Radio spectrum occupancy in South Africa

by Gerhard Petrick

The wide range of spectrum users deploying an even wider range of systems and technologies results in a spread of protection requirements and abilities to cope with interference. Signals that may be “harmful interference” to one spectrum user may not even be detectable by another.

A previous article (EngineerIT August 2006) reviewed the ground-breaking radio frequency interference (RFI) survey conducted as part of South Africa’s bid to host the square kilometre array (SKA) telescope. This article will review some of the results and comment on the spectrum usage trends observed.

Proponents bidding to host the international SKA radio telescope were required to conduct RFI measurements over at least 12 months at their respective candidate sites. These measurements were to aid in identifying a suitably radio-quiet site at which the new generation radio telescope may be built.

Just as light and poor air quality would interfere with and limit optical astronomy, radio signals from mobile phone- and broadcast- and telecommunications towers limit the ability of a radio telescope to detect very weak signals from space.

A detailed measurement procedure and measurement equipment capability was specified. Although the prescribed noise temperature (or sensitivity) of better than 300 K was difficult to achieve, this was still orders of magnitude (around 60 dB) higher (or less sensitive) that what is required for radio astronomy observations.

Redefining harmful interference

The International Telecommunications Union has published recommendations on signal threshold levels harmful to radio astronomy\(^1\) and parameter applicable to band sharing\(^2\).

The aspirations with the SKA are to establish the radio telescope in a very radio-quiet area and to conduct observations in frequency bands that are not specifically allocated and protected for radio astronomy. The support of the SKA host

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2. Recommendation ITU-R RA.1031-1, Protection of the radio astronomy service in frequency bands shared with others services.
country in preserving and improving the radio quietness around the SKA core site will be sought through the local frequency spectrum administration.

The parameters for conducting such observations in shared frequency bands are daunting. At the risk of oversimplifying the recommendations, these essentially provide a list of threshold levels or levels of radio quietness that are desired across specific frequencies bands commonly used for radio astronomy. To illustrate the relative level of radio quietness sought, consider that a standard GSM phone (operating at a 900 MHz at a power of 2 W and 1.5 m height) will cause harmful interference if operated within line-of-site and under 200 km from the radio telescope. (Refer to Fig. 1). A basic 20 W mobile communication radio transmitter operating at 150 MHz on a 6 dBi gain antenna would cause interference harmful to radio astronomy even at a distance of more than 500 km from the radio telescope. (Refer to Fig. 2). It quickly becomes clear that higher power broadcast- and radar transmitters pose an even greater challenge to radio astronomy.

The ITU-R Recommendation RA.1031-1 on the protection of the radio astronomy service in frequency bands shared with other services states that “It is clear (...) that sharing with a terrestrial transmitter within line-of-sight is unlikely to be possible at frequencies below 10 GHz because of the severe restriction sharing would impose on the transmitter e.i.r.p.[3]”

Even for frequencies up to 40 GHz either the transmitter power must be of the order of a few milliwatts, or the transmitting antenna must provide high discrimination towards the direction of the observatory, for sharing to be possible.”

Considering the above, it becomes clear why the International Radio Astronomy community is looking for the most radio-quiet site in the world to build the SKA and why bidding countries were required to furnish measurement results.

Limitations of the prescribed measurements

The prescribed single point RFI measurements, even with the very sensitive test gear, would at best provide only a picture of those signals that will be a real nuisance to radio astronomy. This measurement result will not sufficiently describe the radio environment to the levels required to assess a site’s suitability for ground-breaking radio astronomy observations.

Single point observations would also be affected by geographical screening at the particular point of observation chosen.

Although geographical screening is important and provides essential protection to a radio astronomy site, measurements in narrow valleys or too close to mountains may give an over-optimistic picture of the RFI, as screening may not be uniform over the large area required to site the SKA core.

The South African SKA project decided to complement the prescribed single point measurements with detailed desktop studies and measurements at an additional 35 points around the core site in the Karoo and including sites in Botswana, Mozambique and Namibia. Refer to Fig. 3.

Desktop studies

The main advantages of desktop studies is that these provide a means of RFI study that is unlimited by equipment sensitivity and can be repeated for numerous points at relatively low cost. Numerous propagation and prediction models are available.

The models use digital terrain information to calculate signal propagation and to predicted

3 Effective incidental radiated power

Fig. 3: RFI measurement points.

Fig. 4: RFI-39 (HartRAO) a) Transmitters with distance from test point and b) Frequencies in operation with distance from test point.
signals levels and paths between points. The validity of desktop RFI studies would, however, depend largely on the accuracy of the prediction tools and the transmitter data-base.

The standard radio frequency planning tools are designed to predict broadcast and telecommunication signal propagation and coverage at significant signal levels (e.g. transited powers between typically +10 to +30 dBW(e.i.r.p.). The reliability of these tools with signal levels applicable to radio astronomy (e.g. -70 dBW(e.i.r.p)) would have to be verified.

With the support of the Independent Communications Authority of South Africa (ICASA) and the respective spectrum users in South Africa a comprehensive data-base of transmitters was compiled. The data-base with more than 270 000 entries was geo-referenced allowing the display of each transmitter and its parameters on interactive maps within a geographical information system (GIS). A number of assumptions were made on the use of mobile devices and these were included in the spectrum usage analysis.

This database allowed detailed coverage predictions as well as statistical analysis of the typical spectrum usage in South Africa. A discussion of the results follows.

Whilst it would have been prohibitively expensive to predict expected signal levels for all the records in the database a few transmitters around the core site were chosen and the expected signal level at the test point predicted. The predicted results tracked the measured results well and gave confidence in the validity of the prediction tools.

Additional measurements

Additional measurements were conducted to provide a more empirical assessment of the main spectrum users, services and signal levels that prevail.

Assessment of measurement results

The measurement results were compared to the statistical analysis of the transmitter data-base per site. It was found that depending on the terrain around the measurement point and the power of transmitters in the vicinity, the single point measurement would typically characterise a 200 km radius area around the test point.

Detailed site measurement reports were compiled. Each site measurement report would include amongst others a statistical analysis of population vs. number of transmitters, as well as fixed- and mobile phones. A plot showing the transmitter data-base entries by frequencies with distance from the test point was generated to indicate spectrum usage trends.

The two extremes in terms of radio-quietness are presented here. The RFI-39 test point was at the Hartebeesthoek Radio Astronomy Observatory near Gauteng whilst the other RFI-K3 was at a test point in the Karoo approximately 80 km from the town of Carnarvon. The number of transmitters found within a radius of 200 km of the test point was under 80 000 for RFI-39 and less than 810 for RFI-K3.

The plots provide a good indication of the degree of radio quietness and remoteness from transmitters.
Radio frequency spectrum usage trends in South Africa

The bands that tend to emerge show the section of spectrum most frequently re-used, i.e. the same frequency being re-used and different sites sufficiently far removed or screened from each others not to cause interference). The GSM 900 MHz band stands out as a band in which frequencies are extensively re-used. The trends in spectrum use become apparent when one looks at the bigger picture and considers every transmitter within a radius of 600 km from a test point.

The broadcast high sites emerge as groupings of transmitters at different frequencies all located at the same distance from the test point. The first band of extensively used spectrum emerges around 400 MHz and relates to UHF communication systems. The next band of heavily utilised spectrum relates to the GSM 900 and 1800 MHz spectrum. A clear band of short-range links imply extensive re-use of the frequency and a large number of transmitters. A number of densely co-located point-to-point links are evident in and around 4, 6.5 and 7 GHz. Further extensive band re-use is evident in clearly defined bands between 17 and 23 GHz.

Measurement results vs. desktop results

The signals observed during measurements related mainly to the radio and television broadcast signals, GSM signals and airborne navigation signals. Detailed spectrum plots were prepared for all measurement up to 26 GHz and included in the site measurement test report.

Most of the signals observed were below 2 GHz with only very few point-to-point links and other microwave signals observed above 2 GHz at two of the test points. This was to be expected as the current trend in transmissions above 2 GHz is that these are on highly directional antennas with very narrow signal beams. In order to detect the signal the measurement system would have to be in the narrow signal path. The likelihood of this occurring by chance is very small.

A number of surprise observations related to the identification of military satellite signals around 250 MHz and communication satellites at 139 MHz.

Fig. 7 and Fig. 8 provide the stark contrast in radio-quietness evidenced between RFI-39 at the Hartebeesthoek Radio Astronomy Observatory near Gauteng and RFI-K3 in the Karoo.

Wrapping up

Wireless services depend entirely on good spectrum management and minimisation of harmful interference for their operation. Limiting interference and ensuring efficient spectrum utilisation are critical to sustainable and reliable wireless communication in future.

Whilst radio astronomy observations are highly susceptible to interference and the quest is on to find the best suited radio-quiet site in the world at which to build the SKA radio astronomers are also developing new ways of dealing with interfering signals and techniques that may allow for observations even if the environment is not as radio-quiet as desired.

Whilst the special protection requirements of radio astronomy will be addressed through the Astronomy Geographic Advantage Bill that will be tabled in parliament shortly, the critical roles of spectrum management and enforcement that ICASA will need to play cannot be overemphasised.

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