Grant Agreement No. : 761390
Call: H2020-ICT-2016-2
Type of Action: RIA

Deliverable D6.6: Second Year Exploitation Plan

Version	**Date**	**Status**	**Editor(s)**	**Remarks**
1.0	11/07/2019	First draft	A. Pallotta	
1.1	26/07/2019	Revision	A.Pallotta, M. Frecassetti	
2.0	09/09/2019	Final	A. Pallotta	Ready for submission
2.1	05/09/2019	Final	V. Ermolov	Final checking

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Confidentiality: PU

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Deliverable's title	
Deliverable's title DREAM Deliverable D6.6: Second Year Explotation Plan	
Customer, contact person, address European Comission / Project Officer	**Order reference**
Project name DREAM	**Project number/Short name** DREAM
Author(s) A. Pallotta, M. Frecassetti, V. Ermolov, P. Roux, J. Ecos	**Pages** 19
Keywords Project overview, achievements, results, exploitation plan, radio technology, millimetre-wave, transceiver, front-end, D-band communications, oscillator, frequency synthesizer, phase noise, power amplifier, BiCMOS, SiGe, power efficiency.	
Summary Exploitation activities of DREAM project outcomes will play a major role both for the industrial, research centers and the academic partners, having a strong mid- and long-term impact on regulation and standardization activities, new products proof-of-concept, IPRs and pre-development activities, as well as on scientific dissemination and education. This document presents an update related to the activities of the project's second year on the overall exploitation strategy of the DREAM project and the exploitation plan of each consortium member.	
Confidentiality	Confidential

Contents

List of Acronyms and Abbreviations

3GPP	3rd Generation Partnership Project
5GPPP	5G infrastructure Public Private Partnership
ACM	Access Control Manager
AP	Access Point
ATPC	Automatic Transmit Power Control
BiCMOS	Bipolar Complementary Metal-Oxide Semiconductor
BS	Base Station
CMOS	Complementary Metal-Oxide Semiconductor
EC	European Commission
EMF	Electromagnetic Field
FD-SOI	Fully Depleted Silicon On Insulator
FP7	Seventh Framework Program
IC	Integrated Circuit
IoT	Internet of Things
IPC	Institute for Interconnecting and Packaging Electronic Circuits
IPR	Intellectual Property Rights
IQ or I/Q	In-phase/Quadrature-phase
KPI	Key Performance Indicator
LCP	Liquid Crystal Polymer
LTCC	Low Temperature Cofired Ceramic
LTE	Long Term Evolution
LTE-A	Long Term Evolution Advanced
M2M	Machine to Machine
MSE	Mean Square Error
mmWave	Millimeter Wave
PCB	Printed Circuit Boards
QoS	Quality of Service
RAN	Radio Acccess Network
RF	Radio Frequency
RRH	Remote RadioHead
Rx	Receive
SiGe	Silicon Germanium
SME	Small Medium Enterprise
SoC	System on Chip
STO	Standardization Office
TA	Technical Annex
Tx	Transmit
UE	User Equipment
WP	Work Package
WSN	Wireless Sensor Network

1. Introduction

In parallel to the dissemination activities, the exploitation of the project objectives plays a major role in the DREAM project, being the ambition of the project having a strong industrial impact towards regulation and standardisation bodies, and fostering a well-ahead of competitors demonstration and pre-development product activities. The exploitation activities of the DREAM consortium will take several forms in order to to best fit the research results and to maximize the impact on the society of the main project outcomes.

The exploitation of the project results started in parallel with the project life-time and will be extended after the project completion. The exploitation strategies vary among the DREAM consortium partners and, in general, can be split into two main branches:

1. On the one hand the academic partners, i.e. both universities and research institutes, that have rather similar interests and exploitation capabilities. In fact they research and develop, for instance, new technologies with the main aim of transferring them to the industry.
2. On the other hand the SMEs and industrial consortium partners, who have specific plans related to their business models and to the potential intercepted market window for each specific product line [1].

The coordination of the activities of the second branch is performed within the Work Package 6 (WP6), "Dissemination, Exploitation and Standardization" and more specifically in Task 6.3 "Exploitation". Confidentiality issues and the different business interests of the partners involved require particular care, in order to handle properly potentially diverging interests. Among the main exploitation activities of the project, the following ones can be mentioned as reference parameters:

- market introduction of products containing some of the mmWave technologies developed during the project lifetime;
- number of patents filed in areas strictly related to the project scope;
- any spin-off coming out of the main outcomes of the project.

Each partner will protect innovations initiated or created in the project according to the rules defined in both the Grant Agreement and the Consortium Agreement.
The purpose of the this document is to present the exploitation strategy of the DREAM project and the plans of each consortium member.The proposed plans are around future activities and therefore are to be taken as indications of the intentions of the project partners, knowing that with time some change or diversion from the original plan can most probably take place.

This report is structured into the following Sections. Section 1 (Introduction), Section 2 elaborates on the objectives, the main concepts, the major expected results and innovations in each WP of the TA project. Section 3 introduces the approach to be followed in the exploitation of the results and how the knowledge and IPR will be managed in the project. The partner-specific plans for the exploitation of results are presented in Section 4. The conclusions are presented in Section 5.

2. Project objectives and main concepts

The objectives and the main concepts of the DREAM project are presented in the following subsections.

2.1 Project strategic and technical objectives

Providing broadband wireless communications to a majority of European citizens is a major objective of the European Commission. With a current annual growth rate in the range of 70%, the mobile data traffic of the smartphones, tablets, machine-to-machine and other portable devices dramatically challenges the 4G wireless cellular network, which is currently under deployment. To sustain this growth, the high data-rate millimeter-wave (mmWave) technologies, that demonstrate striking capabilities for the short- and medium-range wireless communications, can bring a tremendous performance improvement.

The main goal of the DREAM project, through the exploitation of the radio spectrum in D-band (130-174.8GHz) and by the antenna array beam forming technology, is to enable wireless links with data rate exceeding current V-band and E-band wireless backhaul solutions by at least a factor of 10 and thus, to bring wireless systems to the speed of optical systems.

DREAM will develop the key radio, antenna and packaging technologies for the implementation of a mmWave transceiver front-end addressing the backhauling links in the future and beyond 5th generation heterogeneous cellular mobile networks. Those technologies will take advantage of the wide unlicensed or light-licensed frequency bands which are available to allow a flexible spectrum usage as well as peak capacities above 100Gbit/s aggregated throughput.

Installed in the dense urban environments, miniature mmWave small-cell access-points connected to the cellular network through the optical fibre or D-band wireless backhaul will support massive data exchanges for mobile users with low latency, low interferences, high QoS and low power consumption per bit. They will also contribute to a reduced exposure of the public to electromagnetic fields (EMF) thanks to lower transmitted power and reduced skin penetration at mmWave, steerable directive antennas focusing the signals in the directions of interest, and reduced data traffic through the lower frequency legacy base stations (BS).

The technical objectives of the project are listed in the following:

1) Technical Objective 1: demonstrate the feasibility of low-cost SiGe BiCMOS transceiver analog front-end enabling link data rate up to 100Gb/s in D-band. The project targets to enable innovative mmW systems beyond 100GHz delivering data rate exceeding current V band and E band wireless backhaul solution by at least a factor of 10.

2) Technical Objective 2: provide mobile access to content-rich data using a fast and broadband link, which faces the challenge of bringing mmWave radios to both the access points and the User Equipment (UE) in order to exploit the large bandwidth available. Fast mobile broadband access, with low latency enabling high speed end-to-end connectivity even at the cell edge (100Mb/s minimum), will be enabled by the D-band very high throughput inter-small cell backhauling links.

3) Technical Objective 3: Increase the flexibility and the cost saving of the operator networks. The D-band inter small cell backhauling can route data hungry application traffic to fibre network available close to the access points. In order to optimize the inter-small cell data transferring, to get flexible backhauling and network mesh re-configurability, an important feature of the link solution will be the antenna beam steering functionality.

4) Technical Objective 4: Reduction of the power consumption of the access and small cell backhaul links (green radio): the use of mmWave radios and directive antennas in the short distance links (user access and small cell backhaul) results in a reduced emitted power requirement, more efficient transmitter implementation and a better efficiency of the spectrum usage (higher order modulations with large spectral efficiency can be used due to the more favourable link budget and lower interferences). The project targets to reduce significantly the radios and network power consumption by using mmWave in comparison with existing solutions using lower frequency bands.

In the following sections, the key DREAM project concepts and more detailed descriptions of the expected project results are presented per each technical Work Package.

2.2 Main DREAM concepts

DREAM' vision of 5G mobile networks is a heterogeneous network composed of sub-6 GHz macro-cells overlaid by small cells providing radio access in mmWave frequency bands. These small cells are linked together and to the core network through high data rate wireless backhaul link operating in D-band as well. While macro-cells will provide broadband and high QoS coverage over extended areas and support mobility, mmWave small cells will enable very high data rate radio access to mobile users and extended traffic capacity locally, for instance in areas with a high density of users or with specific needs for high-data rate communications. In this concept, small-cell off-loading technology developed in 3GPP will allow managing the traffic and splitting the data/control traffic when possible to benefit from the improved performances available in mmWave small cells. The mmWave spectrum contains several candidate frequency bands to implement radio access and wireless backhaul, the selection of these bands will be done in the next two to five years by regulation bodies based on various criteria including technical feasibility, commercial opportunities and compatibility with other services; DREAM work is focused on the the 130-174.8GHz band (D band), which is currently available and benefits of a very huge bandwidth and then of a very high data rate potential throughput.

D-band radio equipment can be very compact and low cost thanks to the latest integration technologies enabling full transceiver modules to be integrated in a single package. Such key requirements will enable this technology to be embedded in future mobile UE and in compact and aesthetic Access Points to be installed close together in the urban environment, typically on urban utility poles, street lightings or buildings.

The implementation of this concept requires the development of new D-band radio transceivers front-end and antenna systems with high efficiency, beam-steering capability and cost-efficient manufacturability. It will also require new networking functions taking into account the specifics of mmWave communications, which are a relatively short communication range, beamsteering and spatial multiplexing antennas, and the availability of very large frequency resources.

2.3 Major expected results and innovations

The major expected results and innovations are presented in the following sub-sections, elaborating on the technical WPs of the project.

2.3.1 WP1

WP1 (*Applications, Technology Specifications and Architectures)* defines the heterogeneous wireless network with mmWave small cell access and backhauling. From scenarios and use cases, a top-down approach specifies the solution architecture, the system requirements and then the D-band small cells with access point, from which derives a bunch of different transceiver front-end architectures and the set of specifications for the chosen solution.

The main outcomes of this WP, described in detail in the deliverables D1.1, D1.2 and D1.3 are the selection and definition of use cases and scenarios, the related KPI definition and the preliminary considerations regarding link budget studies and demonstrator link configuration.

WP1 provides an analysis of D-band frequency arrangement, correspondent regulation and propagation characteristics. The modeling of the whole system and the related specification are then obtained.

2.3.2 WP2

WP2 (*Radio analog front-end for antenna beam steering*) will cover the development of all the D-band analog frontend transceiver functional blocks, such as IQ-mixers, low-noise amplifiers, frequency multipliers, and power amplifiers, required to provide cost-efficient, high data rate wireless back- and front haul radio links.

The design rely on the advanced 55nm BiCMOS technology of ST to cope with the integration of the complete D-band frontend on a single chip set to ensure cost effectiveness, compactness and amenability to mass fabrication. The main challenges lay in the achievement of ICs that enable a D-band radio with the bandwidth and performance defined in WP1, in close cooperation with WP3 in IC die-to-antenna feeding line transition co-design. Designed, fabricated and tested chips will be delivered to WP4 for integration, towards the demonstrator implemented within the activity defined in WP5.

2.3.3 WP3

WP3 (*Antenna Technology Including Beam Steering Control*) will specify and design low form factor directive steerable planar antenna array solutions for backhauling, including as a design criteria a minimization of the exposition of EMF inside the small cell environment. This work package will deliver antenna prototypes to be embedded in the WP4 prototype substrate package integration.

The expected results in terms of antenna prototypes are the following:

- Different beam steering techniques such as phased arrays, reflect arrays, transmit arrays and integrated lens antennas will be compared in order to select the most promising technique,
- Mutual coupling reduction between array elements will be studied for optimal beam steering performance,
- Medium-gain beam steering antenna array (phased array) for the access point in V-band,
- Co-simulation of antenna elements with RFICs will be done,
- Digital control interface for the RFICs will be also developed.

Design will be done based on specifications from WP1 in close cooperation with WP2 in RF, LO and IF impedance level. Designed antennas will be delivered to WP4 for integration.

2.3.4 WP4

WP4 (*Subsystem Validation and Integration platform*) will provide D-band radio front-end prototype modules to WP5, including the integration of the analog transceiver chip set as well as the beamforming antenna array, the design of power suppliers, the RF and baseband interfaces, integration of RF and DC subsystems and a digital interface for beam steering control. Suitable integration platform technologies will be studied such as low-temperature co-fired ceramics (LTCC), liquid crystal polymers (LCP) and PTFE films and the optimal technology is selected for integration platform. It will house the radio analog building function chip set designed in WP2, and provide support to the WP5 demonstration activities.

2.3.5 WP5

WP5 ((*Proof of Concept, Demonstrator*) is a demonstrator, which is able to show the main KPIs defined in deliverable D1.1. In specific, a real-time base-band unit will be provided, able to handle a high throughput, perform functionalities like ATPC, ACM and channel estimation (MSE) and to optimize connection in a reasonable way. The analog front-end, integrated in WP4, will access the basic functionalities from the base-band unit. Beamforming algorithms will be implemented in the beam foming control. Prototyping will interconnect these parts. A demonstrator with one Tx and one Rx, able to perform beam steering and providing a proper connection will be the result of this WP. Results of the WP5 will be used for standardization activities in D-Band.

3. Plan for the exploitation of project results

In this section, the general approach to the exploitation of the project results and the principles for the management of knowledge and IPR are presented. Regulation and standardisation, which are important ways of impacting the ecosystem, and the proposed plan towards the related standards, is separetly presented in deliverable D6.4. Here, the partner-specific exploitation plans have been described.

3.1 Overall approach to exploitation

Exploitation activities of the DREAM consortium will take several forms in order to leverage at best the obtained project results. Therefore, exploitation activities are structured along several dimensions:

- The exploitation actor will influence the type and target audience of an exploitation activity, where a distinction can be done between the industrial and academic actors of the project;
- The exploitation type depends on the achieved research result and on the time horizon of the exploitation activity. For instance, some activities may have a direct impact within a short time frame on products (pre-)development whereas other activities may leverage research results with a long-term impact on the telecommunications sector through standardisation activities or with the introduction of products targeting more far-ahead market windows;
- The exploitation target is the audience of the obtained result and can either be internal, i.e. related to members of the DREAM consortium, or external, i.e. referring to a broader community, e.g. standardisation bodies.

The exploitation structure is summarised in Figure 1

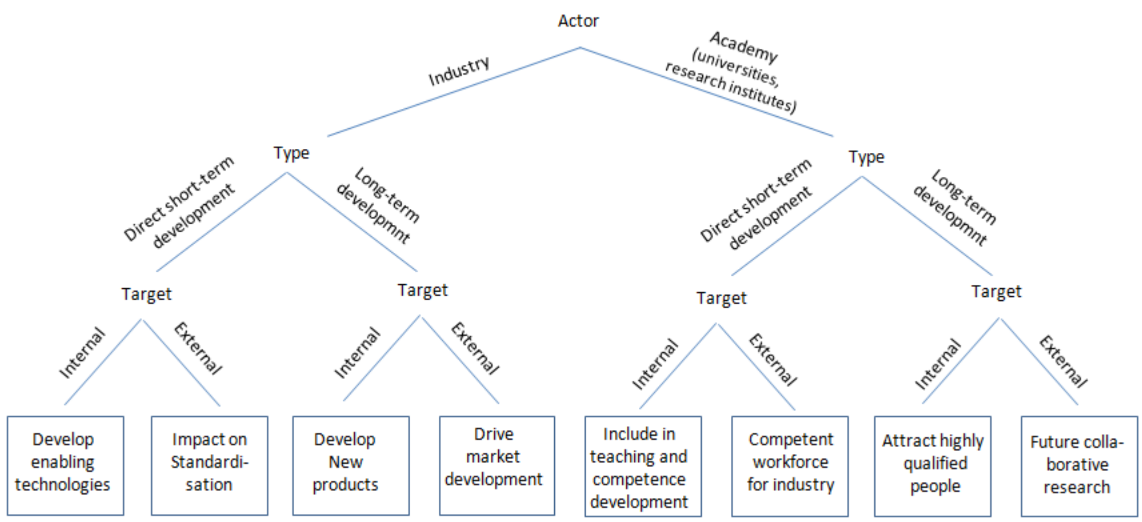

Figure 1: Structure of the exploitation activities

The **industrial partners** (i.e., operators, manufacturers, and SMEs) are focusing their exploitation activities on improving in the mid-long term their market position, with the strong intention to leverage on the project results to obtain leadership positions in the new market segments resulting from the broad deployment of mmwave technologies. Regulation and Standardisation activities, which are an important step of the pre-deployment process, are addressed in the deliverables: D6.4 “Standardization activity”.

Industrial partners usually exploit the newly obtained technical improvements internally, enhancing the existing product lines or even creating new disruptive devices and equipment. A manufacturer uses the acquired know-how to develop new enabling technologies and new products, and to improve its competitive advantage and business position on the markets. Operators and SMEs can speed up the deployment of new network technologies resulting in new usage scenarios and potentially new customers. All the project partners will ensure that the mentioned competitive advantages take place by transferring the results from the research units to the (pre-)development, marketing, and maintenance units. It is seen important that also high-level managers, ranging from board members and Chief Technology Officers to product and marketing managers will be kept posted on the main project results.

Industrial partners will also exploit direct technical improvements externally, the ultimate objective being to improve the competitive advantage and business position on the markets. Here, the timely availability of services and products are the key prerequisites for success. It is also possible to set-up new customer relationships by creating a community around the new offerings and the new enabling technologies coming out of the project results.

DREAM intends to show-case its results to the forthcoming beyond 5G EU-funded projects in order to ensure an early adoption of the main project outcomes within the telecommunications research community, as a solid foundation for future European and world-wide beyond 5G research, innovation and pre-deployment activities.

All in all, the industry-driven exploitation of results is perhaps the most important exploitation aspect of this project. It will shape the forthcoming technological landscape by making DREAM’s outcomes a core ingredient of future networking systems. It will ensure that European companies and markets continue to play a leading role worldwide, thus ensuring (if not even increasing) the number of working places in Europe in key technology areas for the years to come.

The exploitation goals of **academic partners** (i.e., universities and research institutes) are complementary to those of the industrial partners. In the short-term, they will exploit the project results to organise tutorial-style and research seminar-style into training schools of high academic standing. Technical developments will be integrated quickly into the teaching curricula and research agendas, giving themselves as well as their graduates a competitive edge, compared to other universities. Also, the research institutes have the objective of maturing technologies and transfering them to industry.

The academic partners will also be capable to educate a high-skilled workforce for the industry and the academia; this development will be particularly important for SMEs, who are often not able themselves to train personnel in very-advanced and breakthrough new technologies.

The academic exploitation has also a longer time horizon. By publishing high-quality papers, the academic partners will obtain improved international visibility thus being more able of attracting to their institutions and keeping in their ranks the best international Ph.D., M.Sc. and graduate level students. Academic partners will make sure that the main project outcomes will be carried over into future national and international research projects. The academic partners will also exploit the project results to organise tutorial-style and research seminar-style into training schools or summer schools of outstanding academic relevance.

3.2 Management of knowledge and IPR

In the first half of the project there have been no issues among the project partners w.r.t. the availability of the needed background- (when at all needed) and the foreground-IPs.

The principles followed by all the consortium partners have been and will be the ones defined and agreed in the DREAM Consortium Agreement [4], w.r.t. Section 8 ‘Foreground’, Section 9 ‘Access Rights’ and Section 11’Miscellaneous’. No relevant issues are to be reported on the management of the IP among the project partners.

3.3 Partner-specific plans for exploitation

The current status of DREAM partner’s exploitation plan is presented in the following.

3.3.1 ST-I

The exponential grow of data traffic sent over the mobile networks, with the advent of 3G, now the LTE, the LTE-A and in the near future of the 5G and its evolution, will cause the proliferation of distributed RAN (Radio Access Network) architectures and the RRHs, (Remote Radio Heads). Following this very likely market trend, ST is considering adding the D-band transceiver related products to their portfolio as an additional opportunity of increasing their available market by developing a proper BiCMOS based low cost and low power technology well working within the mmWave frequency range. In this way, ST should offer to customers involved in the mmWave backhauling market both an advanced BiCMOS-based technology allowing to develop their own D-band transceiver analog front-end architecture solution or a complete ASSP (Application Specific Standard Product) chip set making easy the development of their RRH products as well. Furthermore, ST is planning to extend their System-on-Chip (SoC) portfolio to both the control and data plane layers of the baseband, taking advantage of the latest advances in multicore SoC technology as the nano-scale FDSOI CMOS technology.

ST could also expand its available market by including solutions for mmWave-based small cell backhaul in its portfolio – a market area that is likely to scale up with the increasing demand for data capacity. The requirement for non-crowded spectrum becomes more critical in urban and sub-urban environments, especially as the number of installed links begins to grow as more high-capacity sites at smaller distances are to be served. Since multiple network operators already use the long-established microwave bands in the same area, at some point in time, excessive bandwidth might become more difficult to be sourced at legacy bands to cover their needs adequately. In order to avoid any potential congestion issue, networks operators could turn to mmWave bands, which have not been extensively used, so this part of the electromagnetic spectrum offers an alternative path to evolve wireless transmission networks effectively.

The exploitation activities of the DREAM consortium will take several forms in order to best fit the research results and to maximize the impact on the society of the main project outcomes. Exploitation activities will play a major role both for the industrial and the academic partners, having a strong mid- and long-term impact on standardization activities, new products proof-of-concept and pre-development activities, as well as on disseminating new research results and providing new generations of students with highly competent skills, very much requested from the market of the future.

Among the main exploitation activities of the project, the following three are identified as reference parameters:

- market introduction of products containing some of the mmWave technologies developed during the project lifetime;
- number of patents filed in areas strictly related to the task where ST-I in involved;
- any spin-off coming out of the main outcomes of the project.

Concerning the first parameter, ST-I is leading the WP2 (*Radio analog front-end for antenna beam steering*), where it will contribute to a D-band (130GHz-174.8GHz) transceiver front-end specifications and will support the design of some of the main building blocks to improve the transceivers performance in order to allow its integration in the small cell backhaul apparatuses. This work package will deliver the chipset prototypes to be used in the antenna and package integration activities handled in WP4.

The RF Business Unit of the DMA division, in ST-I, addresses two business areas: the RF Front-end Module of Mobile Devices and the RF Products for Wireless Infrastructure applications.

Below is a table comparing the main process features of the main SiGe Bipolar and BiCMOS technology industrial manufacturers, where compared to bulk CMOS, BiCMOS with Silicon Germanium (SiGe) Heterojunction Bipolar Transistors (HBT) allows a much higher cut-off frequency at a given technology node together with a higher voltage capability.

Table 1: Competition analysis between main BiCMOS process suppplier

Company	NXP		GLOBALFOUNDRIES		HITACHI	Infineon Technologies		IHP	TowerJazz		STMicroelectronics	
Name	HiP6MW	HiP6MW2	BiCMOS8XP	BiCMOS9HP	NA	B7HF200	B11HFC	S13G2	SBC18H3	SBC18H4	BiCMOS9MW	BiCMOS055
Status	Prod	Prod?	Prod	Pre-prod.	?	Prod.	Pre-prod.	Prot.	Prod.	Prod?	Prod.	Prod.
CMOS node	180nm		130nm	90nm	130nm	Bipolar-only	130nm	130nm	180nm	180nm	130nm	55nm
Wafer Size	200mm		200mm		200mm	200mm		200mm	200mm		200mm	300mm
SiGe HBT structure	Self-aligned SEG epi		Self-aligned NSEG epi.		Self-aligned SEG epi.	Self-aligned SEG epi.		NSEG epi.	Self-aligned NSEG epi.		Self-aligned SEG epi.	
SiGe HBT f_T / f_{MAX} (GHz)	200/280	260/350	260/320	300/350	255/325	190/250	240/380	300/500	240/280	240/340	220/280	320/370
BEOL (w/o Alu cap)	5 Cu levels (0.8 µm top metal)	6 Cu levels (2×0.8 µm top metals)	3 Cu+2 Al levels (1.25 µm + 4.0 µm)	9 Cu levels (4×1X, 2×2X, 2×4X, 1x3µm) + 4µm Al	NA	4 Cu levels (0.6/0.6/1.2/2.5 µm)	6 Cu levels (0.29/0.32/0.32 /0.32/1.0/2.8µ m)	5 thin + 2 thick Al (2µm+3µm)	Up to 6 Al levels with at least 1 thick top metal		6 Cu levels (0.26/0.35/0.35 /0.9/3.0/3.0µm)	8 Cu levels (0.16/0.2x4/0.9 /3.0µm)+Al
TL (µ-strip)	1.25 dB/mm @ 77GHz	<1 dB/mm @ 80GHz	0.9 dB/mm @ 60GHz	NA	NA	NA	NA	NA	NA	NA	0.5 dB/mm @ 60GHz	0.5 dB/mm @ 60GHz

To reach similar frequencies, bulk CMOS designs have to use much smaller process nodes. This makes it necessary to compromise on the design and most of the time leads to lower overall power performance and higher cost.

The ST's road map for the BiCMOS technology is preliminary pictured in Figure 2

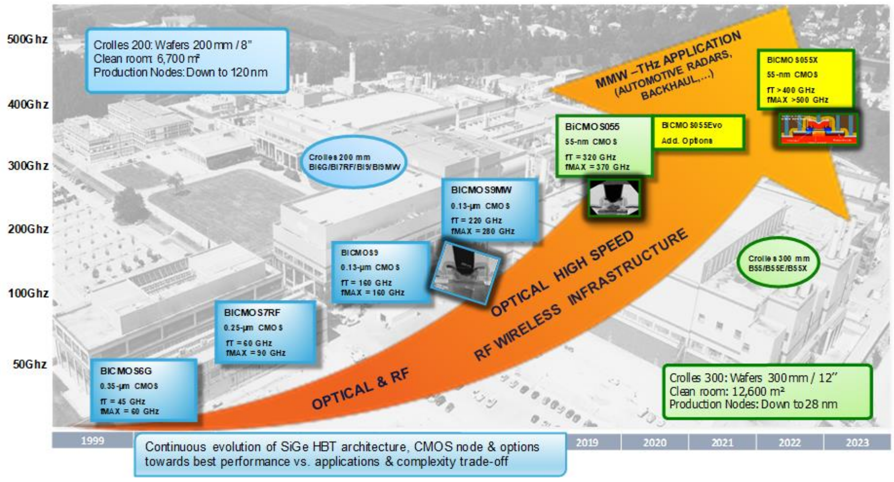

Figure 2: ST's BiCMOS road map. Increasing the SiGe based HBT enables new high volume applications exploiting the mmw frequency spectrum

The RF BU is responsible for the ST COT (Customer-On-Technology) business based on the BiCMOS process technologies. ST's BiCMOS process technology allows a full monolithic integration of all key function of RF Front-end module of mobile devices offering the industry's best in class figure of merit for antenna switch and antenna tuning devices.

The shift from GaAs to BiCMOS process technologies combined with the need to support multiband and multistandard creates growing opportunities in the Cellular phones and WiFi markets.

For the Wireless Infrastructure market the RF BU provides products for Macro to Small cells as well as for mobile Backhauling application. This includes both standard products and ASIC products. COT business is also supported providing advanced BiCMOS process technology to customers developing RF products. The wireless infrastructure, due to the exponential increase in mobile data traffic, is undergoing significant changes toward Heterogeneous Architectures creating new opportunities. The RF BU target is to grow the revenues of the existing standard products and to drive the development of new ones for the emerging opportunities.

The expected planned results and innovations are the following:

- An advanced BiCMOS process platform, based on an higher f_T/f_{MAX} SiGe:C HBT, to enable the high volume production of the future 5G and beyond mmw transceiver front-end chipsets,

- Beyond state-of-the-art analog transceiver front-end IPs based on the 55nm BiCMOS process, as the D-band frequency synthesizers, the power amplifiers, the up and down converter, the low noise amplifier and the phase shifter,

- Assessment of innovative design technique for mmw LO phase noise reduction in future direct conversion transceiver architecture,

- Assessment of innovative design technique for PA having a mmw output power being comparable with more expensive III-V transistor based technologies,

- Enrichment of the patent portfolio related to innovative circuital architecture IP enabling effective implemention of mmw applications.

- 130–174.8GHz backhaul transceiver chipset for beyond 5G mmWave up to 100Gb/s wireless link demonstration.

A patent related to an innovative circuit schematic to get a spurios-free frequency by-3 multiplier, has been proposed in collaboration with ST-I.

3.3.2 NOKIA-IT

NOKIA X-Haul portfolio today includes solutions able to transport data rate up to 10Gbps exploiting frequency band up to 86GHz, fitting with the requirements of current mobile backhaul network. The evolution of the network and the forthcoming 5G will reshape the backhaul network scenario, asking, mainly, for more capacity and lower latency. In additional to that, the market is looking for new backhaul solutions that have to be cost effective and more energy efficient. To cope with this scenario, it is generally perceived as mandatory, for a backhaul radio solution, to investigate the use of the bands above 100GHz, the so called upper millimeter bands and, in additional to that, to investigate different approaches than those today adopted.

These are the main motivations that stimulate NOKIA in making continuously strategic investments devoted to evolve its portfolio.

The introduction of a new product using new bands implies the need to face some not trivial tasks, starting from the “right to use” of such bands (regulation), passing through the identification of an efficient, effective and feasible solution, up to the chance to place that solution on the market (standardization).

NOKIA, in considering adding a D-band transceiver to its current portfolio, is motivated to investigate, through DREAM, the following main three points:

- Whether the D-Band will be devoted to this scope (for Fixed radio) and whether in a proper manner to address a 100Gbps wireless network/solution (Regulation).

Thanks to the work carried out by NOKIA during the first year of the project, this point could be considered today already achieved.

- Whether a 5G and beyond backhaul radio solution: a) exists, b) is feasible using technologies today available, c) is energy and cost effective

The solution is, at the time being identified and preliminary studies included into D1.1 and D1.2 indicated with a good confidence it feasibility, that anyway has to be proved considering the final DREAM demonstrator. Point c) will be assessed later

- Whether the identified solution can be adopted for a commercial product. Then the solution can respect the EU mandatory “Radio Equipment Directive 2014/53/EU” (RED) [2]. RED directive is setting the essential requirements for safety and health, electromagnetic compatibility, and the efficient use of the radio spectrum, a radio solution has to fulfill.

The radio profile of DREAM solution is already designed considering what, reasonably, can be achieved and can be proposed as candidate profile into next ETSI Harmonised standard. To pass to next step for this last point, we need to wait the results of measurements.

Considering this last point, measurements, or better the system assessment, we have identified that another challenging stream has to be investigated. Here we have identified two main points:

- First: after a first market survey, we discover that current measurements instrumentation are not yet suited for carrying out, with the expected accurancy, the traditional measurement on a radio in D-Band. This point is true even considering the adoption of a traditional approach for the radio architecture, that is not the DREAM case anyway.
- Second: Considering the adopted DREAM architecture, where the antenna port doesn’t exist phisically, poses the problem to find a new assessment method, that can satisfy the principles set out in the “Radio Equipment Directive 2014/53/EU”. In fact, without the antenna port, it is made unfeasible the definition and the measurements of the transmit power level and its tolerance, the measurements of the transmitter spectrum mask and a plenty of other essential parameters that were considered/defined till now as essential for RED compliancy.

These last points open a new field of investigation, strictly correlated to D-Band solutions that shall be resolved, in advance, to enable the chances to introduce on the market a radio D-band solution.

As a conclusion, we can say that, DREAM approach, includes a broader view of all the activities connected to the definition and the introduction of a real product on the market, given then the chances to touch plenty of different and interdisciplinary aspects, that we believe will be beneficial, not only for a manufacturer like NOKIA, but for all the partners involved.

Here a preliminary and not exhaustive list of the main activities and achievements NOKIA is interested in exploiting:

- Contribute and influence the regulatory aspects to fit with DREAM needs
- Solutions and architectures for wireless system 100 Gbps capable
- Chipset solution based on SiGe components for Transceivers in D-Band and beyond
- Front-end solution and architecture for Millimetre-wave Frequency bands up to 170GHz
- Flexible duplexer approach and assessment of ZDD approach using two antennas
- Antenna with beam-forming and beam-shaping capability
- Contribute and influence the standardization activities, anticipating the issues due to the new approach adopted in DREAM and the lack of dedicated instruments
- Contribute to the standardization activities to find out a new assessment approach that can be applied to radio solutions in D-Band and in particular to solution where the traditional approach cannot be followed.
- Contribute to define the specifications and arrangement of testbench and relevant measurements instrumentation necessary for D-Band equipment radio assessment.
- Considering the distributed approach in RX and TX side, and relevant implication on Digital parts, such as predistortion
- Energy Efficiency aspects as part of green approach to the future network
- Define(d) the standardization radio profile up to 100 Gbps suited for frequency band above 100GHz

These are the main points identified so far that NOKIA are willing to cope with, for improving the know-how and for consolidating our expertise in Microwave and Millimetre-wave backhauling network ecosystem. We expect as well, to gain new skill in measurement techniques at millimetre-wave frequencies up to 170GHz, in dealing with ultra-high capacity data rate (100Gbps) and in general in all millimetre-wave area application.
It is expected that, from these activities, we will have an important and a direct impact on the future NOKIA know-how with concrete effects for NOKIA future business and products portfolio.

3.3.3 CEIT

CEIT is a research center closely linked to academy that provides industry with services through the development of research projects and trains young researchers. The ICT division of CEIT develops communication solutions and ICs. During the last years, CEIT has been involved in projects operating in the mmW range. Many of the researchers at CEIT are also lecturers at TECNUN (the technological campus of University of Navarra). Thus, the experience and state-of-the-art know-how of the researchers can be translated to the teaching at university and to the training of young researchers. On the other hand, CEIT uses the acquired know-how to support industry in the development of new products and applications in the mmW range.

Within DREAM, CEIT’s main functions are in WP1, in the system level analysis, architecture definition and subsystem specification; in WP2 in the design of the phase-shifter, integration of the transceiver’s ICs and control of the ICs; in WP3, in the study of the interface between the ICs and the antenna element and in the design of the digital control for beam-forming; in WP4, in the demonstrator assembly and test; and in WP5, supporting the setup of the testbed.

CEIT address two kind of markets in his exploitation. The first market is aligned with its academic profile. CEIT’s team working in DREAM are also lecturers in the degree and master in telecommunication engineering at TECNUN. CEIT is using the experience acquired in DREAM to increase the base of knowledge of the lecturers at TECNUN, enriching, the education at TECNUN and the training of young researchers at CEIT. Also the participation in DREAM, together with the publications resulting from the project, is being exploited to increase the reputation of CEIT and TECNUNwithin the academic ecosystem in its region and internationally. Gaining reputation is important to attract students to university and also talented engineers to the research center.

The second market is aligned with its role to support the industry. Here, CEIT considers two aspects for the exploitation of the results of the project. Firstly, the participation in the project will help to position CEIT stronger as a provider of solutions for mmW communication systems. CEIT is including the project as a reference in his commercial presentations to potential customers. This positioning will be exploited to offer design services and to participate in future collaborative projects. Secondly, CEIT is developing in DREAM blocks for the ICs. CEIT will analyze the best way to exploit the IPR of these blocks.

3.3.4 VTT

VTT has actively promoted the utilization of mmW technology in commercial applications. Our target is to support the European industry in entering the emerging mmW market with a high business potential. High data rate D-band link is the excellent example of commercial mmW applications. VTT's strategy is to transfer the results of the DREAM to industry through IPR and know-how licensing and product development projects.

VTT has world class competences in design mmW components and systems up to W band. The participation in the DREAM will help VTT to expand competences as a provider of solutions for mmW communication systems up to D band. This position will allow to offer design services in D band and participating in future projects with industrial partners . Due to novelty of utilization of D band for communication, there is limited expertize in radio measurements in D-Band with the needed accuracy. We expect to gain new skill in measurement techniques in the project at D band and in dealing with ultra-high capacity data rate (100Gbps).

3.3.5 UniPV

The University of Pavia (UniPV) is a public multi-disciplinary University. As such, its primary mission is to provide education and to perform high-quality research within all the fields of knowledge, comprising humanities, law and economics, science and technology, medicine.

Professors and researchers of the Department of Electrical Computer and Biomedical Engineering of UniPV are involved in the DREAM project. The Department occupies a leadership position in education and research within the broad area of information and communication technologies (ICT). The school of engineering has been ranked in the top-five among Italian Universities. The Department groups over 30 research labs supported by private and public funding. The high scientific quality of the research activity is proved by hundreds of papers published every year on top-quality international conferences and journals. Several research collaborations are ongoing with private companies, and public research institutions in Italy and abroad. Of particular importance are the research achievements in the field of Microelectronics, which place the Department among the top institutions in Europe. Professors and researchers of the Department present every year new research results at the top international conferences in this field. Many international semiconductor companies tightly collaborate with the University to train students of high profile and have design centers in close proximity to the engineering campus. Most companies host students for their graduation projects and participate, in co-operation with the University, in national and European research programs. STMicroelectronics supports a Laboratory housed inside the campus. Engineers graduated from Laurea Magistralis are nowadays employees of the most important international semiconductor companies in Italy and abroad.

Researchers belonging to the Analog Integrated Circuit Laboratory are taking active part to the DREAM project. The Lab is aimed at the conception, design and realization of integrated circuits for diverse applications, ranging from wired and wireline communications to healthcare. It is managed by two faculty members and hosts an average of 10 students and post-doc. In the framework of DREAM, researchers will mostly contribute by investigating D-band frequency synthesis integrated circuits with the advanced silicon process provided by STMicroelectronics.

The exploitation of the DREAM project offers great opportunities to strengthen the leadership of the Department among other education and research institutions. This will be pursued following distinct but strictly connected actions described below.

Rise the reputation of the department. Keeping high international visibility and scientific reputation is the primary ambition of each University. For the academic community this is mostly achieved through a continuous scientific dissemination activity with publications on high-quality journals and presentations made by researchers and professors at international conferences of high visibility. But for an engineering department, the reputation in front of companies is likewise important. And this requires addressing research problems that may have a mid-term impact on development of new products. The DREAM consortium mixes Industrial partners with public institutions, addresses a cutting-edge multidisciplinary topic of the ICT and make available to UniPV a state-of-the-art silicon technology. DREAM is therefore a perfect framework to produce scientific publications with high impact on both academia and industry. Particular attention will be placed by UniPV to the dissemination of know-how gained within DREAM through high quality publications, such that the activity can consolidate the reputation of UniPV and rise further its visibility at international level.

Attract talented students to be enrolled in basic and advanced education and research programs. University of Pavia has recently proposed a new master program in Microelectronics, taught in English, with the purpose of attracting and better selecting talented students from all over the world. To be competitive, the Master program needs to include state of the art and multidisciplinary research topics such as the activity carried out within the DREAM. Seminars within the Master lectures will be organized to promote the DREAM project and attract the curiosity of students to join PhD programs. The know-how developed in the project will be also integrated quickly into the teaching material, gaining competitiveness against other universities.
From a research perspective, keeping a high quality profile requires constant brainstorming and innovations that can be described as of an intellectually arduous nature. When comparing European and US research teams, US ones usually group many more students, up to 15-20 in major Universities. To stay competitive on a global scale, human capital and talent is a critical component. European projects like DREAM allow hiring new students, graduate in particular, and provide them financial support increasing the critical mass dedicated to research activities.

Expand funding and cooperation. For engineering disciplines tightly connected to cutting-edge technologies, like microelectronics, maintaining advanced research with relevant outcomes requires large groups, wide networks and continuity in funding programs. To continue keeping up the high scientific profile, professors of the Department need to maintaining a tight relation with industries and other institutions in the field. A good balance between private and public projects and funding is a target. Very advanced topics will be conducted in the framework of large collaborations and public funding. Private agreement can lead to advanced research activities as well as more medium and short-terms prototyping in view of possible products or UniPV spinoffs. Establishing a close academia–industry collaboration is key to promote sharing of knowledge and potential commercialization of design ideas. UniPV will become more effective by working with major players in ICT on large-scale and long-term research projects. This is important not only for bringing in funding, but also helps generating new innovations and ideas to fuel the development of new products and processes as well as building a competent and cohesive research team. In addition, a strong and vibrant relationship with the collaborators will keep UniPV positioned at the cutting edge of design and key technologies. Presently, University of Pavia has a good link with STMicroelectronics and a common Lab is shared inside the campus. DREAM is a very good research program besides supporting students and/or post-docs. After completing the European program, we hope to continue the activity within the common Lab under STMicroelectronics support. The intention is stabilizing this model so that a new research activity is carried out in the framework of an European public initiative, having both UniPV and STMicroelectronics as partners.

A patent related to an innovative circuit schematic to get a spurios-free frequency by-3 multiplier, has been proposed in collaboration with ST-I.

3.3.6 III-V Lab

III-V Lab develop key components in advance, validate modern concepts or build demonstrators for millimeter wave wireless systems and high-speed optical systems. We have currently developed transceivers from 6 GHz to 86 GHz that are currently used in NOKIA X-Haul products for data transport.

DREAM will enable us to improve our know-how in the development of high D-band integration chips to cope with the new challenges facing millimeter wave communication systems, as well as to consolidate and develop our capabilities in the field of millimeter wave characterization.

This will enable III-V Lab to increase its impact in promoting mmW transceivers for telecommunications and other applications to its parent companies Nokia and Thales, whether through new designs, projects or prototypes.

The DREAM project has already provided us with a better understanding of the future challenges of designing integrated circuits for active antennas with frequencies above 100 GHz. This allows us to bring our expertise to our parent companies to discuss standards and define the characteristics of future products.

3.3.7 Erzia

ERZIA is focused mainly in aerospace and defense markets. Its specialized teams design and manufacture radiofrequency, microwave and millimeter wave electronic systems and provide high reliable satellite communications. The company was founded in 2002 to become a worldwide reference of advanced engineering, performance, reliability and ruggedness, with the goal of enabling customers to outperform in the most hostile environments.

ERZIA also contributes to the advancement of science, technology and engineering, by taking part in European H2020 projects. In the current DREAM project, ERZIA is looking forward to gain and enhance its expertise to the future 5G communication systems in D-Band.

The exploitation plan for ERZIA from the DREAM project is foreseen as follows:

- Expand its Low Noise Amplifier product offering up to D-Band. Our current offering goes to 100GHz
- Expand its Up/Downconverter Subsystems product offering up to D-Band. Our current offering goes to 50GHz

Beamforming Systems for various applications. It would be new product development based on specific customer needs.

Thanks to the work and results in the DREAM project ERZIA will include integration techniques beyond 100 GHz in future opportunities. Indeed, the knowledge and techniques suited to D-band from other partners will enrich and improve future designs/products in the THz region.

4. Conclusions

As stated by the European Commission, good dissemination and exploitation of results shall be a strategic objective of all funded projects. As the DREAM project will provide essential contributions to the development of future mobile networks, from the medium- and long-term perspectives, special attention has been given to dissemination, exploitation of results and to the impact on the standardization bodies. The dissemination activities have been reported in deliverables D6.5 “Year 2 dissemination plan”, while D6.7 reports on the “Year 2 - standardization activity”. This document has given an update of the detailed preliminary plan for the exploitation activities.

The exploitation of results, instead, plays a major role for both the industrial and academic partners, with the target of strongly impacting the standardization, product pre-development and education of competent people.

In this document, the exploitation activities are structured along several dimensions, i.e. the actor (i.e., industrial and academic), the type (short-term to medium-term, long-term), and the target (internal, external). Furthermore, the proposed specific plans for each partner are also presented. This report structure will be finally updated in the third exploitation plan reporting in month M36.

References

[1] DREAM Project (Horizon 2020- ICT-09-2017), Proposal, 08/11/2016

[2] Radio Equipment Directive 2014/53/EU (RED): https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32014L0053.