(min)	Time (UT)	title	abstract	speaker	band	type
Day 1: Introduction						
25	11:00	Preparing ALMA for the next decade and beyond	ALMA continues to provide dramatic views into our cosmic origins and yet has the opportunity to capitalize on the technological developments over the two decades since its initial design to provide deeper, clearer, and more profound insights. Having defined its upgrade path for the next decade and beyond, ALMA is in the midst of finalizing the updated system and subsystem specifications for the Wideband ALMA 2030 Sensitivity Upgrade. I will describe the fundamental goals and their motivation as well as describe the critical role that updated front ends will play in the overall upgrade plan. In the end I will outline the timeline and path toward the upgrade, highlighting the challenges and opportunities that will be presented along the way.	Stuartt Corder	programmatic	invited
25	11:25	The ALMA Frontend		Giorgio Siringo	programmatic	invited
25	11:50	The ALMA Signal Chain Working Group: bridging the gap between Frontends and Correlator for ALMA 2030	The ALMA Signal Chain Working Group has been established by the ALMA Management Team to assess the requirements for bringing the astronomical signal from the Frontends inside the ALMA antennas to the central 2nd Gen Correlator. This assessment shall be done from a system point of view and take into consideration also matters like support infrastructure and operations. The, still preliminary, findings by the SCWG will be summarized on this occasion.	Gie Han Tan	programmatic	invited
15	12:15	Sensitivity and a Wideband Metric for ALMA	In this talk I will present a few overview notes on the kinds of sensitivity and imaging speed improvements in the front end receivers we can expect or hope for.	Tony Mroczkowski	programmatic	contributed
30	12:30	**Discussion (lead: John Carpenter)**		John Carpenter		
120						

(min)	Time (UT)	title	abstract	speaker	band	type
Day 2.1: Receiver optics						
5	11:00	Antenna losses and efficiency - 'hidden' contributions to system sensitivity	Significant effort is being put into obtaining the lowest receiver noise performance (Trx) for the ALMA bands. However, there are additional factors which will contribute to the system sensitivities. With the low Trx in the lower ALMA bands, additional components such as forward efficiency and ohmic losses (eta_tel) can have a non-negligible contribution to the system temperature. In the higher bands, antenna efficiency (eta_mb) can be significantly lower, due to losses from surface imperfections in the dish and optics. The results are presented of recent measurements of these effects in the ALMA system. (1) Skydips were used to estimate eta_tel, along with some measurements of Tsys in very high sky transparency conditions (with pwv<0.2mm). (2) Single-dish brightness temperature measurements of planets of known brightness (mostly Uranus) were used to estimate eta_mb and hence the antenna surface rms accuracy based on the Ruze formula. The discrepancy between these measurements and the surface astroholography results are briefly discussed.	Bill Dent	programmatic	contributed
5	11:05	Development of complex permittivity measurement system	Since errors in the permittivity properties of optical materials have a significant impact on the performance of receiver systems, an accurate understanding of the complex permittivity by actual measurement is essential for the design of optical systems. NAOJ has been promoting the development of a millimeter-wave band complex permittivity measurement system to improve the design accuracy of receiver optics. We have adopted two measurement methods, free-space method (FS) and Fabry-Perot resonator method (FPOR). Using the developed system, we measured the dielectric constant and dielectric loss tangent of low-loss polymer materials. The dielectric constant values obtained by both methods were in good agreement, demonstrating the validity of the developed system. It was also demonstrated that the dielectric loss tangent can be measured in the order of 10^-4 by using the FPOR.	Ryo Sakai		contributed
5	11:10	Development of receiver optics components using AM technology	NAOJ is performing R&D studies related to additive manufacturing (AM) technologies based on metal 3D printing. This technology is evolving day by day in the world, both instruments and methods, and is used for diverse industries, e.g., aerospace, medical, automotive, ISS. Benefits of AM are rapid prototyping, design optimization with topology methods, cost and lead time reductions. We have focused this research on the development of receiver optics component, especially the ALMA Band1 corrugated horn. Through these studies, we have also learned some practical disadvantages of additive manufacturing, which need to be compensated by other existing technologies. In addition, the material/physical properties of components produced by AM should be checked carefully because they may change during the manufacturing process and through aging. We will present the current status of this research and would like to discuss the usefulness of AM for the development of future receivers.	Keiko Kaneko	1-2?	invited

5	11:15	Development of silicon vacuum windows	We have been developing vacuum windows for radio astronomy receivers by using high resistivity silicon wafers with anti-reflection (AR) structures. The AR structures were fabricated by forming sub-wavelength structures on the silicon surface using deep reactive ion etching. The AR structure height can be precisely controlled by introducing silicon on insulator (SOI) wafers, because the buried oxide layer of the SOI wafer can stop the device layer silicon etching. We designed and fabricated the silicon vacuum window with double-sided AR structures by bonding two SOI wafers with a double-layer AR structure optimized for use between 600-1100 GHz. The transmission of the fabricated AR structures was measured using terahertz time-domain spectroscopy. In this presentation, we will present the silicon vacuum window fabrication techniques and the characteristics of the transmission of the AR structures.	Shohei Ezaki	9-10	contributed
5	11:20	Development of new optics for a 7-beam receiver in 72-116 GHz band onboard the Nobeyama 45-m telescope	We are developing a new 7-beam heterodyne receiver in 72-116 GHz band for the Nobeyama 45-m telescope in order to understand the early stage of star formation by deuterium fraction. The RF receiver system consists mainly of feed horn, OMT, waveguide type triplexer (72-77, 86-93, and 109-116 GHz), and CLNA. With this system, we can carry out simultaneous observations of various lines such as N2D+, N2H+, and CO, in those frequency bands, efficiently. Optics with the fractional bandwidth of ~50 % is required to achieve the goal. We use corrugated horns with high return loss, low cross-polarization, and symmetry beam pattern in 67-116 GHz band (Gonzalez et al. 2020, SPIE). To make the system simpler and more compact than that with ellipsoidal mirrors, we employed dielectric lens that couples the horn to the telescope optics. In addition, the anti-reflection structures which suppress the reflection in the surface so as not to affect beam shape and noise temperature are being investigated by electromagnetic analysis and experiments.	Yasumasa Yamasaki	2-3	contributed
30	11:30	**Discussion**	Alvaro?	Martina Wiedner		invited
55						
(min)	**Time (UT)**	**title**	**abstract**	**speaker**	**band**	**type**
Day 2.2: Receivers (MMIC/HEMT)						
5	12:00	ALMA Band 1 receiver status	We are presenting the ALMA Band 1 receiver status. It will cover the project management efforts, as well as the production integration/verification and system performance measurement efforts for the first 45 units out of a total of 73 Band 1 production receivers to be delivered to ALMA. The infrastructure, integration, evaluation, and test results of the fully-assembled Band 1 receiver systems will be described.	Yau De(Ted) Huang	1	invited

5	12:05	Band 2 receiver development	We will report on the scientific rational and technical merits of a wideband receiver to be implemented in ALMA Band 2, with the aim to cover an on-sky bandwidth of 67-116 GHz, and a minimum instantaneous IF band of 4-16 GHz in two sidebands. This contribution will focus on the development and optimization phases of the Band 2 project, started in 2012 and resulted in the prototype receiver, which is used as a technology demonstrator and also a test bed for the key elements: vacuum lens, optics, low noise amplifiers, 2SB room temperature receiver. Multiple technical solutions for most of these receiver components have been developed and tested by Band 2 collaboration individually and also as part of the full receiver prototype. We will present results of these developments, trade-offs and selections made for the key technologies, and also final performances of the receiver prototype.	Pavel Yagoubov	2	invited
5	12:10	NRC-HAA Cryogenic Radio Receiver Development	The Radio Instrumentation Team (RIT) team at NRC Herzberg in Victoria, Canada, is developing a dual linear polarization, cryogenic radio astronomy receiver covering the frequency range of 30.5 to 50.5 GHz for the next generation Very Large Array (ngVLA) project. The specification of this receiver development is aligned with ngVLA Band 5 requirements. This receiver is designed for a noise temperature of less than 25 K over the bandwidth. The proposed receiver uses a vacuum vessel and a two-stage cryopump system for a cryogenic environment which provides 16 K and 70 K stages. The proposed receiver consists of a cryostat with a cooled feed horn, a turnstile OMT plus two integrated noise couplers for noise calibration, two mHEMT MMIC cryogenic low noise amplifiers with noise temperature lower than 14 K, IR filters, and a vacuum window to create a low-loss transmission of electromagnetic fields into the cryostat. The RIT team is also working on designing and developing various high-efficiency and wideband feed horns, vacuum windows, and OMTs. So far, a compact, low noise octave band OMT, multiple octave band feed horns, and a vacuum window covering the frequency range of 25-50 GHz have been designed. Most of the waveguide components designed and developed for the ngVLA Band 5 and octave band receiver are scalable to higher and lower frequency bands.	Sara Salem Hesari	1	invited
5	12:15	Cryogenic LNA Development at UoM	The presentation will describe the progress to date of the "ALMA Band 2 Cryogenic RF Low Noise Amplifier" study, towards improving the performance of the LNAs for ALMA Band 2. Work has built on a previous study and has been undertaken mainly to improve the cryogenic performance of the low noise amplifier. LNA designs using the 35nm InP process at Northrop Grumman Corporation (NGC) will be presented including simulations and measured results. The amplifier packaging and transitions will also be described. The presentation will also show some preliminary work on pushing the noise limit for cryogenic LNAs at 125 – 211 GHz and 211 – 373 GHz.	Danielle George	2-7	invited
30	12:20	**Discussion**		Doug Henke		
50						

(min)	Time (UT)	title	abstract	speaker	band	type
Day 3: Receivers (SIS)						
5	11:00	Wideband Technology development for ALMA receiver upgrades at NAOJ	NAOJ have studied wideband receiver technologies at submillimeter wavelengths toward implementation as future upgrades into the ALMA telescope. We have developed critical components and devices such as waveguide components and superconductor-insulator-superconductor (SIS) mixers targeting radio frequencies (RF) in the submillimeter-wave region and an intermediate frequency (IF) bandwidth of 3-22 GHz. Based on the developed components, a preliminary demonstration of a wideband RF/IF sideband-separating SIS mixer was performed. In this talk, our current status of the technology developments for a submillimeter-wave receiver will be presented.	Takafumi Kojima		invited
5	11:05	SIS based mixers development for radio astronomy	Superconductor-insulator-superconductor (SIS) mixers are used in the most sensitive heterodyne receivers for sub-mm and mm waves. SIS mixers are installed on all state of the art sub-mm observatories such as the Atacama Pathfinder Experiment (APEX) and the Atacama Large Millimeter Array (ALMA). While sensitivity of an SIS mixer is quantum limited a current state of the art performance of receiver systems can still be improved. In this report we summarize our development effort to improve SIS mixer performance in several frequency bands that are relevant for the ground based astronomy. We have calculated, fabricated and measured a optimized mixer design for the 211-275 GHz frequency range, which could be used for LLAMA observatory in Argentina, for the Millimetron space mission and additional stations in the VLBI network of the Event Horizon Telescope. For the near future development we consider a 2SB mixer design for the 211-275 GHz which is conceptually close to the successful ALMA Band 9 2SB mixer. A receiver is based on single SIS mixer connected to RF hybrid block. The mixer design was developed using 3D electromagnetic modeling in CST microwave studio. The mixer is based on Nb/AlOx/Nb SIS junction embedded in a Nb/SiO2/Nb microstrip line. A good matching between a 500x1000 µm waveguide and the SIS junction was achieved by using quasi-triangle orthogonal waveguide single-sided or double-sided probes. We improved further our modeling approach for the Band 9 mixers which demonstrated an IF bandwidth of up to 20 GHz. We also optimized a mixer design for 790-950 GHz band. The mixer description and achieved performances will be presented at the conference.	Kirill Rudakov	6	contributed
5	11:10	On Extending the IF Bandwidth of ALMA Band # 6 SIS Mixers	A development goal defined by ASAC is: “Larger bandwidths and better receiver sensitivity: enabling gains in speed”. This broad goal requires careful scrutiny, as for a given SIS mixer extending the IF frequency range from 4-8 GHz (for Band #6 from 5-10 GHz) to 4-12 GHz, 4-16 GHz and ultimately to 4-20 GHz will always result in higher, on the average, receiver noise, reducing the implied benefits. This is because the noise of HEMTs increases proportionally with frequency. A perfect noise match is only possible at discrete frequencies within IF band resulting in larger average noise penalties for wider IF bandwidth. Therefore, a theoretical and experimental study has been undertaken to assess the expected noise penalties for the current design of Band #6 SIS mixer working with 4-12 GHz, 4-16 GHz and 4-20 GHz IF amplifiers. New designs of broadband IF amplifiers covering 4-12 GHz, 4-16 GHz and 4-20 GHz using commercially available devices from Diramics have been developed. The Diramics’ devices deliver state-of-the-art minimum noise temperatures at 15 K ambient that is 2.5 K at 10 GHz and 10 K at 40 GHz. These noise temperatures are also very close to the natural noise temperature limits of InP cryogenic HEMTs. For example, an IF amplifier optimally noise matched with SIS mixer output impedance at 10 GHz would contribute at a minimum about 12.5 K to receiver noise temperature for a mixer with conversion loss of 7 dB (minimum IF noise temperature multiplied by available conversion loss). An IF amplifier optimally noise matched with SIS mixer output impedance at 20 GHz would contribute at least 25 K to receiver noise. The amplifier designs have the same form factor as the IF amplifiers currently in use and therefore can be integrated with the existing Band # 6 SIS mixers. All amplifier designs are to be tested with the same SIS mixer, removing any uncertainties related to the non-repeatable mixer performance. The early experiments indicate that optimal from the noise point of view direct integration of 4-12 GHz amplifier with Band 6 SIS mixer is indeed possible (the current Band 6 SIS mixer is optimally integrated with HEMT amplifier over 5-10 GHz IF bandwidth). For larger IF bandwidths the expected variation of noise temperature of SIS/HEMT amplifier tandem across IF band is too large which favors the use of cryogenic isolators. This large variation is a result of both SIS mixer output impedance and optimal noise impedance of IF amplifiers varying over IF bands. The average noise penalty across the total IF bandwidth is strongly dependent on SIS mixer conversions loss. For the current SIS mixer design and assumed 7 dB conversion loss the average noise penalty across the IF band for 4-16 GHz and 4-20 GHz as compared with 4-12 GHz version, is estimated at 15 K and 30 K, respectively, The early experiments indicate that optimal from the noise point of view direct integration of 4-12 GHz amplifier with Band 6 SIS mixer is indeed possible (the current Band 6 SIS mixer is optimally integrated with HEMT amplifier over 5-10 GHz IF bandwidth). For larger IF bandwidths the expected variation of noise temperature of SIS/HEMT amplifier tandem across IF band is too large which favors the use of cryogenic isolators. This large variation is a result of both SIS mixer output impedance and optimal noise impedance of IF amplifiers varying over IF bands. The average noise penalty across the total IF bandwidth is strongly dependent on SIS mixer conversions loss. For the current SIS mixer design and assumed 7 dB conversion loss the average noise penalty across the IF band for 4-16 GHz and 4-20 GHz as compared with 4-12 GHz version, is estimated at 15 K and 30 K, respectively,	Marian Pospieszalski	6	invited
5	11:15	ALMA Band 6v2 Receiver Upgrade	We report on our proposal to develop an upgrade for the existing 211-275 GHz ALMA Band 6 receiver, referred to as “Band 6v2”, which complies with the strategies defined in the ALMA Development Roadmap to 2030 and with the recommendations of the ALMA Front-end & Digitizer Requirements Upgrade Working Group. The goal is to deliver an improved production-level receiver based on (i) a new Cold Cartridge Assembly (CCA) with increased sensitivity over an expanded IF band and a modestly expanded RF band, and (ii) a new low-noise Warm Cartridge Assembly (WCA) which contains a new lower AM sideband noise Local Oscillator source with a baseband YIG oscillator operating at twice the frequency of the current one. The new Band 6v2 receiver will be backward-compatible with the current Band 6 and will be able to be plugged into the ALMA FE (Front-End) cryostat as a replacement for the existing units. We will describe the current ALMA Band 6 receiver, our plan to address its shortcomings, and the expected performance of the ALMA Band 6v2 receiver. The Band 6 receiver upgrade will result in several benefits including a reduction in integration time by a factor of ~1.5 to as much as 3 in the worst parts of the current IF (assuming a typical sky temperature), an increase in the IF bandwidth from the present 5.5 GHz per sideband per polarization to at least 12 GHz (4-16 GHz) and potentially to 16 GHz (4-20 GHz), and an increase in RF coverage by 8 GHz, to 209-281 GHz from the present 211 275 GHz. The project will focus on exploring several different receiver configurations for the ALMA Band 6v2 sideband separating (2SB) SIS receiver, with improvements to all the major receiver components, including optics, OMT, mixers, IF section and local oscillator. The presentation will provide a brief overview of all of the above mentioned aspects of the project.	Alessandro Navarrini	6	invited
5	11:20	ALMA Band 6 Local Oscillator Noise Improvement	ALMA Band 6 Local Oscillator Noise Improvement K. Saini, D. Vaselaar, M. Mereles (NRAO Central Development Laboratory, Charlottesville, VA, USA) This presentation will report on the findings of a NA ALMA Cycle 7 development study to identify the root cause of the excess AM noise in the existing Band 6 front-end local oscillator and on the effort to remedy the problem. The noise temperature of the existing ALMA Band 6 receiver is noticeably poorer at the lower end of its sky frequency coverage range. This is particularly true at the IF band edges. This is unfortunate, since simultaneous coverage of 13CO and 12CO lines (at 220.4 GHz and 230.5 GHz) use this RF/IF frequency combination. At least some of the receiver sensitivity degradation is attributable to the excess noise from the front-end local oscillator system. In this presentation, I will discuss the experimental results of the alternative LO architectures investigated to improve the AM noise performance of the Band 6 local oscillator and review the advantages and disadvantages of each LO scheme that was evaluated. Finally, I will make recommendations for the necessary changes to LO modules to alleviate the Band 6 excess LO noise. These results and the noise improvement are also pertinent to the ALMA Band 6v2 receiver development project that is being proposed in response to the ALMA Cycle 9 Call for NA Development Projects, in that it will inform the choice of the SIS mixer scheme (balanced versus unbalanced) to be pursued for the Band 6v2 receiver configuration.	Kamaljeet Saini	6	contributed

(min)	Time (UT)	title	abstract	speaker	band	type
5	11:25	The status of SIS Process Development at GARD	A. Pavolotsky (*), T. Kojima (+), V. Belitsky (*), S. Masui (+^) (*) Group for Advanced Receiver Development, Chalmers University of Technology, Sweden; (+) Advanced Technology Center, National Astronomical Observatory of Japan, Japan; (^) Graduate School of Science, Osaka Prefecture University, Japan GARD runs the supported by ESO study to develop SIS process technology capable of fabricating mixer chips for Next Generation ALMA receivers. In this project, NAOJ joins to help characterization of SIS junction capacitance. Also, at the later project stage, NOVA plans to contribute with a Band 9 demonstrator design and characterization of the fabricated mixer chip. Currently, the project focuses its effort on AlN-barrier SIS junction technology refining, its calibration in respect of achieving the designed junction tunnel barrier transparency (RnA-product), as well as its specific capacitance, Cs. The latter relies on the collaboration with NAOJ as having ultimate equipment and experience for this purpose. Also, we are beginning our process development towards SIS junctions of the smaller sizes targeting to reach <1um2 junction area as a goal. At the Conference, we will present the achieved by the date results of the study in respect of the AlN-barrier SIS junction calibration of RnA and Cs, as well as communicate the status of the work towards the smaller size SIS junctions.	Alexey Pavolotsky	5-9	contributed
5	11:30	The development of low-noise, wide-band SIS mixer receivers based on a zero-IF architecture.	The Submillimeter Array was conceived more than 2 decades ago as the world's first submillimeter interferometer capable of sub-arcsecond imaging in the frequency range from 200 to 700 GHz. It began full science operations in 2004 with a suite of double side band SIS mixer receivers operating in the 230, 345, and 690 GHz bands. The 345 and 690 GHz receiver sets were co-polarized and could be used in conjunction with the 230 GHz receiver sets, which were operated in the orthogonal polarization. Each of the receivers had a 2 GHz-wide intermediate frequency, and a purpose-built ASIC correlator combined the signals from the different antenna pairs for a total processed on-sky bandwidth of 2x2x2 GHz. Incremental improvements to the receivers, coupled with the development and deployment of a new correlator, have resulted in significant improvements in sensitivity, both in terms of receiver noise and on-sky bandwidth, which is currently 2x2x12 GHz, since the receivers now provide double-side-band output across an IF band 12 GHz-wide. Several years ago, we proposed a major upgrade to the SMA, the wSMA, which includes improvements to much of the instrumentation infrastructure at the observatory site – e.g., receiver coupling optics, cryogenics, signal transmission system, which would result in even lower noise and wider bandwidth performance. In this presentation, I will discuss the current status of the wSMA, which will become operational during the next several years, and plans to further improve its performance through the use of low-noise, wideband SIS mixer receivers based on a zero-IF architecture.	Ray Blundell	5-8	invited
25	11:35	**Discussion**		Neil Phillips		
60						
(min)	**Time (UT)**	**title**	**abstract**	**speaker**	**band**	**type**
5	12:00	Broad IF band vs. Broad RF Band	At the Conference, we present status and progress of the project supported by ESO ALMA Upgrade studies. The project aims to develop cold cartridge components, optics and 2SB SIS mixer operating between 200-400 GHz. We will discuss considerations that provide ground for IF/RF broadband mixer development and show progress in the designing optics, OMT, options for the mixer chip and mixer block components.	Victor Belitsky	6-8	invited
5	12:05	Development of a new wideband heterodyne receiver system (RF: 210–375 GHz, IF: 4–21 GHz) for the Osaka 1.85-mm mm-submm telescope	We report the development of a wideband receiver system using a corrugated horn covering 210–375 GHz (56% fractional bandwidth; Yamasaki et al. 2021, PASJ), wideband waveguide multiplexers (Masui et al. 2021, PASJ), and a wideband SIS-mixer with an IF (intermediate frequency) output of 4-21 GHz (Kojima et al. 2020, A&A). In the system, the RF signal from the horn is divided into two frequency bands by a wideband diplexer with a fractional bandwidth of 56%, and then each frequency band is further divided into two bands by each diplexer. One of the SIS-mixers connected has a wideband 4–21 GHz intermediate frequency (IF) output. This receiver system has been installed on the 1.85 m telescope of Osaka Prefecture University located at the Nobeyama Radio Observatory. We succeeded in simultaneous observations of six CO isotopologue lines with the transitions of J = 2–1 and J = 3–2 toward the Orion KL as well as on-the-fly mappings toward the Orion KL and W 51 with the developed system.	Toshikazu Onishi	6-7	invited
5	12:10	Development of Band 7+8 Cartridge Receiver	Please note that It was already registered as number 14. We will present the design and performance of a 275-500 GHz cartridge receiver which covers both ALMA band 7 and band 8 frequency ranges. The receiver has dual-linear polarization and sideband-separation capabilities providing four IF outputs of 4-8 GHz IF frequency. Wideband components such as a splined horn with optics, an OMT, high-jc AlN barrier SIS mixers, RF hybrids, and diplexed LO using the combined ALMA WCAs have been developed meeting their nominal requirements and assembled into a standard ALMA cartridge.	Jung-Won Lee	7-8	contributed
5	12:15	On-going mixer developments at IRAM	I will present our current work on mixer developments for various internal and external projects in the frequency range from 67 to 375 GHz. These include multi-beam array receivers for the 30-m telescope, receivers with increased IF bandwidth and the upgrade of the ALMA Band 7 receiver.	Doris Maier	2-7	invited
5	12:20	Dual Band upgrade of NOEMA Receivers	The NOEMA (Northern Extended Millimeter Array) Interferometer is a Radio-Astronomical Observatory composed of twelve (the twelfth will be operational by the end of 2021) 15-m Antennas located on the Plateau de Bure, in the French South Alps. Each of these antennas is equipped with a cryogenic millimeter wave heterodyne quadri-band receiver, covering frequencies from ~70GHz to 365GHz. This receiver is composed of four dual-polarizations state-of-the-art side band separating SIS modules delivering (for each side band) ~4-12GHz IF signals. The four modules cover respectively 70-116GHz (band 1); 127-179GHz (band 2); 200- 276GHz (band 3) and 276-365GHz (band 4), and each of the four beams currently looks at a different region of the sky. A major upgrade ongoing for these receivers is to combine band 1 and band 3 beams with a dichroic filter to enable these two beams to observe simultaneously the same region of the sky. In the same time, to fully use this new capability of the receivers, a second correlator will be constructed, and the number of IF chains and laser racks for IF transport will also be doubled, to be able to treat simultaneously 64GHz of band (= 2 frequency bands x 2 polarizations x 2 side bands [4-12GHz]) per antenna instead of 32GHz.	Anne-Laure Fontana	2-7	contributed
5	12:25	Developing for ALMA's future at NOVA	An overview will be given of the current, and currently foreseen, development activities at the NOVA Sub-mm Instrumentation Group (University of Groningen), mostly in the light of the ALMA 2030 Development Roadmap. Many of the main activities are centered about an ESO-cofunded study on the possibilities of upgrading the current ALMA DSB Band 9 (600-720GHz) receivers. Sideband-separating (2SB) operation is particularly fruitful for high-frequency atmosphere-dominated bands like Band 9. A 2SB mixer, with an IF bandwidth of 4x 4-12GHz and an image rejection ratio (IRR) in excess of 20dB at most frequencies (better than 15dB everywhere), has been deployed successfully in the SEPIA660 instrument on APEX. An important goal of the study is the further extension of the IF band to at least 4-20GHz, for a total IF bandwidth of 64GHz, four times as wide as the current ALMA 2SB bands. Other subjects under study are the extension of the RF band beyond 600-720GHz, and a drastic improvement of the polarimetric performance (dominated by the beam squint and the cross-polar leakage of the optics). Outside of this study, developments include a scaled version of the Band 9 2SB mixer for the 780-950GHz band of FLASH (MPIfR Bonn, APEX) with demonstrated IRR performance very similar to the Band 9 mixer; a 210-275GHz mixer (Band 6) primarily for LLAMA (Argentina), enabling it to participate in the EHT array, and possibly for space applications (Millimetron) as well; digitally corrected image rejection; and finally participation in projects targetting further enhancement of the fundamental performance of SIS junctions, crucial for any sub-mm receivers envisioned for the near to mid future.	Ronald Hesper	9	invited

5	12:30	Calculation and Analysis software for SIS-Mixers	In the last few years, we have been witnessing a fast development in the field of Astrochemistry. Such advances are largely due to the improvements of low noise instruments and new observational facilities. The constant improvement of the superconductor–insulator–superconductor tunnel junction (SIS-junction) contributes to identifying weak submm and mm molecular lines, which allow us to resolve chemical-rich environments such as thick stellar envelopes, planetary disks and molecular clouds. In view of the aforementioned facts, we present the development of a software package for SIS-Mixer analysis and simulation. The python software package, based on QMix software, will allow us to pair single junctions that have similar performance for sideband separating (2SB) architecture designs by the analysis of measured IxV curves, calculating mixer gain and correlating the temperature noise. The 2SB mixers perform a lower temperature noise compared to a double sideband mixer. However, the two mixers in the 2SB mixer block shall have similar performance. Acquiring those performance parameters requires a couple of days for each single junction, consuming a lot of time in the production process which is a sensitive factor for large interferometers such as ALMA. With this tool, currently in development, the selection phase of pair junctions for 2SB architecture would be less time consuming when compared to the present process, thus creating more opportunities for further optimisations. We will apply the analysis to ALMA band 9 mixer measurements which are performed on a new type of the mixer block optimized for machinability and low cost series production.	Daniele Ronso Lima	9	contributed
25	12:35	**Discussion**		Kamaljeet Saini		
60						

(min)	Time (UT)	title	abstract	speaker	band	type
Day 4.1: Arrays						
5	11:00	Design of optical components (for FPAs)	Nowadays there is a considerable scientific interest in increasing the field of view of submillimeter wave observatories in order to enable a much faster wide field mapping. This would enable telescopes to survey large regions of molecular clouds and image nearby galaxies. We present our study of multi-pixel architectures that could allow for orders of magnitude increase in mapping speeds, thus significantly expanding the capabilities of current facilities like the ALMA observatory. The results of the study will be useful also in the development of future sub-mm single dish facilities, such as AtLAST, which aims at the delivery of a new and deeper insight of the submillimeter sky. Indeed, the development of focal plane arrays would significantly enlarge the fraction of the sky covered in a single observation, thus enabling the mapping of thousands of radio sources in a reasonable time. The purpose of our study is the design of a multipixel array horn aperture focal plane that ensures a high polarization purity, reduced aberrations for off-axis beams and as compact as possible to satisfy the technical specifications based on scientific requirements and engineering constraints on weight, size and thermal load, which represent a serious technological challenge.	Sabrina Realini	FPA	invited
5	11:05	Preliminary optics investigation for ALMA multibeam receiver	Implementation of multibeam receiver for ALMA will significantly increase ALMA's mapping capability, and it is recommended as one of the mid-term opportunities in ALMA development roadmap. In this presentation, I will report preliminary study works for multibeam receiver optics, which is conducted in NAOJ recently. The goal of this study is to investigate the possibility to realize high-performance ALMA multibeam receiver optics without major modification of current cryostat and antenna structure.	Haoran Kang	FPA	contributed
5	11:10	Focal plane array concept for ALMA	Focal plane arrays (FPA), integrated into total power antennas, are noted as a desired technology for ALMA development during the 2030s. For full compatibility with ALMA, a dual-linear, sideband-separating (2SB) architecture is necessary. We report on a conceptual design that uses a "unit cell" approach for the front-end 2SB block using waveguide. Each pixel uses a turnstile OMT for linear polarization, hybrid-tees for isolated power division and higher mode termination, and hole couplers for LO injection. A 5-layer quasi-platelet layout is used such that the "unit cell" is replicated to facilitate arrayed designs. Mixers are separately housed within a simplified DSB mixer block (using standard split-block) that allows for separate mixer qualification. In collaboration with ASU, a waveguide hybrid-tee, scaled for ALMA Band 6, is currently under development to explore the machinability and performance of the component itself, and the notion of using platelet designs at Band 6 frequencies.	Doug Henke	FPA	invited
5	11:15	Development of a 2 x 64 pixel heterodyne focal plane array receiver for the 450-500 GHz and 800-820 GHz bands	The Cologne instrumentation group is in the process of developing a 2 x 64 pixel focal plane array heterodyne receiver. The receiver is split by polarization into 2 channels at a frequency of 450-500 GHz and 800-820 GHz respectively, with an IF-band of 4-8 GHz for both channels. The receiver is a mapping instrument, predominantly for the CO and CI emission lines in the bands, to be installed on the FYST telescope at the CCAT-prime observatory, planned for early 2023. To fit well into the observatory, we designed a compact receiver with relatively compact optics and manageable cryostats using a separate cryostat for each channel. Each cryostat contains 2 cold heads and has an outer diameter of about 50 cm. To optimize the sky coupling we do not use an optical combining of local oscillator and sky signal, but instead use balanced SIS waveguide mixers with 2 separate input ports, feeding in the local oscillator (LO) by waveguide. Balanced mixers suppress LO AM-noise and we are expecting a good system stability with this configuration. The consequence of these constraints is that the cryogenic focal plane unit of a channel combines the mixers with cold optics including IF and DC coupling and the local oscillator distribution in a compact block of 80mm x 80 mm x approximately 50 mm, with lateral pixel dimension of 10mmx10mm. This block excludes the LNA's, where we depend on the smallest commercially available LNA of LNF. The cold optics consists of 64 small Cassegrain telescopes, one for each pixel. The optics is made in two perfectly fitting pieces for all 64 pixels in one and is the assembly support for waveguide blocks consisting of 2 halves split over the E-plane. Machined in these block are a splined diagonal horn for each pixel, connecting waveguides and pockets for various circuit boards and connectors. The required machining is relatively straight forward, increasing the chances of success and keeping it affordable. The RF, IF and DC functionality is all done in planar circuits. The balanced SIS mixer 90° hybrid and the 2 SIS mixers are on one 9 µm thick Si board and for 460-500 GHz done entirely in Niobium technology and contacted to the block with Au beam leads. The best DSB noise temperature measured so far is 100K. The magnetic field to suppress the Cooper pair tunneling is supplied by 2 small permanent magnets To fit the IF combining circuit of the mixers inside the footprint it is designed in superconducting lumped element technology. The technology is fully compatible with the mixer technology and could be integrated with the balanced mixer on one chip, but is at the moment still on a separate substrate. Separate measurements of the IF circuits show a fairly good correspondence with the designed performance. The distribution of the local oscillator power has been the main driver to split the mixers in units of 4 pixels per block, resulting in 2 blocks per rows, and 8 blocks per column for the total focal plane array. In one 4-block the LO is distributed by 3 small separate chips that are implemented at waveguide junctions. The chips contain a 90° hybrid very similar to the one in the mixer, and an on-chip TiN load at the fourth port of the hybrid. Separate characterization of the LO distribution chips is in progress, showing a good -3dB division per chip, and a reasonable performance of the load. The distribution of the LO power over the 8 rows of 4 blocks is still a work in progress. The emphasis of the presentation will be on the design, fabrication and analysis of the first test results of prototype blocks for cryogenic focal plane unit for the 460 GHz channel.	Netty Honingh	FPA	invited
5	11:20	Heterodyne Array Receivers for Space and Ground Based Applications	Heterodyne array receivers have been successfully built for ground-based telescopes. Here we will present the first detailed design for a space application, the Heterodyne Receiver for the Origins Space Telescope (HERO). HERO follows the traditional design, but limited cooling power and the limited electrical power of the satellite pose major challenges. Minor challenges are limited availability of space and weight. For the eight 3x3 pixel arrays of which 4 can operate simultaneously we attributed 20mW at 4.5K, 35mW at 35K and 205 W at the satellite temperature. Therefore we propose to use SiGe cryogenic low noise amplifiers, with a dissipation of about 0.5mW for 6 GHz bandwidth. The power of the backends also needs to be reduced drastically to about 1 W for 6 GHz bandwidth. CMOS ASIC backends are one option, ADC, followed by FFTs and ACCs another. To reduce the volume and mass, we propose the cover the RF bandwidth of 486 GHz to 2700 GHz in only 4 bands, each with about 50% relative width. The design might not only be a helpful starting point for any heterodyne array on a satellite, but the low heat and power consumption might be also an essential first step for large (100 to 1000 pixels) heterodyne arrays for ground based telescopes or simply a more energy efficient alternative for any ALMA single pixel or array receiver.	Martina Wiedner	FPA	invited
5	11:25	Development of hybrid technology (InP/Si) integrated modules for future mm-wave arrays	Millimeter-wave transistor based technologies are steadily progressing in areas such as electrical performance (noise and bandwidth), thermal management, power consumption, and miniaturization of complex receiver functionality, and are becoming a viable option for future large-format (> 20 pixels) heterodyne arrays for radio-astronomy. InP and Si-based MMIC technologies have progressed enough so the promise of extreme receiver miniaturization in a small footprint is quickly becoming reality. InP has continued with the dominance in mm-wave cryogenic electrical performance, whereas Si-based circuits have emerged as good candidates in terms of high integration of functionality, and low power consumption. In this talk, we will show recent developments in the design of InP/Si active devices, and discuss about hybrid integration (InP/Si) with the aim of prototyping modules that mix the best of both technologies, increasing the performance of future large mm-wave arrays.	Rodrigo Reeves	FPA	contributed

(min)	Time (UT)	title	abstract	speaker	band	type
5	11:30	Demonstration of a Millimeter-wave Multibeam Receiver Implemented with Superconducting MMICs	Coherent focal plane array receivers are employed in radio astronomical observations for imaging celestial objects with high frequency resolution. At mm/sub-mm regime the complexity of coherent receiver frontends, which are conventionally constructed with metal waveguide circuits, imposes a limit on the number of pixels arrayed in the focal plane of a radio telescope and results in a narrow field of view. We have been developing an innovative approach to enable compact focal plane heterodyne detector arrays with SIS mixers for wide field-of-view astronomical observation at mm and sub-mm wavelengths. The new scheme is characterized by the adoption of silicon membrane-based waveguide probes, which allows superconducting monolithic microwave integrated circuits (MMICs) to couple signal and LO from CNC-machined waveguides through multiple paths. A 2 x 2 dual-polarization balanced SIS mixer array has been implemented with this scheme and assessed at 2 mm wavelengths. This compact array has demonstrated uniform LO distribution and low crosstalk between pixels. The RF performance of component pixels has been confirmed to be little affected by the high degree integration. The potential implementation of the HPI scheme at THz frequencies is also implied.	Wenlei Shan	FPA	invited
40	11:35	**Discussion**		Ciska Kemper		
75						
(min)	**Time (UT)**	**title**	**abstract**	**speaker**	**band**	**type**
Day 4.2: Beyond 2030						
5	12:10	Superconducting Parametric Amplifiers for Radio Astronomy	Superconducting parametric amplifiers have become a promising technology for very demanding applications such as quantum computing and radio astronomy. They can reach high amplification with noise very close to the quantum limit. When implemented in the form of a spatially-modulated transmission lines, they can also achieve broadband operation. Moreover, their operation frequency is only limited by the properties of the superconductor used for their implementation which could allow them to operate in frequencies as high as 1 THz. During this talk I will present advances made in the modelling of such devices and the joint collaboration between JPL and NRAO aimed to achieve operation in the W band.	Fausto Mena		invited
5	12:15	ALMA 2030 and beyond: front end technology improvement.	Large improvement in a sensitivity and a mapping speed of submm instruments like ALMA creates a significant discovery space in observational astrophysics. Performance of high spatial and spectral resolution instruments can readily be improved by decreasing noise temperature and increasing a raw instantaneous bandwidth of a receiver unit. These are the mainstream directions for front end development which do not imply significant change of its architecture. In the real situation other aspects of front end operations, such as amplitude/phase calibration accuracy and speed, a sideband ratio calibration and an atmospheric noise and transmission instability makes for a significant part in a total observing efficiency. Improving any of these aspects will have a large impact.	Andrey Baryshev		contributed
			In this presentation we analyze the noise performance of current system and discuss its improvement limits both in sensitivity due to quantum limit and in instantaneous bandwidth. We will propose and discuss the impact of an advanced high dynamic range digital amplitude calibration scheme and sideband ratio correction/calibration using combination of analogue and digital techniques as main results of ALMA digital front-end ESO study.			
			We will revisit a simultaneous multiple/dual frequency receiver front end concept which has a key advantage in efficiently correcting atmospheric phase and amplitude calibrations, while improving a system bandwidth and versatility for many observational situations.			
			Finally we will consider impact of technological developments which do require a significant change of ALMA system architecture and may lie beyond 2030 horizon, such a focal plane array. We will compare both separated beam and phase array feeds architectures focal plane arrays. A concept of frequency array receiver, which is the single pixel receiver covering total instantaneous RF bandwidth of several ALMA bands will be analyzed for both interferometer application and a single dish such as AtLAST.			
5	12:20	Development of a multiband heterodyne receiver with 49 GHz of instantaneous IF Bandwidth	Increasing the IF bandwidth in heterodyne receivers is one of the main priorities of the ALMA Development Roadmap. One alternative approach to this problem is to increase the number of IF outputs to achieve the same goal of reducing observation time. In this work, we propose the use of a multiband heterodyne receiver architecture in conjunction with digital sideband separation to achieve complete RF coverage with multiple IF outputs. The selected band to test this architecture is ALMA Band 2+ (67-116 GHz), obtaining an instantaneous IF bandwidth of 49 GHz with four IF outputs. We will present a comprehensive analysis of the proposed design, showing its advantages and limitations, as well as giving possible options of how this architecture can be implemented in the upper-frequency bands of ALMA.	David Monasterio		invited
30	12:25	Discussion	Tony	Tony Mroczkowski		
45						