DRAFT ONLY
Copy: ISSC

Questions directed to the Engineering Management Team from the Site Evaluation and Selection Working Group

Note: This document should also be forwarded to the Science Working Group for comment.

1. Background

At the request of the ISSC, the Site Evaluation and Selection Working Group (SESWG) has prepared a draft document on issues which impact on site selection for the SKA. In preparing this draft document a number of technical issues were raised, which the SESWG considers would need to be investigated by one or more of the expert technical groups. Such information will be necessary input to countries, which express an interest in the possible hosting of the SKA.

2. Questions

A. Possible range of SKA array configurations

Given that the location of an SKA Central Site is (defined as an area of about 100 km diameter) dependent, not only on specific site related issues, but can also be influenced by the location of SKA stations extending beyond the SKA Central Site itself (i.e. "remote SKA stations"), are there any necessary requirements as to site location and maximum interference levels for the remote SKA stations? What is the likely range or variation in locating remote SKA stations relative to the SKA Central Site (where the majority of SKA stations are assumed to be located)?

B. Requirements for spectrum having low ambient noise levels

The ITU specifications (Rec. ITU-R, RA 769-1, "Protection criteria used for radio astronomical measurements", ITU, Geneva 1995) can readily be extended across a wide frequency range to indicate desirable maximum levels of interference. For the SKA, which may ultimately operate across a wide frequency range (for example, 150 MHz to 23 GHz):

(a) For the SKA Central Site, what proportion of spectrum (total, and also contiguous bandwidth (which may be a function of frequency)) should have a "natural" low ambient noise level? If “transient” or “intermittent” signals are present, what is an acceptable period of time for such signals to exist without seriously affecting radio astronomy observations?
(b) What is the frequency distribution for the range of SKA Scientific observations requiring a low ambient noise level?
(c) What are the worst-case and desirable ambient noise levels at an SKA Site Central for high-sensitivity radio astronomy measurements, taking into account any effect, that interference mitigation techniques might have, to reduce the impact of a high ambient noise level or presence of communications signals.

C. Maximum power density levels for the SKA Central Site

What are the maximum spectral power density levels of interfering signals which can be tolerated on the SKA Central Site?

Note: The ISSC is requested to emphasize in their covering letter that non-compliance by a country or entity with any of the requested attributes for the SKA Central Site, should not necessarily deter the country or entity from offering a positive response.

On hosting the next generation radio telescope - the SKA

A brief for soliciting an expression of interest.

Introduction

This brief is being provided as background information to those countries or entities, which may have a potential interest in hosting the international radio telescope called the Square Kilometre Array ("SKA"). Although a final submission to host would not be required before the year 2005, this request is a call for expressions of interest from countries or entities, which may wish to host the SKA.

This brief is divided into two parts as follows:

Part A General Background Information; this part provides information about the SKA and hosting issues, including the potential advantages

Part B General Specifications (Preliminary); this part provides preliminary information on aspects which would need to be considered in detail for a final submission to host the SKA (around 2005)

Part A - General Background Information

1. The SKA as an international project

Major radio astronomy organisations in the World are collaborating to design and build a new international radio telescope. It is a facility having a total (antenna) collecting area of one square kilometre - the Square Kilometre Array or "SKA". As such it will be around 100 times more sensitive than any existing facility, and will require a new approach to siting.

This brief addresses two related issues: the hosting of the SKA and provision of a site with radio-quiet characteristics.

The planning of the development of the SKA has been under consideration by the international radio astronomy community for about a decade. To progress development and government recognition, a Memorandum of Understanding was signed in 2000 by representatives from five countries (Australia, Canada, China, India and the USA) and the region of Europe, to establish the International SKA Steering Committee (ISSC). Subject to individual agreements with the governments of the countries covered by this MoU, it is proposed that building the SKA could commence around the year 2010. To enable design work to proceed, it is planned that one or possibly two appropriate sites would be

designated by the ISSC in about 2005. Further information about international aspects of the SKA is given in Attachment A.

Therefore, countries or entities, which consider that they may be willing to host the SKA, and hence designate one or more appropriate sites, are requested to provide an expression of interest to the ISSC; the contact name and address and desired date for receipt are given in Attachment B. The contacts representing the radio astronomy community for each country/region are given in Attachment C.

The following sections summarise the SKA and the general requirements for it's siting. This information is being provided as background material to enable potentially interested countries to gauge their interest and capabilities for hosting. More detailed technical specifications will be provided at a later date for those countries desirous of carrying out detailed studies for a final submission in around 2005.

2. Hosting the SKA

2.1 Advantages in hosting

It is considered that there are many advantages in hosting an international facility such as the SKA. Benefits include scientific and political prestige, tourism potential, and general employment opportunities for facility operation, maintenance and general upgrading of the SKA. In addition, during construction and for major upgrades, there is expected to be significant infrastructure contracts. Also, where a country has a competitive advantage in SKA technologies, it may form strategic linkages with companies associated with countries that are party to the SKA effort.

2.2 Responsibilities of the ISSC and a hosting country

The host country will be expected to implement the necessary legislation and/or regulation to ensure that agreed levels of radio-frequency interference (RFI) are maintained over a specified period. In addition the degree of control of the SKA site by the ISSC, including the length of tenure will need to be agreed. In return for the advantages in hosting, a country or entity wishing to host the SKA is requested to provide an indication of the extent of additional financial in kind support which could be made available for the facility.

At the same time, the ISSC will need to provide assurance to the host country or entity that operational (including maintenance) funding would be provided for continued operation of SKA for a fixed period in the first instance. Such discussions would form part of the negotiations to be undertaken prior to the ISSC decision on hosting in around 2005.

Part B - General Specifications (preliminary)

3. The SKA layout

The SKA consists of a distributed antenna system extending to continental distances (2000 - 3000 km). Each antenna (or antenna group) - called a "station", occupies an area of land several hundred metres in diameter. Most of the stations (three-quarters) will be located on an area of about 100-km diameter ("the SKA central site"). A country or entity must be willing to designate an area for the SKA Central Site and to ensure that it has the least radio communication activity on Earth. The

stations outside the SKA central site will be very sparsely spaced across continental distances. Although these stations must be strategically placed to avoid interference, the protection required will be less than for the SKA central site, the area of such protection being 5 to 10 km in diameter. The design of the SKA will give maximum flexibility for future developments and upgrades. It is essential that an SKA central site should be adequately protected against any increase in RFI levels over a lifetime of about 80 to 100 years. Further information on the SKA is given in Attachment D.

4. The desired characteristics for the SKA Central Site

4.1 Spectrum issues and protection

The International Telecommunications Union (ITU) has set interference limits to specific frequency bands allocated (generally on a worldwide basis) to the radio astronomy service. Because radio astronomy uses very sensitive receiving systems for reception of "signals" from the Universe, the specified interference levels have been set significantly lower than that required for general radio communications. However, the amount of spectrum allocated to the radio-astronomy service is not great, which severely inhibits the desired amount of information required to establish a satisfactory "picture" of the Universe.

The SKA is expected to cover the approximate frequency range 150 MHz to about 23 GHz.

Ideally, the SKA central site should have an effective background electro-magnetic level, which approaches the ITU-designated levels across a significant proportion of the operating frequency range of the SKA. These levels are specified in Attachment E. Several approaches may be adopted to ensure that the desired background levels are achieved. One major factor is likely to be the choice of a site in a remote area so that the impact of radio communication use is minimal.

Following formal agreement, the chosen country or entity would need to ensure that the necessary legislation and/or regulation is in place to protect the SKA central site against any significant increase in RFI levels. Such protection may include spectrum regulation and land use issues. As part of its final submission, the country or entity will need to have defined the RFI quality of the proposed site. This will require extensive electromagnetic measurements to have been carried out, which could be supported by information from the transmitter database of the country's spectrum agency. Guidelines for the measurement procedure for both land and satellite-based transmissions are currently being considered by the ISSC; however preliminary general requirements are included in Attachment F.

4.2 Other aspects

Some other aspects, which a country or entity would need to consider in a final submission, are listed below. These may not all be applicable to a particular site, and other aspects may be considered important.

General location:

i) The site should have a high degree of sky-coverage, with a view of a significant part of our own galaxy ("Milky Way"). Also, locations close to the geomagnetic equator should be avoided.

Specific engineering issues:

ii) Impact of weather conditions (eg. degree of potential flooding, high winds, snowfall, etc.);

iii) Topography and geology aspects, particularly as they impact access, construction and operational costs;
iv) Environmental and ownership issues;
v) Logistics, including access to support services, general transport (including airport), and water;
vi) Power provision for (a) the more remote SKA-stations, and (b) the closer-spaced stations, processing centre and administration/accommodation etc. The latter should have a high degree of reliability and be free of radio-frequency interference, impacts of corona discharge, etc.
vii) Building aspects (on-site processing centre, administration/accommodation);
viii) Provision (and/or availability) of optic-fibre to the national and international networks from the on-site processing centre for remote control by, and high-data transfer to, participating countries, and for interconnecting the SKA-stations to the on-site processing centre;
ix) Degree of security required for infrastructure protection.

Operational issues:

x) Staff will need to be located at the SKA central site to provide ongoing operation and maintenance, and for engineering upgrades from time-to-time. Recommendations should be made on staffing aspects, transport, housing, etc, particularly for remote locations.

Attachments

A. International aspects of the SKA

B. Contact information for the ISSC

C. Country representatives: the radio astronomy community

D. Information about the SKA

E. Preliminary guidelines for specification of radio-quietness

F. Preliminary guidelines for measurement of radio-quietness

Attachment E

Preliminary guidelines for specification of radio-quietness

The International Telecommunication Union, with input from the radio astronomy community has approved a Recommendation defining power levels, which are considered harmful to high-sensitivity radio astronomy observations [E1]. Although developed for the allocated frequency bands for radio astronomy observations, we can use the Recommendation to provide a benchmark over a wideband for the stations located on the SKA central site. (The more remote stations do not require operating in such low-noise environments). Also, interference mitigation schemes may permit higher levels of

interference to be tolerated; consequently the levels of interference being proposed are the effective levels following the application of an appropriate mitigation scheme.

To provide a benchmark for effective threshold signal levels, the most critical case, namely spectral-line observations which typically use receiver bandwidths of the same order as or less than potential interfering signals, is considered.

In the ITU Recommendation, the following radio telescope parameters are assumed (with some additional notes):

- Receiver bandwidth and total system temperature as indicated in Table E1 (columns (b) and (c)). Note that the parameters for the frequencies shown in square brackets (column (a)), are estimated values to enable the required threshold interference signal levels to be shown over a wide frequency range.
- The threshold interference signal levels (column (e)) are one-tenth (-10dB) of the power relative to the system noise (column (d)).
- The reception of ground-based interference signals is via the sidelobes of the antenna with a gain of 0 dBi towards the horizon.
- The receiver integration time is 2000 sec. (For other integration times T_1, the improvement in receiver sensitivity is $\sqrt{(T_1/2000)}$, or $5 \log(T_1/2000)$ dB. The SKA in its most sensitive mode of operation is likely to use $T_1 \geq 12$ hours, giving a sensitivity improvement of greater than 6 dB. (Where interfering signals are intermittent in nature (e.g. many communication signals), the effective reduction in interference is given by $5 \log (T_1/t)$ dB, when T_1 is the integration time and t is the time that an interfering signal is present in a given channel).
- For satellite signals, the interference level will typically be enhanced through the higher-level sidelobes (relative to 0 dBi). It may not be possible to perform high-sensitivity radio-astronomy observations in spectrum where satellites are transmitting unless the transmission is of short duration and/or effective interference mitigation schemes are employed.

Table E1 can also be used as input into the process of defining suitable parameters for a measurement system to determine the background ambient noise level of a possible site, as determined by low-level communication signals and other man-made noise. In particular a measurement system, which uses high-gain test antennas and a receiving system with a narrow bandwidth, will assist in detecting low-level signals. Alternatively, a receiver based on radio telescope technology which enables long integration times to be achieved, will significantly assist in achieving a very high effective sensitivity.

Ref [E1] ITU Recommendations, ITU-R, RA 769-1, "Protection criteria used for radioastronomical measurements", ITU, Geneva, 1995.

Table E1 Threshold levels of interference detrimental to spectral-line observations [1]						
	Receiver System characteristics			Threshold level of interfering signal [2]		
Frequency (MHz) a	Spectral line channel BW (Hz) b	Total system temp. (K) c	System noise level (dBW) d	Receiver input power (dBW) e	Power flux density (dBW/m2) f	Spectral power flux-density (dBW/m2/Hz)) g
[150]	10k	350	-201	-211	-206	-246
[200]	10k	200	-203	-213	-205	-245
327	10k	140	-205	-215	-204	-244
[500]	15k	70	-207	-217	-201	-242
1420	20k	30	-210	-220	-196	-239
4830	50k	30	-208	-218	-183	-230

Notes:

[1] Ref: Rec. ITU-R RA.769-1, Table2. Values for frequencies shown [ ] have been included for completeness.

[2] Interference threshold which introduces an error of 10% (-10dB) relative to the system noise; refer to columns (d) and (e).Columns (f) and (g) express the signal level of the interferer incident on the antenna.

Note: Revisions to Fig F1 yet to be made.

Attachment F

Preliminary guidelines for determination of radio-quietness

1. Introduction

An important factor in the choice of an SKA site is the degree to which the general ambient noise level approaches the ITU recommended interference level over a significant proportion of the desired operating frequency range of the SKA, i.e. nominally 150 MHz to 23 GHz.

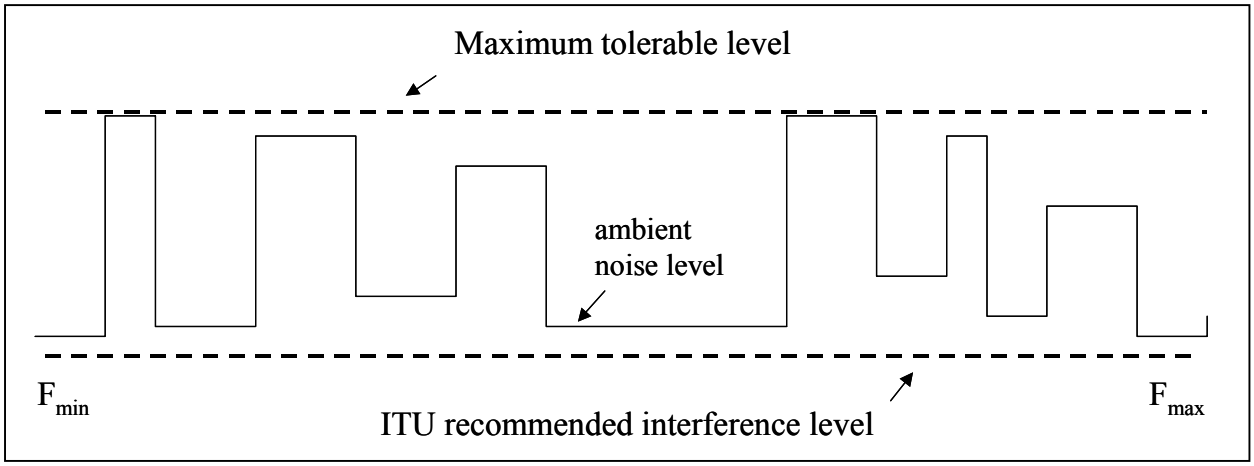

Fig.F1: Idealised spectrum occupancy (and vacancy)

Fig. F1 is an idealised representation of the spectrum of interest at a particular location where F_{min} is the minimum frequency (150 MHz) and F_{max} is the maximum frequency (23 GHz). Because particular services tend to be assigned to a block of spectrum, services which have widespread application may substantially occupy a significant proportion of the allocated spectrum for that service, even at a remote location. We shall designate such spectrum as "used spectrum".

However, other spectrum particularly if the location is remote, will have little or no use, so that any received signal levels will tend to be close to the ambient noise level of the area ("unused spectrum"). This spectrum is of greatest use to high-sensitivity radio astronomy observations. Therefore, a measure of the mean ambient noise level for each block of unused spectrum, and the bandwidth distribution of such spectrum are important factors to be quantified. For the used spectrum, the peak level and bandwidth distribution are important factors to be quantified. In particular the peak power levels at the SKA site must be less than the value to cause overload of the sensitive receiving systems.

In planning a measurement program, it will be necessary to determine the peak signal levels and band occupancy for the used spectrum, and the mean ambient received noise level and band vacancy for the unused spectrum. To achieve this, the different directions for both land-based and satellite downlink signals must be taken into consideration. Also, methods for system calibration must be employed to ensure adequate integrity of the measured data. Although no specific equipment is being recommended for the measurement program, requests for general information relating to equipment requirements and methodology can be discussed with a representative appointed by the ISSC.

Other Discussed Action of the SESWG

1. RFI Measurement Programs

Stage 1: Preliminary measurements by countries/entitities

Stage 2: Final measurement of RFI on contending countries/entities proposed sites by SKA Project Office with standard set of equipment.

Actions:

(1) Complete draft measurement strategy and standards report by SESWG within 6 months. To be made generally available on WWW.

(2) Countries/entities are advised to liaise with their spectrum agencies regarding existing knowledge of communications activity and proposed future services which could affect a potential SKA central site.

2. Other uses for a radio-quiet zone:

The ISSC and other scientific bodies are requested to advise the SESWG of other potential uses of a radio-quiet zone, as information may become available.

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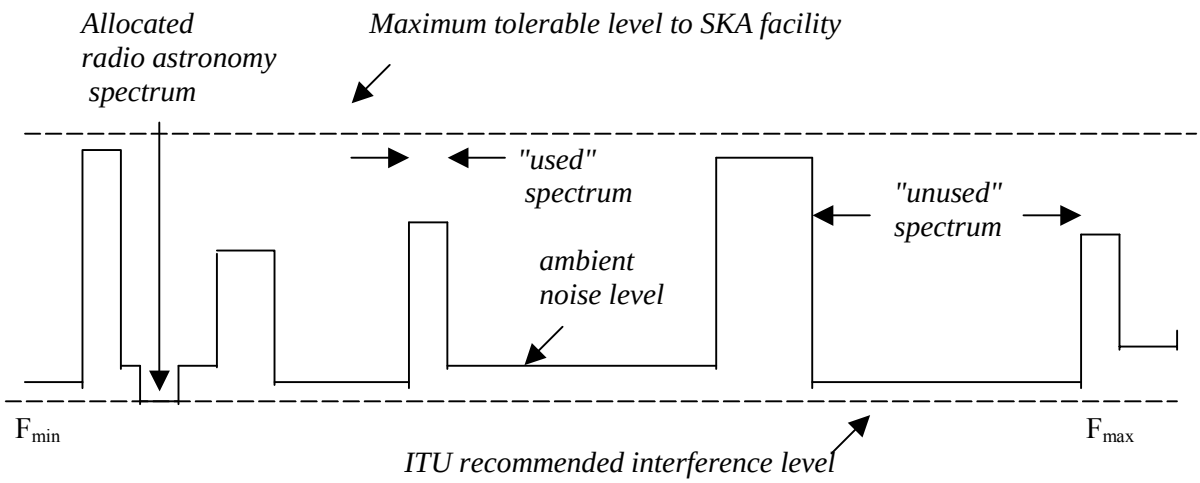
Figure F1


Allocated
radio astronomy
spectrum
Maximum tolerable level to SKA facility
"used"
spectrum
"unused"
spectrum
ambient
noise level
F_{min}
F_{max}
ITU recommended interference level