Particle Swarm Optimization based Radio over Fiber System with Optimized CNR and Bandwidth

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Abstract: A radio over fiber system is a technology laced with both the wired and wireless techniques to carry on with an efficient system of communication. In this paper, we have discussed the architecture of radio over fiber system including all the components of generation and transmission connected via an optical fiber of length 10 km. carrier to noise ratio and bandwidth are two prominent factors. To bring about optimized values of these functions particle swarm optimization was used. PSO algorithm is applied on the carrier to noise ratio and bandwidth. the results obtained are found with respect to received power in percentage form and it was found that beyond 80-90% the noise power goes beyond the acceptable levels heavily degrading our signal and consequently bandwidth keeps on increasing as the input power is increased but an enhancement in noise power limits this unlimited use of bandwidth.

Keywords: PSO-Particle Swarm Optimization RoF-Radio over fiber, LD-Laser Diode, RF-Radio Frequency, DE-MZM.

Introduction

The communication era has been developing ever since the 1980s at a great speed and thrives to achieve more at the same rate. However, due to the crowded spectrums, there has been a retardation in the IT industry to compete with the modern day high speed demanding customers. To solve this problem scientists and engineers have culminated wireless and wired technologies together to exploit the advantages of both the modes and provide high data rates and give an equally economical solution. This is where RoF systems come into play. It includes the communication via both antenna and optical fiber.[1] The mobile subscriber or BS sends a signal through a wireless medium which is intercepted by an antenna at the CS. However, then the signal is fed to the transmitter of Radio over fiber system where optical to electronic conversion takes place. Here the signal is converted into an optical signal with the aid of laser diode and RF oscillator and then modulated with MZM modulator or EAM modulator, depending on the personal choice, as if one wants to have better performance then latter is used whereas for more economic solution former one is preferred. Then comes the role of wired technology, this very signal is sent to the receiver side via an optical fiber. The receiver side consists of the photodetector and a filter which again converts the optical signal to electrical signal and transmits to the other BS or mobile subscriber through antenna transmission[2]. This amalgamation of both the technologies provide high data rates, low attenuation, low cost, efficient output and higher scope of effective transmission without data being lost at the CS. Even after employing all the techniques as mentioned above phase noises of laser and RF oscillator plays a dominant role which leads to a severe degradation of Carrier to Noise ratio and bandwidth availability. So to keep this phaise noise under check. First of all a standard CNR value is found using standard parameters including no phaise noise. Further, the actual CNR when phaise noise of both laser diode and the photodetector is included then the real time CNR is found. CNR so found is seen to deviate from the standard value quite a lot. So here the PSO algorithm is used to obtain the least CNR penalty and required bandwidth values at length of 10 km. CNR penalty refers to the variation in the predefined value of CNR set according to the standard values and the actual CNR obtained in the real-time environment. Here comes the role of Particle swarm optimization which goes through all the value of CNR and gives the value pointing least deviation.

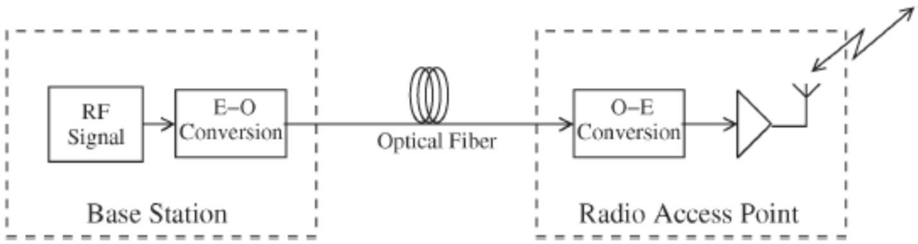

Fig.1-Block diagram of radio over fiber system

Experimentation Work

RoF system consists of two operations, first one is electrical to optical conversion which takes place using laser for generating an optical signal, RF oscillator providing reference signal, MZM modulator modulating the generated signal at Quadrature bias which gives least power wastage and the second operation is optical to electrical conversion which takes place using a photodetector.

$Z_{LD}(t) = Amp.\exp j\,(\omega_{LD} t + ph_{LD}(t))$ (1)

$Z_{RF}(t) = Vol_{RF} \cos\,(\omega_{RF} t + ph_{RF}(t))$ (2)

where Amp and Z_{RF} define amplitudes from the LD and the RF oscillator, ω_{LD} and ω_{RF} define angular frequencies of the signals from the LD and the RF oscillator, and $ph_{LD}(t)$ and $ph_{RF}(t)$ are phase-noise processes. After these signals are fed to the system, at the end the CNR is obtained as shown in equation (3)

$$CNR = \frac{\text{the power of the carrier signal}}{\text{the power contained in the noise signal}} \quad (3)$$

For calculating reference CNR the values are set at we set p_0 (reference total carrier power/required power) to 0.5 and $GammaRF_0$ (reference oscillator linewidth) to pi. When the conditions are set, then reference CNR case obtained is such that it has a 1-Hz linewidth of RF Oscillator and zero Laser Linewidth. D, fiber dispersion parameter is set to 17 ps /nm.km and wavelength to 1500 nm with 30 G-Hz RF carrier.[1] In next step, Particle Swarm Optimisation is applied as follows. Here, the phase noises of RF oscillator and Laser Diode are minimized by accelerating the each particle towards its pbest and gbest locations at each time steps.

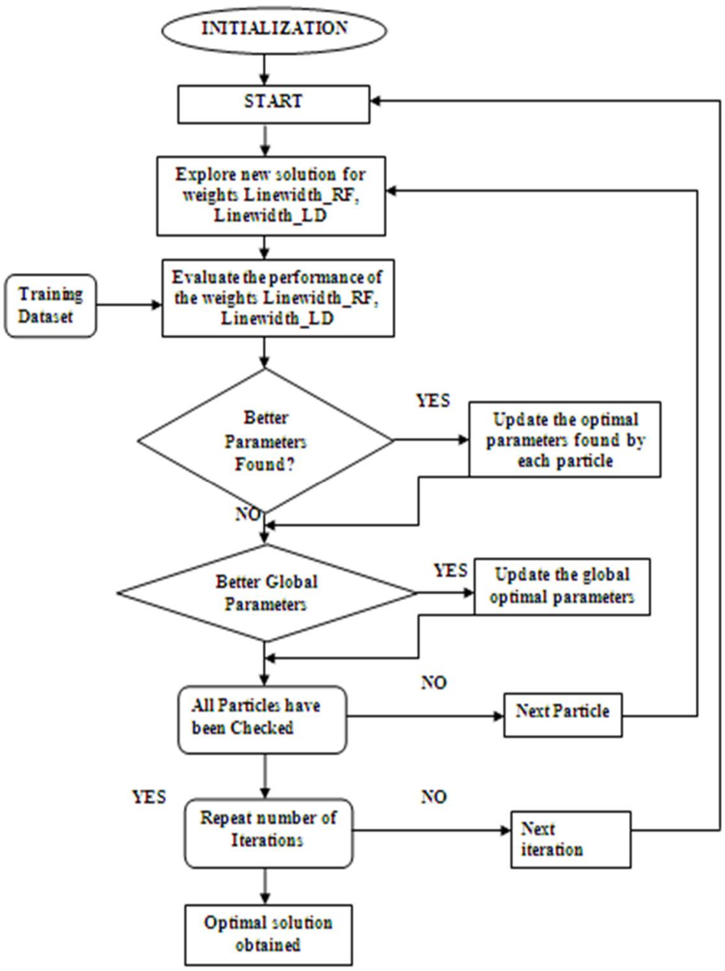

Fig.2-Steps to be followed in PSO algorithm

Table 1.Parameters used in the radio over fiber system

Simulation Parameters	Value
Attenuation, α_{fiber}	0.20 dB/km
Wavelength,λ	1550nm
Frequency of RF oscillator,$_{oscillator}$	40GHz
Fiber dispersion parameter,Dis	17ps/nm.km
Length of the fiber, L_{fiber}	10 km

Results and Discussion

The results obtained after carrying out the above process are presented in this section. First of all the optimized function is shown in a graphical form and in subsequent figures both the carrier to noise ratio and bandwidth is presented along with the changing trends.

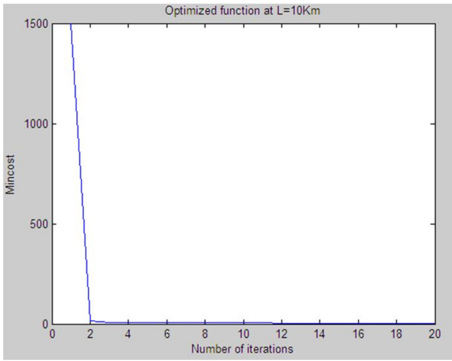

Fig.3-Optimized function at length of fiber of 10Km

The optimization process takes place at a fiber length of 10 Km as shown in Figure 3. It indicates the optimization of fitness function at the vertical axis and number of iterations at horizontal axis. The fitness function is the squared error function which involves an actual Carrier to Noise ratio and reference Carrier to Noise ratio. By using the standard values, CNR (reference) is obtained to be around 28dB. Carrier to noise ratio which was obtained practically during actual transmission was compared with the reference carrier to noise ratio, as mathematically obtained. Then further the ratio plotted with respect to the percentage of received power shows that above a certain limit of 80-90 percent noise power increases beyond limits and thus degrades the signal to an unacceptable level. So the power to be used has to be kept in mind.

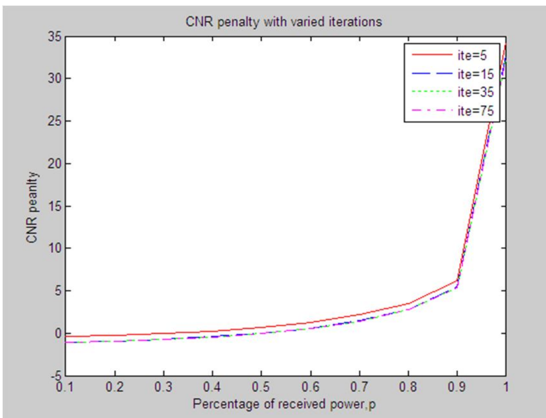

Fig.4-Variation of CNR penalty w.r.t received power

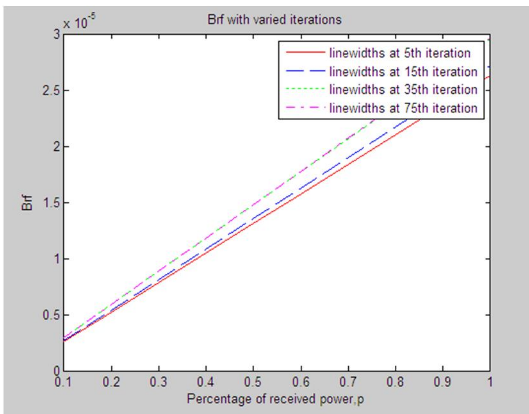

Fig.5-Variation of bandwidth w.r.t received power

The bandwidth required by a signal is directly proportional to the percentage of received power. The bandwidth required for a particular value of received power is totally dependent on the phase noise process of RF Oscillator and it has the very meagre effect of laser diode phase noise process. The value keeps on increasing, however as shown in the above figure that when the percentage of received power reaches 90% of its value, the noise power increases to an appreciable level and starts increasing the CNR penalty. Hence above this percentage, the value of bandwidth must be carefully decided not just according to the direct relationship on increment. Further one shall see that what trend has been followed while changing the linewidths of both the devices at same time.

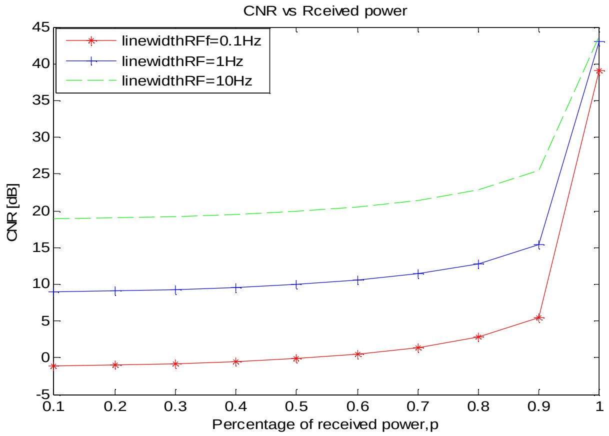

Fig.6-CNR Penalty with respect to percentage of received power with Laser Linewidth= 100MHz

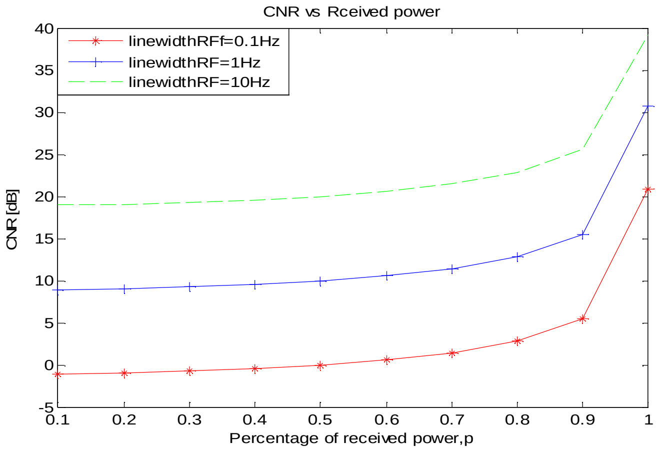

Fig.7- CNR Penalty with respect to Percentage of received power with Laser Linewidth=300MHz

In the above case, CNR penalty with respect to the percentage of received power has been shown in the graphical form while the signal is being transmitted through a fiber of length 10 km and has been explained above. The window for p is extended from 0.1 to 1 which represents a percentage of 10% to 100% respectively. The linewidth of the RF Oscillator has been swept from 0.1 Hz to 10 Hz. It can be clearly seen that as the linewidth of laser diode was being enhanced a minor difference in the CNR penalty was observed and studying each graph carefully it can be stated that even a point difference in RF oscillator linewidth brings a beyond doubt deterioration. The increase in laser diode linewidth reduced the steepness of penalty after 90% power has been used whereas during the initial power holdings no significant effect of laser diode was seen. But RF oscillator played a great role when power deployed is below a certain level and more effect was seen.

Conclusion

The power received at the transmission end must be very carefully chosen so that the two focused parameters of the carrier to noise ratio and bandwidth do not deteriorate beyond the acceptable levels. The accurate values of internal parameters leading to a suitable carrier to noise ratio were effectively obtained by PSO algorithm. Concluding all, it can be said that in spite of having a very large bandwidth scope in radio over fiber systems, it must be limited so that the noise power does not exceed the kind level and degrades the output signal shown in terms of CNR penalty.

References

[1] Tae-Sik Cho, Changho Yun, Jong-In Song and Kiseon Kim, “Analysis of CNR Penalty of Radio-Over-Fiber Systems including the Effects of Phase Noise From Laser and RF Oscillator”, IEEE Journal Of Lightwave Technology, vol. 23, no. 12, 2005.
[2] A. M. J. Koonen and M. García Larrodé, “Radio-Over-MMF Techniques—Part II: Microwave to Millimeter-Wave Systems”, IEEE Journal of Lightwave Technology, vol. 26, no. 15, 2008.
[3] Varghese Antony Thomas, Mohammed El-Hajjar, and Lajos Hanzo(2015),“Performance Improvement and Cost Reduction Techniques for Radio Over Fiber Communications,” IEEE Communication Surveys & Tutorials, vol. 17, no. 2, 2015.
[4] Varghese Antony Thomas, Mohammed El-Hajjar and Lajos Hanzo, “Millimeter-Wave Radio Over Fiber link Optical Upconversion Techniques Relying on Link Non Linearity,”, IEEE Communications Surveys And Tutorials,vol.1,no.4,2015.
[5] Vishal Sharma. Amarpal Singh, Ajay K. Sharma, “Transmission performance of OSSB-RoF system using MZM electro-optical external modulator,” Optik 124,pp.1555-1559, 2013.
[6] Hai Zhao, Chunhe Song, Dan Liu,”A optimized particle filter based on PSO Algorithm,” International Conference on Future BioMedical Information Engineering, 2009.
[7] Caiqin Wu and Xiupu Zhang, “Impact of Nonlinear Distortion in Radio Over Fiber Systems with Single-Sideband and Tandem Single-Sideband Subcarrier Modulations,” IEEE Journal of Lightwave Technology, vol. 24, no. 5, 2006.
[8] Ayhan Yazgan and I.Hakki Cavadar, “A comparative study between LMS and PSO algorithms on the optical channel estimation for radio over fiber systems,” Elsevier Optik no. 125, 2014.