ATNF Interference Mitigation – Strategic Plan

AT/31.6.7/041

1. Introduction

Strategic interference mitigation is concerned with developing ways of processing radio telescope data, either off-line or in real time, to minimise the effects of RFI. As well as direct applicability to existing and upgraded instruments (e.g., ATCA, VLA), interference mitigation strategies are central to the system design of the next-generation radio telescope, the square-kilometre array (SKA). While aiming to demonstrate and exploit mitigation techniques using Parkes and the ATCA, many of the ATNF's projects are, in fact, ultimately directed towards the SKA application.

The attached diagram is a summary showing the main ATNF operational and strategic interference mitigation (IM) projects. These projects complement US and Dutch IM efforts and, indeed, the themes of the ATNF work have allowed us to assist NRAO by supporting a Major Research Instrumentation request submitted recently to the US National Science Foundation. NRAO is seeking funding of $US1M p.a. over their triennium funding period 2000-2002; the ATNF has undertaken to fund its three strategic directions (see diagram) to at least 30% of this amount over the same period.

Broad descriptions of the strategic projects are given below.

2. Robust Receivers for Radio Astronomy

This projects has two parts:

(a) a design study to examine the deficiencies of conventional receivers in high RFI environments and to suggest effective ways of implementing more robust systems for upgraded and new-generation telescopes, including the square-kilometre array;
(b) delivery of a prototype centimetre-wave receiver (2.5 – 3.5 GHz) based on new engineering approaches.

Four already identifiable areas of new engineering include:

(i) high dynamic range circuit elements, including low-noise amplifiers, based on monolithic microwave integrated circuits (MMICs), a developing technology to which the ATNF is committed via a separate $A2.4M project;
(ii) very low-loss RF band-stop filters based on high-temperature superconducting planar filters, an area in which the ATNF and its Australian partners have exceptional capabilities in areas ranging from design through to the final testing and integration stages;
(iii) IF band-stop filters using photonic elements (including optical-fibre grating resonators), an emerging and still experimental technology which may prove especially applicable in new-generation, wideband, telescopes relying on optical fibre signal distribution;

(iv) adaptive RFI cancellation technology using hardware digital signal processing, a technology which has been demonstrated in basic form by NRAO but which requires more development to be practical in broadband astronomy systems subject to multiple interferers.

Of these four areas of engineering, only (i) forms part of the ATNF undertaking to NRAO's Major Research Instrumentation proposal.

3. Post-Correlation Interference Cancellation

This is an investigative project designed to explore the closure phase properties of interference received in either the focal plane (as in a single-dish telescope) or in the aperture plane (as in arrays). The project aims to build on first results from the AT Compact Array and the Parkes Telescope which show that interference obeys closure phase relationships to a high degree of accuracy, at least with array phase rotation inoperative. The study aims to establish the validity of phase closure relationships in the presence of phase rotation; to complete a theoretical study of the differences and similarities between the post-correlation approach and RF/IF adaptive nulling; and to produce workable self-calibration algorithms for interference removal in both array data and data collected from single-dish telescopes having multi-feed arrays (such as the 13-beam Parkes system).

4. Software Radio Telescope (Including Null Steering)

This project involves sampling and processing telescope data streams prior to detection or correlation, initially using the S2 VLBI recording system for data transport. Fully-sampled data will be processed using either workstations (for initial algorithm development) or a super-computer based at the Swinburne University of Technology in Melbourne. A number of software interference excision techniques will be explored, with particular emphasis to be directed to array pattern null-steering techniques. As well as the obvious development of improved imaging software, the work has value in testing and evaluation of hardware algorithms prior to any on or off-line implementation. In effect, the project will include a powerful general-purpose computer as part of the telescope receiving system: an experimental version of the architecture needed in next-generation instruments such as the square-kilometre array.

Preliminary work is underway at the ATNF and initial results (exploiting the flexibility of the AT Compact Array systems) suggest that basic interference suppression techniques can be demonstrated early in 2000. Milestones include the definition of a software environment for supercomputer signal processing; the international release of an atlas of actual RFI to assist other workers in the field; the development and trial of data acquisition hardware and correlation software; the demonstration and formal comparison of classes of interference excision algorithms; and a top-level design study for hardware processors.

Much of this research will be conducted by a recently-appointed ATNF postdoctoral fellow, and colleagues working at the Swinburne University of Technology and the SETI Institute. Swinburne has also pledged substantial supercomputer resources to the project.

5. Resources Summary

The table below sets out capital and manpower needed to pursue various strategic projects over the course of the next triennium. Resources quoted are incremental; in some cases it is assumed that manpower and incidental funding comes from existing operational base levels.

Project	**Item**	**Priority**	**Capital Cost ($Ak)**	**ATNF Manpower (m-yr)**
Robust Receivers	Design Study	1	20	1
	High Dynamic Range RF/IF Modules (MMIC)	1	50	2.5
	Bandstop Filters: High Temp. Superconductor	1	30	0.5
	Bandstop Filters: Photonic	1	25	
	Digital Adaptive Canceller	1	150	3
Post-Correlation Signal Processing	Aperture Plane (Arrays)	1	10	
	Focal Plane (Single Dish)	1	10	
Software Radio Telescope	Interference Atlas	1	40	0.5
	Cancellation Algorithm Development	1		
	Development Workstation + DMA Card	1	30	
	Tape-Computer Interface	1	10	0.3
International Collaboration	Overseas Advisory Travel/Expenses	1	30	
	Workshop	1	20	0.3
	Group Member Travel	2	30	

6. Notes on Individual Items

Design Study

This study will be conducted in conjunction with US and Dutch co-workers. The intention is to define the requirements for various receiver stages (in both conventional and SKA applications) and to identify ways in which dynamic range can be preserved without unacceptably compromising, e.g., equivalent noise temperature. The study would also examine broadly issues associated with digital signal processing, especially as they relate to RF, IF and signal distribution system definition.

High Dynamic Range RF/IF Modules (MMIC)

This project will examine circuit devices and system topologies suitable for realising RFI-tolerant, highly integrated, cm-wave, receivers. An obvious application is the SKA but products of the project, such as low-noise amplifiers, mixers and IF amplifiers, also have application in upgraded telescopes requiring highly linear processing stages prior to e.g. digital notch filters or adaptive cancellers. The intention is to make use of the growing ATNF MMIC design capabilty and to transfer promising system topologies to planned multi-project chips.

Bandstop Filters: High Temperature Superconductor (HTS)

When sensitive receivers are subject to very high-level interference (e.g. TV and certain satellites), the only feasible way to maintain system linearity may be to excise the interference prior to the receiver. In low-noise astronomy applications, filters to block the interference must be exceedingly low loss (<0.1 dB) if the noise temperature of the radiometer is not to be raised too much. HTS filters may offer a way of realising filters which have good shape factors (sharp edges in the frequency domain), yet low loss. The filters use a planar construction and operate at 70K, making them compatible with the relatively standard cryogenic coolers used on radio telescopes. The ATNF is collaborating with James Cook University, CTIP, and Australian industry in this development. Although this work is the subject of an Australian Research Council funding application, the estimates given assume no additional project impetus; the ARC outcome should be known by the end of 1999.

Bandstop Filters: Photonic

Photonics is the branch of engineering dealing with the combination of optical and electronic signal processing. Developments in photonics have made it plausible to contemplate broadband, high dynamic range, signal distribution networks, together with integral optical-fibre band-elimination filters. This technology is obviously most attractive in telescopes making extensive use of fibre, such as a number of proposed SKA designs. It is proposed that a design and prototyping contract be undertaken by the Sydney-based Photonics Co-operative Research Centre.

Digital Adaptive Canceller

NRAO has demonstrated a prototype, narrowband (1 MHz), adaptive RFI canceller using generic digital signal processing hardware. This project aims to construct a similar cancellation system, but to extend the single-unit bandwidth to at least 32 MHz, perhaps using custom hardware and a parallel processing architecture. While straightforward adaptive filter algorithms could form the heart of the processor, there is considerable scope for collaboration with the “software radio telescope” project in the development of improved cancellation algorithms.

Post-Correlation Signal Processing

Resource estimates in this area relate to incremental costs in providing a relatively powerful development workstation, together with an allowance for staff support to the principal investigator.

Interference Atlas

This project involves the collection of single-dish and array data streams containing a wide selection of astronomy and interference signals. The intention is to use the data as a convenient test set for ATNF and international programs developing software or hardware RFI mitigation techniques. Data will be available in standard astronomical and engineering formats (FITS, Matlab), most likely via optical media such as CD or DVD. Resource estimates cover the production and distribution of an initial CD set, the purchase of a DVD ROM writer (when media formats are standardized), and the release of a DVD atlas.

Development Workstation and Tape Computer Interface (TCI)

These components are the main elements of the ATNF section of the software radio telescope; similar equipment already exists at Swinburne. The TCI allows signals from an S2 VLBI playback terminal (the ATNF standard) to be captured by a direct memory access (DMA) card in the workstation. Data streams corresponding to outputs of individual antennas in the ATCA, or beams in the Parkes multi-beam, are then available as inputs to software-based RFI cancellation algorithms.

International Collaboration

Interference mitigation is a fast-moving area of radio science, with a number of international groups producing new results. To ensure that programs remain complementary, and to maximise creative output, it is essential that local researchers foster and participate in collaborative gatherings. The resource estimates include travel and expenses for international experts visiting the ATNF, funding for at least one international workshop to be held in Sydney, and travel expenses for ATNF staff wishing to participate in off-shore conferences.

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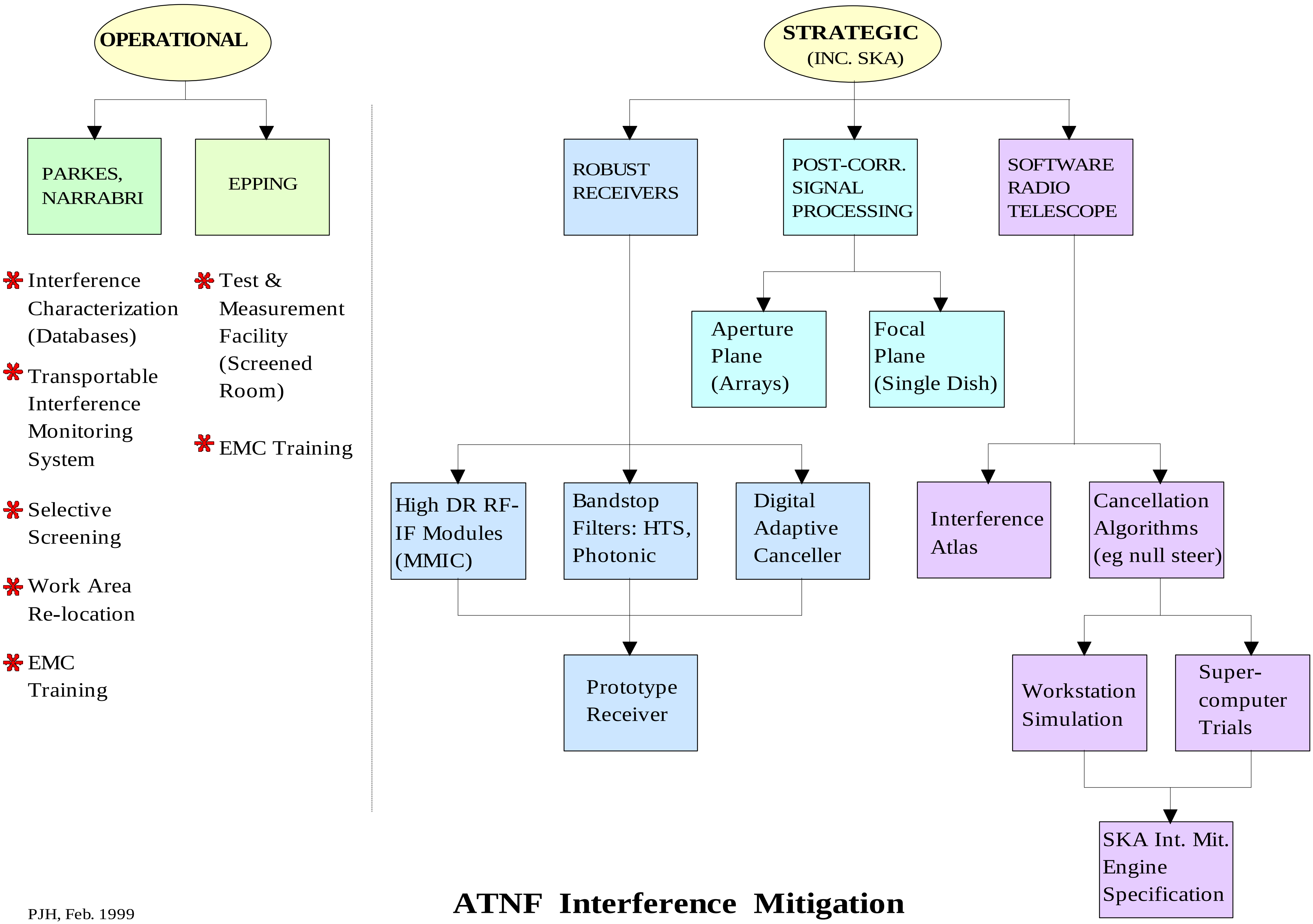

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