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Studying fibre-optic link used to transmission an analogue signals

Streszczenie. *Transmisja światłowodowa w porównaniu do innych mediów transmisyjnych, takich jak kable koncentryczne czy falowody mikrofalowe posiada wiele zalet, m.in.: niewielkie tłumienie czy możliwość przesyłania sygnałów o szerokim paśmie. W pracy przedstawiono wyniki badań szerokopasmowego systemu transmisji wykorzystującego łącze światłowodowe. Przeprowadzono pomiary charakterystyki częstotliwościowej oraz przetwarzania. Ponadto została zarejestrowana odpowiedź układu na sygnał impulsowy. (**Badania łącza światłowodowego wykorzystywanego do transmisji sygnałów analogowych**)*

Abstract. *Fibre-optic transmission, compared to other transmission media, such as coaxial cables or microwave waveguides, has numerous advantages, i.a.: minor attenuation or the ability to transmit broadband signals. The paper discusses the results of studying a broadband transmission system, which utilizes a fibre-optic link. The measurements of frequency and transfer characteristics were taken. Furthermore, the response of the system to a pulse signal was recorded.*

Słowa kluczowe: Transmisja światłowodowa, nadajnik optyczny, odbiornik optyczny
Keywords: Fibre-optic transmission, optical transmitter, optical receiver

Introduction

Fibre-optic transmission, compared to other transmission media, such as coaxial cables or microwave waveguides, has numerous advantages. They include: minor attenuation (below 1 dB/km of line) or the ability to transmit broadband signals (up to several dozen GHz). Fibre-optic communication is currently commonly used for transmitting signals over large distances. Moreover, fibre-optic cables enable light propagation along the lines with virtually any shape, with the ability to create bends with a very small radius. Propagation properties of a fibre-optic link remain constant over a broad range of temperature, pressure and humidity changes. They also exhibit high resistance to the destructive impact of outside conditions (high temperature, humidity). Excellent dielectric properties of optic fibres enable their successful application in the presence of strong electromagnetic fields. Low powers of the transmitter and receiver enable the application of battery power supply [1, 2, 4, 7]. Such advantages are very important for special applications.

There are several companies worldwide, which distribute systems for fibre-optic transmission of analogue signals with the bandwidth in the order of several GHz. The manufacturers are mainly companies from the USA. The basic element of a transmitter system is an optical radiation source. Fibre-optic telecommunication systems use light-emitting diodes and laser diodes (e.g. Distributed Feedback Laser diodes). In order for an analogue signal to be sent while maintaining a low level of distortion, a fibre-optic transmitter has to ensure the stability of a laser diode operating point. The main causes for changing characteristics of a laser diode are temperature variations. To prevent that, analogue fibre-optic transmitters have a thermo-electric cooler. Whereas fibre-optic receivers use PIN photodiodes or avalanche photodiodes. They enable detecting a modulated signal (with a very broad band reaching several dozen GHz), with a short rise time, in the order of several dozen picoseconds and a narrow carrier wave spectrum. An important issue impacting the range and quality of transmitted signals is also the selection of wavelengths. A range from 1,3 μm to 1,55 μm (e.g. II and III transmission window) is very favourable due to very good fibre-optic transmission properties, i.e., lower attenuation and dispersion. Electrical signal connectors used for fibre-optic transmission of signals are mainly SMA 50 Ω. Whereas the optical connectors most often used in practice are: ST (Straight Tip), FC (Ferrule Connector), SC (Standard Connector) and LC (Little Connector). Moreover, each of the aforementioned connectors, due to ferrule tip polishing type is available in two versions: UPC (Ultra Physical Contact) and APC (Angled Physical Contact) [3, 5, 6].

Research

The research was conducted as part of the execution of a task PSOB/16-062/2014/WAT/P titled “Developing a construction concept for a portable meter for high power electromagnetic fields”, within a project DOB-1-3/1/PS/2014 titled “Methods and manners of protection against HPM pulses”. The meter constructed by the project participants shall be characterized by an operating band from 100 MHz to 12 GHz.

The fibre-optic transmission system was executed by one of the American companies, as per the requirements of the project participants. It shall constitute one of the main blocks of the meter for high-power HPM electromagnetic fields.

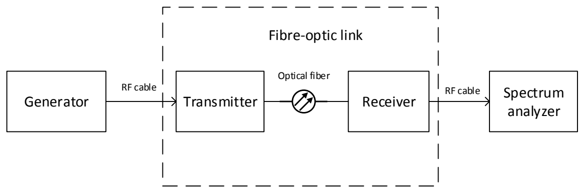

Fig. 1. Block diagram of a laboratory test stand for the determination of the frequency and transfer characteristics.

The first stage involved determining the frequency characteristics for a band from 100 MHz to 12 GHz, with a constant level of the input signal and a fibre-optic link transfer characteristic, in the range from -25 dBm to 6 dBm for selected frequencies. The knowledge of these features is necessary to limit the distortions induced by the system. The measurements were taken using an HP 8350B generator and an HP 8757D spectrum analyzer. In the course of the research, it was necessary to calibrate the measuring system, in order to eliminate the impact of attenuations contributed by the measuring cables. For the duration of the tests, the fibre-optic transmitter was supplied

from a 12V battery, while the receiver was powered by a 12V laboratory power supply. The block diagram of a laboratory test stand for the determination of the frequency and transfer characteristics is shown in figure 1. It did not take into account the power supply elements.
View of a laboratory test stand is shown in figure 2.

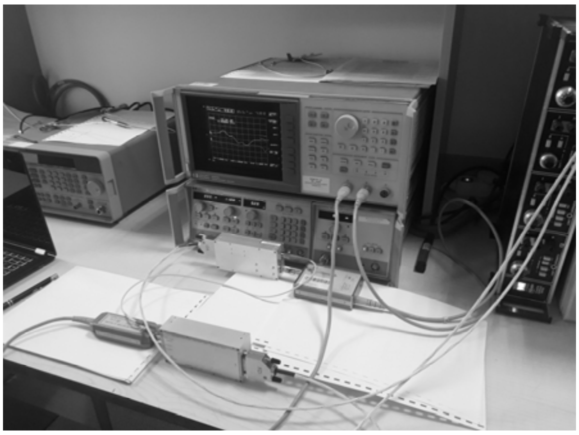

Fig.2. Laboratory test stand for the determination of the frequency and transfer characteristics.

Due to the fact that the studied fibre optic link was dedicated to the transmission of signals with a very short duration (in the order of several nanoseconds) and very high dynamics, the second stage involve twofold recording of the system response upon a pulse signal excitation. Next, a double measurement was taken for the case, in which a fibre-optic link was disconnected. The fibre-optic link functioning was validated at the Laboratory of Electromagnetic Compatibility at the Warsaw University of Technology. The source of an electromagnetic field pulse was the DS 110 generator by *DIEHL*. The HV signal was induced in a D-dot probe after passing through a balun, sent via an RF cable through a penetration to a room outside of an electromagnetically tight reflection-free chamber. Next, the signal was attenuated with *Huber+Suhner* attenuators [8]. A limiter was used in order to additionally protect the optical transmitter against a too high input signal level. A DPO 70404 digital oscilloscope by *Tektronix* was used to record the fibre-optic receiver output time waveforms. During the tests, the oscilloscope operated in the single trigger mode, recording an attenuated signal induced in the D-dot probe. The block diagram of a laboratory test stand for the recording of a pulse-induced output signal is shown in figure 3.

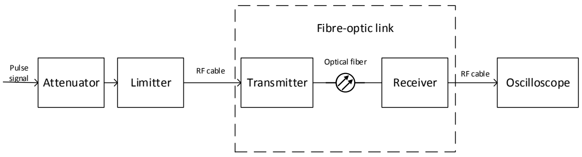

Fig. 3. Block diagram of a laboratory test stand for recording the output signal

The fibre-optic cable length during the tests was 40 m. Figure 4 shows a DS110 generator of high-power electromagnetic pulses by Diehl and a D-dot probe with a balun.

Research results

The frequency characteristics was measured for a range from 100 MHz to 12 GHz, with a harmonic excitation of 0 dBm. The measurements were preceded by the calibration of a measurement line, in order to take into account the attenuation of RF reference cables. The frequencies were selected in such a way, so that the measurements, with the observed variations of the input signal level, were taken with a lower frequency step. Within the frequency ranges where the output signal level varied slightly, the measurements were taken with a larger frequency step. The results of the tests covering the frequency characteristics a fibre-optic link with coaxial cables are shown in fig. 5.

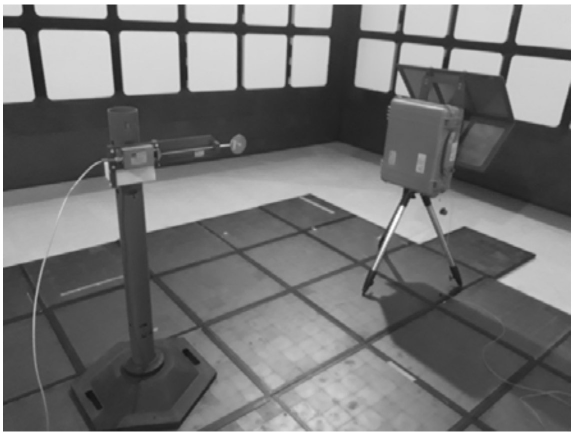

Fig. 4. Pulsed electromagnetic field generator with a D-dot probe and a balun

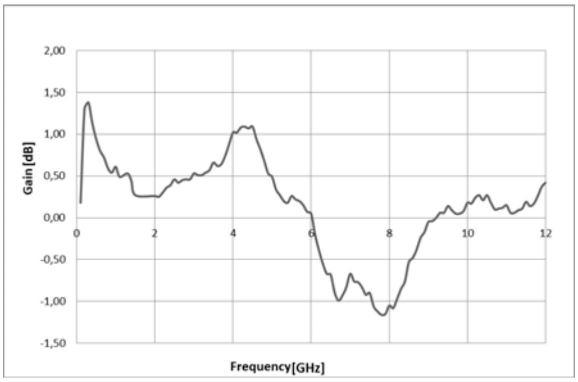

Fig.5. Frequency characteristics

Within the studied band of 100 MHz to 12 GHz, the system is characterized by frequencies of no more than ± 1,5 dB, relative to a level of 0 dB. In the band from 100 MHz to 6.1 GHz and the band from 9.2 GHz to 12 GHz, the system strengthens the signal, while in the band from 6.1 GHz to 9.2 GHz, the input signal is attenuated.

Figure 6 shows the transfer characteristics for a harmonic excitation with a frequency of 1 GHz, 7.5 GHz and 10 GHz. The input signal level was changed within a range from - 25 dBm to 6 dBm.

Approximation with the least squares method was applied based on the conducted measurements. Furthermore, the linear correlation coefficients were calculated, using the built-in *corrcoef* function of *MATLAB* software by *MathWorks*. Linear correlation was not less than 0.9999 in each case.

The time form of the signals recorded at harmonic excitation is shown in figures 7,8,9 and 10. Two tests were conducted at each configuration of the measuring system.

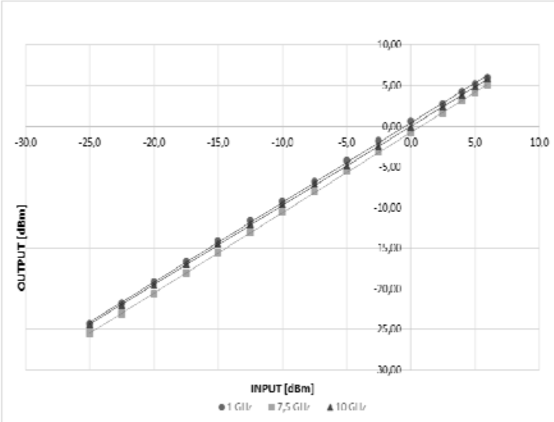

Fig.6. Transfer characteristics

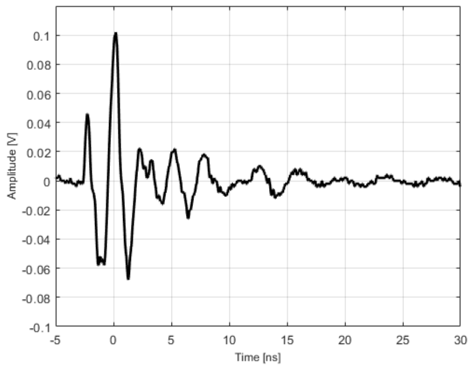

Fig.7. Time characteristic - test 1 with a fibre-optic link

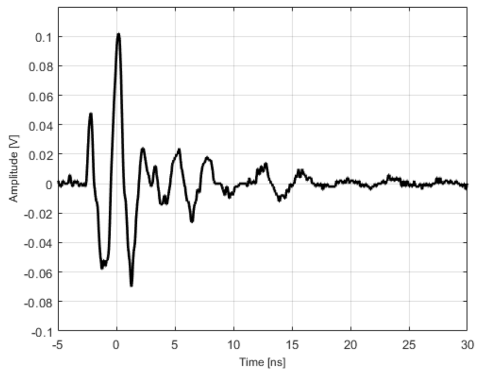

Fig.8. Time characteristic - test 2 with a fibre-optic link

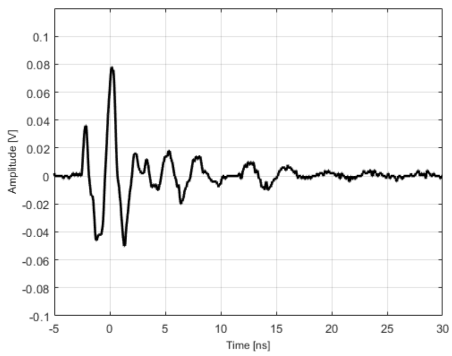

Fig.9. Time characteristic – test 1 without a fibre-optic link

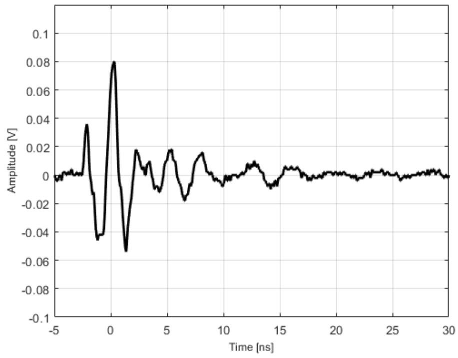

Fig.10. Time characteristic – test 2 without a fibre-optic link

The signals recorded in two tests are characterized by high repeatability. It makes it possible to compare the waveform in different configurations of the test stand.

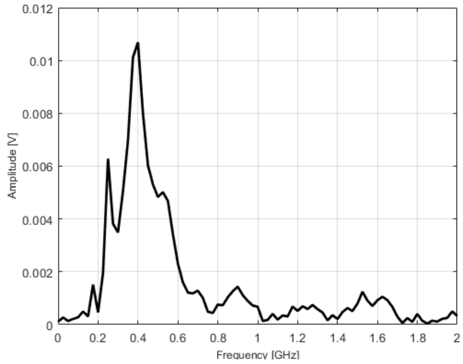

Fig.11. Signal spectrum - test 1 with fibre-optic link

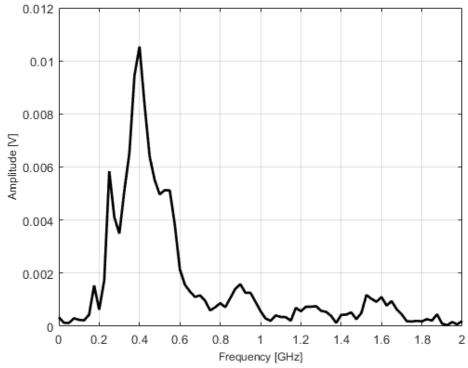

Fig.12. Signal spectrum - test 2 with fibre-optic link

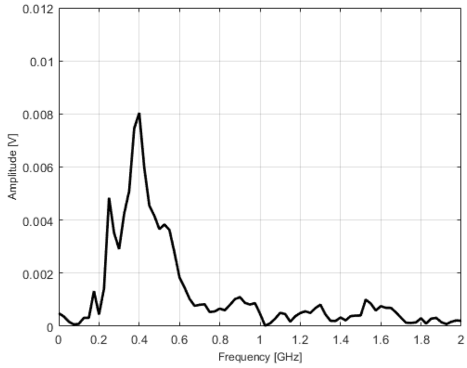

Fig.13. Signal spectrum – test 1 without fibre-optic link

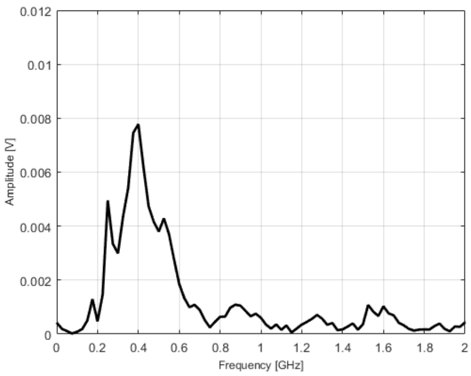

Fig.14. Signal spectrum – test 2 without fibre-optic link

Based on the time waveform of the recorded signals, shown in figures 7, 8 ,9 and 10, their spectra were plotted (fig. 11, 12, 13 and fig. 14). The calculations and characteristics were executed in the *MATLAB* software.

The characteristics shown in figures 7, 8, 9, 10, 11, 12, 13 and 14 indicate that adding a fibre-optic link does not cause significant changes of the time- and spectral-form shapes of the signal. Slight decrease of the value of the measured signal after disconnecting the fibre-optic link was observed for each of the measurement tests. It is associated with a minor enhancement of the signal level by a fibre-optic link, within a band covering the spectrum of the recorded waveform.

Conclusions

Based on the conducted tests, it can be concluded that a fibre-optic link is characterized by parameters enabling its application for designing an HPM meter for a frequency range from 100 MHz to 12 GHz.

Minor fluctuations of the frequency characteristics and the linearity of transfer characteristics make it possible to transmit an input signal with very small distortion.

Based on the conducted tests, it can also be stated that a fibre-optic link has the ability to transmit a pulse signal with a duration in the order of several nanoseconds. Satisfactory repeatability of the recorded waveforms for each of the tests was achieved.

However, it should be noted that the tests were executed for excitations of a pulse field form determined by the parameters of the applied generator (the band of generated pulses, in particular). Despite the positive results obtained at that stage of the research, we cannot guarantee the correct functioning of a fibre-optic link during the transmission of signals with a different spectrum.

The research result presented in the paper are an effect of implementing the project DOB-1-3/1/PS/2014 ",Methods and manners of protection against HPM pulses".

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