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|  | | **SE40(20)032** |
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| WGSE Project Team SE40 | |  |
| SE40-web meeting 5, 14 May 2020 | |  |
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| Date issued: | |  |
| Source: CRAF, SKAO | | |
| Subject: Compatibility-study software (terrestrial & EPFD) for SE40\_40 (“Compatibility analysis (inter-service and intra service) for S-PCS below 1 GHz”) | | |
| Group membership required to read? (Y/N) | N | |

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| **Proposal:**  To recognize the attached Jupyter notebooks, which contain the terrestrial compatibility study and the EPFD software to be used for compatibility studies for S-PCS<1GHz vs. RAS. |
| **Summary:**  RAS compatibility studies were made with the Python programming language, using several packages from the Python scientific stack (numpy, scipy, matplotlib) and a package developed by CRAF, called “pycraf” that implements some of the relevant ITU-R recommendations, e.g., Recs. ITU-R P.452-16, RA.769-2, RA.1631-0, which are used for the terrestrial part of the compatibility study. Furthermore, the EPFD method was implemented, making use of the same Python packages plus the cysgp4 package. The latter provides functionality to determine satellite orbits. |
| **Background:**  The RAS operates several observatories in CEPT countries using these frequencies, such as the 100-m telescope at Effelsberg (Germany), Jodrell Bank (UK), LOFAR (core station in the Netherlands, but many international stations all over Europe), Medicina (Italy), Nançay (France), or Pushchino (Russia). The affected RAS bands 150.05−153 MHz and 406.1−410 MHz are of high importance for a large variety of astronomical questions but also for solar physics research.  ECC Draft Report “Compatibility analysis (inter-service and intra service) for S-PCS below 1 GHz” investigates the compatibility of several nGSO satellity constellations operating at frequencies of 137, 149 and 400 MHz. The satellites, as well as the TT&C and subscribers on the ground, could potentially interfere with RAS stations operating in the bands 150.05−153 MHz and 406.1−410 MHz. Compatibility studies were previously provided for all three cases, analyzing the single-interferer scenario for the ground-based transmitters and aggregation studies (based on the EPFD methodology as described in Rec. ITU-R M.1583) for the satellite constellations. At SE40 M68 several participants kindly asked, whether the software that was used for the studies could be made available. |

# Installation of the Software\_\_\_\_\_\_\_\_\_\_

The provided software (Jupyter[[1]](#footnote-2) notebooks) needs a Python[[2]](#footnote-3) 3.5 (or higher) installation and several libraries (called packages in the Python terminology) from the “scientific stack”, as well as some other packages, e.g., for calculation of path propagation losses (pycraf[[3]](#footnote-4)) and satellite-orbit determination (cysgp4[[4]](#footnote-5)). For the installation of this software, it is recommended to use the Anaconda[[5]](#footnote-6) Python distribution, which can be downloaded for all three major computing platforms (Linux, MacOS, Windows 10) from the following website:

<https://www.anaconda.com/distribution/#download-section>

Anaconda ships with a package manager, “conda”, that can install packages in binary form, thus avoiding that the end user has to install C/C++ compilers, which can be a lot of work on platforms such as Windows 10.

After installing Anaconda, one needs to install the necessary packages. This is best done in a “conda environment” (a kind of virtual environment), such that the package (versions) necessary for the software don’t interfere with other programs that may already be present. To do so, open an **Anconda command prompt** (terminal) and run:

conda create -c conda-forge --yes -n pycraf-se40 python=3.7 astropy basemap cysgp4 cython h5py ipywidgets jupyterlab jupyter\_nbextensions\_configurator matplotlib nodejs numpy pandas "pycraf>=1.0.2" pyproj pyqt pytest pytest-astropy pytest-qt xlrd

This will create an environment, “pycraf-se40”, which then must be activated (every time!) before it can be used:

conda activate pycraf-se40

The software, which is provided here, is in the form of Jupyter notebooks. While it can easily be run in plain Python, Jupyter adds some convenience by allowing to integrate Python code, accompanying text (based on Markdown, with LaTeX support) and images/videos. To use the provided notebooks, open the Anaconda prompt/terminal in the folder that contains them, activate the environment, and run Jupyter:

jupyter-lab

A browser should then open, showing the Jupyter Lab web application, in which the notebooks can be opened and used.

# Running the Software

To use the software, one simply “run all cells” in Jupyter (or steps through each of them one by one, see Jupyter manual for details). Note that a fair amount of RAM is necessary for the EPFD calculations, and that the software greatly profits from parallelization on multi-core platforms. Therefore, a powerful workstation will significantly speed-up the calculation. (Depending on the number of iterations and constellation size, it can take up to a few hours even on a workstation with 16+ CPU cores and 132 GByte of RAM).

# Documentation

All packages used in the provided notebooks are fairly well documented. Therefore, the user is referred to the various online manuals and tutorials, which are made available by the package maintainers.

# License

The notebooks are provided under the GNU General Public License[[6]](#footnote-7) v3.0

1. <https://jupyter.org/> [↑](#footnote-ref-2)
2. <https://www.python.org/> [↑](#footnote-ref-3)
3. <https://github.com/bwinkel/pycraf> [↑](#footnote-ref-4)
4. <https://github.com/bwinkel/cysgp4> [↑](#footnote-ref-5)
5. <https://www.anaconda.com/> [↑](#footnote-ref-6)
6. <https://www.gnu.org/licenses/gpl-3.0.en.html> [↑](#footnote-ref-7)