ROADART

H2020 - 636565

Research On Alternative Diversity Aspects foR Trucks

FINAL SYSTEM ARCHITECTURE COMMUNICATION PLATFORM

Deliverable Identifier: **D4.1**

Delivery Date: 30 April 2016

Classification: Public

Editors: S. Held, IMST GmbH

Document version: V2.0

Contract Start Date: 1 Mai 2015

Horizon 2020

Call: H2020-MG-2014_TwoStages

Topic: MG-3.5a-2014

Type of action: RIA

Revision History

Version	Date	Description and comments	Edited by
0.1	07 Nov 2016	First Draft Version	S. Held
0.5	05 Dec 2016	Completed	S. Held
0.8	05 Dec 2016	Review	J. Thomas
0.9	06 Dec 2016	Review	J. Siemons
1.0	06 Dec 2016	Final	S. Held
2.0	18 May 2017	Deliverable classification change from *Restricted* to *Public* after unanimous agreement of the partners and the PO	C. Oikonomopoulos

Contents

Table of Figures

Acronyms

BPF	Band Pass Filter
CACC	Cooperative Adaptive Cruise Control
CAM	Cooperative Awareness Message
DC	Direct Current
DDS	Data Distribution Service
DSRC	Dedicated Short Range Communication
GbE	Gigabit Ethernet
GNSS	Global Navigation Satellite System
ITS	Intelligent Transport Systems
IQ	Inphase, Quadrature; complex baseband sample
LAN	Local Area Network; typically Ethernet based
LNA	Low Noise Amplifier
LPF	Low Pass Filter
OFDM	Orthogonal Frequency-Division Multiplexing
PA	Power Amplifier
PCB	Printed Circuit Board
RF	Radio Frequency
RTI	Real-Time Innovations, Inc.
RX	Receive

SMA	SubMiniature version A; coaxial radio frequency connector
SPI	Serial Peripheral Interface
T2T	Truck to Truck
T2I	Truck to Infrastructure
TX	Transmit
V2V	Vehicle to Vehicle
V2I	Vehicle to Infrastructure
VLAN	Virtual LAN
WP	Work Package

1 Introduction

1.1 Background

This document is the result of a deliverable for the ROADART project. This project aims to evaluate diversity techniques and antenna concepts in order to develop an in-vehicle platform for cooperative ITS systems for trucks and heavy duty vehicles in the Horizon 2020 call MG-3.5a-2014 “Cooperative ITS for safe, congestion-free and sustainable mobility.”

The ROADART project is defined by means of 9 work packages (WPs):

- WP1 Requirements and Design
- WP2 Channel Measurements, Characterization and Modelling
- WP3 T2X Communication Techniques
- WP4 Development of the ITS communication platform
- WP5 Robust Cooperative Adaptive Cruise Control
- WP6 Integration
- WP7 Test, Demonstration and Evaluation
- WP8 Dissemination and exploitation
- WP9 Project Management

This deliverable is part of WP4: Development of the ITS communication platform.

The project and the objectives will be further explained in section 1.1.1 and 1.1.2.

1.1.1 The project

The main objective of ROADART is to investigate and optimise the integration of ITS communication units into trucks. Due to the size of a truck-trailer combination the architecture approaches investigated for passenger cars are not applicable. New architecture concepts have to be developed and evaluated in order to assure a sufficient Quality of Service (QoS) for trucks and heavy duty vehicles. An example of a specific use case is the platooning of several trucks driving close behind each other through tunnels with walls close to the antennas that support the communication systems. Due to the importance of tunnel safety, significant research effort is needed in order to check the behaviour of the antenna pattern, diversity algorithms and ray tracing models especially for trucks passing through tunnels. V2V and V2I systems specified from the C2C Communication Consortium are focussing on road safety applications. The ROADART project aims to demonstrate especially the road safety applications for T2T and T2I systems under critical conditions in a real environment, like tunnels and platooning of several trucks driving close behind each other. Besides that traffic flow optimization and therefore reducing Greenhouse Gas emissions are positive outcomes of the use cases demonstrated in this project. Demonstration and Evaluation of the use cases will be performed by simulation and by practical experiments on several levels. Besides evaluation on component and system level, the complete system will be evaluated in practice.

1.1.2 Objectives

The ROADART project aims to evaluate diversity techniques and antenna concepts in order to develop an in-vehicle platform for cooperative ITS systems for trucks and heavy duty vehicles in the Horizon 2020 call MG-3.5a-2014 "Cooperative ITS for safe, congestion-free and sustainable mobility."

1.2 The objective of this deliverable

The objectives of WP4 are:

- Develop the final system architecture based on the outcomes of WP1, WP2 and WP3. The architecture depends on the diversity technique chosen for the demonstration.
- Develop appropriate antennas for the integration into the trucks at the identified places in WP3/WP4.
- Develop the hardware for the RF modules placed on the truck.
- Develop the communication unit consisting of wireless communication modules and a microprocessor.
- Develop the protocol software for ITS V2V communication according to the up to date standardization from the C2C Communication consortium.
- Implement the interfaces to the control unit and the RF Modules.

This deliverable describes the final system architecture of the RF modules and the communication unit.

1.3 Structure of the document

The document is structured as follows.

First the system context of the RF modules and the communication unit is defined in section 2, and then the logical and physical nodes are explained in section 3 and 4.

2 System Context

The system context of the Roadart communication system is shown in Figure 1, while the interfaces of the communication system can be seen in Figure 2.

Two trucks can be seen, forming a platoon. Each truck has one radio (RF1 or RF2) and one antenna inside both the left and right mirror. Those units are digitally connected to a communication unit, which is placed inside the cabin.

The system RF1, RF2 and the communication unit form a distributed antenna system with digitally connected remote radio heads. The advantage of the digital connection is: the distance between the RF modules and the communication unit does not degrade the signal quality.

Figure 1 System Context

The external interfaces (refer to Figure 2) of the communication system are:

- Power supply for every radio (RF1/RF2) and for the communication unit
- One antenna SMA connector per radio
- One control port (Ctrl) per radio to support antenna beam switching
- An Ethernet port at the communication unit to connect to the truck network

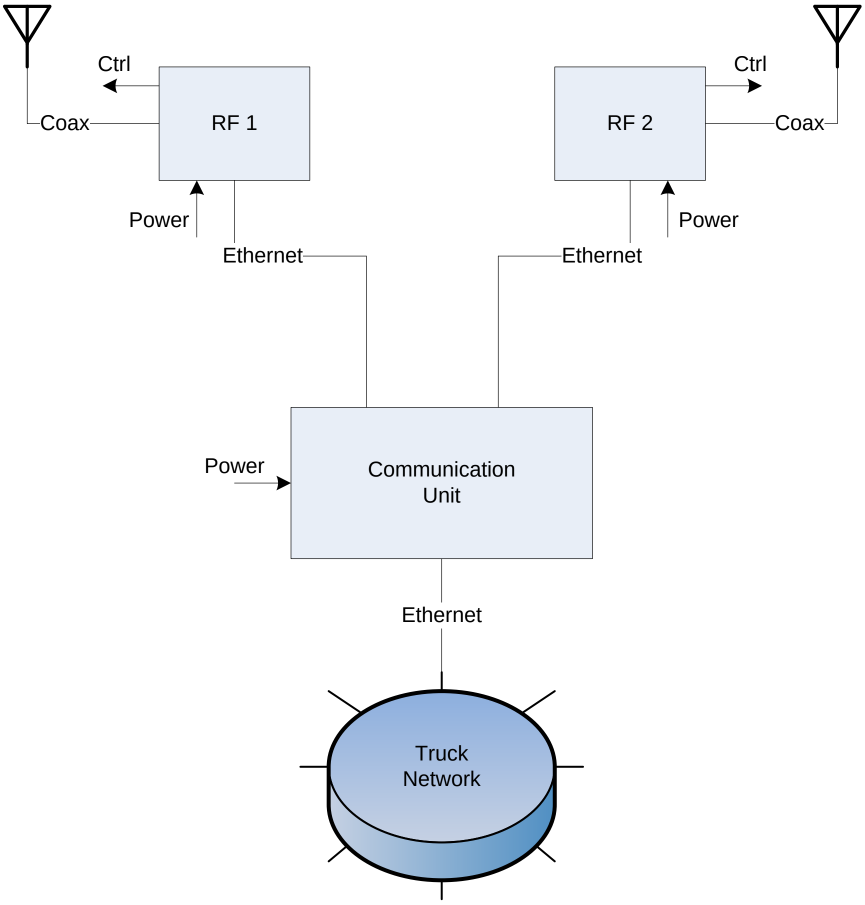

Figure 2 External Interfaces

Both RF modules are identical.

To achieve RX-diversity, the RF modules and the communication unit both are involved in the decoding process of a DSRC packet. The system then acts as a distributed diversity receiver, where the radios are connected via a digital link in contrast to the common case, where long lossy coaxial RF cables are used.

3 Logical / Functional System Structure

3.1 Overview

Let's consider one of the RF modules for a functional view. Figure 3 shows the structure of a single unit.

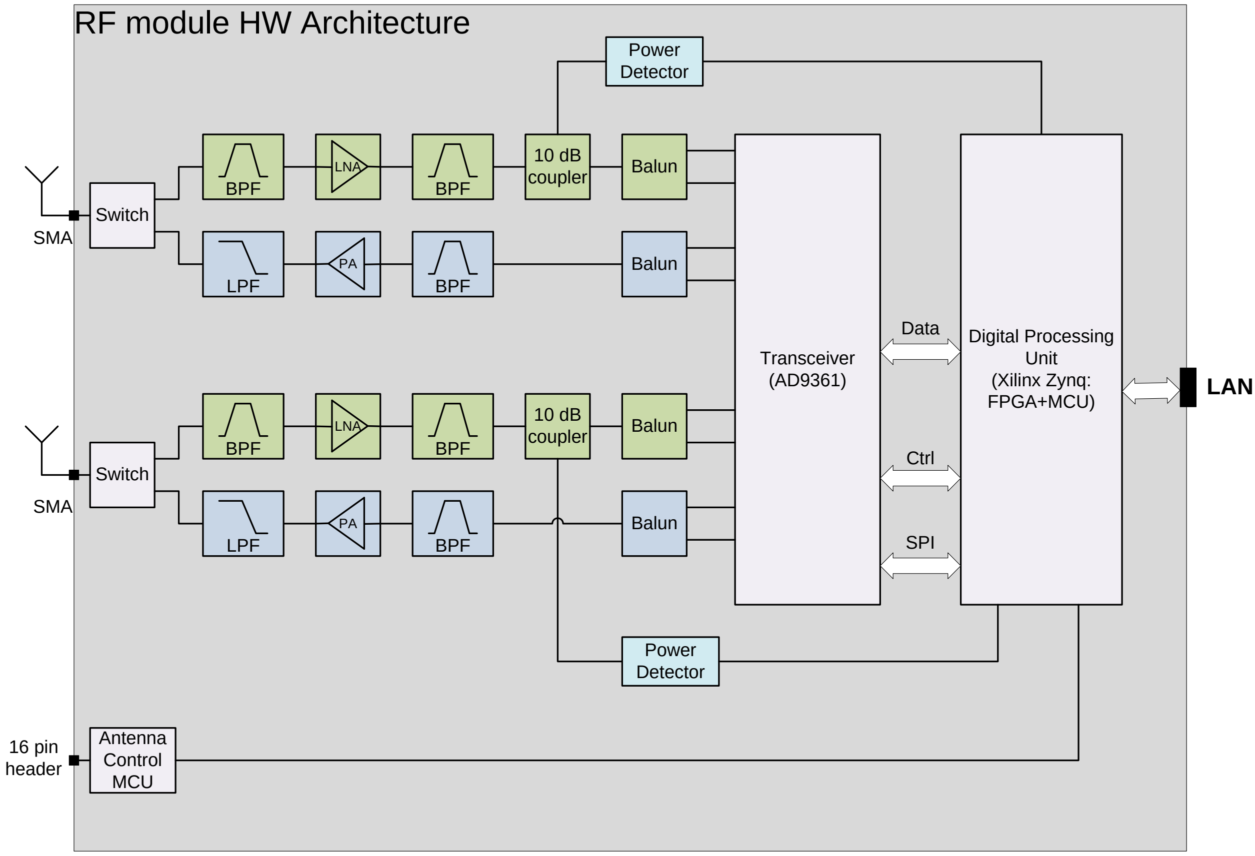

Figure 3 Logical / functional view

The frontend consists of two complete RF paths (RX and TX). Both RX and both TX chains share a local oscillator respectively. It is therefore not possible to receive two different channels at the same time. The tuning range covers 5855 MHz to 5925 MHz (channels: G5-SCH1..G5-SCH6, G5-CCH).

The second antenna port and associated transceiver is optional. In Roadart, two RF modules with one antenna each are used to create a distributed diversity receiver.

The unit is able to generate digital and/or analog control signals to perform antenna switching or beam steering.

3.2 Digital Signal Processing

The digital processing unit (Zynq) processes the raw baseband IQ samples. The end result is not the raw packet data, but an intermediate representation, which is used by the maximum ratio combining algorithm inside the communication unit.

A high level view of the proposed split of the signal chain is depicted in Figure 4:

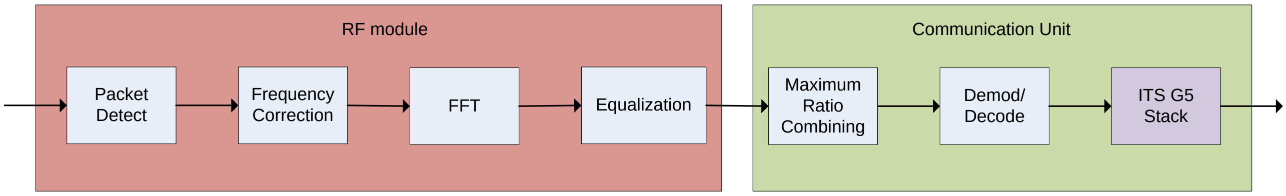

Figure 4 Signal Chain Split

The proposed split allows to implement a receive diversity algorithm entirely on the communication unit, because channel dependent effects have been dealt within the RF module. If receive diversity is employed, the communication unit would combine two data streams coming from the Equalization blocks of RF1 and RF2 (e.g. with maximum ratio combining).

The Ethernet interface between the RF module and the communication unit transports the raw baseband IQ samples (i.e. the equalised OFDM symbols without DC, guard and pilot subcarriers) and the receive signal strength indication (RSSI) for the current packet.

4 Physical System Structure

4.1 RF Module

A rendered 3D view of the RF module is presented in Figure 5. The relevant connectors are marked. The dimensions are given in Figure 7.

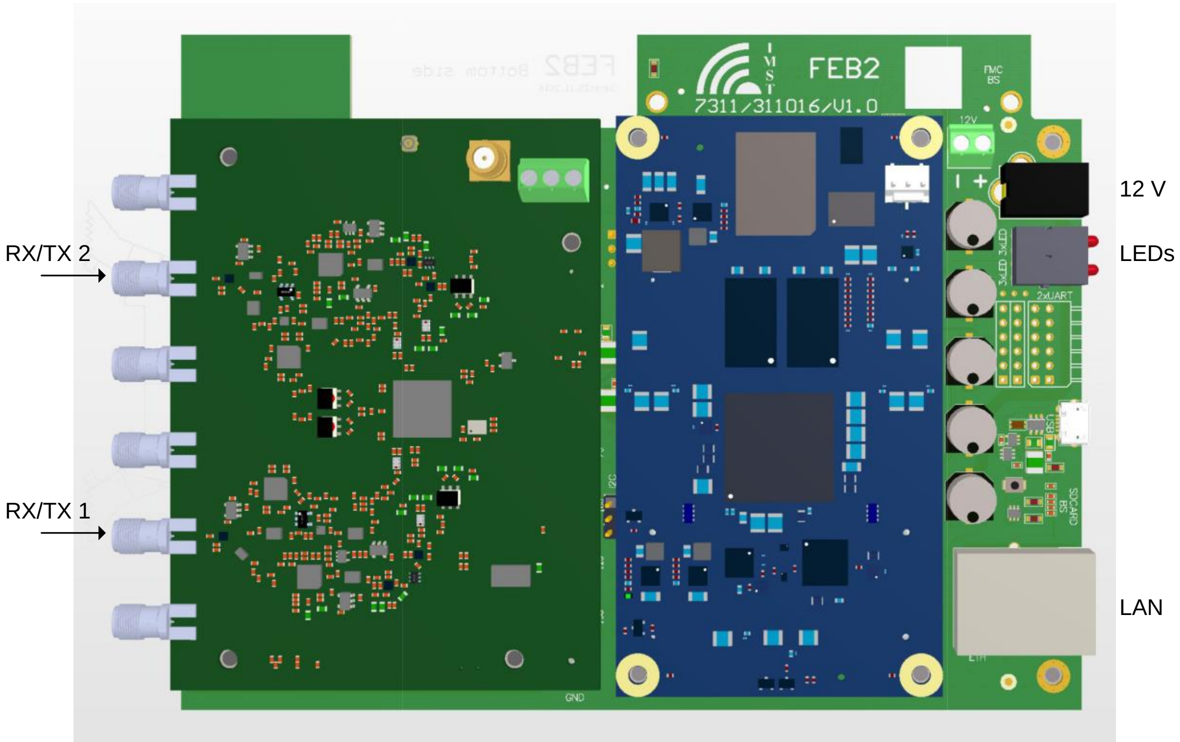

Figure 5 PCB Physical View (Top)

It is possible to place the PCB into an enclosure for a more rugged operation. Refer to Figure 6 for a suitable housing.

Figure 6 Enclosure Hammond 1455P1601

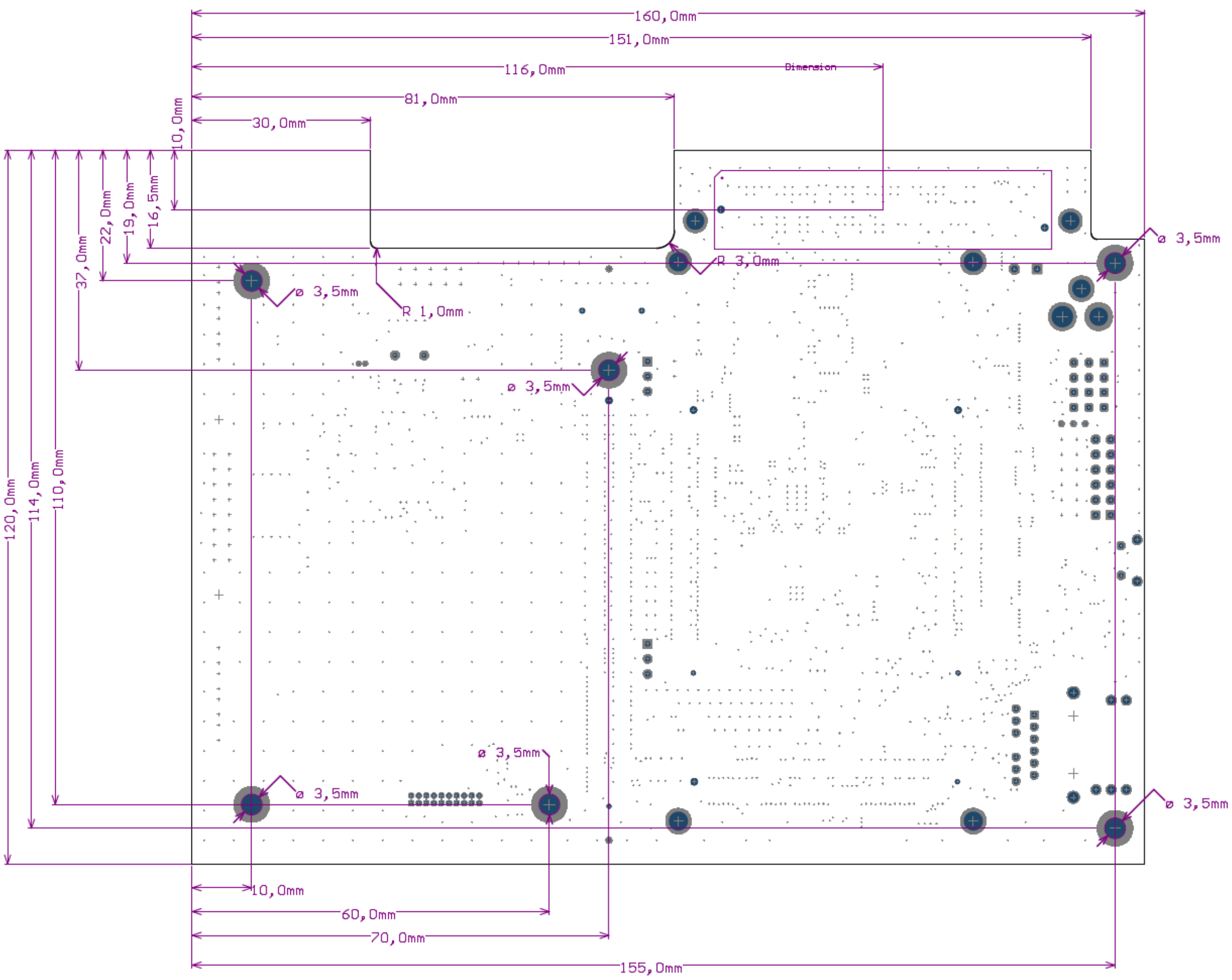

Figure 7 Dimensions

The outside dimensions of the enclosure are 160 mm x 125 mm x 30.5 mm. The SMA connectors will extend the length by some millimeters. All other connectors flush with the enclosure faces.

4.2 Communication Unit

The communication unit is a standard PC or laptop. It must be capable of processing the pre-processed packet data from the RF modules in a short time to support low latency operation.

The three required Ethernet ports can be realized with help of a standard 1 GbE switch. If strict separation of RF module and truck communication is required, a laptop with two Ethernet ports has to be used (or a VLAN capable switch).

As the operating system, Linux with realtime extensions has been chosen. This allows an easy implementation of the maximum ratio combining algorithm in user mode as a high priority process. If required, parts can be implemented as a kernel module to further reduce latencies. Linux provides complete implementations of required network stacks and infrastructure, all available as modifiable source code.

Figure 8 shows the functional view of the communication unit.

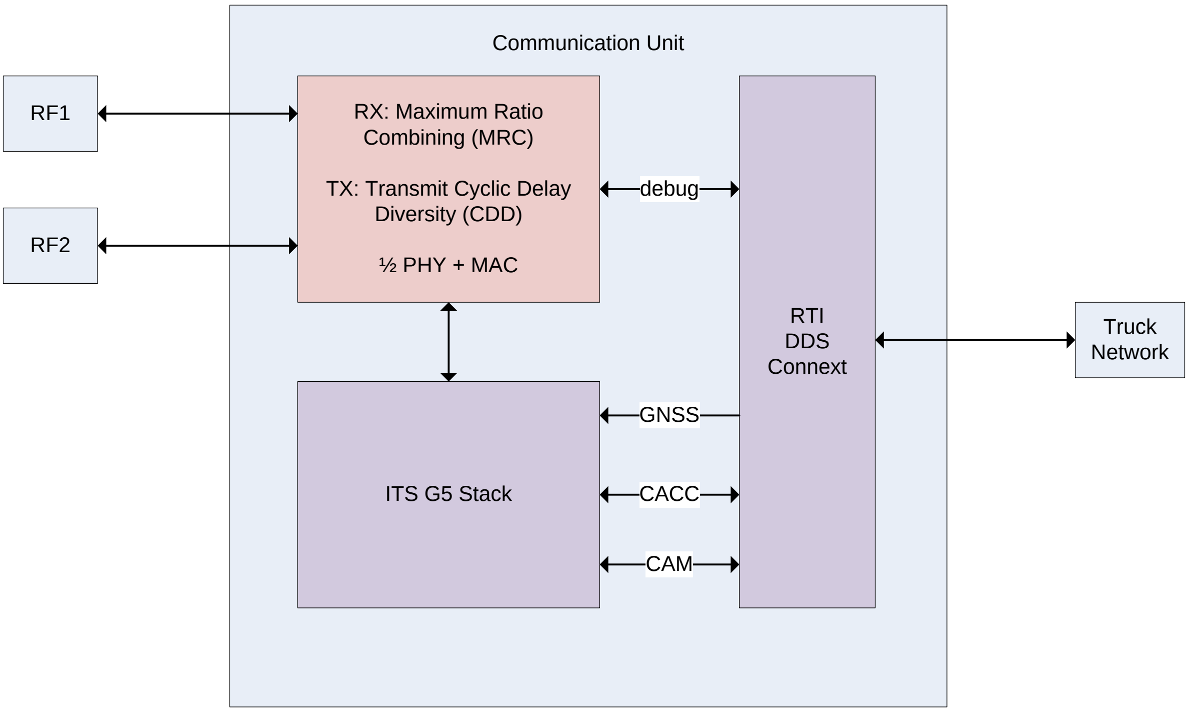

Figure 8 Communication Unit

The GNSS messages originating from the truck network are used by the ITS G5 stack to update its current position. The change in position eventually triggers the generation of CAM messages, which are transmitted over the air.

Received CAMs are delivered to the truck network via the DDS realtime protocol.

The Roadart specific (Robust-)CACC messages are handled transparently (the message is not altered in any way). Received CACCs are delivered via the DDS realtime protocol and incoming CACCs from the truck network are broadcasted over the air.

References

[1] H. Manufacturing. URL http://www.hammondmfg.com/pdf/1455P1601.pdf.