Improvement in 1.2 Hz Total Power Instability of KVN 129 GHz SIS Mixer Receiver

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Abstract— **We present works for improvement on IF total power instability of Korean VLBI network 129 GHz SIS mixer receiver. To reduce the fractional power instability to 10^{-4}in 1 second integration, which has been set up as the specification ofpower instability in case of a receiver having an SIS mixer. In our 129 GHz SIS mixer receiver, we sometimes suffered from much larger power (~10^{-2}) instability at 1.2 Hz that typically hampered normal pointing and continuum observations in single-dish observations. To improve this instability, vibration-isolation mechanism for the cold head of the receiver was applied but it was proved not influential. Indeed, we found that the spectrum of power instability just follows cold LNA's1/f noise floor well when the LNA was terminated with 50 ohm loadshowing no trace of the discrete 1.2 Hz peak. After confirming 1.2 Hz instability due mainly to gain change of the mixers itself by temperature fluctuations of the cooling system we measured the instability variation by adjusting mixer bias voltages. Further reduction is planned with mixer temperature varied using a PID temperature controller.**

INTRODUCTION

Possible mechanisms of output power instability that have been so far suspected in the technical literatures can be listed as follows:

- temperature modulation of the SIS mixer and low noise amplifier
- acoustic noise pickup by the LNA and the local oscillator causing direct gain change or variation of LO pumping power to the SIS mixer
- microphonic noise pickupat critical bias wires from motor vibrations of a cryocooler
- SIS mixer bias noise and ineffective suppression of the Josephson effect
- LNA gain fluctuations of the cryogenic low noise amplifier and bias noise

From the beginning of the deployment, 129 GHz SIS mixer receivers on three telescopes of Korean VLBI Network have showed IF total power instability with 1.2 Hz period. Because 1.2 Hz period manifests itself that the origin of the instability has certainly connection with the 4 K cryocooler driven at 60 Hz AC power supply, we can, at least, rule out the last two cases as direct origins of this instability.

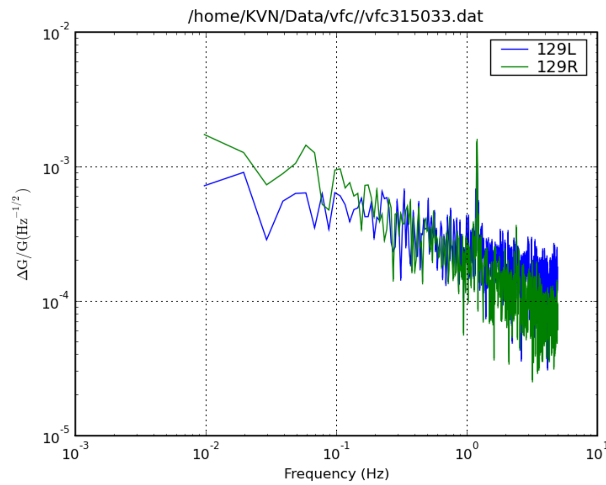

Fig. 1A spectrum of 1.2 Hz fractional power instability typically shown at nominal mixer and LNA bias settings(operation temperature~ 4.7 K)of circular-polarization KVN 129 GHz receiver

Fig. 1 shows a typical spectrum of IF power output normalized to its DC component with a distinct (~10^{-2}) peak at 1.2 Hz as well as 1/f-like noise floor. In general, this kind of instability among receivers are totally uncorrelated in interferometric observations but causes degraded antenna pointing and calibration observationsin single-dish mode. We report how the origin of this instability had been tracedand discuss the direction and implication for future improvement.

VIBRATION ISOLATION

Bias wires of the receiver are wrapped along two G10 supports that separate thermal stages in the receiver cartridge. Wires of constantan span almost one meter and so are intrinsically vulnerable to microphonic noises from vibration. To isolate the vibration from the rotating motor of the coldhead as well as shocks from helium flow, coldhead mount has been changed to one that has shock-absorbing gel mounts and a short cylindrical bellows. Thermal links to the 50 K radiation shield that is secured onto the front lid of the receiver chamber has changed to several flexible OFHC straps. No precise measurement of mechanical accelerations exerted to the thermal stages of the cartridge were taken but it was confirmed that vibration transferred to the receiver chamber was quite reduced. Nonetheless, this vibration isolation was not effective in reducing power instability implying that other mechanisms are under playing.

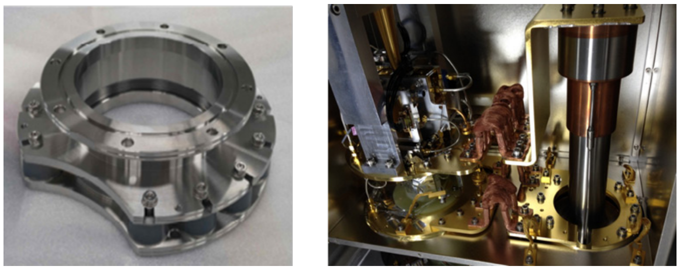

Fig. 2coldhead mount with shock-absorbing gels and bellows (left), thermal connections of the cold finger inside the receiver chamber (right)

POSSIBLE LNA EFFECTS ON STABILITY

The cryogenic LNAs used in the receiver are CaltechWeinreb group'sCITRYO4-12A using DC power supplies from the original manufacturer. If there would be gain instability due to LNA bias changes, those relevant biases can be servoed. However, in our case, servoing is not readily feasible because the MMIC in the LNA has the drains of all 3 stages connected together.

From communications with Weinreb, gain sensitivity of the LNAto gate voltage change is known to be about 0.3 dB/100 mV i.e. 0.06% / 1mV. Thus for 10^{-2} gain change would need 1.6 mVvoltage change, say, ground difference. Drain voltage sensitivity is designed to be less. Furthermoresince the gate has 11:1 voltage divider in the module 1.6 mV gate voltage would need the gate supply change of 17.6 mV, which is unlikely in our case.

Another possible case may be temperature fluctuation of the LNA. About 1 K of the LNA noise is known due to losses in the input circuit and the MMIC at 15 K. If the instability would originate from this input loss of 1.06, required temperature fluctuation causing 10^{-3} gain change might range as high as 6 K assuming 400 K average input noise. Typical temperature fluctuation at the bare cold finger of 4 K GM cryocooler RDK-415DP is about $\pm$ 50 mK.Therefore we need to find other sources in order to explain the measured fractional instability.

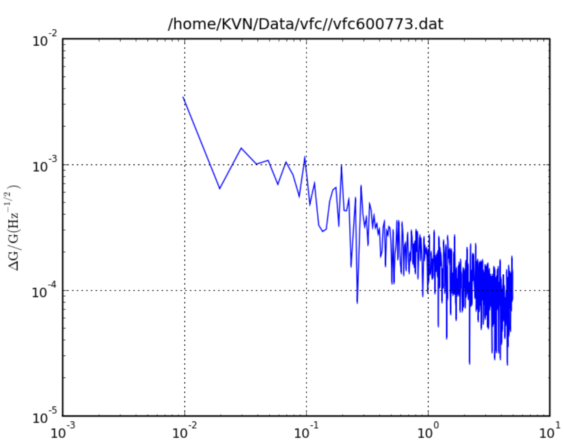

Fig. 3power spectrum of fractional power instabilitymeasured with cold LNA disconnected from the output of the SIS mixers

MIXER GAIN MODULATED WITH TEMPERATURE CHANGE

After some efforts in vain, we measured the spectrum of the output power with only cryogenic LNA terminated with coaxial load disconnecting the SIS mixer from its input. Fig. 3 shows the spectrum in which the 1.2 Hz peak disappears. This finding is implying that the SIS mixer itself causes the power instability. For more detail, correlation between the temperature fluctuation of the mixer block and fluctuation of the output power was investigated. Upper plot in Fig. 4 shows time series data that roughly reflects higher total output power as temperature goes lower and vice versa.

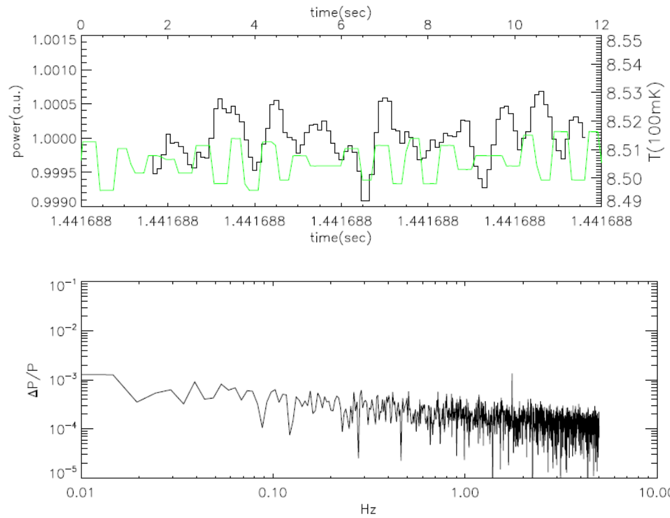

Fig. 4Co-measured power stability(black) and temperature variation of the mixer blocks(green, right axis, in 100 mK unit omitting common 4 K) in the upper plot and power spectrum of the fractional gain(bottom).

Important observation in Fig. 4 is that with only 2 mK p-p temperature variation 10^{-3} power fluctuation results. Fig. 5 shows order-of-magnitude reduction of the peak fractional instability values by adjusting mixer gain with different bias settings than normal.

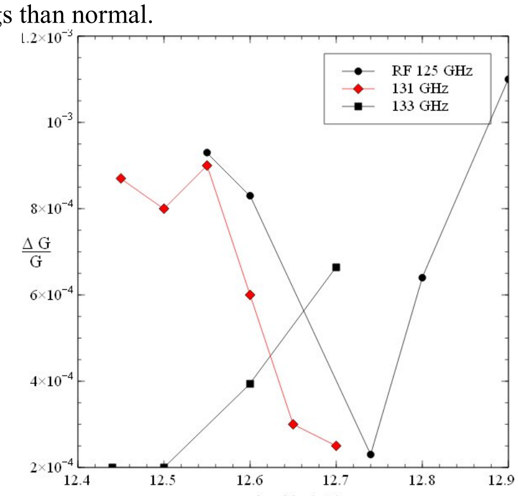

Fig. 5Suppression of 1.2 Hz peak by changing mixer bias voltage to point of lower sensitivity at different LO frequencies (KVN Seoul station)

One previous study[1] reports that given fractional stability of 10^{-4}, typical optimum mixer bias voltage does not guarantee more relaxed temperature modulation, mainly becausemixer's conversion gain varies most sensitively near this bias. But temperature modulation range can be more relaxed at lower-than-optimum bias voltage. The measurements in Fig. 5 show similar trend.

FURTHER REDUCTION OF INSTABILITY

It's not certain that PID controlling will work in stabilizing operation temperature at mixers' location in the receiver cartridge with less than 2 mK p-p resolution. In addition, extensive tests using automated bias sweeping setup is planned during annual maintenance period starting from June.

CONCLUSIONS

We have tracked possible origins of 1.2 Hz total power instability in KVN 129 GHz SIS mixer receiver. Finding the fluctuation due mainly to temperature modulation of the conversion gain of the SIS mixers, we reduced gain change and power instability by lowering bias voltage of the mixers. Test for further reduction is planned using a PID temperature controller.

ACKNOWLEDGMENT

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