CARBON BASED SMART SYSTEM FOR WIRELESS APPLICATION

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WORK PACKAGE 1 : System specifications

DELIVERABLE D1.1

Report on identified potential applications

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WORK PACKAGE 1: System specifications

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1 INTRODUCTION

This deliverable outlines the main applications identified in the NANORF project. The application of smart antennas for next-generation communication systems is particularly attractive since in the near future there will be a huge expansion of such infrastructures, and since wireless LAN's will be employed not only in metropolitan networks for wide-band mobile communications, but also in indoor entertainment and communication devices. The development of such enabling technologies will be therefore of great importance and will also create business opportunities in these fields. Cost reduction is mandatory for synthetic aperture radar applications utilizing active antennas. This can be done at hardware level by acting on the main cost drivers of the antenna namely T/R modules and integration & testing. Technological steps are needed at T/R module level to increase RF/DC/TTC integration and packaging and to improve MMIC HPA efficiency. Transmit/Receive modules are key building blocks for modern radar and communications arrays. There are a lot of studies on technologies to enable the next generation of T/R module for communication systems. Next generation T/R modules should be thin and inexpensive to fabricate, test and integrate into radar systems. Frequencies supported will range from microwave through the millimeter wave and maybe even beyond. There is also a need for new technologies allowing the achievement of nano T/R modules with low power, high integration level for low range distance applications such as for example automotive applications (autonomous cruise control, pre-crash detection systems, blind spot detection, parking aid, side impact detection and stop and go traffic radar) or mobile communications.

Air traffic is expected to double by the year 2020. Airports capabilities to treat the increase of traffic will rapidly become the bottleneck of the whole transporting chain. The major airports have today to face several types of issues:

- Firstly, they approach their ultimate capacity in term of passengers.
- Secondly, the delays necessary between the take-off of two succeeding planes is increasing with the size of the plane, due to wake vortex in the drag of heavy aircrafts.
- Moreover, the level of safety should be maintained and even increased (wake encounter events could increase in-line with the increase in traffic).
- Finally, the runway throughput should be regulated with the trend in changing traffic mix : "Super" Heavy Aircrafts (A380, B747-8) have to coexist and share the same infrastructures as Very Light Jets.

Hence the need is to develop Dynamic Wake Vortex Hazard Mitigation Systems. Reflect Array antennas are a major possibility in order to develop the next generation weather radar and wake vortex detection radars. Adaptive receivers are key building blocks in the future front end radar systems. The trend in radar architecture is to limit the analog signal processing to the front end of the radar. Thus, in future radar systems, the A/D converters will directly follow the receiver. This implies new constraints on receiver specifications in term of frequency agility, hence the need to develop to deliver fast and reliable tunable filters. A motivation for using tunable filters could be as a possible replacement to a use of many fixed frequency filters in order to save space and increase the level of integration of the receiver modules in future generations of air traffic management radar systems, for example. A tunable filter could also result in a lower over-all cost assuming that such a filter will be less costly to implement compared with using several (fixed frequency) filters.

The heart of this project is focused on the development of carbon nanotube material and graphene-based components to address the various applications described. NANO-RF will focus on some key device architecture: (i) CNT and graphene based FET, (ii) CNT based NEMS, and (iii) CNT based antenna using vertical or lateral individual and/or arrays of CNTs (iv) RF graphene devices. The goal being to demonstrate the feasibility of a nano-system: a T/R module based on CNTs and graphene.

2 IDENTIFIED POTENTIAL APPLICATIONS

T/R modules remain the single most complex component in the active array antenna. Where in the early days performance was the most critical issue, today it is cost due to the high number of modules required for an active array radar design. This could lead to less performing but cheaper, highly reproducible T/R modules from a stable production line. In the long term the antenna will become digital. In consequence the T/R module has to perform more functions and the complexity will increase accordingly. It is important to realize that higher complexity does not necessarily imply higher cost. The key is in keeping the component count low which is easily possible by using highly integrated semiconductor technology. Analogue to digital conversion at a reduced number of bits will take place within the modules. Therefore low cost receiver technology is needed, which could be based on direct conversion techniques.

The T/R module's most critical components are: a power amplifier (PA), a low noise amplifier (LNA) respectively within transmit and receive paths, a high isolation with low insertion loss back end switch component (SPDT), and finally a radiating element (antenna). Moreover, there are oscillators, mixers and filters (Figure 1). A recent trend in smart systems is the integration in a three-dimensional (3D) manner, i.e. stacking integrated circuits and components vertically in order to meet the challenges of performance enhancement, miniaturisation, power consumption, and thermal management. A key element in 3D integration is the vertical interconnection bridging the stacked components. NANO-RF will explore the possibilities of using CNTs as the interconnection material and assess their performance and reliability. Using CNT and graphene based devices as the main building blocks for the components of a T/R module will bring about a totally new concept towards its miniaturization. In fact, each of these components will benefit from several properties of the CNTs and graphene as well as from the high-density of integration between them.

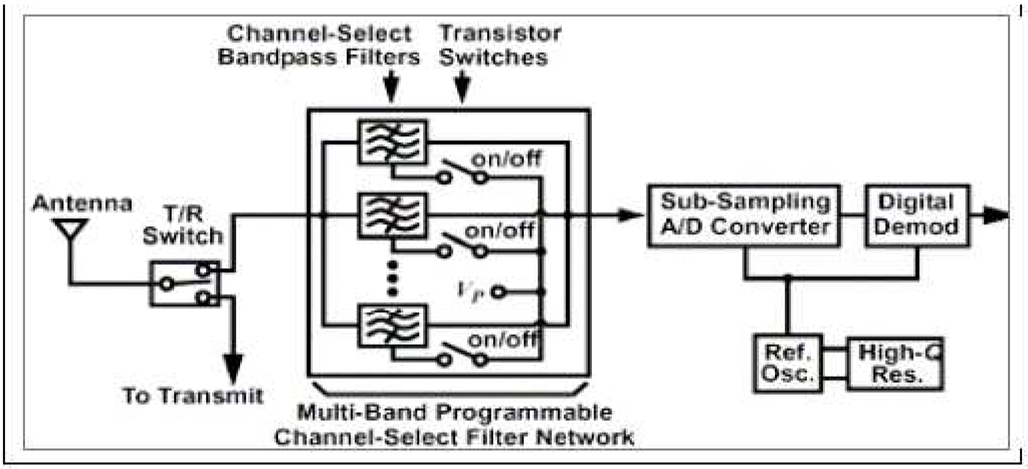

Figure 1 T/R module's most critical components

Active Array Antennas mainly suffer from the high price, which prevents broader usage of this fascinating technique today. For military application a lot of effort is being made to bring the cost down (mostly in X-band) and space-borne SAR will take advantage of these developments, as well as weather radars in a new and more compact generation. The successful use of a reflect antenna array within an X-band weather radar will lead to major simplification of the mechanical structure combined with a faster scan cycle. The end result is simpler, smaller, and more reliable than today's weather radar systems, and which at the same time provides more data. The inherent shortcoming of long-range radars of not seeing beyond the horizon because of earth curvature blockage (and thus not detecting low-altitude weather phenomena a distance apart) is at times addressed by dense radar network. This approach, however, suffers from the high cost of radars. A low-enough priced X-band radar could address could address this need and thus expedite the emergence of dense radar networks. Additionally, there are applications where the long range of a C-band radar is not fully exploited (e.g. at mountainous areas, local weather watches, and mobile and certain atmospheric research applications). The benefits of the new antenna construction would provide a significantly higher perceived customer value and improve the supplier's competitiveness. A small enough size would also likely increase the demand for mobile weather radars.

Reflect arrays can be said to combine some of the best features of the conventional printed phased array and parabolic reflector antennas. Reflect arrays are much less expensive than standard phased arrays and provide ample space for drivers and receiver electronics. They are space fed; therefore, they do not suffer from the high transmission-line (corporate feed) loss as the array size increases. The individual elements of the array are designed to scatter the incident field while impressing the appropriate phase shifts in such a way as to form a plane wave-front that propagates in a prescribed direction or, more in general, to create the required radiation pattern. The elements of the array can be microstrip patches or waveguide apertures, operating on linear, dual or circular polarization. The phase shift needed in order to synthesize the scattered wavefront adaptively can be achieved in mainly different ways (i) by varying the geometry of the radiating elements or its electrical properties using tuning device within the radiating elements, or (ii) using tuning elements that are separate but EM coupled to the radiating element. The tuning elements can be e.g. PIN diodes and RF MEMS. This is an application where the inherent advantage of using RF NEMS technology lies due to their low power consumption, high linearity, low loss, and high isolation. The RF NEMS can be integrated into the antenna design to achieve a higher degree of functionality for the reflect array.

Another potential application that can be addressed by the NANORF project is the development of tunable microwave filters and phase shifters. Front-end circuits like filters, matching and phase shifting circuits are key components in many RF systems. A lot of research has been made within this field, especially during the last decade or so. Modern radar and communication systems have created a need for finding novel RF front-end solutions that can result in a reduced complexity and potentially also lower cost (e.g. using tunable filters and phase shifters for adaptive receivers). Traditionally, tunable front-end filters have been realized as non-planar filters that are bulky and the size and weight of such filters limit their use in highly integrated RF systems. In terms of planar filters, solid state (p-i-n diode or transistor) based varactor-tuned filters are much smaller in size but the relatively high losses and low linearity of such filters have been limiting factors for a wider use in wireless RF systems. A disadvantage with using p-i-n diodes as filter tuning elements is that they will consume relatively high levels of DC power which also can be a limiting factor in many systems. Better performance can be achieved with RF NEMS (compared to solid state technology) and it can be applied to filters, matching networks and phase shifters.

A possible alternative to the use of classic passive front-end filters (either fixed frequency or tunable) is tunable filters or narrow-band band-pass LNAs that potentially can be designed with a high gain and out-of-band rejection (selectivity) and also low noise figure over a wide frequency tuning range. Using such tunable active components (filters) it can be possible to implement different RF functions (such as frequency-agile front-end filtering and low-noise amplification) in a single circuit and even on the same chip. This may prove to be a viable solution for certain wide-band/multi-band applications where cost and miniaturization are important driving factors (e.g. through high level integration). A motivation for using tunable (active or passive) filters could be as a possible replacement to a use of fixed frequency filters in order to save space and increase the level of integration in future radar systems. Relatively few results have been presented for tunable active filters (or frequency-agile PAs/LNAs) using variable MEMS matching networks. The need to address these components within the NANORF project will provide novel alternatives with miniaturized devices and better performance. In summary, key devices developed in NANORF are summarized in Figures 2 and 3 below.

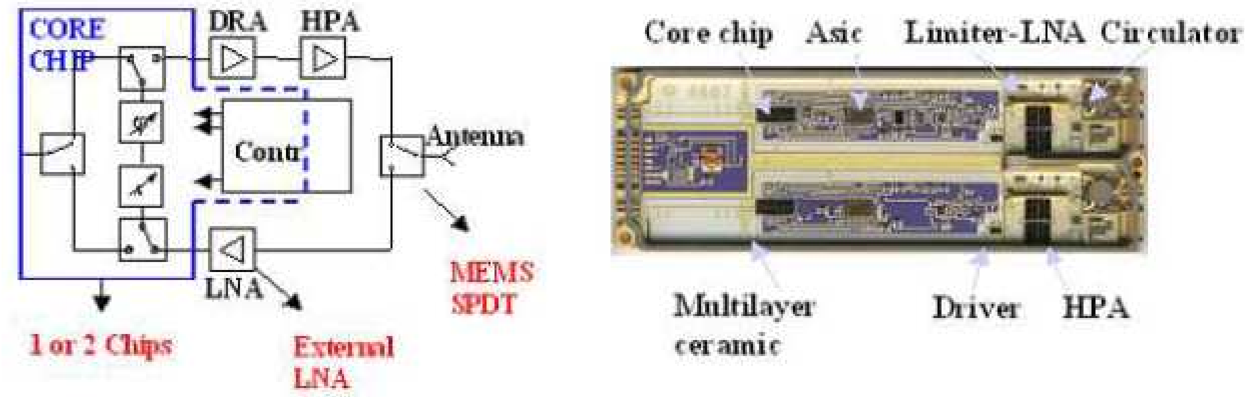

Figure 2 : T/R module for active antenna. NANORF will aim to replace circulators u NEMS SPDTS and also HPA and LNA by CNTS/Graphene transistors

		short-term solution	mid-term solution	long-term solution
HPA	S-band	Si BJT -> GaAs HBT	GaN HEMT	CNT/ Graphene transistors
	X-band	GaAs HBT, P-HEMT	GaN HEMT	CNT/ Graphene transistors
	C-Ku band	GaAs P-HEMT	GaN HEMT	CNT/ Graphene transistors
Core-chip	all bands	GaAs P-HEMT	SiGe HBT	CNT/ Graphene transistors
LNA	all bands	GaAs P-HEMT	GaN HEMT	CNT/ Graphene transistors
T/R Switch	all bands	Power switch	Power MEMS	Power NEMS

Figure 3 Technological trends for T/R front-end modules