

Radio Signal Generation over Fiber by Optical Injection Locking

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Abstract— Advancement in digital optical communication over long-haul access and access networks is fostering the emergence of millimeter-wave technologies that will enable transport of fast enough data streams in the future. To connect remote users, these signals are used in converging optical/wireless technologies by integrating Worldwide Interoperability for Microwave Access (WiMax), Wireless Fidelity (WiFi), Long Term Evolution (LTE) and currently 5G technologies.

The optical injection locking (OIL) method is studied by applying the correlated system technique of two slave lasers controlled by a master laser. The theoretical and experimental demonstrations consisted in generating several times the reference frequency f_m of the desired RF (radio frequency) signal. Optisystem software was used for the simulation.

Keywords— Radio Over Fiber (RoF), Remote Heterodyne Detection (RHD), Coherent Heterodyne, Optical Injection Locking (OIL), telehealth

I. INTRODUCTION

Nowadays, we are not only witnessing a steady increase in bandwidth-intensive services, but also a drastic demand for these services even in most remote areas. Indeed, with the advent of Cloud computing, Internet of Things, video on demand, decentralization of certain remote access services, biomedicine, etc., a progressive limitation of infrastructure over time is inevitable. The customer demand for mobility and very high speed leads to the use of radiofrequency signals in the millimeter range (30-300 GHz), will allow in the future to carry sufficiently fast data flows (> 1Gbs). Millimeter waves are short ranges. To ensure wide very high speed coverage of a given area, it is necessary to deploy many radio access points using hybrid technology called Radio over Fibre (RoF). This is called a multicellular network (pico-cellular or femtocellular networks). RoF enables optical/wireless convergence by integrating global interoperability for microwave access (WiMax), wireless fidelity (WiFi), long-term evolution (LTE) and 5G technologies[14].

This convergence will facilitate the transmission of any type of medical signal. MIMO techniques will be used at

various base stations to cover any signal requirements based on the types of medical equipment deployed to manage telehealth of elderly people or other purpose in real time. This includes, among other things, medical diagnoses, telesurgery, home tele-assistance, teleradiology, telepsychiatry, telepsychology, universal access and services, distance learning, etc.

The RoF [1] consists of using an optical infrastructure to connect different radio access points. RoF technology enables the centralization of RF signal processing functions such as frequency conversion, modulation and multiplexing at a central station. The latter is then responsible for optically supplying base stations with a very high frequency carrier for example, therefore eliminating the presence of microwave oscillators and modulators in each of the considered base stations. On the other hand, the cost of devices generating millimeter waves remains expensive. Signal generation techniques are intensity modulation and direct detection, remote heterodyne detection, frequency conversion [6][7][8].

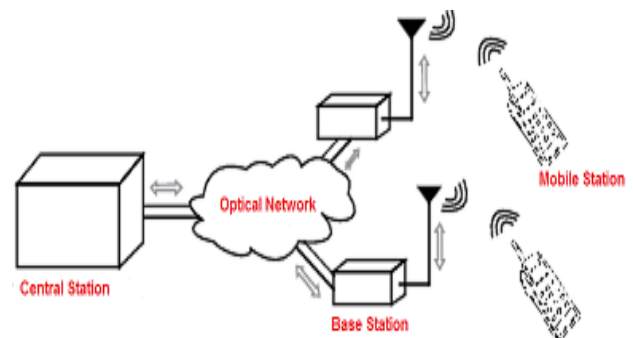


Figure 1. [15]Radio over fiber technologies

Intensity Modulation Direct Detection (IM-DD) is a very simple technique to implement. It consists in modulating the intensity of an optical source by the electric signal itself and to perform a direct detection using a photodetector located

downstream of the considered optical fiber. We obtain in output of the photodetector an electrical signal of the same frequency as that of the transmitted signal. Thus these systems require costly high frequency optoelectronic equipment at the central station to generate millimeter signals.

Frequency conversion or harmonic up-conversion consists in transposing a baseband signal into a millimeter signal at the base station (BS) level for the downlink or ascending channels, either in the electrical or optical domain. This technique requires an upstream RF or optical mixer and a good downstream filter to recover the desired transposition frequency.

The technique of generating a microwave signal by optical beat detection is based on the photodetection of a mixture of two optical waves whose frequency interval is equal to the desired millimeter frequency. This technique is known as Heterodyne Detection or Remote Heterodyne Detection (RHD). The RoF through its ability to generate millimeter waves by optical heterodyne becomes an alternative with great potential. Remote Heterodyne Detection (RHD) consists of detecting at a photodiode the frequency difference between two optical waves (or two continuous currents after the O/E conversion). This heterodyne frequency is therefore the frequency of millimeter radio signal to be transmitted [1] [6]. The RHD methods [1] [8] are Optical Injection Locking (OIL), Optical Phase-Locked Loop (OPLL), Optical Injection Phase-Locked Loop (OIPLL). In this article, we study OIL.

II. RELATED WORKS

In this OIL method, several approaches were made by researchers. Indeed a first study of the possibility of synchronizing by optical injection a laser on one of the sidebands of a modulated master laser was made [6]. This method has the disadvantage of sharing the optical power of the master laser [4] [6] [7][16][17]. Only one of several sidebands is used for the heterodyne beat; the power budget is therefore low because the optical power supplied by the master laser is low [7]. Then another montage is proposed; this time, two slave lasers each hooked onto one of the sidebands of the modulated master laser, as shown in Figure 2. Therefore, the master laser no longer participates in terms of power to the heterodyne beat and we can take advantage of the whole of the power delivered by slave lasers [1] [4][6]-[13]. In a reduced version [8] [10], a single longitudinal multimode slave laser was substituted for two slave lasers with a longitudinal mode spacing equal to the desired frequency f_{RF} .

L. Goldbert of Naval Research Laboratory managed to hang the slave lasers on the sidebands $(-2, +2)$, $(-3, +3)$, $(-5, +5)$. The master laser was modulated at 2.63 GHz [4], 5.83 GHz [9] [10] [11], about 2 GHz [12] respectively.

Braun and all were able to lock the slave lasers on the -10 and +10 sidebands. The master laser was modulated at 3.125 GHz [13].

Direct modulation has been used in several experiments.

In this article, we will show theoretically and practically that slave lasers can be hooked to any sideband depending on the radio frequency signal that we want to generate. We use external modulation.

The article is constructed as follows. The system model is described in section III. Section IV shows theoretical calculations. In section V, simulation and results are presented. The article is concluded in section VI.

III. SYSTEM MODEL

Remote heterodyne detection using two independent lasers is certainly the simplest method for generating millimeter band signals [1] [6]. We use Optical Injection Locking (OIL) technique to keep a frequency gap between the two lasers constant and to minimize the phase noise of the generated millimetric signal. The problem of stability of the heterodyning method comes from the independence between the two lasers used. In order to solve this problem, it is necessary to correlate the two lasers. Phase coherence of the two lasers can be obtained by optical injection. Figure 2 [1] gives the principle of a system correlated by double optical injection with a master laser and two slave lasers.

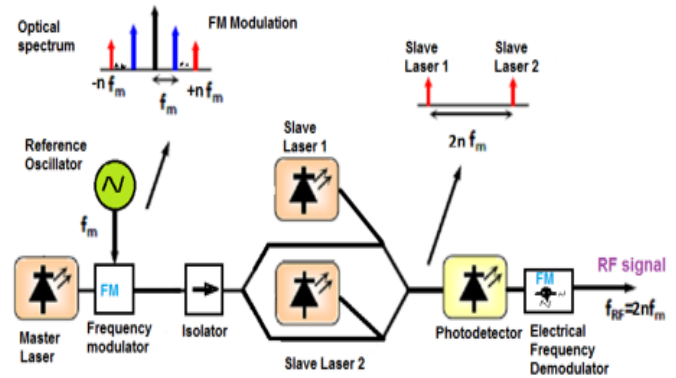


Figure 2. System correlated by double optical injection [1].

The master laser is modulated with a reference oscillator. The optical signal generated comprises the carrier frequency of the laser f_p as well as the reference frequency of the oscillator f_m and its harmonics, due to the parasitic frequency modulation. The spectrum of the master laser is therefore composed of several spectral lines on either side of the carrier f_p spaced from f_m . The output signal of the master laser is injected into the two slave lasers, each hooked onto one of the sidebands of the modulated master laser. By modulating the master laser at f_m , we therefore succeed in generating a microwave frequency f_{RF} equal to a multiple of the reference frequency f_m of the signal applied to the master laser. We propose to prove these results by theoretical calculations and simulations.

IV. THEORETICAL CALCULATIONS

Let $m(t)$ and $v_p(t)$ be two signals named modulating signal and carrier respectively; $m(t) = A_m \cos(2\pi f_m t)$;

$v_p(t) = A_p \cos(2\pi f_p t)$. At the output of the master laser, the frequency-modulated signal is given by the following expression: $s(t) = A_p \cos(\theta_i(t))$. By definition, the instantaneous frequency f_i is controlled by the modulating signal $m(t)$ around a carrier f_p : $f_i = f_p + K_f m(t)$; K_f is the sensitivity of the modulator (in Hz.V^{-1}). The

instantaneous pulsation is: $\omega_i = 2\pi f_p + 2\pi K_f m(t)$. The instant phase of the modulated signal is given by the following expression:

$$\theta_i(t) = \int \omega_i dt = 2\pi f_p t + 2\pi K_f \int m(t) dt.$$

The expression of the modulated signal is therefore:

$$s(t) = A_p \cos(2\pi f_p t + 2\pi K_f \int m(t) dt) \quad (1)$$

Replacing $m(t)$ by its value in the equation (1) we have:

$$s(t) = A_p \cos\left(2\pi f_p t + 2\pi K_f \int A_m \cos(2\pi f_m t) dt\right) \quad (2)$$

$$s(t) = A_p \cos\left(2\pi f_p t + K_f \left(\frac{A_m}{f_m}\right) \sin(2\pi f_m t)\right) \quad (3)$$

$$s(t) = A_p \cos(2\pi f_p t + \beta_f \sin(2\pi f_m t)) \quad (4)$$

Where $\beta_f = K_f \left(\frac{A_m}{f_m}\right)$ is the frequency modulation index

for the signal $m(t)$. The frequency deviation is given by:

$$\Delta f = K_f A_m.$$

By developing expression (4), we have:

$$s(t) = A_p [\cos(2\pi f_p t) \cos(\beta_f \sin(2\pi f_m t)) - \sin(2\pi f_p t) \sin(\beta_f \sin(2\pi f_m t))] \quad (5)$$

When $\beta_f < 1$, we talk about narrow-band Frequency Modulation and when $\beta_f > 1$, we talk about broadband Frequency Modulation.

A. Narrow-band Frequency Modulation

In narrow-band frequency modulation we consider $\beta_f < 1$ and approximate $\cos(\beta_f \sin(2\pi f_m t)) \approx 1$; $\sin(\beta_f \sin(2\pi f_m t)) \approx \beta_f \sin(2\pi f_m t)$. The equation (5) gives:

$$s(t) = A_p (\cos(2\pi f_p t) - \beta_f \sin(2\pi f_p t) \sin(2\pi f_m t)) \quad (6)$$

Finally linearization formulas allow us to write:

$$s(t) = A_p \left(\cos(2\pi f_p t) - \left(\frac{\beta_f}{2}\right) (\cos 2\pi(f_p - f_m)t - \cos 2\pi(f_m + f_p)t) \right) \quad (7)$$

The signal $s(t)$ shows that for $\beta_f < 1$, the spectrum of the output signal is composed of the carrier f_p , and the two components at the frequencies $f_p \pm f_m$; such a signal is called a narrow-band FM signal. If the modulated master laser hooks the two slave lasers respectively to -1 and +1, they suppress everything except $A_p \left(\frac{\beta_f}{2}\right) (\cos 2\pi(f_p - f_m)t$ and $A_p \left(\frac{\beta_f}{2}\right) (\cos 2\pi(f_p + f_m)t$ [5]. We obtain at the output of the coupler a signal $s_{RF}(t)$:

$$s_{RF}(t) = A_p \left(\frac{\beta_f}{2}\right) (\cos 2\pi(f_p - f_m)t) * A_p \left(\frac{\beta_f}{2}\right) (\cos 2\pi(f_p + f_m)t)$$

which means:

$$s_{RF}(t) = \left(\frac{A_p \beta_f}{2}\right)^2 (\cos 2\pi(f_p - f_m)t) \cos 2\pi(f_p + f_m)t$$

Linearization formulas allow us to write:

$$s_{RF}(t) = \frac{1}{2} \left(\frac{A_p \beta_f}{2}\right)^2 (\cos 4\pi f_p t + \cos 2\pi(2f_m)t) \quad (8)$$

After filtering, we obtain an RF signal whose frequency is twice the frequency of the modulating signal.

$$s_{RF}(t) = \frac{1}{2} \left(\frac{A_p \beta_f}{2}\right)^2 \cos 2\pi(2f_m)t \quad (9)$$

It can be concluded that narrow band modulation by double injection makes it possible to generate a radiofrequency signal with a frequency twice the frequency of the modulating signal.

B. Broadband Frequency Modulation

The broadband frequency modulation is considered when $\beta_f > 1$. We can no longer use the approximation:

$\cos(\alpha + \beta_f) \approx \cos(\alpha) - \beta_f \sin(\alpha)$. However, we can use the following expression:

$\cos(\alpha + \beta_f) = \Re\{e^{j(\alpha + \beta_f)}\}$; We can express the signal $s(t)$ by: $s(t) = A_p \cos(2\pi f_p t + \beta_f \sin(2\pi f_m t))$

$s(t) = A_p \Re\{e^{j(2\pi f_p t + \beta_f \sin(2\pi f_m t))}\}$; where A_p is fixe and the carrier signal is $e^{j2\pi f_p t}$; the periodic signal is $e^{j\beta_f \sin(2\pi f_m t)}$.

The periodic function with period $T_m = \frac{1}{f_m}$ can be decomposed into complex Fourier series.

$$e^{j\beta_f \sin(2\pi f_m t)} = \sum_{n=-\infty}^{+\infty} c_n e^{j2\pi n f_m t} \quad (10)$$

Where $c_n = \frac{1}{T_m} \int_{t_0}^{t_0 + T_m} f(t) e^{-j2\pi n f_m t} dt$;

$n = \dots, -2, -1, 0, 1, 2, \dots$ and $f(t) = e^{j\beta_f \sin(2\pi f_m t)}$. we can choose the beginning of the integration interval at $t_0 = 0$ then

$$c_n = \frac{1}{T_m} \int_0^{T_m} f(t) e^{-j2\pi n f_m t} dt$$

$$c_n = f_m \int_0^{T_m} e^{j\beta_f \sin(2\pi f_m t)} e^{-j2\pi n f_m t} dt$$

$$c_n = f_m \int_0^{T_m} e^{j[\beta_f \sin(2\pi f_m t) - 2\pi n f_m t]} dt;$$

Let's put $x = 2\pi f_m t$; $\frac{dx}{dt} = \frac{d(2\pi f_m t)}{dt} = 2\pi f_m$;

$dt = \frac{dx}{2\pi f_m}$; we'll have :

$$c_n = f_m * \frac{1}{2\pi f_m} \int_{0*2\pi f_m}^{T_m*2\pi f_m} e^{j[\beta_f \sin(x) - nx]} dx$$

$$c_n = \frac{1}{2\pi} \int_0^{2\pi} e^{j[\beta_f \sin(x) - nx]} dx$$

The coefficient c_n corresponds to Bessel's functions of the first kind and of order n noted $J_n(\beta_f)$ [3].

$$J_n(\beta_f) = \frac{1}{2\pi} \int_0^{2\pi} e^{j[\beta_f \sin(x) - nx]} dx$$

Bessel's functions are obtained from the following expression [2]:

$$J_n(\beta_f) = \sum_{k=0}^{+\infty} \frac{(-1)^k \left(\frac{\beta_f}{2}\right)^{n+2k}}{k!(n+k)!}$$

The properties of Bessel's functions of the first kind $J_n(\beta_f)$ are :

1. $J_n(\beta_f)$ is real
2. $J_n(\beta_f) = (-1)^n J_{-n}(\beta_f)$
3. $\sum_{n=-\infty}^{+\infty} J_n^2(\beta_f) = 1$

Finally, if we use the proprieties of the Bessel functions, we obtain :

$$e^{j\beta_f \sin(2\pi f_m t)} = \sum_{n=-\infty}^{+\infty} J_n(\beta_f) e^{j2\pi n f_m t}$$

$$s(t) = A_p \Re \{ e^{j2\pi f_p t} e^{j\beta_f \sin(2\pi f_m t)} \}$$

$$s(t) = A_p \Re \{ e^{j2\pi f_p t} \sum_{n=-\infty}^{+\infty} J_n(\beta_f) e^{j2\pi n f_m t} \}$$

Finally we have :

$$s(t) = A_p \sum_{n=-\infty}^{+\infty} J_n(\beta_f) \cos(2\pi f_p t + 2\pi n f_m t) \quad (11)$$

Finally the modulated signal gives :

$$s(t) = A_p [\dots + J_{-n}(\beta_f) \cos(2\pi f_p t + 2\pi n f_m t) + \dots + J_0(\beta_f) \cos(2\pi f_p t) + \dots + J_n(\beta_f) \cos(2\pi f_p t + 2\pi n f_m t) + \dots] \quad (12)$$

The equation number (12) means that the spectrum of the modulated signal in broadband frequency modulation consists of an infinite number of spectral components [2] Figure 3.

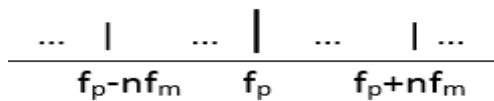


Figure 3. Spectrum of the modulated signal

If the FM modulated master laser hooks the two slave lasers respectively at n^{th} and l^{th} harmonics, a great part of the signal is suppressed. The slave laser 1 removes all other

harmonics except the n^{th} [2][3][4]. The slave laser 2 also removes all other harmonics except the l^{th} [2][3][4]. The FM signal at the output of the coupler is given by :

$$s_c(t) = A_p J_n(\beta_f) \cos(2\pi f_p t + 2\pi n f_m t)^*$$

$$A_p J_l(\beta_f) \cos(2\pi f_p t + 2\pi l f_m t)$$

$$s_c(t) = (A_p)^2 J_n(\beta_f) J_l(\beta_f) \cos(2\pi f_p t + 2\pi n f_m t)^* \cos(2\pi f_p t + 2\pi l f_m t)$$

Linearization formulas allow us to write :

$$\text{Let's ask } D = \frac{1}{2} J_n(\beta_f) J_l(\beta_f) (A_p)^2 ;$$

$$s_c(t) = D [\cos(4\pi f_p t + 2\pi(1+n)f_m t) + \cos(2\pi(1-n)f_m t)] \quad (13)$$

After filtering, we obtain a signal radio-frequency :

$$s_{RF}(t) = \frac{1}{2} J_n(\beta_f) J_l(\beta_f) (A_p)^2 \cos(2\pi(1-n)f_m t) \quad (14)$$

If the modulated master laser hooks the two slave lasers respectively in the n^{th} and the l^{th} harmonics, we obtain a radio frequency signal which is $f_{RF} = (1-n)f_m$

If the FM modulated master laser hooks the two slave lasers respectively at $-n^{\text{th}}$ and n^{th} harmonics, a great part of the signal is suppressed. The slave laser 1 removes all other harmonics except the $-n^{\text{th}}$ [2][3][4]. The slave laser 2 also removes all other harmonics except the n^{th} [2][3][4]. The FM signal at the output of the coupler is given by:

$$s_c(t) = A_p J_{-n}(\beta_f) \cos(2\pi f_p t - 2\pi n f_m t)^*$$

$$A_p J_n(\beta_f) \cos(2\pi f_p t + 2\pi n f_m t)$$

$$s_c(t) = (A_p)^2 J_{-n}(\beta_f) J_n(\beta_f) \cos(2\pi f_p t - 2\pi n f_m t)^* \cos(2\pi f_p t + 2\pi n f_m t)$$

Linearization formulas and properties of $J_n(\beta_f)$ allow us to write :

$$s_c(t) = E [\cos(4\pi f_p t) + \cos(4\pi n f_m t)] \quad (15)$$

$$\text{with } E = (-1)^n \frac{1}{2} J_n^2(\beta_f) (A_p)^2$$

After filtering, we obtain a signal radio-frequency:

$$s_{RF}(t) = (-1)^n \frac{1}{2} J_n^2(\beta_f) (A_p)^2 \cos(2\pi(2n)f_m t) \quad (16)$$

If the modulated master laser hooks the two slave lasers respectively at $-n^{\text{th}}$ and $+n^{\text{th}}$ harmonics, we obtain a radio frequency signal with $f_{RF} = 2nf_m$.

V. SIMULATION AND RESULTS

A. Simulation model

Simulation consists in experimentally proving that when the carrier of the master laser is modulated with a reference frequency f_m and the modulated signal is injected into two correlated slave lasers (50%; 50%), a RF equals to an integer of times f_m is generated. In our research we have opted for a simulation software for innovative optical communications systems that designs, tests and optimizes virtually any type

of optical link in the physical layer of a wide range of optical networks ; Optisystem is a simulator based on a realistic modeling of fiber optic communication systems. OptiSystem is compatible with Optiwave's OptiAmplifier and OptiBPM design tools and can do a co-simulation with matlab. Figure 4 shows the simulation models performed in this work.

In the parameterization of the slave lasers, depending on the desired RF, one of the two is hooked on the sideband (+n) ; automatically the other is positioned on the sideband (-n). Concretely a difference of nf_m is created between the carriers of the two slave lasers. This means that if $F_{pslave1}$ is

the carrier of the slave laser 1 then the carrier of the slave laser 2 will be $F_{pslave2} = F_{pslave1} + nf_m$ with f_m the modulating frequency of the master laser. In the two slave lasers, only the harmonics $-nf_m$ and $+nf_m$ are respectively preserved, the others being suppressed. This means that only one line for each slave laser will be visible when viewing with a spectrum analyzer. At the output of the frequency demodulator, two lines appear on the screen of the spectrum analyzer whose spacing corresponds to $f_{RF} = 2nf_m$.

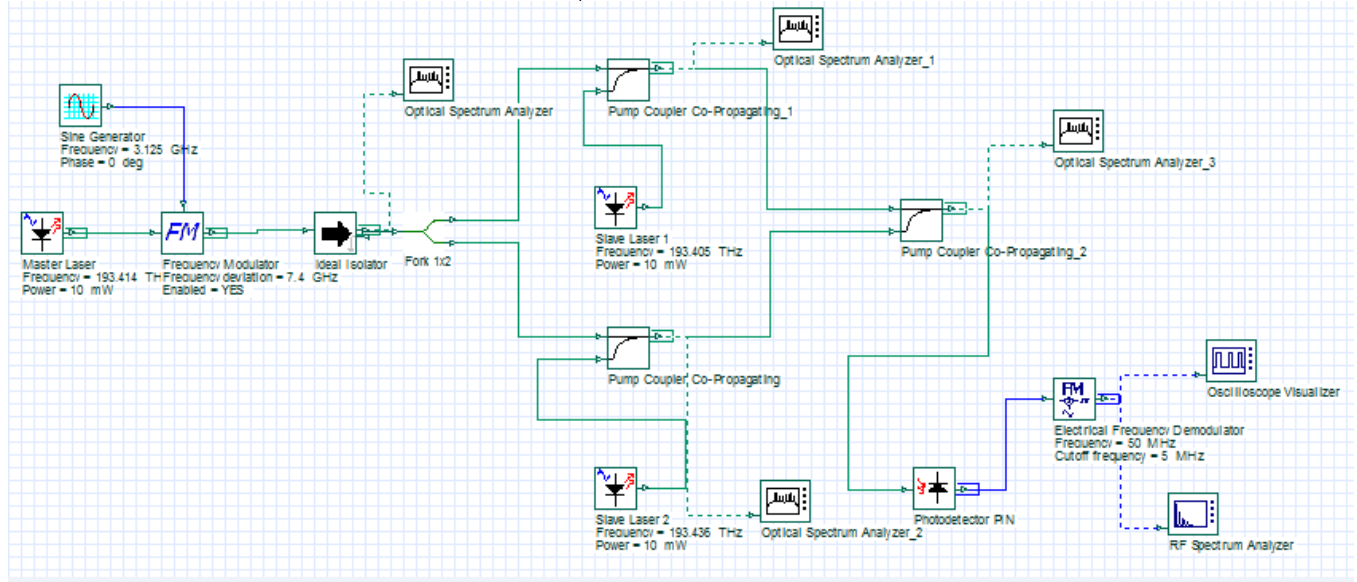


Figure 4. Signal generation by Optical Injection Locking (OIL) with optisystem

In Figure 4, Sine Generator = Generator of f_m

The tests were done by hooking the slave lasers on several harmonics. The results are presented in the next section.

B. Results of the simulation

We first did the test by hooking the slave laser 2 on the harmonic 1 and having obtained the expected result ; we proceeded with tests on other harmonics. we present in detail the results of the test on the tenth (10th) harmonic; the results of the test on the other harmonics are recorded in the summary table TABLE I.

The carrier of the master laser is $f_p = 193.41449$ Thz corresponding to a wavelength of $1550 \mu m$. The slave laser 1 has the carrier $f_{pslave1} = 193.40451$ Thz and $f_{pslave2} = f_{pslave1} + nf_m$ with $n = 10$. So $f_{pslave2} = 193.43576$ Thz. At the output of the isolator, the spectrum of the modulated master laser is visualized in Figure 5.

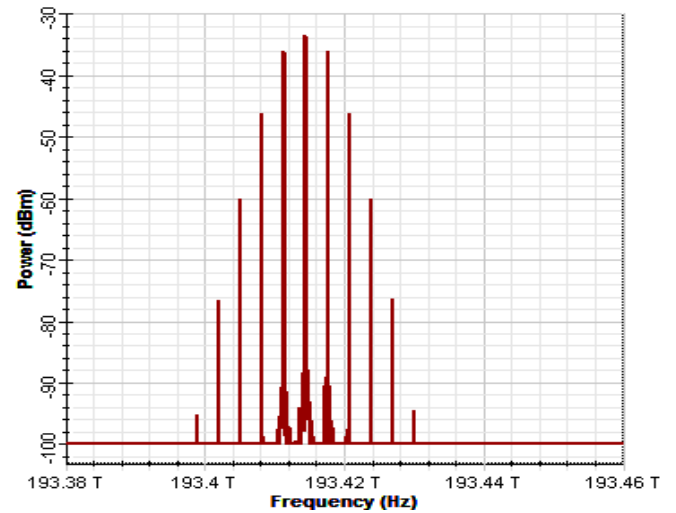


Figure 5. Spectrum of the modulated signal of the master laser at the output of the isolator

The 40 dB calibrated isolator between master laser and slave lasers allows one-way light propagation to reduce optical feedback. Each of the two slave lasers being hooked to the harmonic ± 10 removes all other harmonics and presents the only line at the output.

At the output of the coupler the signal is always optical. The spectrum analyzer connected at this level is optical. In Optisystem 7.0 that we used, the optical spectrum analyzer does not have <<Negative Frequencies>> option, unlike the electric spectrum analyzer that has.

Thus the optical spectrum analyzer visualizes the two sidebands in the same place Figure 6. This is because, for the same reason, we see that on the screens of optical spectrum analyzers connected to the level of the slave lasers the lines are on the positive harmonics. So the two bands are superimposed.

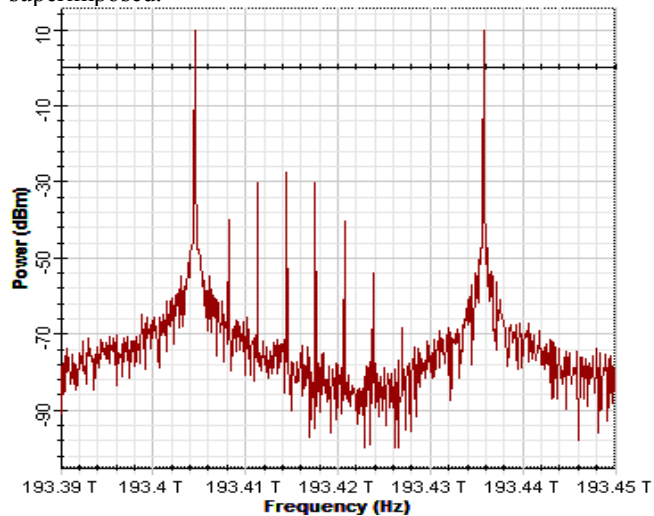


Figure 6. Spectrum at the output of the coupler

This makes it seem at first sight that only the upper sideband is represented. It is then up to the electric spectrum analyzer to put the two sidebands in order (lower band, upper band). Hence the result that we see in Figure 7.

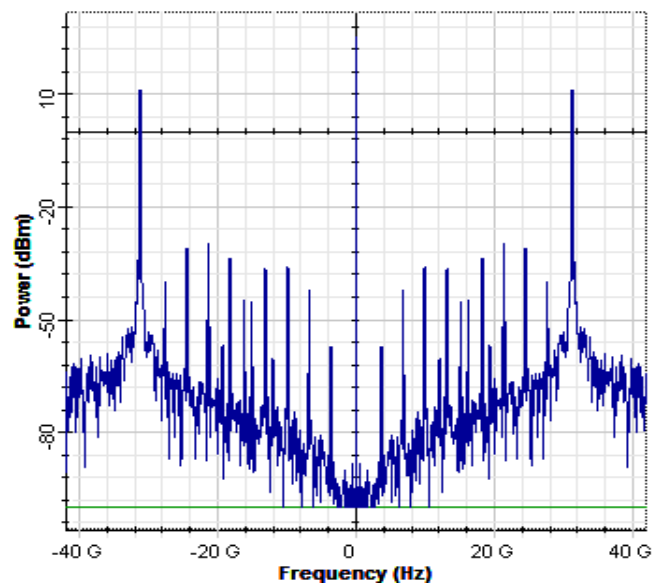


Figure 7. Spectrum at the output of the FM demodulator

A WonderWare Screen Ruler (software tool) was used to evaluate spacing between the lines and deduce the value of f_{RF} . We read 231px for spacing while we have 74px for 20 GHz. So $f_{RF} = (231 \times 20) / 74 \approx 62.5$ GHz. So $f_{RF} = 62.5$ GHz = 20×3.125 GHz = $20f_m$ as predicted. The 62.5 GHz frequency is used in indoor WPAN.

C. Summary of the results

The Optical Injection Locking (OIL) technique is very important. Indeed UMTS-3G signal of 2 GHz is generated from 1 GHz. LTE signal that works at 2.6 GHz is generated from 1.3 GHz. 28GHz Local Multipoint Distribution System (LMDS) signal is generated from 2.34 GHz.

The results of the simulation recorded in the TABLE I below show that, for the future wireless network (WLAN), Wireless Personal Area Network (WPAN) and WiMAX networks, the OIL technique is welcome because we can generate broadband from a low bandwidth. This is very interesting for broadband coverage in rural areas through radio over fiber (RoF) technology. Whatever the wireless technology that the medical equipment needs to connect to the network, the optical injection locking technique can generate the necessary signal from a weak signal.

TABLE I. SIGNAL GENERATION BY OPTICAL INJECTION LOCKING (OIL)

f_p in Thz	f_m in Ghz	$F_{p \text{ slave1}}$ in Thz	$F_{p \text{ slave2}}$ in Thz	Sideband	$f_{RF} = 2nf_m$	f_{RF} in Ghz	Applications
193.41449	1.00000	193.40451	193.40551	1	$2f_m$	2	UMTS.3G
193.41449	1.30000	193.40451	193.40581	1	$2f_m$	2.6	LTE
193.41449	1.25000	193.40451	193.40701	2	$4 f_m$	5	WLAN
193.41449	1.50000	193.40451	193.40901	3	$6 f_m$	9	WiMAX
193.41449	1.75000	193.40451	193.41151	4	$8 f_m$	14	WiMAX
193.41449	2.00000	193.40451	193.41451	5	$10 f_m$	20	Indor WLAN
193.41449	2.34000	193.40451	193.41855	6	$12 f_m$	28.08	LMDS
193.41449	2.50000	193.40451	193.42201	7	$14 f_m$	35	WiMAX
193.41449	3.62500	193.40451	193.43351	8	$16 f_m$	58	Indor WLAN
193.41449	3.33000	193.40451	193.43448	9	$18 f_m$	59.94	WPAN
193.41449	3.12500	193.40451	193.43576	10	$20 f_m$	62.5	WPAN

VI. CONCLUSION AND FUTURE WORK

This paper investigated on the generation of millimetric signals thanks to optical injection locking method by applying

the correlated system technique of two slave lasers controlled by a master laser. This technique makes it possible to generate an integer number of times the frequency f_m of the reference oscillator called in RHD the modulating signal. Theoretical demonstrations and simulation have been performed. It is shown that Wireless broadband technologies can benefit from this technique through the Radio over Fiber (RoF) system. This solution improves the effective benefit of broadband accessibility and quality.

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