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Generation and Transmission of FCC-Compliant Impulse Radio Ultra Wideband Signals over 100-m GI-POF

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Abstract We demonstrate a novel technique for generation and transmission of IR-UWB signals over 100 metres 50-μm core GI-POF. IR-UWB pulses are made by linearly combining two 3rd-order derivatives of Gaussian pulses with different pulse-shaping factors.

Introduction
The increasing demand for high-bandwidth multimedia wireless services is hampered by the lack of available spectrum. The short-reach Ultra Wideband (UWB) technology was adopted by the US Federal Communications Commissions (FCC) as an attempt to make more radio spectrum available. UWB technology combined with optical fibers for reach extension may provide an attractive solution for high-speed data access for mobile/nomadic users at home. The selection of the impulse signal type is important as it determines the performance of UWB systems. As described in, Gaussian monocycle pulses and doubllets can provide better bit-error rates and multipath resilience among different impulse signals. Basically, these waveforms can be created by a sort of band-pass filtering of a Gaussian pulse, i.e., filtering acts in a manner similar to differentiating the Gaussian waveforms. However, these widely used pulses do not fully satisfy the FCC rules. Hence, different pulse design techniques have been proposed recently such as the pulse design technique in3,4.

In this paper, we propose a new approach to generate an UWB pulse based on the concept of linear combination of 3rd order derivatives of a Gaussian pulse. Since differentiation is a way to move energy to higher frequency bands, we exploit pulse design techniques proposed in to design pulses with better transmitted powers than the widely adopted Gaussian pulses, while respecting the FCC mask.

IR-UWB transport using plastic optical fibers
For large-scale short-range applications, multimode fibers (MMFs) offer the advantage of easy installation as their larger core diameter and numerical aperture allow large alignment tolerances. More importantly, plastic optical fibers (POFs) can enable short low-cost broadband transmission links, such as in in-home networks. When compared to silica MMFs, graded-index POF (GI-POF) offers further advantages such as smaller bending radius (<5mm), better tolerance to tensile load and stress, and simpler connectorization. Therefore, impulse radio UWB (IR-UWB) over GI-POF provides an attractive solution for in-building networks.

Theory and experiments
We consider a weighted sum of two third-order derivatives of Gaussian pulses with different pulse-shaping values of $\sigma_{G1}$ and $\sigma_{G2}$. The weighted sum value $y_{\omega3}(t)$ is given by

$$y_{\omega3}(t) = \alpha_{1} x_{i1}(t, \sigma_{G1}) + \alpha_{2} x_{i2}(t, \sigma_{G2})$$

where $x_{i2}(t, \sigma_{G2})$ is the third order derivatives of Gaussian pulses, expressed by

$$x_{i2}(t, \sigma_{G2}) = \left( \frac{3t}{\sqrt{2\pi}\sigma_{G2}} \right) \exp \left( -\frac{t^2}{2\sigma_{G2}^2} \right)$$

with $i = 1, 2$ and $\sigma_{G1} = 55$ ps and $\sigma_{G2} = 49$ ps. The Fourier transform of $y_{\omega3}(f)$ is given by

$$Y_{\omega3}(f) = \alpha_{1} X_{i1}(f, \sigma_{G1}) + \alpha_{2} X_{i2}(f, \sigma_{G2})$$

where

$$X_{i2}(f, \sigma_{G2}) = \left( j2\pi f \right)^{3} \exp \left( -\frac{(2\pi f \sigma_{G2})^2}{2} \right)$$

Based on the above analysis, in Fig. 1, we show the experiment setup to generate and transmit IR-UWB over 100 metres of GI-POF. The generated signal is used to directly modulate a DFB laser at 1302 nm wavelength.

Fig. 1: Transmission experiment setup
The modulated signal is then transmitted over 100 metres of 50-μm core perfluorinated GI-POF and detected by a 25-μm photo-detector (PD). Based on the principle above, IR-UWB pulses have been constructed off-line using MATLAB and copied to the AWG. We use a real-time oscilloscope running at a sampling rate of 50 GSamples/s to show the time-domain waveform and an RF spectrum analyzer to present the IR-UWB spectrum.

The waveform of the generated IR-UWB signal based on the combination of two 3rd order derivatives of Gaussian pulses discussed above is shown in Fig. 2. In Fig. 3, we can see that the spectrum of the generated IR-UWB is fully compatible with FCC mask, which has a central frequency of 6.44 GHz and a 10-dB bandwidth of 5.96 GHz. The spectrum is discrete because of the 250 MHz repetition rate of the AWG. It is also observed that spectral components above 7 GHz are attenuated, which is due to the frequency response of the AWG.

After 100-m transmission, the time-domain waveform is shown in Fig. 4. There is no degradation after POF transmission except the attenuation due to the fibre and coupling losses. Fig. 5 finally shows the spectrum of the received IR-UWB signal after transmission. The signal spectrum is still very nicely fitting into FCC mask without much distortion due to the POF transmission. However, a few unstable spectral lines appear below 0.9 GHz after transmission, probably due to random mode mixing effects in the GI-POF. The decrease at the high end of the spectrum in Fig. 5 is due to the limited bandwidth of the GI-POF link.

Conclusion
We experimentally generated an IR-UWB signal which fully complies with the FCC-indoor spectrum mask, even in the most severely power-restricted band from 0.96 GHz to 1.61 GHz based on a weighted sum of 3rd order derivatives of Gaussian pulses. The experimental results show successful transmission of IR-UWB with fractional bandwidth of about 92% over 100m GI-POF. Furthermore, our proposed IR-UWB over GI-POF has a potential application in high speed short range communications networks such as in-building networks.

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References