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TECHNOLOGY DEVELOPMENT FOR THE SQUARE KILOMETER ARRAY
WORK DONE UNDER NSF/ATI GRANT 0138263 2002.5 - PRESENT

The US SKA Consortium

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ABSTRACT

This report summarizes work done under a three-year grant from the NSF for preliminary work for the SKA project. Areas of work include optics of LNSD concepts, development of antenna concepts that address science requirements, investigation of broadband feeds, several studies of radio frequency interference characterization and mitigation, development of an SKA simulator, studies of an SKA correlator, configuration analyses, and studies of survey capabilities of SKA designs based on the LNSD concept. The grant has also supported travel by members of the USSKA Consortium to attend International SKA Steering Committee meetings in Capetown, South Africa and Penticton, CA. The grant also supported US participants in an SKA science workshop in Leiden (November 2003) and it has has supported the International SKA Project Office (salary and travel for the Director).

Subject headings: Square Kilometer Array; antennas; radio frequency interference (RFI)

1. INTRODUCTION

The grant supports technology development for the US concept for the Square Kilometer Array under the auspices of the US SKA Consortium, involving 11 member institutions. Cornell University is the lead institution on the NSF grant and J. Cordes is the PI. It also supports subcontracts for antenna and feed design and operations of the International SKA Project Office (ISPO). Under the received funding, work at the following institutions is supported: Caltech/JPL, Chalmers University (Sweden), Cornell University/NAIC, Haystack Observatory/MIT, Ohio State Observatory, Virginia Polytechnic, ASTRON (Netherlands) (ISPO).

During the 2003-2004 reporting period, the OSU invesigator (S. Ellingson) moved to Virgia Tech, which has now become part of the US SKA Consortium. Funds have also been contributed to the International Project Office to support 1/3 FTE for the Project Director position, currently held by Dr. Richard Schilizzi (ASTRON, the Netherlands). As part of the work lead by S. Weinreb at Caltech, funds were directed to Dr. P-S. Kildal (Chalmers University, Sweden) to investigate a new design for a broadband feed antenna.

In the following, we describe the work areas of the grant, activities and findings and publications.

2. PRELIMINARIES

Under the grant, we have focused on those items we considered most crucial for developing the US concept for the SKA, the Large-N Small Diameter (LNSD) approach, where N is the number of antennas in the array. The crucial areas are identified while taking into account that significant, complementary activity is taking place for other projects that nonetheless provide input to SKA development: the Allen Telescope Array (ATA), the Deep Space Network (DSN), and the Low Frequency Array (LOFAR). LOFAR is proceeding in the Netherlands and is being redefined in the US. Nonetheless, the significant amount of work done on LOFAR internationally contributes to the overall project definition for the SKA.

The SKA will allow a huge increase in the *discovery space* of radio astronomy while providing an arsenal of tools to be used for analysis and understanding of known and newly discovered sources.

A strawman version of the LNSD concept for the SKA consists of:

1. An array of $\sim$ 4400 small-diameter paraboloids ($\sim$ 12 m) arranged in a scale-free configuration on baselines from 15 m to $\gtrsim$ 5000 km.

2. An operating frequency range from ~ 0.15 to $\gtrsim 25$ GHz.
3. Transmission of wideband signals from individual antennas (inner $\gtrsim$50% of array) and from antenna stations ($\lesssim 50\%$) to a central processor for correlation and/or beam forming.
4. Modes of operation that will allow a wide range of imaging and non-imaging science, including high-dynamic range mapping on scales from arcminutes to submilliarcseconds and blind surveys for pulsars, other sources of transient signals, searches for ETI, and overall flexibility to allow appropriate observations of new kinds of sources that almost certainly will be discovered.
5. Redundancy and fault-tolerance for minimizing maintenance and operations costs.

We emphasize that the nominal 12 m diameter is just that; only after detailed electromagnetic analyses, manufacturing feasibility studies, consideration of electronics and signal processing costs will a dish diameter be chosen.

3. ANTENNAS, ANTENNA OPTICS AND RECEIVERS

Antenna Optics Studies (G. Cortès, Cornell working with S. Weinreb (CIT/JPL), P-S. Kildal (Chalmers), and the ATA group):

2002: We explored the design space for a classical symmetric antenna design for the SKA using an ATA feed. We obtained the values of the system magnification (Sub-reflector eccentricity) for a 12m aperture antenna and 1.2m sub-reflector diameter. We obtained a value of f/D=0.3469 with a sub-reflector subtended angle of 45 deg and a foci separation of 0.8m for a Cassegrain design, and 0.4m, for a Gregorian configuration. We obtained full antenna radiation patterns with the feed in a prime focus configuration, from 150 MHz to 1.200 GHz. We also obtained the antenna noise temperature as a function of elevation form 0 to 90 deg. And finally, obtained the antenna G/Tsys as a function of frequency. One of the conclusions was that a prime focus symmetric configuration antenna with an ATA feed will comply with the SKA specs for frequencies ¿ 0.600 MHz.

2003: Analysis of the TRW feed: we analyzed and corrected the TRW feed patterns for polarization. We found that the polarization angle of the TRW feed rotates back an forth as a function of frequency. We found the optimum polarization angle of the feed patterns from 0.5 to 2.5 GHz. Then we used the corrected patterns to evaluate the prime focus antenna performance for a symmetric SKA concept with this type of feed.

In order to make this evaluation we varied the focal ratio of the prime reflector from f/D=0.25 to 0.65, and obtained full antenna radiation patterns, values of Gain and Aperture efficiency, and Antenna noise temperature as a function of elevation from 0 to 90 deg for frequencies from 0.5 to 2.5 GHz.

We found the optimum aperture efficiency (Gain) occurs at f/D=0.5, but the optimum value of A/Tsys, for an antenna elevation of 45deg, occurs at f/D=0.385

We completed the implementation of a Physical Optics (PO) code for the low frequency end analysis of the SKA for frequencies below 1.4 GHz. Using the PO code we analyzed the US-SKA off-set design using the TRW feed at prime focus, at 0.500 and 1.400 GHz. For this design we found high values of cross-pol, around -14.5 dB, for both 500 MHz and 1.4 GHz. Other than that, the overall antenna pattern was well defined, with a side-lobe level of -20dB at 500 MHz, and -18.4 dB at 1.400GHz.

We also analyzed the symmetric design using the TRW feed at prime focus at 0.5 and 1.4 GHz. We found a better cross-pol performance, with cross-pol values better than -23.4 dB at 500MHz and better than -18.4 dB at 1.4 GHz

2004: We made an study to obtain reliable data on the low frequency end performance of a symmetric antenna design for the SKA, between 100 and 200 MHz. In order to improve performance by reducing the spillover for prime focus operation, we analyzed two types of extension meshes that will be perfect reflectors at the low frequency and have a cross-section of half or less compared to a solid metal sheet.

One (Mesh-A) consists of a 2 m cylindrical extension to the 12m rim dish and the other, (Mesh-B) is a parabolic extension to 16m in diameter. We calculated full antenna radiation patterns at 100 and 200 MHz, using two different feeds that have equivalent radiation patterns as the Kildal or TRW feed's patterns.

Both, Mesh-A and Mesh-B showed improvement compared with the No-mesh 12m design in terms of reduce ground noise. Nevertheless, at these frequencies, the sky brightness temperature is very high and dominates the antenna noise temperature compared with the ground noise emission. In terms of A/T, Mesh-B gives better performance. In particular, Mesh-B brings the antenna well within the specifications for the SKA at 200 MHz.

Included in this study, we analyzed the input Matching efficiency as a function of frequency. It is showed a periodic reduction in antenna efficiency as a function of frequency resulting from the presence of standing waves between the main reflector and the prime focus feed of the order of +/- 0.2 dB. This coupling may be minimized by the use of a cone spoiler, to move energy away from the blocked portion of the main reflector.

Work in Progress: Focal plane array studies from 700 MHz to 1.4 GHz.

Antenna and Manufacturing: (S. Weinreb, CIT/JPL)

Hydroforming Process Model

2002-2003: The process for hydroforming precise reflectors has been empirically developed by Andersen Mfg Co. A computer model of the process can help to improve accuracy and quantify parameters which may change as large number of reflectors are formed. A model study was conducted for several months by Dimitrios Antsos, a Caltech Ph.D. experienced with computer modeling, utilizing the LS DYNA non-linear finite-element analysis program. The results predicted the reflector spring back of approximately 8mm to within 0.5mm and are documented in a final report, Sheet Metal Hydroforming for Parabolic Antenna Applications.

2003-2004: A versatile 12m/16m antenna was conceived with a hydroformed aluminum inner 12m diameter for frequencies up to 35 GHz surrounded by a 2m wide mesh surface to form a 16m reflector for frequencies under 2 GHz. This doubles the sensitivity of the US SKA concept in the frequency range 0.1 to 1.4 GHz of great scientific interest. The design was described by Weinreb at the SKA 2004 Penticton Symposium in the paper, US SKA 12/16m Concept. Under NASA funding: 1) three 6m symmetric reflectors were hydroformed by Andersen Mfg Co to an rms accuracy of 0.2mm which would be excellent for the SKA frequency range. 2) a 6m antenna was cut in half and rejoined as a test of a transportation method for 12m antennas from factory to site.

Antenna Mount Mechanical Design

2002-2003: A highly-experienced antenna mechanical engineer, Roger Schultz, was contracted to perform a design and cost study of the US SKA antenna element starting with a 6m design. (This design was the basis of 6m antennas that have been constructed at JPL.) The work was documented in 6m Antenna Design Presentation, April 8, 2003.

2003-2004: Roger Schultz continued the mount design fro the 12m/16m reflector and completed a conceptual design which includes the cut and join operation to facilitate shipment. An initial computation of the rms deflection of this structure due to gravity gives .05mm which is excellent for SKA. Further studies and optimization of the design will be performed in late 2004 and 2005. The present status is documented in Radio Astronomy Antennas by the Thousands, presented at the SKA 2004 Penticton Symposium.

Wideband Antenna Feed Design (S. Weinreb, CIT/JPL)

2002-2003: A log-periodic feed with a phase-center which does not change with frequency was invented by Per-Simon Kildal, a professor at Chalmers University, Sweden, and his group has been contracted for optimization and testing of the feed for the SKA application. Dual-polarized feeds with good efficiency over decade bandwidths appear to be feasible. The work during this period is documented in Studies of Chalmers Feed for US-SKA Collection of Project Memos and in the MSEE thesis of Rikard Olsson, A Study of Wideband Feeds in Cylindrical Shield for Use in Large Radio Telescopes. The latter report shows that it is difficult to obtain good efficiency with a log-periodic feed in a cylindrical cryogenic vacuum dewar unless the dewar diameter is a few times greater the feed width. For feeds at frequencies ¿ 1.2 GHz, the feed width will be ¡ 12.5cm and this would not be a problem in a dewar of 30cm diameter.

2003-2004: The work of Kildal and Olsson continued with further optimization of the feed geometry for dual polarization, consideration of the back reflector design, construction and

test of a single-polarization, 1 to 6 GHz first prototype, and design and fabrication of a dual-polarization, 1.2 to 11 GHz , second prototype that will be tested in late 2004. The work has been documented in a paper, A Novel Low-profile Log-periodic Ultra Wideband Feed for the Dual-reflector Antenna of US-SKA, presented at the 2004 IEEE Antennas and Propagation Meeting. In addition, Olsson has written 3 more memos; the titles and abstracts of these memos are included in Chalmers Memos 1 to 8 Abstracts.

Wideband MMIC LNA Design

2002-2003: The SKA requires very low noise amplifiers with decade bandwidth. Monolithic Microwave Integrated Circuits (MMIC) technology utilizing indium-phosphide (InP) transistors is the choice technology for this g oal In addition all the decade bandwidth feeds have balanced output which requires a differential input LNA or active balun. Both these devices were successfully des igned and tested at Caltech by S. Weinreb and N. Wadefalk. The results are described i n Caltech Status Report -2003 reported to the US SKA meeting in Pasadena, October 3, 2003.

2003-2004: A test set for testing the noise of cryogenic active and passive baluns driven from a floating 200 ohm generator impedance (typical for wideband antennas) and measurements at 15K, 77K, and 300K are reported in the memo, Noise Testing of Active and Passive Baluns, by N. Wadefalk and S. Weinreb, September 7, 2004. The test results show that the active balun has excellent low noise in the frequency range 0.5 to 10 GHz, with values ¡ 8K at 12K physical temperature and ¡ 20K at 77K physical temperature. MMIC LNAvs for 11 to 34 GHz have been designed and are being fabricated and the development of a 0.7 to 1.4 GHz LNA with a goal of ¡ 10K noise at 200K (thermoelectric cooler) has started. The latter is an necessary part of a low cost focal plane array for the 12/16m antenna concept.

Satellite Time Transfer System:

2003-2004: A system for transferring a phase reference from one location to another via a commercial satellite was designed, built, and tested by Joseph Bardin, a UCLA graduate student under supervision of S. Weinreb. The system achieves 3ps accuracy in a test with co-located terminals and outperforms hydrogen masers for time durations ¿ 10,000 seconds. Further tests with separated stations are needed. The work is reported in the paper, Local Oscillator Distribution Using AGeostationary Satellite, by J. Bardin, S. Weinreb, and D. Bagri presented at the SKA 2004 Pentiction meeting and submitted to the special SKA issue of Experimental Astronomy.

4. CORRELATOR STUDIES

6/2002 - 9/2003: The MIT team also worked on data processing architectures for large-N arrays. Recognizing that the scaling of advanced correlator designs is likely to place constraints on LNSD designs, methods for minimizing interconnection costs and efficiently utilizing low-cost FPGA-based computing resources were investigated. This work was synergistic with, and heavily supported by, MIT involvement in the development of low frequency arrays, funded independently by the NSF.

9/2003 - 9/2004: Correlator architectural work was continued and extended during this period. The principal purpose of this work was to develop a detailed design for use with the proposed Mileura Widefield Array (MWA) demonstrator, but applicability to the SKA problem has been a consistent and important consideration. The basic design is described in "Design of the LOFAR Wide Field Correlator" by Morales and Cappallo (2004) (link at web.haystack.mit.edu/MWA/mdocumentation.html). The adaptation of this design to wider bandwidths for the MWA demonstrator, and the physical realization of the correlator are seen as important pathfinder activity for LNSD correlation methods.

5. CHARACTERIZATION AND MITIGATION OF RFI

Work on radio frequency interference has been on several fronts, as is appropriate for the many types and affects of RFI.

RFI Characterization and Mitigation Algorithms: (S. Ellingson, OSU and VT).

2002-2003: Using data we had already collected using Arecibo, thoroughly analyzed the radar waveforms observed. Identified many exploitable aspects of the modulation, as well as a few

things which represent difficulties for RFI mitigation (like, the prevalence of very weak, long-delayed multipaths in an exponential decay with respect to time and distinct from discrete aircraft echos).

Used a 200-MSPS (50 MHz BW) data acquisition system at Arecibo to collect more data with higher time resolution.

Using data described above, evaluated the performance of both time-domain pulse blanking algorithms as well as a novel coherent estimation and subtraction technique against the Arecibo radar datasets. Found, interestingly, that it is usually the failure to detect weak pulses, as opposed to the quality of the removal, that tends to be the limiting factor in RFI mitigation performance. Results published in ApJS.

Did a study to try to better understand the ultimate limits of performance of adaptive canceling techniques generally. Developed some simple expressions for maximum suppression in terms of signal to noise ratios for various types of algorithms in this class of techniques. (Technical report and a conference presentation).

With Gerry Harp of the SETI Institute, developed a class of algorithms for large-N nullforming that allow arbitrary and deterministic selecton of pattern constraints simultaneously in both angle and frequency, achieving wideband performance with a single complex multiply per antenna element. (Technical report)

Using the experimental Argus radio telescope at Ohio State, conducted several high-sensitivity all-sky surveys; some in L-band, one at VHF. Documented in several technical reports.

2003-2004: Organized and served as co-chair of the "Workshop on RFI Mitigation in Radio Astronomy" (RFI2004), which was collocated with SKA 2004. Details (web sites, etc) appear below.

Using Argus as a testbed, conducted a detailed characterization of the Iridium waveform, and developed pulse-blanking and array nulling techniques to mitigate it. (Presented results at RFI2004.)

Also using Argus, demonstrated the ability of an uncalibrated array to "blindly" detect the presence of RFI anywhere in the sky, with nearly the full sensitivity of the array. Further demonstrated the ability to estimate the number of sources present, and (using a very rudimentary single-source calibration) to locate them in the sky.

Served as organizer and chair of the Working Group on RFI Measurements, which was convened by the Int'l SKA site selection committee to develop the standard for measurement of RFI at candidate SKA sites. Resulted in a technical report (the measurement protocol).

Served as chair of the LOFAR technical advisory committee (until the international consortium dissolved in Feb 2004), which addressed many issues pertaining to RFI and it's implications for large arrays.

Served as an evaluator for site reports on RFI at the 3 candidate LOFAR sites.

RFI Identification and Mitigation using Simultaneous Arecibo-Green Bank Observations
(R. Bhat Haystack/MIT, J. Cordes, Cornell)

2002-2004: RFI mitigation is a critically important issue in radio astronomy using existing instruments as well as in the development of next-generation radio telescopes, including the SKA. Most designs for the SKA involve multiple stations with spacings up to thousands of kilometers and thus can exploit the drastically different RFI environments at the different stations for efficient RFI identification and mitigation procedures. As demonstrator observations for SKA-like instruments, and with the general goal of development of RFI excision methods for science applications that involve fast-sampled spectrometer data (e.g. pulsar astronomy, transient searches), we conducted simultaneous observations with the Arecibo and Green Bank Telescopes in November 2003. As part of this experiment, data were gathered on the Crab Nebula pulsar, the M33 galaxy, and some UGC galaxies in the L band frequency range from 1.1 to 1.9 GHz. The receivers and spectrometers used at the two telescopes are of similar design, and in addition data recording was made at identical resolutions in time and frequency, a prime requirement for such experiments. The work led to the development of an algorithm for identification and excision of RFI in fast-sampled spectrometer data. It involves application of

a two-dimensional median filter, followed by a series of thresholding and excision performed in stages, and possibly in multiple passes, to yield the best results. We demonstrated the method to be sensitive to a wide variety of RFI, and can be used to generate RFI "masks" for input to applications such as pulsar data processing and spectroscopy in bands heavily contaminated by RFI.

The prevalence of impulsive RFI has long been recognized as a major difficulty in transient event detection schemes applicable to time series data. We exploited the dual-site, wideband nature of our data on the Crab pulsar to explore effectiveness of multiple-site and multiple-subband approaches to help discriminate between real events (e.g. giant pulses) and the spurious ones caused by RFI. The basic idea involves examining the coincidence vs anti-coincidence of the detected events after taking into account the dispersion, instrumental and other delays, and a comparison of their detailed characteristics such as strength, spatial grouping, time-frequency signature etc. Our analysis also shows the subband technique to be an efficient scheme for filtering out real signals from the likely forest of events in the subbands with RFI-rich environments. While such multi-site and multi-subband based approaches are especially relevant for SKA-like instruments (i.e. multiple stations at large separations), the general scheme can be extended and suitably adapted for the current and planned multi-pixel instruments such as the Arecibo L-band Feed Array (ALFA) and the Mileura Widefield Array (MWA).

This work was presented at the RFI2004 workshop in Penticton (2004 July) and submitted to Experimental Astronomy (in press). A follow-on analysis will be submitted to the Astrophysical Journal.

6. CONFIGURATION STUDIES

Work done by C. Lonsdale et al. (Haystack)

6/2002 - 9/2003: Efforts also included parameterization of SKA configurations for the Large N - Small D USSKA concept and evaluation of families of SKA arrays evaluated. These searches and results were presented at both the International SKA meeting in Geraldton (July 2003 by C. Lonsdale) and at the Columbus, OH. URSI meeting (June 2003 by R. Bhat). Software modules to generate families of SKA configurations for the Large N - Small D concept were developed and used to drive automated searches through configuration space.

7. SKA SIMULATOR DEVELOPMENT

6/2002 - 9/2003: During this period, Haystack simulator efforts concentrated on adapting the LOFAR simulator package, developed for a low frequency moderate baseline length array, for use in full SKA simulations. This involved expanding the software to handle 1000's of individual stations instead of 10's. The new package is now called MAPS (MIT Array Performance Simulator) and was developed at MIT to output synthetic SKA data sets that incorporate noise and widefield image plane effects such as ionospheric disturbances and station-level beamforming. These data sets are analysed using script driven routines written to call standard radio astronomical imaging packages (MIRIAD, AIPS, AIPS++) to calculate figures of merit for SKA configurations. These figures of merit include synthesized beam shape, size, and a full description of beam noise statistics.

9/2003 - 9/2004: For the past year, Haystack has collaborated with a group at Swinburne University in Melbourne, Australia to make MAPS available to the US and International SKA communities via a web interface. The MAPS code was exported to a 150 node supercomputing cluster in Swinburne and users can run compute intensive simulations by submitting jobs via a graphical user interface (http://astronomy.swin.edu.au/ska/Simulator/). Due to its flexibility, MAPS has been chosen as the software package to evaluate all SKA concepts and is now the kernel of simulation and configuration efforts for the international SKA effort. A workshop for MAPS applications was given by R. Bhat at Swinburne University in February 2004.

9/2003 - 9/2004: MAPS has also been a key part of new algorithm development for USSKA concept arrays. An issue of concern is whether data from the large number of antennas in the USSKA concept can be processed and imaged with an affordable amount of computational power when the SKA is constructed. In a recent paper by Lonsdale, Doeleman and Oberoi (2004), MAPS simulations and analytical arguments are used to show that the computational burden should be tractable. This paper, presented at the International SKA Penticton meeting, describes and demonstrates new techniques made possible by high speed digital architectures that can dramatically reduce computation costs of imaging in wide fields of view. Two posters at the Penticton meeting also described MAPS architecture and SKA configuration results.

9/2003 - 9/2004: Haystack personnel have also been active members of the SKA Simulation Working Group (SSWG), which is tasked with developing measures and figures of merit to rank and judge various SKA configuration concepts.

8. STUDIES OF TRANSIENT DETECTION AMID INTENSE RFI

Work done at Cornell and Haystack.

Transient detection is related to the RFI study using simultaneous data from the GBT and Arecibo, we have investigated a number of aspects of transient detection.

2002:2003: In a major campaign at Arecibo we observed the Crab pulsar and characterized its giant pulses at 6 frequencies from 0.4 to 9 GHz. The broad distribution of pulse amplitudes is power law in form and does not have any apparent maximum amplitude. The largest seen in one hour of data $\sim$ 160 kJy at 0.4 GHz. The implications for the SKA are that this particular pulse would be detectable to about 5 Mpc. Larger pulses undoubtedly occur and can probably be detected from the Virgo cluster. This would provide very important tools for determining the electron density and magnetic field in the intergalactic medium. This work appeared in 2004 in the Astrophysical Journal (Cordes et al. 2004).

2003-2004: We have considered a number of detection algorithms for short-duration transients (microseconds to seconds) These algorithms operate on dynamic spectra obtained typically with several hundred frequency channels and millions of time samples. Our studies extend standard pulsar analyses by searching for aperiodic but dispersed signals with unknown pulse widths. We do so using matched filter algorithms and also using 'friends of friends' algorithms that first threshold the intensity in the frequency-time plane and then investigate their clustering. Experimentation along these lines was the central part of Kate Becker's MS Thesis (Cornell), *Courting Serendipity: The Search for Transient Radio Signals.* In addition to developing algorithms using pulsar data and simulated data, we also searched for transient events from extrasolar planets and/or their host stars using Arecibo data (null results).

9. STUDIES OF WIDEFIELD SURVEYS WITH THE SKA AND THEIR FEASIBILITY

Work done at Cornell by J. Cordes, W. Vlemmings et al.

To address some of the key science areas identified for the SKA, — in particular pulsar surveys and SETI — and also characterization of the transient radio sky, we have considered some of the technical requirements on the SKA. To conduct high-throughput surveys, a wide field of view (FOV) needs to be processed. By 'wide' we mean the nominal 1 deg^2 specification at 1 GHz. This is a challenging prospect because it places constraints on the array configuration and its connectivity. The number of pixels needed to sample the FOV goes as the square of the maximum baseline that is processed. Additionally, the antennas used must be connected directly to a central processor.

In our analysis we have assessed the number of operations needed to sample the FOV and also to do the post processing.

We have characterized the yield of pulsar surveys with the SKA compared to those being done with existing instruments. We have also defined a 'completeness coefficient' for transient surveys that is parameterized in terms of the instantaneous FOV and the transient time scale.

This work is written up in draft form in a technical memo *Widefield Surveys for Transients, Pulsars and ETI with the SKA*.

10. OTHER ACTIVITIES

Preparation of Whitepapers for the LNSD Concept

Support of the International SKA Project Office

11. PUBLICATIONS AND PRODUCTS

Optics, Antennas, Feeds and related subjects:

German Cortes, "Symmetric Antenna Configuration for the SKA Array Elements based on the ATA Feed". US-SKA Consortium Meeting, Ithaca, NY, Oct 2002

German Cortes "Antenna Analysis Tools Development for the SKA". US-SKA Consortium Meeting, Pasadena, CA, Oct 2003

German Cortes, "Low Frequency End Performance of a Symmetrical Configuration Antenna for the Square Kilometer Array SKA". Poster Presented at the 2004 International SKA meeting in Penticton, British Columbia, Canada, July 2004.

paper submitted to Journal of Experimental Astronomy, International Journal of Astronomical Instrumentation and data Analysis, Kluwer. to appear in Jan-2005

German Cortes, "Antenna Temperature Calculation Notes", US-SKA Technical Memo Series. Ithaca, Sep 2004. Submitted to the Antenna working group of the International Consortium of the SKA.

Antsos, D, Sheet Metal Hydroforming for Parabolic Antenna Applications, Caltech Report to S. Weinreb, April 8, 2003. File: AntsosRep03B.pdf

Bardin, J., Weinreb, S., and Bagri, D., Local Oscillator Distribution Using A Geostationary Satellite, Presentation at 2004 SKA Symposium, Penticton, BC, Canada, July 21, 2004, and Submitted to SKA Special Issue of Experimental Astronomy. File TimeTransferPaper1.pdf

Olsson, R. and Kildal, P-S, Studies of Chalmers Feed for US-SKA Collection of Project Memos Chalmers Reports to S. Weinreb, March 31, 2004. File: ChalmersMemos1-5.pdf

Olsson, R. A Study of Wideband Feeds in Cylindrical Shield for Use in Large Radio Telescopes, MSEE Thesis, School of Electrical and Computer engineering, Chalmers University Of Technology, Goteborg, Sweden, August 24, 2003. File: Olsson MSThesis.pdf.

Olsson, R., Kildal, P-S, and Weinreb, S., A Novel Low-profile Log-periodic Ultra Wideband Feed for the Dual-reflector Antenna of US-SKA , 2004 IEEE URSI/APS Antennas and Propagation Meeting, Monterey, CA, July, 2004. File: APS Presentation 2004.pdf

Olsson, R., Chalmers Memos 1 to 8 Abstracts , Compilation by S. Weinreb of abstracts of memos available from rikard.olsson@elmagn.chalmers.se. File: ChalmersMemo1to8Abstracts.pdf

Schultz, R, 6m Antenna Design Presentation Caltech Presentation to S. Weinreb, April 8, 2003, File: SchultzRep03.pdf.

Schutz, R. , Radio Astronomy Antennas by the Thousands, Presentation at 2004 SKA Symposium, Penticton, BC, Canada, July 20, 2004. File: Radio Astronomy Antennas by the Thousands.pdf

Wadefalk, N., and Weinreb, S. Noise Testing of Active and Passive Baluns Caltech Microwave Group Memo, September 7, 2004. File: BalunTests04.pdf

Weinreb, S. Caltech Status Report -2003, Presentation to the US SKA meeting in Pasadena, October 3, 2003. File: StatusRep03A.pdf

Weinreb, S., Versatile 12m/16m Antenna for the SKA, Presentation at 2004 SKA Symposium, Penticton, BC, Canada, July 21, 2004, File: SKA12-16mConcept.pdf

Correlators and Postprocessing:

Lonsdale, C., Doeleman, S. & Oberoi, D. 2004, "Imaging Strategies and Postprocessing Computing Costs for Large-N SKA Designs", to appear in Experimental Astronomy - Proceedings of the Penticton SKA meeting.

Radio Frequency Interference Characterization and Mitigation:

Journal Papers

S. Ellingson, "RFI Mitigation and the SKA," submitted to Experimental Astronomy, August 2004. http://www.ece.vt.edu/ swe/mypubs/expa04.pdf

N. Niamsuwan, J.T. Johnson, S.W. Ellingson, "Examination of a Simple Pulse Blanking Technique for RFI Mitigation," submitted to Radio Science, August 2004. http://www.ece.vt.edu/ swe/ska1/RFI2004_NJE.pdf

S.W. Ellingson and G.A. Hampson, "Mitigation of Radar Interference in L-Band Radio Astronomy", Astrophysical Journal Supplement Series, 147(1):167-176 (July 2003). Attached: 57544.web.pdf

S.W. Ellingson, "Beamforming and Interference Canceling with Very Large Wideband Arrays", IEEE Trans. Antennas and Propagation, Vol. 51, No. 6, June 2003, pp. 1338-46. Attached: 01208754.pdf

S.W. Ellingson and W. Cazemier, "Efficient Multibeam Synthesis with Interference Nulling for Large Arrays", IEEE Trans. Antennas and Propagation, Vol. 51, No. 3, March 2003, pp. 503-511. Attached: 01201327.pdf

Conferences/Workshops

S. Ellingson and P. McDougle, "Iridium: Characterization and Countermeasures," Workshop on Mitigation of Radio Frequency Interference in Radio Astronomy (RFI2004), Penticton, BC, 2004. http://www.ece.vt.edu/ swe/rfi2004/16.pdf

N. Niamsuwan, J. T. Johnson, and S. W. Ellingson, "Examination of a simple pulse blanking technique for RFI mitigation," Workshop on Mitigation of Radio Frequency Interference in Radio Astronomy (RFI2004), Penticton, BC, 2004. http://www.ece.vt.edu/ swe/rfi2004/3.pdf

S.W. Ellingson and G.A. Hampson, "Detection and Localization of L-Band Satellites Using an Antenna Array", 2004 IEEE Antennas & Propagation Soc. Int'l Symposium, Monterey, CA, June 2004 (1:177-180). http://www.ece.vt.edu/ swe/argus/aps04a.pdf (paper) http://www.ece.vt.edu/ swe/argus/aps04_slides.pdf (presentation)

G.A. Hampson, S.W. Ellingson, and J.T. Johnson, "Design and Demonstration of an Interference Suppressing Microwave Radiometer", (PDF) 2004 IEEE Aerospace Conference, Big Sky, MT, March 2004. Also, here are the presentation slides (PDF). http://www.ece.vt.edu/ swe/mypubs/aes04.pdf (paper) http://www.ece.vt.edu/ swe/mypubs/grant_aero.pdf (presentation slides)

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S.W. Ellingson, "Detection of Tones and Pulses using a Large, Uncalibrated Array", 2003 IEEE Antennas & Propagation Soc. Int'l Symposium, Columbus, OH, June 2003 (4:196-9). http://www.ece.vt.edu/ swe/argus/aps03b.pdf (paper) http://www.ece.vt.edu/ swe/argus/argus2.pdf (tech report with more details on RFI mitigation aspects)

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G.R. Harp and S.W. Ellingson, "Wideband Nulling with a Single-Tap Beamformer", 2003 URSI National Radio Science Meeting, Columbus, OH, June 2003.

Seminars

S.W. Ellingson, "Wide Field Searches for Radio Transients", U. of Minnesota Astrophysics Colloquium, Apr 30, 2004. http://www.ece.vt.edu/ swe/argus/um040430.pdf

S.W. Ellingson, "Interference Mitigation in Radio Astronomy and Remote Sensing", Virginia Tech ECE Dept. Graduate Seminar, Feb 2004. http://www.ece.vt.edu/ swe/mypubs/vt040210.pdf

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R. Ambrosini, R. Beresford, A.-J. Boonstra, S. Ellingson (ed.), and K. Tapping, "RFI Mitigation Protocol for Candidate SKA Sites", SKA Memo 37, May 23, 2004. http://www.skatelescope.org/documents/wgrm5.pdf

S.W. Ellingson and G.A. Hampson, RFI and Asynchronous Pulse Blanking in the 1230-1375 MHz Band at Arecibo, The Ohio State University ElectroScience Laboratory Technical Report 743467-3, Feb 2003. http://www.ece.vt.edu/ swe/mypubs/ap021109a.pdf

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S. Ellingson, "Characterization of the 1350 MHz Radar Received at Arecibo" (PDF), Nov 24, 2002; revised Nov 25, 2002. http://www.ece.vt.edu/ swe/ska1/ap021122.pdf

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S.W. Ellingson, "A High-Resolution Survey of RFI at 1200-1470 MHz as Seen by Argus" (PDF), October 29, 2002. http://www.ece.vt.edu/ swe/argus/rfi021016b.pdf

S.W. Ellingson, "A Survey of 1200-1800 MHz Using a Discone and a Spiral with the Argus Front End" (PDF), October 12, 2002. http://www.ece.vt.edu/ swe/argus/rfi021009b.pdf

S.W. Ellingson, "Deterministic Space-Frequency Nulling for Large Wideband Arrays", Oct 2, 2002. http://www.ece.vt.edu/ swe/ska1/wbbf.pdf

S.W. Ellingson, "Characterization of Some L-Band Signals Visible at Arecibo", The Ohio State University ElectroScience Laboratory Technical Report 743467-2, September 2002. http://www.ece.vt.edu/ swe/mypubs/ar_char.pdf

S.W. Ellingson, "A Study of Adaptive Canceling for Microwave Radiometry and Spectrometry" (PDF), The Ohio State University ElectroScience Laboratory Technical Report 743467-1, Sep 2002. http://www.ece.vt.edu/ swe/mypubs/rfi0201.pdf

S.W. Ellingson, "Analysis and Mitigation of Radar at the RPA" (PDF), informal report, Sep 2002. http://www.ece.vt.edu/ swe/ska1/rparadar.pdf

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Outreach

Web site for VT-based work on this project (but including RFI-relevant info from other projects): http://www.ece.vt.edu/ swe/ska1/

Organizer and co-chair of "Workshop on Mitigation of Radio Frequency Interference in Radio Astronomy (RFI2004)", Penticton, BC, July 2004. - Proceedings website: http://www.ece.vt.edu/ swe/rfi2004/ - Associated editor for Special Section on this topic to appear in the journal Radio Science Fall 2005.

Chairman, "Working Group on RFI Measurements" (WGRM)(Formed in February 2003 to develop standardized measurements for evaluation of RFI at SKA candidate sites). Website: http://esl.eng.ohio-state.edu/ swe/wgrm/docserv.html

Chairman, LOFAR Technical Advisory Committee, July 2002 - June 2004.

One of 5 evaluators of site RFI measurement reports for the LOFAR site selection process, 2003.

Transients:

Becker, K. 2004, *Courting Serendipity: The Search for Transient Radio Signals.* MS Thesis, Cornell University.

J. Cordes and M. McLaughlin, "Searches for Fast Radio Transients", 2003, Astrophysical Journal, 596, 1142 (Work supported by this grant in part and also by a pulsar grant to J. Cordes)

M. McLaughlin and J. Cordes, "Searches for Giant Pulses from Extragalactic Pulsars", 2003, Astrophysical Journal, 596, 982 (Work supported by this grant in part and also by a pulsar grant to J. Cordes)

J. Cordes, "Widefield Surveys for Transients, Pulsars and ETI with the SKA", Astrophysical Journal, in preparation.

"The Brightest Pulses in the Universe: Multifrequency Observations of the Crab Pulsar's Giant Pulses", (Cordes, J. M., Bhat, N. D. R., Hankins, T. H., McLaughlin, M. A. & Kern, J.), 2003, Astrophysical Journal, 2004, in press. (This work was supported in part by JMC's pulsar grant in addition to the SKA grant. Implications for SKA detection of giant pulses from extragalactic pulsars were discussed in the paper).

11.1. *Journal Publications*

1. S.W. Ellingson and G.A. Hampson, "Mitigation of Radar Interference in L-Band Radio Astronomy," *ApJS,* 147, 167
2. J. Cordes and M. McLaughlin, "Searches for Fast Radio Transients", 2003, Astrophysical Journal, 596, 1142 (Work supported by this grant in part and also by a pulsar grant to J. Cordes)
3. M. McLaughlin and J. Cordes, "Searches for Giant Pulses from Extragalactic Pulsars", 2003, Astrophysical Journal, 596, 982 (Work supported by this grant in part and also by a pulsar grant to J. Cordes)
4. J. Cordes, "Widefield Surveys for Transients, Pulsars and ETI with the SKA", Astrophysical Journal, in preparation.
5. "The Brightest Pulses in the Universe: Multifrequency Observations of the Crab Pulsar's Giant Pulses", (Cordes, J. M., Bhat, N. D. R., Hankins, T. H., McLaughlin, M. A. & Kern, J.), 2003, Astrophysical Journal, 2004, in press. (This work was supported in part by JMC's pulsar grant in addition to the SKA grant. Implications for SKA detection of giant pulses from extragalactic pulsars were discussed in the paper).
6. S.W. Ellingson, "Beamforming and Interference Canceling with Very Large Wideband Arrays," IEEE Trans. Ant. & Prop., 51, 1338 (June 2003).
7. S.W. Ellingson and W. Cazemier, "Efficient Multibeam Synthesis with Inter- ference Nulling for Large Arrays," IEEE Trans. Ant. & Prop., 51, 503 (March 2003).

11.2. *Books and other Non-Periodical, One-Time Publications*

1. M. Kramer, D. C. Backer, J. M. Cordes, T. J. W. Lazio, B. W. Stappers, S. Johnston, "Strong-Field Tests of Gravity Using Pulsars and Black Holes" 2004, to be published in SKA Science Book.

2. J. M. Cordes, M. Kramer, T. J. W. Lazio, B. W. Stappers, D. C. Backer, S. Johnston, "Pulsars as Tools for Fundamental Physics & Astrophysics" 2004, to be published in SKA Science Book.

3. T. J. W. Lazio, J. M. Cordes, A. G. de Bruyn, J.-P. Macquart, "The Microarcsecond Sky and Cosmic Turbulence" 2004, to be published in SKA Science Book.

4. J. M. Cordes, T. J. W. Lazio, M. A. McLaughlin, "The Dynamic Radio Sky" 2004, to be published in SKA Science Book.

5. P. Wilkinson, K. Kellermann, R. Ekers, J. M. Cordes, T. J. W. Lazio. "Exploration of the Unknown" 2004, to be published in SKA Science Book.

11.3. *Technical Reports*

1. 'Multibeaming discussion at Groningen' (Cordes, J. M. & Taylor, R.) 2002 October, `www.astro.cornell.edu/ cordes/documents/multibeaming.groningen02.pdf`

2. 'Addendum to Whitepaper on the Large N - Small D Design Concept', 2003 May 31, `www.astro.cornell.edu/ cordes/documents/USSKA.response.pdf` (USSKA Consortium Document)

3. 'SKA Concepts Designs – ISAC Comments', November 2002, Memo 28, `www.skatelescope.org/ska_docments.shtml` (C. Carilli and the International SKA Science Advisory Committee (J. Cordes a member of ISAC))

4. 'Radio Transients, Stellar End Products, and SETI Working Group Report' (J. Lazio, D. Backer, J. Cordes, J. Jonas, M. Kramer, M. Rupen, J. Tarter) (report from Bologna meeting on the SKA, January 2002), Bologna, IT

5. 'SKA Scientific Memorandum: Telescope Response Times (J. Lazio and J. M. Cordes), 2003 May.

6. S. Ellingson, "Characterization of the 1350 MHz Radar Received at Arecibo," Nov 25, 2002, see 11.5.2.

7. S. Ellingson & G. Hampson, "RFI and Asynchronous Pulse Blanking at Arecibo," Nov 12, 2002, see 11.5.2.

8. S.W. Ellingson, "A Survey of RFI below 270 MHz," October 29, 2002, see 11.5.2.

9. S.W. Ellingson, "A High-Resolution Survey of RFI at 1200-1470 MHz as Seen by Argus," October 29, 2002, see 11.5.2.

10. S.W. Ellingson, "A Survey of 1200-1800 MHz Using a Discone and a Spiral with the Argus Front End," October 12, 2002, see 11.5.2.

11. S.W. Ellingson, "Characterization of Some L-Band Signals Visible at Arecibo," Sep 27, 2002, see 11.5.2.

12. P. F. Goldsmith, "Notes on SKA Operations and Antenna Maintenance Budget, version 0.3, 21 Apr 2003).

13. "2004 Update on the Large-N/Small-D SKA Concept: Technology Development and Demonstrators" http://www.astro.cornell.edu/ cordes/SKA/LNSD.IEMTResponse.2004.pdf, by the US SKA Consortium.

14. Working Group on RFI Measurements, "RFI Measurement Protocol for Can- didate SKA Sites," May 23, 2003. Currently available at http://esl.eng.ohio- state.edu/∼swe/wgrm/wgrm5.pdf (Note: This URL is likely to change in the next few months).

11.4. *Presentations/Workshops*

1. J. Cordes, "The Dynamic Radio Sky and Future Instruments", talk presented at the 202nd meeting of the American Astronomical Society in special session, The Dynamic Radio Sky, 28 May 2003, Nashville, TN

2. J. Cordes and R. Taylor, "Multibeaming and Response Times for the SKA", at International SKA Meeting, August 2002, Groningen, Netherlands

3. J. Cordes, "'Issues for Studies of Radio Transients with the Square Kilometer Array", URSI Meeting, 2003 June, Columbus, Ohio

4. G. Hampson and S. Ellingson, "Modular Digital Backends for Microwave Radiometry," ALFA Pulsar Consortium Meeting, NAIC/Arecibo Observatory, November 1, 2002.

5. J. Cordes, "'Issues for Studies of Radio Transients with the Square Kilometer Array", URSI Meeting, 2003 June, Columbus, Ohio

6. S.W. Ellingson, "Report of the WGRM," 2003 Int'l SKA Workshop, Geraldton, WA, Australia, July 2003.

7. S.W. Ellingson and G.A. Hampson, "Characterization & Mitigation of L-Band Ground-Based Aviation Radars," 2003 URSI National Radio Science Meeting, Columbus, OH, June 2003.

8. G.R. Harp and S.W. Ellingson, "Wideband Nulling with a Single-Tap Beam- former," 2003 URSI National Radio Science Meeting, Columbus, OH, June 2003.

11.5. *Web Sites and Other Internet Sites*

1. The official US SKA Consortium website (now hosted at Cornell): `www.usska.org`

2. OSU SKA-RFI Document Server, `http://esl.eng.ohio-state.edu/~swe/ ska1/docserv.html`. This web site serves as an archive of all OSU documents and reports related to this topic. This web site will be moved to Virginia Tech sometime in the next few months.

3. Cornell: Memos and other documents pertaining to the USSKA Consortium's LNSD concept and other technical and scientific issues. `www.astro.cornell.edu/~cordes/SKA`.

11.6. *Other Specific Products*

1. Datasets of coherently-sampled and integrated spectra collected at Arecibo, capturing a large number of RFI sources over several hundred MHz of the L-band spectrum, are freely available.

2. Datasets from the Arecibo Observatory and the Green Bank Telescope obtained simultaneously using correlator systems at both sites. Proprietary software is now being developed along with visual displays of the interference at the two sites.