A HIGH PERFORMANCE, 318 GHz SUBHARMONIC (x3) BALANCED MIXER

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ABSTRACT

The 300-3000 GHz sub-millimeter-wave (SMMW) spectrum offers ample opportunities for space-borne remote sensing, as reflected in a partial list of US and European planned space missions—for example, SWAS, MLS, MIRO. Because of these opportunities, the current shortfalls of SMMW receiver technology underscore the need for its further advancement.

Mixer technology leads the way in facilitating SMMW receiver—consistently exhibiting earlier availability and faster maturity—relative to the necessary solid-state local-oscillators (LO), and desirable low-noise amplifiers SMMW technologies. Such an uneven rate of progress has created technology "gaps" in which SMMW receivers often fall victim.

This paper describes the developments of a new class of high performance, higher order subharmonic (>x2) mixers uniquely suitable to accommodate the present underdeveloped state of SMMW LO technology.

I. INTRODUCTION

The 300-3000 GHz sub-millimeter-wave (SMMW) spectrum offers ample opportunities for space-borne remote sensing, as reflected in a partial list of US and European planned space missions—for example, SWAS, MLS, MIRO. Because of these opportunities, the current shortfalls of SMMW receiver technology underscore the need for its further advancement.

Mixer technology leads the way in facilitating SMMW receiver—consistently exhibiting earlier availability and faster maturity—relative to the necessary solid-state local-oscillators (LO), and desirable low-noise amplifiers SMMW technologies. Such an uneven rate of progress has created technology "gaps" in which SMMW receivers often fall victim.

This paper describes a new class of high performance, higher order subharmonic (>x2) balanced mixers, uniquely suitable to accommodate the present underdeveloped state of LO technology for SMMW receiver.

Subharmonic (x2) mixers, employing readily available up to 150 GHz Gunn LOs, have successfully facilitated space-borne low-noise receivers throughout the 30-300 GHz MMW spectrum [1]. But, similar subharmonic (x2) mixers [2] let alone fundamental mixers [3], implemented at SMMW frequencies, presently require Gunn-based LO assemblies, which include efficiency challenged frequency multipliers, or bulky and/or reliability challenged laser based LOs.

Harmonic (xN) mixers with N>2 constitute an immediate bridge for matching available up to 150 GHz Gunn LOs, for 450 GHz receivers (harmonic x3 mixers) and for 600 GHz receivers (harmonic x4 mixers). Furthermore, with a frequency doubler [4] following the LO such harmonic (>x2) mixers may facilitate SMMW receivers well above 1 THz.

Unfortunately, harmonic (>x2) single-ended mixers exhibit rapid degradation in conversion-loss and noise-figure performance, and present formidable challenges matching to broadband IF amplifiers [5].

This paper describes a new class of even-subharmonic (x(2N+1)) balanced two-diode mixers, featuring performance advantages in comparison with single-diode subharmonic (xM) mixers (for M=2N+1) at similar SMMW frequencies.

The paper reports the performance of a 318 GHz subharmonic (x3) balanced mixer prototype which had been integrated with a 106 GHz LO and an IF amplifier to yield a SMMW receiver. This 318 GHz receiver yields promising performance when tested at narrow-band or wide-band outputs.

II. MIXER DESCRIPTION

Two mixer diodes connected to a mixer ports as shown in Figure 1—in series to RF port, and in anti-parallel to the LO and IF ports—constitute a balanced mixer configuration. We have implemented this mixer configuration, as a SMMW waveguide structure with RF (WR-2) and LO (WR-6) waveguides, and a pairs of whiskerless mixer diodes (University of Virginia) on a suspended printed circuit at the IF mixer port. The feedhorn at the RF port is implemented as an integral part of the mixer structure.

The output current (I) of this mixer generally consists of the following series of low-frequency (IF) current components (i):

$$I_{IF}(\omega) \propto \Sigma_N \, i_{(2N+1)} \cdot \{\cos[((2N+1)\cdot\omega_{LO}t)-(\omega_{RF}t)]\}$$

For N=0, this expression depicts the well known fundamental balanced mixer, but for N>0, the same expression highlights a family of odd-subharmonic balanced mixers. Filters at the RF port of the mixer determine the accessible external inputs, the relevant LO harmonic N, and the mixer's output (to the exclusion of other possible outputs).

A paper by Schuppert [6] provides a comprehensive account for the advantages offered by such subharmonic (x3) balanced mixers, in comparison to a single ended harmonic (x3) mixers. Among the most notable advantages are: a lower mixer IF impedance facilitated by two diodes in parallel, easier matched to IF amplifiers over wide frequency bands; better conversion-loss, due to the exclusion of all even subharmonic mixing by virtue of symmetry (not filters); and simpler mixer RF circuitry, facilitated by two diode in series, easier matched to a waveguide with height closer to standard.

III. MEASURED DATA

The 318 GHz receiver had been tuned and tested over a variety of wide-band IF outputs: with an instantaneous 2-8 GHz IF output (IF amplifier with ~2 dB noise-figure) the receiver features an average DSB noise-figure of 12.2 dB (Figure 3); and with an instantaneous 6-16 GHz output (IF amplifier with ~2 dB noise-figure) the receiver yields an average DSB noise-figure of 13 dB (Figure 4). Each one of these two different wide-band receivers represents a mixer with waveguide back-shorts set at different positions. As a narrow band 318 GHz receiver with an instantaneous IF output of 7-8 GHz (IF amplifier with ~2 dB noise-figure) the receiver yields 11.5-12 dB DSB noise-figure, with waveguide back-shorts set for optimum performance with this IF amplifier.

In all tested 318 GHz receiver configurations the 106 GHz LO power requirements ranged a modest $+7\pm1$ dBm, as depicted in Figure 5 for the case of a narrow band receiver.

IV. ACKNOWLEDGEMENTS

The author would like to acknowledge the contributions of Mrs. Cynthia A. Schnitzer for testing the receiver and Mrs. Cuc Nguyen for assembling the mixer.

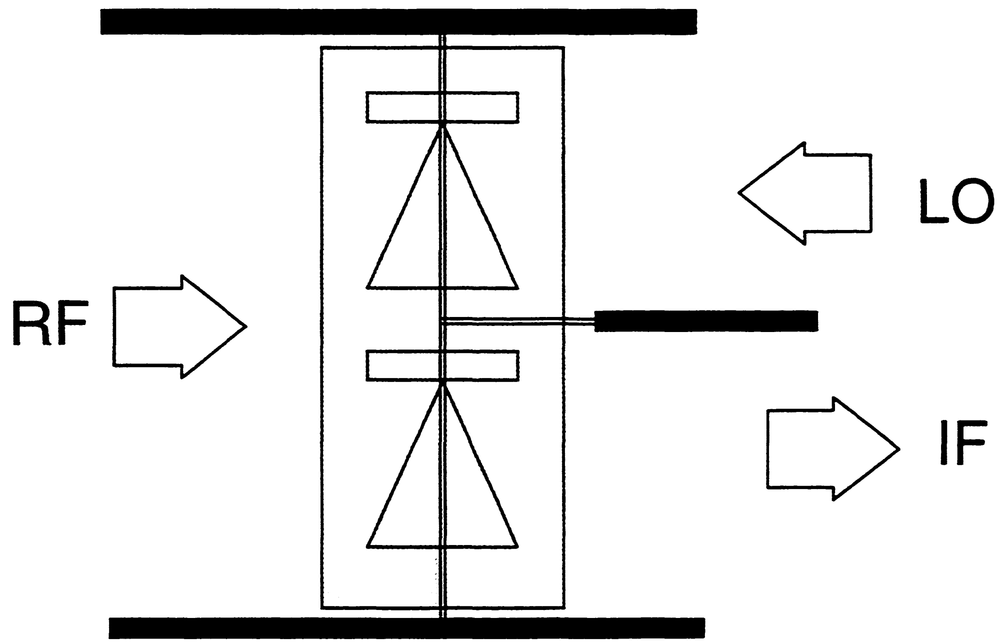

Figure 1. The Electrical Equivalent Circuit For Odd-Subharmonic (x(2N+1)) Balanced Mixers (Diodes in Series to RF, And in Anti-Parallel to LO And IF Mixer Ports)

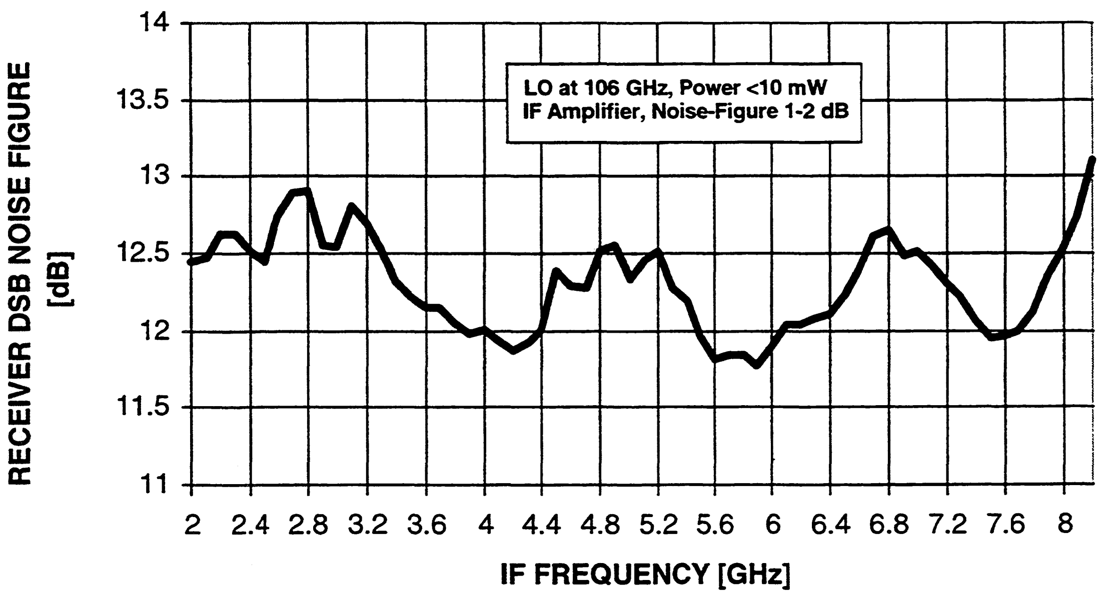

Figure 2. Measured Performance of a 318±8 GHz Wide Band Receiver, with a Subharmonic (x3) Balanced Mixer

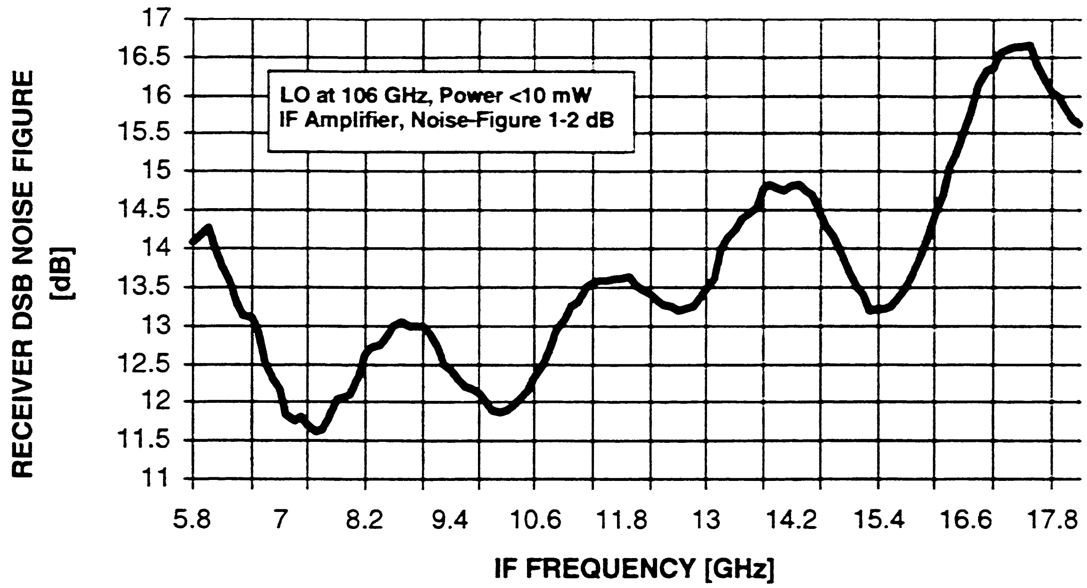

Figure 3. Measured Performance of a 318±18 GHz Wide Band Receiver, with a Subharmonic (x3) Balanced Mixer

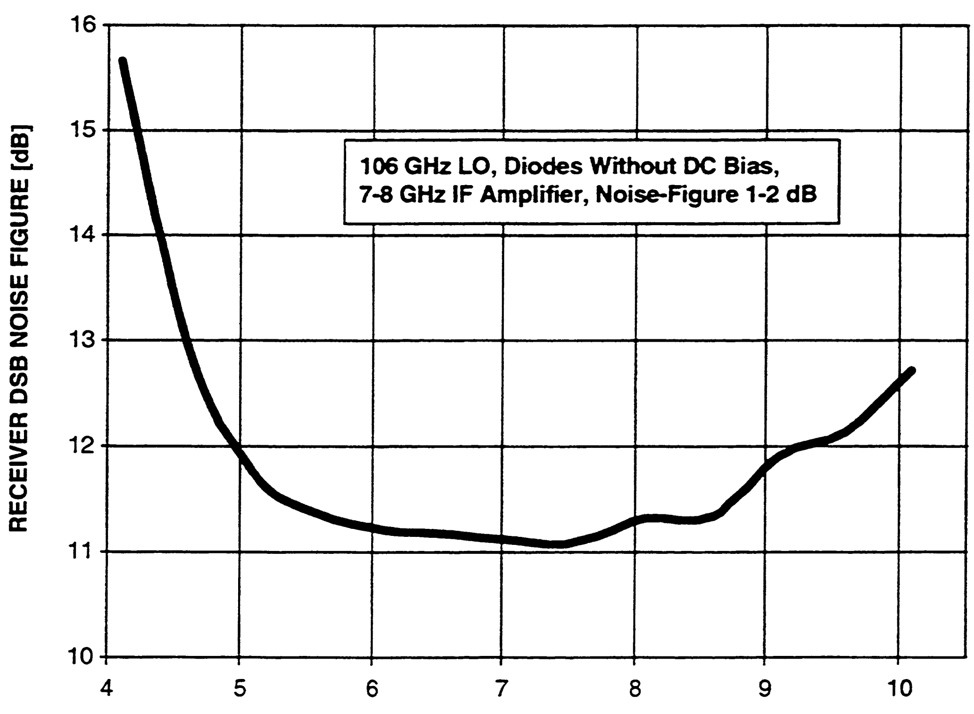

Figure 4. 106 GHz LO Power Requirements for the 318 GHz Narrow Band Receiver, with a Subharmonic (x3) Balanced Mixer, Requiring Low LO Power Drive

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