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Dissemination Level

| Dissemination Level | | |
|---------------------|---|---|
| PU | Public | X |
| PP | Restricted to other programme participants (including the Commission Services) | |
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| CO | Confidential, only for members of the consortium (including the Commission Services) | |

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1 Introduction

The impact of radio frequency interference (RFI) on astronomical and geodetic observations, or remote sensing, is of major concern for all observatories around the world. The high sensitivity receivers (radiometers) installed in radio telescopes are a very expensive system, with state-of-the-art components in most cases, built to carry out top-level scientific observations.

The existence of RFI can damage the amplifying stages of these ultra low noise receivers or drive them into saturation and, hence, generate intermodulation. These effects impede the detection of cosmic radio signals and can even blind the receiver, making it useless.

Current developments in centimetre-wave and microwave receiver technology are focused on processing ever-wider frequency bands. This trend is contrasted with the existence and future deployment of new technologies with larger bandwidths at higher frequencies, like UWB, which can use several bands in the range 3.1 - 10.6 GHz, or automotive and helicopter radars at 76 - 81 GHz, for instance.

At this time, broad-band receivers (2 - 14 GHz) are installed in VGOS radio telescopes in Haystack, Goddard and Kokee Park (USA), Yebes (Spain), Ishioka (Japan) and Wettzell (Germany), and new ones are planned in Onsala (Sweden), Ny-Alesund (Norway) and Metsahovi (Finland). In addition, the Horizon2020 RadioNet project plans to build a prototype broad-band VLBI receiver in the range 1.5 - 15.5 GHz (BRAND-EVN WP6). In the microwave range, the NanoCosmos project is under development in the Yebes observatory, with 18.5 GHz instantaneous bandwidth receivers in Q (31.5 - 50 GHz) and W (72 - 116GHz) bands.

Therefore, it is very important to monitor the local RFI environment to determine the suitable counter measurements or mitigation techniques to avoid unwanted effects on sensitive receivers.

A workshop on Detection and Measurement of RFI in radio astronomy was organised on June 8-9, 2017 by the Instituto Geográfico Nacional (IGN, Spain), with financial support from RadioNet in the Yebes Observatory. The purpose of this workshop was to join the efforts of scientists and engineers in the analysis of the impact of RFI, its detection and measurement and hardware and software solutions to minimize their effects.

The workshop's webpage is available at: <http://www.oan.es/rfi2017/>

2 Summary & Impact

The workshop on RFI detection and measurement gave the opportunity to many scientists and engineers to show their work in the field of RFI analysis, its detection and measurement as well as hardware and software solutions to minimize their unwanted effects on high sensitivity radio astronomy receivers, which are equipped with state-of-the-art components to carry out top-level scientific observations and measurements. Although all institutes working on RFI instrumentation are already doing a great job in avoiding and suppressing unwanted emissions, this topic is more and more dominating the work of engineers and scientists in radio astronomy. In this workshop, attendees learned how other observatories are facing RFI issues, so they collected got new ideas on how to start or improve their work in this field.

Many interesting results have been shown in the workshop. As an example, an important step in the field of high-temperature superconducting filters is presented here (HTS) (Fig. 1). These are very low loss filters that can be installed in front of the low-noise amplifiers (LNA) in order to avoid out of band saturation of the LNA. The penalty of a little increment in receiver noise produced by these filters is largely compensated with the benefits that they produce, as they allow the operation of amplifiers in the linear regime in the presence of RFI signals.

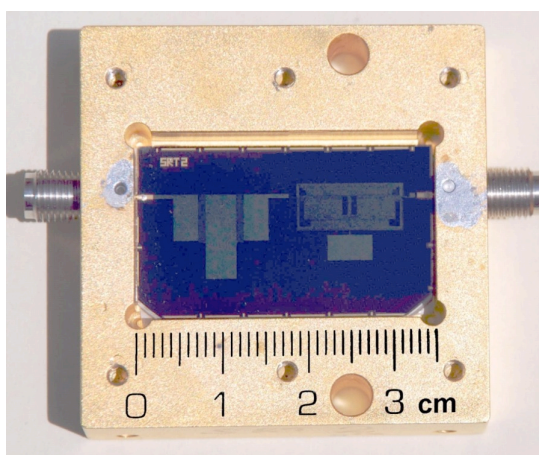


Figure 1: Example of HTS filter (Credit: S. Mariotti, IRA/INAF).

The speakers have shown that RFI is a severe and very common problem to all observatories, although every site has its individual RFI population. Therefore, the knowledge of RFI measurements with appropriate instrumentation to get valuable and comparable results has to be invested at all RadioNet facilities. At the end, efforts against spectrum pollution have to be joined through the Committee on Radio Astronomy Frequencies (CRAF), whose frequency manager (Dr Talayeh Hezareh) gave an inspiring talk about CRAF activities and future telecommunication services with impact on radio astronomy.

After the meeting, a tutorial was given to show attendees how to use the portable RFI equipment available at the Yebes Observatory. This will allow other observatories without this instrumentation to carry out RFI measurements on their own with the Yebes equipment, which can be borrowed. This portable RFI equipment is also used for the development of the RadioNet BRAND receiver, as the success of this project is strongly depending on the knowledge of RFI at the respective sites.

The workshop presentations are available at: http://www.oan.es/rfi2017/show_presentations.shtml

3 Agenda

Day 8-June-2017

- 8:30 *Bus departure from Guadalajara Yebes Observatory.*
 9:00 *Arrival and registration.*
 9:30 Workshop Opening and Logistics José A. López Pérez (IGN).
 9:40 Welcome and Yebes Observatory introduction José A. López Fernández (IGN).

Session 1: Local RFI environments (Chairman: Reinhard Keller.)

- 10:00 The INAF RFI group: recent results in spectrum management & monitoring Pietro Bolli (INAF)
 10:30 RFI measurements at the 65m Tianma Telescope Bin Li (Shanghai Astronomical Observatory)
 11:00 *Coffee Break*
 11:30 RFI measurements in the framework of BRAND-EVN project José A. López Pérez (IGN)
 12:00 RFI Survey for the Thai 40-m Radio Telescope Phrudth Jaroenjittichai (NARIT)
 12:30 RFI Measurements at the Argentine Institute of Radio astronomy I.A.R. G. Gancio (IAR)
 13:00 *Lunch Break.*

Session 2: RFI surveys and mitigation (Chairman: Jose A. López-Pérez)

- 14:00 An evaluation of local interferences in the 0-3 GHz band. A case study in Mecó (Spain) Pablo Lopez Espí (UAH)
 14:30 Radio Environment of NSRT and RFI Mitigation Qi Liu (Xinjiang Astronomical Observatory)
 15:00 Wideband RFI mitigation Jan-Willem W. Steeb (Stellenbosch University)
 15:30 *Coffee Break*
 16:00 ESAC RFI Survey in the SMOS 1400–1427MHz Passive Band Ekhi Uranga (ESAC, ESA)
 16:30 RFI measurements with Yebes VGOS broad-band receiver Pablo García (Yebes Observatory).
 17:00 *Visit to the 40-meter radio telescope*
 18:30 *Bus departure to Guadalajara*

Day 9-June-2017

- 8:30 *Bus departure from Guadalajara to Yebes Observatory*

Session 3: RFI management (Chairman: Pietro Bolli)

- 9:00 Spectrum management for Radio astronomy in Europe and beyond Talayeh Hezareh (CRAF)
 9:30 RFI Protection Activities in IAA RAS Aleksey Tsaruk (Institute of Applied Astronomy)
 10:00 An RFI Mitigation Project at the Italian Radio Telescopes Giampaolo Serra (INAF)
 10:30 RFI mitigation tests conducted at GGAO Lawrence M. Hilliard (NASA)
 11:00 *Coffee Break.*
 11:30 High Temperature Superconductor microwave filters for the Sardinia Radio Telescope Sergio Mariotti (INAF-IRA)

Session 4: Hardware for RFI detection (Chairman: José A. López Pérez)

- 12:00 Effective solutions for detection and measurement of RF & uW spectrum using Real-time Spectrum analyser solution Andrew Benn (Keysight Technologies)
 12:30 Industry solutions for RFI monitoring, detection and location Thomas Krenz (Rohde-Schwarz)
 13:00 *Lunch Break*

Session 5: Yebes RFI portable equipment tutorial (Speaker: José A. López Pérez)

- 14:00 RFI equipment tutorial - RFI measurement demo
 16:00 *Coffee Break*
 16:30 *Workshop closure*
 17:00 *Bus departure to Guadalajara*

4 Participants

Forty-one attendees came to the workshop, mainly from Europe (80.5% from Germany, Italy, Spain, Sweden, Latvia, Russia and Poland), but also from Asia (12.2% from China and Thailand), America (4.9% from USA and Argentina) and Africa (2.4% from South Africa).

In relation to the gender of the attendees, the fraction of women attending the workshop was 19.5%, and 22% were young researchers and students.

Invited experts gave very interesting talks about RFI detection and measurement (Pietro Bolli), HTS filters development (Sergio Mariotti) and frequency management (Talayah Hezareh).

The global feeling of the attendees about the workshop was very good as it was a great opportunity to meet with experts in this field.

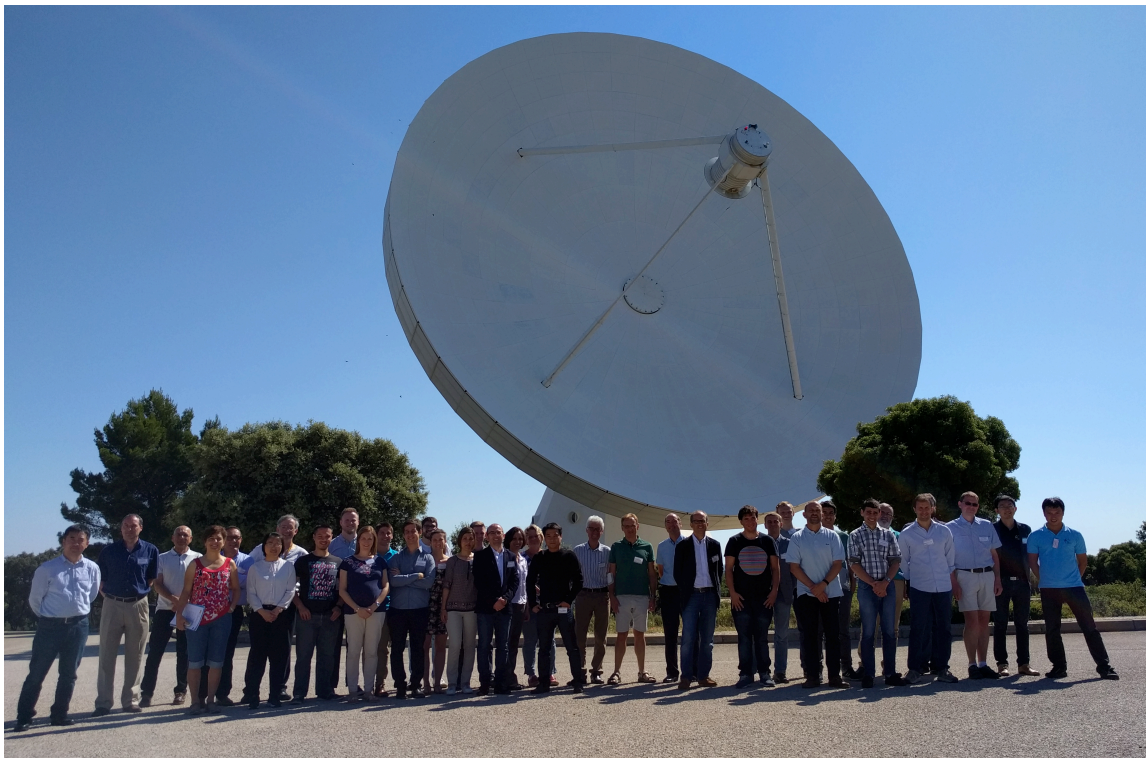


Figure 2: Yebes RFI workshop attendees.



Detection and measurement of RFI in radio astronomy

| | Surname | Name | Institution | Country | Signatur 8 th June | Signatur 9 th June |
|----|------------------|--------------|--|----------|----------------------------------|----------------------------------|
| 1. | Arribas Alonso | J. Julián | Keysight Technologies | Spain | | |
| 2. | Avalos | Jaime | Leipzig University | Germany | | |
| 3. | Bandudej | Kamorn | National Astronomical Research Institute of Thailand | Thailand | | |
| 4. | Barbas | Laura | IGN - Yebes Observatory | Spain | | |
| 5. | Beltrán Martínez | Francisco J. | IGN - Yebes Observatory | Spain | | |
| 6. | Benn | Andrew | Keysight France SAS | France | | |
| 7. | Bleiders | Marcis | VIRAC | Latvia | | |
| 8. | Bolli | Pietro | INAF - Arcetri Astrophysical Observatory | Italy | | |
| 9. | Cabrero | Juan F. | ISDEFE-INTA | Spain | | |

Yeves, Spain, June 8-9th, 2017



Detection and measurement of RFI in radio astronomy

| Surname | Name | Institution | Country | Signatur 8 th June | Signatur 9 th June |
|---------------------------|------------------|---|-----------|----------------------------------|----------------------------------|
| 10. Carreno | Héctor | Keysight Technologies Spain | Spain | | |
| 11. Castill-Fraile | Manuel | European Space Astronomy Center | Spain | | |
| 12. Flygare | Jonas | Onsala Space Observatory, Chalmers University of Technology | Sweden | | |
| 13. Gamella | Carmen | ESA | Spain | | |
| 14. Gancio | Guillermo | Instituto Argentino de Radioastronomía | Argentina | | |
| 15. García Álvaro | Sonia | IGN - Yebes Observatory | Spain | | |
| 16. García Carreño | Pablo | IGN - Yebes Observatory | Spain | | |
| 17. García Miro | Cristina | Madrid Deep Space Communications Complex | Spain | | |
| 18. García Pérez | Oscar | IGN - Yebes Observatory | Spain | | |

Yebes, Spain, June 8-9th, 2017



Detection and measurement of RFI in radio astronomy

| | Surname | Name | Institution | Country | Signatur 8 th June | Signatur 9 th June |
|-----|------------------------|------------------|--|---------------|----------------------------------|----------------------------------|
| 19. | Gomez | Miguel | IGN - Yebes Observatory | Spain | | |
| 20. | Gordillo Pintor | Cecilia | ISDEFE-INTA | Spain | | |
| 21. | Hezareh | Talayeh | CRAF (Committee on Radio Astronomy Frequencies) | Germany | | |
| 22. | Hilliard | Lawrence | NASA | United States | | |
| 23. | Iacovone | Domenico | e-geos s.p.a. - asi (italian space agency) | Italia | | |
| 24. | Jaroenjittichai | Phrudth | National Astronomical Research Institute of Thailand | Thailand | | |
| 25. | Keller | Reinhard | Max-Planck-Institut for Radio Astronomy | Germany | | |
| 26. | Krenz | Thomas | Rohde & Schwarz | Germany | | |
| 27. | Krishnan | Hariharan | Indian Institute of Astrophysics | India | | |

Yebes, Spain, June 8-9th, 2017



Detection and measurement of RFI in radio astronomy

| | Surname | Name | Institution | Country | Signatur 8 th June | Signatur 9 th June |
|-----|-----------------|--------------|--|---------|----------------------------------|----------------------------------|
| 28. | Li | Bin | Shanghai Astronomical Observatory | China | | |
| 29. | Liu | Qi | Xinjiang Astronomical Observatory, Chinese Academy of Sciences | China | | |
| 30. | Llorente | Álvaro | ESA | Spain | | |
| 31. | Lopez Ruiz | Samuel | IGN - Yebes Observatory | Spain | | |
| 32. | Lopez-Espí | Pablo-Luis | Universidad de Alcalá | Spain | | |
| 33. | Lopez-Fernandez | Jose Antonio | IGN - Yebes Observatory | Spain | | |
| 34. | Lopez-Perez | Jose Antonio | IGN - Yebes Observatory | Spain | | |
| 35. | Marín | Rubén | Rohde & Schwarz | Spain | | |
| 36. | Mariotti | Sergio | INAF-IRA | Italy | | |

Yebes, Spain, June 8-9th, 2017



Detection and measurement of RFI in radio astronomy

| | Surname | Name | Institution | Country | Signatur 8 th June | Signatur 9 th June |
|-----|-----------------|-------------|--|--------------|----------------------------------|----------------------------------|
| 37. | Muñoz Vilches | Antonio | M ^o Industria - DG Telecomunicaciones | Spain | | |
| 38. | Patino | María | IGN - Yebes Observatory | Spain | | |
| 39. | Razzak | MD Abdur | High Energy company Ltd | Bangladesh | | |
| 40. | Sackey | Joseph | Jetcom Enterprise | Ghana | | |
| 41. | Sánchez Montero | Rocío | Universidad de Alcalá | Spain | | |
| 42. | Serna | José Manuel | IGN - Yebes Observatory | Spain | | |
| 43. | Serra | Giampaolo | INAF-Observatory of Cagliari | Italy | | |
| 44. | Singwong | Dan | National Astronomical Research Institute of Thailand | Thailand | | |
| 45. | Steeb | Jan-Willem | Stellenbosch University | South Africa | | |

Yebes, Spain, June 8-9th, 2017



Detection and measurement of RFI in radio astronomy

| | Surname | Name | Institution | Country | Signatur 8 th June | Signatur 9 th June |
|-----|----------|--------------|---|---------|----------------------------------|----------------------------------|
| 46. | Sun | Yunxia | Shanghai Astronomical Observatory | China | Yunxia Sun | Yunxia Sun |
| 47. | Sundaram | GA Shanmugha | Amrita Vishwa Vidyapeetham University | India | | |
| 48. | Tercero | Félix | IGN - Yebes Observatory | Spain | | |
| 49. | Teuber | Ute | Max-Planck-Institut for Radio Astronomy | Germany | Ute Teuber | Ute Teuber |
| 50. | Thomas | Ivan | Paris Observatory | France | | |
| 51. | Tsaruk | Aleksey | Institute of Applied Astronomy of the Russian Academy of Sciences | Russia | Aleksey | Aleksey |
| 52. | Uranga | Ekhi | European Space Agency | Spain | Ekhi | |
| 53. | Wolak | Pawel | Torun Centre for Astronomy | Poland | Wolake | Wolake |

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 Pablo Observatorio de Yebes Spain. Pablo
 Pablo

Yebes, Spain, June 8-9th, 2017

5 RadioNet contribution

The RadioNet project supported the RFI workshop with a total amount of 1.500 EURO.

A portion of RadioNet funds were devoted to support the travel expenses of an expert in the RFI field (300 €):

- Pietro Bolli (INAF Arcetri Astrophysical Observatory / Italy) - responsible for RFI and former CRAF secretary. His expertise in the topic of the workshop is high. He gave a talk about RFI measurements and hardware,

The remaining RadioNet support was used to cover organisational/logistical expenses of the workshop.

6 Publications

No official publications were planned, however the workshop presentations have been uploaded to the workshop home page at: http://www.oan.es/rfi2017/show_presentations.shtml

7 Acronyms

| | |
|-----------|---|
| BRAND-EVN | Broad-bAND EVN – work package in RadioNet project |
| CRAF | Committee on Radio Astronomy Frequencies |
| EVN | European VLBI Network |
| HTS | high-temperature superconducting filters |
| IGN | Instituto Geográfico Nacional |
| RFI | Radio Frequency Interference |
| VGOS | VLBI Global Observing System |
| VLBI | Very Long Baseline Interferometry |

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