8	9	10
First	234	179	121	108	103	97	95	95	93	93
Second	176	130	116	102	104	100	96	96	92	89
Third	50	49	49	50	49	49	48	40	49	40
Fourth	101	88	87	84	84	84	84	83	83	85

Table 1 shows that the highest induced voltage by the first and second model experiments at D = 1 cm and D = 10 cm, is 234 mV and 93 mV for single wire cable pair and 176 mV and 89 mV for twisted cable pair, respectively. Meanwhile, the lowest induced voltage is obtained in a coaxial cable with a maximum value is 50 mV and the lowest is 40 mV. For the experiment using a copper shield reduce the induced voltage compared with using the first and second model experiment, however not better than the use of coaxial type cable in the third experimental model. Then the experiment of induced voltage was conducted using single wire cable pair on the first model by varying the distance between cable pair (lt) of transmitting cable source. The experimental results are discussed in sub-section D.

3.4 Effect of Distance Variation lt

The lt variation is given to the transmit cable from a distance of 1 cm to 5 cm. Fig. 6, shows the graphic of comparison results of induced voltage on the receiver cable. It can be seen that for variated the distance lt at 1 cm (represented in green line) and at a distance of 5 cm (represented in dark blue line) there is not much change in the induced voltage received, while the variation in distance D has a considerable influence on changes in induced voltages.

Furthermore, it represented that the greatest reduction value of induced voltage where the gradient slope starts at the distance from 1 cm to 5 cm and starts to stagnate at 6 to 10 cm. At the distance 1 cm, the value of the induced voltage received is 198 mV when the lt is given 1 cm, and 206 mV when the lt is 5 cm. Meanwhile, increasing the distance at 10 cm, the induced voltage is 114 mV at lt is 1 cm and 118 mV at lt is 5 cm.

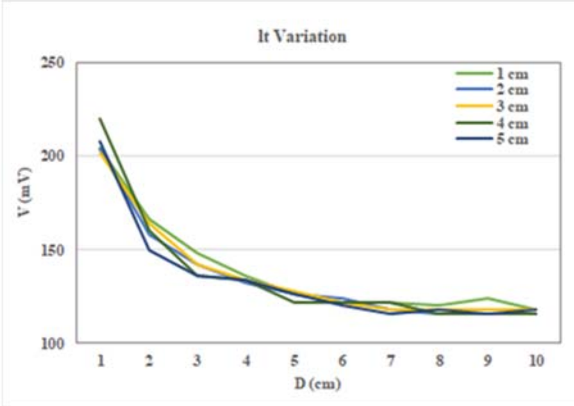

Fig. 6: Induced voltage of lt variation

4. Discussions

From all experiment results, it can be noted that the induced voltage by the power cable is affected by the transmit signal through the data cable. When using 2 pair single wire cables, the induced voltage value is greater when the distance between the two cables is very close. However, it is smaller when a greater distance is given. The lt distance does not many influences the effect of reduction EMI induced voltage value by the receiver cable.

The comparison of measurement results can be seen in Fig 7. The use of twisted cable in the second model (orange line) significantly reduces the value of the induced voltage received compared to the first measurement model, particularly for the distance from 1 to 3 cm. The greater the distance, given the graph, coincides with the use of a single wire cable pair (blue line). Twisted cable between the power cable and receiver cable will reduce the energy of the magnetic field generated in each cable. In this study, the two pair cables, each carries a positive charge that causes a positive magnetic field generated and another carries a negative charge that generated a negative magnetic field. These two magnetic field interactions will work to eliminate each other, therewith reducing interference with the result that the induced voltage is reduced[24-25].

The use of shielding with copper foil in twisted cables (grey line) can help to reduce the induced voltage by more than 50% at a distance of 1 cm compared to unshielded cable. Moreover, the use of coaxial cable (yellow line) is the most suppressing the amount of crosstalk in UAV cable. Compared with a single wire cable, the induced voltage can be reduced by almost five times by using a coaxial cable type. In a coaxial cable, the jacket on the cable is electrically connected with an inner conductor and reduces the effect of external electromagnetic field interference, and acts as an external working conductor.

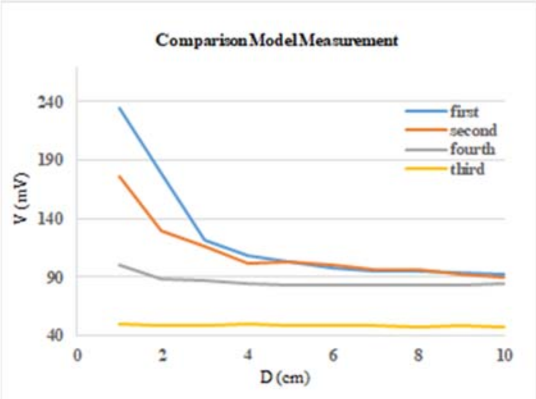

Fig. 7: Induced voltage comparison of all models experiment

Compared to using a single wire cable with copper foil shielding, the shield is not electrically connected with inner conductors and only attenuates the electromagnetic field. In addition, coaxial cable has double shields that are galvanized and connected to either one or both of the cables. This achieves the smallest possible value of the resulting coupling impedance ZT and thus the best shielding effect[26-27]. Moreover, the magnitude of the impedance in the coaxial cable is equal to the value of the load R1 50 ohms, so that the entire signal will be transmitted to the load and no back wave that causes electromagnetic leakage in the cable.

It can be seen that the reduction in the value of the induced voltage due to crosstalk is influenced by the type of cable and the distance between the cables as discussed previously. Increasing the distance of more than 4 cm between the transmit cable pair and the receive cable pair, can reduce the amount of EMI induced voltage received by almost 60% by using a single wire pair cable. As initial research to observed the effects of EMI on UAV cable, further research using various type of waveforms also need to be done.

5. Conclusion

Based on the experiment results, it can be concluded that using the 2 pair single wire cables have the greatest induced voltage resulting from transmission signal of data cable about 30% higher than twisting the cable. The use of shielding copper and coaxial cable was proven to be effective in reducing the amount of crosstalk in cables. The use of copper shielding can be reduced by more than 50% at a distance of 1 cm than twisting the cables without shielding. Furthermore, the use of coaxial cable is the most suppressing induced voltage almost five times better than the use of 2 pair single wire cables. Moreover, the effect of the distance between the data and power cables greatly affects the amount of crosstalk between cables especially for the experiment using single wire cable pair. By increasing the distance by more than 4 cm, the induced voltage greatly reduced almost 60%.

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References

1) D. Bellan and S. A. Pignari, "Statistical superposition of crosstalk effects in cable bundles," China Communications, vol. **10**, no. 11, pp. 119-128, 2013, doi: 10.1109/CC.2013.6674216.
2) T. N. Dief and S. Yoshida, "System identification and adaptive control of mass-varying quad-rotor," *Evergreen*, vol. **4**, no. 1, pp. 58-66, 2017.
3) T. N. Dief and S. Yoshida, "System Identification for Quad-rotor Parameters Using Neural Network," *Evergr. Jt. J. Nov. Carbon Resour. Sci. Green Asia Strateg*, vol. **3**, no. 01, pp. 6-11, 2016.
4) D. Jiang, V. Murugadoss, Y. Wang, and J. Lin, "Electromagnetic Interference Shielding Polymers and Nanocomposites - A Review," *Polymer reviews*, vol. **59**, no. 2, pp. 280-337, 03/2019, doi: 10.1080/15583724.2018.1546737.
5) K. Tserpes, V. Tzatzadakis, and J. Bachmann, "Electrical Conductivity and Electromagnetic Shielding Effectiveness of Bio-Composites," *Journal of Composites Science*, vol. **4**, no. 1, p. 28, 2020, doi: 10.3390/jcs4010028.
6) N. Ismail, H. Sharudin, Z. M. Ali, A. Shariffuddin, and N. Kamel, "Computational Aerodynamics Study on Neo-Ptero Micro Unmanned Aerial Vehicle," Evergreen, vol. **8**, no. 2, pp. 438-444, June 2021, doi: https://doi.org/10.5109/4480726
7) W. Zhang, S. Lv, and X. Guan, "Application of lightweight materials in structure concept design of large-scale solar energy unmanned aerial vehicle," in IOP Conference Series: *Materials Science and Engineering*, vol. **242**, no. 1, 2017: IOP Publishing, p. 012009.
8) R. R. Gaynutdinov and S. F. Chermoshentsev, "Emission of electromagnetic disturbances from coupling paths of avionics unmanned aerial vehicles," in 2017 *International Siberian Conference on Control and Communications (SIBCON)*, 29-30 June 2017 2017, pp. 1-5, doi: 10.1109/SIBCON.2017.7998580.
9) A. Gupta, H. Kumar, L. Nagdeve, and P. Arora, "EDM Parametric Study of Composite Materials: A Review," Evergreen, vol. **7**, pp. 519-529, 12/01 2020, doi: 10.5109/4150471.
10) N. I. Ismail, H. Sharudin, M. MahadzirM., Z. M. Ali, A. A. Shariffuddin, and N. I. Kamel, "Computational

Aerodynamics Study on Neo-Ptero Micro Unmanned Aerial Vehicle," Evergreen, 2021.
11) D. Zhang, E. Cheng, H. Wan, X. Zhou, and Y. Chen, "Prediction of Electromagnetic Compatibility for Dynamic Datalink of UAV," *IEEE Transactions on Electromagnetic Compatibility*, vol. **61**, no. 5, pp. 1474-1482, 2019, doi: 10.1109/TEMC.2018.2867641.
12) Y. Wu, Q. Ma, and P. Xu, "Progress of Electromagnetic Compatibility Design for Unmanned Aerial Vehicles," vol. **316**, ed. Les Ulis: EDP Sciences, 2020.
13) S. V. Averin, V. Y. Kirillov, E. V. Mashukov, S. B. Reznikov, and D. A. Shevtsov, "Ensuring the electromagnetic compatibility of onboard cables for unmanned aerial vehicles," *Russian Aeronautics*, vol. **60**, no. 3, pp. 442-446, 2017/07/01 2017, doi: 10.3103/S1068799817030175.
14) R. R. Gainutdinov and S. F. Chermoshentsev, "Methodology to ensure the intrasystem electromagnetic compatibility of UAV avionics," *Russian Aeronautics*, vol. **59**, no. 4, pp. 613-618, 2016/10/01 2016, doi: 10.3103/S1068799816040279.
15) K. M. Davis, "Development of Prototype Light-Weight, Carbon Nanotube Based, Broad Band Electromagnetic Shielded Coaxial Cables," D.E., University of Dayton, Ann Arbor, 28108054, 2020. [Online]. Available: https://search.proquest.com/dissertations-theses/development-prototype-light-weight-carbon/docview/2447832782/se-2?accountid=17242
16) R. Balakrishnan, S. A. Thomas, and S. Sharan, "Crosstalk and EMI Reduction using enhanced Guard Trace Technique," in 2018 *IEEE Electrical Design of Advanced Packaging and Systems Symposium (EDAPS)*, 16-18 Dec. 2018 2018, pp. 1-3, doi: 10.1109/EDAPS.2018.8680903
17) A. Ghosh and S. K. Das, "Interference Effects of Via Interconnect in Three Layer Printed Circuit Board," *ACES Journal*, vol. **33** no.9, September 2018.
18) R. R. Gaynutdinov and S. F. Chermoshentsev, "Study of crosstalks in the cables of unmanned aerial vehicle," in 2017 *International Siberian Conference on Control and Communications (SIBCON)*, 29-30 June
19) P. Mathur and S. Raman, "Electromagnetic Interference (EMI): Measurement and Reduction Techniques," (in English), Journal of Electronic Materials, vol. **49**, no. 5, pp. 2975-2998, May 2020 doi: http://dx.doi.org/10.1007/s11664-020-07979-1.
20) B. Plaza, O. Ramajo, D. López, D. Poyatos, and D. Escot, "Assessment of FEM simulations in EMC test setups for small aeronautical platforms," Journal of Electromagnetic Waves & Applications, Article vol. **32**, no. 17, pp. 2228-2245, 2018, doi: 10.1080/09205071.2018.1503098.
21) V. Chamola, P. Kotesh, A. Agarwal, Naren, N. Gupta, and M. Guizani, "A Comprehensive Review of Unmanned Aerial Vehicle Attacks and Neutralization Techniques," (in eng), *Ad Hoc Netw*, vol. **111**, pp. 102324-102324, 2021, doi: 10.1016/j.adhoc.2020.102324.
22) I. Stancic, A. Ljubičić, and M. Cecić, "Identification of UAV Engine Parameters," *WSEAS Transactions on Systems and Control*, vol. **10**, pp. 179-185, 04/01 2015.
23) What is the difference between the voltage P-P noise and RMS noise specifications? [Online]. Available: https://rfmw.em.keysight.com//bihelpfiles/PowerSupport/whm/Advanced/Content/05%20-%20Questions%20for%20many%20models/General%20Instrument%20Information/Difference%20between%20P-P%20noise%20and%20RMS%20noise.htm
24) M. Sarma and S. K. Sarma, "Effect of AC Power Line on UTP Cable: A Review," in *2013 4th International Conference on Intelligent Systems, Modelling and Simulation*, 29-31 Jan. 2013 2013, pp. 549-552, doi: 10.1109/ISMS.2013.79.
25) Shielding (Interference and Protective Measures) https://dam-mdc.phoenixcontact.com/asset/156443151564/83109be622cfd14d8e90dddd18465486/1188791_EN_Schirmung_LoRes.pdf (Accessed December 16,2021)
26) A.G. Shcherbinin and A. S. Mansurov, "A numerical study of the efficiency of a cylindrical electromagnetic shield," *Russian Electrical Engineering*, vol. **88**, no. 11, pp. 728-731, 2017/11/01 2017, doi: 10.3103/S1068371217110128.
27) J. Leuchter, Q. H. Dong, J. Boril, and E. Blasch, "Electromagnetic immunity of aircraft wireless and cables from electromagnetic interferences," in *2017 IEEE/AIAA 36th Digital Avionics Systems Conference (DASC)*, 17-21 Sept. 2017 2017, pp. 1-6, doi: 10.1109/DASC.2017.8102143.