INTER V1.0

USERS GUIDE

INTERactive INTERference characterisation

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1. Purpose and Scope:

INTER is designed to assist observers and engineers to interactively characterise Radio Frequency Interference (RFI) at the various ATNF and related sites. It is designed as a tool for predicting RFI, in order to minimise and mitigate its effects on planned observations. It is, also, a tool for identifying observed sources of RFI.

Two sources of interference are characterised:

1) local terrestrial transmitters and;

2) satellite emissions.

Terrestrial transmitter characteristics are obtained from the Australian Communications Authority (ACA) database. This is a comprehensive listing of ***all*** licenced spectrum users for the entire Australian continent.

Satellite positions and velocities are calculated using the NORAD SGP4/SDP4 orbital propagation models, and two-line orbital elements. The satellite frequency database is continually updated and revised, because accurate and reliable satellite frequency information is difficult to obtain. This is due to the fragmented international nature of the satellite business, where there is no single organisation controlling satellite launches, etc. Also, the competitive, commercial nature of the satellite business, as well as national security concerns (as in the case of military satellites), adds to the difficulty by imposing a high level of secrecy.

2. Data Presentation:

The characterisation zone for each site, is approximately 200 km centred on the chosen site. This is a realistic boundary given natural terrain shielding effects at ATNF observatories and Earth curvature.

Information is displayed in one of two ways:

1) Location Plots:

The geographical distribution of terrestrial interferers is presented for each site. Clusters corresponding to cities and towns are obvious, as are some features such as roads and railway lines.

Satellite positions are displayed on an animated plot of the sky visible from the chosen site. Geostationary and geosynchronous satellites (GEO's) are plotted as red data points. Low Earth Orbit satellites (LEO's) are plotted as green data points.

Each of the two displays above, can be manipulated, or operated on, to maximise the information obtained.

2) Flux/Power Density Plots:

Worst-case interference flux/power density plots are presented for the entire spectrum, ie. in the form of *flux or power density* vs *frequency*.

For terrestrial transmitters, the simplest possible model is used, corresponding to a flat Earth with no terrain shielding effects. Worst-case power densities are approximated using a simple isotropic propagation model (the actual transmitting antenna orientation being unavailable from the ACA database). The model is independent of orientation angles, and assumes any antenna to be a point source radiator, whereby the radiation from the point source radiates in all directions equally in a spherical fashion. The power density, at distance d, is given by the radiated power over the surface of the sphere. The equation is given as:-

$$P_d = P / 4\pi d^2 \qquad (\mathrm{W/m^2})$$

The corresponding value in dBm is given as:-

$$P_d\,(\mathrm{dBm}) = 10 \log_{10}(P_d / 10^{-3})$$

If an effective radiated power (EIRP) is available in the ACA database, it is used instead, in effect assuming that a directional antenna has its maximum gain in the direction of the telescope.

Spectral flux densities are calculated by dividing with the carrier bandwidth.

Propagation calculations, similar to those outlined above, are used for satellite interferers. Satellite visibilities are presented in the form of worst-case monthly and real-time animated plots. The pass geometry, for each satellite, is examined over a one-month period and the monthly minimum distance of each satellite, to the site, is used to calculate the worst-case density levels.

Flux densities are presented in the units $dBW/m^2/Hz$ (where 1 Jy = -260 $dBW/m^2/Hz$). Power densities are presented in the units dBm/m^2. The two types of display can be toggled between.

3. Getting Started:

To gain access to INTER, an ATNF UNIX account is required. This can be obtained by contacting Gina Spratt at email: gspratt@atnf.csiro.au.

From either a SUN workstation or X-Win on a PC, rlogin to either " **auriga**" or "**sculptor**" (one of the two off-line ULTRA-1 SUN workstations at Parkes). Rlogin is preferred to telnet, because the rlogin encrypts the account password when transmitting it over the network, ie. type, for example:-

```
rlogin auriga -l account-name
```

The password is then prompted for. Once logged-in, typing "inter" will start the session.

Site Selection:

Following an introduction screen, a map of Australia is presented in the site selection screen. This shows the locations of all the ATNF, and related, sites. With the left mouse button, click on the red square corresponding to the required observatory site.

Accessing a site not displayed, first requires a database file to be produced, for the new site (see below). On subsequent calls, the yellow "New Site" button is clicked (with the left mouse button) and the relevant site information is entered again, in order to access the database previously produced.

NOTE: The database file for this new site should be located in the current directory, so be sure to first change directory to it. Also, any output from the program will be placed in the current directory.

Creating a database file for a new site:

To create a database for a new site, the yellow "New Site" button, below the map, is clicked. The relevant site information is prompted for to fully produce the database for the site. These include:-

Site Latitude	(eg. -33.0)
Site Longitude	(eg. 149.573)
Site Data File	Transmitter licence file (subset of ACA database)
Site Time Zone	Time zone of site for use in satellite p redictions
Site Height	Height above sea level of site

The database thus produced, will be a subset of the ACA database. Reading the entire ACA database takes approximately 20 minutes. On subsequent calls, this smaller subset database is read, and takes just a few seconds to do.

Frequency Selection:

From the site selection screen, the frequency selection menu appears. With the left mouse button, click on one of the three options presented. They are: -

ALL Frequencies

RANGE of Frequencies

SINGLE Frequency only

If '**ALL frequencies**' is selected, the entire database is read and only fundamental frequencies are plotted.

If '**RANGE of frequencies**' is selected, the low and high frequencies of the range are prompted for. Any transmitter having a 2nd or 3rd harmonic in the requested range, is plotted also.

If '**SINGLE frequency only**' is selected, the desired frequency is prompted for. Any transmitter having a 2nd or 3rd harmonic that falls on the desired frequency, or which has a bandwidth which causes it to straddle the desired frequency, is plotted also.

4. Locations Screen:

Following the frequency selection menu, the locations screen is displayed. This screen is divided into three areas. The main transmitter locations plot on the right, the keystrokes menu window on the left and the messages window at the bottom.

Operations are performed on the transmitter locations plot, by one of two ways:

1) Pressing (on the keyboard) the bracketed letter of the operation description, or

2) Clicking, with the left mouse button, the operation description in the keystrokes menu window.

The locations plot, displays the positions of all the transmitters requested. The observatory site is in the centre and is marked by a green square. For the pre-defined ATNF sites, the names of some of the major cities and towns is also displayed.

When the locations screen is first accessed, the number of transmitters found to have the specified fundamental frequencies, is printed in the messages window. In addition, if RANGE or SINGLE frequency options were selected, the number of transmitters with 2nd and 3rd harmonics, are also printed.

Operations:

(G)raph flux/power density: (Press ‘g’ or click on the description).

This displays the flux/power density plots (see below).

(L)ocation plot - top level: (Press ‘l’ or click on the description)

This displays the top level location plot for the terrestrial transmitters. This plot is displayed when the locations screen is first accessed. It is used as a quick way to return to the top level, after a zoom-in operatioin has been performed.

(2)nd Harmonic: (Press ‘2’ or click on the description)

If either the ‘RANGE’ or ‘SINGLE’ frequency options were selected, then the locations of the transmitters with 2nd harmonics, are plotted. All 2nd harmonics are displayed as blue data points. Emission levels, with respect to the carrier, are assumed to be at a level of **-40 dB**.

The plots of the 2nd harmonic transmitters can be removed by selecting this operation again.

(3)rd Harmonic: (Press ‘3’ or click on the description)

If either the ‘RANGE’ or ‘SINGLE’ frequency options were selected, then the locations of the transmitters with 3rd harmonics, are plotted. All 3rd harmonics are displayed as yellow data points. Emission levels, with respect to the carrier, are assumed to be at a level of **-60 dB**.

The plots of the 3rd harmonic transmitters can be removed by selecting this operation again.

(D)ata point change: (Press ‘d’ or click on the description)

This changes the style of the data points. The default data point style is a dot. Often, however, they are difficult to see, especially if just a few data points are plotted. By selecting this operation, the data points are made larger and easier to see.

The default data point style is returned, by selecting this operation again.

(Z)oom in/out: (Press ‘z’ or click on the description)

Zoom in/out operations are performed until the zoom mode is exited.

The left mouse button will **zoom-in** at a point centred on the cursor position. This operation zooms-in with a factor of two (ie. $\div 2$) and can be performed successively in order to zero-in on a particular transmitter..

The middle mouse button will **zoom-out** at a point centred on the cursor position. This operation zooms-out with a factor of two (ie. x 2) and can be performed successively only up to the top level plot, ie. the operation will not zoom-out beyond that level.

The right mouse button will **exit the zoom mode**.

NOTE: The zoom mode must be exited before another operation can be performed.

(I)dentify data point: (Press ‘i’ or click on the description)

Clicking any of the mouse buttons, will display information on any transmitter that lies within a radius of 1% of the plot limits, centred on the cursor position. This is referred to as the information selection circle. The information (as contained in the ACA database) is displayed on the Information Display Screen (see below).

NOTE: At the top level location plot, a large number of transmitters can lie within the information selection circle. It is advised that the desired location is first zoomed-in on, before the operation is peformed. This allows a single transmitter to be selected more effectively.

<u>(V)iew satellite positions:</u> (Press ‘v’ or click on the description)

This operation presents an animated display of the positions of any interfering satellites visible from the chosen site. The user is first prompted about what is to be displayed:

Multiple or Single satellites (m/s)? If multiple is chosen (by pressing ‘m’) then all the satellites visible from the chosen site are displayed. If single is chosen (by pressing ‘s’) the name of the satellite is prompted for. The name will be printed in upper case to make comparisons with the listed database names easier.

Print satellite names (y/n) ? If yes is chosen (by pressing ‘y’) then the satellites are displayed with their listed database names. If no is chosen (by pressing ‘n’) then the satellites are displayed as asterixes instead.

Current time (y/n) ? If yes is chosen (by pressing ‘y ’) then the satellites will be displayed in real-time using the current system time from the computer. If no is chosen (by pressing ‘n’) then the local standard starting date and time are prompted for. The year, month, day of the month, hour, minute and second are entered as separate integer values.

Following this, the positions of the satellite/s are displayed on a sky plot of the site. The white circle represents the horizon, and in the case of Parkes, the inner red circle is the 60° zenith angle horizon of the telescope. The local standard date and time are displayed to the right of the plot.

To make changes to the display, it must first be stopped by pressing ‘s’ or clicking on the description in the keystrokes menu window.

The display can be kept running during an observation, and consulted regularly, in order to avoid observing in regions of the sky where satellites are present. Also, observations can be planned (by selecting the non-current time option) to minimise satellite RFI.

Satellite selection criteria: Every effort is made to include in the display, all satellites that have the potential to interfere with observations. Unfortunately however, not all satellites that can interfere, are displayed. There are two reasons for this:-

1) Accurate frequency information (ie. **frequency, EIRP, bandwidth**) may not always be available for a satellite, as in the case for military and spy satellites;

2) Orbital elements for the satellites may not be available.

Consequently, only those satellites are displayed for which *accurate frequency information* **AND** *orbital elements*, are available.

The orbital elements are updated daily from the NORAD database. The satellite frequency database is, also, continually revised and updated as new information is gleaned or as satellites enter or cease operation.

(S)ave as GIF file: (Press ‘s’ or click on the description)

This operation saves a particular plot of transmitter locations as a GIF file. The name of the gif file is prompted for in the messages window (the .gif extension should be included in the name). For example:-

parkes_lband_locations.gif

The file is saved in the current directory, and can be accessed after the INTER session.

This operation is useful if plots of particular transmitter locations are required for future reference. For example, if the user wants the locations of all transmitters with emissions in L-band, the ‘RANGE of frequencies’ option in the frequency selection menu, would be selected. The 2nd and 3rd harmonics can be plotted and the user can zoom-in to a particular position, then save the plot. The file can be printed onto an overhead transparency for later display at a meeting or conference.

(B)ack to the beginning: (Press ‘b’ or click on the description)

This returns to the site selection screen, where another session can be started.

(Q)uit program: (Press ‘q’ or click on description)

This ends the INTER session, and exits the program.

5. Flux/Power Density Screen:

This screen is accessed by selecting the '(G)raph Flux/Power Density' option in the locations screen. The screen is divided into three areas. The main flux/power density plot on the right, the keystrokes menu window on the left, and the messages window on the bottom.

Operations are performed on the flux/power density plots, by one of two ways:

1) Pressing (on the keyboard) the bracketed letter of the operation description, or

2) Clicking with the left mouse button the operation description in the keystrokes menu window.

When the flux/power density screen is first accessed, the flux densities of the transmitters are displayed as the default. Normally, the frequency (x-axis) scale is logarithmic. However, if the difference in the frequency limits is less than an order of magnitude, then it is plotted on a linear scale.

Operations:

(Z)oom in: (Press 'z' or click on the description)

With the left mouse button, click on the lower and upper frequency limits of the plot to be zoomed-in on. The order is not essential, since the limits will be put in the correct ascending order, ie. the lower frequency on the left and the upper frequency on the right.

If the difference in the frequency limits of the zoomed-in plot is less than one order of magnitude, then the new plot will have a linear frequency scale.

(B)ack to top level: (Press 'b' or click on the description)

This returns the plot to the top level frequency scale, ie. with the frequency limits originally displayed when the flux/power density screen was first accessed. This operation is used after a zoom-in has been performed.

(2)nd Harmonic: (Press '2' or click on the description)

If either the 'RANGE' or 'SINGLE' frequency options were selected, then the flux/power densities of the transmitters with 2nd harmonics, are plotted. All 2nd harmonics are displayed as blue data points. Emission levels with respect to the carrier are assumed to be at a level of **-40 dB**.

The plots of the 2nd harmonics can be removed by selecting this operation again.

(3)rd Harmonic: (Press '3' or click on the description)

If either the 'RANGE' or 'SINGLE' frequency options were selected, then the flux/power densities of the transmitters with 3rd harmonics, are plotted. All 3rd harmonics are displayed as yellow data points. Emission levels with respect to the carrier are assumed to be at a level of **-60 dB**.

The plots of the 3rd harmonics can be removed by selecting this operation again.

(W)orst-case Sats: (Press 'w' or click on the description)

On the first day of every month, the minimum monthly distance of each satellite to each of the various observatory sites is calculated for that month. These monthly minimum distances are used to calculate the worst-case flux/power densities for each of the satellites, and plotted.

Only the fundamental frequencies are calculated for, and only for the pre-defined ATNF, and related sites. If the 'New Site' option was selected in the site selection screen, then worst-case satellite plots are not available.

Worst-case satellite flux/power density levels are plotted in red, and can be removed by selecting this operation again.

This operation is useful for planning purposes, because it gives an observer an overall look at the levels of interference likely to be encountered.

(V)iew Real-Time Sats: (Press 'v' or click on the description)

This operation presents, on an animated plot, the real-time flux/power density levels from each satellite. Only those satellites that are currently visible (ie. above the horizon) are calculated for. As a satellite rises above the horizon, it's flux/power density plot suddenly appears, and as it sets, it disappears. In addition, as the distance of the satellite decreases, its density level can be seen to rise, and as it recedes, it falls.

The flux/power density levels for Low Earth Orbiting (LEO) satellites are plotted as green data points. The levels for Geostationary and Geosynchronous (GEO) satellites are plotted in red data points. Only the fundamental frequencies are calculated for.

Before displaying the animated plot, The user prompted as to whether the plot is to start from the current, local standard time. If yes is chosen (by pressing 'y'), then the current time is taken from the system clock of the computer. If no is chosen (by pressing 'n'), the user is prompted for the starting year, month, day of the month, hour, minute and second, in local standard time, as separate integer values.

This operation is useful, because it allows an observer to visually check for satellite RFI in real-time. The animation can be left running during an observing session, and regularly consulted to alert the observer to a possible RFI problem.

<u>((D)ata point change:</u> (Press ‘d’ or click on the description)

This changes the style of the data points. The default data point style is a dot. Often, however, they are difficult to see, especially if just a few data points are plotted. By selecting this operation, the data points are made larger and easier to see.

The default data point style is returned, by selecting this operation again.

<u>(R)x Bands:</u> (Press ‘r’ or click on the description)

This operation is used to display the various receiver band-limits. The limits are those based on the receivers at Parkes Observatory. They are plotted as red vertical lines, and cover the 440 MHz line, the 660 MHz line, L-band, S-band, C-band and X-band.

The lines can be removed by selecting this operation again.

This operation is useful for when an observer wants to identify a density level within a particular band.

<u>(I)dentify data point:</u> (Press ‘i’ or click on the description)

There are two modes to this operation: **Information** mode and **Identify** mode.

Information: A flux, or power, density data point is clicked on with the left mouse button. The information (as contained in the ACA database), on any data point that lies within a radius of 1% of the plot limits, centred on the cursor position (the information selection circle), is displayed on the Information Display Screen (see below).

NOTE: The plot must first have a linear frequency scale, so be sure to zoom-in first.

Identify: A position in the density plot window, is clicked on with the middle mouse button. The density level and frequency, at that point, will be printed in the messages window.

Clicking the right mouse button, will exit this operation.

<u>(C)hange flux/power density:</u> (Press ‘c’ or click on the description)

This operation allows the user to toggle between the flux density and power density displays. The default display is the flux density plot.

Flux densities are in the units $dBW/m^2/Hz$ (where 1 Jy = -260 $dBW/m^2/Hz$).

Power densities are in the units dBm/m^2.

(S)ave as GIF file: (Press ‘s’ or click on the description)

This operation saves a particular plot of flux/power densities as a GIF file. The name of the gif file is prompted for in the messages window (the .gif extension should be included in the name). For example:-

parkes_lband_densities.gif

The file is saved in the current directory, and can be accessed after the INTER session.

This operation is useful if plots of particular flux/power densities are required for future reference. For example, if the user wants the power densities of all transmitters with emissions in L-band, the ‘RANGE of frequencies’ option in the frequency selection menu would be selected.The 2nd and 3rd harmonics can be displayed and the user can zoom-in to the L-band region, then save the plot. The file can be printed onto an overhead transparency for display at a meeting or conference.

(E)xit to locations plot: (Press ‘e’ or click on description)

Exits the density screen and returns to the locations screen at the top level plot.

Q)uit program: (Press ‘q’ or click on description)

This ends the INTER session, and exits the program.

6. Information Screen:

This screen is accessed when the '(I)dentify data point' operation is selected, and acted on, from either the locations screen or the flux/power densities screen. The information displayed is from the ACA database.

The screen is divided into four areas: the main information display on the left, the small location map on the top right, the keystrokes menu window on the middle right and the messages window at the bottom.

The Information Display:

At the top of the information display, is printed the number of licences found to exist within the selected information circle. Below that, is the list number of the licence currently displayed. For example :-

The were 4 licences near the requested position
Licence 1 of 4 currently displayed

Then follows the information taken from the ACA database. These include:-

Latitude	The site latitude
Longitude	The site longitude
Assigned Centre Frequency (MHz)	Centre frequency of occupied bandwidth
Flux Density (dBW/m^2/Hz)	Calculated
Power Density (dBm/m^2)	Calculated
ITU Emission Designator	As per the ITU standard format
Est. Isotropic Radiated Power (W)	Referenced to a point source radiator
Transmitted Power (W)	Max. Power permitted to be produced
Antenna Azimuth	This field is not yet fully populated
Licensee	The owner of the licence
Licensed Bandwidth (Hz)	Bandwidth used for licence charging
Antenna Gain (dBi)	Main lobe gain referenced to a pt. source
Forward/Back Ratio	Ratio of forward gain to reverse gain
Beamwidth of main lobe (deg.)	Angle between the -3dB beamwidth pts.
Antenna Size (m)	Parabolic antenna size or # of elements
Antenna Type	A description of the antenna type used
Antenna Code	Unique abbrev. code (see dbase notes)
Date Approved	Date frequency assignment approved

Above the information display, the frequency source type is indicated, ie. whether the information is for a fundamental frequency source, or a 2nd or 3rd harmonic source.

If the 'RANGE' or 'SINGLE' frequency options were selected, at the beginning of the INTER session, then as each display is 'ended', any 2nd or 3rd harmonics information is successively displayed, if they exist.

The Small Location Map:

A white triangular data point displays the location of the transmitter source, relative to the observatory site (the green square in the centre).

This is particularly useful, when the information screen was accessed from the flux/power density screen, since the density plots don't indicate where the transmitters are located.

The Keystrokes Menu:

(N)ext licence: (Press 'n' or click on the description)

If more than one licence was found, this operation is used to display the next consecutive licence in the list.

When displaying each of the licences in turn, the white data point, indicating the transmitter location, can be seen to jump about in the small location map.

(B)ack one licences: (Press 'b' or click on the description)

If more than one licence was found, and the currentlydisplayed licence is forward in the list, then this operation moves backwards through the list, one licence at a time.

(J)ump 5 Licences: (Press 'j' or click on the description)

If more than five (5) licences were found, this operation jumps forward 5 licences in the list.

(V) back 5 Licences: (Press 'v' or click on the description)

If more than five (5) licences were found, and the currently displayed licence is forward more than 5 licences in the list, then this operation jumps backwards 5 licences in the list.

(S)tart again: (Press 's' or click on the description)

If more than one licence was found, and the currently displayed licence is forward in the list, then this operation quickly returns the display to the first licence in the list.

(P)rint to Postscript File: (Press ‘p’ or click on the description)

This operation outputs the information to a postscript file for future reference. The postscript file name is prompted for in the messages window (the .ps extension should be included in the file name). For example:-

```
1499MHz_information.ps
```

The file is saved in the current directory and can be accessed after the INTER session. To gain a hard-copy of the file, just send it to a printer. For example:-

1) `lpr 1499MHz_information.ps`

or

2) `mpage -1 -b 1499MHz_information.ps`

(E)nd: (Press ‘e’ or click on the description)

This ends the information session , and returns to the screen that it was originally accessed from, ie. either the locations screen or the densities screen.

If however, there existed 2nd or 3rd harmonic data sources in the selected information circle, then they are displayed in turn, before completely ending the information session.

7. References:

"Records of Radiocommunications Licences"
Database on CD-ROM
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1 June, 1998.

"Spacetrack Report No. 3"
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December, 1980.

"Interference Characterisation of Australian Astronomy Sites"
by Peter J. Hall, Ananda S. Mohan and Robert S. Soretz
Proceedings URSI Large Telescope Working Group
Sydney, December 1997.

"Measurement and modelling of noise and interference for communication and radio astronomical applications"
Final year undergraduate thesis by Robert Soretz.
UTS School of Electrical Engineering
Spring, 1997.

Academic Supervisor:	Dr. Ananda Mohan Sanagavarapu
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<u>Web Site:</u>

The ATNF RFI Characterisation web page at:-

http://www.parkes.atnf.csiro.au/people/jsarkiss/rfi/