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LEAKAGE MAGNETIC FIELDS OF THE ELECTRIC BLDC MOTORS OF SMALL UAV

Josef Blažek*

Modern electric motors with permanent magnets and electric commutation (brushless DC - BLCD motor) have become the most useful in the power drive of the small UAV, RPAS or drones. The main interest of our project VEGA 1/0585/15 is to explore all possibilities of the drones' identification oncoming to the areas of interests. Within these projects were made indicative measurement of the electromagnetic energy radiation of the set of BLDC motors of different power drive and construction.

In the initial part of the contribution the measurement methodology of ELF and LF leakage magnetic field by help of the four - channel digital magnetometer VEMA using data recording and subsequent mathematical and graphical processing of these data is solved. It has been shown that relevant results for the comparison of different motor such as spatial interpretation of their leakage magnetic fields brings the gradient method with determined *xx* and *yx* components of the magnetic field. Higher frequency components in the examined fields, mainly components given by PWM power drive motor regulation were measured by the magnetometer based on the induction principle.

Keywords: leakage magnetic field, BLDC motor, magnetometer, FFT spectrum

1 INTRODUCTION

UAVs (Unmanned Aerial Vehicles) are becoming more often used also in the civil sector [1], but as other technologies, they can be used to make intentional casualties. The main interest of our VEGA 1/0585/15 project is to explore all possibilities of the drones' identification/detection oncoming to the areas of interests. In the one of phases of project will be analyzed possible sources of physical quantities – signals generated on UAV as a side product of their activity. There will be also analyzed acoustic noise of engines and propellers, electromagnetic field of engines, regulators and connecting wires in the spectrum from ELF (extremely low frequency) until the frequencies corresponding to the activity of PWM (Pulse-Width Modulation) regulators.

Modern electric motors with permanent magnets and electric commutation (brushless DC - BLCD motor) have become the most useful in the power drive of the small UAV, RPAS (Remotely Piloted Aircraft Systems) or drones. Within this project were made indicative measurements of the electromagnetic energy radiation of the set of BLDC motors of different power drive and construction.

2 THEORY

Brushless DC motors (BLDC) do transfer electric power very well into mechanical power with little power loss [2], [3]. There can be achieved power coefficients higher than 90 %. Brushed motors stay in the range of 50 % to 80 % max. Due to minimum power loss, BLDC motors can be built smaller and lighter. BLDCs are very reliable since there are no brushes that tear. Additionally, brushes cause EMI which must be eliminated with filters. No need for that in the BLDCs [4], [5].

Figure 1 shows a typical BLDC motor. This one has 14 permanent magnets on the rotor and 12 poles on the stator (stator teeth) [6].

Fig. 1. The design of BLDC motors, [6]

A similar structure, that is, with the parameters 14N12P also had all of the measured motors. Load of motors was chosen as real operating realized using standard propeller.

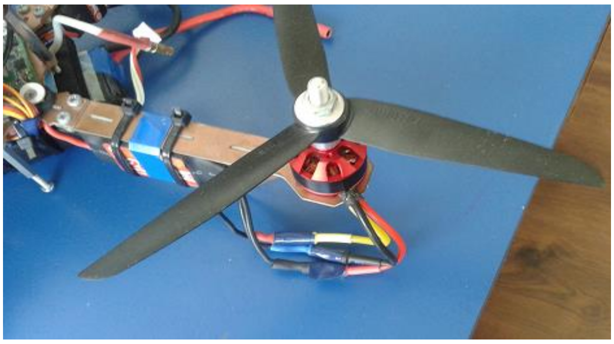

Fig. 2. BLDC motor with propeler on small UAV

For the measurements were selected BLDC motors of different power:

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* University of Security Management in Košice, Kukučínova 17, 040 01 Košice, Slovakia; josef.blazek@vsbm.sk

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- Air 3020B with parameters KV = 600, with output up to 800W, load - propeller APC1206,
- Park 480 with KV = 850, max power 480W and propeller Gemfan 11047,
- smallest BLDC motor type Ray c2822-27 with KV = 1200, power 80 W and propeller GWS08045.

Each of the engines was powered by its regulator of a recommended type. The controller to set the minimum and half speed was used.

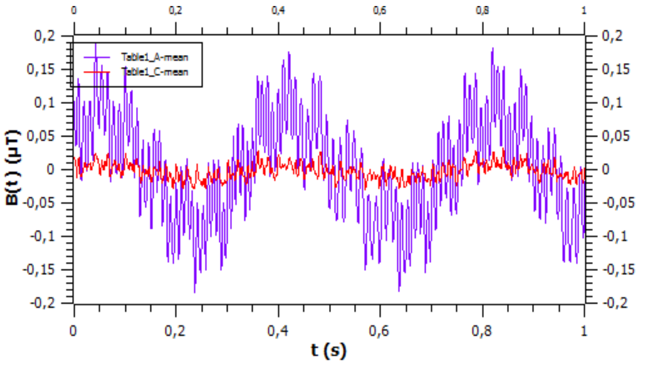

Fig. 3. Time record of centred flux density *BxA* and *BxC*, motor Air 3020B, hand driven

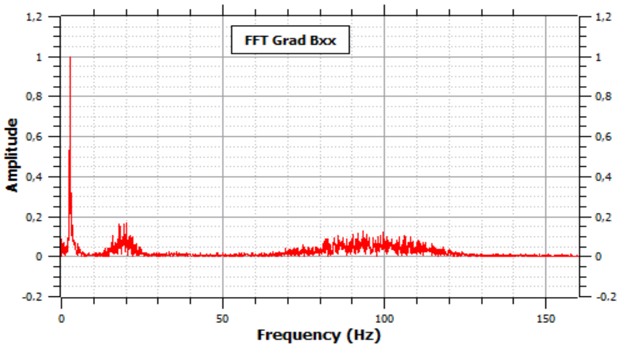

Fig. 4. Normalized FFT spectrum of *GBxx*, motor Air 3020B, hand-driven

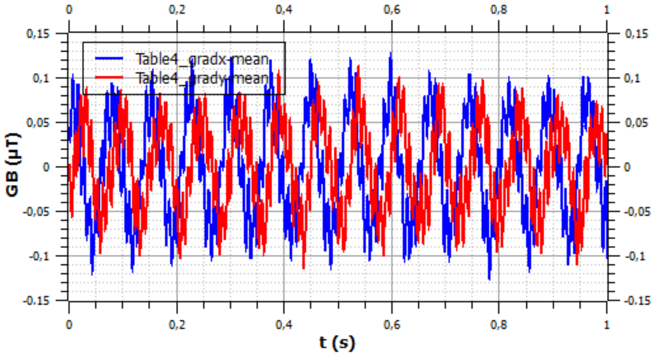

Fig. 5. *GBxx*(*t*) and *GByx*(*t*), 1 s time record, motor Air 3020B, min. revolutions

Figure 5 and 6 show signals of motor Air 3020B with the minimum revolutions speed.

The frequency spectrum is clean. Minimum speed of the motor Air 3020B correspond with the frequency of 13.5 Hz, magnetic poles are given on frequency 95 Hz.

The measurement results with the minimum speed of the engine Park 480 are shown from Fig. 7 to Fig. 8.

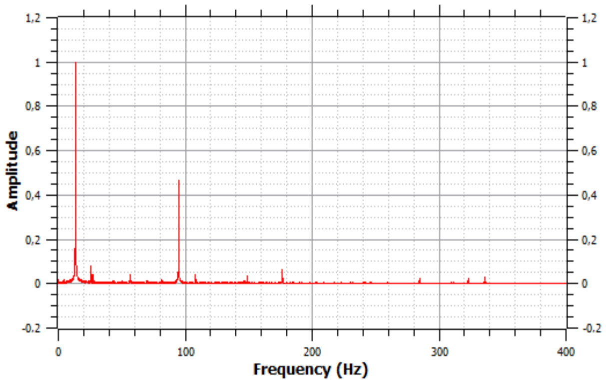

Fig. 6. Normalized FFT spectrum of *GBxx* signal, motor Turnigy Air 3020B, min. revolutions

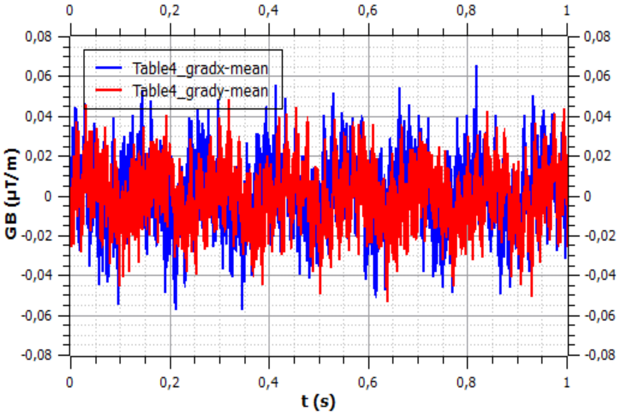

Fig. 7. *GBxx* and *GByx*, 1s time record, Park 480, min. revolutions

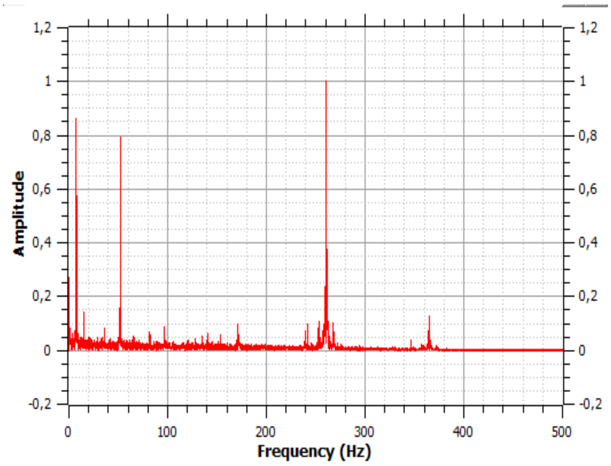

Fig. 8. Normalized FFT spectrum of *GBxx*, Park 480, min. revolutions

In the initial part of the contribution is solved the measurement methodology of ELF and LF leakage magnetic field using the four-channel digital magnetometer VEMA-04.1 using options of data recording.

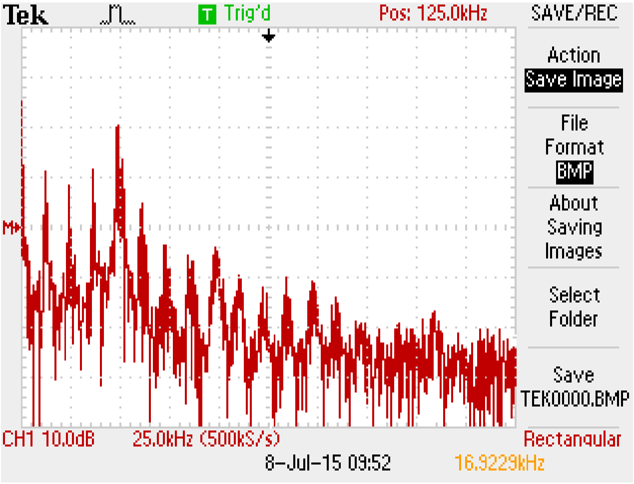

Fig. 9. FFT spectrum, motor Air 3020B, min. revolutions

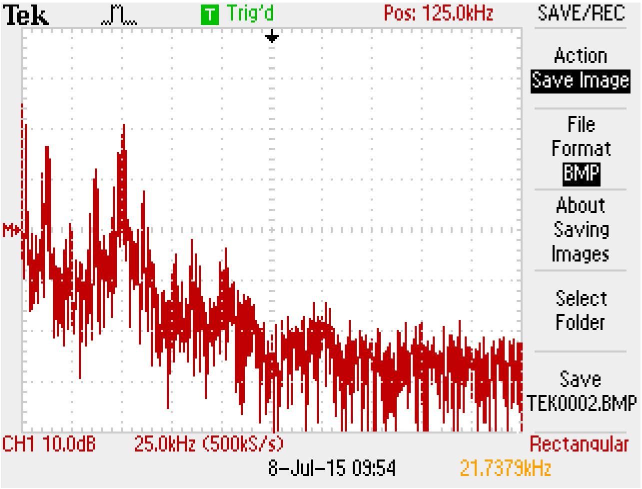

Fig. 10. FFT spectrum, motor Air 3020B, 50 % of max. power

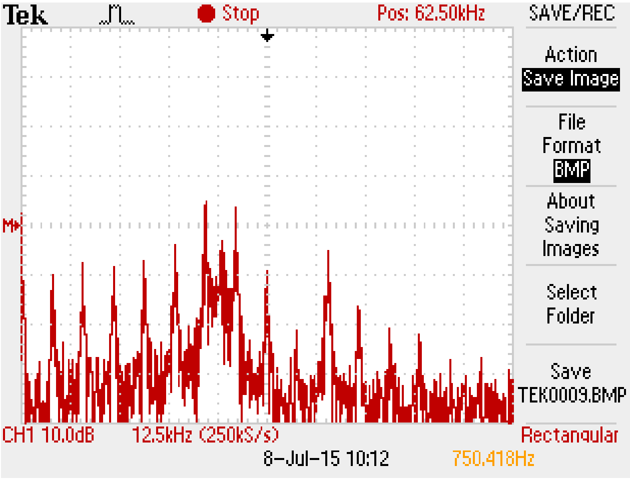

Fig. 11. FFT spectrum, motor Park 480, min. revolutions

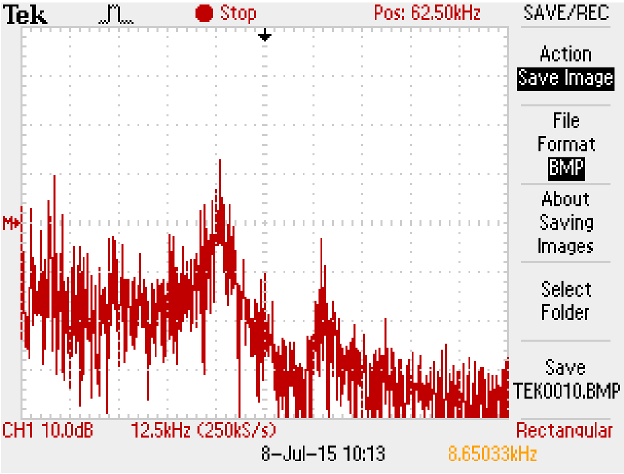

Fig. 12. FFT spectrum, mot. Park 480, 50 % of max. power

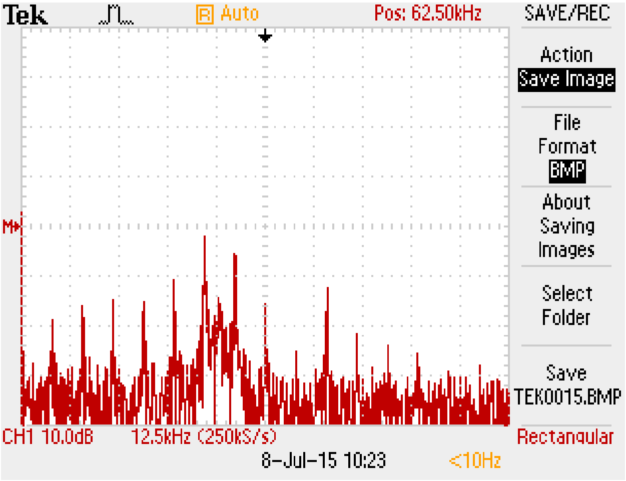

Fig. 13. FFT, Ray c2822-27, min. revolutions

This magnetometer is a vector magnetic analyzer from DC to 500 Hz frequency band. Simultaneous sampling in its four channels is 1 kHz, sensitivity digit/2nT and amplitude dynamics of 100 dB. Its four probes allows arbitrary geometrical configuration [7]. In our case the probes were arranged in order to measure a component of a gradient *Bxx*, *Byx*, *x*-axis both in a radial direction from the center of the motor. The first probes were placed at a distance of 0.5 m and the second at a distance of 1 meter, so our basis for measuring a gradient was 0.5 meters.

The VEMA magnetometer was set so that 10-second measurements recorded in .txt format. The data are collected from all four probes. In the *x*-axis were placed the probes A and C, the *y*-axis pointing of the probe B and D. With the embedded mathematical formulas are obtained data as the min and max value, mean, dispersion, correlation, FFT spectrum.

For results visualisation the open-source software QtiPlot was used.

Higher frequency components in the examined fields, mainly components given by PWM power drive motor regulation were measured by the magnetometer based on the induction principle.

This was carried out using an oscilloscope Tektronix TDS 2014C and induction probe in the form of a flat coil. Surface normal vector of the probe was pointing to the *x*-axis, the distance from the motor was 0.2 m.

3 EXPERIMENTS AND RESULTS

Experiment was performed in normal non-shielded laboratory conditions. Fig. 3 shows magnetic flux density of probes A and C where it is centred on zero around DC component of the measured signal. That this was not necessary and to be directly repressed 50 Hz signal component we may do the difference of data probes. Other images in this contribution are based on the difference of data probes A, C for component *Bxx* and difference of probes B, D to see *Byx*. That given difference is divided by the distance of the probes we get one component of the gradient.

Each of the BLDC motor was at first measured without the power supply, it has been hand-driven. This mode determines the leakage magnetic field by the construction of the engine. Selected results for motor Air 3020B are shown in Fig. 3 and 4. In the figures, it is well seen that the major components of the field is determined by the revolutions of rotor with permanent magnets. These revolutions were at 2.9 revolutions per second, thus the measured signal is 2.9 Hz. Peak-peak amplitude of the magnetic field at a distance of 0.5 m reaches a value of magnetic flux density Bxx approximately 0.36 μT, respective value of the amplitude gradient *GBxx* is 0.36 μT/m and *GByx* is about 0.25 μT/m.

On figures Fig. 3 and 4 is further evident the motor design with seven pole pairs on the rotor. This structure had all of the measured motors. The interaction of the permanent magnet rotor and stator poles of the magnetic circuit is causing the AC component of the field in the time interval of signals for each pole pair.

FFT spectrum in these figures documenting minimum speed 7.5 Hz and seven times multiple this frequency given by the motor design. These spectrum components have been shown on the frequency 52 Hz. Interesting is a very important component of the frequency on 260 Hz in the case of the engine Turnigy Park 480. Similar results gave the Ray motor, too.

Higher frequency components in the examined fields, mainly components given by PWM power of motor regulation were measured by the induction coil and oscilloscope Tektronics TDS 2014C. All selected engines have been measured in two modes.

The first mode is the minimal revolutions, the second mode has been defined to half the maximum power of each machine.

From the measurement result are the most interesting frequency spectrums of signals. This is shown in Fig. 9 – 13.

Spectrum of signals measured at minimum speed BLDC motor is determined by the base frequency of PWM regulators. Which in our case was 8 kHz for motor Park 480 and Ray c2822-27. On figures is well seen even multiples of the fundamental frequency. When power increased, there is noticeable lift in the spectrum up to about 50 kHz, it is already in the LF band of radio-frequency.

CONCLUSION

The assumptions have been confirmed, it means that relatively small leakage flows of different BLDC motor are interesting for further research in the issues of drones detection when we use suitable sensors, measurement methods and process the variables of weak low frequency magnetic fields. It is a research of the Vega project on the University of Security Management in Košice.

In the future the University of Security Management with the Technical University of Košice cooperation, we are planning to add the measurements of the motor leakage fields in the special chamber of the Faculty of Aeronautics, Technical University in Kosice by help of selective micro-voltmeter or low frequency spectrum analyzers.

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