The Parkes Telescope Frequency Conversion System

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Abstract:

A new receiver down-conversion system has been commissioned on the Parkes 64 metre radio telescope. This system, capable of accepting all radio astronomy bands in the range 300 MHz to 6.1 GHz, will allow rapid, computer-controlled selection of receivers mounted on the telescope focal-plane position translator. The system requirements, design concepts, and construction details are discussed.

1. Introduction:

A recent upgrade of the focus cabin at Parkes observatory, included the installation of a translator system to enable rapid repositioning of receiver packages. This has allowed observers to change receiving bands in as little as 2 minutes, depending on the packages involved.

The previous conversion system consisted of a single downconversion to UHF in the focus cabin, and then a manually configured conversion system in the control room as required. This conversion system was rather daunting in use, did not lend itself to computer automation, and was not easily repeatable from one observing session to the next.

A new conversion system was hence called for, based heavily on that installed at the Narrabri Compact Array and at Mopra, and using some of the same modules.

2. System Overview:

The conversion scheme used is based on, and uses some of the same modules as the ones used on the Australia Telescope National Facility (ATNF) Compact Array antennas, at Narrabri, and the Mopra antenna, at Coonabarabran [1]. Some of the features of the Parkes system are:-

1. Astronomers must be able to observe simultaneously two widely separated spectral line features within a receiver passband. Alternatively, in the case of a dual band receiver (eg. The S-X receiver covering 2.2-2.5GHz and 8.0-9.2GHz), spectral line or broadband noise observations may be made simultaneously for each of the bands.

2. Dual polarisation is required for each of the observing frequencies, necessitating a total of four conversion channels. However, as the modules are paired, only two independent Local Oscillator (LO) systems are needed.

3. The input bands are 300-750MHz (UHF-band), 1.2-1.8GHz (L-band), 2.2-3.6GHz (S-band), and 4.5-6.1GHz (C-band). Observations outside these bands, for example at K-band (22GHz) are accommodated using an extra conversion on the receiver package.

4. Wherever possible signals generated by the local oscillator system should not fall within any signal or intermediate frequency (IF) bands to reduce the incidence of internally generated interference [2]. Unfortunately, due to the very wide S-band (2.2-3.6GHz), one of the LO frequencies may fall inside the band for some observing frequencies.

5. The system must have a high degree of gain, frequency, and phase stability relative to a variety of external influences, the main being temperature fluctuations.

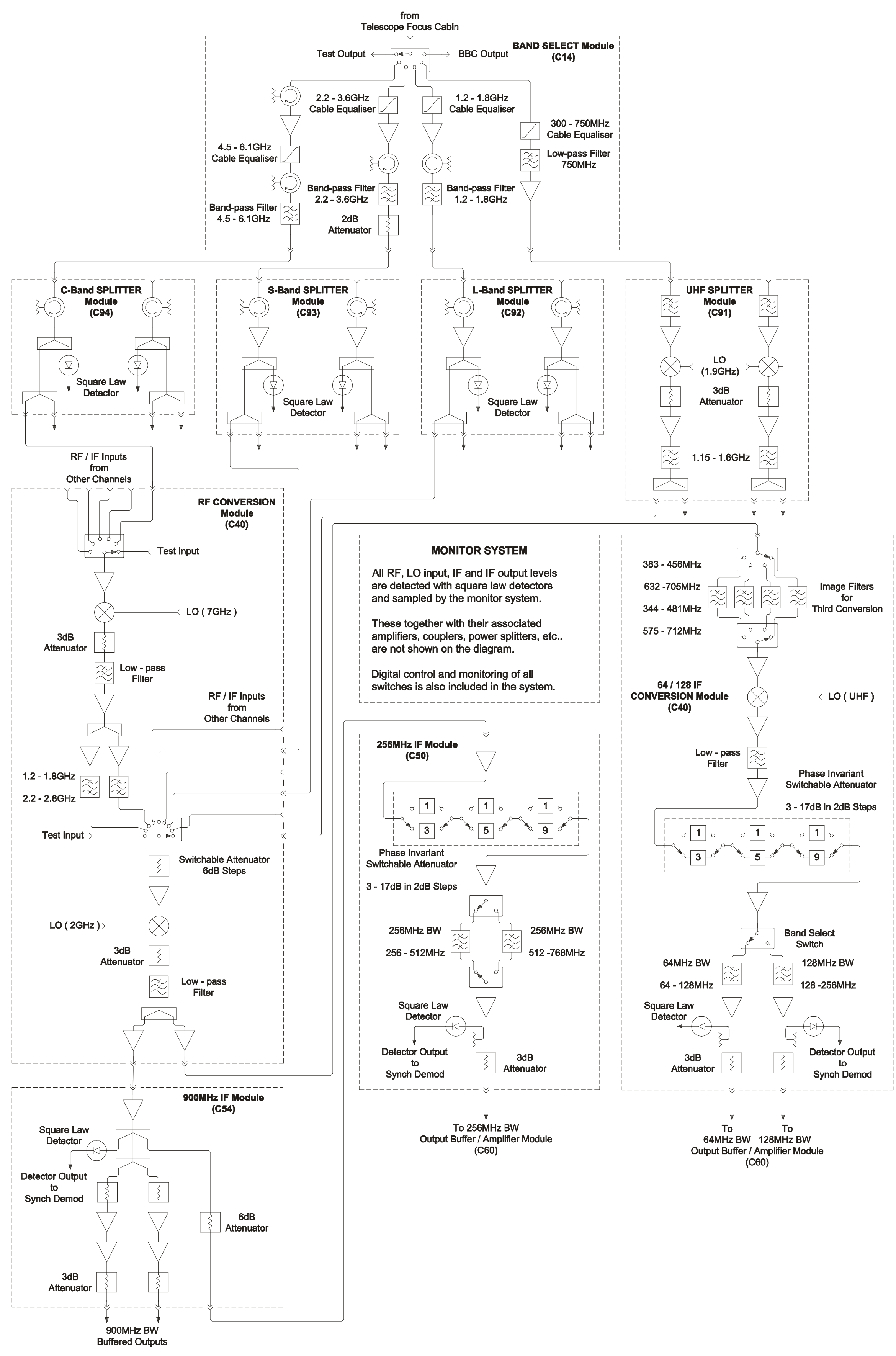


Figure 1: Conversion Rack Block Diagram

6. Frequency switching may be used for observations of a single spectral line. For C-band inputs, frequency switching is available for two spectral lines simultaneously.

7. The system makes available a wide range of output bandwidths; 64MHz, 128MHz, 256MHz, and 900MHz, each with multiple buffered, highly isolated outputs. The multi-beam correlator [3] or Data Acquisition System (DAS) [4] may be used to further reduce the bandwidth for narrow spectral line observations.

8. The system is equipped with a digital control interface, such that the reconfiguration from one observation to the next is accomplished automatically, with minimal manual intervention. In addition, numerous signal levels throughout the conversion chains are digitised to simplify system setup. This control/monitor system may be controlled manually, by a PC, or by the telescope control system (TCS) software over the local network, as required.

9. RFI emission requirements and weight restrictions necessitated locating the bulk of the conversion system in the control room, some 120m from the receivers. This called for the design of a number of wideband cable equalisers.

10. Each channel provides a square-law detector output that enables the total power level in that band to be monitored by the digital interface. If a small (approximately 5% of the total system noise temperature) modulated noise source signal is injected into the receiver feedhorn, a synchronous demodulator can be used to continually monitor the overall gain and noise temperature of the receiver system [5].

11. For efficient telescope operation, the reliability and maintainability of the receiver system as a whole must be high. The slide-in modular system as used on the Compact Array enhances this.

3. Conversion Scheme:

The input bands allowed for are UHF, L, S, and C-band.

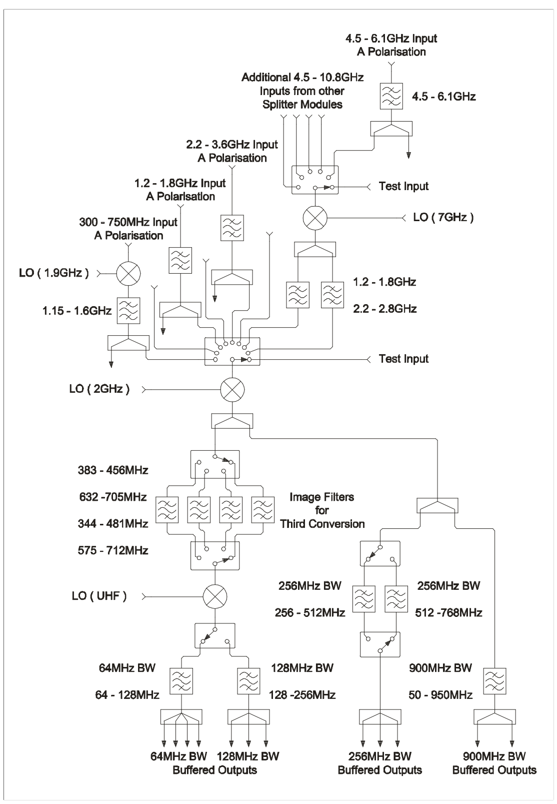


Figure 2: Conversion Block diagram

The C-band signals are downconverted to an L-band or S-band Intermediate Frequency (IF) using a LO (Wiltron synthesizer) near 7GHz. The appropriate L-IF, S-IF, L-RF, or S-band RF is selected and mixed down to a given UHF band. In the case of the very wide S-band RF, a lower sideband conversion is used to eliminate the problem of second harmonic conversion products. 64MHz and 128MHz output bandwidths necessitate a third conversion. Hewlett Packard synthesizers are used as the LO for these last conversions.

The UHF RF input could not be switched directly into the UHF sections of the conversion system, as there is little frequency agility in that section. The conversion modules are designed for L band signals and above. In order to use these modules in the UHF band, the UHF splitter module performs an upconversion with a fixed 1.9 GHz LO. In this way, the 300 - 750 MHz UHF band neatly falls within L band (actually 1.15GHz - 1.6GHz), and may then be accepted by the usual conversion system electronics.

4. Focus Cabin:

A small rack is installed in the focus cabin to allow some control and monitoring of the signals from the receiver packages.

Each of the four channels can select the appropriate output from up to six different receiver packages. A broad band cable equaliser compensates for the attenuation slope of the connection cables over the full 0.3 – 6.1GHz bandwidth.

A step attenuator (0 – 31dB in 1dB steps) is used to adjust the appropriate output level. This device incorporates a MMIC which is wirebonded to the substrate using techniques developed in-house.

The focus cabin electronics may be monitored locally using a similar display panel to that used for the main conversion system. Square law detectors are employed to indicate the total output power on each cable. All electronics are remote controlled from the main telescope control system.

5. Cable Equalisers:

The Parkes system is different to those of the Compact Array antennas in that there are very long cable runs, carrying high frequency (~6GHz) signals. There is considerable attenuation slope across the various RF bands.

In the focus cabin, the cable (Andrew Corp ¼" Superflex FSJI-50) [6] from the receiver front end package to the RF selection modules has 10dB loss at 6.1GHz, but only 2dB loss at 300MHz. A wide band cable equaliser covering this band was developed. It is non-reflective (to ensure a good match and hence low ripple) and used lumped components. Resistors and inductors used in the equaliser are 0402 SMD types, with dimensions of just 0.5mm x 1.0mm [7].

The attenuation slope of the 120m of cable (Andrew Corp ½" Superflex FS54-50B) between the focus cabin and the conversion rack was equalised separately in the four observing bands. The UHF and L-band cable equalisers were straightforward, using two and three sections of lumped components respectively.

For the S-band equaliser, the inductors were replaced by microstrip lines to provide the appropriate reactance slope. The return loss of this equaliser is better than 20dB across almost all of the band, rising to 18dB at 3.6GHz.

In C-band, the attenuation slope is steep, as the cable loss is greater than 42dB at 6.1GHz, and 35dB at 4.5GHz. A six section cable equaliser, using only microstrip lines and 0402 SMD resistors was developed for this band. As the signal loss is so high a low noise amplifier (1dB noise figure) preceeds this equaliser.

6. Conversion Modules:

The modules are the same as used elsewhere in the ATNF. As indicated previously, the down conversion is very flexible and the signal path is quite complex, passing through many subassemblies.

To integrate this sophisticated system into a reasonable space, planar microstrip circuitry is used for all these subassemblies. These circuits must have very good amplitude and phase stability, in particular the filters. For this reason, RT duroid (RT/6002, RT/6006, and RT60010.5) manufactured by Rogers Corp [8] has been selected. The phase/temperature characteristics of the filters developed in this manner are superior to most standard commercial filters tested.

7. Wideband IF Modules and Buffers:

In order to ensure the conversion system is capable of supporting simultaneous use of the DAS, AT and multi-beam correlators, a number of buffered outputs for each output bandwidth have been provided. Each of the 4 channels has 4 of 64MHz, 3 of 128MHz, 3 of 256MHz, and 2 of 900MHz bandwidth (BW) outputs available. One complete set of outputs for each channel (64, 128, 256, and 900MHz BW) have been provided at the front of the conversion rack. The remaining system outputs are cabled to bulkhead connectors in the rear of the rack for permanent connection to the DAS and correlator patch panels elsewhere in the control room. To ensure that spurious sampler/conversion products coupled between the outputs for each channel were reduced as far as practicable, the output buffers were designed to maximise the isolation between each of the different bandwidth outputs for a given channel.

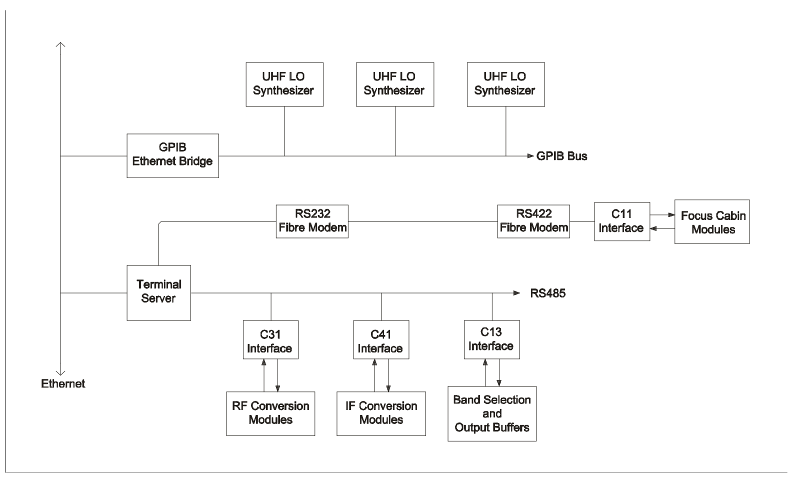
The full-band output of the L and S band conversion is connected to a 900MHz IF module where it is amplified and split three ways. One of these outputs is then connected to the 256MHz IF module and the remaining two outputs are further buffered for use as general purpose outputs. Care was taken in component selection and design of the sub-assemblies and modules to maximise the isolation between each of the buffered outputs and the output for the 256MHz IF module. A square law detector is included in each channel for system temperature monitoring.

The 256MHz module provides two selectable IF frequency bands; 256 to 512MHz and 512 to 768MHz. The IF signal path contains a phase invariant attenuator, allowing the output signal level to be varied over a 14dB range in 2dB steps with less than 0.5 degree phase variation across the full attenuation range. Again, a square law detector is included for system temperature monitoring.

The 64MHz and 128MHz IF outputs from the UHF conversion and the 256MHz IF output from the 256MHz IF module are split and amplified in one module for each channel. Each module has three RF sub-assemblies that provide four 64MHz, three 128MHz, and three 256MHz bandwidth buffered outputs for each channel. Once again care was taken to maximise the isolation between each of the buffered outputs and minimise the gain/phase variation with temperature. The isolation achieved between the module outputs ranges between 40dB for the 256MHz outputs and greater than 60dB for the 64MHz and 128MHz outputs. The signal level at each output is nominally -15dBm, which is sufficient to be input without further amplification to the Parkes AT correlator.

8. Control and Monitoring:

The conversion system is controlled by computer via an ethernet network. A terminal server drives an RS-485 bus which is connected to the conversion rack, whilst the LO synthesisers are driven with GPIB, using an ethernet-GPIB bridge. An overview of the control and monitoring hardware is shown below:-



The conversion system can be controlled either from the remote bus, or locally using a purpose built display board. Serial links connect the display board to a number of interface modules.

These interface modules provide interface logic between the dataset bus and the actual RF switches and attenuators. It is possible to set all of the controls simply by writing to a register within the interface module, and then to interrogate the status of a control simply by reading from the register. A 16 bit ADC and 48 input analogue multiplexer is also provided in each interface module to provide analogue monitoring of signal levels throughout the conversion chain.

An event signal input to the interface modules serves to synchronise all changes in the system configuration to the start of an integration cycle. In this way, almost no observing time is lost as the result of minor system reconfigurations, as is commonly done from one cycle to the next.

The interface modules and display utilise programmable logic [9] to greatly simplify board design. Much of the logic design was carried out using VHDL. The interface module firmware has since been reused in other applications, both at Parkes and the Narrabri Compact Array. The Compact Array antennas will shortly be retrofitted with similar conversion system control hardware and software.

A suite of programs, written under Unix and Windows, allow remote control and monitoring of the entire conversion system via TCP/IP using an intuitive graphical user interface. The conversion system is physically connected to the Parkes local area network, which in turn is connected to the internet. It is hence possible for astronomers and engineers to remotely control the system from the ATNF labs in Sydney.

9. Results:

The system has been used for observations at L band, S band, and K band. Although it is still relatively early in the lifetime of the system, it has thus far shown excellent long term gain stability, with clean passband spectra.

The Compact Array conversion system, upon which it is based, shows better than +/-0.05dB gain variation over a 12 hour observing period.

10. Acknowledgements:

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