Abstract—Heterodyne receivers at millimeter and sub-
millimeter wavelength are widely used for radiometric spectral
line observations for atmospheric remote sensing or radio
astronomy. The quantitative analysis of such observations
requires an accurate knowledge of the mixers’s sideband ratio.
In addition, its potential sensitivity to spurious harmonics needs
to be well understood. In this paper, we discuss a measurement
technique for these receiver characteristics, which is based on a
scanning Martin Puplett Interferometer used in conjunction with
a wide band digital autocorrelation spectrometer for the analysis
of the intermediate frequency band. We present measurement
results of different double sideband and sideband separating
mixers, which were developed for the proposed 340GHz multi-
beam limb sounder STEAMR.

I. INTRODUCTION

The Stratosphere Troposphere Exchange and Climate
Monitor Radiometer (STEAMR) is a Swedish multi-beam
limb sounder for the proposed ESA Earth Explorer
Mission PREMIER. Its scientific objectives are to study
chemical, dynamic and radiative processes in the upper
troposphere and lower stratosphere (UTLS) region with
unprecedented spatial and temporal resolution. STEAMR
includes fourteen sub-harmonically pumped heterodyne
mixers, each of them covering two 12 GHz wide sidebands
between 324-336 and 343-355 GHz. The baseline design uses
double side band (DSB) mixers with integrated low noise
amplifiers [2]. As an alternative option also sideband
separating (2SB) mixers have been investigated [3]. For the
quantitative analysis of the observed spectral lines it is
essential to know the sideband ratio of the DSB mixers and the
image rejection of the 2SB mixers accurately. In general these
characteristics will be frequency dependent. Additionally the
receivers can be also susceptible to spurious harmonic mixing
products from other than the two desired sidebands.

II. MEASUREMENT SETUP

The Frequency response of different DSB and 2SB mixer
prototypes of STEAMR has been determined with a scanning
Martin Puplett Interferometer (MPI). This polarizing dual-
beam interferometer consists of three wire grid polarizers, a
fixed rooftop reflector, and a second rooftop reflector mounted
on a motorized translation stage. After the MPI a rotating
mirror is used to switch between an ambient temperature and a
liquid nitrogen blackbody calibration target. From the
oscillations of the ratio hot/cold (“Y-Factor”) with varying
path length difference in the two interferometer arms the
frequency response of the mixer can be calculated with a
Fourier transformation. Similar setups for sideband response
measurements are already described in the literature, but
usually they use a single power detector with relative wide
bandwidth at the intermediate frequency (IF) port of the mixer
[4]. Our setup uses a prototype of the STEAMR digital
autocorrelation spectrometer [5], which resolves a bandwidth
of 6.6 GHz with 256 channels. This allows a more detailed
two dimensional Fourier transform of the interferogram,
which results in a much higher frequency resolution and
reveals more details on the variability of the sideband
response.

Figure 1 shows the schematic test setup with the scanning
MPI interferometer and the receiver chain. The mixers under
test were either a DSB mixer Omnisys Instr. or different
versions of the 2SB mixers from Rutherford Appleton
Laboratory. The subharmonic Local Oscillator (LO) was
generated with a synthesized signal generator operating
between $f_s = 13.5$ and 14.5 GHz followed by an active
multiplier chain. Spurious harmonics of this LO will also
contribute to the mixing products and can lead to a spurious
response of the mixer under test. The Intermediate Frequency
(IF) band of $4 – 15$ GHz is amplified with an LNA and
analyzed with the autocorrelation spectrometer which can be
centered in different parts of the IF band.

Fig. 1. Interferogram with a 340GHz DSB mixer using a single 25MHz wide
channel of the digital autocorrelation spectrometer.
III. DATA ANALYSIS

Figure 2 shows a typical interference pattern with the 340 GHz DSB mixer for a single 25 MHz wide channel of the autocorrelation spectrometer. For a first approximation of the sideband ratio between the Upper (USB) and Lower Side Band (LSB) the beating fringes can be fitted with two cosine functions of a periodicity corresponding to the LO and IF frequencies. The amplitude and phase of the two cosines is derived using a linear least squares fit algorithm. The ratio of the amplitudes corresponds to the sideband ratio, whereas the fitted phase is only needed to compensate the uncertainty of the zero path length position.

The analysis can be easily extended towards higher order harmonics and other spurious signals. For that purpose additional cosine functions are added to the fitting matrix. The period of the dominant harmonics is derived from a Fast Fourier Transform (FFT) analysis of the two dimensional data set (position z and IF frequency) for a given LO setting. An example for the DSB mixer is given in Fig. 3.

Fig. 2. Interferogram with a 340 GHz DSB mixer using a single 25MHz wide channel of the digital autocorrelation spectrometer.

IV. RESULTS

Figure 4 gives an example of the fitted sideband response of the DSB mixer. The fast periodic ripple on the blue trace is an artifact due to standing waves in the test setup. The main reasons for these standing waves are reflections at the liquid nitrogen surface in the cold target, as well as alignment errors and other imperfections of the MPI. The black line in Fig. 4 is a moving average and represents the sideband response of the mixer. For a given LO frequency the sideband response varies significantly over the IF band. Repeated measurements at different LO frequencies showed that the results depend highly on the selected RF bands.

Similar measurements were performed with the 2SB mixer prototypes. In this case it was possible to compare the MPI results with active sideband response measurements using a coherent sub-millimeter wave source. This setup has a higher dynamic range, but it does not allow a straightforward analysis of the harmonic response. Further details on the different sideband measurement methods and a validation of the test results with atmospheric observations are given in [6].

Fig. 4. Fitted sideband response of the DSB mixer prototype at an LO frequency of 336 GHz.

V. DISCUSSION

The presented MPI test method allowed to determine the frequency dependent sideband response of DSB and 2SB mixers and showed that it can vary substantially over the IF bandwidth. The science requirements of STEAMR and similar remote sensing missions aim for a sideband ratio knowledge with a relative accuracy of 0.1%. Although the presented test method is close to meet this requirement, further investigations on the effects of standing waves and spurious harmonics are needed.

REFERENCES