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REVIEW on "RECEIVERS for RADIO ASTRONOMY" REPORT

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Download at <http://rx2017.inaf.it/RX2017/review.html>



OVERVIEW of the TALK

Part 1

REPORT FRAMEWORK

Part 2

REPORT CONTENTS

Part 3

RECOMMENDATIONS

Part 1
REPORT FRAMEWORK
Terms of Reference,
Working Group,
Executive Summary

PART 1: MOTIVATIONS

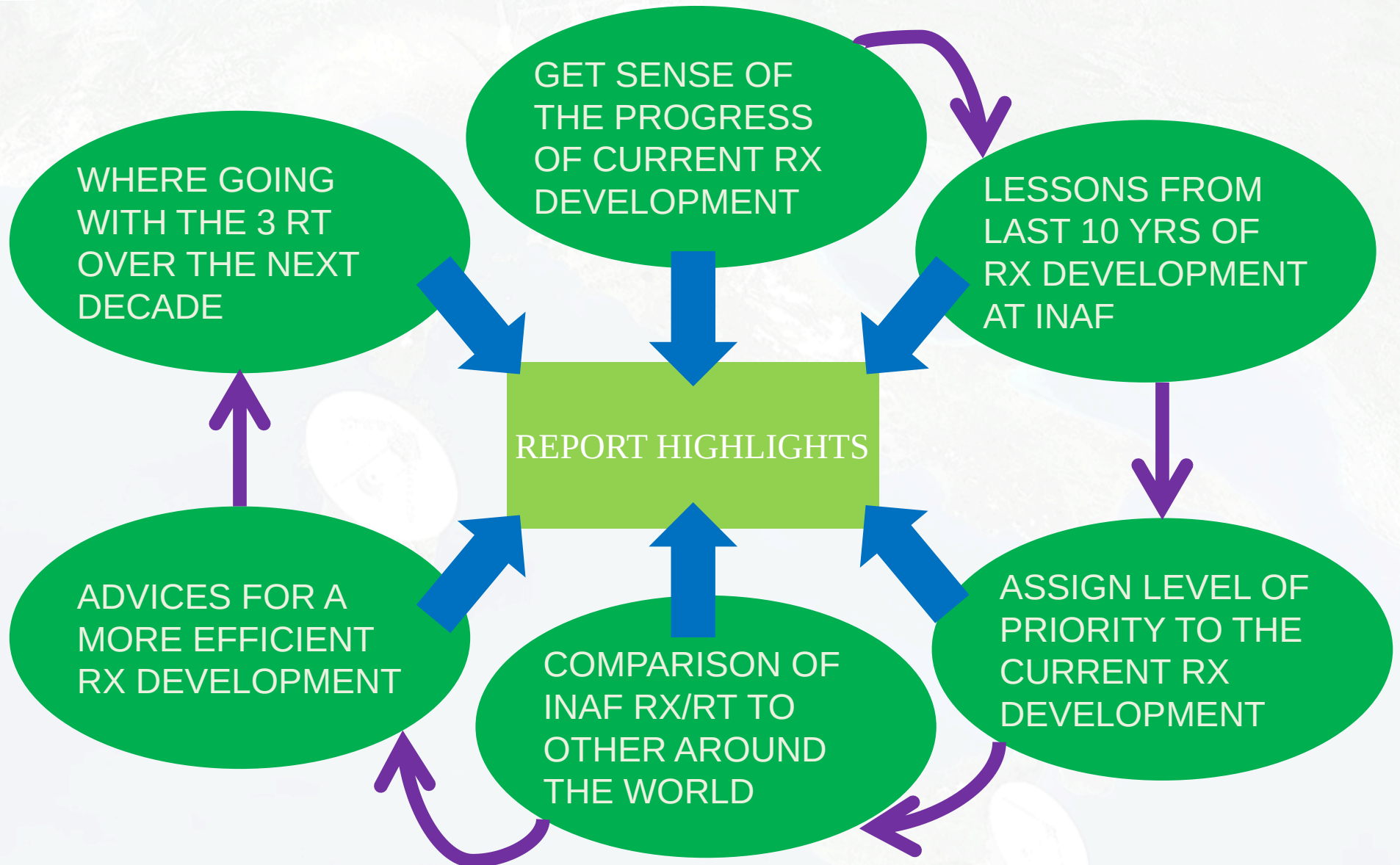
INPUT COMING FROM STEVEN TINGAY, HEAD OF SECTION II OF THE INAF SCIENTIFIC DIRECTORATE, ON SPRING 2016

<<...to review the existing and future radio astronomical receivers for the INAF radio telescope facilities. This initiative is the first step of a more general process aimed at harmonizing and coordinating efforts and resources in radio astronomy. The receiver review included the front-end developments underway within INAF, the existing instrumentation requiring major maintenance/repair, and a roadmap for future receiver developments at INAF. >>

FUTURE (*Tingay talk at the Workshop*)

- ❖ Development of a “five+ year plan” for receiver development at INAF, agreed by the major stakeholders (scientists, technologists, and observatories/institutes)
- ❖ Science-driven and serves the broad community
- ❖ Project managed: Project Scientist, Project Engineer, Project Manager for each development
- ❖ A Project Plan for each project (science case, reviewed design process, accurate costs and schedule, staff dedicated to task, milestones etc)

PART 1: DESIRED OUTCOME



PART 1: TASK FLOW

APPOINTED WORKING GROUP

P. Bolli, M. Beltrán

INAF – Osservatorio Astrofisico di Arcetri

M. Burgay, P. Marongiu, T. Pisanu

INAF – Osservatorio Astronomico di Cagliari

C. Contavalle, A. Orfei, C. Stanghellini, G. Zacchioli, A. Zanichelli

INAF – Istituto di Radioastronomia

Period: June 6th, 2016 to April 13th, 2017

69 PEOPLE INVOLVED

20 IRA 20 OAC 8 OAA 2 OACt 2 INAF-HQ 1 IASF-BO 2 ASI 2 UNIVERSITIES 12 FOREIGN PEOPLE

Workshop on March 21, 2017 at INAF Headquarter, Roma

- ✓ 49 PARTICIPANTS
- ✓ Streaming at <https://www.youtube.com/watch?v=wpcV8YdV6HQ>
- ✓ Report: 260 pages A4 size, 12 Chapters + 4 Appendices

- *Report final version 7.1 – June 1st, 2017* (communication to INAF DS and President)
- *Report version 8.0 – October 17th, 2017* (under publication, about 60 copies)
- Paper in progress on the results of the international survey, to be submitted on a referred review.

Part 2
REPORT CONTENTS
Chapters 1 to 10 + Appendices

PART 2: INFRASTRUCTURE

ITALIAN TELESCOPES

MAIN CHARACTERISTICS			
	MEDICINA	NOTO	SRT
<i>Inauguration Date</i>	October 18 th , 1983	October 28 th , 1988	September 30 th , 2013
<i>Location</i>	Medicina (Bologna)	Noto (Siracusa)	S. Basilio (Cagliari)
<i>Diameter (m)</i>	32	32	64
<i>Optics</i>	Parabola/Cassegrain	Parabola/Cassegrain	Shaped Parab./Greg.
<i>Foci</i>	Primary/Secondary	Primary/Secondary	Prim./Second./BWG
<i>Total Surface Accuracy</i>	700 to 900 micron	350 to 400 micron	305 to 500 micron
<i>Active Surface</i>	No	Yes	Yes
<i>max/min Antenna Gain (K/Jy)</i>	0.16/0.11 C/K-band	0.16/0.11 C/Q-band	0.66/0.52 K/L-band
<i>Pointing Accuracy</i>	0.002° Az/El	0.002° Az/El	0.002° Az/El
<i>Frequency Agility</i>	Yes	Partially Yes	Yes
<i>Major maintenances status</i>	Completion in 2018	To do	Completed in 2017

PART 2: INFRASTRUCTURE

BACK-ENDS AT THE ITALIAN TELESCOPES

Technical Specs	TotalPower	XARCOS	SARDARA	DFB3	DBBC2	DiFX Correlator
Features	Continuum	Full Stokes spectroscopy Zoom mode	Full Stokes spectroscopy	Pulsar; spectroscopy	VLBI	- 3 servers - 50TB storage - 10G connection + 40G Infiniband - VDI standard - 720GB/h correlation rate with 3 antennas @ 1Gb/s
Nr. of Input	2; 4; 14	8 or 16	2	4	16	
Input BW (MHz)	300; 730; 1250; 2000	125; 250	300; 500; 1250; 2300	256; 512; 1024	512; 1024; 0.512 to 32 in Baseband mode	
Integ. time	1 - 1000 ms	10 s	Up to 0.5 ms	0.1 ms	1 – 60 s	
Channels	Not applicable	2048	1024 or 16348	2048 to 8192	firmware not available	
Freq. or Time Resolution	Not applicable	Up to 250 Hz	90 KHz	0.008 – 8 ms	1 Hz	
Interface	Ether./TCP	Ether./TCP	Ether./TCP	Ether./TCP	FILA10G	

PART 2: INFRASTRUCTURE

OPACITY EFFECTS AT THE ITALIAN SITES: A COMPARISON

GLOBAL mm VLBI ARRAY (GMVA) at 86 GHz

Station	Altitude (m)	D (m)	Tsys at zenith (K)	Gain (K/Jy)	SEFD (Jy)
GBT	807	100	100	0.73	137
Effelsberg	319	80	140	0.14	1000
Plateau de Bure	2552	33	180	0.22	818
Pico Veleta	2850	30	100	0.15	654
Yebes	931	40	150	0.09	1667
VLBA (8x25m)	300/././3763	25	100	0.040	2500
KVN (3x21m)	120;260;320	21	200	0.062	3226
Onsala	20	20	250	0.049	5102
Metsähovi	33	14	300	0.017	17647
LMT (prelim)	4640	32	240	0.14	1714
ALMA	5059	80	90	1.32	68

BEWARE! Assumed Opacity = 0.1

SRT today (estimate at 86 GHz)

Opacity	Tsys (K) EL=45°	Gain (K/Jy) EL=45°	SEFD (Jy) EL=45°
0.25	124	0.14	865
0.35	148	0.12	1182

Assumed receiver noise = 50K at 86GHz

FOR LARGE TELESCOPES POINTING IS AN ISSUE!

MEDICINA refurbished (estimate at 86 GHz)

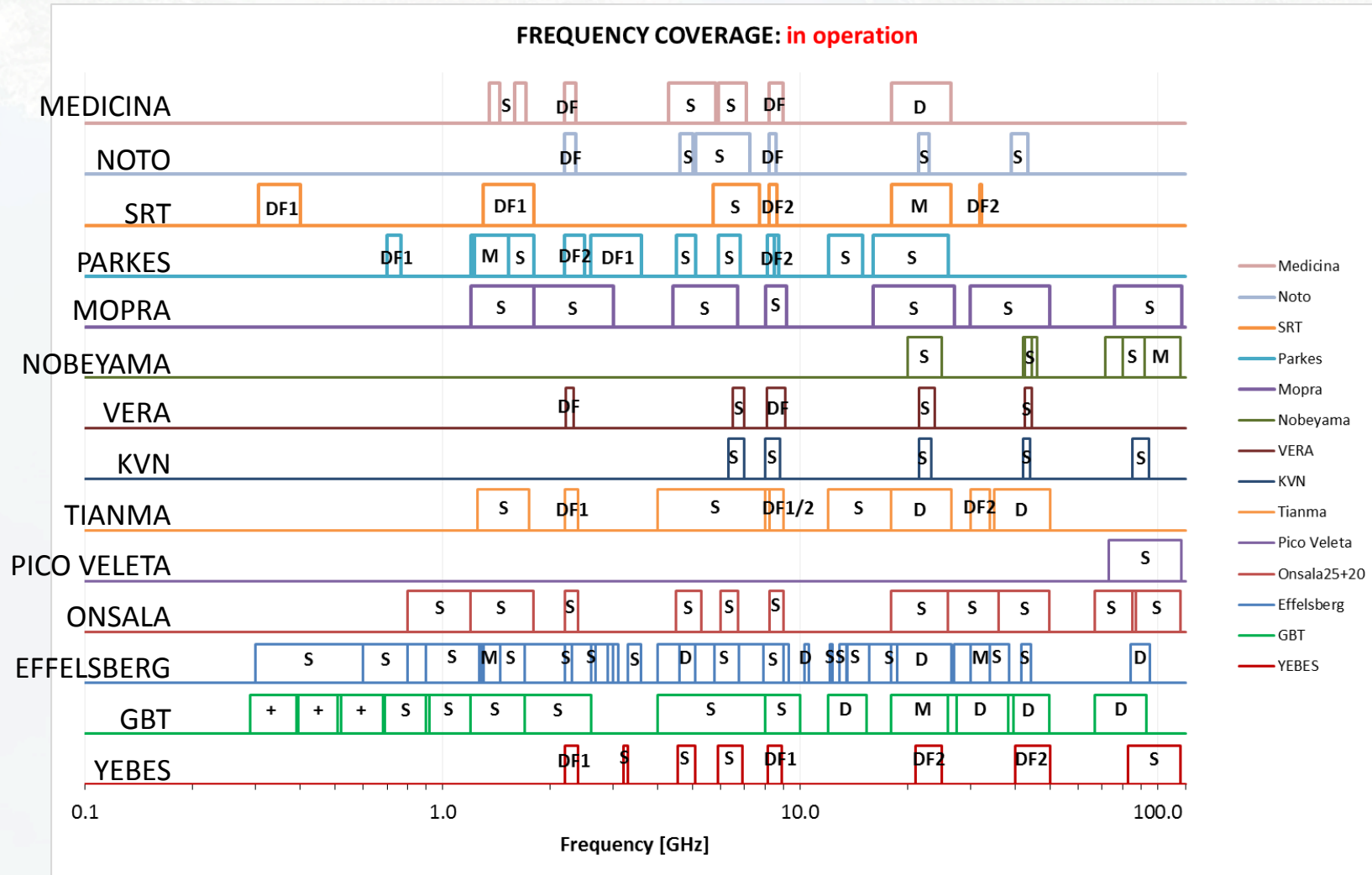
Opacity	Tsys (K) EL=45°	Gain (K/Jy) EL=45°	SEFD (Jy) EL=45°
0.25	124	0.09	1383
0.35	148	0.07	2089

Assumed receiver noise = 50K at 86GHz

PART 2: RECEIVERS IN OPERATION

OFFER OF FREQUENCY BANDS

S = mono-feed; D = dual-feed; M = multi-feed; DF = dual frequency; + = crossed dipoles



PART 2: RECEIVERS

AGILITY IN CHANGING THE BANDS

FREQUENCY AGILITY			
TELESCOPES	Primary to Secondary	Among Primary focus receivers	Among Secondary focus receivers
MEDICINA	4 min	≤ 45 sec	≤ 14 sec
NOTO	4 min	10 sec	4 hour
SRT	4 min	2 min	2 min
Parkes		2 min + manual change	
Mopra			some min
Nobeyama			1 min
VERA			No agility
KVN			Simultaneity
Tianma			seconds
Pico Veleta			2-bands simultaneous
Onsala25			sec to 1 hour
Onsala20			sec to 30 min
Effelsberg	30 min	1 min + manual change	30 sec
GBT	10 min	2 hour	1 min
Yebes			No data

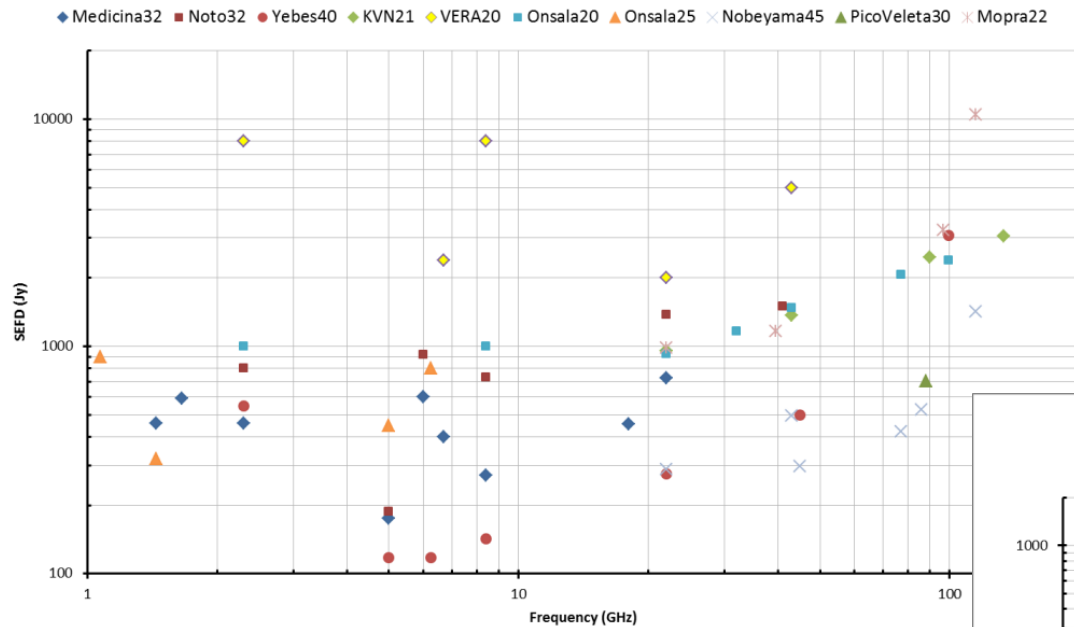
DYNAMIC SCHEDULING POSSIBLE.

VERY IMPORTANT TO OBSERVE AS MUCH AS POSSIBLE AT HIGH FREQUENCIES!

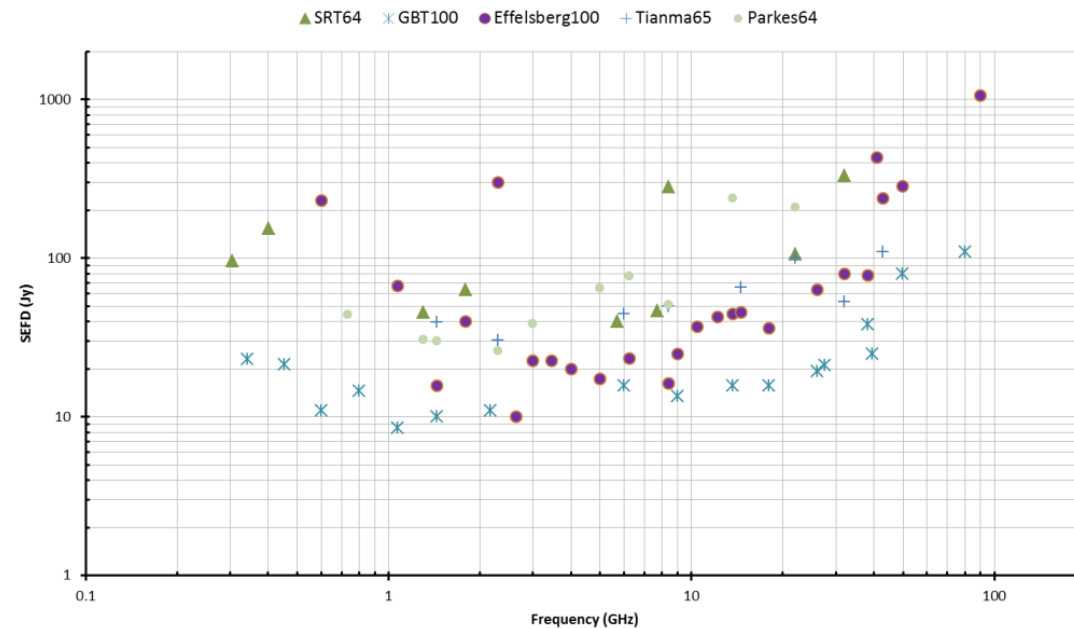
PART 2: RECEIVERS IN OPERATION

PERFORMANCE

SEFD of receivers in operation: **medium class antennas**



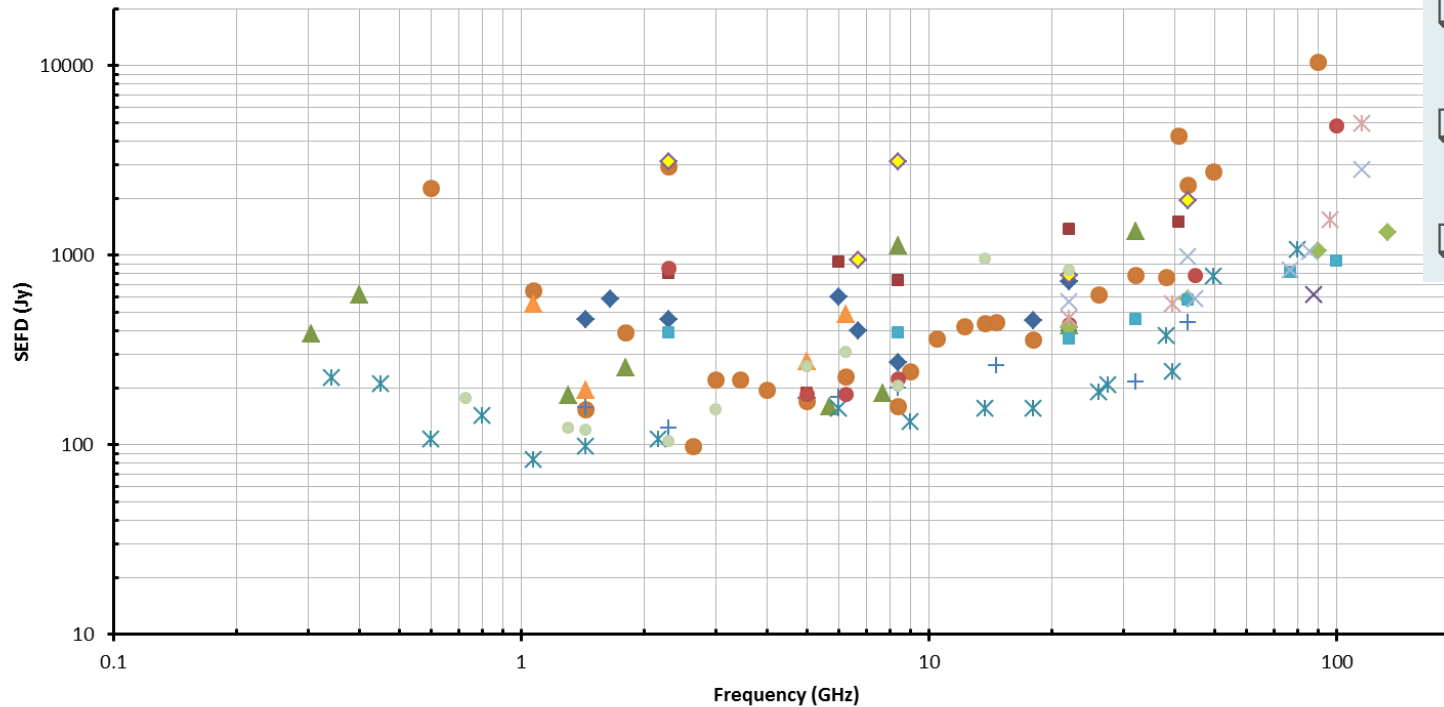
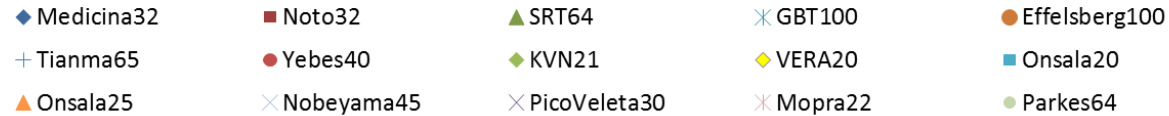
SEFD of receivers in operation: **large class antennas**



PART 2: RECEIVERS IN OPERATION

NORMALIZED PERFORMANCE

Normalized SEFD of receivers in operation

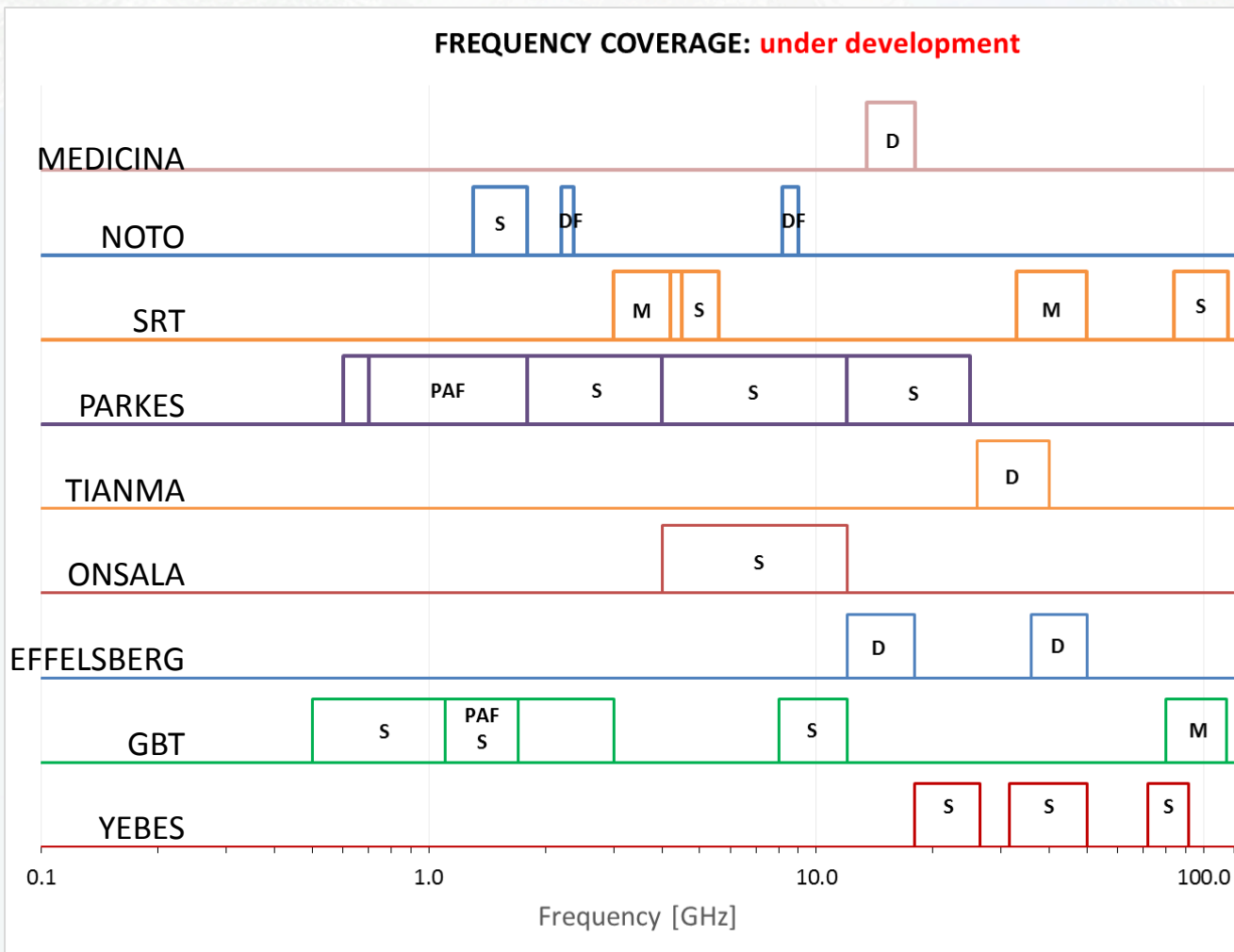


RESIDUAL EFFECTS

- ☐ SURFACE ACCURACY
- ☐ OFFSET ANTENNA
- ☐ RX NOISE
- ☐ ATMOSPHERE

PART 2: RECEIVERS *UNDER DEVELOPMENT*

S = mono-feed; D = dual-feed; M = multi-feed; PAF = phased array feed



TREND

- ☐ ENLARGE the BANDWIDTH
- ☐ BOTH POLARIZATIONS
- ☐ FILL FREQUENCY COVERAGE GAPS
- ☐ SPECIFIC MULTI-PIXEL RECEIVERS

PART 2: RECEIVERS

INTERNATIONAL PROJECTS & IDEAS for FUTURE

INTERNATIONAL PROJECTS OF ITALIAN TELESCOPES INTEREST

iALMA 2+3
1 feed, 67-116 GHz

PHAROS/PHAROS2
PAF 4-8 GHz

BRAND
1 feed 1.5-15 GHz, VLBI

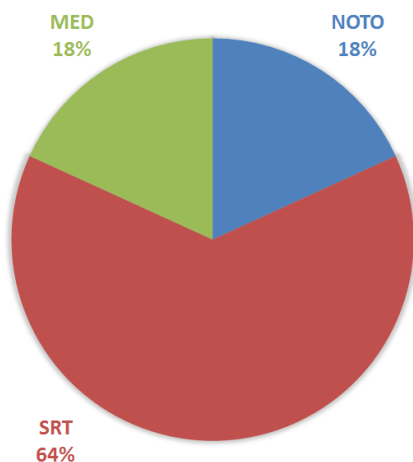
CALL FOR IDEAS

15 IDEAS FOR NEW RXs
BANDS 1-100GHz

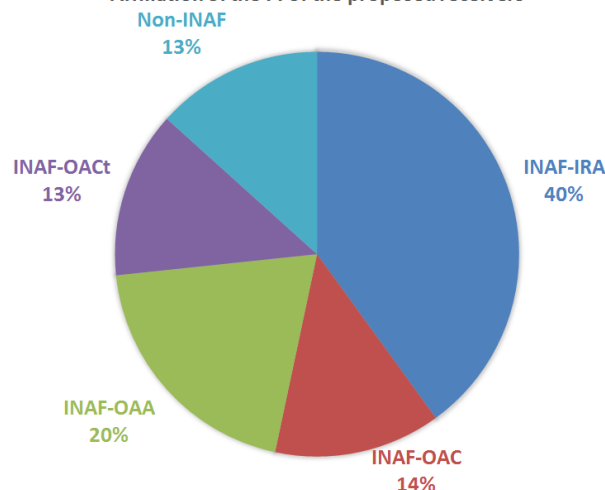
FROM A LARGE COMMUNITY
PAF/M/D/S/DF/Simultaneous Triband/Bolometer

INTERACTION & SYNERGIES

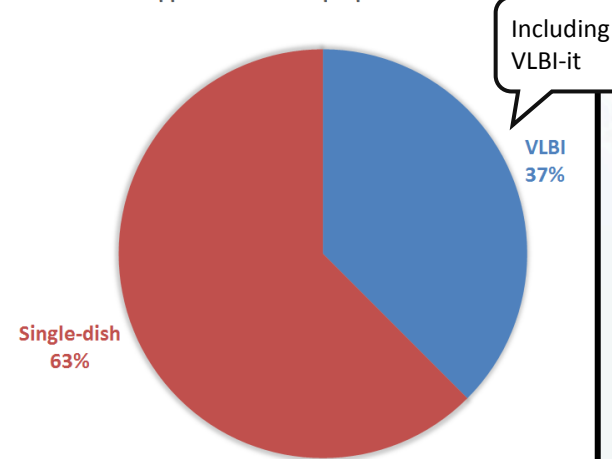
Radio telescopes for the proposed receivers



Affiliation of the PI of the proposed receivers

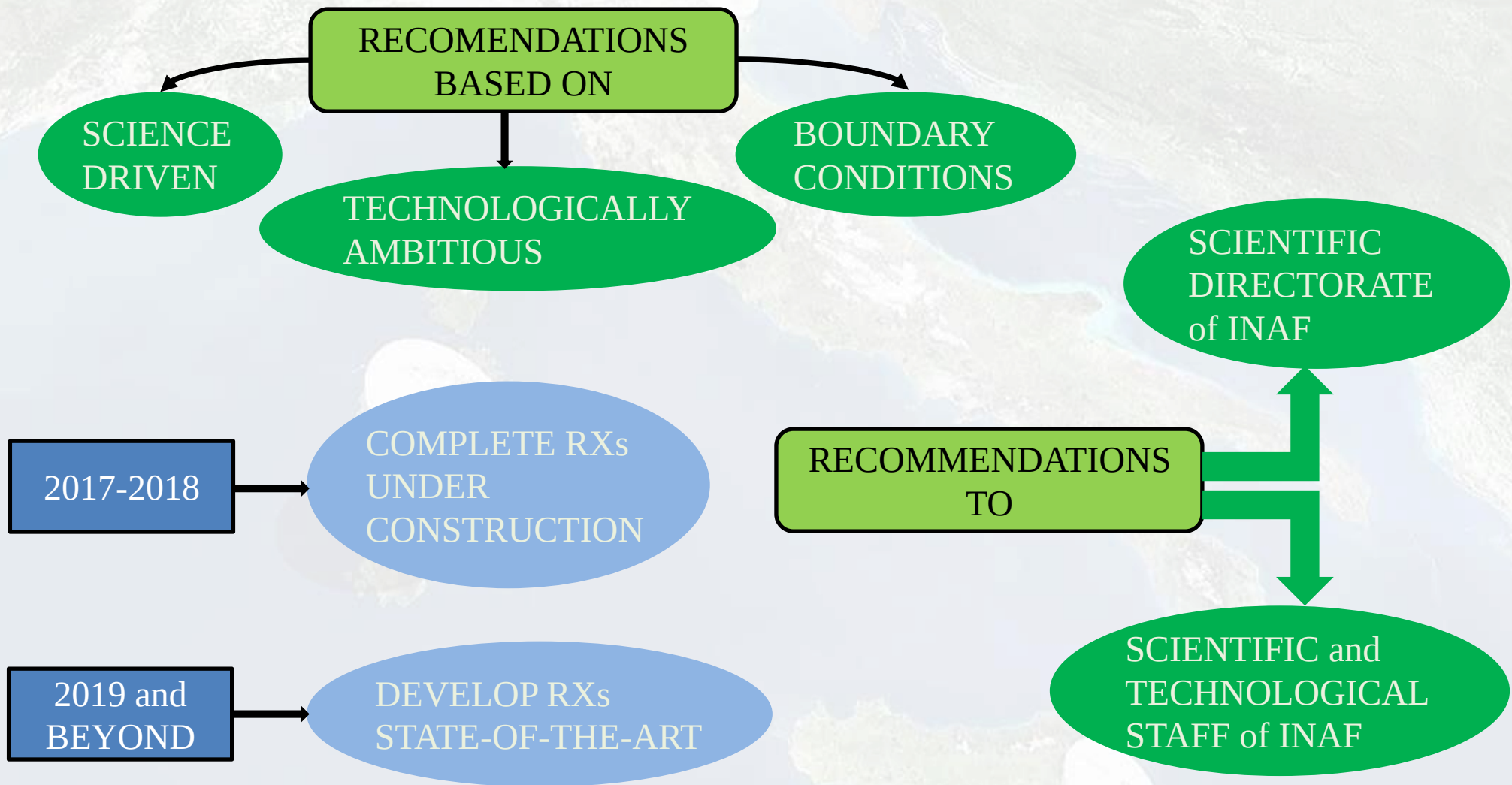


Application for the proposed receivers



Part 3
RECOMMENDATIONS
Chapters 11, 12

PART 3: AIMS, RECIPIENTS and TIME SCALE



PART 3: 2017-2018

RXs FINALIZATION at SRT

	BAND(GHz)	REMARKS
S-band	3-4.5	Unique in International scenario. SD continuum observations
C _{low} -band	4.2-5.6	Most used in VLBI. Hottest topics in today radio astronomy
Q-band	33-50	Unique in Intl scenario. SD spectroscopy; join more VLBI networks
iALMA 2+3-band	67-116	SD spectroscopy; join more VLBI networks

RX FINALIZATION at MEDICINA

	BAND(GHz)	REMARKS
Ku-band	13.5-18	Continuous coverage 13-26GHz for continuum and redshifted spectral lines

RX FINALIZATION at NOTO

	BAND(GHz)	REMARKS
TELESCOPE		Recover a full and reliable operation of the antenna
S/X/L-band	2.2-2.4/8.2-9.0/1.3-1.8	Mandatory to serve our commitment in EVN and Geo-IVS
W-band	85.9-86.5	Join more VLBI networks. Very low priority.

PART 3: 2019 and BEYOND

RECOMMENDED RX at SRT

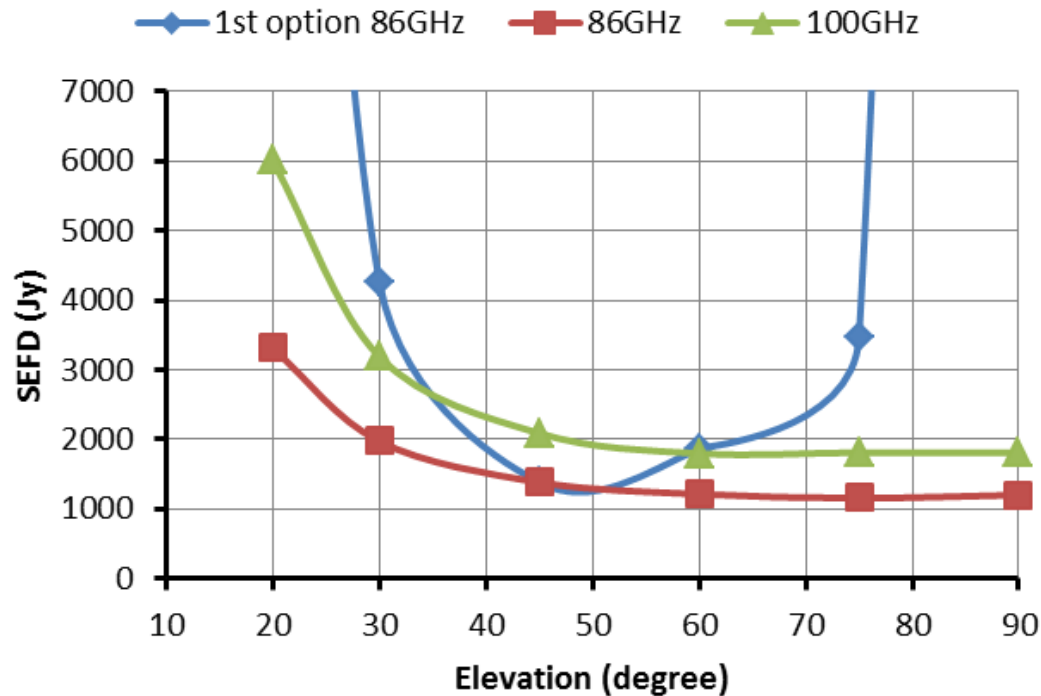
MFEED W-band (19 pixel)	Considerable interest in such front-ends emerged from the Call for Ideas (2 proposals).
PAF C-band	Relevant interest both as a technological demonstrator and as a new receiver to perform cutting-edge science (3 proposals from the Call for Ideas). A PAF receiver matches with the involvement of INAF in the SKA AIP project (PHAROS2).

VALUABLE PROJECTS FOR FUTURE EVALUATION

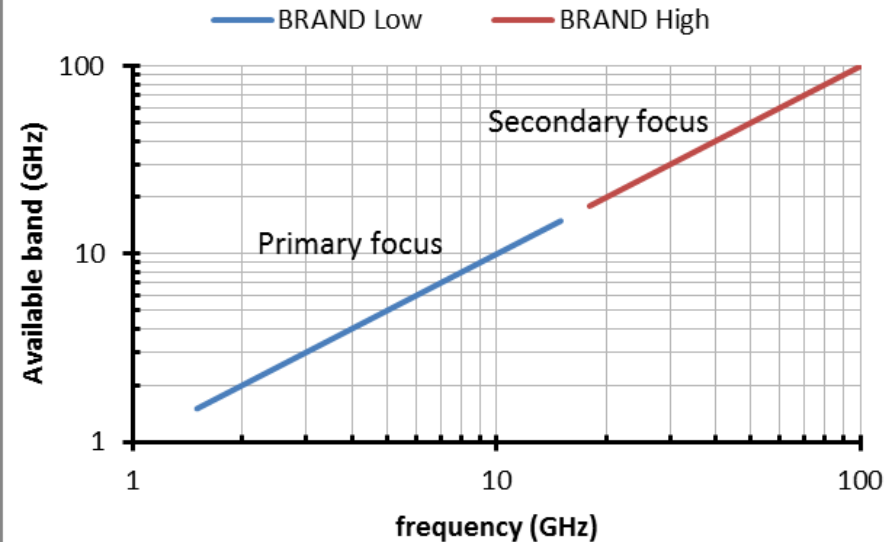
BRAND	6 astro VLBI current frequencies by one RX only. New bands up to 15.5 GHz. Includes the new standard for Geodetic observations (1 proposal).
W-band 400 pixel BOLOMETER	Coming from De Bernardis (Roma-La Sapienza). New scientific application for SRT (similar activities at IRAM and GBT).

PART 3: 2019 and BEYOND

MED32 PARTIALLY OR TOTALLY REFURBISHED



FUTURE Simultaneous frequency?



RECOMMENDED RX at MEDICINA

SIMULTANEOUS K/Q/W-band

A niche in which also the smaller Italian radio telescopes can give a substantial contribution. Strong collaborations are already in place with the KVN and VERA arrays (1 proposal from the Call for Ideas).
Calibrating tropospheric delay at 3mm, via K-band, increase coherence time.
IT NEEDS AN UPGRADE OF THE ANTENNA SURFACE ACCURACY.

PART 3: TIME LINE and WORKLOAD

STATUS	RT	RX	2017	2018	2019 and BEYOND
UNDER CONSTRUCTION	SRT	S-band	OAC	OAC	THE CONSTRUCTION OF 4 OVER 6 RX IS IN A QUITE ADVANCED STAGE, BUT <i>i</i>ALMA FOR SRT NEEDS VERY FAST DECISIONS.
	SRT	C _{low} -band	IRA,OAC,OAA	OAC	
	SRT	Q-band	IRA,OAC	IRA	
	SRT	iALMA 2+3	IASF-BO	IASF-BO	
	MED	Ku-band	IRA,OAA	IRA	
	NOTO	S/X/L-band	IRA	IRA	
	NOTO	W-band		IRA	
NEW PROJECTS	SRT	PAF C-band			OAC
	SRT	MFEED W-band			OAC
	MED	SIMULTANEOUS K/Q/W-band			IRA

PART 3: DEVELOPMENT at 3mm

STATUS	RT	RX NAME	FREQUENCY RANGE (GHz)	Inst.neous BW (MHz)	OUTPUT and POL.
WORK IN PROGRESS	SRT	ex-IRAM	84-116	500	1 C
WORK IN PROGRESS	SRT	iALMA 2+3	67-116	8000	2 L
STAND BY	NOTO	MPIfR	85.9-86.5	100	1 C
AVAILABLE	NOTO	ex-IRAM (x2)	84-116	500	1 C
NEW PROJECTS (from Call for Ideas)	SRT	MFEED 19	70-116	> 8000	2 L x 19
	SRT	BOLOMETER 400	80-100	20000	400
	MED	SIMULTANEOUS K/Q/W-band	18-26/33-50/80-110	TBD	2C/2C/2C

PART 3: FINANCIAL CONSIDERATIONS

STATUS	RT	RX	2017-2018 (K€)	2019 and BEYOND (K€)
UNDER CONSTRUCTION	SRT	S-band	Fully funded	
	SRT	C _{low} -band	Fully funded	
	SRT	Q-band	600 (19 feeds) 180 (7 feeds)	
	SRT	iALMA 2+3	80	
	MED	Ku-band	Fully funded	
	NOTO	S/X/L-band	80 (Now Funded)	
	NOTO	W-band	Negligible	
NEW PROJECTS	SRT	PAF C-band		2700
	SRT	MFEED W-band		1700
	MED	SIMULTANEOUS K/Q/W-band		2400 (w AS) 1600 (w/o AS)
TOTAL			760 (19 feeds) 340 (7 feeds)	6800 (w AS) 6000 (w/o AS)

PART 3: A PROPOSAL

PROJECT MANAGEMENT

Project Scientist & System engineering methodologies

Each new receiver should be assigned to a well-designed management scheme to limit delays & financial issues and to maintain high the scientific interest of the receiver.

Local responsibility

Each project should be in charge of a specific group and locally managed. Interactions and scientific collaborations among classical groups and also extended to other INAF groups (IASF, SKA group) are encouraged.

Coordination

The development of radio astronomical instrumentation coordinated under the supervision of Section II of the INAF Scientific Directorate.

Call for Projects

A survey of the interest of the astronomical community in new instrumentation should be conducted by INAF periodically.

Permanent commission

Composed by astronomers and technologists who will regularly meet to review the status of the ongoing projects and issue recommendations.

A satellite map of Europe with several large satellite dish antennas overlaid on it. The antennas are located in the British Isles, Scandinavia, and the Mediterranean region. The text "Decisions needed!" is written in a large, orange, handwritten-style font across the center of the map.

Decisions
needed!