Implementation of UWB Radio-Over-Optical Fiber Transmission in the 60GHz

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Abstract—Ultra-Wideband radio-over-optical fiber (UROOF) technology demonstrates the potential for providing wireless broad-band service for the next generation optical communication system. The performance of MB-OFDM UWB over fiber transmission system is investigated considering optical modulation and demodulation impact. The recent wireless network providers require high transmission bandwidth with voice, data and multimedia service for fixed and mobile users. A radio-over-fiber system capable of very high efficient data transmission and based on multiple-input multiple-output (MIMO) and orthogonal frequency-division multiplexing (OFDM) is presented here. We will develop an ultra-wideband radio-over-optical fiber (UROOF) concepts and technologies for a number of important in-house applications characterized by a best processing gain of about 17.78dB.Channel capacity 870Mbps for 100 users at 60GHz. We also discuss future trends in the field of UWB UROOF technologies in 60 GHz.

Key words: Multimode Fiber, OFDM, Radio over Fiber, Ultra-Wideband, MIMO

I. INTRODUCTION

Now a days due to the various demands of system and mobile users with data capacity for wireless communication have been adequately provided by voice and data services. The demand of the broadband services today has much research on millimetre communication for wireless access network in terms of speed, efficiency of Radio Frequency (RF) devices. The wireless system as suffered many losses in the transmission as well as atmospheric attenuation, to overcome these problem use of Radio over Fiber system is done. It has low attenuation, electromagnetic interface, and large bandwidth.

The existing practical applications of short-range communication mainly takes the form of the Wireless Local Area Network (WLAN), Wireless Personal Area Network (WPAN), and Wireless Body Area Network (WBAN), which cover distances from tens of meters down to Sub-meters. In order to provide the higher data rates in future wireless systems, we should increase spectral efficiency (SE), design the systems with larger bandwidths, and reduce the costs per bit [6]. One of the most important candidate techniques for short-range communications that can satisfy these requirements is ultra-wideband (UWB) wireless communication [7]. UWB signals are characterized by an extremely large bandwidth. UWB frequency bands belong to 3.1–10.6 GHz according to the spectral mask defined by the Federal Communications Commission (FCC).WLAN and WPAN applications might be allowed to be deployed also across the frequency range of 57–66 GHz [4]. A very weak intensity comparable with the parasitic emission level is limited by a level of -41.3dBm/MHz defined by the FCC, low complexity, high data rates, and localization and tracking features.

Modern UWB communication systems may be realized both in the impulse form and in multiband(MB) form shown in Fig. 1(a) [6]. In the case of the impulse radio (IR), information is carried in a set of narrow pulses of electromagnetic energy where the bandwidth is approximately proportional to the pulse width. In the MB case, the UWB spectrum is split into a number of sub bands, which allows the use of narrowband techniques within each sub band. The MB UWB OFDM technology combines the advantages of SE data modulation formats (DMFs) and OFDM.

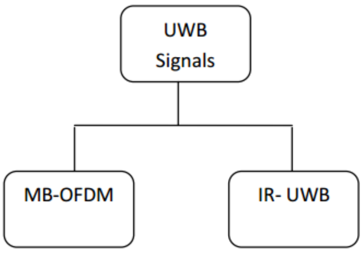

Fig. 1: UWB Signals Configuration

However UWB wireless technology applications are limited by short propagation distances of electromagnetic waveforms and multipath factors such as long delay and the difference between the output and the input signal. For successful future applications, it is necessary to increase the data-transmission range at least up to10–30 m.

Recently, we proposed a new concept that combines the advantages of the high-data-rate wireless short-range communications based on UWB technologies and, in particular, high SE and the optical fiber communication technology. The proposed concept called UWB radio over fiber (UROOF) enables the transmission of UWB radio signals over optical fiber by superimposing the UWB radio frequency (RF) signals of 60 GHz on the optical continuous-wave (CW) carrier .It has the following advantages [5] :

1) The bandwidth of the modulated carrier can reach a few percent of the carrier frequency providing the optical communication systems with the potential of carrying information at bit rates up to 1Tb/s.
2) The fiber losses are extremely low compared with other channel materials exhibiting a minimum loss of about 0.2dB/km near the wavelength 1550 nm.
3) The conversion process becomes transparent to the UWB modulation method.
4) The high costs of additional electronic components required for synchronization and other processes can be avoided.
5) The integration of all the RF and optical transmitter/receiver components on a single chip is possible.

The optical infrastructures can be developed to be capable of delivering broadband multimedia and above

1000-Mb/s traffic to subscribers in remote areas. UROOF technology can be used in security systems for collecting data from a large number of sensors andcameras equipped with UWB and transmitting it over optical infrastructures.

A. Ultra-Wideband Radio – Over – Optical – Fiber Transmission Channel with optical link -

We used a UROOF transmission system consisting of an Ultra-wide band (UWB) transmitter, directly modulated Vertical cavity surface-emitting laser (VCSEL),Multimode fiber (MMF) of λ=1.55μm , and a PIN diode as a photodetector (PD) shown in Fig. 2.

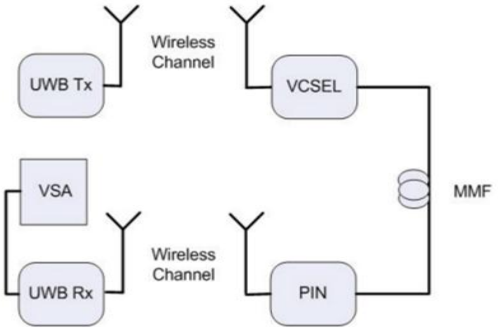

Fig. 2: Transmission line consisting of an optical link and a wireless channel

The VCSEL is characterized by low power consumption, high-speed modulation with low driving current, narrow circular beam for direct fiber coupling, low-cost and small-packaging capability, with vertical micro cavity [14]. When laser is optimised with MMF then it is designed with 1550nm VCSEL. In fig. 2 the optical link used is Multimode fiber (MMF). Multimode fibers is less expensive and has large core diameter (50-100) μm. Due to large core diameter it has higher light gathering capacity. So we use maximum number of user. The PIN diode is used as a photodetector (PD) which detect the optical signal comes through MMF.

II. LITERATURE REVIEW

There are several experimental works done on frequency (3.1 GHz to 10.6 GHz) band. In first paper we discuss about Channel capacity, Bit rate, Processing gain, Error vector magnitude, Packet error rate. In second paper we compare Bit rate and data transmission range of Bluetooth, IEEE 802.11 and Ultra-wide band (UWB) respectively. Third paper shows the relation between Error vector magnitude (EVM) and Signal to Noise ratio (SNR).

A. M. Ran, B. I. Lembrikov, and Y. Ben Ezra2010:

In this paper, the author describe the UWB frequency band from 3.1 GHz – 10.6 GHz. He discussed in detail the structure, theoretical models, and performance characteristics of a UROOF system.He presented original experimental and simulation results concerning the proposed UROOF system performance, UWB frequency up-conversion, and photonic IR-UWB generation. He calculates the packet error rate (PER), error vector magnitude (EVM), channel capacity with oscillator power. The packet error rate(PER), dependence on the MMF length for the different frequency band.The error vector magnitude depends on VCSEL bias current for different local oscillator (LO)signal power. He calculate the optical/wireless infrastructures for capable of delivering broadband multimedia and above 1000-Mb/s traffic to subscribers in remote areas. . He also calculate the channel capacity for 100 user is 58 Mbps in 4 GHz. In UWB frequency band from 3.1 GHz – 10.6 GHz the data transmission range less than 10 meter.

B. Jeff Foerster, Evan Green, DavidLeeper 2001:

In this paper the author describe the different type of data transmission scheme. He compare the channel capacity ,data transmission range at different frequency band for IEEE 802.11, Bluetooth and Ultra-wide band (UWB). In Bluetooth the data transmission rate is 10 Mbps for 10 meter range. For the IEEE 802.11 the data transmission speed is projected to have an operating range of 50 meters and a peak speed of 54Mbps.The projected spatial capacity of this system is therefore approximately 83000 bits/sec/square-meter. He also describes the data transmission rate for Ultra-wide band (UWB) is 50 Mbps for the 10 meter range at 4 GHz. Following the same procedure, the projected spatial capacity for this system would be over 1,000,000 bits/sec/square-meter. The power spectral density at this frequency range is -41.3dBm/MHz . This paper has identified several areas that show the promise of UWB for use in high-rate, short- to medium range communications for the Wireless Local Area Network (WLAN), the Wireless Personal Area Network (WPAN), and the Wireless Body Area Network (WBAN), which cover distances from tens of meters down to sub-meters.

C. Hisham A. Mahmoud and H useyin Arslan 2009:

In this paper, measured EVM is related to SNR for non-data aided receivers, called true EVM. True EVM is related to the SNR for QAM and PAM signals. The EVM-SNR relation is evaluated for signals detected over AWGN channels, Rayleigh fading channels, and for channels with IQ impairments. The derived expressions are verified using computer simulations. The presented results show that when considering nondate aided receivers, using EVM-SNR relations derived for data aided receivers (or assuming high SNR) results in poor SNR estimation especially for high modulation orders or low SNR values. On the other hand, using proposed true EVM expressions results in accurate SNR estimation independent of modulation order and SNR value.

From the above given reference paper we conclude that the small channel that capacity of 57.9Mbps,small processing gain of 6.02dB ,low data rate of 1000Mbps and high path loss of 4GHz frequency band for 10 users. So by the use of Ultra-Wideband radio-over-fiber (UROOF) transmission at 60GHz we increase channel capacity, processing gain data rate and decrease the path loss.

III. PRINCIPLE OF THE SCHEME

The fundamentals of UROOF technologies have been discussed in Fig. 3. Radio over Fiber system, is the integration of RF and optical network and it increase channel capacity of mobility and application systems, as well as decreasing cost and power consumption. ROF system provide easily to service broadband network both fixed and mobile standard. The transmission line consisting of the optical link channel.

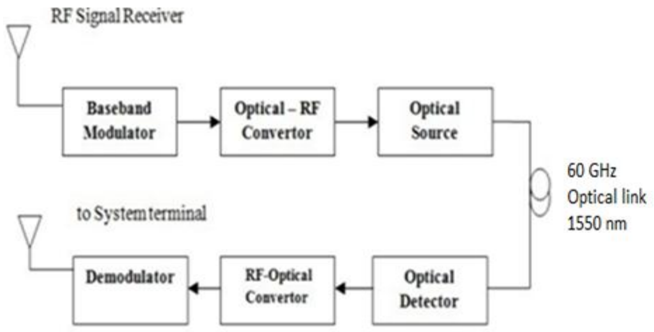

Fig. 3: Block diagram of Radio over Fiber

The transmitter side the Baseband Modulator modulate the Radio frequency (RF) signal. The RF modulated signal converted into Optical signal by Optical-RF Convertor. The optical is signal transmitted by optical source (VCSEL or LED) through MMF optical link. At the receiver side the optical detector (PIN Photodiode or Avalanche Photodiode) detect the optical signal which is transmitted by optical source. After that optical signal convert into RF signal by RF–Optical convertor which is demodulated by demodulator and transmitted to the system terminal.

Here we proposed that use of 60 GHz Multi mode fiber (MMF) as optical link of wavelength 1550 nm. The significance of 60 GHz frequency is that it is very high frequency band which is not match with other lower frequency band. So there is low interference between transmitter and receiver. When we use 60 GHz frequency with multimode fiber we increase the number of user of about fifteen times than use of 3.1 GHz to 10.6 GHz band. There is high data rate 870 Mbps and low path loss -49.22 dB. The Processing gain (PG) also increase of about three times i.e. 17.78dB.

IV. RESULT ANALYSIS

We are measuring the channel capacity; signal to noise ratio (SNR), processing gain (PG), path loss for frequency 4GHz and 60 GHz for 100 user.

The channel capacity for the Ultra-wide band technology with Radio over fiber is given as

$$C = Blog_2[\,1 + \frac{S}{N}\,] \quad \text{(i)}$$

$$\frac{S}{N} = \frac{P_S}{P_n} = \frac{P_S}{(N_u-1)P_S} = \frac{1}{(N_u-1)} \quad \text{(ii)}$$

Where P_S = Average power of the signal,
P_n = Noise power
N_u = No. of user.
C = Channel capacity
B = Bandwidth of channel
$\frac{S}{N}$ = Signal to noise ratio

Channel capacity depends on bandwidth of the channel .When we calculate the channel capacity at 60GHz frequency the number of user and channel capacity increases fifteen (870 Mbps) times than that use of 4 GHz. The channel capacity at 4GHz is 57.9Mbps for 100 user. The same channel capacity we found when 1500 user used the 60 GHz frequency band.

The processing gain for the UWB radio over frequency (ROF) is calculated by

$$PG = 10\log(B/r) \quad \text{(iii)}$$

Where r is data rate in Gbps.

At 4GHz the processing gain is 6.02 dB for 57.9 Mbps data rate but when we use 60GHz frequency band the processing gain is 17.78dB.

The total path loss L_t in dBm for the Ultra-wide band technology with Radio over fiber (ROF) is given as

$$L_t = P_t + G_t + G_r + 174\frac{dBm}{Hz} - NF - 10logB - SNR \quad \text{(iv)}$$

Where
P_t = Transmitted power of UWB antenna in dB
G_t = Gain of Transmitted antenna in dB
G_r = Gain of receiver antenna in dB
P_n = Thermal noise power in dB
NF = Noise figure in dB

The path loss at 4GHz is -22.14dB for 100 user but when we use 60GHz frequency band for same user the path loss is -49.22dB.

V. CONCLUSION

We discussed in detail the structure, theoretical models, and performance characteristics of a Ultra-wide-band radio-over-optical fiber (UROOF) system. Radio over Fiber offers various advantages over the other technology. High channel capacity, High data rate, Low Attenuation, Large Bandwidth and low path loss are the main advantages of Radio over Fiber technology. Here we conclude that the Processing gain is 17.78 dB, channel capacity 870 Mbps with low path loss 49.22dB. Which is best result at 60 GHz frequency for 100 of user when compare with 3.1 GHz to 10.6 GHz frequency band.

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