NEW CARRIER GENERATION APPROACH FOR FIBER-RADIO SYSTEMS TO OVERCOME CHROMATIC DISPERSION PROBLEMS

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ABSTRACT

A new approach for the generation of millimeter wave (MMW) carriers in fiber-radio systems is presented. A subharmonic of the carrier is transmitted to the radio nodes over the fiber-optic network. At each base station the MMW carriers are generated by a phase locked oscillator (PLO) using harmonic mixing technique. Due to the subharmonic reference transmission, chromatic dispersion in the optical path is avoided. Further advantage is the inherent possibility of channel selection to avoid radio interference between adjacent transmitters.

INTRODUCTION

Recently optical generation of millimeter waves has been an intensive research area of microwave (MW) photonics. One main field of the possible applications is the MMW wireless distribution in fiber-radio picocellular systems for broadband services. Due to the lack of available frequency bands having wide RF channels in the lower MW range and the high free space loss at MMW frequencies, optical generation of MMW carriers becomes even more relevant [1].

EFFECT OF CHROMATIC DISPERSION ON MW / MMW TRANSMISSION

A seemingly evident solution is to utilize a MMW external modulator or a direct modulated laser and a high speed photodetector for the MMW transmission over a fiber-optic link. However, chromatic dispersion in standard single-mode fibers (SMF) at λ = 1550 nm leads to a drastic penalty in detected signal strength for a given fiber length and modulation frequency [2].

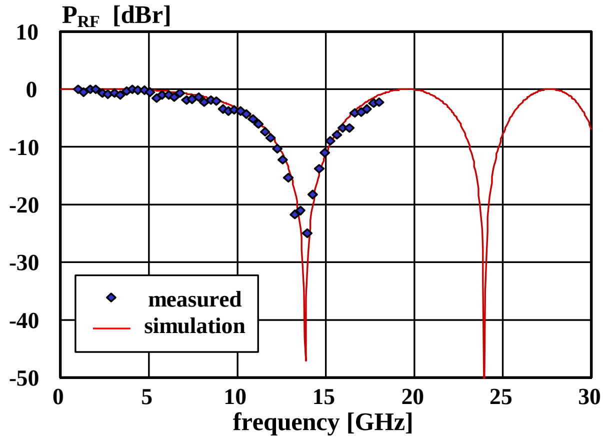

Figure 1. Detected power versus modulation frequency for *L* = 19.2km, λ = 1550nm, *D* =17 ps/km nm.

Fig.1 shows the received power as a function of modulation frequency for a SMF, calculated with a dispersion coefficient of *D* = 17 ps/km nm. The values measured on the *L* = 19.2 km long FDDI ring of our University fit well to the calculated curve. The transmission has minima at specific modulation frequencies destroying the connection. This effect is presented more precisely in Fig.2 providing relationship between fiber length *L* and rejection frequencies. The surface diagram of Fig.3 shows the domains within the effect of chromatic dispersion is negligible. Further rejections are plotted in the frequency band up to 35 GHz for optical links shorter than 30 km. In practical applications this property presents a serious drawback at λ=1,55 μm.

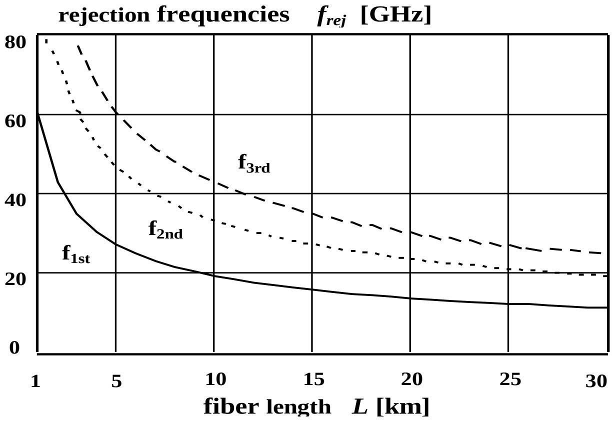

Figure 2. Relationship between the fiber length and the first, second and third rejection frequencies

MMW Generation Concepts

In [2, 3, and 4] perspective optical solutions are investigated to overcome the effect of chromatic dispersion. Self-heterodyning techniques and optical SSB modulation are proposed.

Our approach gives a different solution of the problem. A subharmonic of the carrier signal is added to the information signal and transmitted via the SMF network. It can be seen in Fig.3 that for optical links even longer than 20 km a MW subharmonic of the desired MMW frequency can be transmitted without significant penalty.

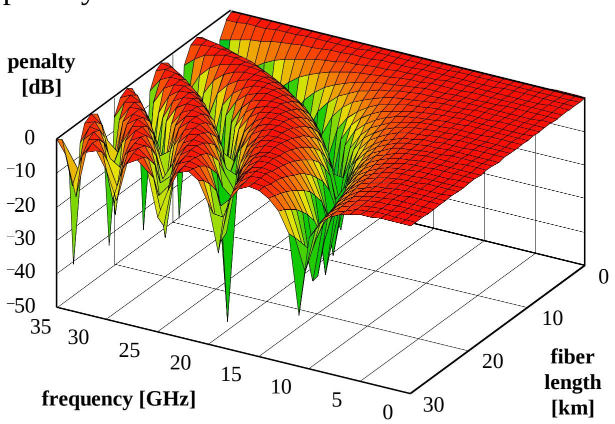

Figure 3. Limitation due to chromatic dispersion in SMF

Furthermore, the optical parts of the system become less demanding (simpler transmitter and receiver are needed due to the relatively low frequency of the reference). Then at the radio nodes the desired MMW carrier is generated by a harmonic mixer (HMX) and a MMW voltage controlled oscillator (VCO) using this optically transmitted reference [5]. The same MW reference signal can be transmitted from the central station to several picocell base stations via the SMF network. Since the reference frequency is smaller than 10 GHz, chromatic dispersion effects can be disregarded. The reference signal must have high stability and good spectral purity. These requirements are easily provided by a low MW frequency PLO. The recent development of GaAs MMIC technique makes the proposed method attractive and applicable up to 100 GHz using a reference frequency lower than 10 GHz.

Radio Node Opto-MMW Transducer

The configuration of the proposed radio node transducing the optically received signals into the MMW wireless channels at the picocell base stations is shown in Fig.4. The MW reference signal is detected and amplified by the photo-receiver. The required bandwidth of the photo-receiver is only a few GHz, determined by the frequency band of the generated MMW, by the selected harmonic number m of the HMX and by the bandwidth of the digital information signal. The optically transmitted reference is splitted into two, half of the reference power is pumping the HMX. The MMW VCO signal is mixed with the m-th harmonic of the reference :

$$f_{IF} = f_{VCO} - m*f_{REF} \ .$$

The intermediate frequency f_{IF} is smaller than 2 GHz allowing further division to f_{IF}/k by a programmable digital divider. In the other path f_{REF} is divided by n. These divided frequencies are compared in the phase detector :

$$f_{IF} / k = f_{REF} / n \ .$$

At the steady state of the PLL, the MMW VCO is running at :

$$f_{VCO} = mf_{REF} + f_{IF} = (m+k/n)f_{REF} \ .$$

By programming the division factor k the MMW frequency f_{VCO} can be set with a step of $\Delta f = f_{REF}/n$ within the VCO tuning range. The phase detector operates at a few MHz so it can be an integrated circuit. For future applications it may be important to increase the frequency of the generated MMW carrier. The main possibilities are to use higher reference frequency or larger harmonic number in the PLL. Another possibility employing harmonic VCO was presented in [6, 7]. Evident advantage of remote upconversion instead of MMW transmission is the possibility of employing circuits and subsystems provided for MW/MMW digital radios [8]. There is a well based technology for the standardized frequency bands of 18, 23, 26 and 38 GHz. Digital radio transmitters operating in these bands have frequency stability better than 30 ppm as required by European Norms. The complexity of the remote station is increased compared to a passive picocell [9]. But remote upconversion ensures easy RF channel separation provided by the PLL. Up to now much effort has been done for the MMW signal generation but only a very few paper dealt with the problem of generating independent carriers for each picocell [10].

EXPERIMENTAL RESULTS

In the experiments a reference frequency of $f_{REF} \cong 2$ GHz and a harmonic number $m = 13^{th}$ were chosen. The reference oscillator was constructed in microstrip technology, using a transistor VCO with possibility of locking to a quartz reference.

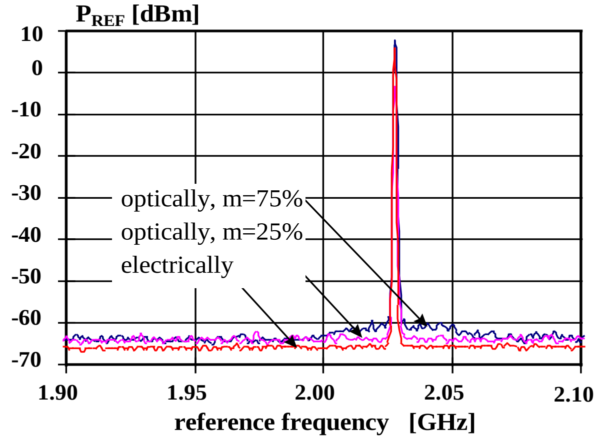

Figure 5. Measured spectra of the reference at the optical link input and output (f_{REF} =2027.5 MHz)

The optical link is composed of an optical source emitting at λ = 1550 nm (HP 83424A), an external modulator (HP 83422A) and a light-wave converter (HP 11982A). The reference was transmitted through the SMF. Fig.5 shows the measured spectra for different optical modulation depths. For comparison the spectrum measured at the oscillator output is plotted also.

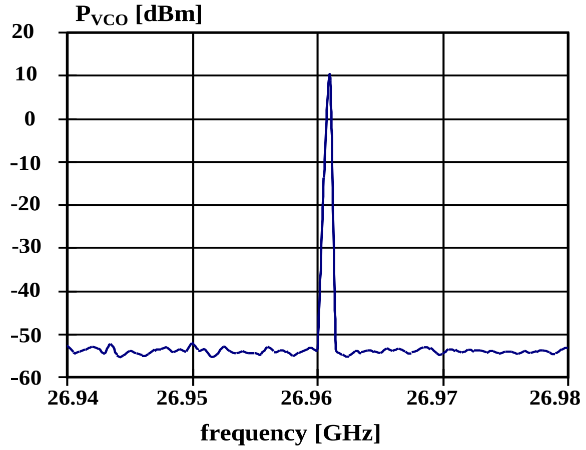

Figure 6. Measured Gunn oscillator power spectrum

The MMW VCO was a varactor tuned Gunn oscillator. The waveguide cavity can be adjusted for rough selection of the desired frequency band (f_{MMW} = 26...34 GHz). For simplicity in the measurements $f_{MMW} \cong 27$ GHz was chosen.

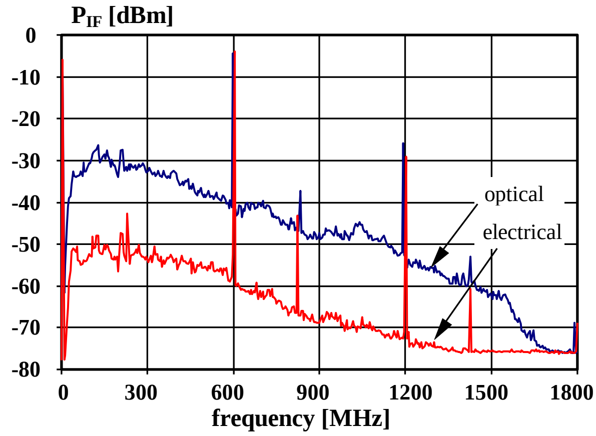

Figure 7. Measured spectra at the HMX IF port

Fig.6 shows the Gunn VCO spectrum measured at the waveguide flange. The output power is 10 mW so further amplification is not necessary for a few km long wireless hops. The electrical tuning range of the VCO is around 200 MHz.

The HMX IF frequency is $f_{IF} \approx 600$ MHz used for the PLL after division (Fig.7).

CONCLUSIONS

A new approach of MW/MMW carrier generation in fiber-radio systems was presented. Using a subharmonic reference transmitted optically to each radio node over the fiber-optic network, the MMW carrier is generated by a PLO using harmonic mixing technique. Due to the sub-harmonic reference transmission, the effect of chromatic dispersion in the optical path is avoided. Further advantage is the possibility of RF channel selection in the picocells to avoid interference between adjacent MMW trans-mitters.

ACKNOWLEDGMENTS

This research is supported by the 'FRANS' (Fiber-Radio ATM Network Systems) project of the European Community. The authors wish to thank the fruitful discussions with the project participants at UCL, ALCATEL-SEL and THOMSON. The authors acknowledge Sándor Domokos and Hewlett-Packard Hungary the donation of the optical test equipment. They thank the continuous support of "OTKA" the Hungarian Scientific Research Fund (No. T017295, F024113, T019839 and T019857).

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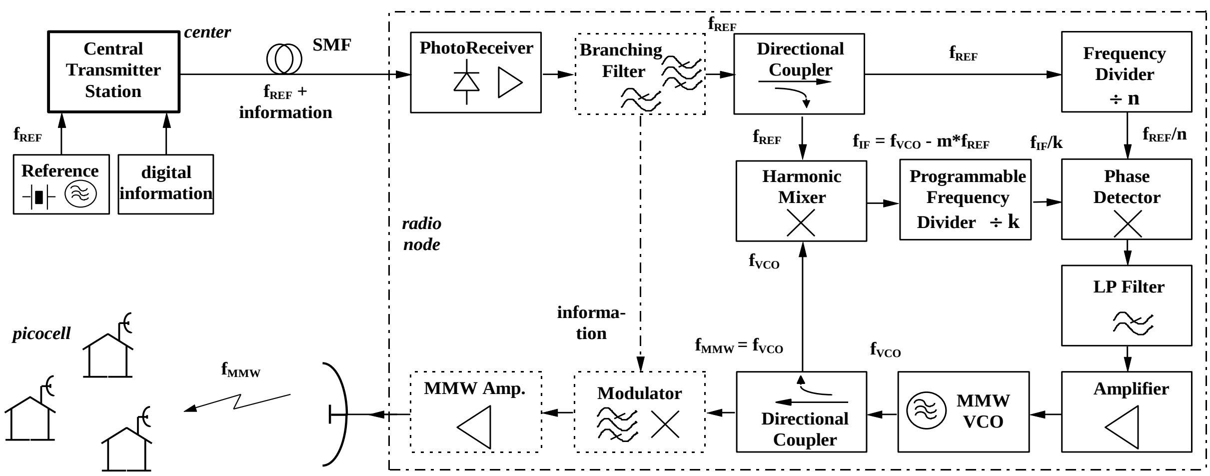

Figure 4. Block diagram of MMW carrier generation using optically transmitted reference