Opportunistic radio transmission in the TVWS for first responders' assistance

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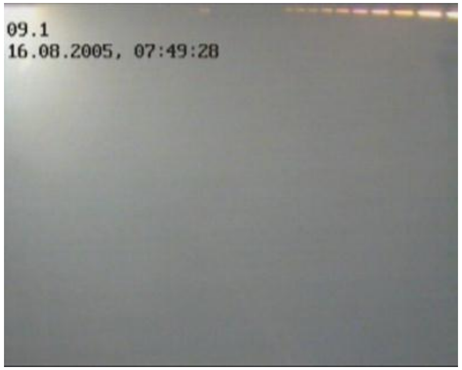
CEA-LETI

Motivation for embedded video in FRs' equipment

The nasty companion of fire: smokes

One minor event happened in the morning of 16th of August 2005 in Saint Gothard tunnel (CH)

4 seconds later



Fire services all over the world agree on the fact that <u>smokes make more casualties than fire</u>.

Most Fire Rescue operations happen in confined spaces: high temperature, smoke require fast decisions!

Communication between First Responders and crisis HQ

- **Weakness of oral report**

Oral report by radio or phone is not sufficient to give a proper account of the situation Stress and individuals' sensitivity make an oral description fairly unreliable.

- **The need for live video feeds**

Visible and Infrared live video help take appropriate decision
Type of measures implemented to fight fire and response time needed to realize actions is a determining factor in restoring the situation

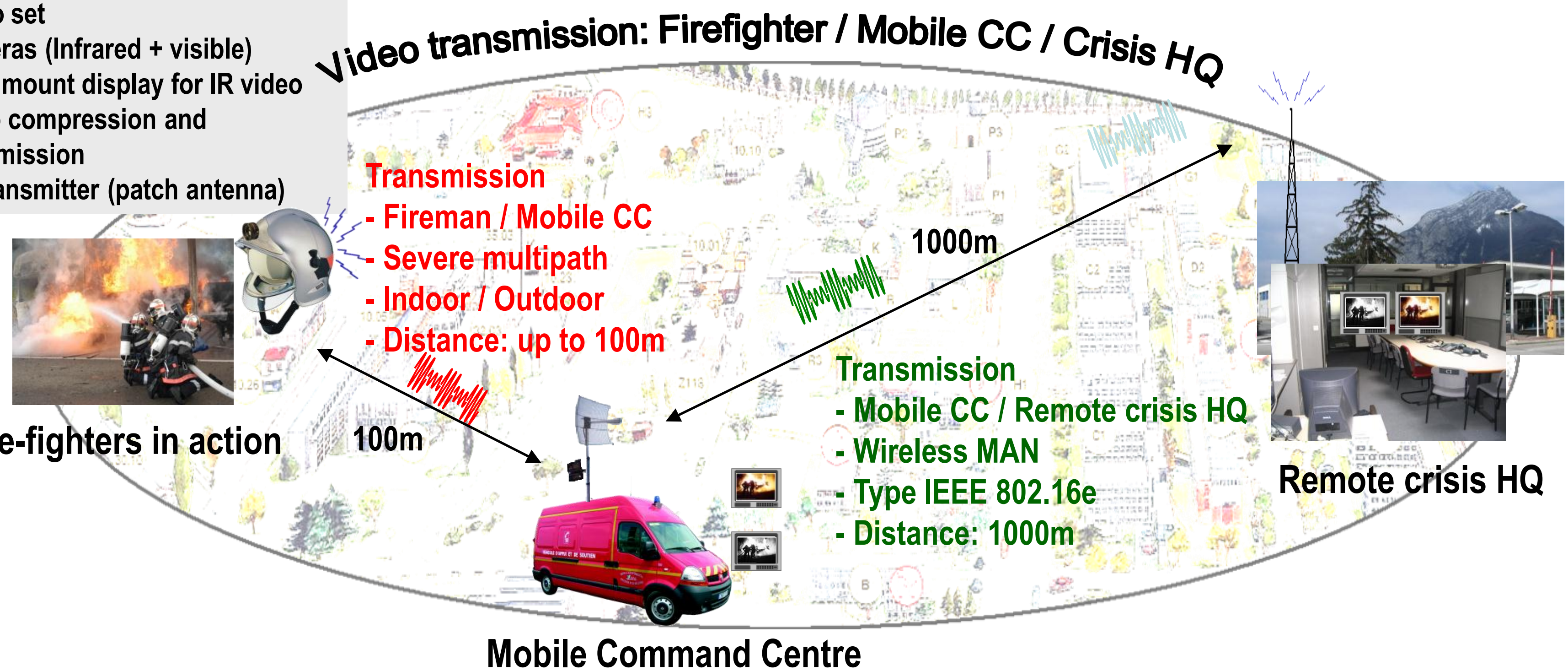
- **Embedded sensors and wireless communication**

Camera and sensors should be integrated in equipment (helmet)
The fire-fighter cannot carry any device in his hands
Information is transmitted to management through wireless communication

Robust Video transmission from first responders to remote crisis management HQ via mobile Command Centre

CEA's technology: communicate with crisis management in emergency situation

First responders' equipment
Audio set
Cameras (Infrared + visible)
Head mount display for IR video
Video compression and transmission
RF transmitter (patch antenna)



Opportunistic transmission in TVWS

Transmission over Wireless MAN

Environment of the First Responders

Harsh Environment

Strong Requirements from the Usage

- Weight
- Antenna fitted on Helmet
  - Limited power
  - Small size (low / no gain)
  - Body obstruction
- Battery has to be carried
  - Limited power
  - Limited autonomy
  - Weight
- Sensors, display and telecom integration
  - Robustness & reliable
  - Easy to use

Reinforced concrete wall

Antenna and Transceiver developed at CEA - LETI

Steel framework

Difficult Propagation Conditions

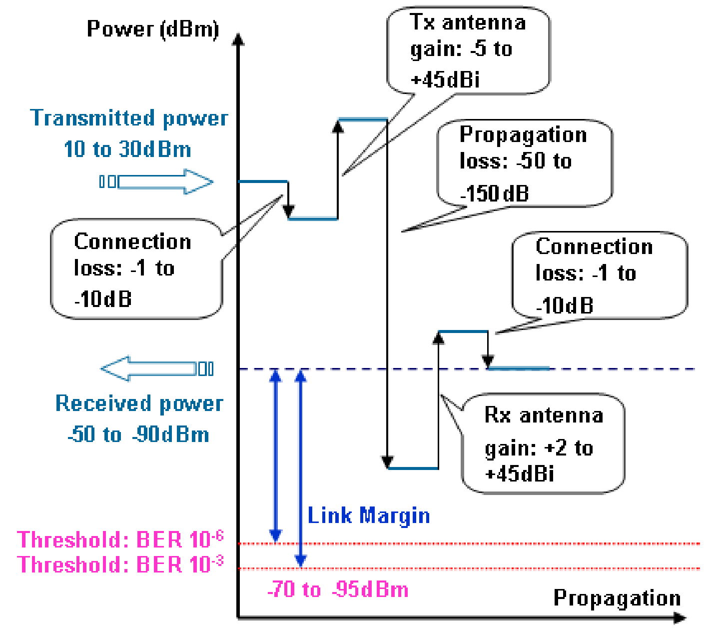
- Indoor or dense urban transmission
  - Multipath propagation
  - Frequency fading
- L.O.S. almost never exists
- De-Polarization of RF
- Building infrastructure
  - Steel structures, reinforced concrete
  - Frequency selective

Opportunistic use of TVWS

- Propagation in the lower part of UHF band (300 to 800Mhz) is very favorable in the FRs' environments (indoor and dense urban).
- Spectrum allocated to the TV is not fully used.
  Most Locations provide White Space for local usage
  Transmitter must take the near-far problem in the vicinity of TV receivers distant from the TV relay

Opportunistic transmission in TV White Spaces

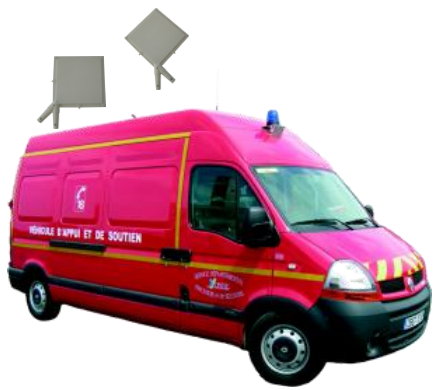
RF band	Frequency	Channel	GRENOBLE Tour sans venin	GRENOBLE Chamrousse	AUXERRE Molesme
V	602	37	DVB-T - R1	DVB-T - R1	TF1
V	610	38			
V	618	39			
V	626				
V	634				
V	642				
V	650	43			
V	658	44			
V	666	45			
V	674	46			
V	682	47			
V	690	48			
V	698	49			M6
V	706	50		France 2	



Opportunist Transmission in the TVWS

RF Receiver

- **Spatial diversity:** 2 antennas spaced by d>λ
- **Polarization diversity:** antenna dual-polarized

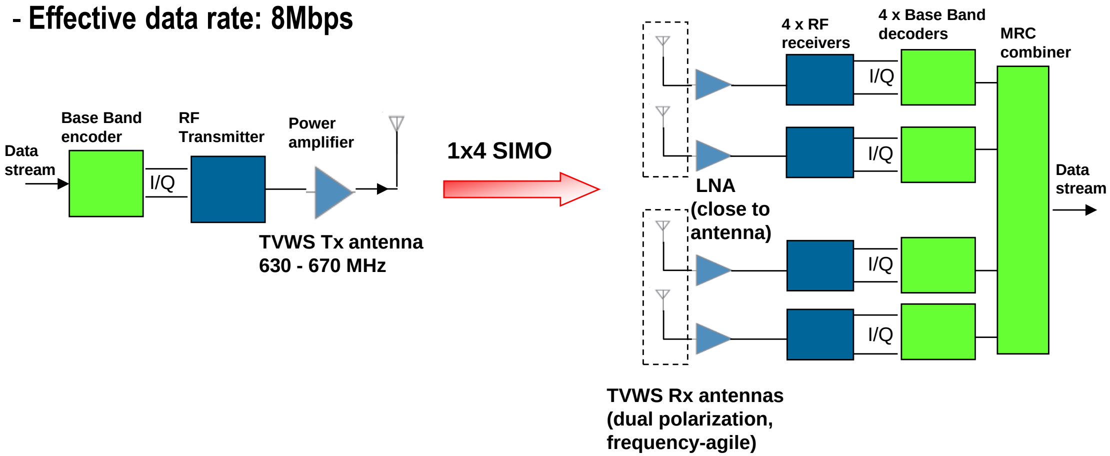


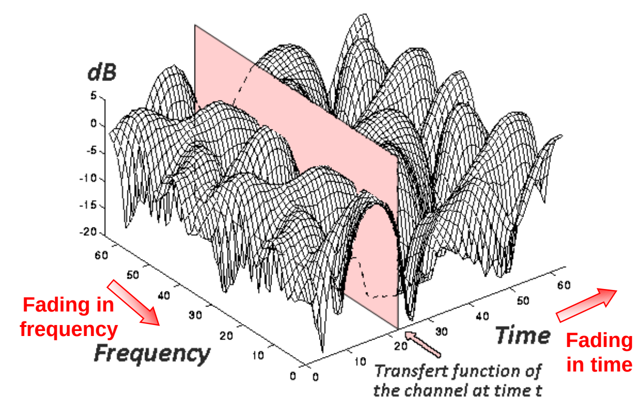
FR Environment
Requires SIMO Architecture for QoS
- **Multipath Environment**
- **Loss of polarization**
- **Doppler and Time varying Channel**
- **Fading in Time and Frequency**

<u>Antenna</u>
- fo = 650MHz (BW: 35MHz)
- Gain: 1.5dB (Omni)

<u>RF Tx</u>
- Frequency agile: 610-690MHz
- BW: 12MHz
- Electrical power = 28dBm

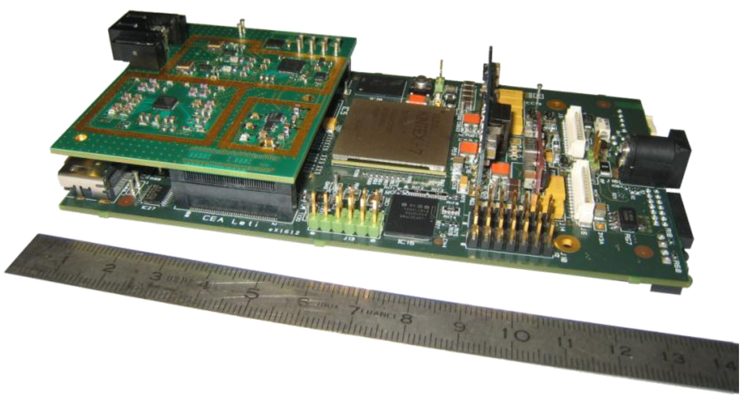
<u>Baseband</u>
- COFDM 1024 sub-carriers
- 12kHz spaced
- IQ modulation
- Effective data rate: 8Mbps





Transmitter Implementation

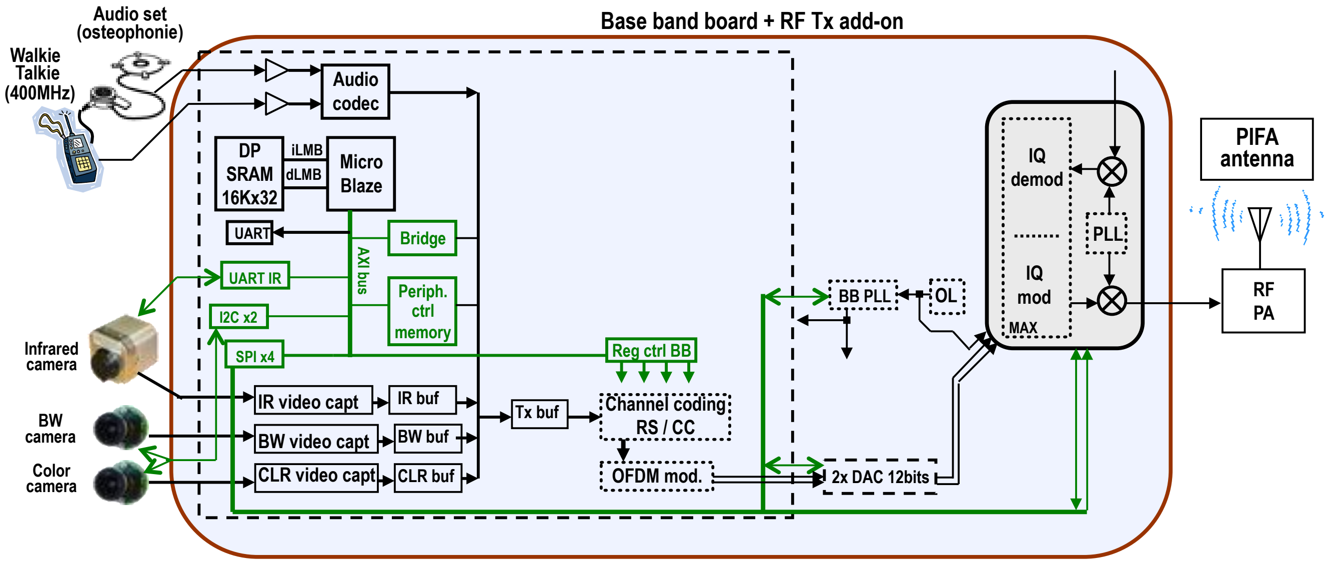
Digital Baseband
- Baseband build around Xilinx Kintex 7 (FPGA)
  - Digital Audio/Video Capture and Framing
  - Channel Coding (Forward Error Correction)
  - OFDM Modulation



RF Transmission
- Direct conversion, zero-IF, baseband to WiMAX RF
- I/Q modulation (adjustable BW from 5 to 20MHz)
- Frequency agile (470-770MHz)
- Power Amplifier 600mW (1dB compression point)
- PIFA Antenna (small form factor, low SAR*)

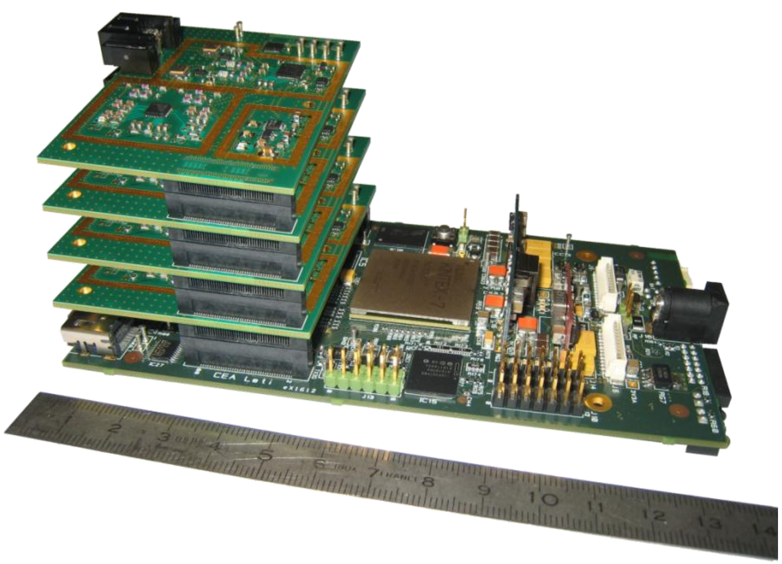
* Specific Absorption Rate

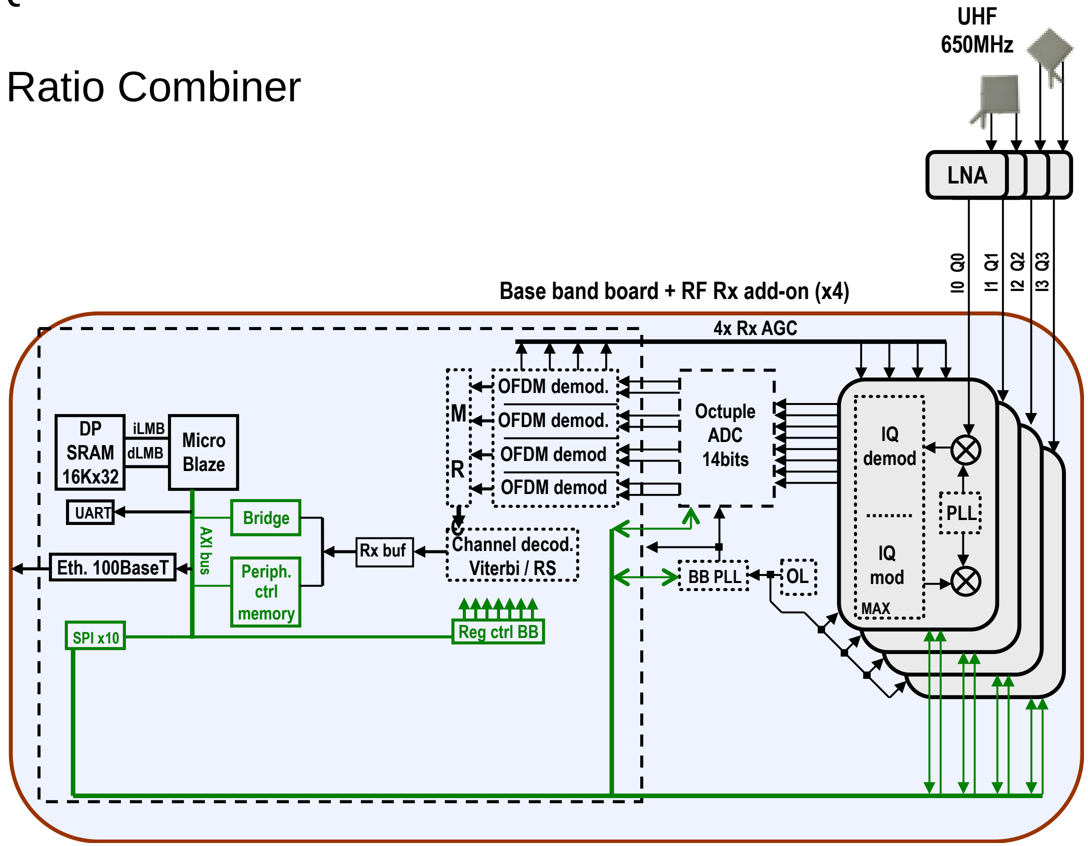
Embedded modules
Li-ion battery powered



Receiver Implementation

- 4 independent RF receivers
  - 2 antennas with dual polarization
    - Polarization and Spatial Diversity
  - 4 LNA at antenna level (remote DC powered)
  - 4 RF Front End Receivers and I/Q demodulations
- 4 I/Q 14bit-ADC
- 4 OFDM demodulation and Maximum Ratio Combiner
- Channel decoding (FEC)
- 100 BASE-T Ethernet

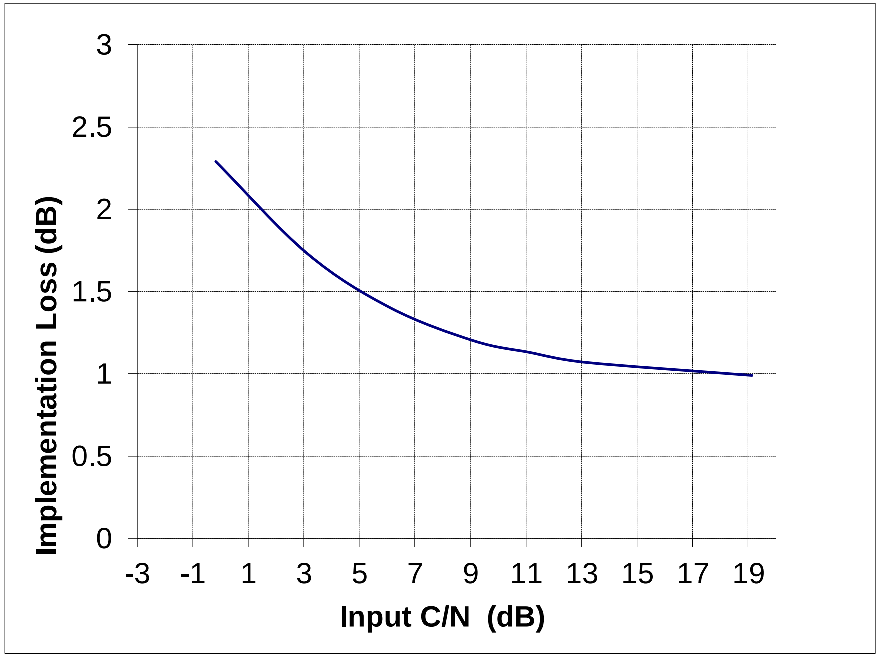




Baseband Implementation

1D Channel estimation / Equalization

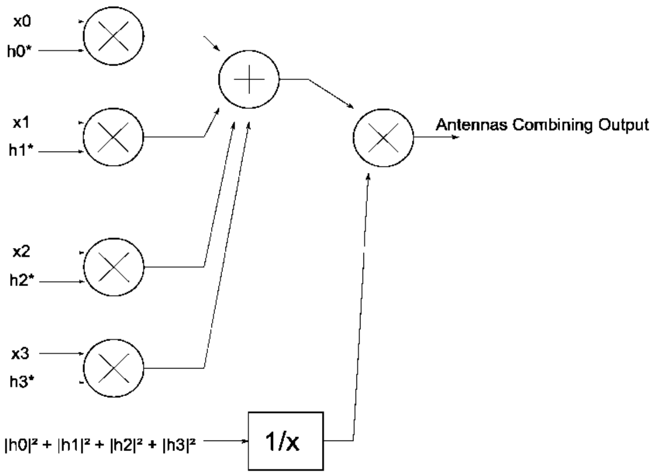
- Estimate Performance of equalization including implementation
- AWGN channel
- OFDM Pilot tones are evenly distributed in the frequency domain every 8 tones (12kHz*8 = 96kHz) and every OFDM symbol in the time domain.



Antenna combining

Implementation

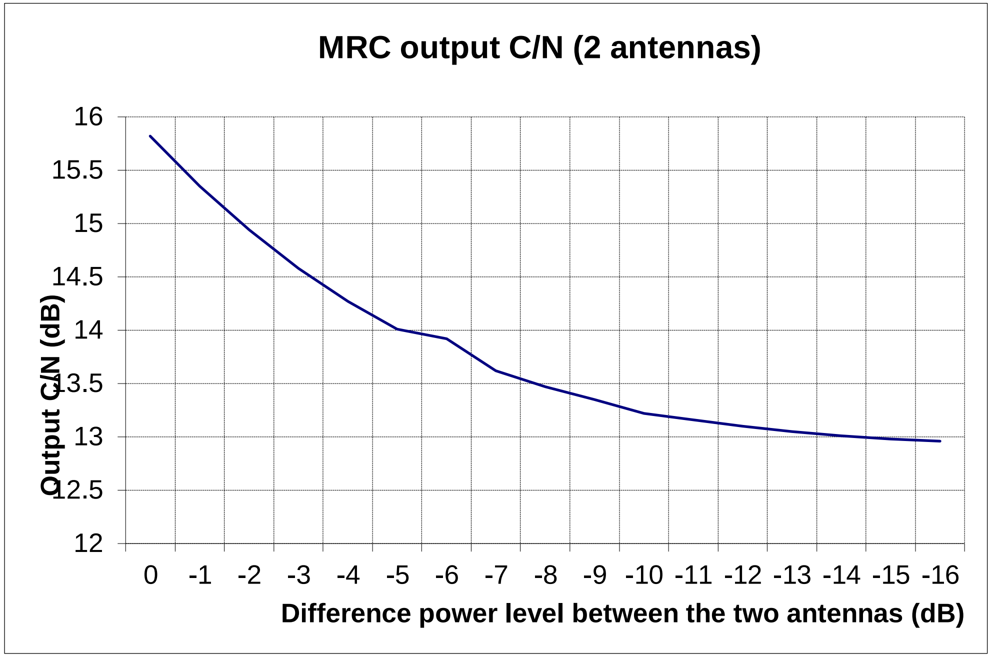
- Increase the weight of the best antenna to decode the considered sub-carrier → use <u>the channel estimation</u> profile.
- Take into account the average power of each antenna → use the <u>gain control</u> information.
- The decoded subcarrier is $y(k) = \frac{\sum_{i=0}^{3} \alpha_i \cdot \hat{h}_i^*(k) \cdot y_i(k)}{\sum_{i=0}^{3} \alpha_i \cdot \left\| \hat{h}_i^*(k) \right\|^2}$ where:
  - $y_i(k)$ the k^{th} received subcarrier of the i^{th} antenna,
  - $\hat{h}_i^*(k)$ the channel estimation coefficient of the k^{th} subcarrier of the i^{th} antenna,
  - g_i the gain to be applied to the i^{th} antenna,
  - $\alpha_i = g_i / min\{g_i\}$.



Antenna Combining

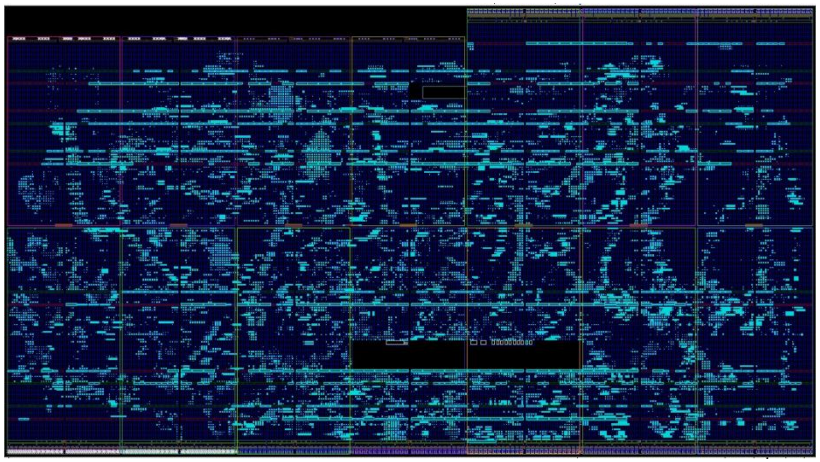
Performance

- Performance of the best antenna for the considered sub-channel.
- Test of 2 antennas with different received power under AWGN channel :



Cost of Baseband Implementation

- Synthesis and Mapping Report
  - Xilinx Kintex 7 (xc7k325t)
  - Around 30% of Receiver occupied



RX	**Number of occupied Slices:** **Number of RAMB36E1/FIFO36E1s:** **Number of RAMB18E1/FIFO18E1s:** **Number of DSP48E1s:**	**15,767 out of 50,950 (30%)** **192 out of 445 (43 %)** **103 out of 890 (11 %)** **506 out of 840 (60 %)**
TX	Number of occupied Slices: Number of RAMB36E1/FIFO36E1s: Number of RAMB18E1/FIFO18E1s: Number of DSP48E1s:	1,150 out of 50,950 (2%) 22 out of 445 (4%) 9 out of 890 (1%) 16 out of 840 (1%)

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Thank You!