Influence of the laser locking characteristics on overtone rejection and signal to noise ratio in optically generated microwaves

Gabriel Campuzano and Philippe Gallion
Ecole Nationale Supérieure des Télécommunications, CNRS URA 820, 46 rue Barrault, 75634 Paris Cedex 13, France

Optical generation, remote control and distribution of microwave signals in radio-over-fiber systems have various advantages among which low-cost components in the numerous base stations and high radio frequency spectral properties stand out. The sideband injection locking technique for generating microwaves has proven to be a very promising method /1/. Basically, two slave lasers with a wavelength difference corresponding to the desired microwave frequency are injection-locked to different side-bands of a subharmonically modulated master laser in order to achieve frequency stability and phase correlation between the optical signals. With the objective to fully characterize and determine optimal parameters this technique was experimentally implemented using DFB semiconductor lasers and novel results concerning high-performance issues are reported.

The optical spectrum of the modulated master laser in figure 1 shows the different sidebands that may be used to lock each slave laser. A modulation frequency of 3 GHz and electrical driving power of 30 dBm was used given that no impedance matching circuit was implemented (effective modulation depth was 12%). These operating conditions as well as the choice of sidebands where carefully selected to obtain the desired RF spectral properties /2/. In order to avoid signal degradation and frequency instabilities, it was found that adjacent sidebands should not be higher than the locking sideband by more than 5 dB.

In a master/slave laser configuration, the locking bandwidth is defined as the maximum frequency detuning range that keeps the slave laser locked for a given injection rate. In principle, the slave laser externally locked to a single sideband should reject all other frequencies, but actually, because of the large gain bandwidth of semiconductor lasers, several adjacent sidebands are also amplified. The power spectrum of the injected slave laser is shown in figures 2 and 3 for positive and negative detuning respectively, which is obtained by slightly varying the biasing current of the slave laser. It is observed that for a positive detuning of 440 MHz, the adjacent sideband rejection rate is 13 dB, whereas a frequency detuning of –560 MHz results in a rejection rate of 20 dB. This is explained by the fact that near the static limit for positive detunings, the threshold gain of the locked mode is higher than that of the free-running mode. Sidebands further away quickly improving spectral purity. Similar results are obtained when varying the injection rate for a given frequency detuning. Nonetheless, the decay of the rejection rate as the injection rate increases arises from a different physical mechanism. The relaxation frequency resonance is modified by optical injection and defines a static/dynamic limit (undamped) of the locking range. Operation just beyond this limit result in a chaotic behavior. Moreover strong signals entering the slave laser cavity unleash competition between the adjacent sidebands due to locking bandwidth overlapping /2/. The impact on the RF spectrum is shown in figure 4 for a 12 GHz generated signal. For similar optical powers of both slave lasers and similar injection conditions, a 4 dB increase of the injection rate (attenuation of the injected signal) results in 2 dB degradation of the signal to noise ratio.

Further experimental observations show that the spectral purity is inherently dependent on the frequency detuning and on the relative power of the chosen modulation sideband with respect to the adjacent sidebands. Likewise the rejection rate and locking stability also deeply depend on the injection rate. By carefully selecting the frequency detuning and the injection rate the overtone rejection ratio can be greatly enhanced.