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Greetings from the Director

I wish all readers, users and all staff of Effelsberg observatory a happy new year!

It seems that it has never been more important to include also wishes for health and well-being in these words at the beginning of the year, which I gladly do!

Obviously, the last year had not developed into the year that we had all expected. It was difficult, often very sad and so many different aspects were challenging. I would like express the gratitude to ***all*** staff, from the operators and engineers to everyone in the support staff, and of course the management team, for their incredible joint effort to operate as normal as possible.

Despite the challenges, the telescope has not only operated successfully without interruption, but also everyone has been kept safe. We hope that we can overcome the remaining challenges, and that we can soon concentrate on more pleasant things again.

One of these will be the 50-year anniversary activities, although some of those may have to be shifted to next year.

In any case, we can get our motivation and inspiration from the scientific output of the telescope, which has remained very strong again last year. Hence, I do not only want to congratulate the observers on their results, but I'd like to also thank them for making the last year a little brighter.

All the best, stay safe, and we hopefully see each other again, literally,

Michael Kramer

Call for proposals – Deadline February 3, 2021, UT 15:00

by Alex Kraus

Observing proposals are invited for the Effelsberg 100-meter Radio Telescope of the Max Planck Institute for Radio Astronomy (MPIfR).

The Effelsberg telescope is one of the World's largest fully steerable instruments. This extreme-precision antenna is used exclusively for research in radio astronomy, both as a stand-alone instrument as well as for Very Long Baseline Interferometry (VLBI) experiments.

Access to the telescope is open to all qualified astronomers. Use of the instrument by scientists from outside the MPIfR is strongly encouraged. The institute can provide support and advice on project preparation, observation, and data analysis.
The directors of the institute make observing time available to applicants based on the recommendations of the Program Committee for Effelsberg (PKE), which judges the scientific merit (and technical feasibility) of the observing requests.

Information about the telescope, its receivers and backends and the Program Committee can be found at https://www.mpifr-bonn.mpg.de/effelsberg/astronomers (potential observers are especially encouraged to visit the wiki pages!).

Observing modes

Possible **observing modes** include spectral line, continuum, and pulsar observations as well as VLBI. Available backends are several FFT spectrometers (with up to 65536 channels per subband/polarization), a digital continuum backend, a number of polarimeters, several pulsar systems (coherent and incoherent dedispersion), and two VLBI terminals (dBBC and RDBE type with Mk6 recorders).

Receiving systems cover the frequency range from 0.3 to 96 GHz. The actual availability of the receivers depends on technical circumstances and proposal pressure. For a description of the receivers see the web pages.

Please note, that observing proposals for the new **Phased-Array-Feed** cannot be accepted yet – the system is still being commissioned.

How to submit

Applicants should use the NorthStar proposal tool for preparation and submission of their observing requests. North Star is reachable at https://northstar.mpifr-bonn.mpg.de .

For VLBI proposals special rules apply. For proposals which request Effelsberg as part of the European VLBI Network (EVN) see: http://www.evlbi.org/proposals/ .

Information on proposals for the Global mm-VLBI network can be found at
http://www3.mpifr-bonn.mpg.de/div/vlbi/globalmm/index.html .

Other proposals which ask for Effelsberg plus (an)other antenna(s) should be submitted twice, one to the MPIfR and a second to the institute(s) operating the other telescope(s) (e.g. to NRAO for the VLBA).

The following deadline will be June 3, 2021, 15:00 UT.

The new Opticon-RadioNet-Pilot

by Alex Kraus

After more than 20 highly successful years, the RadioNet project ended on Dec 31, 2020 (a brief review by the coordinator can be found at https://www.radionet-org.eu/radionet/a-zensus-on-radionets-past-and-future/).

However, the Transnational Access Programme with enhanced support for users of the 100m-telescope and other European observatories will continue in the new Opticon-RadioNet-Pilot (ORP), see:
https://www.radionet-org.eu/radionet/opticon-radionet-pilot-orp-project-approved-by-the-european-commission/
or
https://www.mpifr-bonn.mpg.de/pressreleases/2020/14

The new project will start in March this year – further information about the procedures for the Transnational Access will be given in the next issue of this newsletter.

News from the Observatory

by Alex Kraus

The Covid-19 pandemic still restricts our lives and also some of the activities at the observatory. Nevertheless, our priority was and is to keep the 100-m telescope as well as the LOFAR station operational and so far, we were successful with this task. We hope that the situation will improve throughout this year and that we will be able to welcome observers at the telescope site again soon.

This year, the observatory celebrates its 50th anniversary. Already before the foundation of the Max-Planck-Institut für Radioastronomie in 1966, plans to build a huge radio telescope were made, and after the decision for the site in Bad Münstereifel-Effelsberg the construction started in 1967. On May 12, 1971 the inauguration ceremony took place – first light was already seen a few days before. Since August 1972, the telescope performs regular astronomical observations.

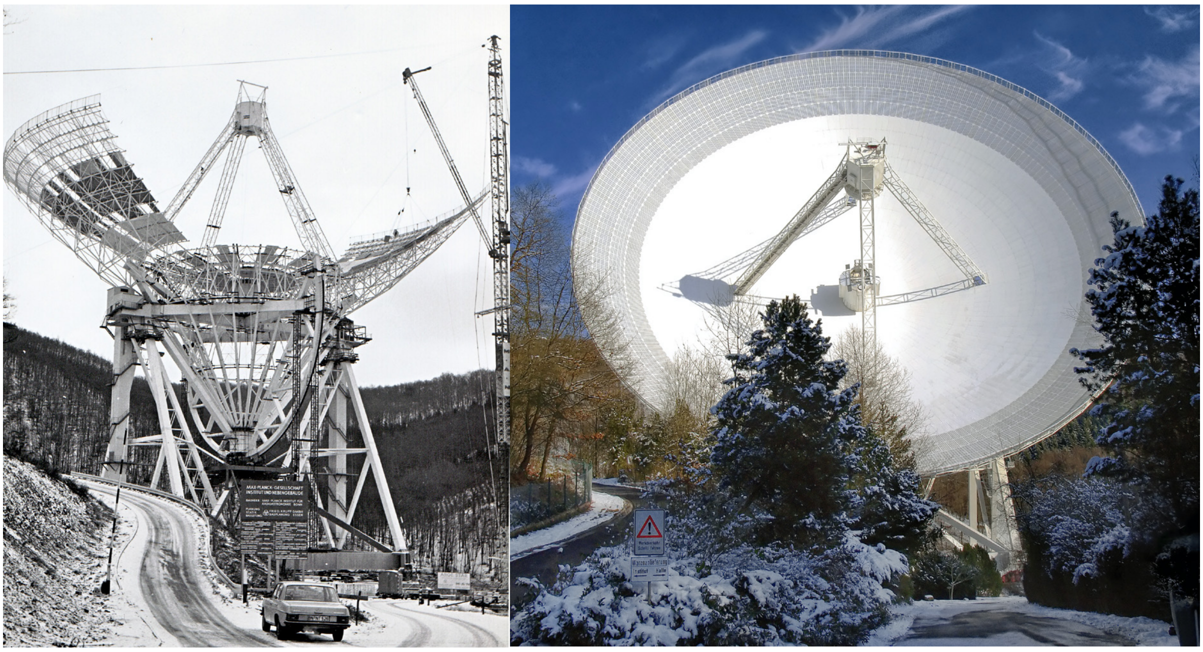
Due to the pandemic, the planned celebration in May had to be postponed – we will hopefully be able to have this event in fall. An open door for the public will take place in summer 2022.

In honour of the telescope, the German ministry of finance (which is responsible for the release of new stamps) will issue a dedicated stamp on April 1st – see: https://www.bundesfinanzministerium.de/Content/DE/Standardartikel/Service/Briefmarken/Briefmarkenthemen_2021_anl.pdf?__blob=publicationFile&v=2.

Additionally, we are currently preparing an illustrated book with lots of pictures from the telescope. Some excerpts will be shown in the next issue of this newsletter.

Last but not least, in summer we plan to open a new hiking trail in the surroundings of the telescope, in addition to the already existing three astronomical trails which present in different scales objects of our Solar System (Planetary Walk), our own Galaxy (Milky Way Walk) and finally several galaxies and quasars in huge distances (Galaxy walk). The new trail will cover the history of the telescope from the first light in 1971 to the most recent developments. We will present this Time Travel Trail in the next issue of this newsletter.

Even after 50 years, the telescope is still going strong and we make a lot of efforts to maintain and improve the hard- and software. In this context, we were happy to receive information from the Max-Planck-Society that our proposal to renovate the main axes power units and the corresponding control systems will be supported. The project will keep us busy for the next 2-3 years, but should not interrupt observations significantly.



Two pictures from the same position – 50 years ago and today.
(left picture taken by Richard Wielebinski, the right one by Norbert Tacken)

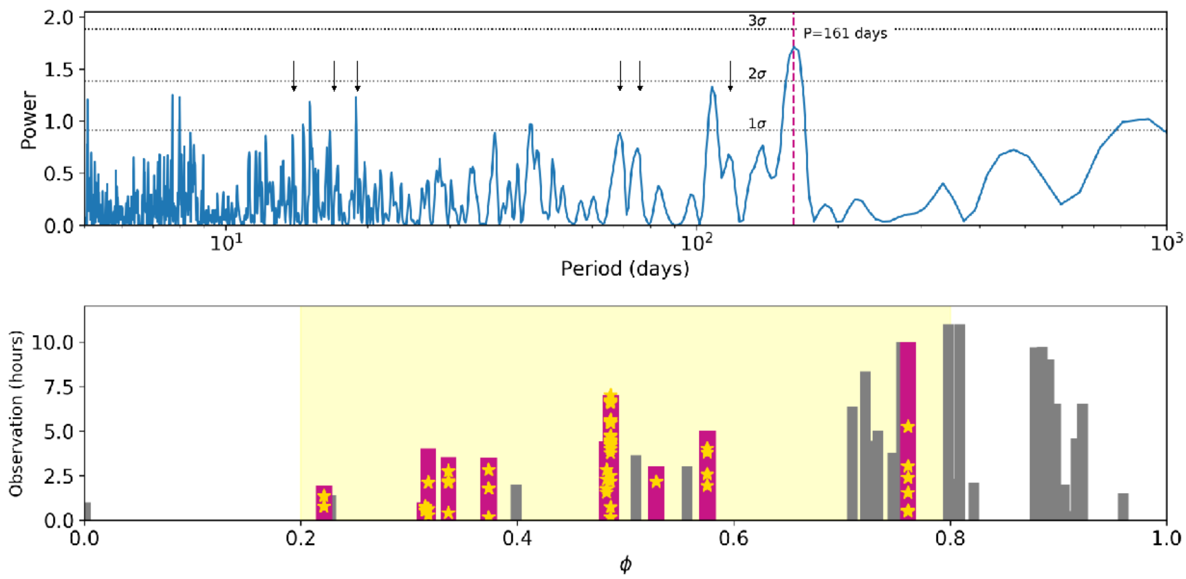
Long-term Study of FRB 121102 with Effelsberg

by Marilyn Cruces and Laura Spitler

Fast radio bursts (FRBs) are a relatively new observational phenomenon consisting of bright flashes of millisecond duration, detected so-far exclusively at radio frequencies and whose origin remains unknown. Although most of the sources are seen as one-off events, there are a couple of FRBs known to repeat. The first known repeating source — and for several years the only known — is FRB 121102.

We performed an extensive multi-wavelength campaign from September 2017 to June 2020 with the Effelsberg telescope, the Green Bank Telescope and the Arecibo Observatory to shadow higher energy experiments like the Gran Telescope Canaria (optical), NuSTAR (X-ray) and INTEGRAL (gamma-ray). The only radio burst at the time of a simultaneous X-ray observation was detected with Effelsberg and allowed us to place a 5σ upper limit of 5x10e47 erg on the 3–79 keV energy of an X-ray burst counterpart.

In total, we observed 128 hours with Effelsberg and detected 36 bursts, one with a pulse width of 39 ms, the widest burst ever detected from FRB 121102. We added to our sample published data acquired with Effelsberg using the identical setup and extended our sample to 57 bursts in 165 hours over roughly four years. Our analysis focusses on the periodicity of the active phases of FRB 121102, the waiting time between consecutive bursts and the energy distribution of the events.

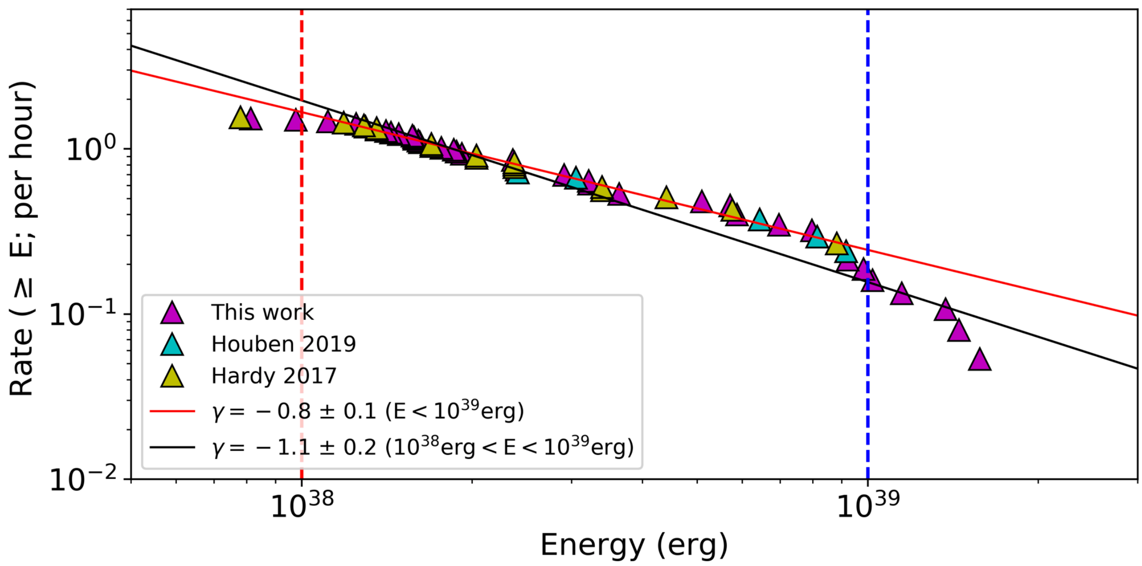


Periodicity analysis for FRB121102. Top: Lomb-Scargle periodogram for the Effelsberg dataset at 1.36 GHz. The vertical dashed line shows the best period prediction and the arrows show peaks coming from the window transform. The horizontal dotted lines show the 1σ, 2σ, and 3σ significance levels deduced from 10,000 bootstrap resamplings. Bottom: phases of the observations based on a 161 days periodicity displayed against the length of its observation. In Magenta are highlighted the epochs with detections for which the yellow-stars indicate the time within a given observation where the bursts occurred. The bars in grey are the observations for which no bursts were detected, and the yellow-shaded region is the estimated active phase. Image from Cruces et al. (2020)

We tested a potential 157-d periodicity previously reported by a team using the Lovell Observatory as the main telescope. We run a Lomb-Scargle periodogram analysis and found a period of 161±5 days and an active phase of roughly 60%, supporting the suggested periodicity. We used the MJD 57075 as a reference epoch and estimated the following active phase to be from MJD 59039 to 59136 followed by a period of inactivity until the next cycle from MJD 59200 to 59297. Interestingly, FRB 121102 was seen active within the 59039 to 59136 window.

We analyzed the waiting time between consecutive bursts on timescales of hours. Time independent Poissonian statistics, as well as Weibull distribution for clustered events, have been previously assumed. We excluded waiting times of tens of millisecond as the 39-ms wide burst of FRB 121102 hints that such events are, in reality, the strongest components of broad bursts. If this is the case, we infer that the strong clustering reported in the literature was likely a consequence of the unknown periodicity and active phase of FRB 121102. If the analysis is limited to the active windows, despite some indication for small clustering, it is less obvious that it indeed differs from the Poissonian case.

We modelled the bursts' cumulative energy distribution with energies from 10^{38}–10^{39} erg and found it is properly described by a power-law with a slope of γ=-1.1±0.2. This value differs from the results of previous studies at other energy regimes. We proposed a single power-law might be a poor descriptor of the data over many orders of magnitude.
We continue the monitoring of FRB 121102 and other repeating FRBs using Effelsberg to comprehend their repeating nature and to constraint the progenitor scenarios.



Cumulative energy distribution of the bursts from FRB 121102 detected by Effelsberg at 1.36 GHz, shown in magenta for the dataset presented in Cruces et al. (2020), in yellow for the detections from Hardy et al. (2017) and in cyan for Houben et al. (2019). The isotropic energy is fit with a power-law estimated through maximum-likelihood. The red-dashed line shows the completeness limit for Effelsberg at ~E=10e38 erg and the blue-dashed line marks the bursts above the saturation limit roughly at E=10e39 erg. Image from Cruces et al. 2020.

Original publication: Cruces et al., Monthly Notices of the Royal Astronomical Society, Volume 500, Issue 1, pp.448-463, arXiv:2008.03461.

Spectrum Compatibility Studies with Python: the *pycraf* package

by Benjamin Winkel

This contribution originally appeared in the CRAF (committee on radio astronomical frequencies) newsletter and is re-printed here with kind permission by CRAF.

The radio spectrum is a precious resource. It has been from the beginning of its use some 100 years ago, but the pressure on administrations to allocate more and more bandwidth to a large variety of services and applications has continually increased. Among these are communications networks, safety of life services, radio and TV broadcasts, radars, and also many scientific applications such as remote Earth sensing, meteorology and radio astronomy.

Whereas some people tend to think spectrum management is mostly a question of lobbying and economic value, the 'bread and butter' of successful sharing is to work out the technical conditions under which a peaceful coexistence of two or more services is possible. In most cases, a new service or application, which seeks access to the spectrum, has to demonstrate that existing services at the same or adjacent frequencies are not affected in a way that limits their operations. This is also true for the same application to be used by different operators. For example, spectrum authorities need to make sure that cell phone providers do not interfere with their business competitors.

At its core, spectrum compatibility studies are a simple three-step procedure.

1. Determination of how much power is radiated towards a potential victim receiver. For this, the power fed into the transmitter system and also the antenna pattern (the gain towards certain directions) are both important parameters that must be incorporated into the calculations.
2. The attenuation along the propagation path must be estimated as it determines the total power that is received at a victim station. For the latter, again the antenna pattern can play a role.
3. The receiver technology and the susceptibility of the interfered-with application to certain kinds of signals must also be considered. Often, spectrum authorities have defined power levels that must not be exceeded at the victim station in order to ensure smooth operations.

Compared with other services, radio astronomy is difficult to protect, as it uses cryogenically cooled receivers and long integration times to reach the sensitivities necessary to observe the extremely weak signals from the distant parts of the Universe. In fact, a cell phone operating on the Moon would produce a signal in radio astronomical systems as strong as the ones received from the most powerful sources in the Universe. Likewise, signals from all-kinds of terrestrial or air- and space-borne services can outshine astronomical signals by many orders of magnitude.

Although the three-step process outlined above is conceptually simple, calculating the actual numbers can be quite challenging. This process starts with the antenna patterns when one immediately notes that the far-side lobe sensitivity of a 100-m class radio telescope cannot be determined experimentally and is difficult to model. It is also the case that state-of-the-art antenna technology in other fields is complex to describe with the required accuracy. Consider for example active antenna systems that use a large number of antenna elements in the aperture plane to produce a beam, which can be electronically steered. Especially for the case of out-of-band emission, where the beam-forming is less efficient, the various technical study groups of the International Telecommunication Union (ITU) and regional spectrum organisations are still working on proper models. Active antenna systems are ubiquitous in modern telecommunication, but a major boost of the technology is now seen with the advent of 5G cell phones. At higher frequencies, above 24 GHz, their base stations will utilise up to 64 antenna elements, which can form beams in quasi- real time to optimise the link budget between base stations and user equipment, such as smartphones or IoT devices. For compatibility studies, not only the gain in the beam direction is important, but the (side-lobe) gain towards the victim station must be computed, which is time- and frequency-dependent.

Even more complicated is the path loss computation. A proper treatment of the problem would involve a complete analysis of the electromagnetic wave propagation over real terrain with all types of different electromagnetic properties. Thus, wet leaves will influence the wave very differently compared with a city with its street canyons. A numerical solution of the size, which is needed for most compatibility problems, is beyond the capabilities of super computers. Therefore, approximation models have been developed from very simple ones to more complex algorithms, which take into account effects such as diffraction at real terrain obstacles, atmospheric absorption or tropospheric scatter.

As such models are an important ingredient for compatibility studies, the Radiocommunication sector of the International Telecommunication Union (ITU-R) has published a large number of so-called recommendations, which contain propagation models for a variety of usage scenarios. Furthermore, recommendations exist, which propose (simplified) antenna models for all kinds of services, e.g., mobile communication, fixed links, or radio telescopes. Protection levels are in part specified in the Radio Regulations of the ITU-R or also defined in Recommendations. For example, the thresholds relevant for the radio astronomy service (RAS) are detailed in Recommendation ITU-R RA.769-2.

The committee on radio astronomical frequencies (CRAF) is an expert committee of the European science foundation (ESF) and was founded by European radio astronomical organisations and institutes. CRAF represents the interests of radio astronomy at all levels of spectrum management, from solving local compatibility issues at observatories to participating in European and international meetings, e.g. the working group meetings of the European Conference of Postal and Telecommunications Administrations (CEPT) or the ITU-R study groups and World Radiocommunication Conferences (WRC).

As explained above, fighting for our (i.e. radioastronomers') interests is strongly linked to the ability to present spectrum compatibility studies that explore under which circumstances protection of RAS stations can be ensured. To increase its effectiveness, CRAF has undertaken considerable work to produce Python software to ease and streamline the creation of compatibility calculations. This software tool is named *pycraf* and is not a stand-alone software, but a library for the Python programming language (a so-called package). While this demands some familiarity with the Python language, which however is not too hard to learn, it makes the software very flexible and versatile, easy to extend, and allows to share our studies under permissive open-source licences with other parties. In the following, a small overview will be given of the features included in *pycraf*, together with some examples and future plans.

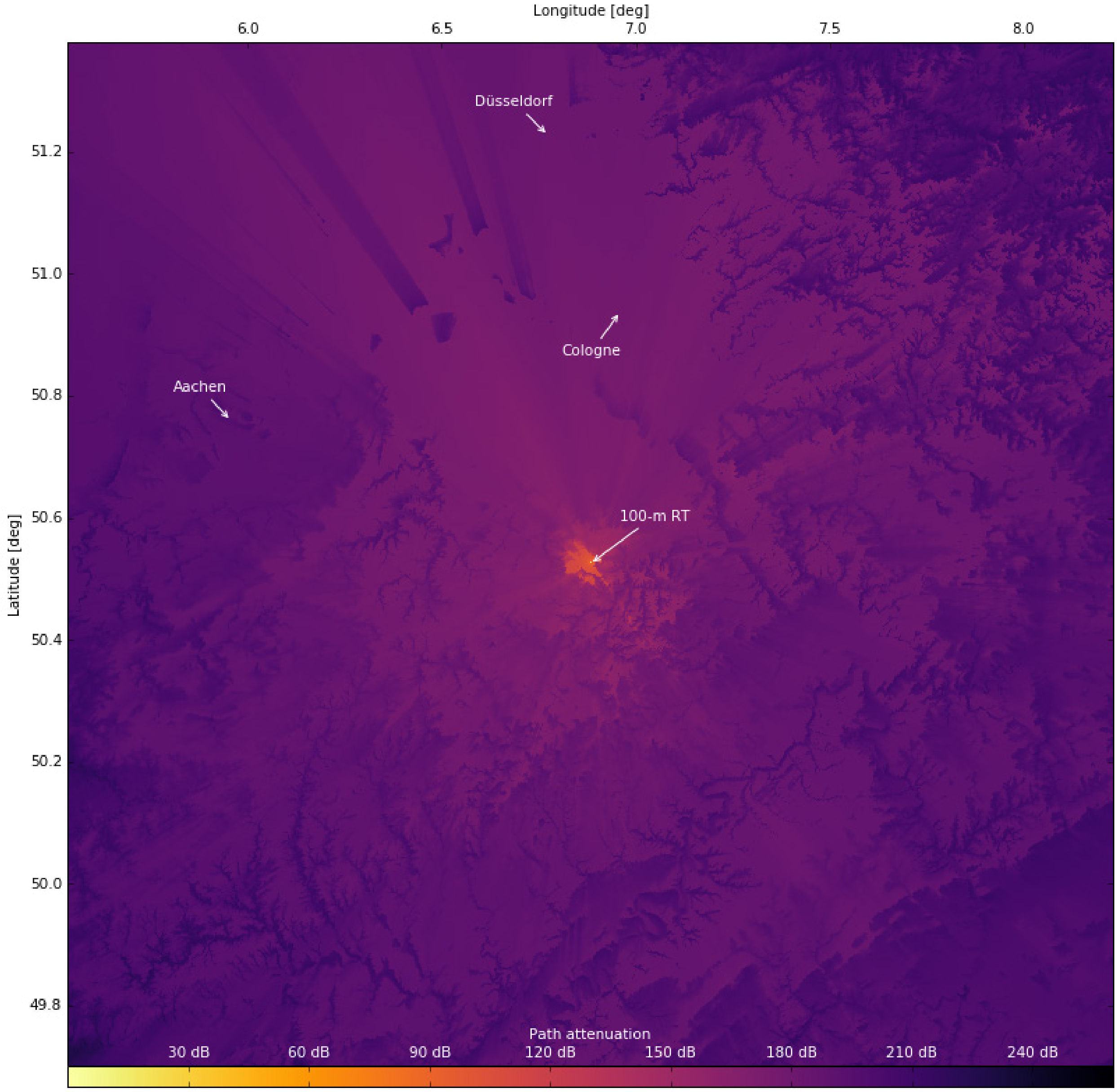


Figure 1:Path attenuation map for the region around the 100-m radio telescope at Effelsberg (Germany) for a frequency of 3.5 GHz. Transmitter height was assumed to be 40 m. Terrain heights play an important role representing obstacles for the diffraction loss calculation in the model (the telescope is situated in a valley in the Eifel mountains).

Probably the most-used feature of *pycraf* is its implementation of the Rec. ITU-R P.452 path propagation model. The method includes line-of-sight (free-space) loss including correction terms for multipath and focussing effects, diffraction (at terrain features), tropospheric scatter, and anomalous propagation (ducting, reflection from elevated atmospheric layers). It also proposes an approach to include clutter effects, but this only accounts for the endpoints of the propagation path, which is why there is often considerable debate as to how realistic the prediction could be. One should emphasize that the model is not fully derived from physics, but is based to a large extent on empirical modelling, which best describes the results from a huge number of measurement campaigns. As the P.452 model requires topographical information along the path of propagation, *pycraf* provides easy access to terrain-height data measured by the space shuttle radar mission (SRTM). It is also planned that the next release of *pycraf* will provide access to the Corine landcover data of the European continent (based on the Copernicus mission), which can be used to derive the clutter zone types with high spatial resolution. In *Figure 1* an example path loss map is shown for an area around the 100-m telescope at Effelsberg (Germany). The colour in each pixel of the map describes how much path loss/attenuation is predicted by P.452 if the receiver is in the centre of the map and the transmitter is located at the respective pixel.

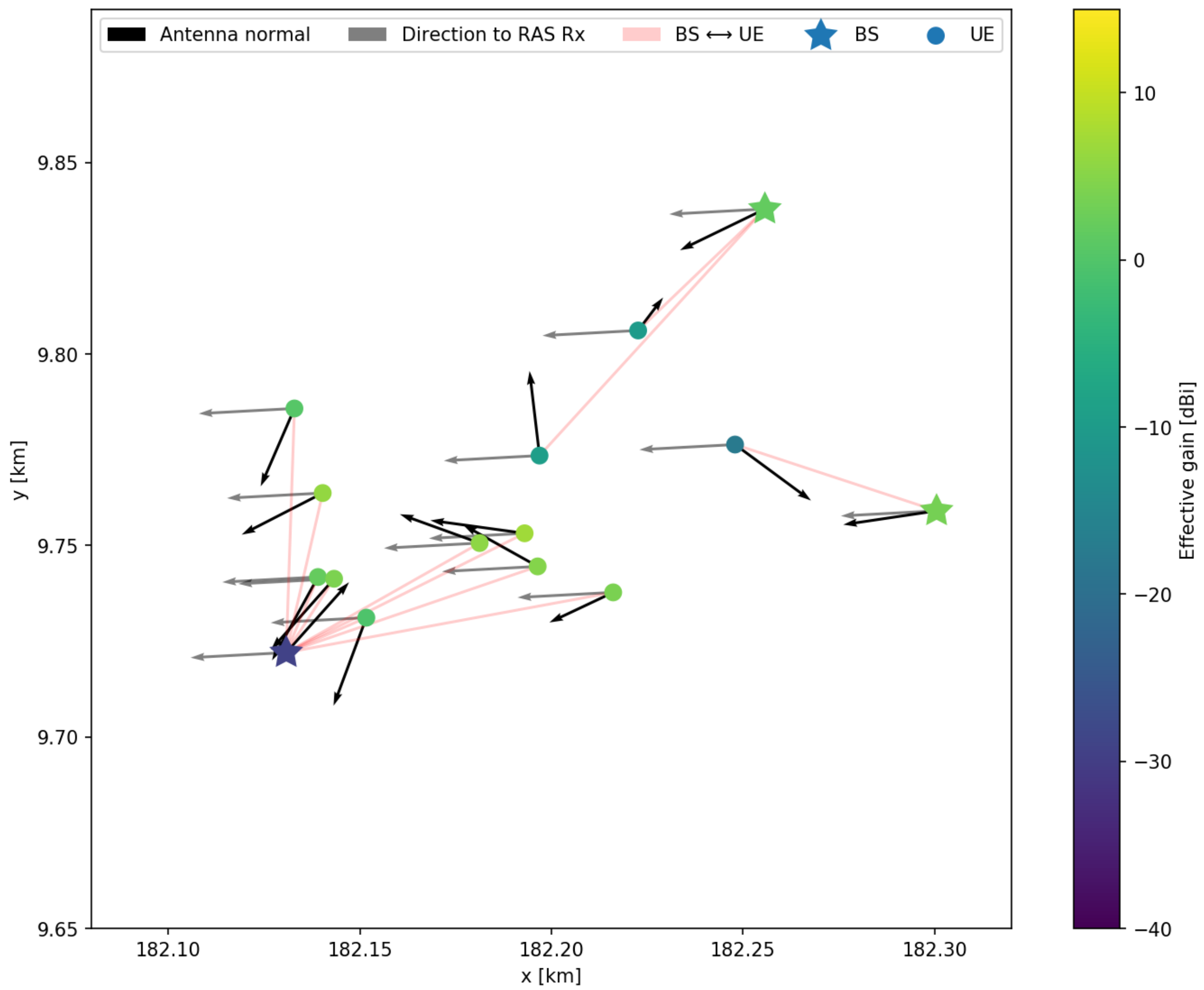


Figure 2: Effective antenna gain of BS and UE devices towards the RAS station for 5G active antenna systems. The figure displays a 2D projection of the 3D simulation.

Such maps are a key ingredient for the studies which explore the compatibility between the RAS and the 5G cell phone networks, which are currently being deployed in Europe using several existing, but also new spectrum allocations. The European 5G pioneer band covers the frequencies from 3.4 to 3.8 GHz. As 5G technology is heavily reliant on active antenna systems (AAS), studies also have to account for beam-forming and the (quasi-) random deployment of cell phones. Given that there are a number of cell phones active in the 'footprint' of a 5G base station antenna, the AAS will form a beam towards each of the user devices in rapid succession. The effective gain of the AAS towards the RAS station, usually being situated in the sidelobes of the antenna, is thus also time-dependent. In *Figure 2* the geometry of the situation is depicted. Three base stations (BS) serving a different number of cell phones ("user equipment" - UE) each within a certain area in front of them. Antenna normal vectors of the BS are visualised with black arrows. The smartphones can have a random orientation of their antennas. As the connecting line between a BS and the associated smartphones is not necessarily aligned with the antenna normal vectors, the beams which are formed are also not aligned with the antenna normals. At the same time, the direction to the RAS receiver (grey arrows) is usually distinct. Therefore, the effective gain towards the RAS station depends on several free parameters and must be determined for each individual device independently. In reality, the link budget between BS and UE is also subject to power control mechanisms, which try to even out some of the spread in the effective path loss between BS and UE depending upon the distance between and the orientation of the two. Obviously, this also needs to be considered.

An actual antenna gain pattern for a 5G base station is displayed in *Figure 3* for a few exemplary beam directions.

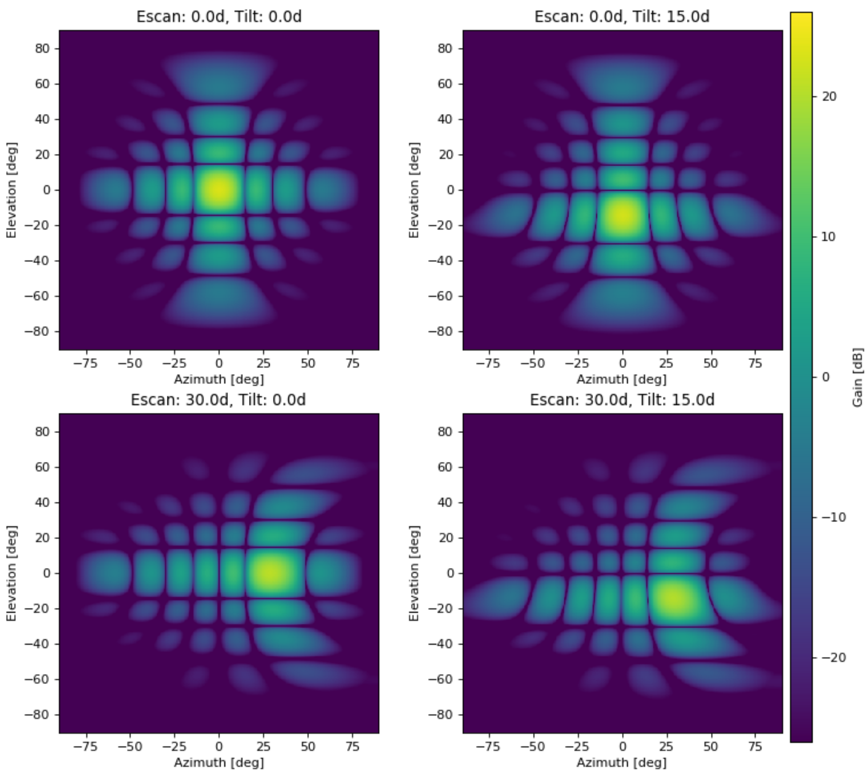


Figure 3: Example antenna gain patterns for 5G active antenna systems, for four different beam directions.

Another useful *pycraf* feature is its implementation of an atmospheric absorption model, as defined in Rec. ITU-R P.676. Whereas this is not as sophisticated as some of the models used in radio astronomy, it provides useful predictions. Furthermore, it must be stressed that most parties involved in the spectrum management process would only accept results, which are based on ITU-R models. Even if these do not always represent the latest state-of-the-art scientific models, this is a reasonable approach as it makes consensus on the technical details of compatibility studies somewhat easier if everyone is using the same models. The P.676 algorithm performs a raytracing of a ray of (radio) light through a layered atmosphere and integrates the overall attenuation along the ray; see *Figure 4*.

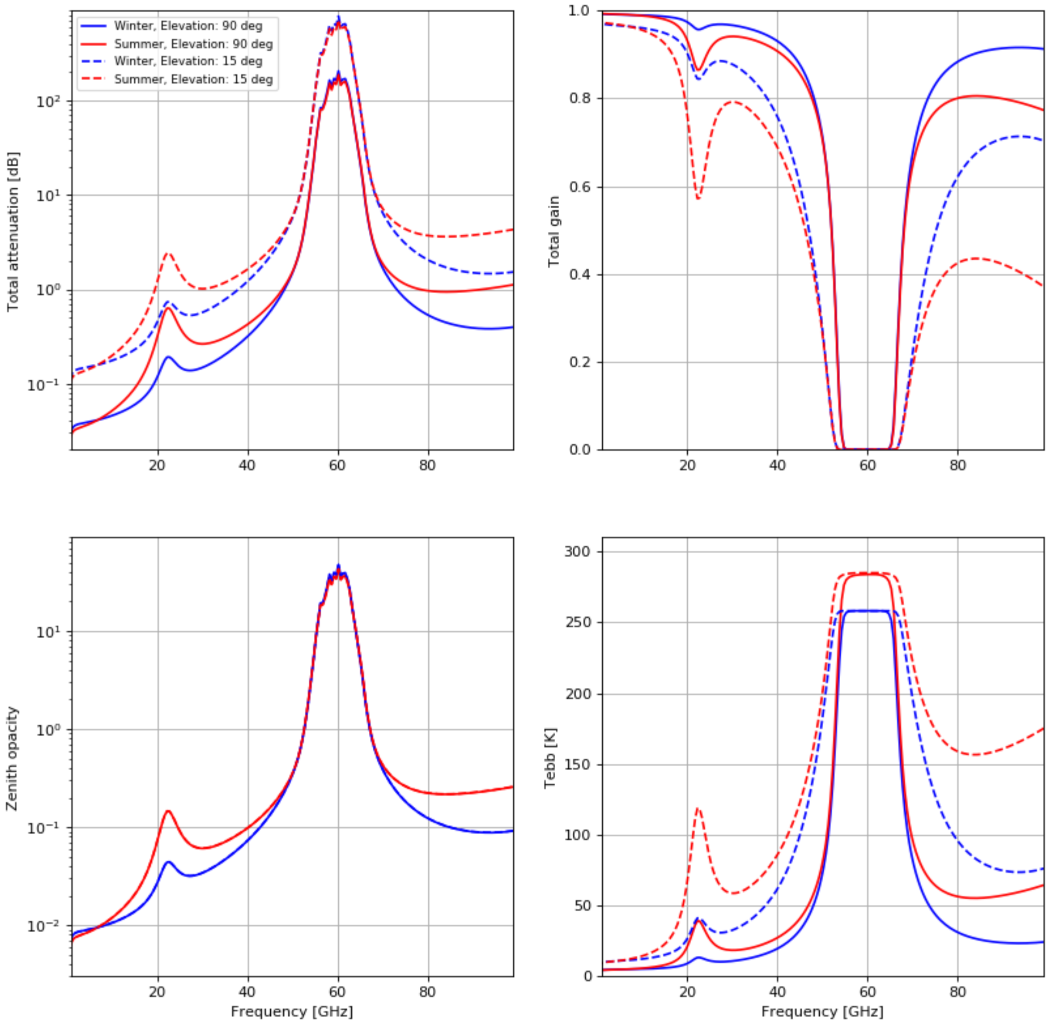


Figure 4: Atmospheric attenuation predicted by Rec. ITU-R P.676 for frequencies up to 100 GHz under various conditions.

In collaboration with SKAO (in particular with Federico Di Vruno), the *pycraf* team has worked towards integrating functionality to perform simulations of entire satellite constellations and

their aggregated power received at a radio telescope. This becomes more and more important as mega constellations such as SpaceX/Starlink or OneWeb, consisting of thousands of small satellites, are being launched into low-Earth orbits, with the aim of providing broadband Internet all over the world. As satellites can cross the main beams of radio telescopes, they represent a high potential for harmful interference, and astronomers are very worried about the situation. First results have been submitted to the CEPT spectrum engineering group SE40, which deals with satellite systems.
The *pycraf* package is hosted on GitHub[1] under open source license (GPL v3). The team would very much welcome contributions, feature requests, and also bug reports. There is also a lot of documentation, with a user manual[2] and several tutorial notebooks (for the Jupyter web frontend) are available.

The author would like to thank Peter Thomasson for careful proof-reading of the manuscript.

Further reading:

- B. Winkel & A. Jessner, *Spectrum management and compatibility studies with Python*, Advances in Radio Science 16, p.177, 2018; https://arxiv.org/abs/1805.11434
- B. Winkel & A. Jessner, *Compatibility Between Wind Turbines and the Radio Astronomy Service*, Journal of Astronomical Instrumentation 8, Issue 1, 2019; https://arxiv.org/abs/1812.04731

[1] https://github.com/bwinkel/*pycraf*
[2] https://bwinkel.github.io/*pycraf*/latest/