A Wideband Upgrade for the Australia Telescope Compact Array

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Overview

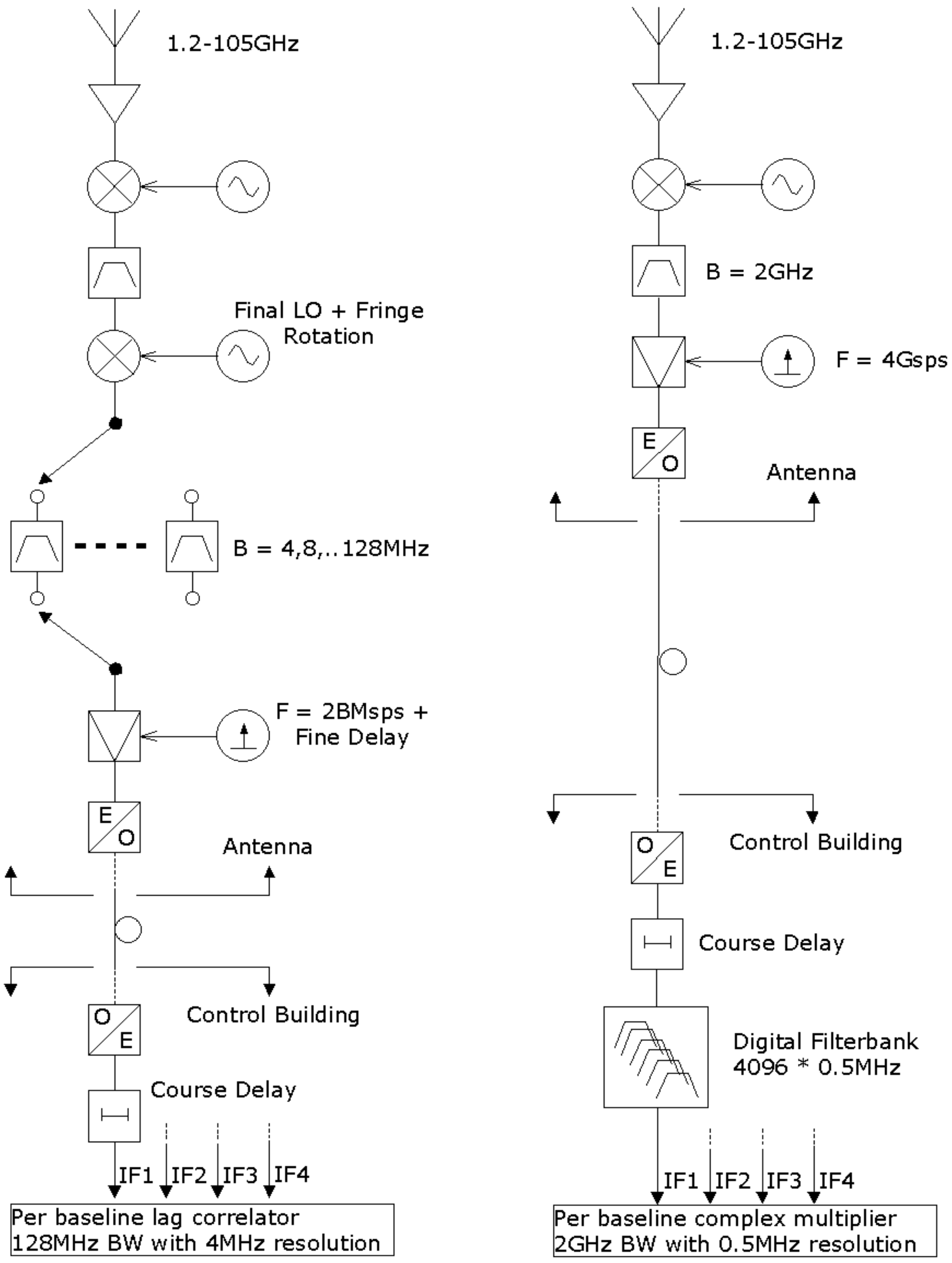
The available signal bandwidth on the Australia Telescope Compact Array (ATCA) is to expand from 128MHz to 2GHz. Central to this development is an FPGA-based digital filterbank correlator featuring high dynamic range and flexible configuration.

The design is distinguished from current 'FX' correlators by rectangular channel passbands, which maximise correlation efficiency without 'sidelobes' or 'ringing'. Implementation of the filterbank in an efficient polyphase structure allows the 2GHz signal bandwidth to be analysed into four thousand channels in only four FPGAs. The use of FPGAs rather than custom chips is economical, and supports reconfiguration of the hardware resource at will to provide a variety of 'zoom' modes. The architecture is also linearly scalable so that the basic two-frequency, full polarisation, 2GHz observation mode can be reconfigured to single frequency, full polarisation 4GHz operation if required.

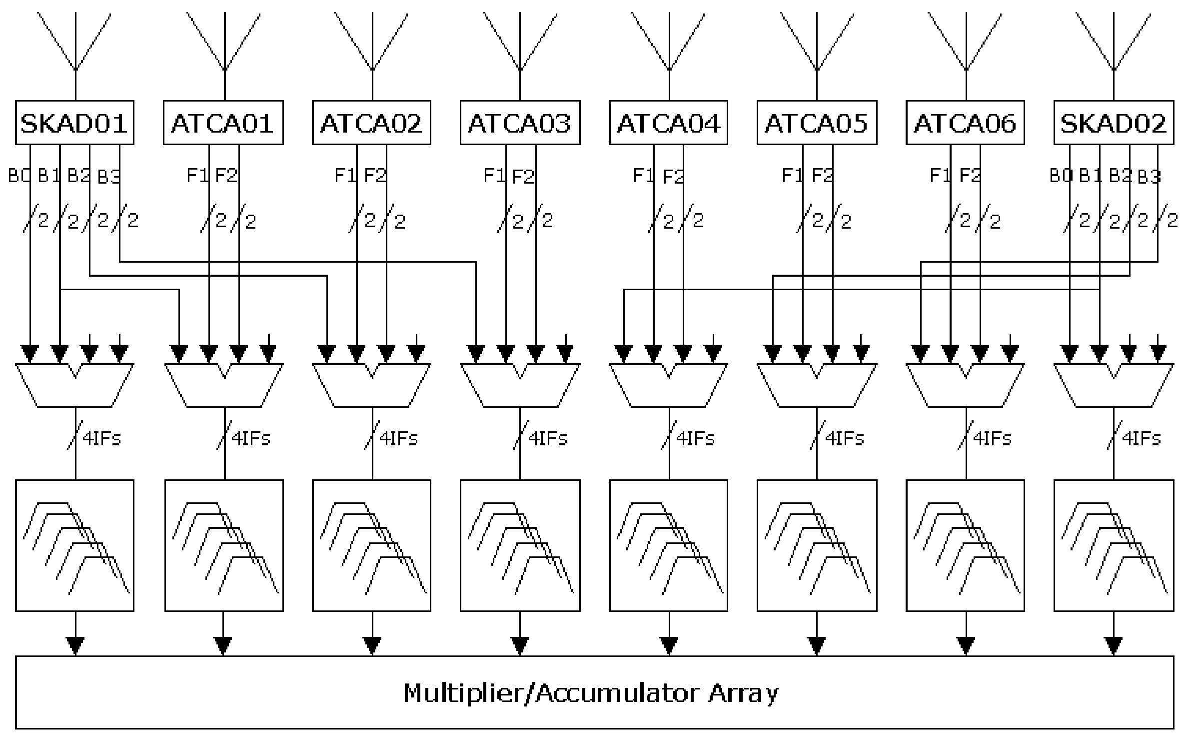
Associated analog to digital conversion requirements will push the limits of high-speed sampling and quantisation techniques. Eight bit data samples and sixteen bit (minimum) internal signal paths through to the integrators will provide performance approaching analog correlation but with the obvious advantages of digital processing. Combined with excellent channel selectivity the system will be significantly more robust against strong interferers than contemporary 2-bit correlators.

The method of acquiring 2GHz bandwidth data to this precision will depend on the state of rapidly developing technology. It has recently become feasible to transmit the analog IFs on optical fibre and so move sampling and quantisation from the antenna to the correlator, thus avoiding self generated RFI. The even more attractive option of photonic sampling in the antenna combined with quantisation at the correlator has been demonstrated, but may not be practical in our timescale.

These new technologies are direct candidates for signal processing on the proposed Square Kilometre Array (SKA). The correlator includes extra ports to incorporate two SKA demonstrator antenna stations into the ATCA, providing both a more powerful instrument and a well-featured test bed for the demonstrators. The extended interferometer structure accommodates the four-beam, single frequency operation of the SKA demonstrators with the single beam, dual frequency operation of the ATCA antennas.



Current System **New System**



Extended Interferometer Structure

Bandwidth and Sensitivity

The current system offers a maximum of 128MHz bandwidth per polarisation sampled at 2-bit resolution and resolved into 32 to 128 channels depending on the overall configuration. The corresponding figures for the new development are 2048MHz, 8-bits and 4096 channels. These translate into immediate benefits in a number of areas.

The sixteen-fold increase in bandwidth and removal of the 14% T_{sys} penalty associated with 2-bit quantisation combine to increase the sensitivity of continuum observations by a factor of 4.5. This is equivalent to increasing observation times by a factor of 20.

The recently available millimetre bands are known for their high density of spectral lines. The number observable at any one time will increase in proportion to the bandwidth.

Imaging quality (dynamic range) is highly dependent on the degree of coverage of the u-v plane, so the multi-frequency synthesis technique will use the increased bandwidth to advantage. In the 3cm band for instance a 60-fold multiplication of the number of independent baselines/u-v tracks will allow full synthesis with only two antenna configurations.

MFS and Zoom Modes

During continuum observations the large number of frequency channels will usually oversample the u-v plane, the exception being low frequency observations involving the SKA antennas. This will allow data contaminated with strong interference to be excised efficiently. The clean channels can then be aggregated to provide an optimal multi-frequency synthesis.

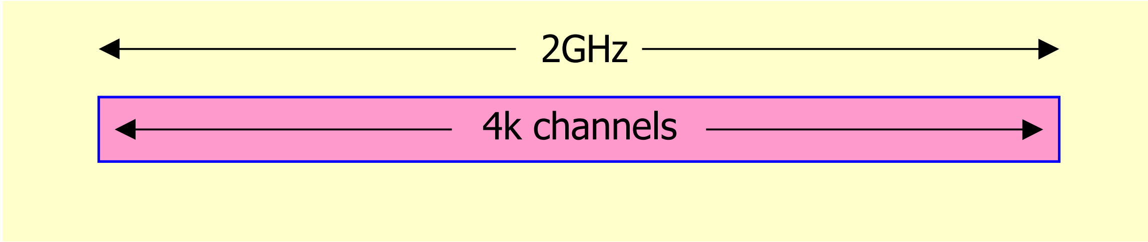
Spectroscopic observations require high resolution across relatively small bandwidths. The FPGA architecture allows the hardware to be completely reconfigured to first select one or more small subbands using simple filters, then subjecting each of these to filterbank analysis. The ability to observe multiple spectral lines simultaneously is a powerful new capability.

Signal Path Dynamic Range

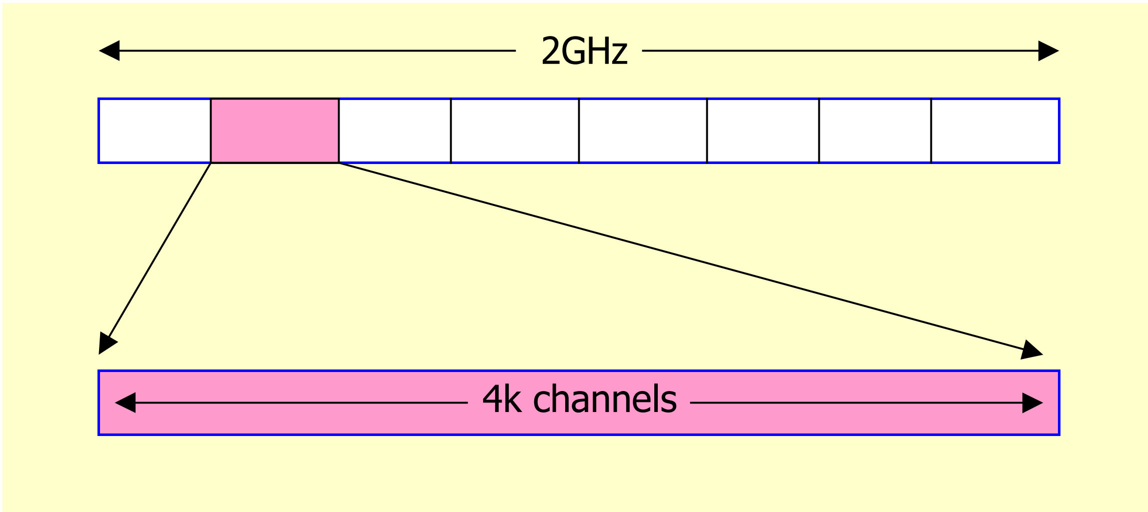
Contemporary radio astronomy receivers use only 2-bit (3 or 4 level) quantised data, in stark contrast with the 16-bit (64000 level) quantising deemed necessary for CD audio disks. With the increasing number of strong signals encountered from LEOS, microwave TV transmitters and wireless telephones this is no longer sufficient and often the whole observing band is corrupted.

The combination of 8-bit sampling and the filterbank architecture with communications quality channel filters, will isolate such signals to a minimal number of channels. Maintaining high internal numerical precision then maximises the opportunity for their correlated components to wash out in the integration process due to fringe rotation.

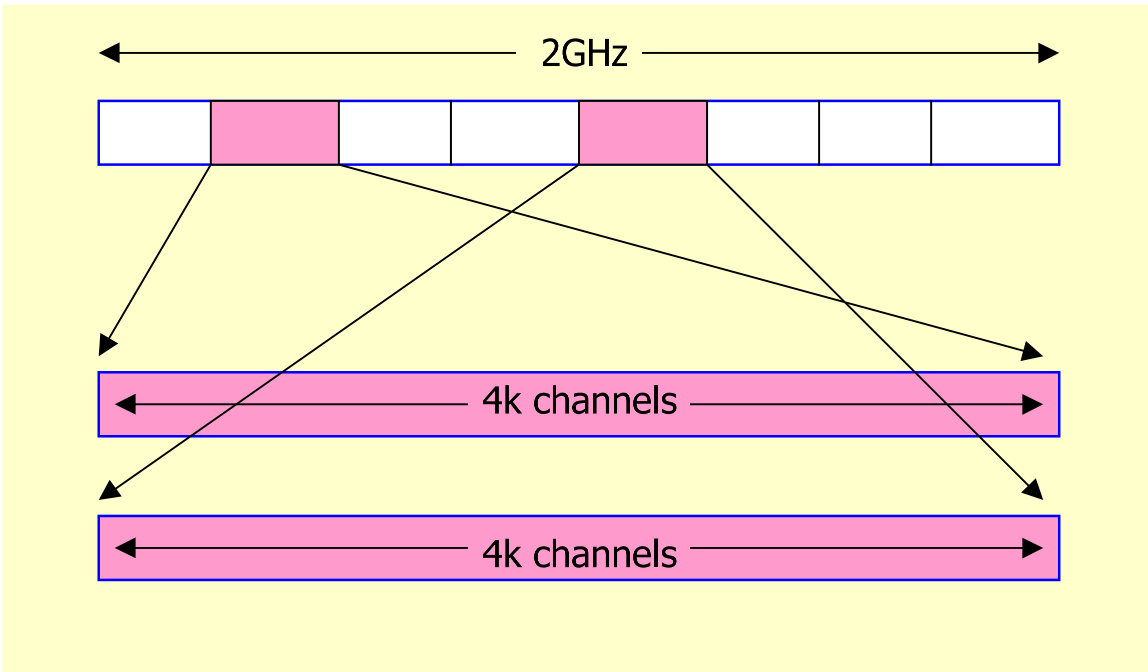
The signal path may also be operated at constant gain. Removing the current gain servos will eliminate another point of vulnerability to strong signals, and provide more stable calibration.



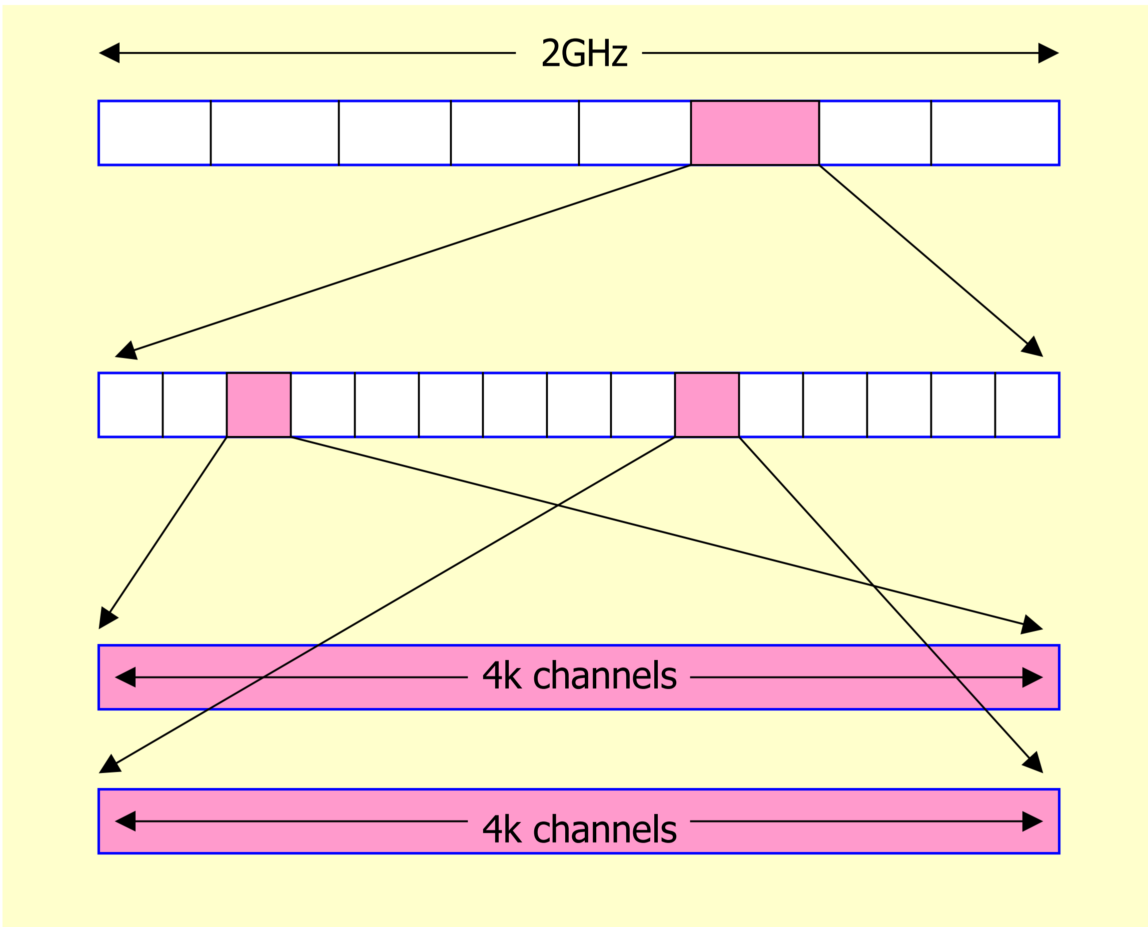
Basic Configuration



Simple Zoom



Multiple Zoom (>2 possible)



Compound Zoom