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NOTES ON CHOICE OF BASELINE DESIGN FOR FIRST LOCAL OSCILLATOR

1999-Sep-02 LRD, revised 1999-Sep-13, revised 1999-Sep-14 JCW

Proposal: Select "Option II" (as defined below) as the baseline plan for ALMA. Discard "Option I" for now, and suspend any work applicable only to it. Continue development of components needed to make "Option III" feasible (especially high-power, mm-wavelength photodetectors), with a view to making it the baseline when and if feasibility is demonstrated. (A final selection and commitment to detailed design is scheduled for 2000-06-30, and this schedule is expected to be maintained.)

FEATURES OF EACH OPTION

The three options are represented by the draft block diagrams of 1999-08-09. Some details of those diagrams are subject to change and are not fundamental to the respective concepts. The essential, distinguishing features of the options are:

Option I (called "conventional" on draft block diagrams):
- Generation of frequencies 28-122 GHz within a PLL, with higher frequencies generated by multiplication outside the loop.
- All synthesis is done at the antenna from fixed-frequency references.
- Fringe rotation and phase switching are implemented at the PLL IF via offset reference.

[Highest reference frequency must be below the lowest synthesized frequency (28 GHz), and not too many times the frequency of the next reference. This leads to the draft design with references at 13 GHz and 125 MHz. In retrospect, the ratio of these may be too high, so we may need to lower the first and/or raise the second. The latter leads to coarser resolution unless an additional reference is included, which increases complexity.]

Option II (called "photonic reference" on draft block diagrams):
- Generation of frequencies 28-122 GHz within a PLL, with higher frequencies generated by multiplication outside of loop. [Same as Opt I.]
- Synthesis of 28-122 MHz is done once at the central building, with the result split and distributed to all antennas. Antenna-dependent offsets such as fringe rotation are not included. Thus, the distributed signal changes with receiver tuning, but stays fixed at any one tuning.
- Distributed signal is used only as reference to antenna PLL, and therefore can be received at low power level (100 nW per driver estimated to be sufficient). The main purpose of antenna PLL is to provide large power at 65-122 GHz (~100 mW) for driving higher frequency multipliers; incidentally, it also provides some phase noise "cleanup" by limiting the noise bandwidth of the distribution link.
- Fringe rotation and phase switching implemented at PLL IF via offset reference. [Same as Opt I.]

[The main point is to reduce the differential-mode multiplication factor compared with Opt I (here we get to 122 GHz in common mode, rather than only to 13 GHz), while also reducing the power that must be generated by a mm-wavelength photomixer compared with Opt III.]

Option III (called "photonic-direct" on draft block diagrams):
- No PLL and no frequency multiplication at the antenna.

- Synthesis of all first LO frequencies (28-938 GHz) at the central building, and transmission to the antenna at the final frequency and phase. Most of the synthesis is common mode, but each antenna has a separate offset that includes fringe rotation and phase switching.
- Transmission via optical carriers, and direct generation of the final LO signal in a photodetector. Output of the photodetector is coupled directly to its SIS mixer (estimated power requirement is 1 uW at 100 GHz to 100 uW at 938 GHz; see MMA#264). For HFET bands, photodetector output would be increased by a power amplifier.

ADVANTAGES (+),DISADVANTAGES (-), AND FEATURES (=)

Option I:

+ Fixed reference frequencies allow continuous operation of round-trip line correction, with no glitches upon re-tuning and no question of repeatability.

+ Less expensive than photonic-reference (one laser plus modulator vs. two lasers and laser phase-lock circuitry).

+ All photonic components available commercially; nothing new required.

+ Reference transmission with suffiently low noise has been demonstrated (although not by us).

+ If round-trip correction is done at the reference frequency (vs. optical frequency), then the relatively low frequency means that higher SNR is needed to achieve required accuracy (10 um -> 0.16deg phase at 13 GHz -> 51 dB SNR within correction loop BW.) Nevertheless, the necessary accuracy is readily achievable with available components and little or no development is necessary.

- Large multiplication factor needed at antennas (938/13=72), which could lead to differential phase drift with temperature, antenna orientation, etc. unless due care is exercised to ameliorate these effects. Requires higher SNR to meet phase noise requirements (-115 dBc/Hz at 1MHz loop BW) than other options, which is probably not a problem.

- Tuning resolution at high frequencies may be inadequate in the draft design (2 GHz at 938 GHz). Small improvements are possible, but very much finer resolution leads to rapid increase in complexity and reduction in stability if unambiguous phase is to be retained. The cost advantage over Opt II (noted above) may disappear if tuning resolution needs to be improved, which appears to be the case from the standpoint of science requirements.

Option II:

+ Lower multiplication factor (938/117=8) produces lower phase noise and phase drift, insofar as it is common mode. SNR requirement may be easier to meet (-93 dBc/Hz at 1 MHz loop BW) than for Opt I, but this is probably not a critical factor.

= Much development is common to photonic-direct option, especially laser-difference synthesizer. If photonic-reference is installed on early antennas of the array, a clear path to Opt III exists.

- The round-trip measurement is more difficult than in Opt I because of the variable frequencies; avoiding glitches when switching from one frequency to another, as in the case of fast switching, has not been demonstrated.

- Requires acquiring photodetectors usable at 122 GHz with sufficient output power for the PLL reference. Although there are indications that these are available, we don't have a reliable source.

- Reference transmission with sufficiently low phase noise has not yet been demonstrated.

- More expensive than Opt I (but see note about tuning resolution under Opt I).

Option III:

+ Greatly simplifies antenna electronics compared with both other options, eliminating all oscillators, multipliers, amplifiers for first LO with the possible exception of the HFET front ends. Front end assembly is mechanically much simpler. This is at the expense of some increase in complexity centrally, where a separate laser-difference PLL is needed for each antenna. On balance, there is a large overall simplification.

+ All frequency multiplication is common-mode, all the way to 938 GHz, leading to the lowest possible phase noise and drift. (Even though a separate slave laser and PLL is needed for each antenna to support fringe rotation and offsetting, the main multiplication is in a common "optical comb generator.")

- Requires high power output photodetectors at sub-mm frequencies, which do not yet exist.

- Round-trip length correction is complicated by fringe rotation, which produces a significant phase change in the round-trip time. Scheme shown in draft block diagram will not work (with difference of optical phases held constant). Correcting based on RT phase of master laser only might work, but is not yet proven; dispersive effects in fiber may be a problem.

- Difficult to transmit lower frequency references on same fiber, so those references have no length correction in the draft design. Since 2nd LO goes to 10 GHz and involves large multiplication (80x), this needs to be improved.

NEW DEVELOPMENTS NEEDED FOR EACH OPTION

Option I:

- Doublers for drivers (up to 8 different ones, ~20% bandwidth)
- Power amplifiers for drivers (3 different ones)
- Multipliers for high frequencies (8 doublers, 4 triplers, 10-23% BW).

Option II:

- Doublers for drivers (up to 8 different ones, ~20% bandwidth)
- Power amplifiers for drivers (3 different ones
- Multipliers for high frequencies (8 doublers, 4 triplers, 10-23% BW).
- Photodetectors for 28-122 GHz in 5 bands, with >100 nW output (lower bands already commercially available)
- Two-laser synthesizer with low phase noise.

- Line length corrector driven from RT optical phases.

Option III:

- Photodetectors for 28-938 GHz with >1 uW at low end to >100 uW (?) at high end, depending on coupling loss and mixer configuration (numbers of junctions, sideband separation).
- Two-laser synthesizer with low phase noise.
- Line length corrector driven from RT optical phases.