THE RESULTS OF TEST OBSERVATIONS WITH 15.6-KHZ FREQUENCY-RESOLUTION 2-GHZ BANDWIDTH FX CORRELATOR SYSTEM

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ABSTRACT

We have carried out the observation with a 2048-MHz 131072-channel FX type correlator system that is the test system of ALMA Second-Generation Correlator and Nobeyama Millimeter Array (NMA). We have successfully detected the first wideband and high-resolution fringe spectrum of Orion-KL IRc2 region and identified more than ten molecular lines and continuum emission simultaneously. This correlator system will be a powerful tools of millimeter and submillimeter astronomy.

INTRODUCTION

We have examined about high-dispersion spectro-correlator for Atacama Large Millimeter/Submillimeter Array (ALMA second-generation correlator) in collaboration with ALMA European correlator team. The ALMA Scientific Advisory Committee (ASAC) recommends that the ALMA second-generation correlator has the highest spectral resolution of 5 kHz and the maximum bandwidth of 2-GHz bandwidth at one IF band with the data sampling frequency of 4 GHz and 3-bit correlation calculation. Thus we Japanese propose a high-performance FX correlator system that always realizes both super-high spectral-resolution (<0.1 km/s at 40 GHz) and wide-band (> 700 km/s at 850 GHz) observations simultaneously up to 850 GHz for each 2-GHz baseband (IF) of the ALMA system.

The test FX correlator system consists of two sets of 4-Gsps 2-bit ADC with GaAs sampling ICs and a test FX-type correlator for the pre-prototype of the high-dispersion ALMA correlator [1]. In the ADCs, input analog signal is sampled with 4096MHz clock using GaAs Decision (sample-hold) chips, and the digital signal is de-multiplexed with 1:16 and 1:4. Three sets of GaAs Decision and 1:16 DMUX chips are installed to make 2-bit resolution. The test FX correlator consists of two Fourier-transform parts and one correlation part, and calculates one cross-correlation spectrum or one auto-correlation spectrum of 131072 (= 128 x 1024) frequency channels over the 2-GHz bandwidth. We have repeated improvement of the ADC and the FX correlator system with the input signal from noise generator in the latter of 2001. First we checked only the ADCs using the Ultra-Wide Band Correlator (UWBC) of the Nobeyama Millimeter Array (NMA) [2], and the ADCs have functioned well. Then the test FX correlator has been connected with ADCs and started the measurements of wide-band spectral performance. As a result of several adjustments, its performance becomes nearly adequate to be used in astronomical observations.

OBSERVATION

From December 2001 to March 2002, we made test observations of the FX correlator system with two sets of antenna and IF transmitter system of the NMA(Fig.1). We have made the simultaneous observations with

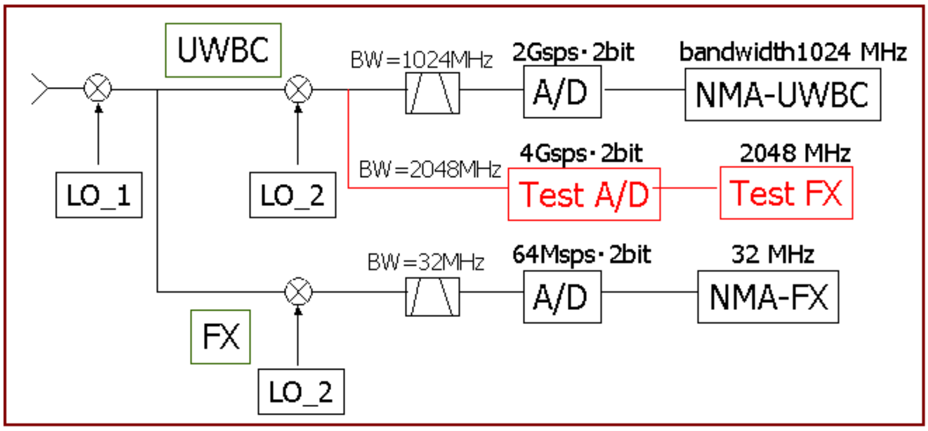

Fig.1 The observation system with NMA for the performance investigation of test FX correlator.

NMA FX and the test FX correlator. We used the minimum baseline pair of antenna in the D and C-array of the NMA. 2GHz-bandwidth IF signals with 90- and 180-degree phase modulation are put into the 4-Gsps ADCs, after sampled, the data are sent to the test FX correlator. Then the FX correlator calculates cross-correlation with 90- and 180-degree phase demodulation, and we can obtain one cross-power spectrum. We used only LSB in the observation. We still have spurious feature every 256MHz (16384ch) in the 2-GHz bandwidth. It is produced in the ADC, so we must improve this problem. In this observations, we have removed the spurious by deconvolution software. Moreover, the ADCs have not been adjusted as a 2-bit ADC and their performance is 1-bit ones(the maximum quantization efficiency 64%) at that moment. Thus we have to adjust the circuit setting the bias voltage and to make the ADCs 2-bit ones (the maximum quantization efficiency 88%).

First we made 86GHz continuum observations of MARS and quasars such as 3C279, 3C273, and 0355+508. We succeed the fringe detection of the continuum emission. The observations of Orion-KL region centered on IRc2 were carried in the center frequency of 86.153452 GHz over the 2-GHz bandwidth. 3C279 was also observed about an hour for the passband and flux calibration. We observed Orion-KL region about 2 hours with B and F antenna and IF transmitter systems at C-array of NMA (baseline length is about 34m).

THE RESULTS OF ORION-KL OBSERVATIONS

An overall 2048-MHz 131072-channel fringe spectrum of Orion-KL IRc2 region is shown in the center of Fig. 2. We can identify more than ten molecular and ionic line emissions, and some of the close-up spectra are also presented in Fig.2. This is very unique and new correlator system to have wideband and high-resolution enough to get such many line profiles one time observation. Moreover, we can find continuum emission from IRc2 region when we bunch several channels of observation data and get the spectrum.

SiO(J=2-1,v=1)maser which is strong and compact is associated with IRc2 and is connected with the extended and weaker v=0 maser emission. IRc2 is the center of these SiO maser outflows coincide with the radio continuum source I. SiO (J=2-1,v=1) line profile in this observation is a little different from past observation [3] because of time variability, but is dominated by two bright features. Besides we also detected weak maser features shown in Wright et al. 1995 in our SiO(J=2-1, v=1) spectrum. These features originate from inside the main maser ring. ^{29}SiO(J=2-1,v=0) emission, which is the isotope of SiO, is distributed along two ridges of positive and negative velocities as for SiO(J=2-1, v=1)[4].

In SO(2(2)-1(1)) line profile, we find expanding ring or “doughnut” of gas. Plambeck et al. (1982) modeled the expanding “doughnut” centered on IRc2. SO traces prominent hot core and compact ridge and extend farther toward the north dust peak [5]. H^{13}CN emission follows the dust emission closely. In H^{13}CN emission, the ridge, hot core, and compact ridge components are all identified. The peak of

CH_3OH(6(-2)-7(-1)E) is in the region where the outflow from Orion-KL impacts the southwest edge of the CS1 condensation. OCS(7-6) emission peak is south of the hot core and western clump and no OCS emission is detected at the northern dust peak. It is thought to be a mixture of compact ridge and hot core components.

Fig.3. shows the spectrum of SiO (J=2-1, v=1;rest frequency 86.243442 GHz) maser with the test FX correlator system and with NMA FX correlator. Resolution for testFX correlator system is about 15.6kHz and about 31.2MHz for NMA FX correlator. The cross-power spectrum with the test FX correlator agrees well with that simultaneously obtained with 32MHz bandwidth (1024ch) FX correlator of the NMA. That means the test FX correlator system is enough to use observations though they still need many improvement. Such a wide-band and high-resolution spectrum enables us to determine the relative intensities of all the detected lines at one-time observation and calibration.

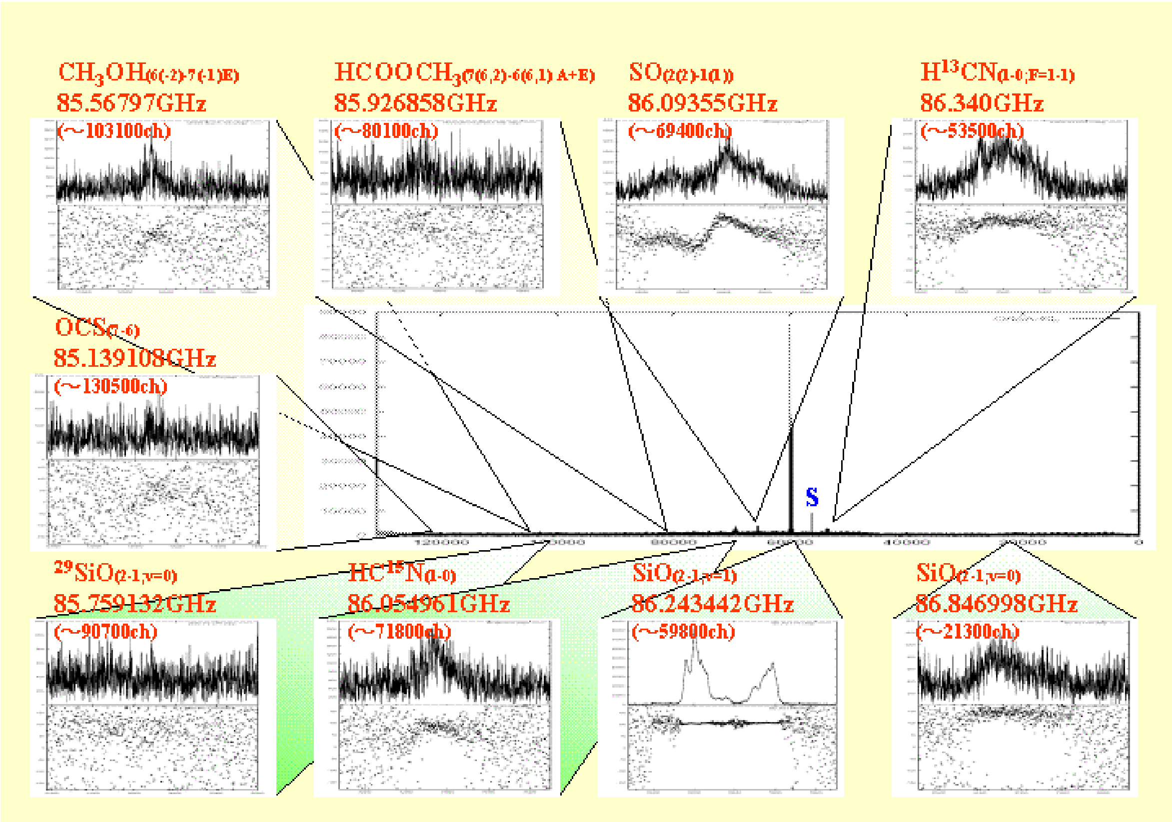

Fig.2. Spectrum from Orion-KL IRc2 regions. Center spectrum is an overall fringe spectrum (2048-MHz bandwidth, 131072-channel). X-axis is inverted to correct frequency channel for LSB observation. “s” in the center spectrum means spurious. There are more than ten lines in the 2048-MHz bandwidth spectrum. Examples of molecular line spectra we detected are around overall spectrum. They are showed 1024-channel near the molecular lines. Other lines without this figure are much more weak.

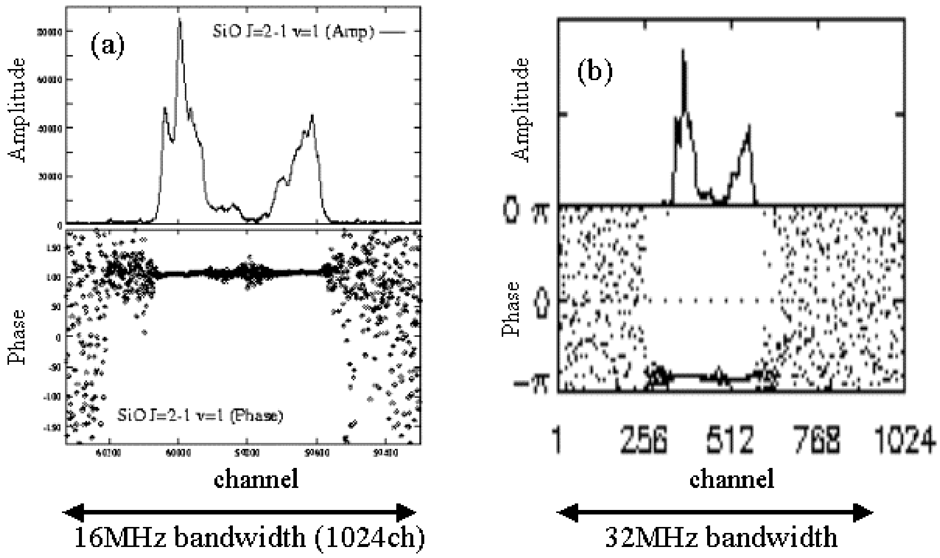

Fig.3. Comparison of SiO (J=2-1, v=1) maser between the test FX correlator and NMA FX correlator. (a) SiO(J=2-1,v=1) maser profile with test FX correlator system. Only 1024channel (16MHz) near the line is picked out. One channel is equal about 15.6kHz. (b) SiO(J=2-1,v=1) maser profile with FX correlator of the NMA, which has 32MHz-bandwidth, 1024-channel.

REFERENCES

[1] Okumura, S. K., Chikada. Y., Momose, M., and Iguchi, S. ALMA Memo 350, February 2001

[2] Okumura S. K., Momose M., Kawaguchi N., Kanzawa T., Tsutsumi T., Tanaka A., Ichikawa T., Suzuki T., Ozeki K., Natori K., and Hashimoto T., 2000, PASJ, 52, 393

[3] Wright, M. C. H., Plambeck, R. L., Mundy, L. G., and Looney, L. W. 1995, ApJ, 455, L185

[4] Baudry, A., Herpin, F., and Lucas, R. 1998, A&A, 335, 654

[5] Wright, M. C. H., Plambeck, R., L., and Wilner, D., J. 1996, ApJ, 469, 216