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The Hybrid Wireless Communication Link

Mr. Pradeep Nayak[1], Tejas R[2], Suraj S Ankolekar[3], Sushma K N[4], Swetha S[5]

Assistant Professor, Department of Information Science and Engineering[1]

Students, Department of Information Science and Engineering[2,3,4,5]

Alvas Institute of Engineering and Technology, Mijar, Moodbidri, Karnataka, India

tejasrao2002@gmail.com, surajankolekar9@gmail.com,

sushma.kn998@gmail.com, sethasanjeevaiah@gmail.com

Abstract: *The paper describes the development of a wirelessly hybrid data connection that employs two channels of transmission using radio waves and optical radiation (FSO, free space optics) (RF - Radio Frequency). Its data range was established under various operating settings based on several factors (such as diode lasers, optics aperture, photodetector phototransistor, signal bandwidth, and beam divergence) of the connection components (visibility and turbulence). The Military Communication Institute in Poland conducted the first testing on the link prototype (TRL 6). The findings show that the employment of an FSO/RF information system may boost connection availability, data transmission security, and immunity to malicious interference. Given the characteristics of this technology, it was found to have a significant degree of military application potential.*

Keywords: Wireless Communications, Quantum Cascade Lasers, Free Space Optics, Data Transmission Security, Hybrid Data Link;

I. INTRODUCTION

These days, radio technology is used in military wireless communication systems to offer a high availability data link across a wide region in a variety of weather situations. The use of radio-communication systems is, however, constrained by several factors, including spectrum license, the impact of contemporary electronic warfare systems, and electromagnetic compatibility of system components, particularly those operating within one object (ensuring co-site compatibility). For a radio planning system, the use of co-site radio communication devices raises the bar. The primary function of the radio planning system is to produce and distribute radio data while considering interference factors. These requirements let the entire radio system function (ensuring internal compatibility of the system components). In some circumstances, insufficient spectral resources prevent the guarantee of optimal performance.

A communication system (due to power reduction of the useful signal in the given radio relations). Therefore, the development of alternative wireless communication technologies without co-site separation and spectrum licensing restrictions is always necessary. Such capacity gaps can be filled by using radio/optical hybrid data links

Two data transmission channels employing optical radiation (FSO) and radio waves make up the hybrid link's architecture (RF). The proposed optical channel uses MCT photodetectors and quantum cascade lasers to operate in the spectral region of 8–12 m (LWIR), in contrast to conventional FSO/RF communication systems. Therefore, compared to currently in use FSO systems operated in the near-infrared (900 nm - NIR) or short wave infrared (1500 nm - SWIR) range, it is less sensitive to worse atmospheric phenomena (fog, mist, or turbulence), harder to detect, interception of data transmissions, and lower risk of interferences. Due to the minimal signal attenuation that radio connections exhibit in adverse weather (such as fog and turbulence), the combination of both technologies into one FSO/RF device enables an increase in data link availability of up to 99.999% of its worth [6, 7]. For military operations, the following is crucial: enhancing data transmission security boosting link availability decreasing the likelihood of detection increasing resistance to intentional interference Figure 1. Schematic diagram of the FSO/RF hybrid data link, FSO – optical channel, RF – radio channel, MUX – multiplexing system.

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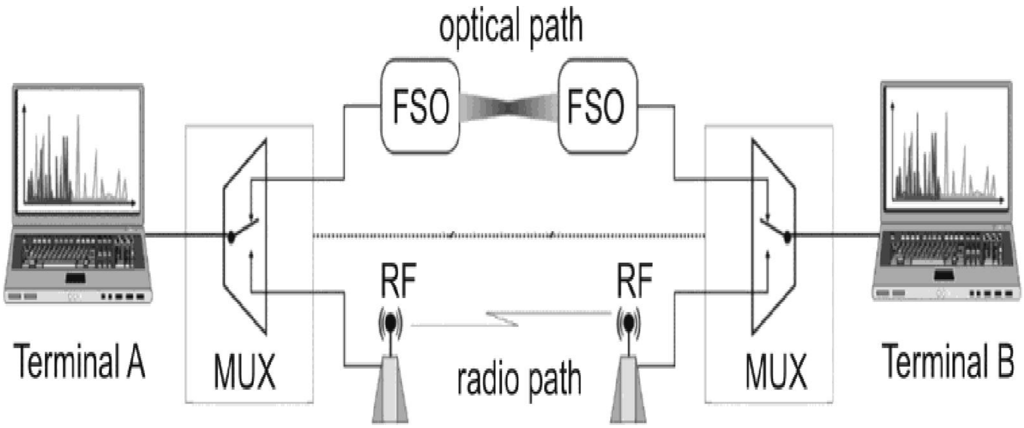

The route a light beam takes as it moves thru an optical medium is known as the optical path (OP). The length of a section in a particular OP, or the Euclidean distance averaged along rays between any two places, is known as the geometrical electro-optic length (GPD), also known as the geometrical path length. By utilizing folded optics, an optical device's mechanical length can be lowered to less than the GPD. The GPD times the medium's refractive index yields the optical path duration in a homogeneous medium.

II. FSO/RF HYBRID LINK PROTOTYPE

Key technologies impacting the characteristics and functioning of the FSO/RF device can be identified via analysis of its construction. Fig. 2 depicts the schematic diagram of the FSO/RF data connection. With the examination of the quality of data transmission in both channels, the collaboration algorithm of FSO and RF transmission channels has been put into practice.

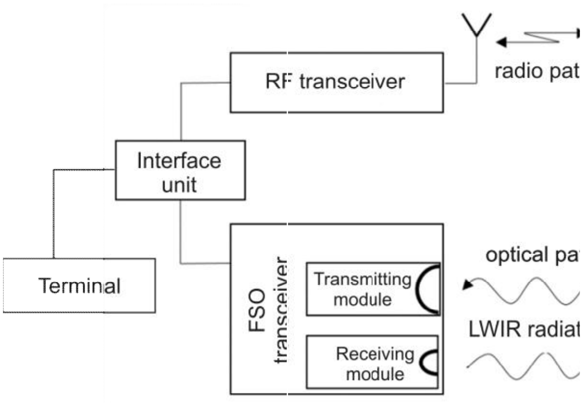

Figure 2. Block diagram of the FSO/RF hybrid link prototype.

Quantum cascade lasers with a 9.3 m wavelength were employed in the FSO transmitter. Utilizing a special optoelectronic technology, the transmitted radiation is actively power-regulated. The implemented method not only allows for the stabilization of laser pulse strength and identification of beam interruption at the receiver (accidental or intentional ones). The possible consequences of data transmission failure make it crucial. This may occur due to malfunctions in the elements of the transmitting and/or receiving paths, perturbations in the field of vision of the transmitting and receiving systems brought on by air conditions or outside objects, or both. The mechanical construction integrates whole components of the FSO transceiver (Fig. 3).

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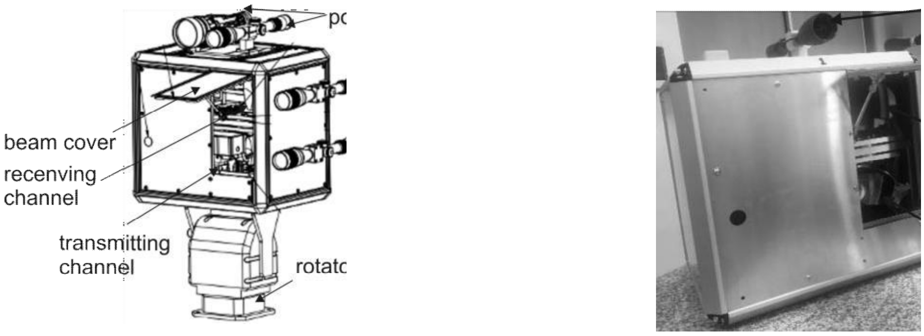

Figure 3. 3D model and view of the FSO head (transceiver and receiver).

III. PRELIMINARY TESTS

The preliminary tests' primary objective was to evaluate the FSO/RF prototype's functions, including the data link's availability, the transmission rate and BER (Bit Error Rate) of both FSO and RF channels, and the turnaround time for remote channel reconfigurations. The measurement settings and perspective of the FSO transceiver/receiver with a GPS positioning system are shown in Figure 4. WLAN was utilized as a radio channel.

Figure 4. View of the test conditions and the FSO transceiver with GPS positioning system.

Transceiver shutters were used to mimic laser beam interruption or unplug the WLAN antenna during tests of the hybrid link's availability. The duration of each channel's switching was timed during this process. The Netperf program was then used to measure the transmission rate, packet losses, and delay time. A specialized version of HYBRYDOL® software from KenBIT Koenig I Wspólnicy Sp.j. was used to calculate the bit error rate. This software compares the matching signals generated locally with the pseudo-random data streams delivered in the packet in both their coded and uncoded forms. The BER value is determined by dividing the number of error bits by the total number of bits received. Table 1 lists the outcomes of the preliminary testing.

Table 1. The results of preliminary tests.

Test name	**Result**	
Automatic switching time	FSO → RF	28s
	RF → FSO	18s
Control switching time	FSO → RF	23s
	RF → FSO	12s
Transmission rate	FSO	10.9Mb/s
	RF	37Mb/s
BER level for different defined transmitter radiation power levels	very low [20%]	no link
	low [40%]	10-2
	medium [60%]	10-5

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	high [80%]	0
	very high [100%]	0

IV. RANGE ANALYSIS OF OPTICAL LINK TRANSMISSION

Some optical route characteristics have a major role in determining the data transmission range. Absorption, scattering, and turbulence phenomena should be taken into consideration while analyzing the attenuation of a beam of light. When operating within the so-called atmosphere transmission window, the first one was decreased. Extinction coefficient value () analysis is done to establish the degree of radiation dispersion. Analytical models, such as those based on visibility, or simulation software (PcMODWIN) are used to calculate its value.

For example, extinction coefficient values for different visibilities and two wavelengths of 1.5μm and 10μm based on the Kim model were determined (Fig. 5).

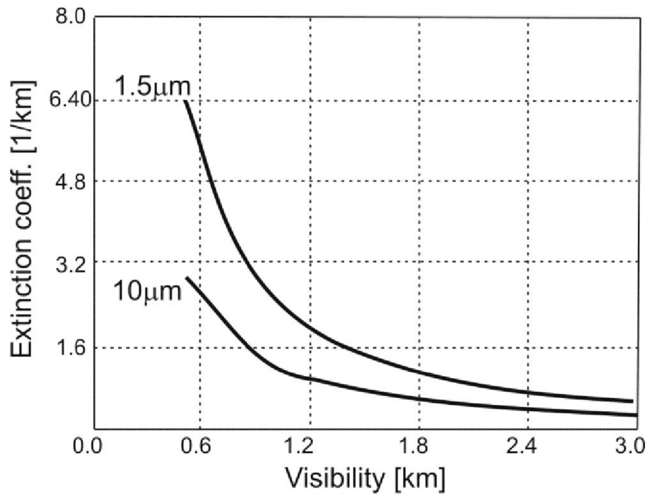

Figure 5. Extinction coefficient vs. visibility for two wavelengths: 10μm and 1.5μm.

Appropriate atmospheric conditions can be established for visibility values. In contrast, the visibility range of 2 km–4 km is similar to the appearance of fog, heavy rain, or moderate snow. As an illustration, the vision range of 50 m–200 m corresponds to dense fog or extremely dense snow. The extinction coefficients for these visibility ranges are, respectively, 78.219.6 and 1.9600.954 [9]. The weather has a significant influence on radiation attenuation and can affect the data range of the FSO. In contrast to the shorter ones, such as NIR and SWIR, operating in the longer wavelength range (LWIR) might extend the link range (Fig. 6).

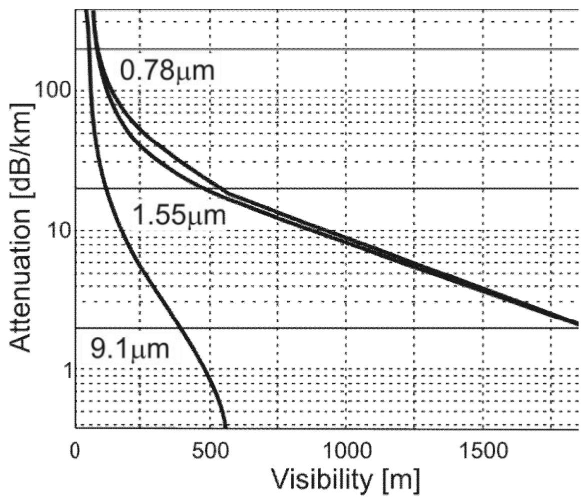

Figure 6. Dependence of visibility on attenuation coefficient for three spectral ranges: NIR, SWIR, and LWIR.

An essential element that can greatly weaken recorded optical pulses is turbulence. The refractivity turbulence structure constant Cn2 serves as a defining characteristic. The range of values for this constant is 10-17m-2/3 (mild turbulence) to 10-12m-2/3 (very strong turbulence). The height of the FSO device site, the kind of surface across which radiation is transmitted, temperature and pressure distribution, and even wind speed, all affect the Cn2 parameter. The value of this parameter can be calculated using a variety of analytical models based on climatic characteristics. Fig. 7 [10] illustrates the dependency of Cn2 on the FSO height as calculated by the Gurvich model.

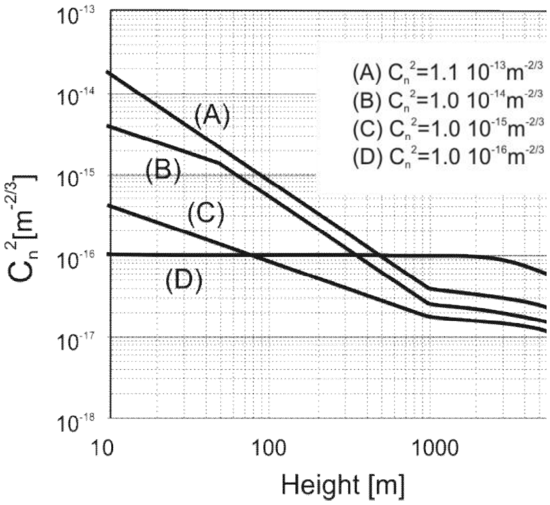

Figure 7. Cn^2 parameter vs. height determined for the Gurvich model with four turbulence levels [10]

Based on the final building criteria for the FSO prototype, an analytical examination of the data set was carried out. The SNR values for various weather conditions (the extinction coefficient) and turbulence levels (values of the Cn2 parameter) were calculated (Fig. 8).

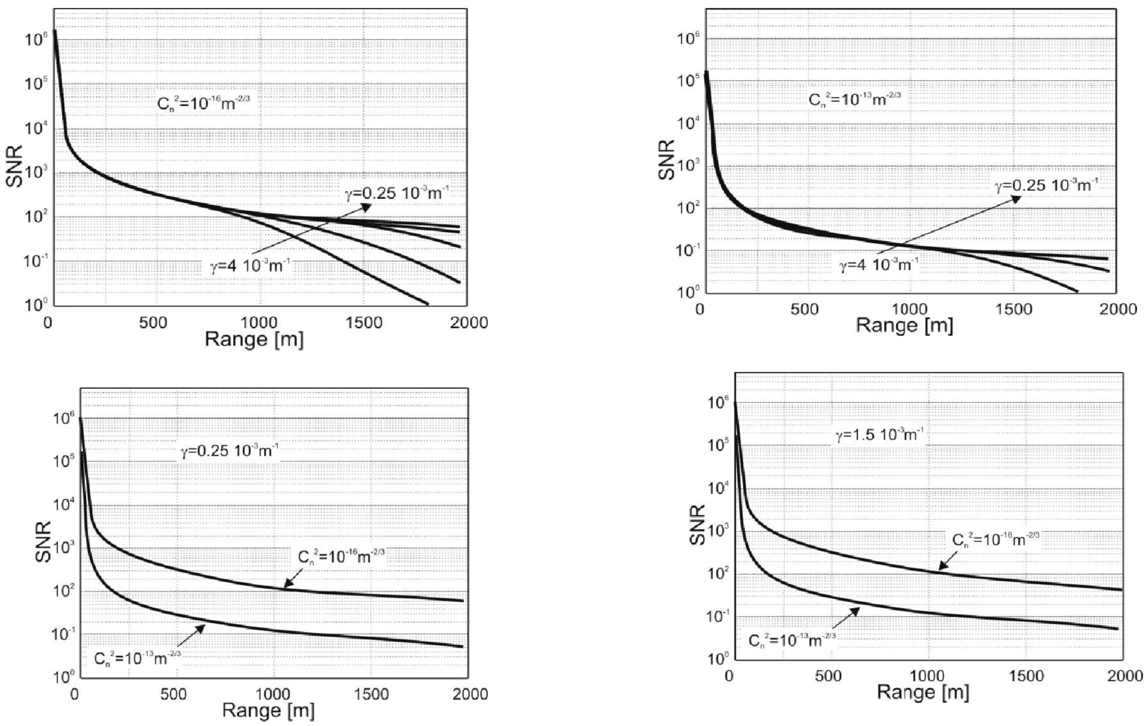

Figure 8. SNR dependence on the data link range of the developed FSO prototype for various weather conditions (determined by $\gamma = 0.25m^{-1}$ - visibility better than 10 km, and by $\gamma = 4m^{-1}$, visibility of 0.5 km)

At close ranges, the impact of turbulence is very noticeable. The impact of scattering likewise develops along with the range. Data transport can be considerably slowed down by intense turbulence. It will happen if the laser beam travels close to the surface of the earth and if there are significant temperature or wind speed fluctuations. However, data transfer across a certain distance is made possible by the use of an additional RF data connection in a hybrid arrangement.

V. CONCLUSION

The f FSO/RF hybrid data connection can guarantee point-to-point communications via mobile communication nodes between command posts and fixed or mobile infrastructure at different levels of command (division, brigade, battalion). In some situations, the employment of FSO/RF technology enables the replacement of previously employed radio devices, which lowers the demand for spectrum and enhances the functionality of other radio devices in the system. Additionally, the higher availability of 99.999% provided by the usage of FSO/RF hybrid devices makes wireless communications more resilient to the effects of electronic warfare systems.

REFERENCES

[1]. Suchański, M., Kaniewski, P., Matyszkiel, R. and Gajewski, P., "Dynamic spectrum management in legacy military communication systems," 2012 Mil. Commun. Inf. Syst. Conf., 1–5 (2012).

[2]. Matyszkiel, R., Polak, R., Lubkowski, P. and Laskowski, D., "Mechanisms of immunization of broadband radio stations for targeted interference," XII Conf. Recognize. Electron. Warf. Syst. 11055, 110550G (2019).

[3]. Kosmowski, K. and Matyszkiel, R., "Verification of the criterion and measures of interferences used in radio planning systems," XII Conf. ReconnaisRecognisen. Warf. Syst. 11055, 110550J (2019).

[4]. Mikołajczyk, J., Bielecki, Z., Bugajski, M., Piotrowski, J., Wojtas, J., Gawron, W., Szabra, D. and Prokopiuk, A., "Analysis of Free-Space Optics Development," Metrol. Meas. Syst., 653-674 (2017).

[5]. Leitgeb, E., Plank, T., Awan, M. S., Brandl, P., Popoola, W., Ghassemlooy, Z., Ozek, F., and Wittig, M., "Analysis and evaluation of optimum wavelengths for free-space optical transceivers," 2010 12th Int. Conf. Transparent Opt. Networks, 1–7 (2010).

[6]. Matyszkiel, R., Polak, R., Kaniewski, P. and Laskowski, D., "The results of transmission tests of polish broadband SDR radios," 2017 Commun. Inf. Technol., 1–6 (2017).

[7]. Wisniewski, M., Dobkowski, A., Pater, G., Matyszkiel, R., Kaniewski, P. and Grochowina, B., "Test results of polish SDR narrowband radio," 2017 Commun. Inf. Technol., 1–6 (2017).

[8]. Mikołajczyk, J., Szabra, D., Matyszkiel, R. and Grochowina, B., "Possibilities of Using FSO/RF Technology in Military Communication Systems," 2018 New Trends Signal Process., 1–4 (2018).

[9]. Guo, F., Tang, J., and Xiao, X., "Foggy scene rendering based on transmission map estimation," Int. J. Comput. Games Technol. 2014, 1-13 (2014).

[10]. Ghassemlooy, Z., Popoola, W. and Rajbhandari, S., [Optical wireless communications: system and channel modeling with Matlab®], CRC press (2019).