Background radio-frequency radiation and its impact on radio astronomy

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Abstract:
The use of radio-frequency telecommunications equipment is dramatically increasing, and one consequence is that background levels of radio-frequency radiation are increasing over much of the Earth's land surface. Radio astronomy telescopes are very sensitive probes of the radio-frequency background levels as they use the most sensitive radio-wave receivers in the world. It is becoming increasingly important for radio telescopes to be located in areas where the background levels of radio-frequency radiation are low.

There is international interest in creating one or more radio-quiet reserves on Earth. A radio-quiet reserve is an area where the levels of radio-frequency radiation are low, and over which regulatory or legislative protection controls the increase in radio-frequency radiation. Inland Australia possesses areas that are still relatively radio-quiet compared to the rest of the world, and Australia is a good candidate country for hosting a radio-quiet reserve.

CSIRO Australia Telescope National Facility and several State Governments are researching to identify if suitable locations for a radio-quiet reserve exist in inland Australia.

1. Spectrum use and astronomy

Recent satellite pictures have dramatically illustrated how much artificial optical light is generated by modern civilisations (see for example http://www.darksky.org/ida/images.html). This light obscures the night sky for many urban dwellers. For example, it is estimated that by the year 2025, the Milky Way will not be visible from anywhere in Italy and already three-quarters of Americans can't see the Milky Way from where they live. This is very culturally significant. The stars were one of the first inspirations for abstract thought for early mankind. They possibly played an important role in expanding the way that humans first started to think abstractly. Again, as Western civilisation emerged into the Renaissance, astronomy played an important role in helping people to think more broadly. Even now, in our fast-paced, visually stimulating society, most people find the sight of the dark night sky filled with stars an awe-inspiring phenomenon. Astronomy satisfies some deep human curiosity about our place in the world. It would be a huge cultural loss to the world if the night sky effectively disappeared from view.

It is not only at optical wavelengths that our view of the night sky is under threat. As our use of telecommunications equipment increases, the level of human-generated radio-frequency radiation is increasing dramatically and it is becoming harder for radio astronomers to study the sky at radio wavelengths. Radio waves can give us information about astronomical phenomena that optical light cannot and, in fact, radio astronomy reveals some of the most fundamental information about the Universe. It has been crucial in uncovering phenomena such as quasars, pulsars and the cosmic microwave background radiation, and has led to three of the five Nobel Prizes awarded for work in astrophysics.

Radio astronomy telescopes are the most sensitive radio-wave receivers in the world. For example, a mobile phone situated on the surface of the Moon would be a fairly strong source in the sky at radio wavelengths; astronomers frequently measure signals from distant sources in the Universe that are tens of thousands of times fainter than this. (If you collected all the energy that has been collected by all radio telescopes over the sixty-year history of radio astronomy, it would light a small bicycle light globe for about 0.1 second.)

The high sensitivity of radio telescope receivers means that they are very sensitive to human-generated radio-frequency emissions. As use of the radio-frequency spectrum increases it becomes more difficult to undertake radio astronomy research, and the problems will be even greater in the future. The next generation of radio telescopes that are currently being designed will be up to one hundred times more sensitive than existing telescopes. Furthermore, the future of radio astronomy largely depends on the ability to detect radiation from outside the narrow (in frequency) bands that have been set aside by the International Telecommunications Union (ITU) for passive use such as radio astronomy.

The reason why astronomers want to observe over a wide range of frequencies is linked to the ability in astronomy to "look back in time". The Universe is expanding as if all matter we see set off from one point in space and time. This is one reason why we believe in the Big Bang formation of the Universe. The parts of the Universe that are now furthest away from us are those that appear to be travelling the fastest away from us. We can see this because radiation from these objects is shifted ("red-shifted") to longer wavelengths by the motion of the objects away from us. The radiation that we can see from very distant objects has had to travel a long time before reaching us, so it was emitted a long time ago. By looking at very distant objects astronomers can essentially look back in time to how objects appeared in the past.

The international radio astronomy community is planning for and designing a next generation radio telescope called the Square Kilometre Array telescope (SKA). The SKA will be so sensitive that it will be able to detect radiation that was emitted at the time soon after the Big Bang formation of the Universe when galaxies were first forming. Using the SKA, astronomers will be able to track the evolution of the very early Universe.

To do this, observations of a range of red-shifted spectral lines need to be made, and so it is no longer adequate for radio astronomy to be restricted to just a few frequencies. At the same time, observing over a wide range of frequencies is getting harder because of other users of the spectrum swamping the faint cosmic signals.

2. Identifying radio-quiet locations

One possible solution to the conflicting requirements of radio astronomy and the telecommunications industry is to identify and protect a few "radio-quiet" areas on Earth, i.e. areas with very low levels of background radio-frequency radiation, where experiments requiring radio-quietness could be conducted. Australia's low population density in the interior means that there are relatively low levels of radio-frequency emission in inland Australia. Inland Australia may possess suitable locations for radio astronomy and other facilities requiring radio-quietness.

Using information from the Australian Communications Authority database, comprising a comprehensive listing of all radio licences for the Australian continent, estimates have been made of radio-frequency levels for various locations. It should be noted that the database is a listing of licences only. Actual transmitters may not be in place all the time and may not be operational all the time.

Power density plots created from information from the database have been created. Two such plots are shown in Figures 1 and 2. They show predictions of spectrum usage in Sydney and in a remote location in Western Australia.

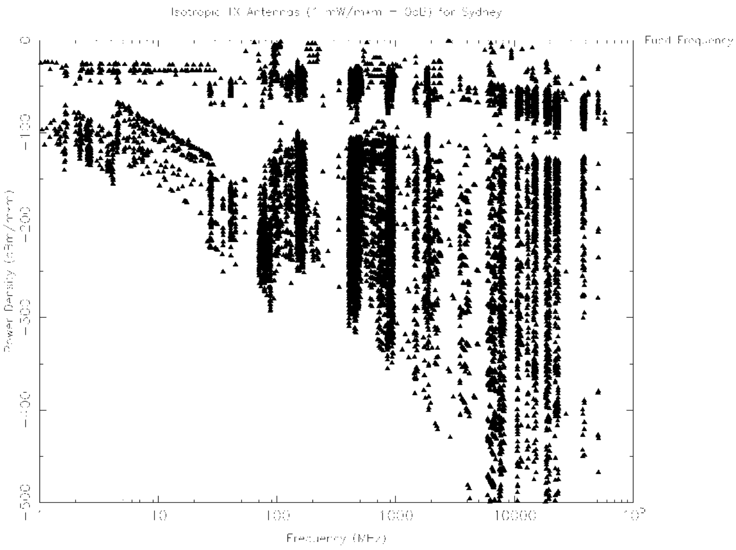

Figure 1. Power density plot showing the power density predicted in central Sydney due to licensed transmitters. Further information is provided in the text.

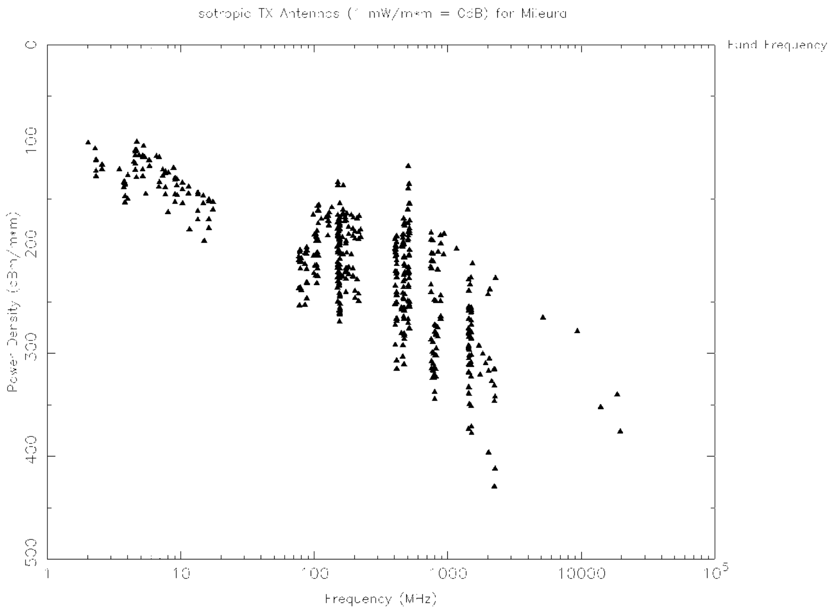

Figure 2. Power density plot for licensed transmitters at a remote location in inland Western Australia. Further details regarding the data presented are contained in the text.

If no antenna information is provided in the database, it is assumed that the transmitter output power is radiated by an isotropic source. A simple propagation model is assumed, corresponding to a smooth, spherical Earth, with a sudden transition from line-of-sight to deep shadow regions. Further details of the calculations are available from [1]. The results are only approximate, but have been used to help identify potentially radio-quiet locations in inland Australia that could provide good sites for future radio telescopes. In addition, the first stage of a radio-frequency spectrum measurement program, undertaken by the Western Australian Government in collaboration with CSIRO, has just been undertaken at a remote location in inland Western Australia. The frequency range explored was 30 MHz to 1.8 GHz, covering spectrum of interest to future radio astronomy facilities. Sensitive measurements were taken of radio-frequency signal strength over a three-week period in April, 2001, and the results are currently being analysed.

3. Radio-quiet reserves

A radio-quiet reserve would be a world-recognised, dedicated area set aside principally for enabling investigations to be undertaken that require low background levels of radio-frequency electromagnetic radiation. More specifically, a radio-quiet reserve would be an area of land:

- Where the levels of radio-frequency electromagnetic radiation are very low across a significant proportion of the radio-frequency spectrum. It may be possible to lower the levels still further by absorbing existing radio communication systems on the radio-quiet reserve into an optic-fibre network.
- Over which there is legislative or regulatory control controlling the increase of radio-frequency radiation levels across the reserve
- Which has a surrounding protection zone, where controls would be implemented controlling the increase of activities generating unacceptable levels of radio-frequency radiation in the reserve.

There is international interest in creating one or more radio-quiet reserves on Earth to protect the radio-quietness of some areas. For example, the OECD Task Force on Radio Astronomy and the Radio Spectrum is investigating the feasibility of establishing radio-quiet reserves, and the United Nations Office of Outer Space Affairs has also recommended that Member States should cooperate to explore new mechanisms to protect selected regions of Earth and space from radio emissions [2].

Investigations by CSIRO are exploring whether, if a suitable radio-quiet location can be identified in inland Australia, it could be set aside as a radio-quiet reserve. The quality of a radio-quiet reserve will probably be determined by the proportion of radio-frequency spectrum that has an electromagnetic ambient noise level below the value recommended by the ITU for conducting sensitive radio astronomy observations. The testing program currently underway in inland WA will determine, at various locations, what proportion of spectrum has a very low ambient noise level.

The international radio astronomy community involved in the design and planning for the Square Kilometre Array telescope intend to choose a site for this international facility in 2005. The SKA central-site would ideally be located in a radio-quiet reserve of order 50km in diameter. Within the next few years, the Australian Government will decide whether it wants to join the international competition in bidding to host this facility. It is estimated that the telescope would attract many tens of millions of dollars to the host country. It will greatly assist Australia's chances of hosting the SKA if Australia can demonstrate that it possesses high-quality radio-quiet sites, and that it can preserve one of these as a radio-quiet reserve.

4. Conclusions

Australia's low population density in the interior results in inland Australia being relatively rich in the natural resource of radio-quietness. Radio-quietness is important for various investigations and, in particular, for radio astronomy, which uses the most sensitive radio-wave receivers in the world to study astronomical phenomena throughout the Universe. Data on the radio-quietness of various locations in inland Australia is being collected and CSIRO, in collaboration with several State Governments, is investigating the possible establishment of a radio-quiet reserve in Australia. It is likely that Australia could offer to host the Square Kilometre Array telescope, a next generation radio telescope currently being planned for and designed by an international consortium of countries including Australia.

5. References

1. Hall, P.J., Ananda, S.M. and Soretz, R.S. 1997, Proc. URSI Large Telescope Working Group, Sydney, December 1997

2. Conclusions and proposals of the International Astronomical Union/Committee of Space Research/United Nations Special Environment Symposium “Preserving the Astronomical Sky”. A/CONF.184/C.1/L.2 (http://www.iau.org/conf184c1l2.html)