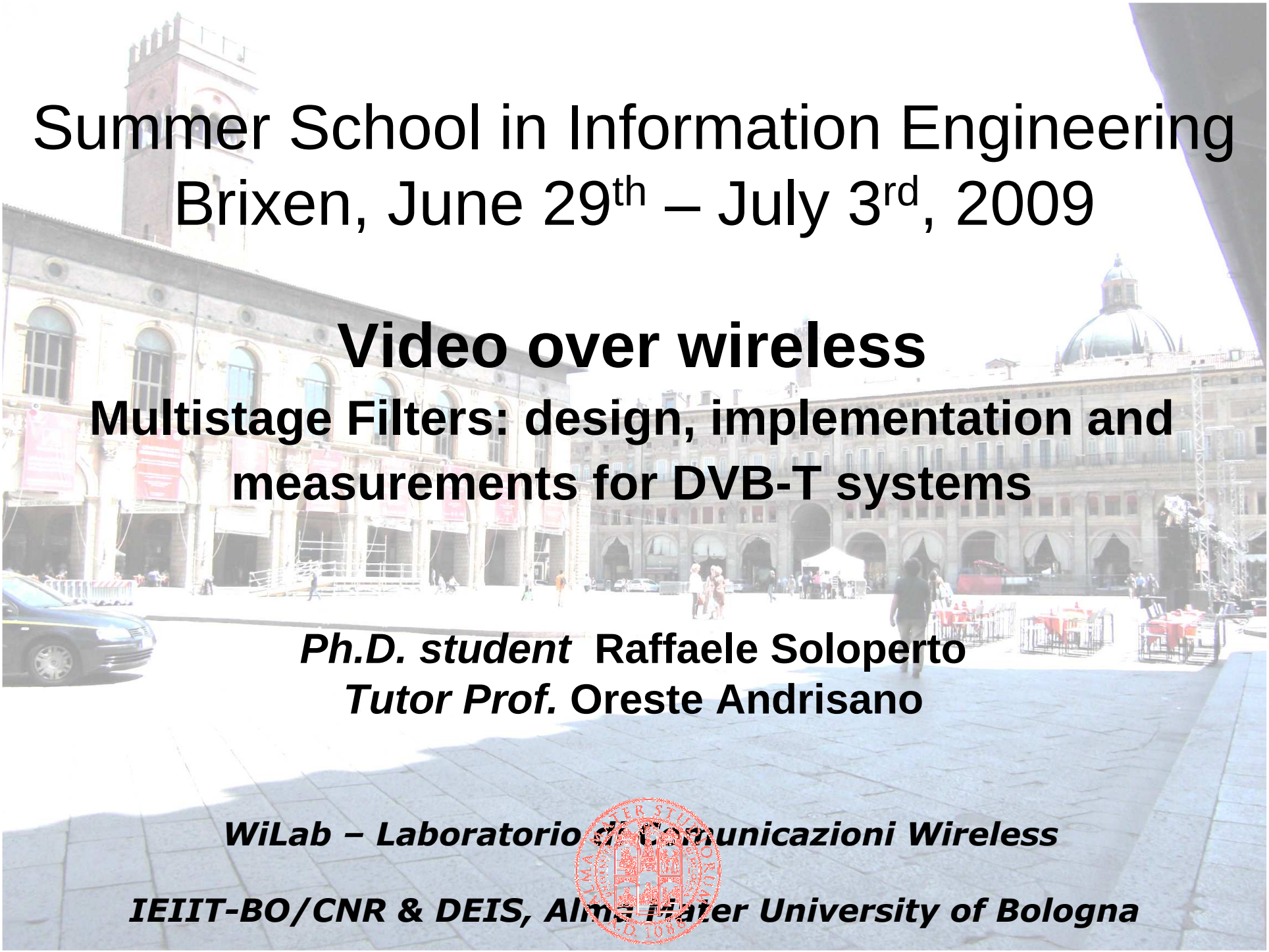


Summer School in Information Engineering
Brixen, June 29th – July 3rd, 2009

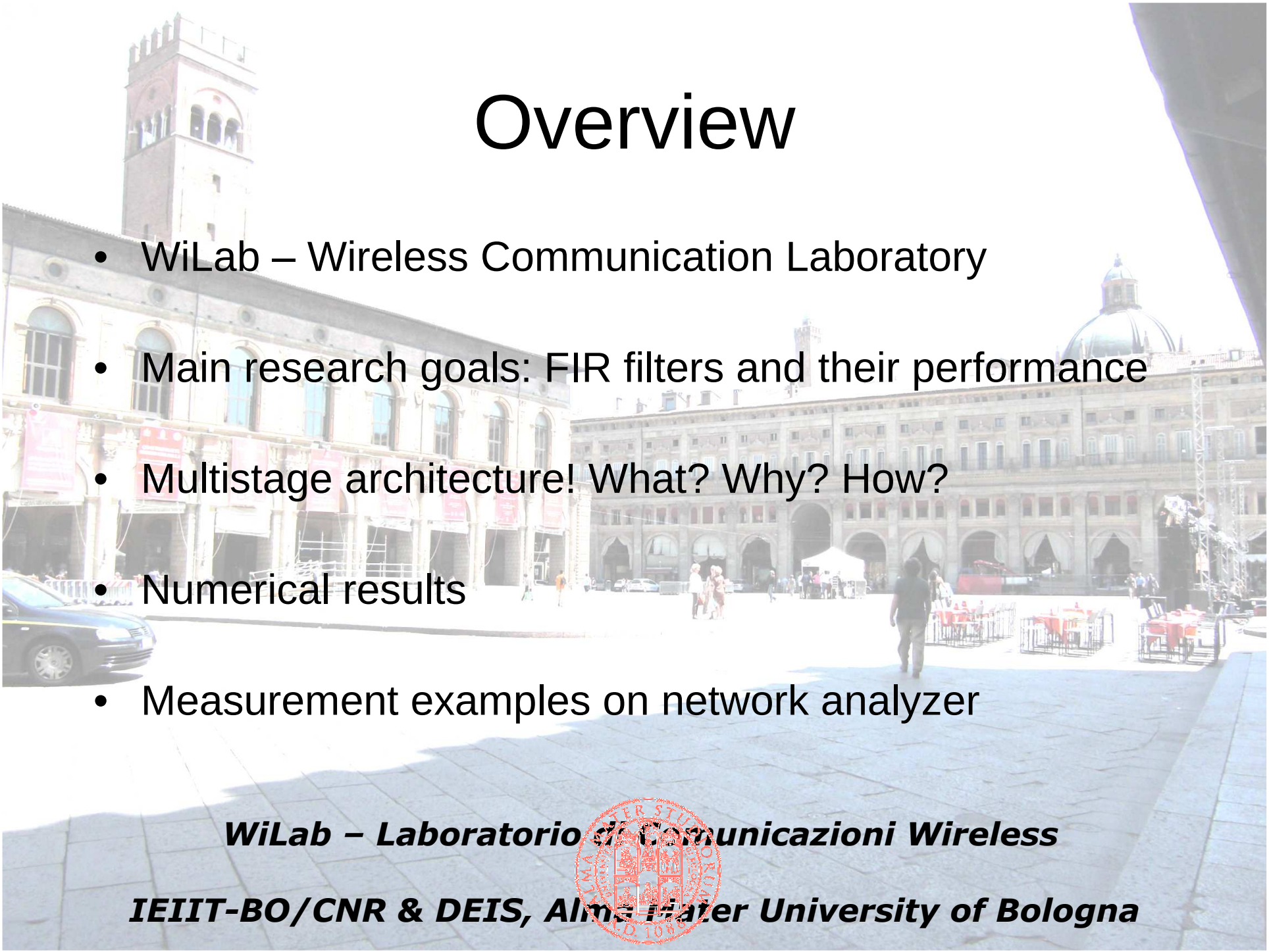
Video over wireless

Multistage Filters: design, implementation and measurements for DVB-T systems

Ph.D. student **Raffaele Soloperto**
Tutor Prof. **Oreste Andrisano**

WiLab – Laboratorio di Comunicazioni Wireless

IEIIT-BO/CNR & DEIS, Alma Mater University of Bologna



Overview

- WiLab – Wireless Communication Laboratory
- Main research goals: FIR filters and their performance
- Multistage architecture! What? Why? How?
- Numerical results
- Measurement examples on network analyzer

WiLab – Laboratorio di Comunicazioni Wireless

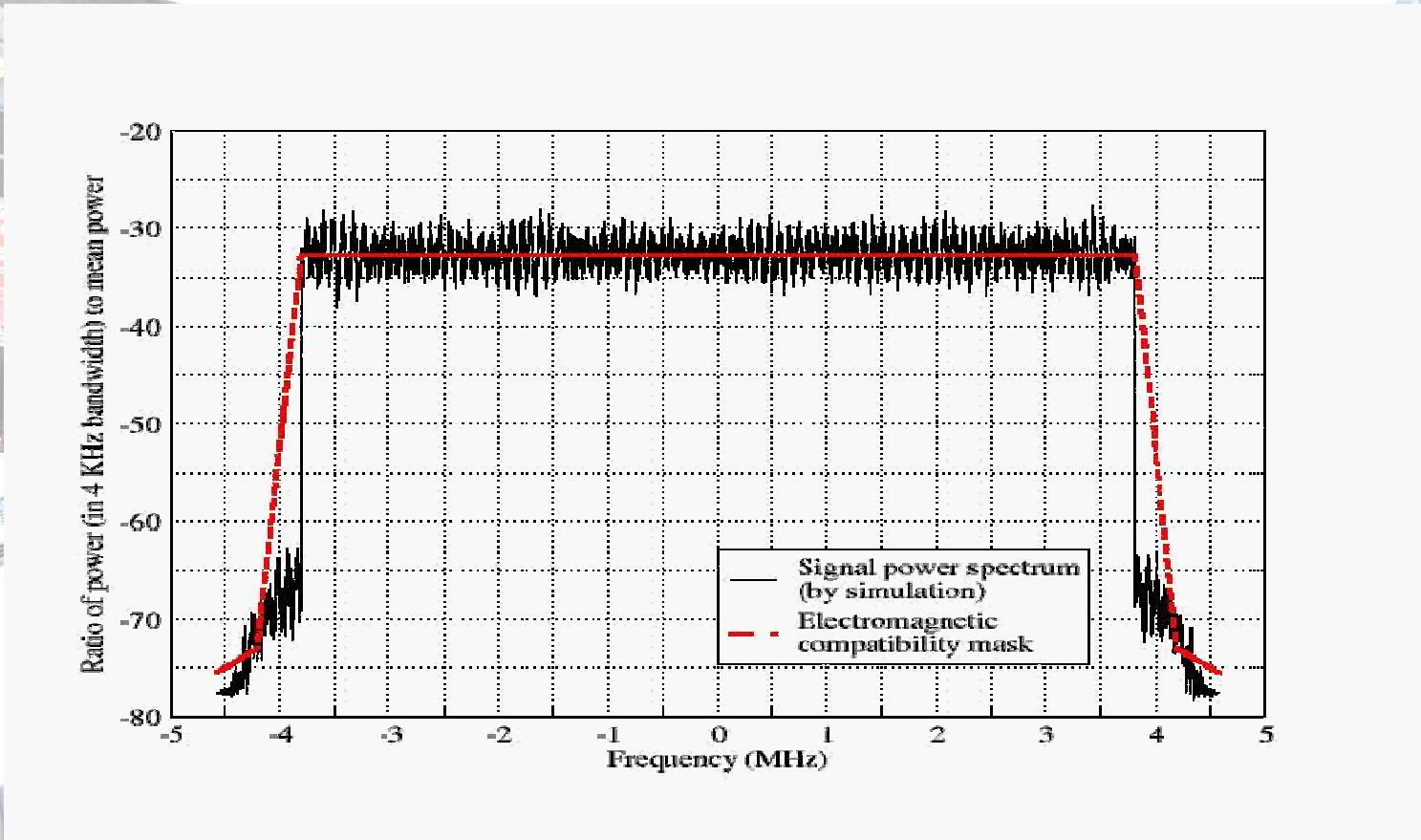
www.wilab.org

WiLab – Laboratori

IEIIT-BO/CNR & DEIS, Alma Mater University of Bologna

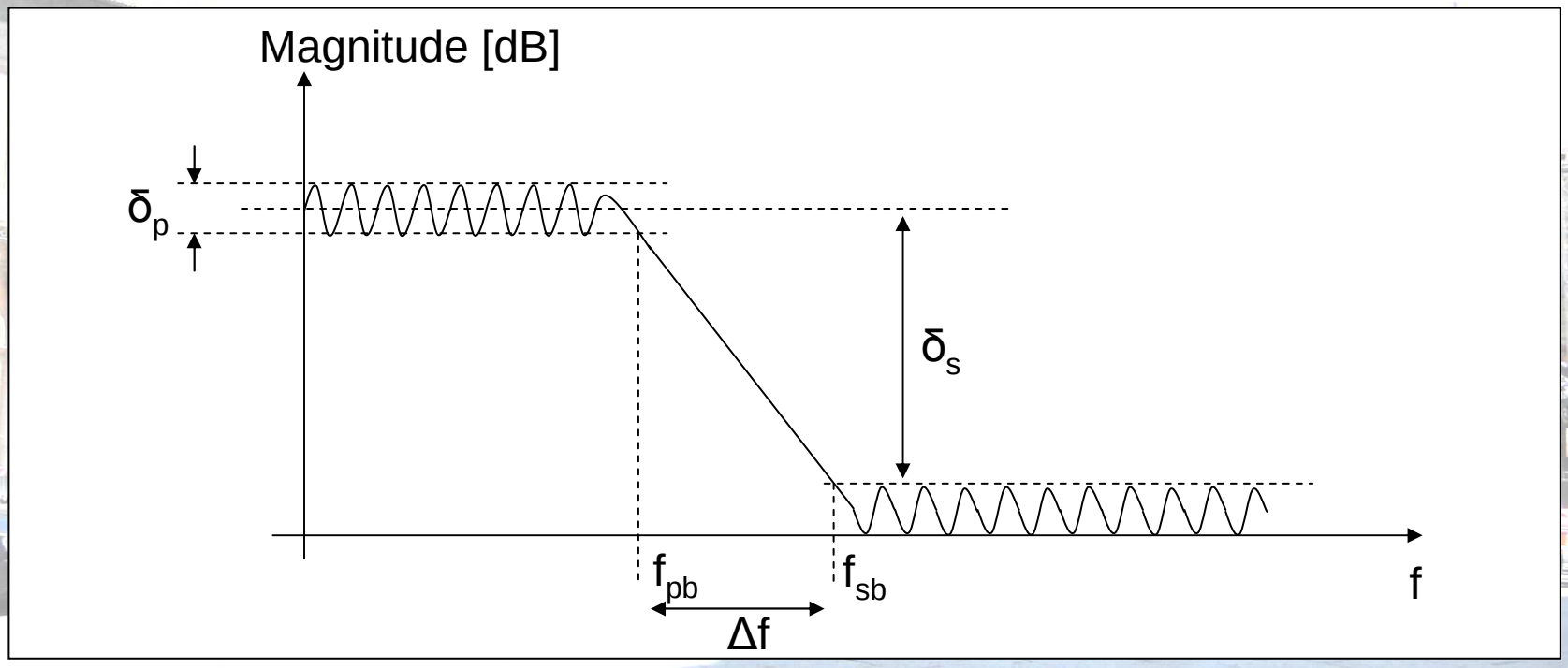
Main research goals

Finite Impulse Response (FIR) for DVB-T/H modulators and repeaters:



Project and design: How? What designer need?

Amplitude characteristic:

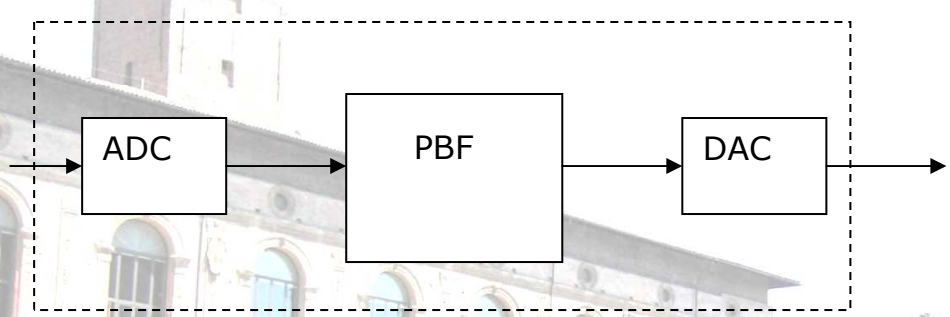


Group Delay [GD] performance is not clearly always reported on requirements plain!

Related to DVB-T system, designer has to consider it

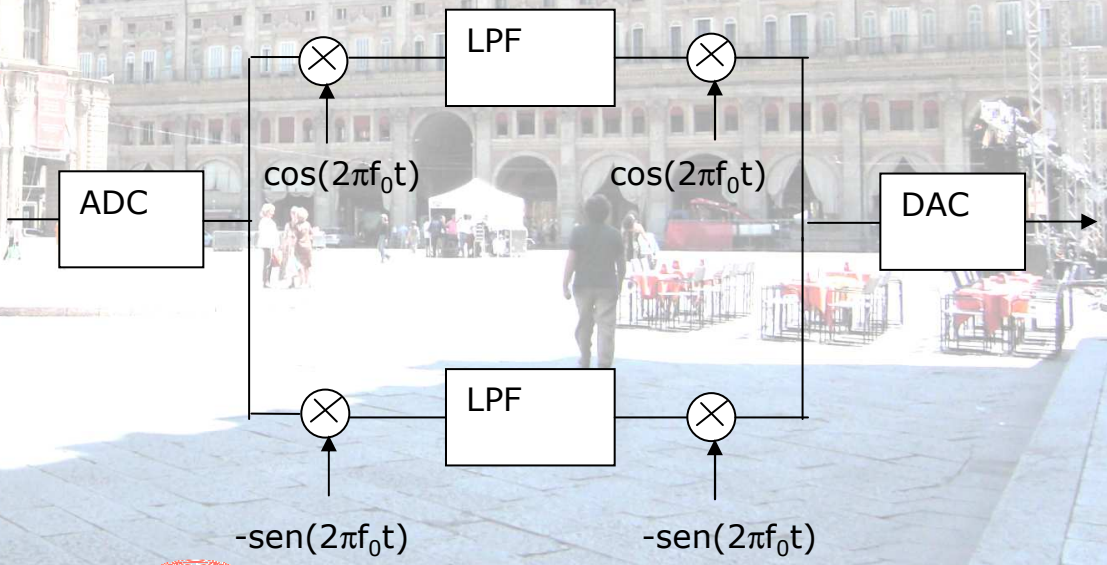
→ strong constraint!

Pass band signal: possible filtering architecture



Band Pass Solution

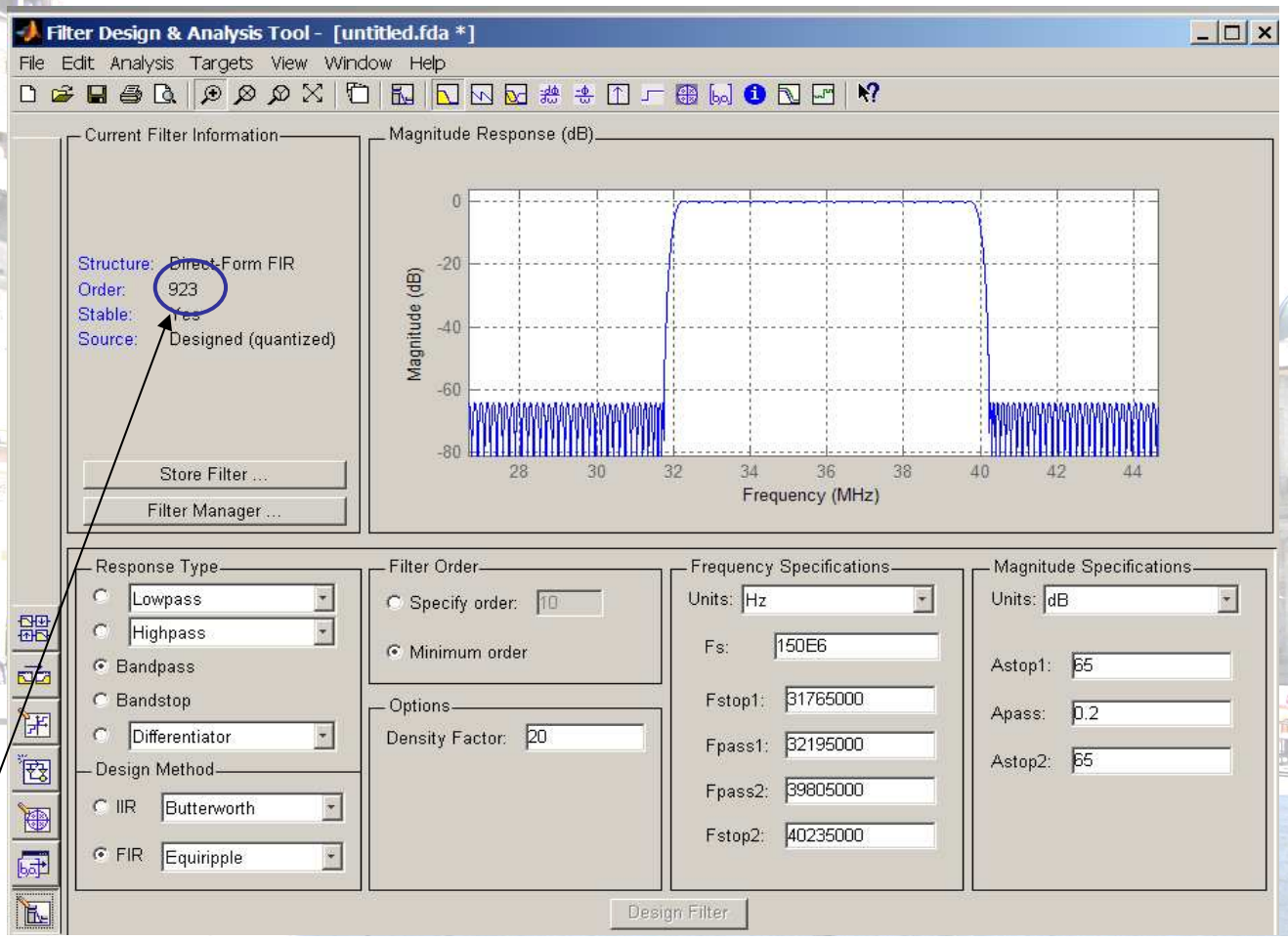
Low Pass Solution



WiLab – Laboratorio di Comunicazioni Wireless

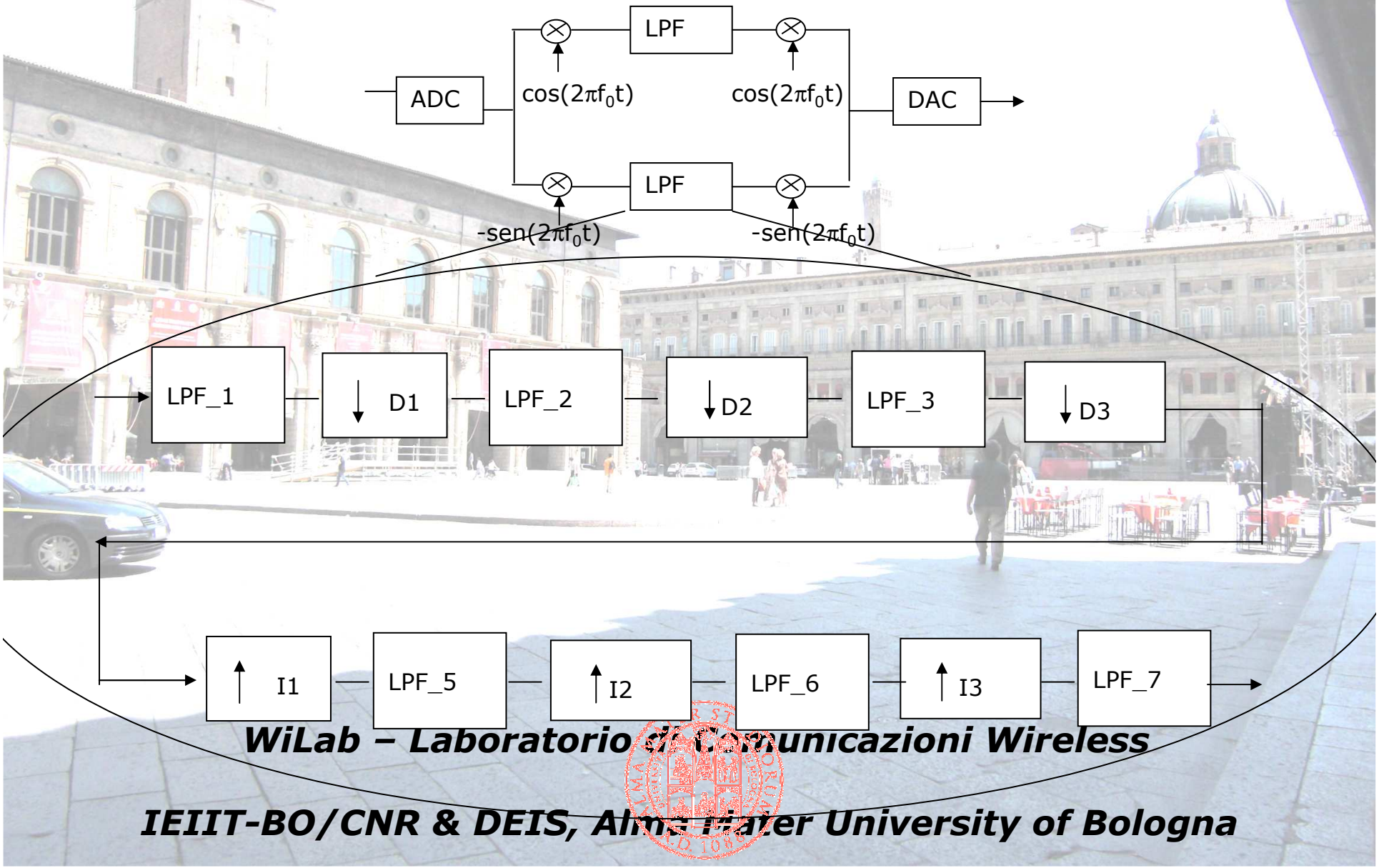
IEIIT-BO/CNR & DEIS, Alma Mater University of Bologna

Pass Band Solution



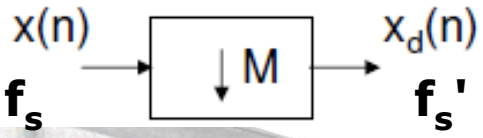
924 taps + Interpolator filter (move from fs=150Ms/s to fs=300Ms/s)

Multi-stage filters: classic architecture



Decimation basics

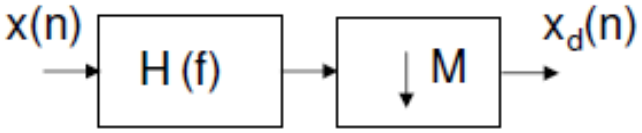
Downsampler



$f_s' = f_s / M$

Problem: Periodic spectral repetition closer than x(n)

Decimator



Solution: A FIR filter before to avoid aliasing!

Multistage Decimator

$M = M_1 M_2 \cdots M_I$

WiLab – Laborat… …cazioni Wireless

IEIIT-BO/CNR & DEIS, Alma Mater University of Bologna

Multistage filters

This chain permits to minimize number of taps (and then the area occupied on board) for strong requirements, but…

GROUP DELAY IS COMPLETELY FORGOTTEN!!

I: # di stadi ⇧ **N: # di prese ⇩** **Group Delay ⇧**

$$\tau_g = \frac{1}{f_s} \sum_{i=1}^{I} \frac{N_i - 1}{2} \prod_{k=1}^{i} M_{k-1}$$

Group Delay formula

$$N \cong \frac{-20log_{10}[\sqrt{\delta_p \delta_s}] - 13}{14.6 \Delta f} f_s + 1$$

Number of Taps (REMEZ approssimation)

WiLab – Laboratorio di Comunicazioni Wireless

IEIIT-BO/CNR & DEIS, Alma Mater University of Bologna

Decimation factor: which is the right order?

$M = M_1 M_2 \cdots M_I$

We derive this formula to analyze which is the right order for decimation factor:

$$\widehat{\tau}_g \cong A(I)\left[\sum_{i=1}^{I-1}\frac{1}{\frac{f_{s_i}}{M_i}-F}+\frac{1}{\Delta f}\right]$$
$$\cong \frac{A(I)}{\Delta f}+\frac{A(I)}{\frac{f_s}{M_1}-F}+\frac{A(I)}{\frac{f_s}{M_1 M_2}-F}+..+\frac{A(I)}{\frac{f_s}{M_1 M_2 \cdots M_{I-1}}-F}$$

Group Delay Minimization Criteria:

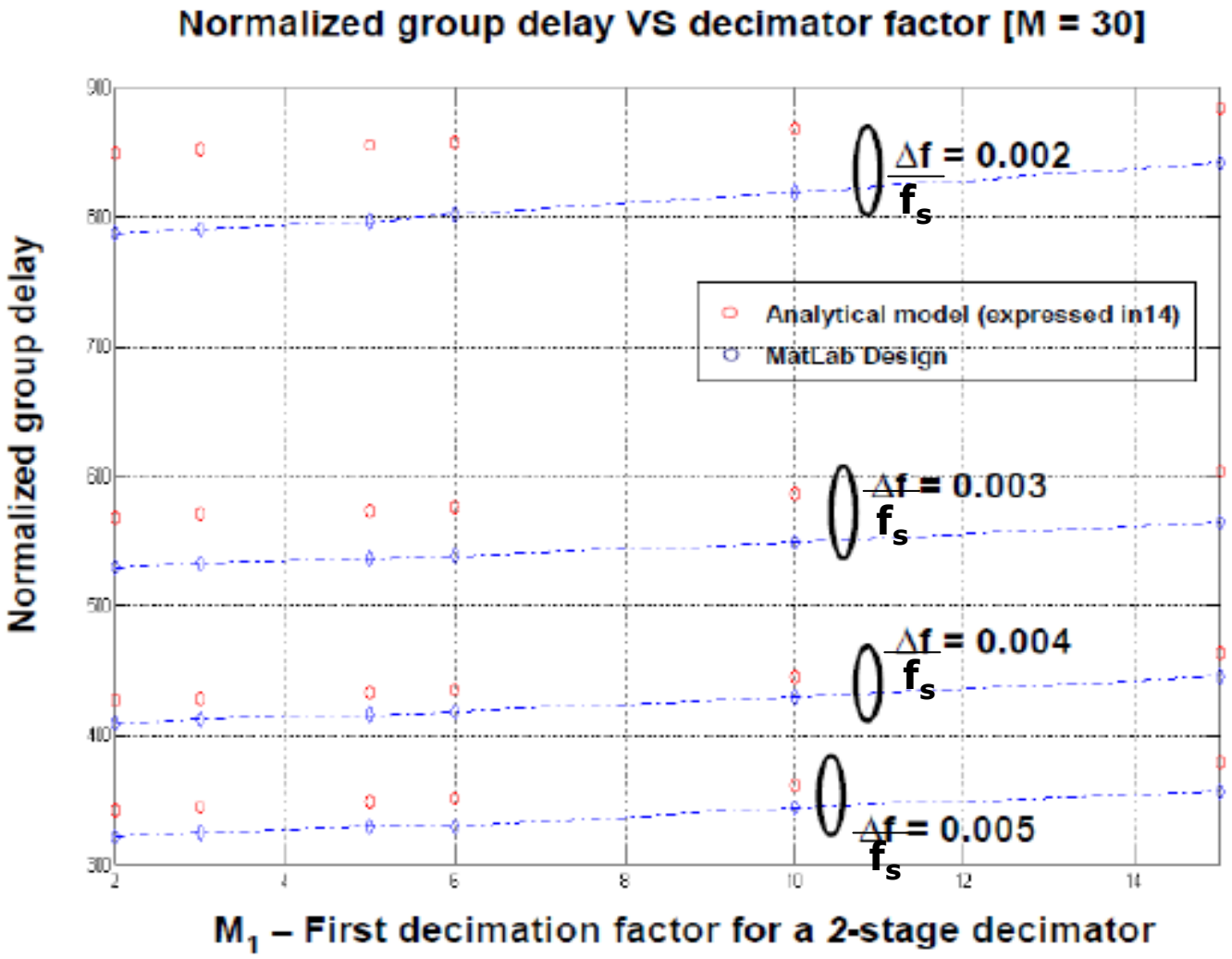
$$M_1^{(min)} \leq M_2^{(min)} \leq \ldots \leq M_{I-1}^{(min)} \leq M_I^{(max)}$$

$$M_I = \frac{M}{\prod_{i=1}^{I-1} M_i^{(min)}} = M_I^{(max)}$$

WiLab – Laboratorio di Comunicazioni Wireless

IEIIT-BO/CNR & DEIS, Alma Mater University of Bologna

Normalized Group Delay vs. First Decimation Factor



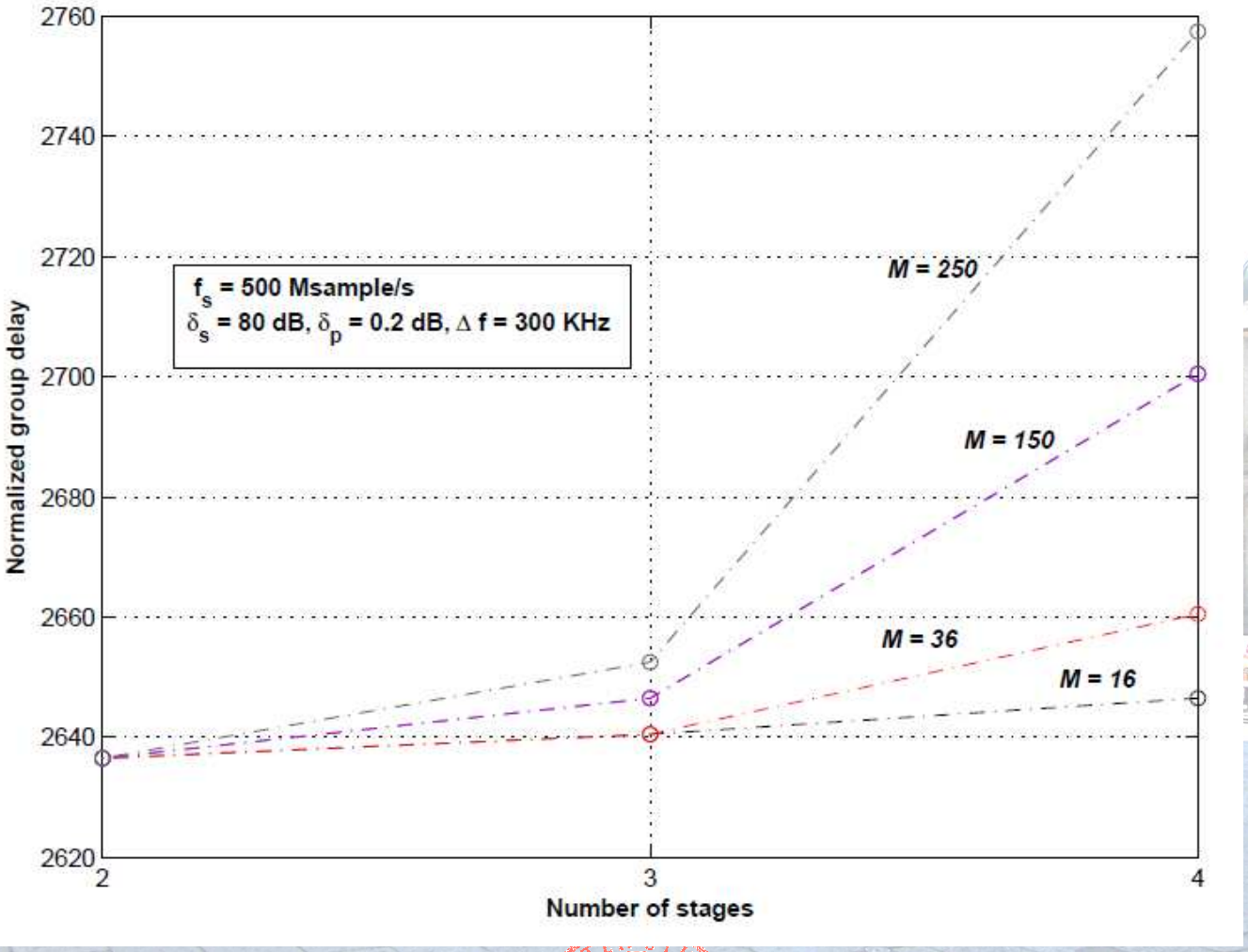
Normalized Group Delay vs. First and Second Decimation Factor

Decimation Factor M = 36

Number of stage I = 3

M_2 \ M_1	1	2	3	4	5	6	7	8	9
1									
2		458.5	465.5			482.5			494.5
3		464.0	474.5	483.5		495.5			
4			485.0						
5									
6		485.5	500.5						
7									
8									
9		503.5							

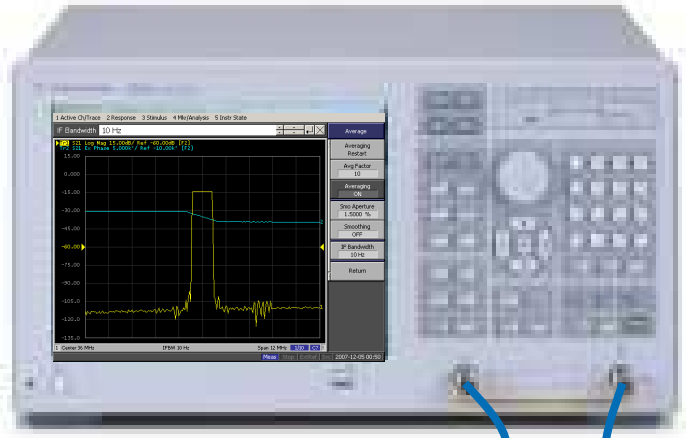
Group Delay vs. Number of stage



IF Filtering: characterization through network analyzer

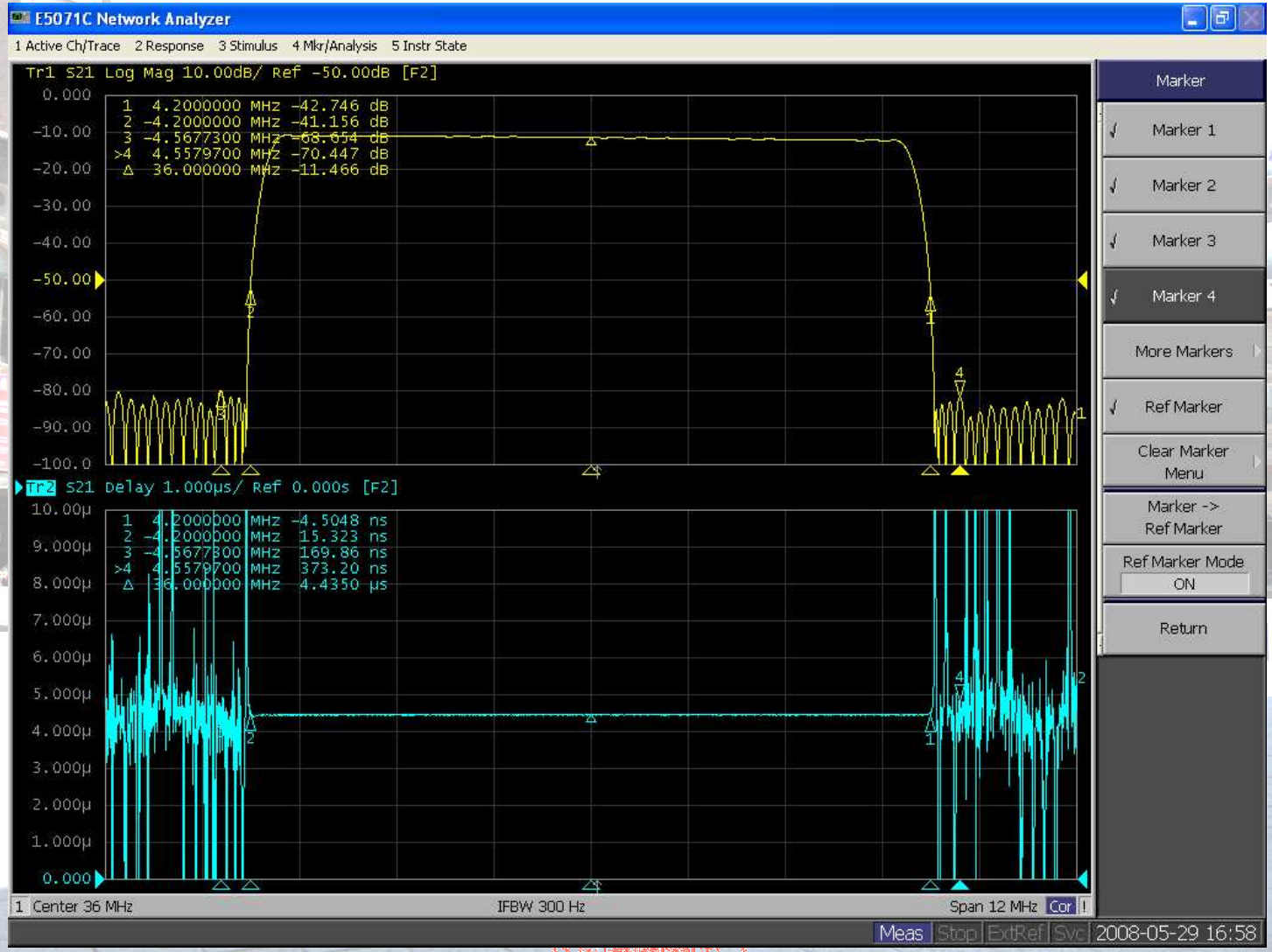
Network Analyzer

ENA - Agilent

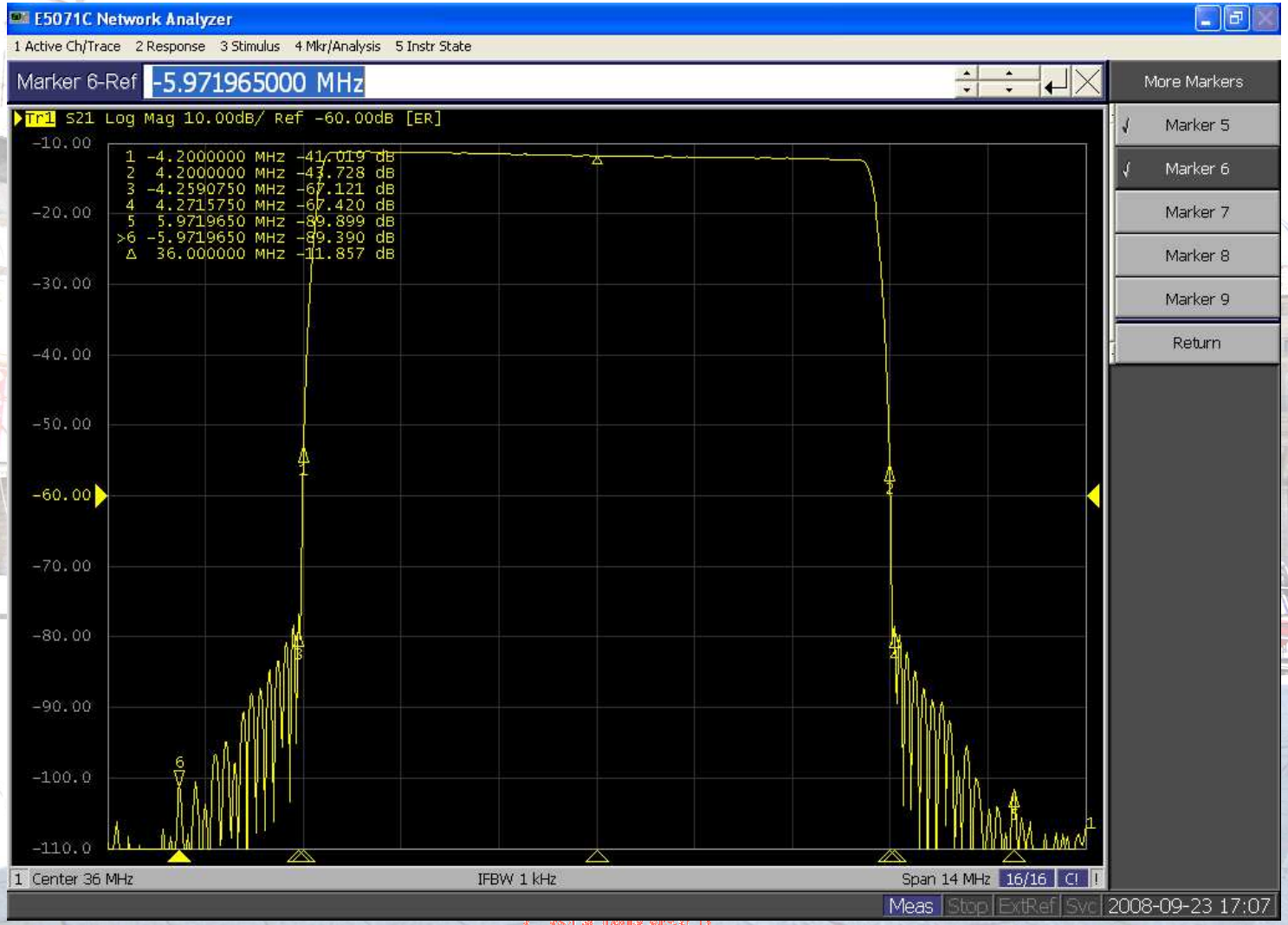


FPGA - Altera Stratix II

On network analyzer

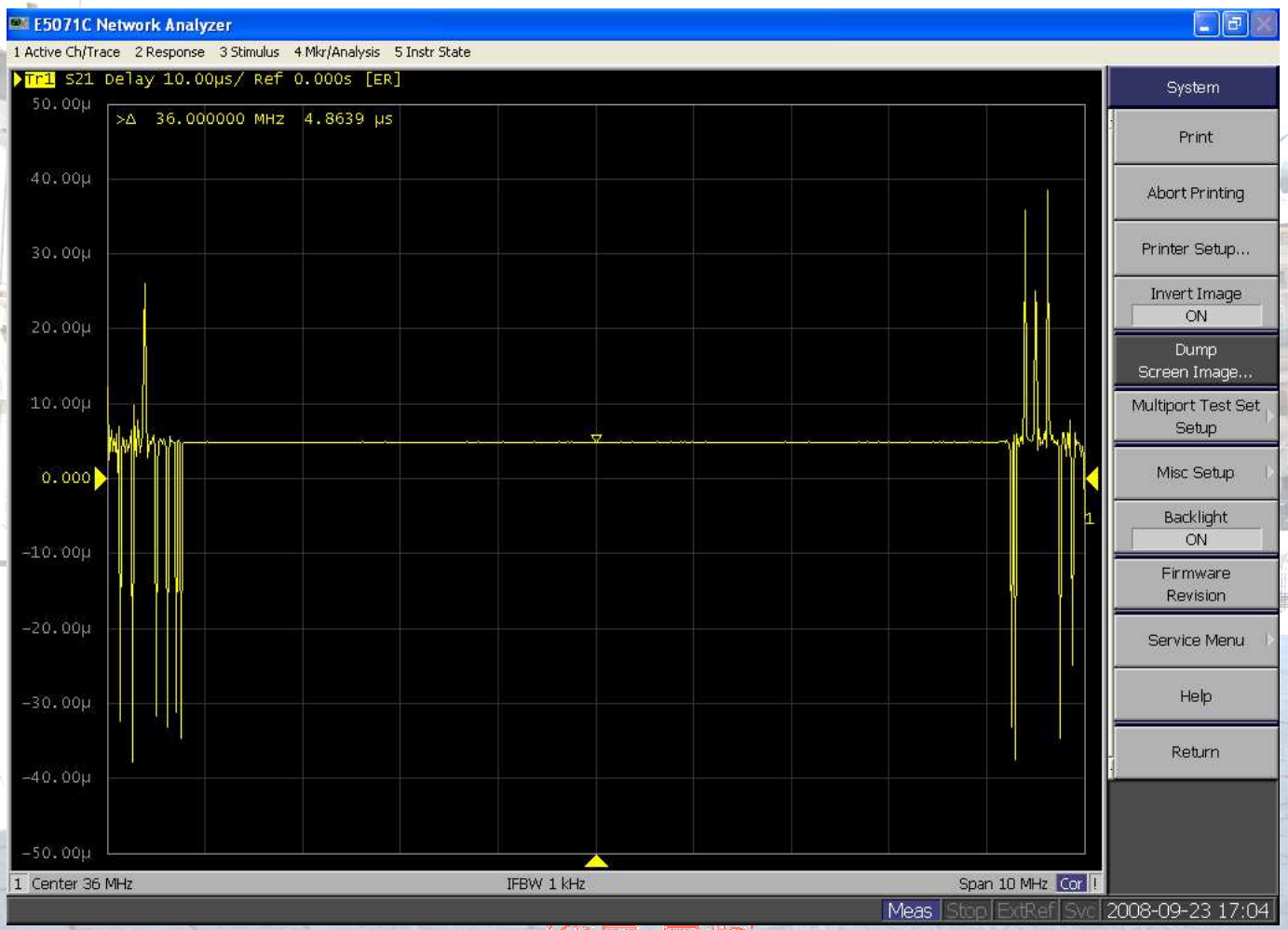


amplitude characteristic



Groud delay

Measured group delay = 4.86us



Conclusions

- Multistage Filters: researches and studies have to be done in order to find best compromise between taps and group delay;
- DVBT2: group delay is a strong requirements?
- Measurements and experiments have to be done to test our criteria on FPGA board.

PAPER:
"On the Design of Multistage Decimators with Minimum Group Delay", R.Soloperto, G.Pasolini and O.Andrisano, submitted to GLOBECOM2009

WiLab – Laboratorio di Comunicazioni Wireless

IEIIT-BO/CNR & DEIS, Alma Mater University of Bologna

Thank you for your attention!

for questions and discussions,
please contact:

Raffaele Soloperto
raffaele.soloperto@unibo.it

WiLab – Laboratorio di Comunicazioni Wireless

IEIIT-BO/CNR & DEIS, Alma Mater University of Bologna