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BER Performance of GMSK Based Radio over Fiber Technology

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Abstract — **As the demand for high bandwidth increased day by day, the microwave based Global System for Mobile (GSM) communication (900/1800) is insufficient to cover the entire range of application like video calling, internet gaming, file sharing, web/email, ambient video. To cover entire range of application a new technology named 'Radio over Fiber (RoF)' has evolved. RoF technology is based on modulation of RF signal using a light wave and its distribution over optical fiber rather than free space. The use of optical fiber increased the system bandwidth efficiently as well as reduces the attenuation and crosstalk. In this paper the bit error rate (BER) performance has been evaluated for the Gaussian Minimum Shift Keying (GMSK) based ROF system. Simulation results show the effects of various parameters such as RF oscillator linewidth, length of optical link and responstivity of photodetector on BER of GMSK based RoF system.**

Index Terms— **BER, BT, Central office (CO), GMSK, Mach-zehender modulator (MZM), Photodetector (PD), Radio access unit (RAU), RoF.**

I. Introduction

Radio over Fiber technology is a technique in which the RF signal is modulated using the optical lightwave. The optical modulated lightwave is distributed over optical fiber and converted back into RF signal using the photo detector (PD) [1]. The general scheme of radio over fiber is sown in figure 1. The use of RoF technology reduce the system cost as the BTS required only optical to electrical (O/E) and electrical to optical (E/O) converter.

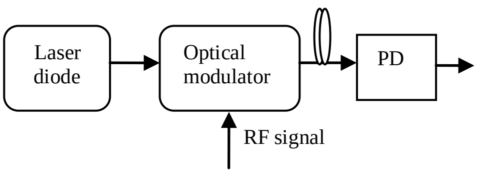

Figure.1 General scheme of RoF

All the signal processing and modulation/demodulation are take place at central office [10]. The performance of the RoF is generally depend upon the method of generating optically modulated RF signal, power degradation due to optical fiber chromatic dispersion, nonlinearity due to an optical power level, phase noise from laser diode and RF oscillator[9]. Several technique have been found for the optical wave generation from RF signal including direct intensity modulator and external modulator. Direct intensity modulation employ the superposition of RF signal over a dc bias current which operate the laser diode [7]. This type of modulation has high value of frequency chirping. The direct modulation operate only upto 10 Hz and it provide better performance only for short distance[8]. To remove the disadvantage of direct modulation we use indirect modulation like Mach zehnder modulator. In MZM the laser diode optical signal and RF signal are separately generated. This completely remove the frequency chirping but nonlinearity is still main problem. In this paper we evaluated the bit error rate for the GMSK modulated RF signal and distribute them over optical fiber for optical single sideband. The optical single sideband (OSSB) has low power consumption as compared to optical double sideband [3]. As we know the GSM 900/1800 technology used worldwide. The replacement of microwave link of this technology with optical fiber increased the system bandwidth as well as reduces the interference and crosstalk problem. Using optical fiber the harmful effect of microwave link will be completely removed. The effect of changing the RF oscillator linewidth on BER with respect to optical fiber length and percentage of received power is studied. Why we take RF oscillator linewidth instead of laser linewidth? The effect of changing the laser linewidth on BER from 10 MHz to 624 MHz is only 1.1 db. But when we change the RF oscillator linewidth from 1 Hz to 10 Hz is 21.2 db [4].

II. CARRIER TO NOISE (CNR) EVALUATION OF ROF SYSTEM MODEL

Generally, RoF systems transmit an optically modulated 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 which is shown in Figure-2. An OSSB signal at base station (BS) is generated by using a Mach Zehender Modulator and a phase shifter. An RF signal from an oscillator is split by a power splitter and a 90◦ phase shifter. First, the optical signals from the optical source (laser diode) and the RF oscillator are modeled as follows [2][4]:

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

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

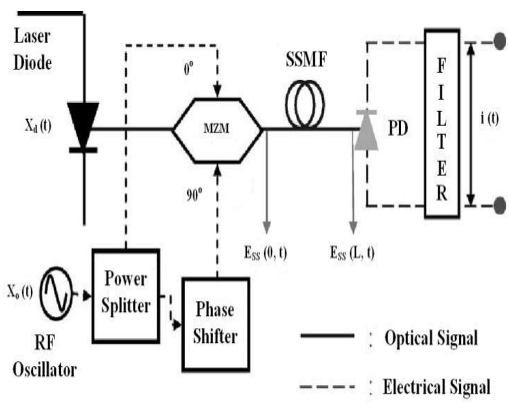

Figure.2 RoF system model [4]

After optically modulating $x_o(t)$ by $x_d(t)$ with a DE MZM, the output signal of the DE MZM is found as:

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

where $\overline{xo}(t)$ denotes the phase-shift version of xo (t), γ(= Vdc/Vπ) and α(= Vo/ √ 2Vπ) define a normalized dc and ac value, Vπ 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. The use of RoF technology reduce the system cost as the BTS required only optical to electrical (O/E) and electrical to optical (E/O) converter.

$$E_{SS}(0,t)=\left[\begin{array}{l}\frac{L_{MZM}}{\sqrt{2}}\left\{A^d.\exp j\left(w_dt+\Phi_dt\right)\right\}\\\left\{\begin{array}{l}\exp j\left[\Upsilon\pi+\frac{\pi}{V_\pi}.\frac{V_o}{\sqrt{2}}cos(w_ot+\Phi_o(t))\right]\\+\exp j\left[\frac{\pi}{V_\pi}.\frac{V_o}{\sqrt{2}}\alpha\pi cos(w_ot+\Phi_o(t)+\theta)\right]\end{array}\right\}\end{array}\right] \quad (4)$$

The output signal can be the OSSB or the ODSB signal by controlling the phase shifter. After solving equation (4), we get the other shown below.

$$E_{SS}(0,t)=\frac{A^d.L_{MZM}}{\sqrt{2}}\left\{\begin{array}{l}\exp j\left[\Upsilon\pi+w_dt+\Phi_d(t)+\alpha\pi cos(w_ot+\Phi_o(t))\right]\\+\exp j\left[w_dt+\Phi_d(t)+\alpha\pi cos(w_ot+\Phi_o(t)+\theta)\right]\end{array}\right\} \quad (5)$$

Since the ODSB signal suffers from fiber chromatic dispersion severely and requires double bandwidth than that of the OSSB signals. Due to that reasons, the OSSB signal will be generated. For generating the OSSB signal, θ and γ are set to $\pi/2$ and 1/2, respectively. Solving equation (5) we get

$$E_{ss}(0,t)=\frac{A^d.L_{MZM}}{\sqrt{2}}\exp j\left(w_dt+\Phi_dt\right)\left\{\begin{array}{l}j\exp j\{\alpha\pi cos(w_ot+\Phi_ot)\}\\+\exp j\{-\alpha\pi\sin(w_ot+\Phi_ot)\}\end{array}\right\}$$

After the transmission of $\boldsymbol{L}_{fiber}$ in km standard single mode fiber (SSMF), the signal at the end of the SSMF becomes:

$$E_{SS}(L,t)\cong\left[\begin{array}{l}A^d.L_{MZM}.L_{add}.10^{\frac{\alpha_{fiber}L_{fiber}}{20}}J_0(\alpha\pi)\\\left\{\begin{array}{l}\exp j\left[w_dt+\Phi_d(t-\tau_0)-\phi_1+\frac{\pi}{4}\right]-\frac{\sqrt{2}J_1(\alpha\pi)}{J_0(\alpha\pi)}\\\exp j\left[w_dt+\Phi_d(t-\tau_+)+w_ot+\Phi_o(t-\tau_+)-\Phi_2\right]\end{array}\right\}\end{array}\right] \quad (6)$$

For CNR evaluation, we use the photo detector square model given as:

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

Where η denote the photo detector responstivity. Using equation (6) into square law model, we obtain the PD current in term of fiber parameter.

$$i(t)\cong\eta\left[\begin{array}{l}A^d.L_{MZM}.L_{add}.10^{\frac{\alpha_{fiber}L_{fiber}}{20}}J_0(\alpha\pi)\\\left\{\begin{array}{l}\exp j\left[w_dt+\Phi_d(t-\tau_0)-\phi_1+\frac{\pi}{4}\right]-\frac{\sqrt{2}J_1(\alpha\pi)}{J_0(\alpha\pi)}\\\exp j\left[w_dt+\Phi_d(t-\tau_+)+w_ot+\Phi_o(t-\tau_+)-\Phi_2\right]\end{array}\right\}\end{array}\right]^2 \quad (7)$$

Solving equation (7) we obtain the following equation.

$$i(t)\cong\eta\left|A_1^d\right|^2\left\{B+2\alpha_1\left[\begin{array}{l}\cos\left\{w_dt+\Phi_d(t-\tau_0)-\phi_1+\frac{\pi}{4}\right\}\\+j\sin\left\{w_dt+\Phi_d(t-\tau_0)-\phi_1+\frac{\pi}{4}\right\}\\\cos\{w_dt+\Phi_d(t-\tau_+)+w_ot+\Phi_o(t-\tau_+)-\Phi_2\}\\+j\sin\{w_dt+\Phi_d(t-\tau_+)+w_ot+\Phi_o(t-\tau_+)-\Phi_2\}\end{array}\right]\right\} \quad (8)$$

Where

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

$$\alpha_1=\frac{\sqrt{2}J_1(\alpha\pi)}{J_0(\alpha\pi)}\quad B=1+\alpha_1^2,$$

After solving equation (8), we get

$$i(t)\cong\eta\left|A_1^d\right|^2\left\{B+2\alpha_1\cos\left[\begin{array}{l}\Phi_d(t-\tau_+)-\Phi_d(t-\tau_0)\\+w_ot+\Phi_o(t-\tau_+)-\Phi_2+\Phi_1\end{array}\right]\right\} \quad (9)$$

From Equation (9), the auto-correlation function $R_I(\tau)$ is given as:

$$\frac{R_1(\tau)}{\eta^2.A_1^{d4}}=B^2+\left\{\begin{array}{l}2\alpha_1^2\cos\left(w_o\tau\right)\exp(-2\Upsilon_t\left|\tau\right|),\left|\tau\right|\le\left|\tau_1\right|\\2\alpha_1^2\cos\left(w_o\tau\right)\exp(-2\Upsilon_d\left|\tau\right|-\Upsilon_d\left|\tau\right|),\left|\tau\right|\ge\left|\tau_1\right|\end{array}\right. \quad (10)$$

Where 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}. It is given as:

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

The PSD function of the photocurrent i(t) is given by the fourier transform of (9). The carrier to noise ratio can be written as:

$$CNR\cong\frac{2\eta^2A_1^{d4}\alpha_1^2p}{N_o.\left(\frac{\Upsilon_o}{\pi}\right)\tan\left(\frac{\pi.p\exp(-2\Upsilon_t\left|\tau\right|)}{2}\right)} \quad (11)$$

III. SIMULATION RESULTS & DISCUSSION

Simulation for the BER performance evaluation based on the CNR equation (eq. no.) has been performed in BATLAB. The effect on BER due to the RF oscillator linewidth with respect to percentage of received power and optical fiber length has been evaluated [5].

$$\text{BER}=\frac{1}{2}\text{erfc}\left(\sqrt{\alpha*\text{CNR}}\right) \quad (12)$$

Using Equation (11) into (12) we get,

$$\text{BER}=\left(\frac{1}{2}\right)erfc\sqrt{\frac{2\alpha\eta^2A_{1d}^4\alpha_1P}{N_0\left(\frac{\gamma_0}{\pi}\right)\tan\left(\frac{\pi.Pe^{-2\gamma_t|\tau|}}{2}\right)}} \quad (13)$$

Figure 3 show the effect of changing the RF oscillator linewidth on BER for different percentage of received power. The parameter table 1 shown below:

Table 1

Parameter	value
Fiber dispersion	17 ps/nm-km
RF carrier frequency	1.8 GHz
Wavelength of LD	1550 nm
Laser linewidth	100MHz
Optical fiber length	4 km
RF oscillator linewidth	1 to 10 Hz
Photodetector responstivity	0.7
Percentage of received power	0.3,0.4,0.6, 0.8

The acceptable BER is obtained when the RF oscillator linewidth lie between 0.5 to 1 Hz. With minimum BER, the percentage of received power required is minimum and increased with the increase in BER.

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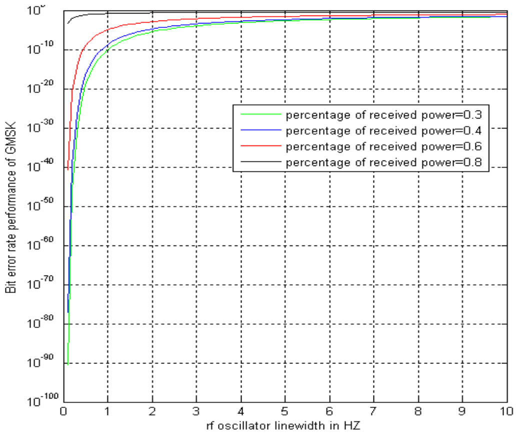

Figure. 3 BER as a function of the RF oscillator linewidth and percentage of received power

Figure 4 show the effect of changing the RF oscillator linewidth on BER for different optical link length. The parameter table 2 shown below:

Table 2

Parameter	value
Fiber dispersion	17 ps/nm-km
RF carrier frequency	1.8 GHz
Wavelength of LD	1550 nm
Laser linewidth	100MHz
Optical fiber length	4,6,8,10 km
RF oscillator linewidth	1 to 5 Hz
Photodetector responstivity	0.7
Percentage of received power	0.8

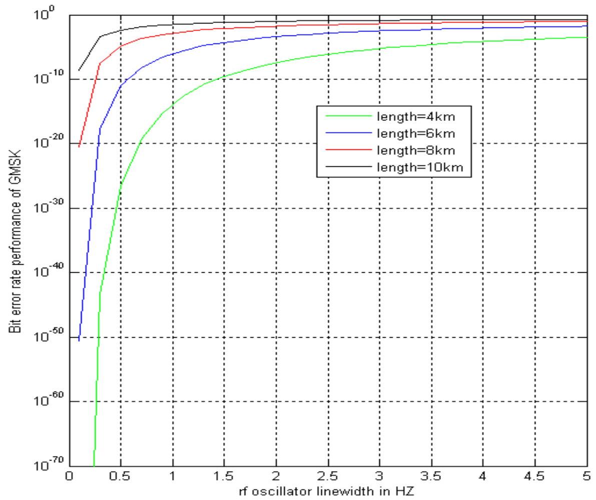

Figure. 4 BER vs RF oscillator linewidth for different length of optical fiber length.

Figure 5 show the effect of changing the RF oscillator linewidth on BER for different bandwidth-bit duration product of GMSK modulation. The parameter table 3 shown below:

Table 3

Parameter	value
Fiber dispersion	17 ps/nm-km
RF carrier frequency	1.8 GHz
Wavelength of LD	1550 nm
Laser linewidth	100MHz
Optical fiber length	4 km
RF oscillator linewidth	1 to 10 Hz
Photodetector responstivity	0.7
Percentage of received power	0.8

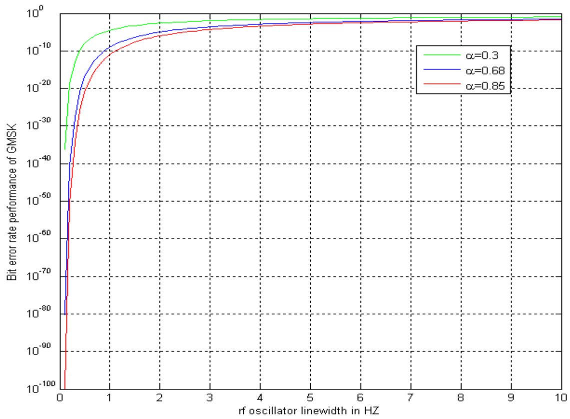

Figure. 5 plot of bit error rate v/s RF linewidth with different value of bandwidth-bit duration product of GMSK.

Figure 5 show the effect of changing RF oscillator linewidth on BER for different value of bandwidth-bit duration product (α) of GMSK modulation. The acceptable BER is obtained when the RF oscillator linewidth lie between 0.5 to 1 Hz.

IV. CONCLUSION

In this paper the BER performance of GMSK based RoF communication system has been evaluated. Effect to RF oscillator line width over different percentage of received power, optical fiber length and bandwidth-bit duration product (α) of GMSK modulation over the continuous range of RF oscillator linewidth has been simulated. It is evident that the BER deteriorates rapidly as the value of received power is increased. The BER is highly sensitive to linewidth of RF oscillator, so its value must be as low as possible.

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