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BER Performance of Millimeter wave using ROF System

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Abstract— ***As the demand of present generation hungary bandwidth applications such as HDTV,CCTV & WLAN,Video Conferencing etc. is increasing day by day where Data rate is required in access of Gb/s,the present microwave based GSM module is insufficient to cover whole range of applications so to attain that Millimeter wave(60 GHz) is used as a RF signal. Although losses at 60 GHz is predominantly very high using existing microwave link so to encounter that impact optical fiber is used to minimize the losses. In this paper the impact of Percentage of Received Power, Laser Linewidth, RF oscillator Linewidth of 64 QAM modulated on BER(bit error rate) performance of the system at (57 to 64 GHz band) using MATLAB software has been evaluated.***

Keywords— ***BER(Bit error rate),RoF(radio over fiber),MZM(Machzehender Modulator,WLAN(Wireless local area networks ,QAM(quadrature amplitude modulation),MM wave(millimeter wave)***

I. INTRODUCTION

Radio over Fiber refers to a technology where light is being modulated by a radio signal and transmitted over an optical fiber link to facilitate wireless access. In RoF system, wireless signals are transported in optical form between a central station and a set of base stations before being radiated through the air. Each base station is distributed to communicate over a radio link with at least one user's station located within the radio range of said base station. Block diagram of RoF system is shown in figure (1)[1]

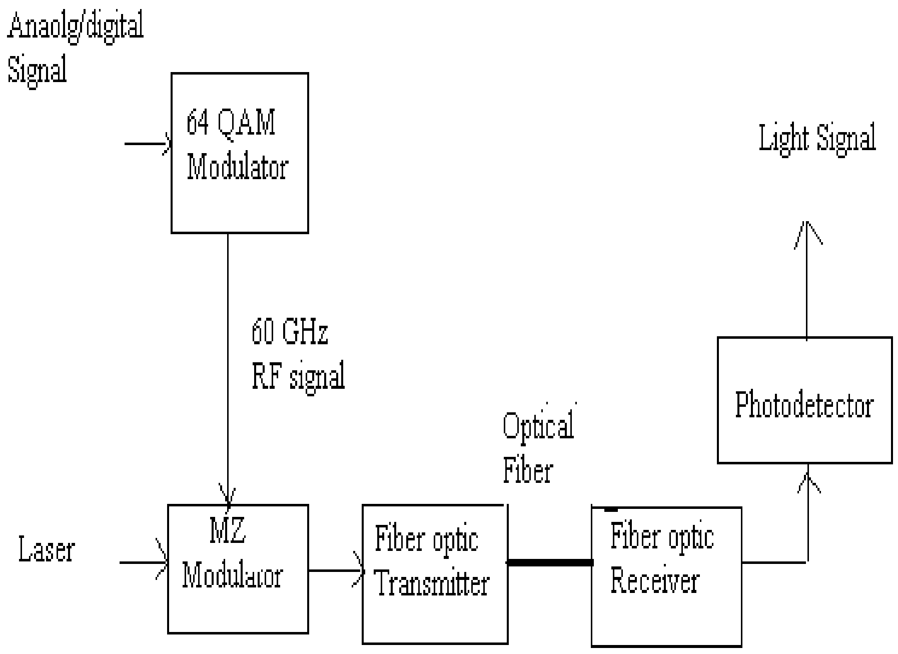
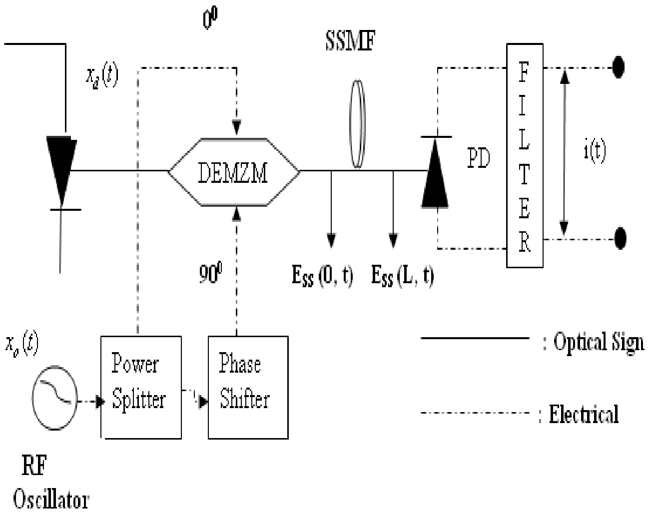


Fig.(1) RoF architecture design[1]

In the Fig. 1.The information Signal i.e. analog or digital signal is 64 QAM modulated to produce a RF signal with center frequency of 60 GHz..This RF signal is converted into Light by Machzehender modulator. At the receiver, the information signal is recovered using photodetector.Several techniques have been used to convert RF signal to optical signal including external modulator and direct modulator.Direct intensity modulator uses a superimposition of RF signal over a dc bias current which operates the laser diode.This type of modulation has high frequency chirping.This type of modulation is used for carrier signal of 10 GHz , data rates in the low Gigabit range and transmission distance is less than 100 km .So, for frequencies above 10 GHz Machzehender modulator is used. It allows the laser to be turned on continuously,data rates in range of Gb/s is attain with the help of machzehender modulator

II Carrier to Noise ratio(CNR)



Fig(2) Basic RoF Signal model

In Fig(2), First, the optical signals from the optical source, laser diode and the RF oscillator are described as

$$x_d(t) = A^d.\exp j(w_d t + \Phi_d(t)) \qquad (1)$$

$$x_o(t) = V_o.\cos(w_o t + \Phi_o(t)) \qquad (2)$$

where A^d and V_o define amplitudes from the optical source and the RF oscillator signal, 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 DE MZM, the output signal of the DE MZM is found as

$$E_{ss}(0,t) = \frac{L_{MZM}.x_d(t)}{\sqrt{2}} \begin{Bmatrix} \exp j\left[\Upsilon\pi + \frac{\pi}{V_\pi}.\frac{x_o(t)}{\sqrt{2}}\right] \\ +\exp j\left[\frac{\pi}{V_\pi}.\frac{\overline{x_o(t)}}{\sqrt{2}}\right] \end{Bmatrix} \qquad (3)$$

where $\overline{x_0}$(t) denotes the phase-shift version of xo(t) provided by DE MZM, γ(= Vdc/V_π) and α(=Vo/√2V_π) define a normalized dc and ac value, V_π is the switching voltage of the DE MZM, LMZM is the insertion loss of the DE MZM, and θ is the phase shift by the phase shifter.

$$E_{SS}(0,t) = \begin{bmatrix} \frac{L_{MZM}}{\sqrt{2}}\left\{A^d.\exp j\left(w_d t + \Phi_d t\right)\right\} \\ \begin{Bmatrix} \exp j\left[\Upsilon\pi + \frac{\pi}{V_\pi}.\frac{V_o}{\sqrt{2}} cos(w_o t + \Phi_o(t))\right] \\ +\exp j\left[\frac{\pi}{V_\pi}.\frac{V_o}{\sqrt{2}} \alpha\pi cos(w_o t + \Phi_o(t) + \theta)\right] \end{Bmatrix} \end{bmatrix} \qquad (4)$$

It is notice that the input RF signals into the DE MZM are $x_o(t)/\sqrt{2}$ and $x_o(t)/\sqrt{2}$ rather than $\overline{x_o}(t)$ and $x_o(t)$ because the input RF signal is 3 dB attenuated by utilizing the power splitter.

For generating the OSSB signal, θ and γ are set to $\pi/2$ and 1/2, respectively. By using (4) and the mentioned conditions, the OSSB signal at the DE MZM can be modelled as:

$$E_{SS}(0,t) = \frac{A^d.L_{MZM}}{\sqrt{2}} \begin{Bmatrix} \exp j\left[\frac{\pi}{2} + w_d t + \Phi_d(t) + \alpha\pi cos(w_o t + \Phi_o(t))\right] \\ +\exp j\left[w_d t + \Phi_d(t) + \alpha\pi cos(w_o t + \Phi_o(t) + 90^0)\right] \end{Bmatrix} \qquad (5)$$

$$E_{ss}(0,t)=\frac{A^d.L_{MZM}}{\sqrt{2}}\exp j\left(w_d t+\Phi_d t\right)\begin{Bmatrix} j\exp j\{\alpha\pi cos(w_o t+\Phi_o t)\} \\ +\exp j\{-\alpha\pi\sin(w_o t+\Phi_o t)\}\end{Bmatrix} \quad (6)$$

Now, We suppose that high-order components of the Bessel function can be negligible since the value of $\alpha\pi$ in the Bessel function is very small due to the fact that $V_\pi << V_o$. After the transmission of L_{fiber} in km on SSMF, the signal at the end of the SSMF becomes

$$E_{SS}(L,t)\cong\begin{bmatrix} A^d.L_{MZM}.L_{add}.10^{\frac{\alpha_{fiber}L_{fiber}}{20}}J_0(\alpha\pi) \\ \begin{Bmatrix}\exp j\left[w_d t+\Phi_d(t-\tau_0)-\phi_1+\frac{\pi}{4}\right]-\frac{\sqrt{2}J_1(\alpha\pi)}{J_0(\alpha\pi)} \\ \exp j\left[w_d t+\Phi_d(t-\tau_+)+w_o t+\Phi_o(t-\tau_+)-\Phi_2\right]\end{Bmatrix}\end{bmatrix} \quad (7)$$

where L_{add} denotes an additional loss in the optical link, α_{fiber} is the SSMF loss, L_{fiber} is the transmission distance of the SSMF, and τ_0 and τ_+ define group delays for a center angular frequency of ω_d and an upper sideband frequency of $\omega_d+\omega_o$. φ_1 and φ_2 are phase-shift parameters for specific frequencies due to the fiber chromatic dispersion.

Now, the system BER performance based on the Photo detector is investigated. For the evaluation of the BER performance,The CNR of the photocurrent is calculated by using an autocorrelation function and a PSD function.The BER is also evaluated, which is defined in terms of CNR. To evaluate the CNR and the BER, the autocorrelation and the PSD function of the photocurrent are utilized.

By using a square-law model, the photocurrent $i(t)$ can be obtained from (7) as:

$$i(t)\cong\eta\left|E_{SS}(L,t)\right|^2 \quad (8)$$

where η defines the responsivity of the PD and $|\,.|^2$ is the square-law detection

$$i(t)\cong\eta\begin{bmatrix} A^d.L_{MZM}.L_{add}.10^{\frac{\alpha_{fiber}L_{fiber}}{20}}J_0(\alpha\pi) \\ \begin{Bmatrix}\exp j\left[w_d t+\Phi_d(t-\tau_0)-\phi_1+\frac{\pi}{4}\right]-\frac{\sqrt{2}J_1(\alpha\pi)}{J_0(\alpha\pi)} \\ \exp j\left[w_d t+\Phi_d(t-\tau_+)+w_o t+\Phi_o(t-\tau_+)-\Phi_2\right]\end{Bmatrix}\end{bmatrix}^2 \quad (9)$$

After solving eqn (9) we obtain the following equation.

$$i(t)\cong\eta\left|A_1^d\right|^2\left\{B+2\alpha_1\begin{bmatrix}\cos\left\{w_d t+\Phi_d(t-\tau_0)-\phi_1+\frac{\pi}{4}\right\} \\ +j\sin\left\{w_d t+\Phi_d(t-\tau_0)-\phi_1+\frac{\pi}{4}\right\} \\ \cos\{w_d t+\Phi_d(t-\tau_+)+w_o t+\Phi_o(t-\tau_+)-\Phi_2\} \\ +j\sin\{w_d t+\Phi_d(t-\tau_+)+w_o t+\Phi_o(t-\tau_+)-\Phi_2\}\end{bmatrix}\right\} \quad (10)$$

Where

$$A_1^d=A^d.L_{MZM}.L_{add}.10^{\frac{\alpha_{fiber}L_{fiber}}{20}}J_0(\alpha\pi)$$

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

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

After solving (10), we get

$$i(t)\cong\eta\left|A_1^d\right|^2\left\{B+2\alpha_1\cos\begin{bmatrix}\Phi_d(t-\tau_+)-\Phi_d(t-\tau_0) \\ +w_o t+\Phi_o(t-\tau_+)-\Phi_2+\Phi_1\end{bmatrix}\right\} \quad (11)$$

From (11), the autocorrelation function $R_I(\tau)$ [4] is obtained as

$$R_1(\tau)=\left\langle i(t).i(t+\tau)\right\rangle \quad (12)$$

$$\frac{R_1(\tau)}{\eta^2.A_1^{d4}}=B^2+\begin{cases}2\alpha_1^2\cos\left(w_o\tau\right)\exp(-2\Upsilon_t|\tau|),|\tau|\le|\tau_1| \\ 2\alpha_1^2\cos\left(w_o\tau\right)\exp(-2\Upsilon_d|\tau|-\Upsilon_d|\tau|),|\tau|\ge|\tau_1|\end{cases} \quad (13)$$

.τ_1 (= $\tau_+ - \tau_0$) is the differential delay due to the fiber chromatic dispersion and is dependent on the wavelength λ, the Carrier frequency f_o, the fiber chromatic dispersion D, and the optical transmission distance L_{fiber}.

$$\tau_1 = D.L_{fiber}.\lambda^2.\frac{f_o}{c} \qquad (14)$$

Where D = $\sigma_M + \sigma_W$; σ_M = pulse spread due to material dispersion.

σ_W = Pulse spread due to Waveguide dispersion.

Pulse spread due to material dispersion may be calculated as[17]

$$\sigma_M = |D_M| \sigma_\lambda \text{ L} \qquad (15)$$

$$\sigma_W = |D_W| \sigma_\lambda \text{ L} \qquad (16)$$

L = length of optical fiber in km.

D_W = Optical Fiber material dispersion coffecient.

D_M = Optical Fiber waveguide dispersion coffecient.

σ_λ = Spectral width of Optical Source.

Now we define the material and waveguide dispersion coeffecient.The material dispersion coffecient for the Single Mode Fiber with refractive index n1, is given as :

$$D_M = -\frac{\lambda_o}{c}\left|\frac{d^2 n_1}{d^2 \lambda_o}\right| \text{ ps/(nm-km)} \qquad (17)$$

Where, n1 = Refractive index of core material.

c = Velocity of light in air.

and Waveguide dispersion factor is given as:

$$D_w = -\frac{n_2}{(\lambda_o)c} v \left|\frac{d^2 v_b}{d^2 v}\right| \qquad (18)$$

n2 = Refractive index of cladding of optical fiber.

V = Normalised frequency.

B = Normalised propagation constant.

Combining both equation (16) and (17) we obtain:

$$\text{D} = -\frac{\sigma_\lambda}{c} L \left[\lambda_o \left|\frac{d^2 n_1}{d^2 \lambda_o}\right| + \frac{n_2}{\lambda_o} v \left|\frac{d^2 v_b}{d^2 v}\right|\right] \qquad (19)$$

where *c* is the Velocity of Light. The PSD function of the photocurrent i(t) is given by the fourier transform of (14). The carrier to noise ratio can be written as[5]

$$CNR \cong \frac{2\eta^2 A_1^{d4} \alpha_1^2 p}{N_o.\left(\frac{\Upsilon_o}{\pi}\right)\tan\left(\frac{\pi.p\exp(-2\Upsilon_t|\tau|)}{2}\right)} \qquad (20)$$

III. Simulation of BER for the 64 QAM modulated RoF signal

The BER for 64 QAM modulated RoF system due to the RF oscillator Linewidth, Laser Linewidth, and Percentage of received power is investigated. BER is represente as

$$BER = \left(\frac{7}{24}\right) erfc\left(\sqrt{\frac{CNR}{7}}\right) \qquad (21)$$

BER of 64 QAM based ROF system

The probability of bit error for 64QAM based modulation is obtained by combining eqn (20) and(21) is given as:

$$BER = \left(\frac{7}{24}\right) erfc\sqrt{\frac{2\eta^2 A_{1d}^4 \alpha_1^2 p}{7.N_o.\left(\frac{\Upsilon_o}{\pi}\right)\tan\left(\frac{\pi.p\exp(-2\Upsilon_t|\tau|)}{2}\right)}} \qquad (22)$$

Various simulation parameters are used as follow

(a) shows the effect of RF oscillator linewidth on BER with different values of percentage of recd power

Table 2 parametersfor simulation of part (a)

Parameters	Value
RF carrier frequency	60 GHz
Wavelength of LD	1550 nm
Laser Linewidth	100 MHz

RF oscillator linewidth	0 to 10 Hz
Percentage of recd power	0.3,0.5,0.8,0.99
Fiber dispersion	17 ps/nm-km

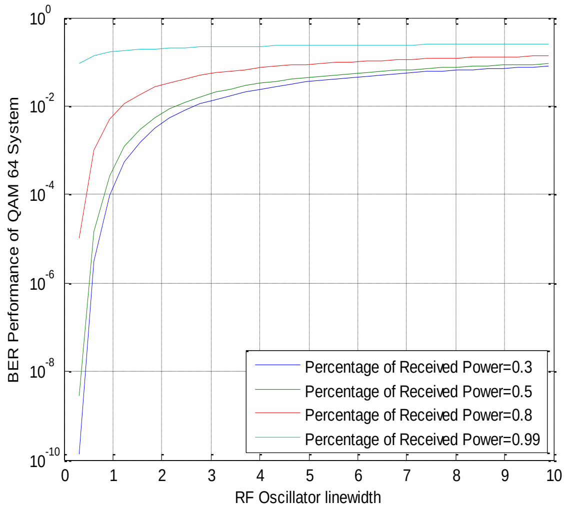


Fig 3 RF oscillator Linewidth vs BER at different values of Percentage of recd Power

Fig (3) illustrates that as the value of BER increases monotonously as we increase the RF Oscillator Linewidth from 0 to 10 Hz. But when RF oscillator linewidth increases above 1 Hz, the BER degrades badly, rising above value 10^{-6} .Thus RF oscillator Linewidth should be maintained below 1 Hz for satisfactory performance of the RoF system.BER deteriorates rapidly increasing its threshold range as the value of p is increased above 0.8.

(b)shows the effect of RF oscillator linewidth on BER with different values of laser linewidth

Table 1 parameters for simulation of part (b)

PARAMETER	VALUE
Wavelength of LD	1550 nm
Laser Linewidth	10,100,300 MHz
RF oscillator linewidth	0 to 10 Hz
RF carrier frequency	60 GHz
Fiber dispersion	17 ps/nm-km

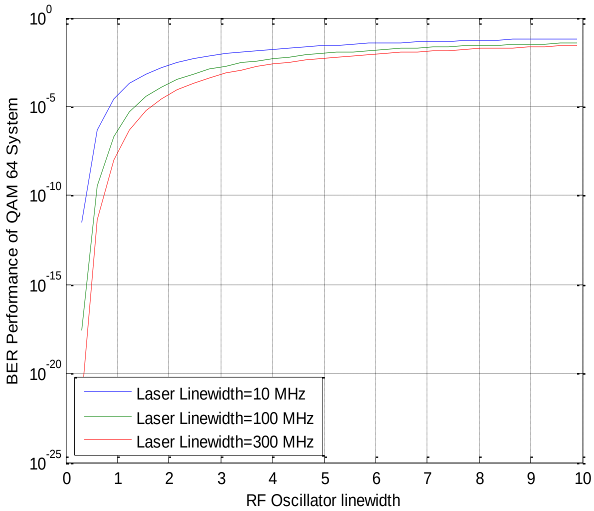


Fig. (4) RF oscillator Linewidth vs BER for different values of Laser Linewidth

Fig (4) illustrates that as the value of RF oscillator Linewidth increases from 0.1 to 1 Hz., the value of BER increases remains within threshold value (below 10^{-6}) The value of BER deteriotes For RF oscillator Linewidth varies from 1 Hz to 10 Hz. There is not so much variation in value of BER as laser linewidth increases from 10,100 to 300 MHz.

(c)shows the effect of changing Percentage of recd power on BER with different values of laser linewidth

Table 3 parameters used for simulation of part(c)

Parameters	Value
RF carrier frequency	60 GHz
Wavelength of LD	1550 nm
Laser Linewidth	10,100,300 MHz
RF oscillator linewidth	5 Hz
Percentage recd power	0.3,0.5,0.8,0.99watt
Fiber dispersion	17 ps/nm-km

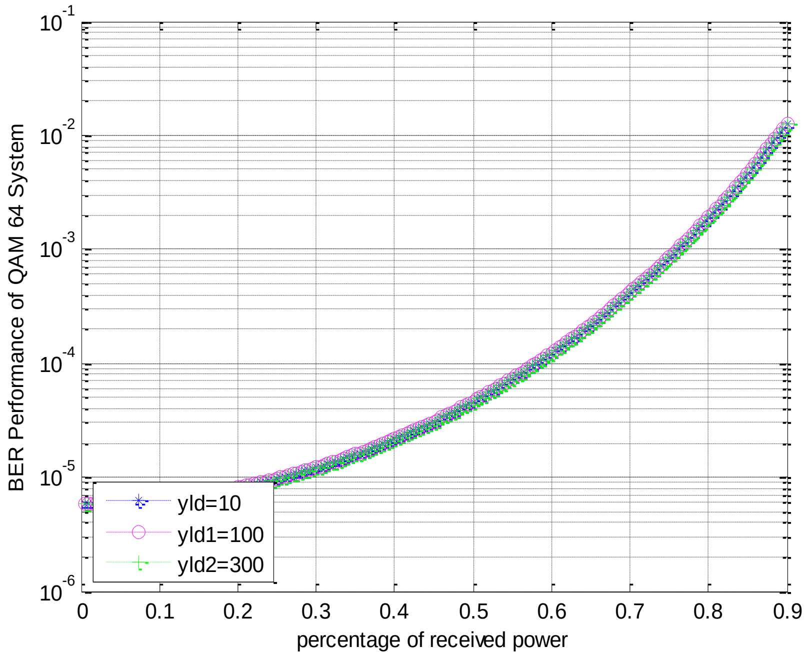


Fig (5) Percentage of received Power vs BER for different values of Laser Linewidth

Fig. (5) illustrates that as the value of percentage of received power increases above 0.8 Watt the value of BER increases above threshold that makes ineffective wireless communication. BER does not change significantly as the Laser Linewidth is varied from 10 MHz to 300 MHz .

IV Conclusion

It is depicted from the simulation results that the BER (bit error rate) value increases as the Laser Linewidth varies with values of 10,100 and 300 MHz but increase in BER value is not significant.Thus, Laser Linewidth is not so much decisive factor for designing of effective wireless communication . RF oscillator Linewidth should be maintained below 1 Hz for satisfactory performance of the RoF system .The value of BER deteriorates , increasing above its threshold value 10-6 as the value of Percentage of received Power increases above 0.8 Watts.So for effective wireless communication the value of p should not exceed 0.8 Watts

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