Investigation of shielding materials impact on the effectiveness of UAV FSO communication systems

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Abstract. The use of Free Space Optics (FSO) for Unmanned Aerial Vehicle (UAV) communication is a relatively new innovation that could become a necessity for all scenarios where real-time delivery of high date rates is essential. The present paper investigates one of the challenges being faced by this type of system, in particular the relationship between shielding materials of the protective dome and the wavelength of the emitted photons.

1. Introduction

One of the crucial factors to determining UAV performance is the existence of reliable, high performance wireless communication links. Optical links have a number of advantages over RF, including high data rates, improved security and many others. The performance of laser based optical systems is not affected by Electromagnetic Interference (EMI) and is not subject to interference with traditional wireless devices such as microwave or radio system [1].On the other hand, in order to protect the system hardware from weather conditions, etc., the construction of a protective dome is necessary. To ensure that the communication performance is not degraded, one must study the effect of the dome presence on the emitted signal.

2. The Use of Free-Space Optics by UAVs

Unmanned Aerial Vehicles are increasingly being used for both civil and military operations and usually carry a large number of sensors for covering landscapes, border monitoring, observing traffic conditions on the roads, etc [2]. UAVs, particularly those flying in swarm formation, therefore require the acquisition of large amounts of data and thus a high rate of data connectivity.

Conventional communications between UAVs and ground stations mainly use RF or microwave systems and low-earth-orbiting satellite links. The data rates provided by such systems are in the order of hundreds of kbit/s or less. On the other hand, the use of optical carrier frequencies which is adopted by Free Space Optical Communication Systems can provide data rates exceeding several Gbit/s [3], [4].

A FSO communication system consists of an optical transmitter, a modulator and a telescope. The receiver consists of a detector, a decoder and a telescope to acquire the optical signal. Essentially, modulated optical beams are propagated through an atmospheric channel, in order to establish short, medium or long reach wireless data transmission. Furthermore the study of the special needs and requirements of the dome which covers the FSO unit on the UAV is also very important.

Currently FSO is being researched for applications involving ground-to-ground (short and long distance terrestrial links), satellite uplink/downlink, inter-satellite, deep space probes to ground, ground-to-air/air-to-ground terminal [5]. Apart from offering higher data rates, other advantages include security aspects, low size and weight demands, small aperture sizes and low power consumption [6].

On the other hand for a FSO system to work an unobstructed line-of-sight must exist. A potential weakness of such a set up therefore, is the susceptibility of FSO links to weather conditions. Fog in particular can cause severe attenuation of the propagated signal with even moderate continental fog resulting in attenuation of 130 dB/km [6]. The above issues must be therefore taken into account when using FSO for UAV applications.

3. Materials used for electromagnetic interference shielding

Electromagnetic interference shielding refers to the reflection and/or adsorption of electromagnetic radiation by a material, which thereby acts as a shield against the penetration of the radiation through the shield [7]. As electromagnetic radiation, particularly that at high frequencies (e.g. radio waves, such as those emanating from cellular phones) tend to interfere with electronics (e.g. computers), EMI shielding of both electronics and radiation source is extremely important for UAV communication systems. When defining the performance of a shielding material, the term often quoted is shielding effectiveness (EMSE). This value, obtained in decibels, provides an indication of the quality of shielding a material possesses [8].

Carbon materials are usually employed in EMI shielding and they include composite materials, colloidal graphite and flexible graphite [7]. Polymer-matrix composites containing conductive fillers are attractive for shielding [9] due to their processability (e.g. moldability), which helps to reduce or eliminate the seams in the housing that is the shield. Electrically conducting polymers are becoming increasingly available, but they are not common and tend to be poor in the processability and mechanical properties. Cement–matrix composites have higher shielding effectiveness than the corresponding polymer-matrix composites. Carbon is a superior matrix than polymers for shielding due to its conductivity, but carbon– matrix composites are expensive [10]. Metals are more attractive for shielding than carbons due to their higher conductivity, though carbons are attractive in their oxidation resistance and thermal stability. A particularly attractive EMI gasket material is flexible graphite, which is a flexible sheet made by compressing a collection of exfoliated graphite flakes without a binder.

Comparatively little research has been undertaken regarding new electromagnetic shielding materials in the past ten years [11]. Fibre reinforced polymer (FRP) composite materials have, however, been identified in recent years as being the desired choice for the replacement of orthodox metallic alloys in many aerospace applications [8].

FSO provides vastly improved electromagnetic interference behavior compared to using microwaves. On the other hand a material presents different characteristics during the propagation of light through it. The use of appropriate material for the dome construction can improve the efficiency of the FSO link. The absorption coefficient depends on the material and also on the wavelength of light which is being transmitted. The absorption coefficient determines the attenuation of light of a particular wavelength. In a material with a low absorption coefficient, light is only poorly absorbed, and if the material is thin enough, it will appear transparent to that wavelength.

The effectiveness of the relationship between shielding materials of the dome and the wavelength of the photons for the FSO communication systems of UAVs will be further investigated in the full paper.

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References

[1] K. Zettl, "High Bit Rate Optical Wireless Systems For Swarm Unmanned Aerial Vehicles: A Feasibility Study," *The Mediterranean Journal of Computers and Networks*, Vol. 3, No. 4, pp. 142-150, 2007.

[2] E. Leitgeb et al. “Investigation in Free Space Optical Communication Links between Unmanned Aerial Vehicles,” *Proc. of the 9th international conference on transparent optical networks (ICTON 2007),* Rome, 2007.

[3] Davide M. Forin, G. Incerti, G.M. Tosi Beleffi, A.L.J. Teixeira, L.N. Costa, P.S. De Brito Andre, B. Geiger, E. Leitgeb and F. Nadeem (2010). Free Space Optical Technologies, Trends in Telecommunications Technologies, Christos J Bouras (Ed.), ISBN: 978-953-307-072-8, InTech, DOI: 10.5772/8488. Available from: http://www.intechopen.com/books/trends-in-telecommunications-technologies/free-space-optical-technologies

[4] J. Wells “Faster than fiber”, IEEE Microwave Magazine, vol. 10, no. 3, pp. 104–112, May 2009.

[5] E. Leitgeb et al. "Current Optical Technologies for Wireless Access," *Proc. Of the 10th International Conference on Telecommunications (ConTEL 2009),* Zagreb., 2009.

[6] C. Chlestil et al, "Reliable Optical Wireless Links Within UAV Swarms”, *Proc. of the 8th international conference on transparent optical networks (ICTON 2006)*, Nottingham, 2006.

[7] D. Chung, "Electromagnetic interference shielding effectiveness of carbon materials." *Carbon*, Vol.39, No 2, pp. 279-285, 2001.

[8] C. von Klemperer, et al. "Metallic filler powders to improve the electromagnetic shielding of FRP laminates," Proc. 17th International Conference on Composite Materials (ICCM-17), Edinburgh, 2009.

[9] L. Xing, J. Liu, S. Ren, “Study on electromagnetic property of short carbon fibers and its application to radar absorbing materials,” *J. Mater. Eng.*, Vol. 1, pp. 19-21, 1998.

[10] X. Luo, D. Chung, “Electromagnetic interference shielding using continuous carbon fiber carbon–matrix and polymer– matrix composites.” *Composites: Part B*, Vol. 30, No. 3, pp.227–31, 1999.

[11] M. Schlechter, “EMI: Materials and Technologies,” http://www.electronics.ca