Physical Damage Simulation on Drone and Wireless Communication Devices by Space Weather Hazard

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Abstract

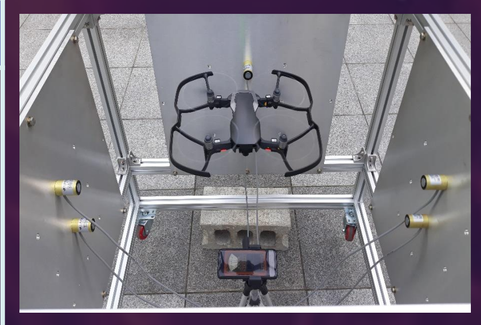
Drones are widely used for industrial purposes as well as for hobbies, and users are increasing rapidly every year. In this study, we tested the effect on the magnetic sensor in the drone by the Space Weather event. Firstly, we build the magnetic field generator capable of simulating the earth magnetic field while we observe the flight status of the drone as controlling the intensity of the magnetic field. When the geomagnetic disturbance alarm level is G5, the change of magnetic field in Icheon(Geomagnetic Latitude 28°N) in Korea is more than 300nT, so we found that it does not have significant effect on drone. Also, when the magnetic field intensity is more than 51μT, the magnetic sensor have become abnormal and regardless of the amount of change, the magnetic sensor has become abnormal. Nextly, the effect of solar radiation on Wifi frequency band is tested. We give change to noise intensity to test the Wifi reception intensity and quality while the solar propagation noise was calculated simultaneously. Although there was little change in Wifi reception intensity in accordance with the intensity of noise, the quality was gradually decreased, and the solar propagation at the time of rapid decline was calculated to be more than 300 million SFU.

Drone Test

- Purpose
  - Flight status was observed when magnetic sensor in the drone was effected by geomagnetic change due to solar storm
- Range
  - Build magnetic field generator to imitate geomagnetic storm and check drone status as we give change geomagnetic field
- Test composition
  - Magnetic field generating device
    - ✓ Electromagnet(24V, 0.26A, 1.796kg/ea)
    - ✓ Frame : Duralumin Profile, Standard HFS8 Series
    - ✓ Electromagnet fixtures: Duralumin 6061 plate, T12, black aluminate treatment
  - Power Supply: MK3305P(programmable DC power supply), 30V 5A * 2, 5V 3A *1
  - Drone : Mavic Air
  - Flight Place: Daejeon, Korea(36° 19' 60" N)
- Test contents

Case 1	Case 2
Regular change in Magnetic field ➢ The voltage is increased at 5 second intervals of 10 ~ 30 V (total variation 8μT) and then it decreases ➢ Observation on the Drone	Sudden change in Magnetic field ➢ Increased Voltage upto 30V ➢ Turned off after 1min ➢ Observation on the Drone

Test environment 1



Test environment 2

- Test result and conclusion

Case 1	Case 2
➢ Compass Errors when the Magnetic Field intensity is over 51μT(28V) ➢ Error occurred in the intensity of normal operation over 51μT(28V) ➢ Returns to normal below approx. 45μT(13V)	➢ Instantly intensity of magnetic field becomes over 52μT(30V) ➢ Compass error occurs

⇒ Absolute value of magnetic field
- ✓ Average intensity of magnetic field in Korea is 40 μT
- ✓ As a result, compass error occurs in certain value of intensity(Approx. 51 μT)

⇒ Magnetic field variation
- ✓ Error occurred in the change of 8 μT assuming dramatic change of magnetic field
- ✓ Normal operation in weak magnetic field intensity in the change of 200 ~ 500 nT (G4 ~ G5 stage)

⇒ Others
- ✓ The magnetic sensor of the drone does not affect the flight due to the multi-calibration device, but there is a risk of the drone loss due to the loss of direction by compass error
- ✓ There is a risk of sensor damage when the sensor repeatedly exposed to strong magnetic field (Requesting sensor correction per test)

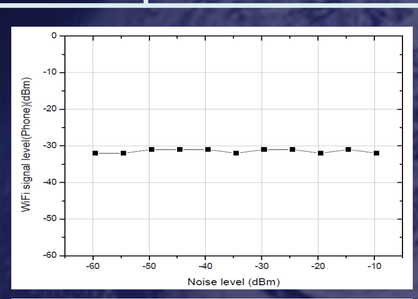
Wifi Test

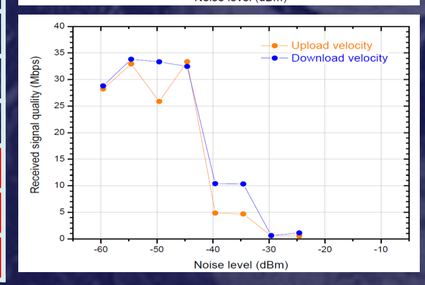
- Purpose
  - Test for WiFi reception signal strength and quality by Solar Propagation Change
- Range
  - The wireless router in 2.4GHz band generates a noise signal of 100MHz and transmits it through an antenna to increase the noise intensity, and observes the reception intensity and quality salvage
- Test Composition
  - Noise Signal Generator, N5182A MAG vector signal Generator
  - Frequency: 100MHz
  - Signal Amp.: ZHL-4W-422+(High Power Amplifier 50ohm 4W 500 to 4200MHz (Minicircuits))
  - Signal Amplifier Output strength: +34dbm
  - Antenna: 2.4GHz Yagi(VSWR 1.5 Gain 16dBi)
  - Wired and Wireless Router(Wifi device): ipTIME N104R(Frequency 2.4GHz, transmit Power 16dBm ±2dB)
  - Cell Phone: Samsung Galaxy S9
- Test Contents
  - Connecting 2.4GHz Wifi Devices
  - Connecting Noise Signal Generator with Signal Amp.
  - Signal Generation with various different Signal
  - Signal Transmission through Amp. setting Antenna towards router
  - Measuring Wifi signal strength, cell phone upload and download Spd. By Noise signal strength
  - Solar Flux Unit Calculation corresponding Noise signal strength
    - ✓ $P_R = \frac{1}{2} G \frac{\lambda^2}{4\pi} F \quad \frac{W}{Hz}$
    - ✓ $kTB = \frac{1}{2} GB \frac{\lambda^2}{4\pi} F_{sfu} 10^{-22}$
    - ✓ P_R : Receiver Power
    - ✓ G : Antenna Gain
    - ✓ k : Boltzmann constant
    - ✓ T : Ambient Temperature, 273K
    - ✓ F_{sfu} : SFU

- Test result and Conclusion

Signal	WiFi signal level (Phone)(dBm)	wifi Speed (Mbps)	Cell phone upload SPD. (Mbps)	Cell phone Download SPD. (Mbps)	Delay Time (ms)	Damage Percentage (%)
-59.59	-32	72	28.23	28.8	76.6	1.7
-54.59	-32	65	32.94	33.82	161.3	3.3
-49.59	-31	72	25.88	33.34	426.5	7.5
-44.59	-31	65	33.36	32.46	407.2	6.8
-39.59	-31	72	4.86	10.4	279.4	4.2
-34.59	-32	57	4.69	10.34	1421.3	5.1
-29.59	-31	43	0.6	0.63	488.9	5.7
-24.59	-31	39	0.55	1.12	741	2.1
-19.59	-32	43	NA (Incomprehensible) / Disconnected			
-14.59	-31	43	NA (Incomprehensible) / Disconnected			
-9.59	-32	43	NA (Incomprehensible) / Disconnected			
Default	-30	65	18.09	23.47	78.8ms	9.70%

Signal	SFU, B=100MHz
-59.59	3.45E+07
-54.59	1.09E+08
-49.59	3.45E+08
-44.59	1.09E+09
-39.59	3.45E+09
-34.59	1.09E+10
-29.59	3.45E+10
-24.59	1.09E+11
-19.59	3.45E+11
-14.59	1.09E+12
-9.59	3.45E+12





⇒ Wifi Reception signal strength in correspondence with Noise signal
- ✓ Signal strength for the Wifi reception is almost constant even if the noise signal strength is stronger

⇒ The quality of received signals according to noise signal
- ✓ Upload and Download speed is dramatically decreased under 39.59dBm
- ✓ No Internet Connection under -19dBm

⇒ No change in WiFi reception strength but signal quality drops

⇒ Over 3.45x10^9 SFU, it causes Wifi quality error

Conclusions

- Two kinds of test related to R(Radio Blackout)-value and G(Geomagnetic Storm)-value among Space Weather Condition Components
- As a test result, in the mid-latitude region like Korea, there was no significant effect on drone magnetic sensors according to the change of magnetic field strength, but if the calibration is not performed during the continuous magnetic field exposure, the magnetic sensor may be misled
- In high-level magnetic field 51μT(28V), it was drone flight is difficult while in the area where magnetic field is relatively weak, there is no disturbance in the drone magnetic sensor even if the magnetic field strength equivalent of G5
- Wifi signal will not be significantly changed by different noise signal but will be influence by reception signal quality
- As a result of calculating the SFU corresponding to the noise signal, the drop in the Wifi will occur over 3.45x10^9 SFU

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