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

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Part 3

RECOMMENDATIONS

Part 1

REPORT FRAMEWORK

Terms of Reference,

Working Group,

Executive Summary

PART 1: MOTIVATIONS

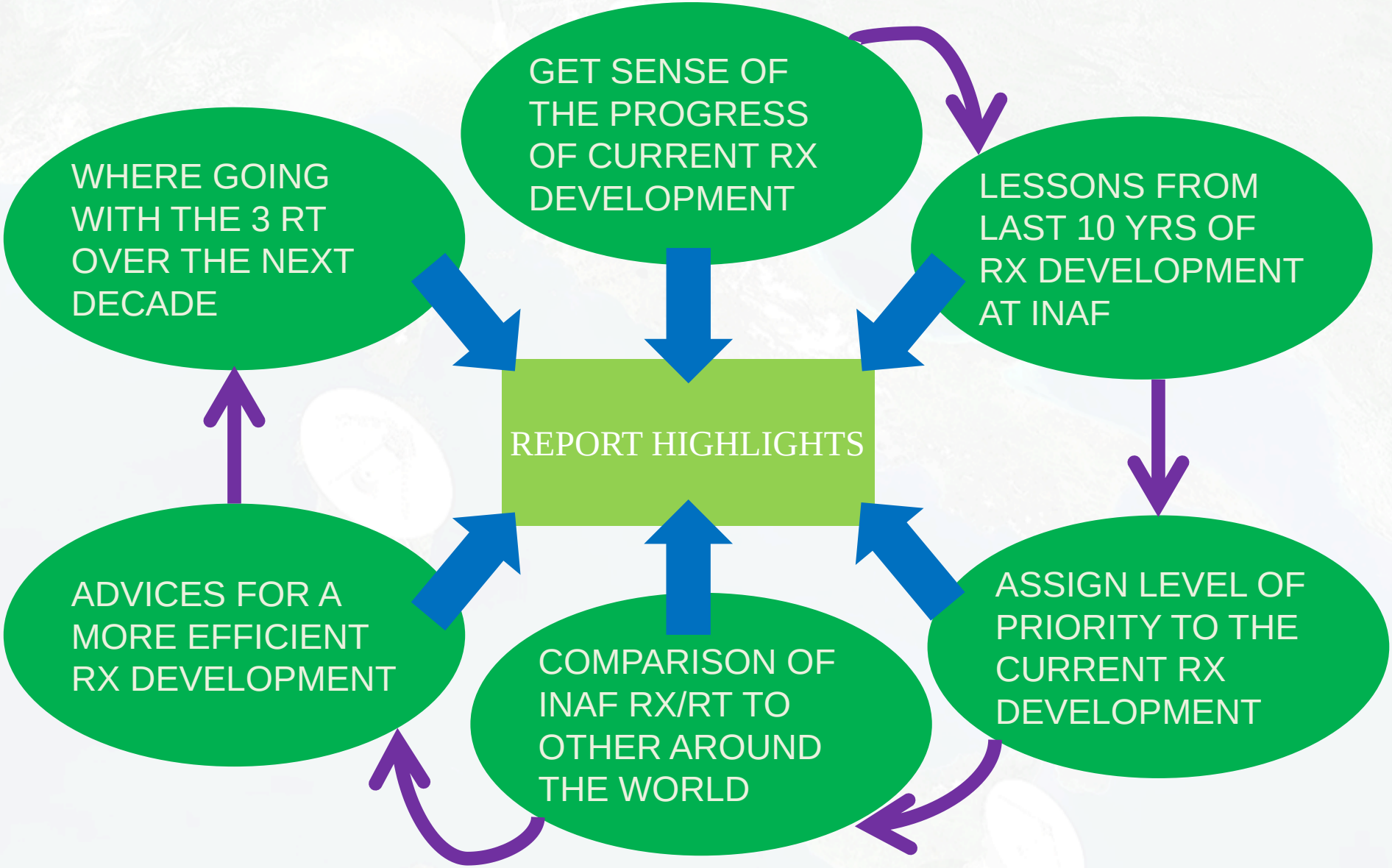
INPUT COMING FROM STEVEN TINGAY, HEAD OF SECTION II OF THE INAF SCIENTIFIC DIRECTORATE, ON SPRING 2016

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

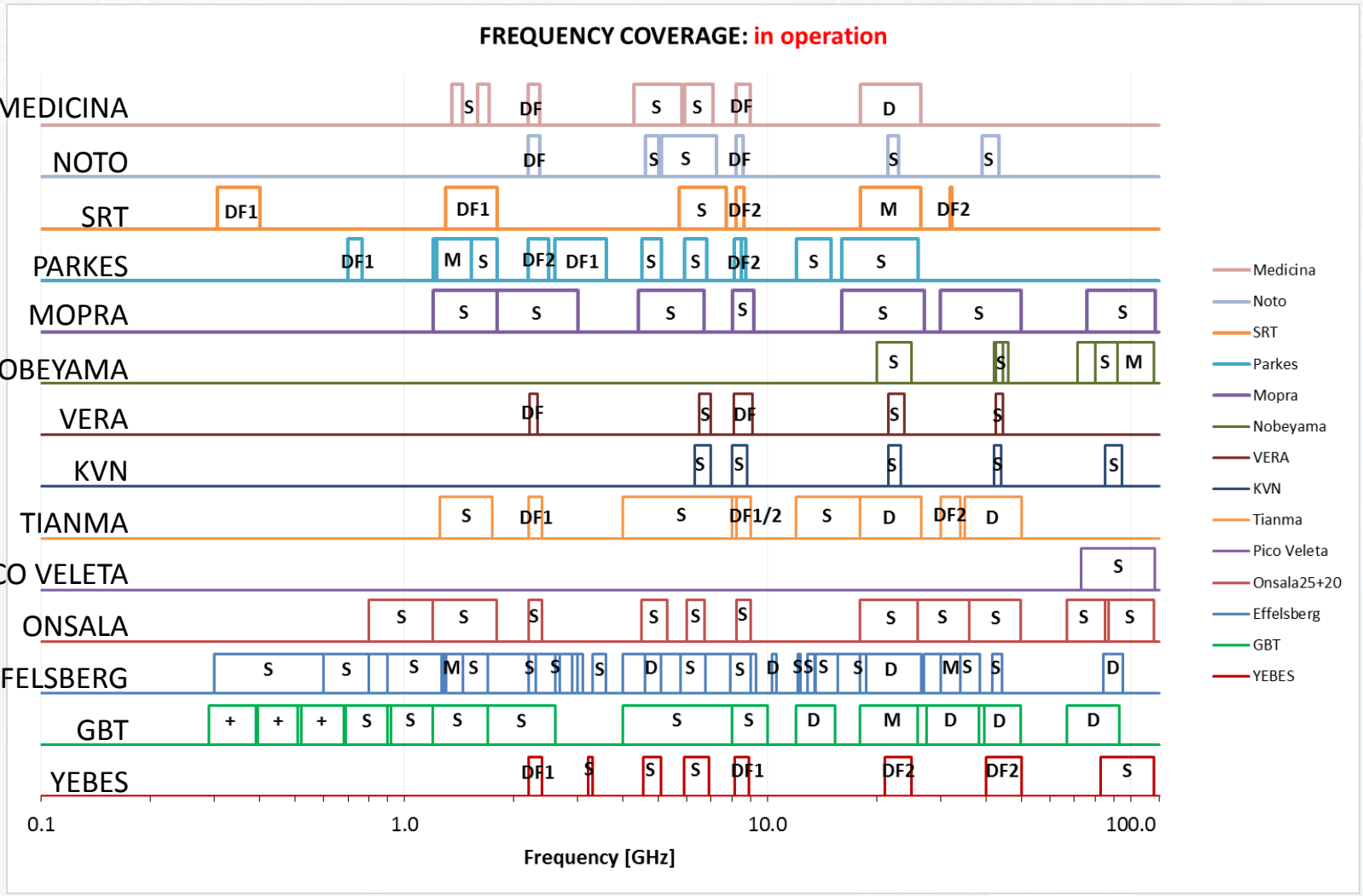
MEDICINA refurbished (estimate at 86 GHz)

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

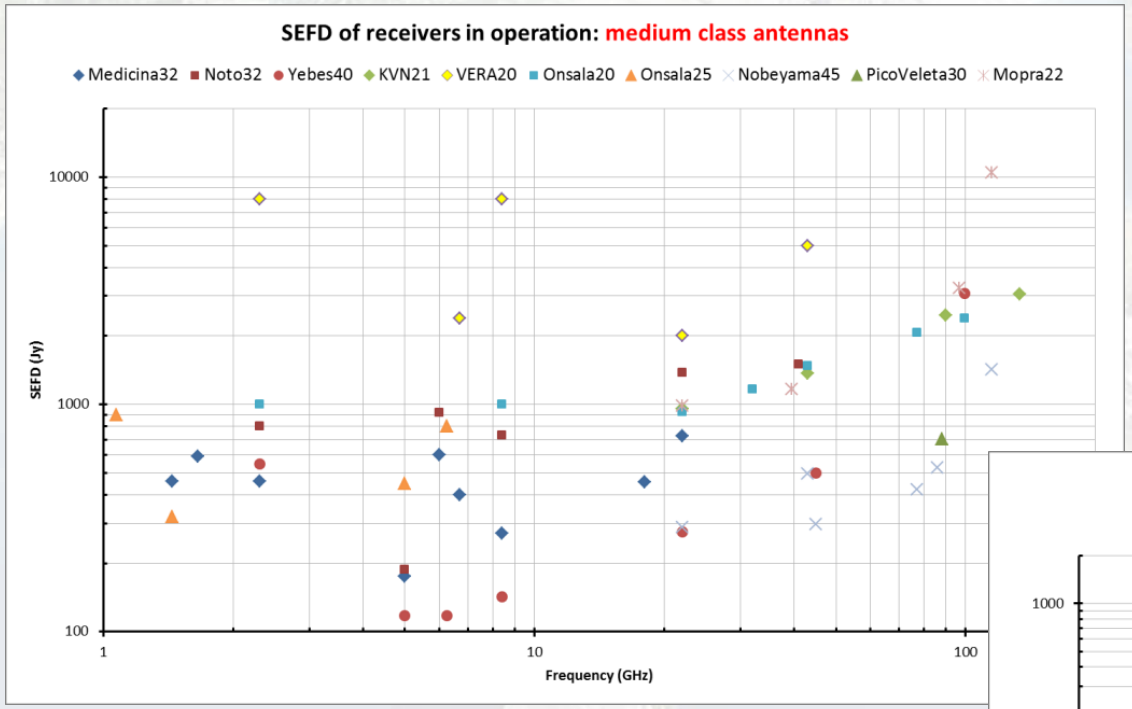


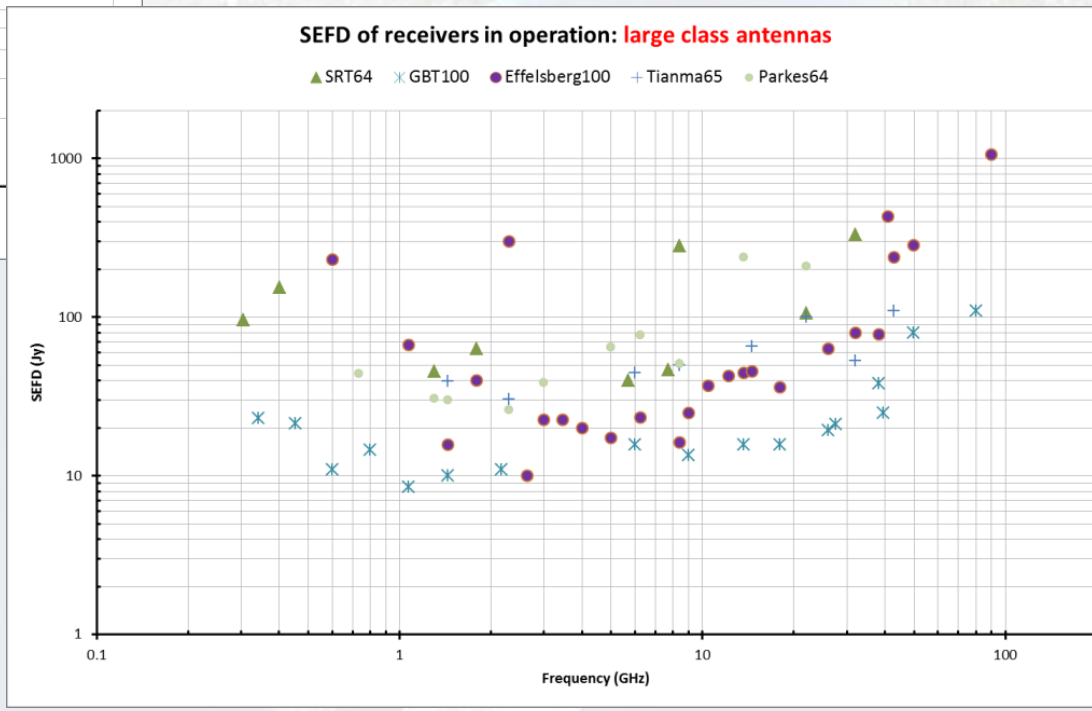
PART 2: RECEIVERS
AGILITY IN CHANGING THE BANDS

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

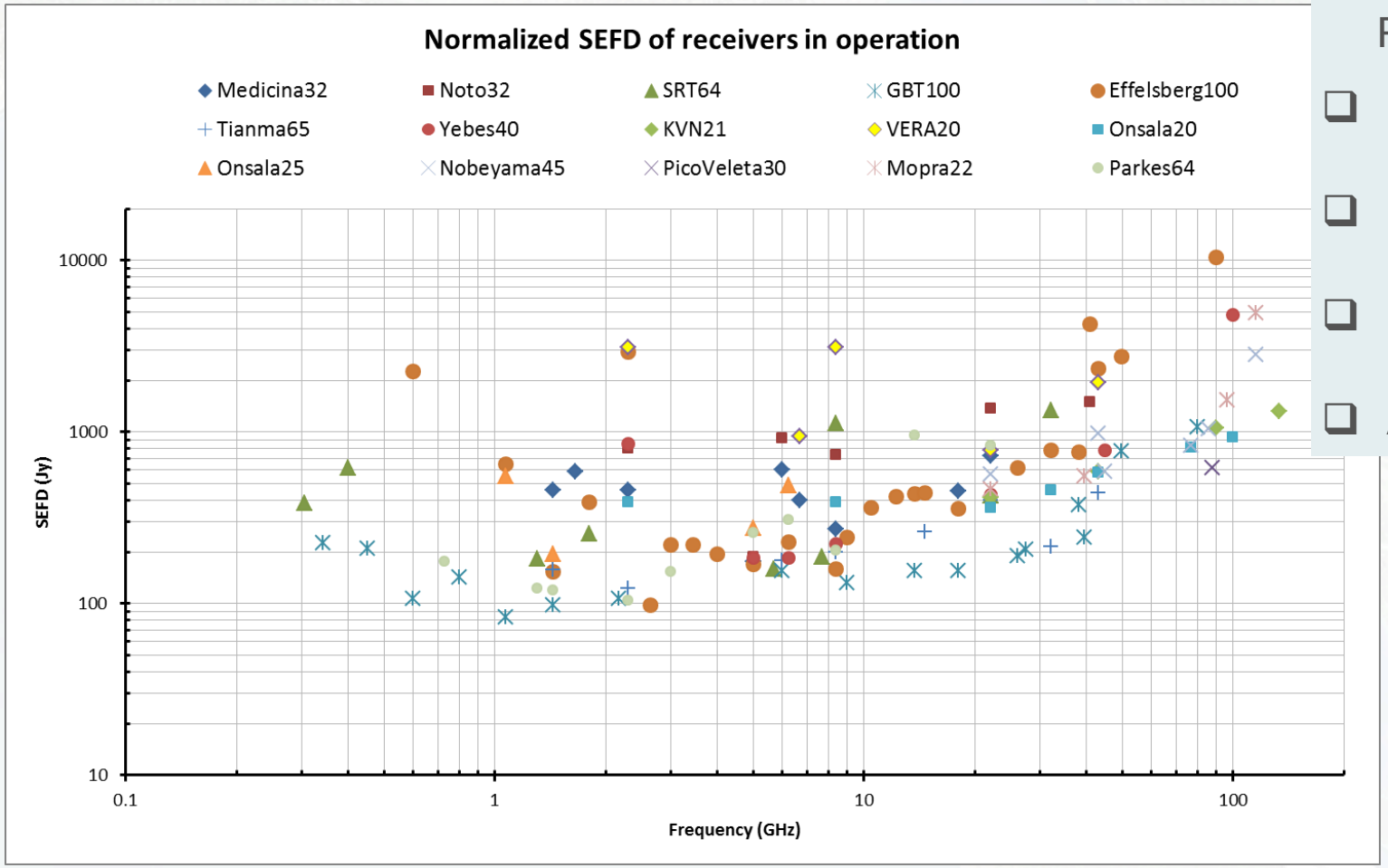
DYNAMIC SCHEDULING POSSIBLE.
VERY IMPORTANT TO OBSERVE AS MUCH AS POSSIBLE AT HIGH FREQUENCIES!

PART 2: RECEIVERS IN OPERATION
PERFORMANCE





PART 2: RECEIVERS IN OPERATION
NORMALIZED PERFORMANCE

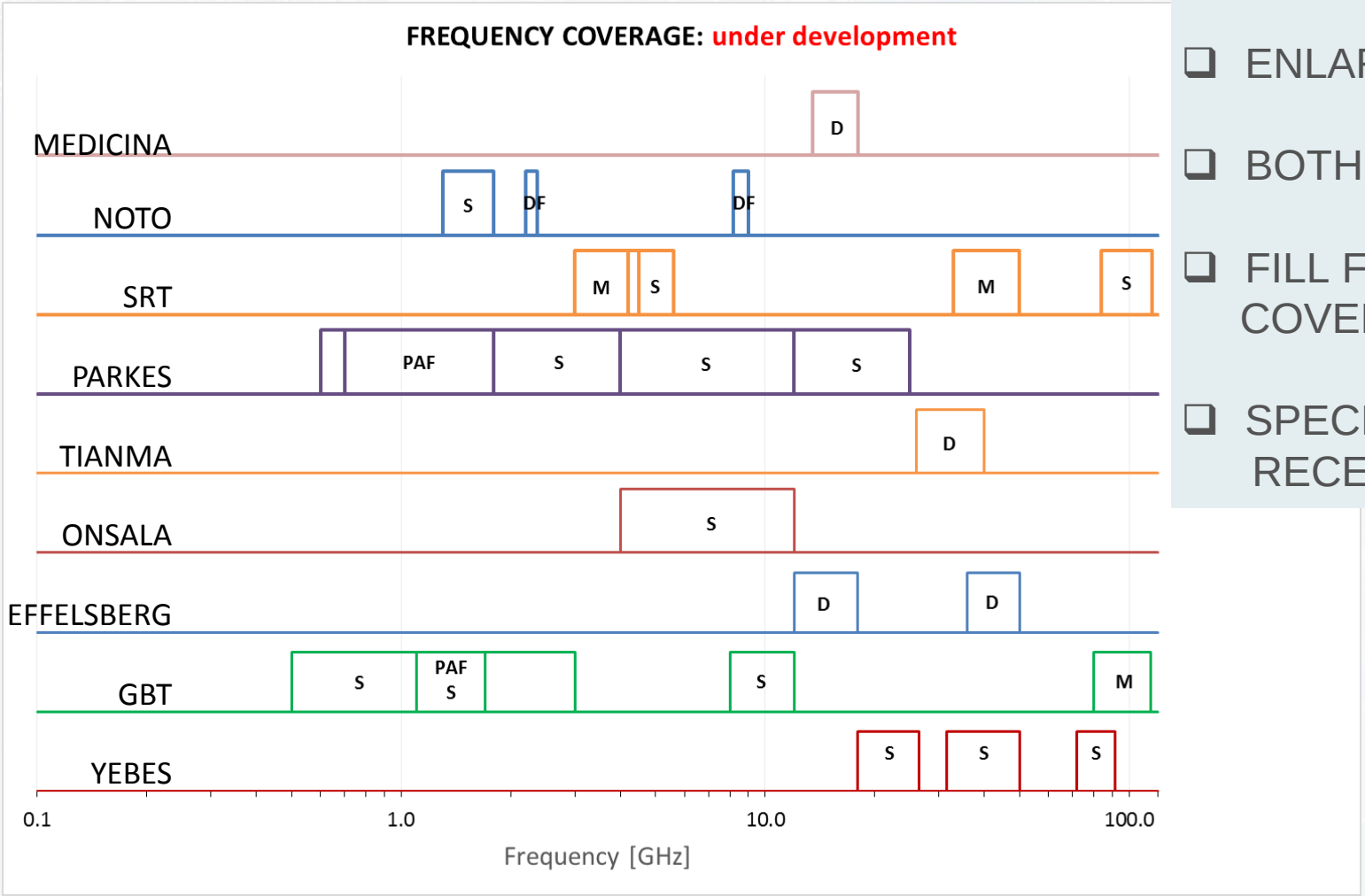


RESIDUAL EFFECTS

- ❑ 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

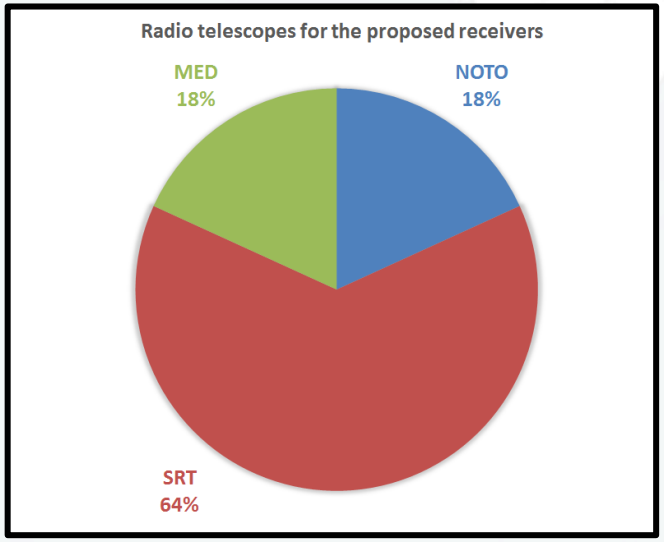
INTERNATIONAL PROJECTS OF ITALIAN TELESCOPES INTEREST

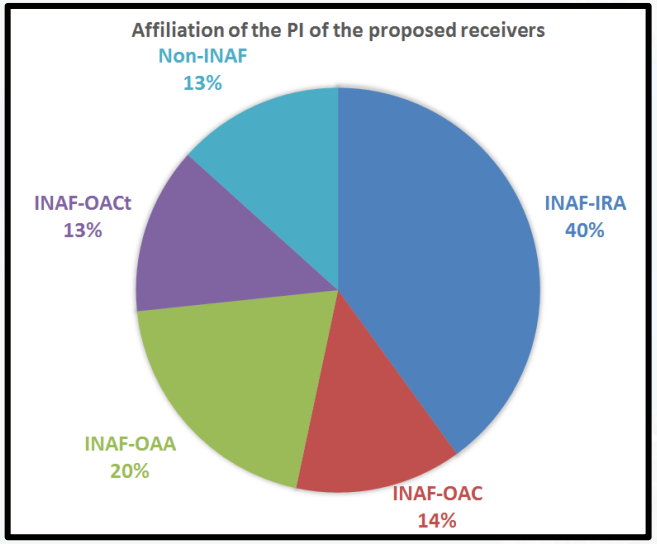
iALMA 2+3	PHAROS/PHAROS2	BRAND
1 feed, 67-116 GHz	PAF 4-8 GHz	1 feed 1.5-15 GHz, VLBI

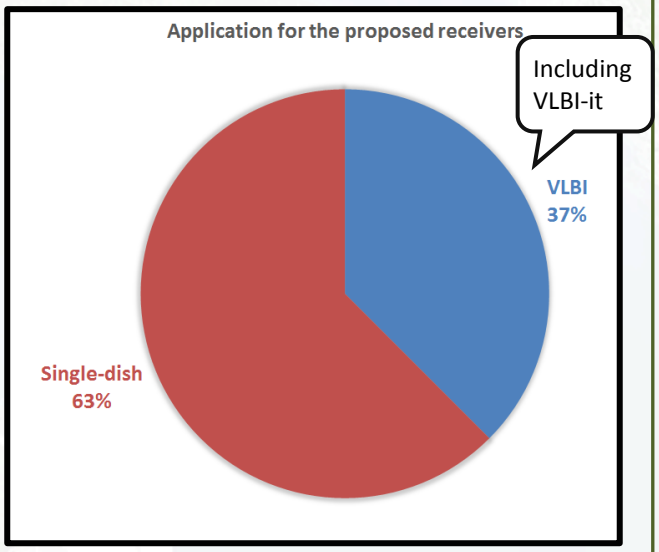
CALL FOR IDEAS

15 IDEAS FOR NEW RXs **FROM A LARGE COMMUNITY** **INTERACTION & SYNERGIES**

BANDS 1-100GHz **PAF/M/D/S/DF/Simultaneous Triband/Bolometer**





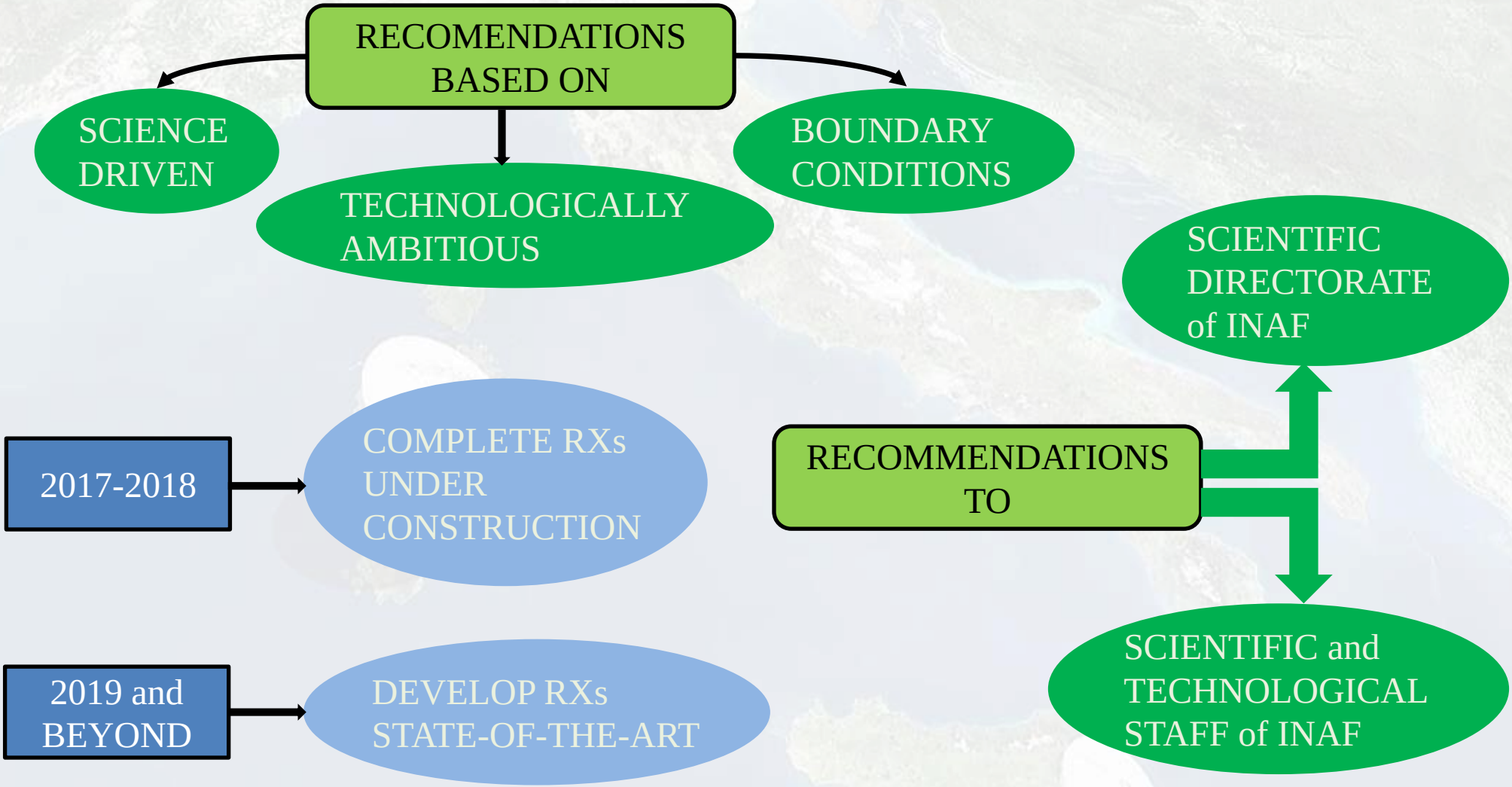


Part 3

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 Intnl 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

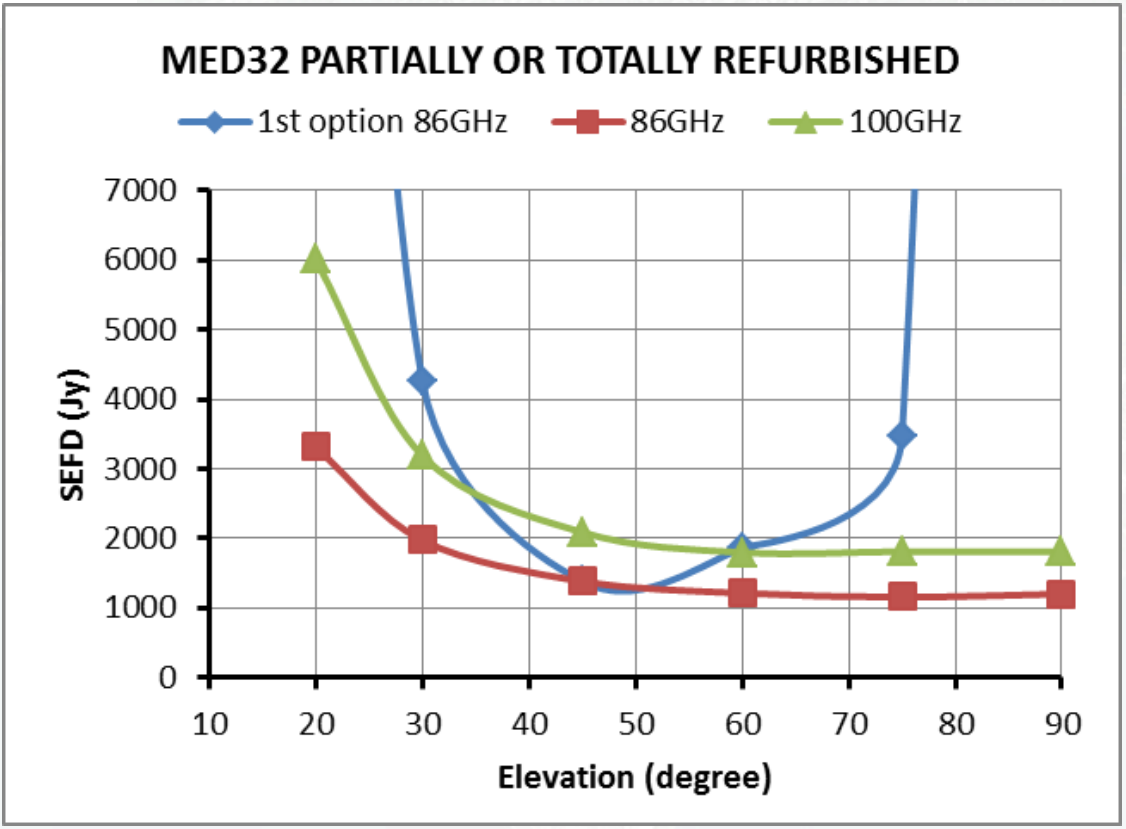
RX FINALIZATION at NOTO		
	BAND(GHz)	REMARKS
TELESCOPE		Recover a full and reliable operation of the antenna
S/X/L-band	2.2-2.4/8.2-9.0/1.3-1.8	Mandatory to serve our commitment in EVN and Geo-IVS
W-band	85.9-86.5	Join more VLBI networks. Very low priority.

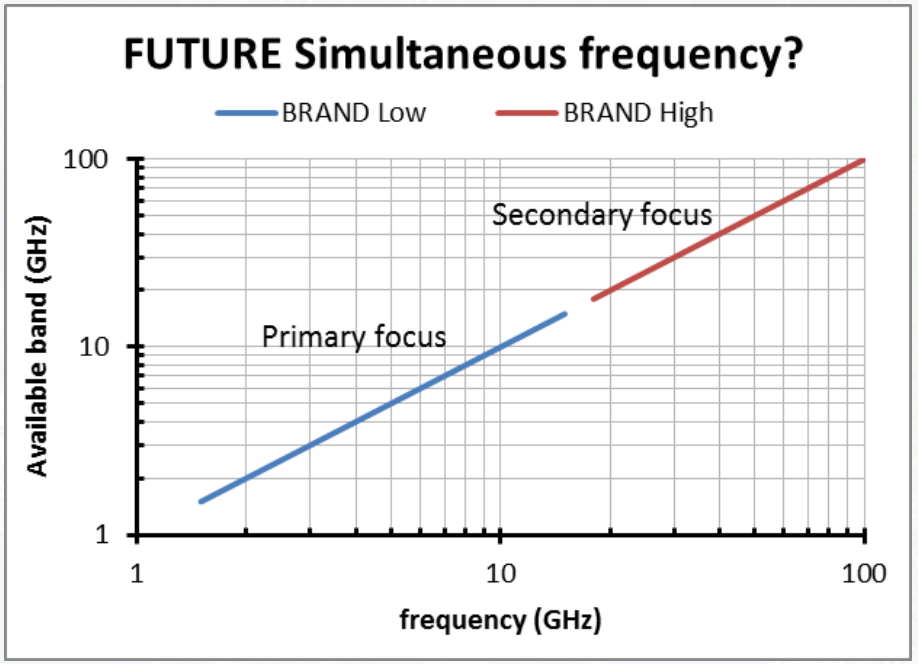
PART 3: 2019 and BEYOND

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





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	
	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

THE CONSTRUCTION OF 4 OVER 6 RX IS IN A QUITE ADVANCED STAGE, BUT *iALMA FOR SRT NEEDS VERY FAST DECISIONS.*

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.


Decisions
needed!