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BER Performance Analysis of RoF System Based On 64-QAM

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***Abstract*: In this paper, performance of radio-over-fiber (RoF) links employing intensity modulation has been investigated in terms of bit error rate (BER). An analytical model including dispersion, laser and radio frequency (RF) oscillator phase noise is constructed to estimate the BER performance for 64-quadrature amplitude modulation (QAM) based RoF system. It has been observed that RF oscillator linewidth and percentage of received power affect the BER significantly. BER deteriorates rapidly as value of percentage of received power increases but for increased RF oscillator linewidths specifically above 1Hz, the BER degrades to great a extent which is not desirable for efficient communication system. BER does not change significantly as laser linewidth varies. Percentage of received power is more decisive factor for BER of 64-quadrature amplitude modulation (QAM) based RoF system.**

***Keywords*: RoF, BER, MZM, Dispersion, Phase Noise.**

I. INTRODUCTION

The Indian telecommunication industry is one of the world's fastest growing industries, with 914.59 million telephone (landlines and mobile) subscribers and 881.40 million mobile phone connections as on October 2011[1]. It stands the second largest telecommunication network in the world in terms of number of wireless connections after China. As the fastest growing telecommunications industry in the world, it is projected that India will have 1.159 billion mobile subscribers by 2013[1]. To meet the explosive demands of high-capacity and broadband wireless access, modern cell-based wire-less networks have trends, projecting continuous increase in the number of cells and utilization of higher frequency bands which leads to a large amount of base stations (BSs) to be deployed; therefore, cost-effective BS development is a key to success in the market [2]. In order to reduce the system cost, radio over fiber (RoF) technology has been proposed. RoF systems transmit an optically modulated radio frequency (RF) signal from a central station (CS) to a base station (BS) via an optical fiber. The RF signal recovered using a photo detector (PD) at the BS arrives at a mobile station (MS) through a wireless channel. This architecture provides a cost-effective system since any RF oscillator is not required at the BS [3], and [4]. However, the performance of RoF systems depends on the method used to generate the optically modulated RF signal, power degradation due to fiber chromatic dispersion, nonlinearity due to an optical power level, and phase noises from a laser and an RF oscillator. Several techniques have been found for the optical generation of mm-waves wireless signals including optical self-heterodyning, up- and down conversion, and external modulation[5],and[6]. In a radio – over-fiber system which carries millimeter-wave(MM) signals, radio spectrum limited capacity can be overcome by using multilevel modulation techniques such as M-ary quadrature-amplitude modulation(M-QAM) techniques[7]-[8]. Regardless of the no. of constellation points, all(QAM) signals can be generated using a single dual-drive Mach-Zehnder modulator[9].The QAM signal generation is greatly simplified with usage of only one dual-drive modulator. Here, we investigate the BER (bit error rate) and effect of phase noises from an RF oscillator and laser linewidth using an external optical modulator. For the analysis of the BER it is expressed in terms of CNR for which the autocorrelation and the PSD (power spectral density) function of a received photocurrent at photo detector (PD) are evaluated [10],and [11].

II. THEORETICAL MODEL

Generally, RoF systems transmit an optically modulated radio frequency (RF) signal from a central station (CS) to a base station (BS) via an optical fiber and the photocurrent corresponding to the transmitted RF signal is extracted by the filter and this signal arrives at a mobile station (MS) through a wireless channel. The M-ary QAM signal generated using a Mach Zehender Modulator is given as [9]:

$$Eqam = \frac{Ein}{2}[\exp(j\phi_1) - \exp(j\phi_2)]$$

Where $\phi_1 = \pi \frac{v_1}{v_\pi}, \phi_2 = \pi \frac{v_2}{v_\pi} + \pi$

Here, v1 and v2 signals from RF oscillator. The phase of v1 and v2 are carefully chosen to generate quadrature signal in the output. The RF signal is optically modulated by laser source with an MZM. The optical signals from the optical source (laser diode) and the RF oscillator are modeled as follows:

$$x_d(t) = A_d \exp j(w_d t + \Phi_d(t)) \quad \text{.......} (1)$$

$$x_o(t) = V_o.Cos(w_o t + \Phi_o(t)) \quad \text{......} (2)$$

Where A_d and V_o define amplitudes from the laser diode and the RF oscillator, ω_d and ω_o define angular frequencies of the signals from the LD and the RF oscillator, and $\Phi_d(t)$ and $\Phi_o(t)$ are phase-noise processes.

After optically modulating $x_o(t)$ by $x_d(t)$ with a Dual Electrode MZM, the output signal is represented as

$$E_{ss}(0,t) = A_d.L_{MZM}\begin{Bmatrix} J_0(\alpha\pi)\exp j\left[w_d t+\phi_d(t)+\pi/4\right] \\ -\sqrt{2}J_1(\alpha\pi)\exp j\left[w_d t+\phi_d(t)+w_o t+\phi_o(t)\right]\end{Bmatrix} \quad \text{...... (3)}$$

Where α is $\frac{v_o}{\sqrt{2}v_\pi}$,and v_π is switching voltage of MZM, L_{MZM} is insertion loss. After the transmission of L_{fiber} in km standard single mode fiber (SSMF), the signal at the end of the SSMF becomes

$$E_{SS}(L,t) \cong \begin{bmatrix} A_d.L_{MZM}.L_{add}.10^{\frac{\alpha_{fiber}L_{fiber}}{20}} J_0(\alpha\pi) \\ \begin{Bmatrix} \exp j\begin{bmatrix} w_d t+\Phi_d(t-\tau_0) \\ -\phi_1+\frac{\pi}{4}\end{bmatrix} - \frac{\sqrt{2}J_1(\alpha\pi)}{J_0(\alpha\pi)} \\ \exp j\begin{bmatrix} w_d t+\Phi_d(t-\tau_+)+w_o t \\ +\Phi_o(t-\tau_+)-\Phi_2 \end{bmatrix}\end{Bmatrix}\end{bmatrix} \quad \text{... (4)}$$

III. CNR EVALUATION

To evaluate the CNR we utilize the autocorrelation function and the PSD of the photocurrent [11]. By using a square-law model, the photocurrent $i(t)$ can be found from (4) as follows:

$$i(t) \cong \eta\left|E_{SS}(L,t)\right|^2 \quad \text{.... (5)}$$

$$i(t) \cong \eta\left|A_{1d}\right|^2\begin{Bmatrix} B+2\alpha_1\cos \\ \begin{bmatrix}\Phi_d(t-\tau_+)-\Phi_d(t-\tau_0) \\ +w_o t+\Phi_o(t-\tau_+)-\Phi_2+\Phi_1\end{bmatrix}\end{Bmatrix} \quad \text{..... (6)}$$

Where

$$A_{1d} = A_d.L_{MZM}.L_{add}.10^{\frac{\alpha_{fiber}L_{fiber}}{20}} J_0(\alpha\pi)$$

$$\alpha_1 = \frac{\sqrt{2}J_1(\alpha\pi)}{J_0(\alpha\pi)}$$

$$B = 1+\alpha_1^2$$

Where η defines the responsivity of the PD and $|\,.|^2$ is the square-law detection. From (6), the autocorrelation function $R_I(\tau)$ is obtained as

$$R_1(\tau) = \left\langle i(t).i(t+\tau)\right\rangle \quad \text{..... (7)}$$

. The PSD function $S_I(f)$ can be written as

$$S_1(f) = F\left\langle R_1(\tau)\right\rangle \quad \text{..... (8)}$$

$$S_1(f) = R_1(\tau)\int_{-\infty}^{\infty} R_1(\tau)d\tau * \exp(-j\tau w) \quad \text{.... (9)}$$

Next in equation (10), the first term represents a dc component, second and third is the broadening effects due to the fiber dispersion and the line widths of the RF oscillator.

$$\frac{S_1(f)}{\eta^2.A_1^{d4}} = \begin{bmatrix} B^2\delta(f)+ \\ \frac{2\Upsilon_o\alpha_1^2.\exp(-2\Upsilon_t|\tau|).\cos\left[2\pi(f-f_o)\tau\right]}{\Upsilon_o^2+\left[2\pi(f-f_o)\right]^2} \\ +\frac{4\alpha_1^2.\exp(-2\Upsilon_t|\tau|)}{(2\Upsilon_t)^2+[2\pi(f-f_o)]^2} \\ .\{\Upsilon_t.\exp(-2\Upsilon_t|\tau|)-\Upsilon_t\cos\left[2\pi(f-f_o)\tau\right] \\ -\frac{4\pi\Upsilon_d(\Upsilon_d+\Upsilon_o)(f-f_o)}{\Upsilon_o^2+\left[2\pi(f-f_o)\right]^2} \\ .\sin\left[2\pi(f-f_o)\tau\right]\}+P(f+f_o)\end{bmatrix} \quad \text{... (10)}$$

Where

$$P(f+f_o) = \begin{bmatrix} \frac{2\Upsilon_o\alpha_1^2.\exp(-2\Upsilon_t|\tau|).\cos\left[2\pi(f+f_o)\tau\right]}{\Upsilon_o^2+\left[2\pi(f+f_o)\right]^2} \\ +\frac{4\alpha_1^2.\exp(-2\Upsilon_t|\tau|)}{(2\Upsilon_t)^2+[2\pi(f+f_o)]^2} \\ .\{\Upsilon_t.\exp(-2\Upsilon_t|\tau|)-\Upsilon_t\cos\left[2\pi(f+f_o)\tau\right] \\ -\frac{4\pi\Upsilon_d(\Upsilon_d+\Upsilon_o)(f+f_o)}{\Upsilon_o^2+\left[2\pi(f+f_o)\right]^2}.\sin\left[2\pi(f+f_o)\tau\right]\}\end{bmatrix}$$

Now the received RF carrier Power P_I is approximately represented as follows

$$P_1 = 2\int_{f_o-\frac{B_o}{2}}^{f_o+\frac{B_o}{2}} PSD(f)df \quad \text{..... (11)}$$

And by using (11), we find ratio p between the total carrier power and the required power as follows:

$$p = \frac{P_1}{P_t}$$

$$p \cong \frac{2}{\pi}\left\{\exp(-2\Upsilon_t|\tau|)\tan^{-1}\left(\frac{\pi.B_o}{2\Upsilon_o}\right)\right\} \quad \text{.... (12)}$$

The CNR induced by the differential delay from the fiber chromatic dispersion and the linewidths from the laser and the RF oscillator is found as

$$CNR \cong \frac{P_1}{2B_o.\left(\frac{N_o}{2}\right)}$$

$$CNR \cong \frac{2\eta^2 A_{1d}^4 \alpha_1^2 p}{N_o \cdot \left(\frac{\Upsilon_o}{\pi}\right) \tan\left(\frac{\pi . p \exp(-2\Upsilon_t |\tau|)}{2}\right)} \quad \ldots. (13)$$

IV. RESULT AND DISCUSSION

Now, we investigate effect on BER due to RF Oscillator Linewidth and percentage of received power laser linewidth as follows:

$$BER = \frac{\left(\sqrt{M} - 1\right)}{\left(\log \sqrt{M}\right)\sqrt{M}} erfc \sqrt{\frac{3CNR(\log M)}{2(M-1)}}$$

For M=64 it can be modified as:

$$BER = \left(\frac{7}{24}\right) erfc\left(\sqrt{\frac{CNR}{7}}\right)$$

$$BER = \left(\frac{7}{24}\right) erfc \sqrt{\frac{2\eta^2 A_{1d}^4 \alpha_1^2 p}{7.N_o \cdot \left(\frac{\Upsilon_o}{\pi}\right) \tan\left(\frac{\pi . p \exp(-2\Upsilon_t |\tau|)}{2}\right)}} \ldots.(14)$$

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Table 1 the Simulation Parameters for BER as a function of the RF oscillator linewidth and percentage of received power.

Parameters	Value
Fiber dispersion	17 ps/nm-km
Optical transmission distance	1 km to 40 km
RF carrier frequency	30 GHz
Wavelength of LD	1550 nm
Half power bandwidth filter	0.5
RF Oscillator linewidth	1Hz to 10 Hz
Percentage of received power	0.3,0.5,0.8,0.99

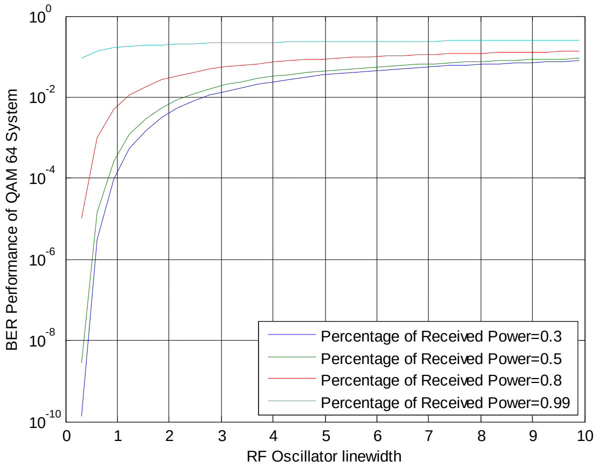

Fig.1. BER as a function of the RF oscillator linewidth and percentage of received power

Now, the result BER is sketched in Fig. 1 with simulation parameters in Table 1. represents the function of the RF Oscillator line width and percentage of received power. It is found that BER deteriorates as the value of p is increased. It is noticed that BER due to RF Oscillator linewidth from 1 to 10 Hz are different for different percentage of power received.
And we have to make a considerable trade of between the bandwidth requirement and the RF oscillator linewidth.

Table 2 the Simulation Parameters for BER as a function of the Laser linewidth and percentage of received power.

Parameters	Value
Fiber dispersion	17 ps/nm-km
Optical transmission distance	1 km to 40 km
RF carrier frequency	30 GHz
Wavelength of LD	1550 nm
Half power bandwidth filter	0.5
RF Oscillator linewidth	1Hz
Laser Linewidth	10 Mhz,100 Mhz,300 Mhz
Percentage of received power	0.1,0.2,0.3,0.4,…………1

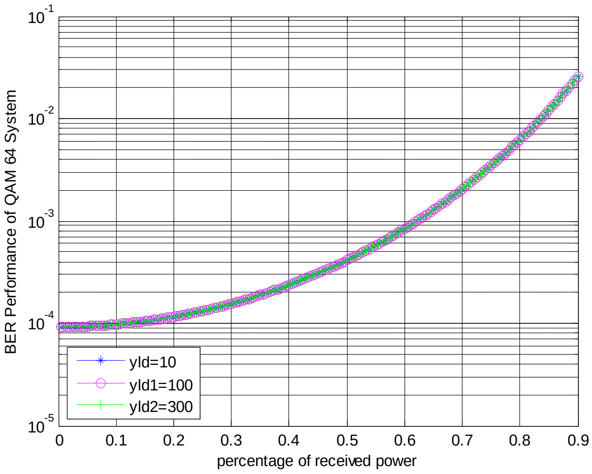

Fig.2 BER as a function of the Laser linewidth and percentage of received power

Here, the result BER is sketched in Fig. 2 with simulation parameters in Table 2. represents the function of the laser line width and percentage of received power. It is found that BER deteriorates as the value of p is increased and there is no significant effect of laser linewidth.

V. CONCLUSION

We have shown that the BER has been investigated due to RF Oscillator for various line widths over different percentage of received power. It is evident that the BER deteriorates rapidly as the as the value of p is increased. We also conclude that the bandwidth of an electrical filter at the receiver should be carefully chosen after considering minimum required signal power ratio p. BER is plotted against p on which filter bandwidth depends.It is also clear that parameter p will be more decisive factor than laser linewidth as BER does not change significantly as laser linewidth varies.

REFERENCES

[1] http://en.wikipedia.org/wiki/Telecommunications_Statistics_in_India.

[2] Y. Kim *et al.*, “Beyond 3G: Vision, requirements, and enabling technologies,” *IEEE Commun. Mag.*, vol. 41, no. 3, pp. 120–124, 2003.

[3] A. Alphones, “Double-spread radio-over-fiber system for next-generation Wireless technologies,” *OSA J. Opt. Netw.*, vol. 8, no. 2, pp. 225–234, Feb. 2009.

[4] T. Koonen, “Fiber to the Home/Fiber to the Premises: What, Where, and When?,” Proceedings of the IEEE, Vol. 94, No. 5, May 2006.

[5] P. Kaur, and R.S.Kaler, “Radio over Fiber Networks,” Proceedings of National Conference on Challenges & Opportunities in Information Technology (COIT-2007) RIMT-IET, Mandi Gobindgarh, March 23, 2007.

[6] N. Mohamed, S.M. Idrus, and A.B. Mohammad, “Review on System Architectures for the Millimeter-Wave Generation Techniques for RoF Communication Link,” IEEE International RF and Microwave Conference Proceedings, December 2-4, 2008.

[7] V.J.Urick, J.X.Qiu, F.Bucholtz,“Wideband QAM-over-fiber using phase modulation and interferometric demodulation,” IEEE photon. Technal. Lett. , vol. 16, no. 10, pp. 2374–2376, Oct. 2004.

[8] J.Hango, K.Kasai, M.Nakazawa,“1-Gsymbols/s 64-QAM coherent optical transmission over 150 km” ,IEEE photon. Technal. Lett. vol. 19, no. 9, pp. 638–640, May 2007.

[9] Vishal Sharma, Amapal Singh, Ajay.K.Sharma,“Simulative Investigation on the impact of Laser-spectral width in single-tone radio-over-fiber transmission system using optical single sideband technique” , Optics and Lasers in Engineerring, vol. 47, pp. 1145-1149,July2009.

[10] B.P.Lathi, Modern Digital and Analog Communication Systems, 3rd Edition, Oxford University Press, 2008.

[11] H. K. Dass, Advanced Engineering Mathematics, 1st Edition**,** S. Chand, 2009.