UNIVERSITÀ DEGLI STUDI FIRENZE
DINFO
Dipartimento di Ingegneria dell'Informazione

Progetto ed applicazioni di sistemi innovativi ad ultrasuoni

Enrico Boni

Laboratorio Progettazione Sistemi Microelettronici (MSDLab)

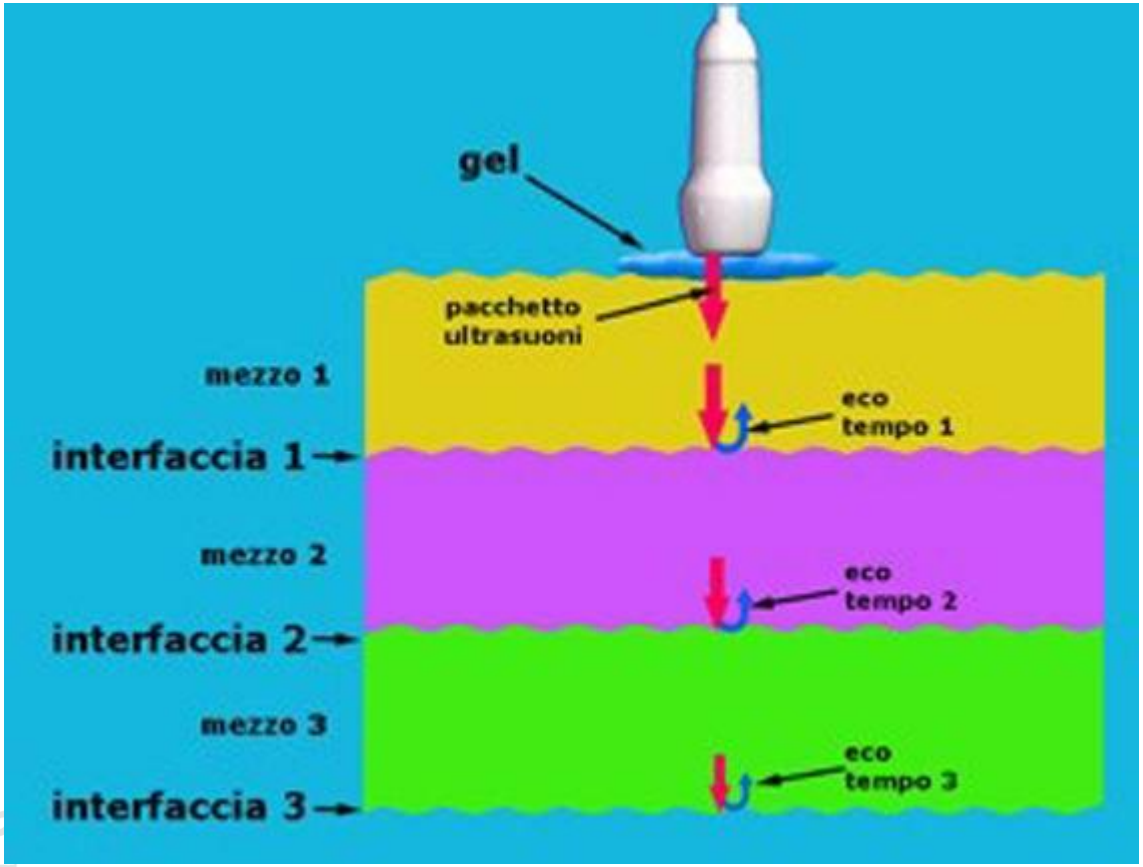
Competenze e interessi personali:

- Sistemi elettronici embedded
  - Per elaborazione di informazioni
  - Per applicazioni di controllo numerico
  - Basati su componenti programmabili (FPGA, uC, DSP, SoC)

Attività di ricerca principali:

- Sviluppo di sistemi ecografici ad ultrasuoni
  - Con caratteristiche tecnologiche avanzate
  - Adatti per attività di ricerca
- Implementazione di metodi innovativi per indagini ecografiche
  - Implementati sulle piattaforme sviluppate
  - Possibile trasferimento tecnologico su sistemi commerciali

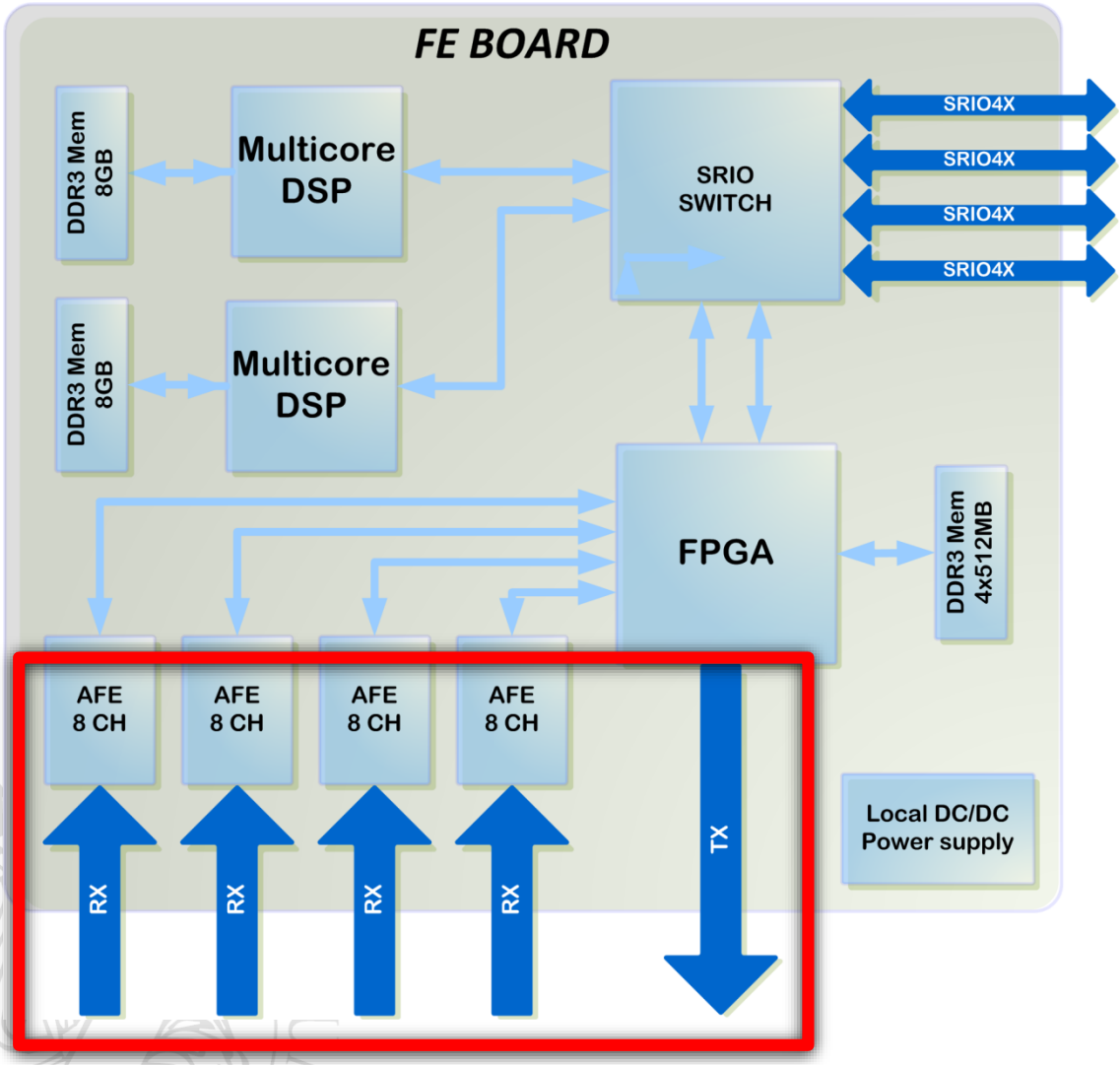
Come funziona un ecografo ad US:



Ultimo sistema di ricerca sviluppato:

- ULA-OP 256:
  - 256 canali attivi
  - Programmabilità completa in Trasmissione, Ricezione, elaborazione

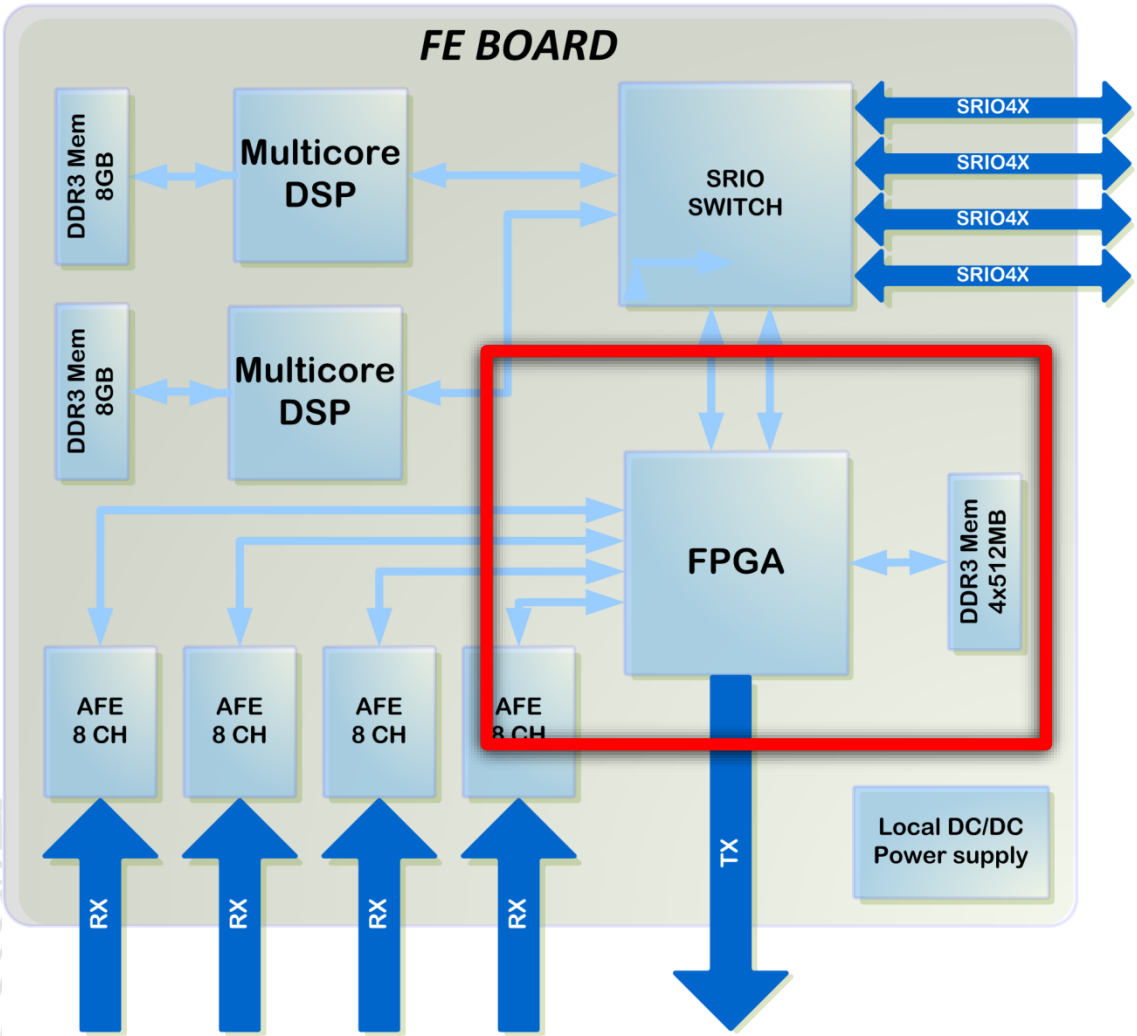
32-Channel Front-End Board



Analog Front-End:

- 32 TX/RX channels
- 32 AWGs on TX
- 32 ADCs 80MSPS, 12bit

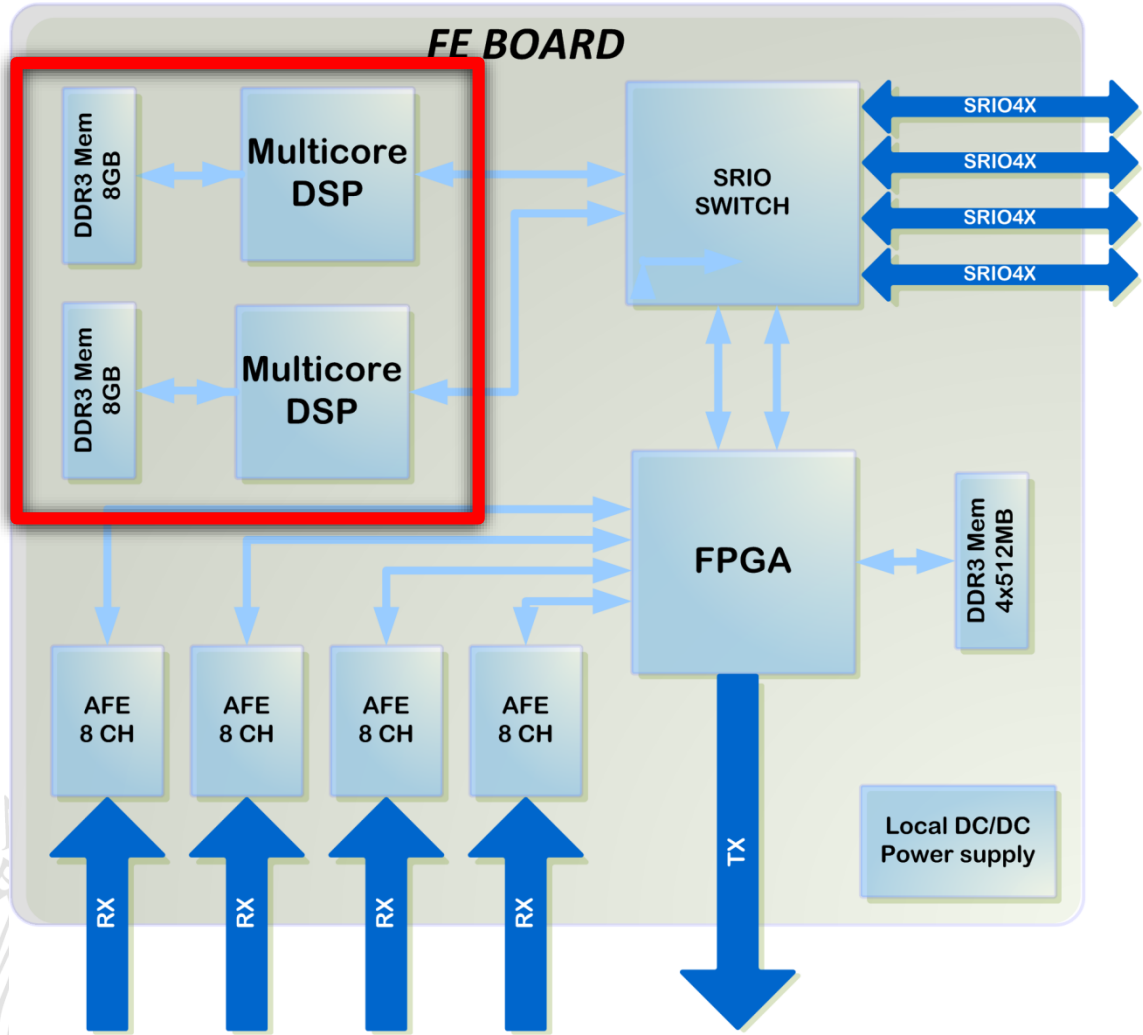
32-Channel Front-End Board



Beamforming FPGA:

- FPGA from Arria V family
- 6 Parallel beamformers
- 1GS/s beamforming capability
- 2 GB of DDR3 Memory

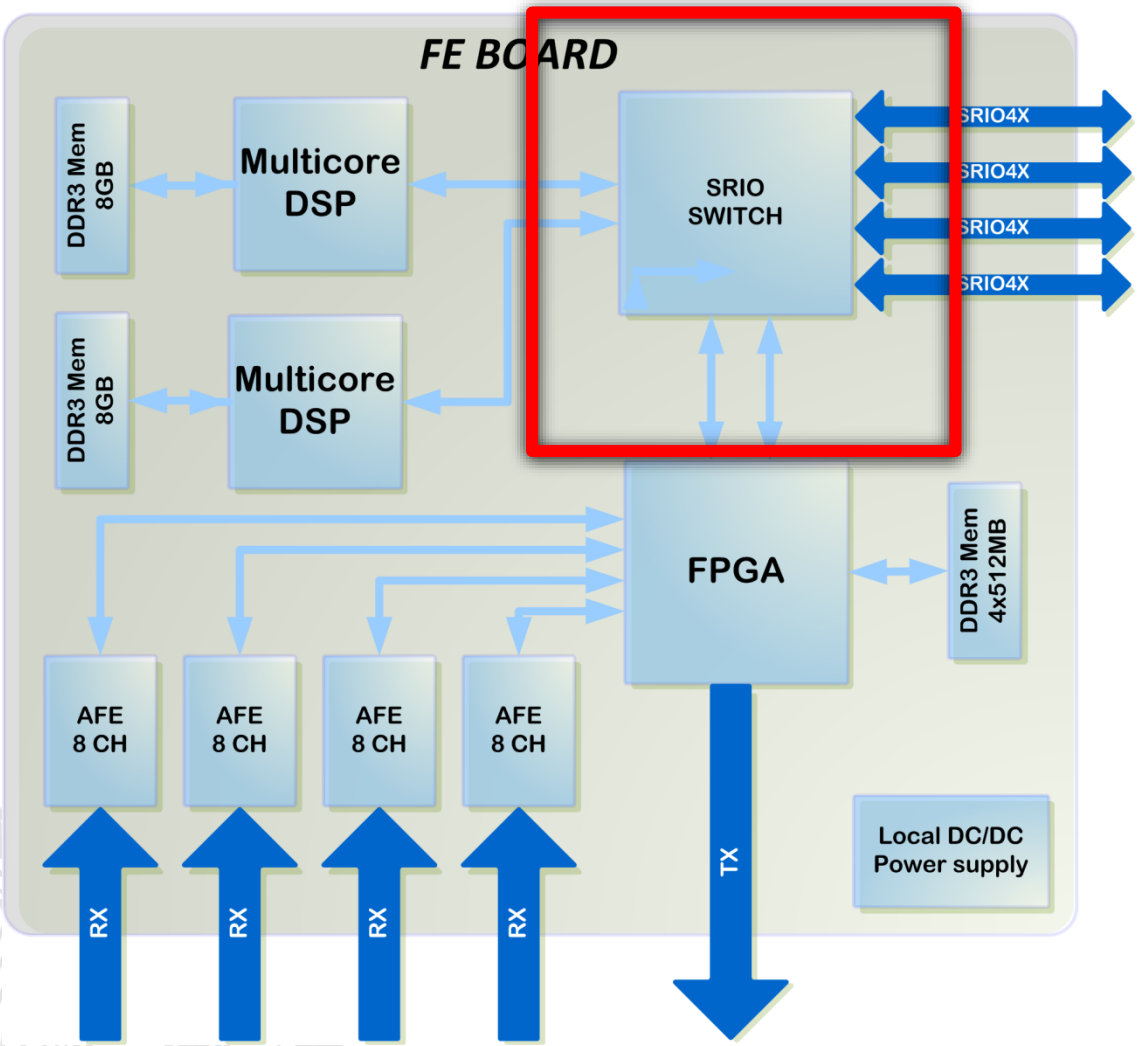
32-Channel Front-End Board



Front-End DSPs:

- 2 multicore DSPs ‘C6678 (16 cores@1.2GHz)
- 600GMAC/300GFLOPS DSPs processing power
- 8 GB DDR3 memory

32-Channel Front-End Board

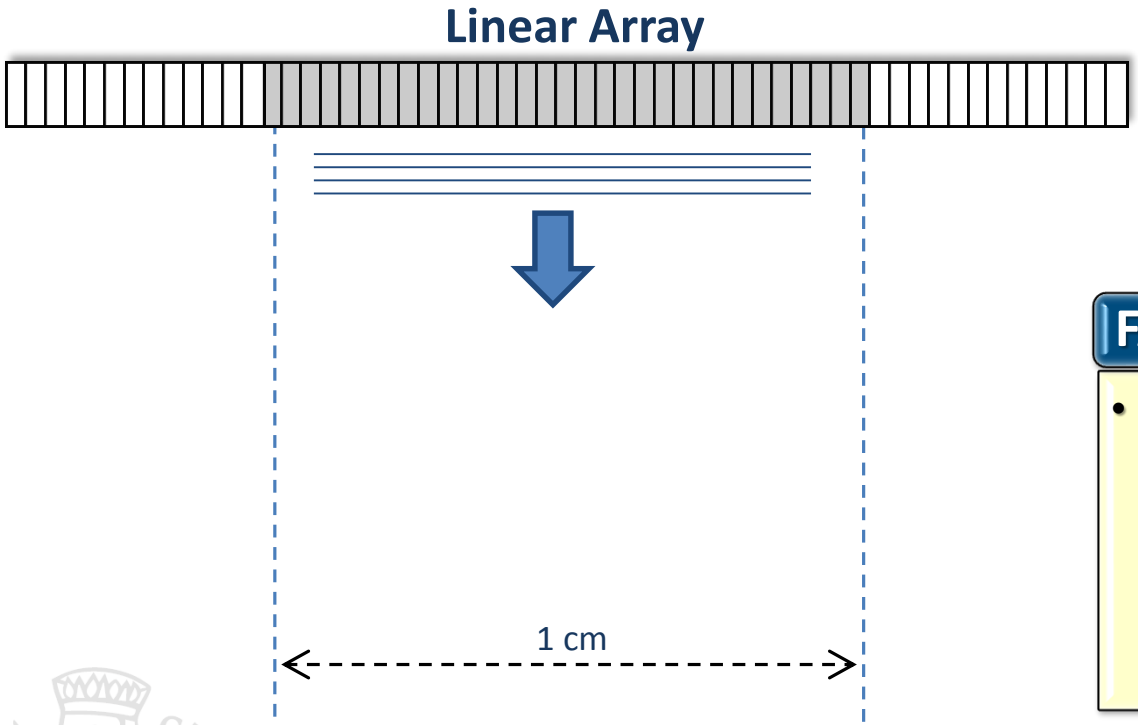


Communication:

- On-board SRIO switch
- 80Gbit/s toward the ring

Applicazioni

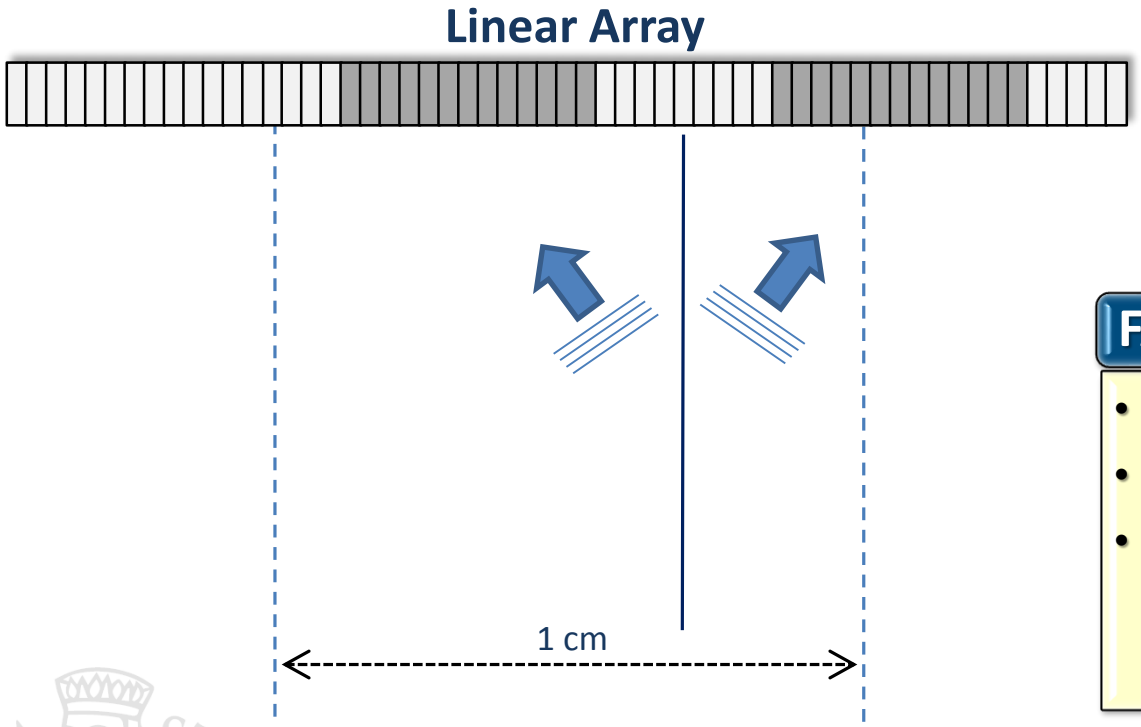
Vector Doppler: Method Basics



FAST VECTOR DOPPLER METHOD

- TRANSMISSION OF PLANE WAVES

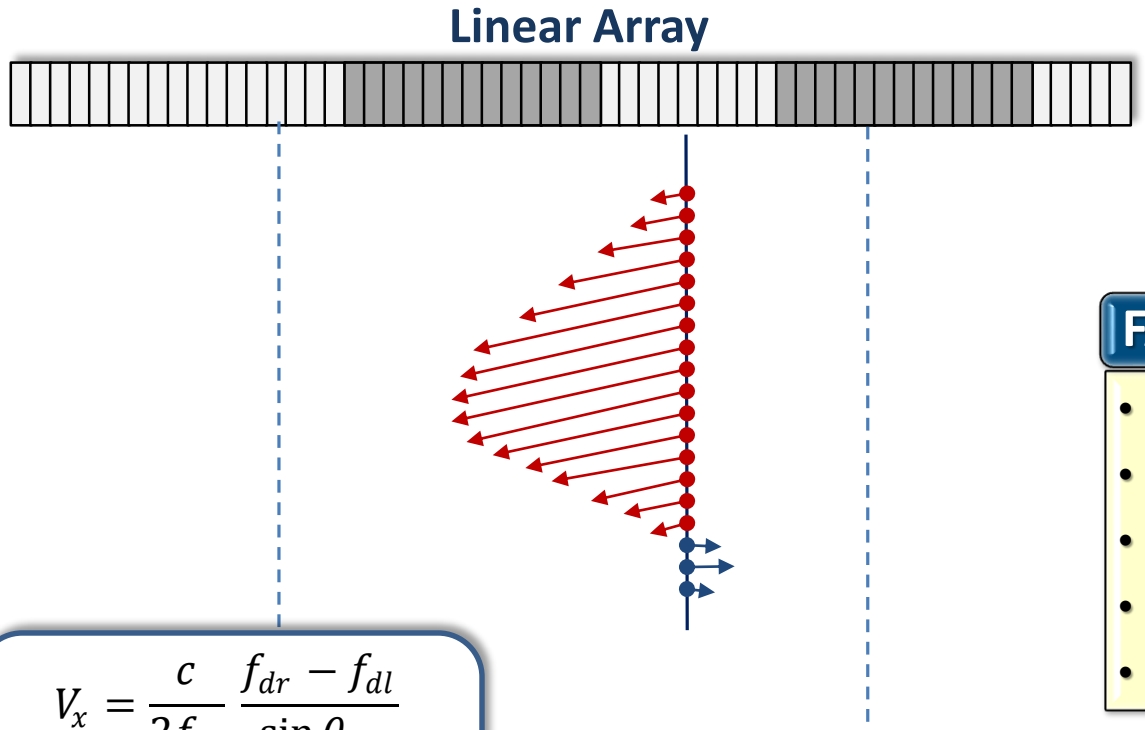
Vector Doppler: Method Basics



FAST VECTOR DOPPLER METHOD

- TRANSMISSION OF PLANE WAVES
- **RECEPTION FROM 2 SUB-APERTURES**
- **DIRECTIONAL & PARALLEL BEAMFORMING**

Vector Doppler: Method Basics



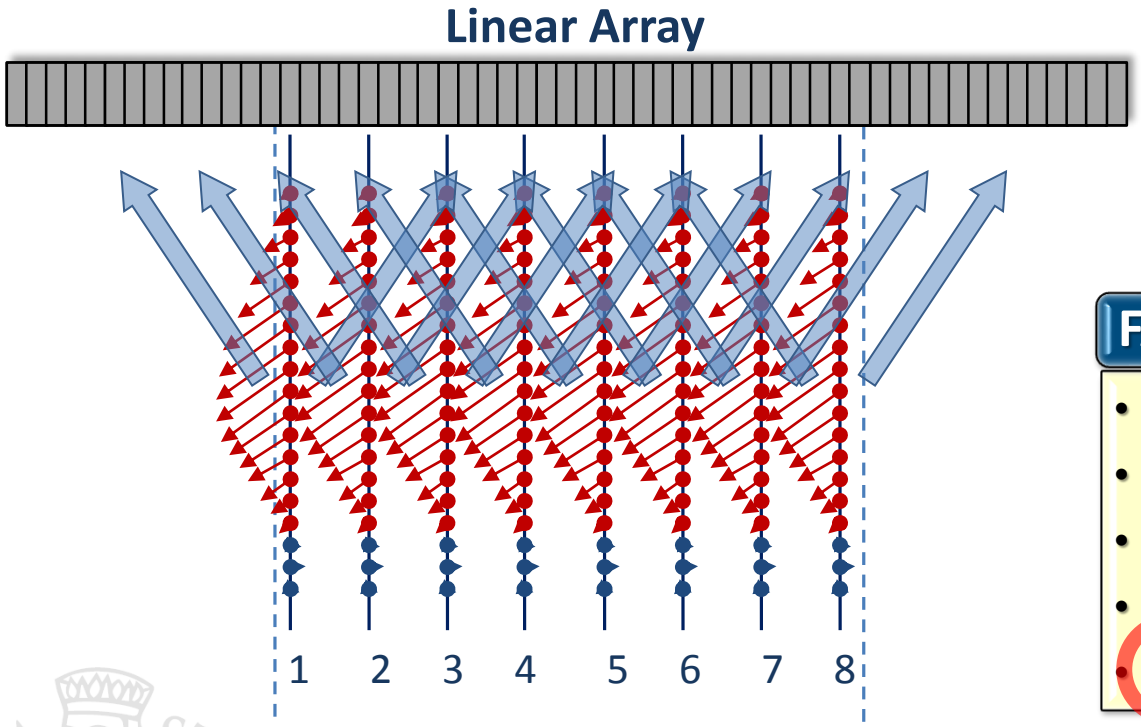
$$V_x = \frac{c}{2f_{tx}} \frac{f_{dr} - f_{dl}}{\sin\theta_{rx}}$$

$$V_z = \frac{c}{2f_{tx}} \frac{f_{dr} + f_{dl}}{1 + \cos\theta_{rx}}$$

FAST VECTOR DOPPLER METHOD

- TRANSMISSION OF PLANE WAVES
- RECEPTION FROM 2 SUB-APERTURES
- DIRECTIONAL & PARALLEL BEAMFORMING
- **MULTI-GATE DOPPLER + TRIANGULATION**
- **1 DOPPLER LINE**

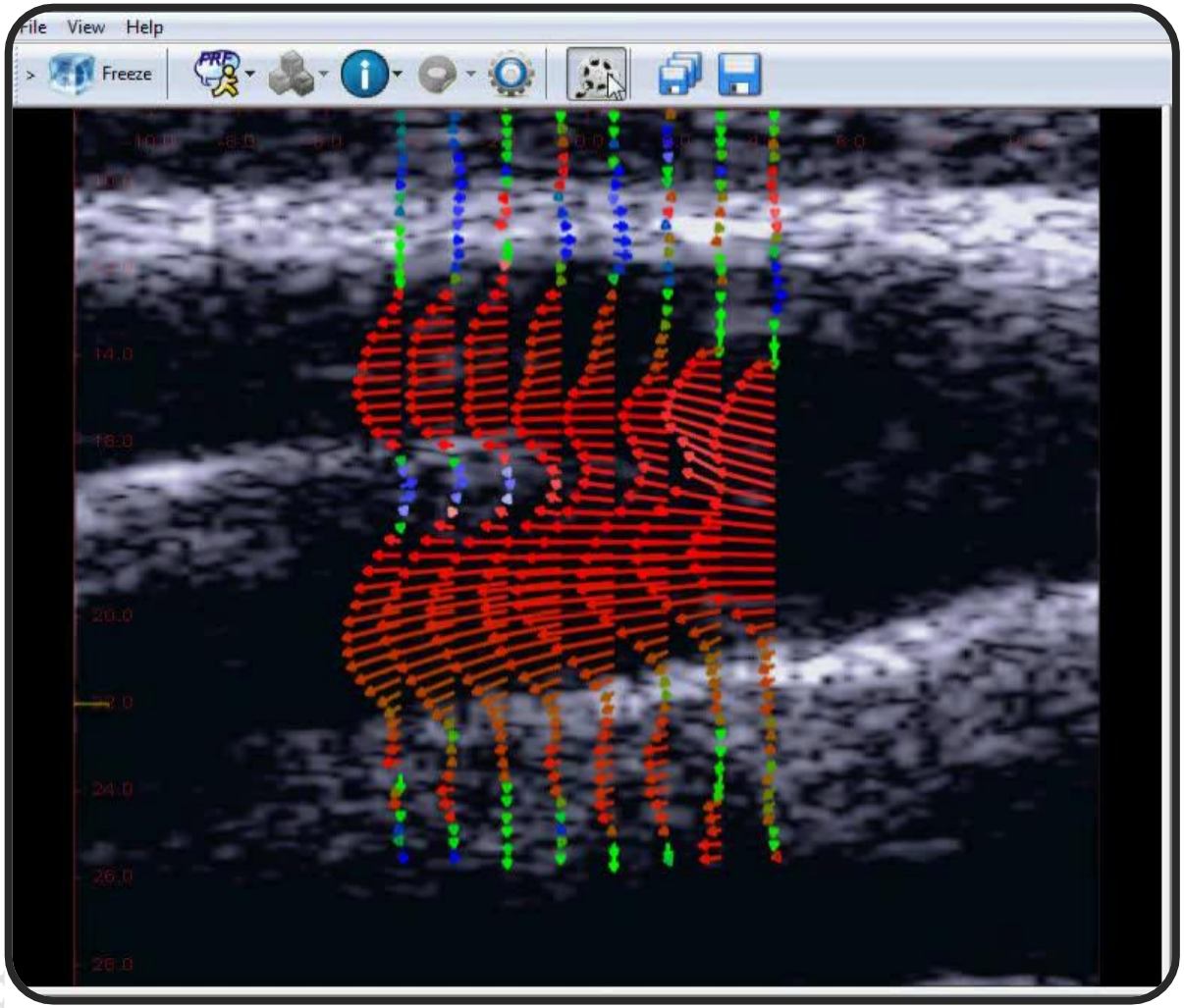
Vector Doppler: Multi-line extension



FAST VECTOR DOPPLER METHOD

- TRANSMISSION OF PLANE WAVES
- RECEPTION FROM 16 SUB-APERTURES
- DIRECTIONAL & PARALLEL BEAMFORMING
- MULTI-GATE DOPPLER + TRIANGULATION
- 8 VECTOR DOPPLER LINES

Multi-line Vector Doppler

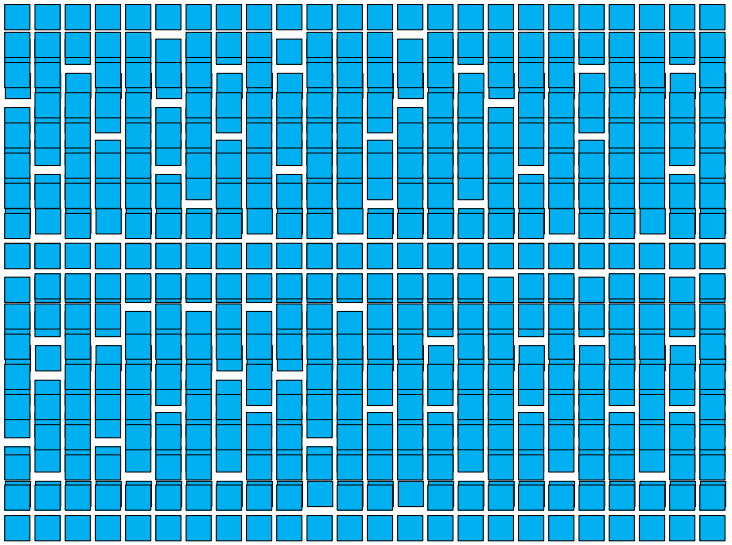


Sviluppo di sonde ecografiche per imaging 3D

Sonda Lineare

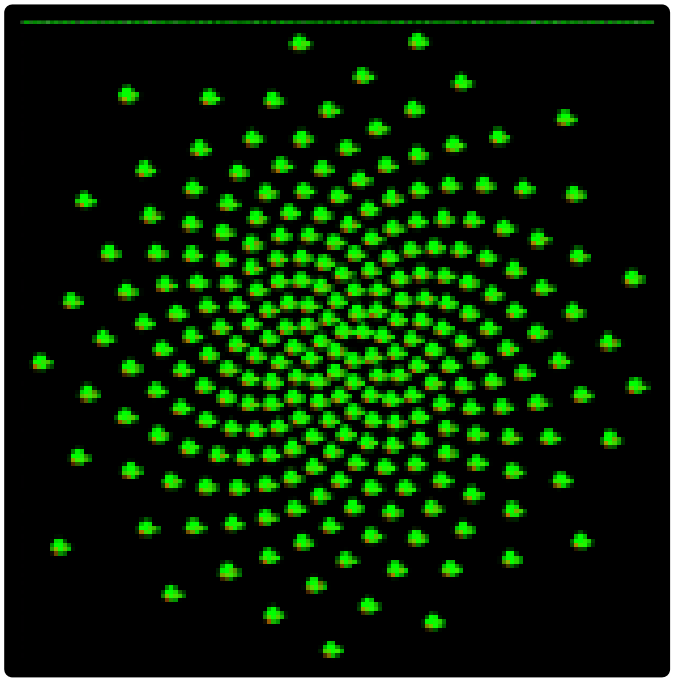
Sonda a Matrice

Sonda sparsa



Sviluppo di sonde ecografiche per imaging 3D

- Sonda SunFlower:

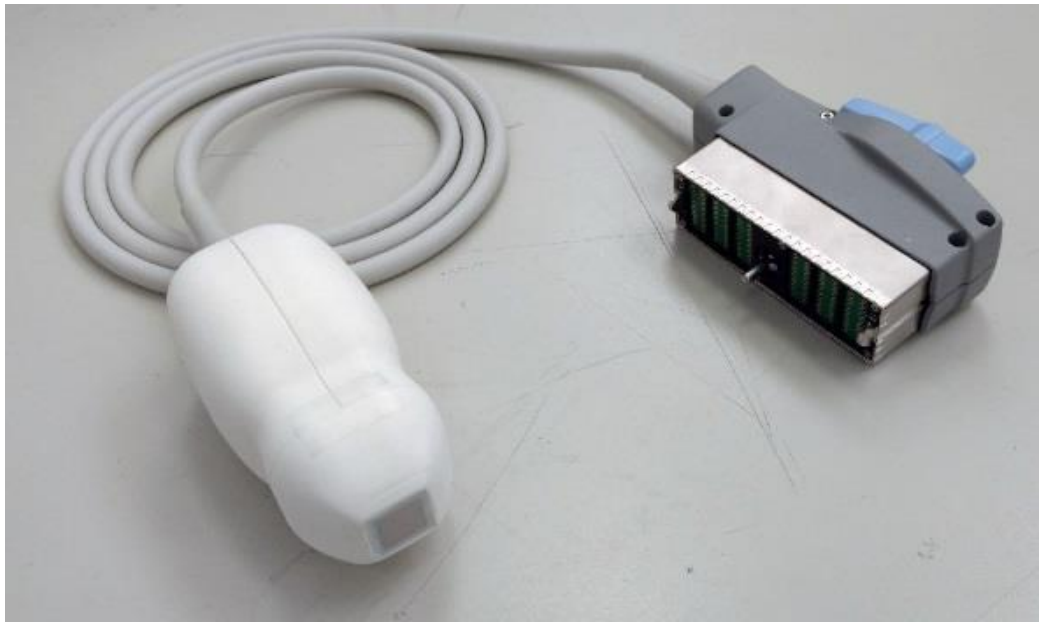


Sviluppo di sonde ecografiche per imaging 3D

- Sonda SunFlower:
  - Numero di elementi ridotto a 256
  - Implementazione sparsa
  - Progetto deterministico

Sviluppo di sonde ecografiche per imaging 3D

- Sonda SunFlower:

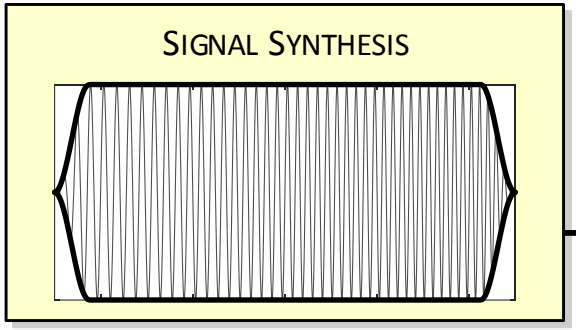


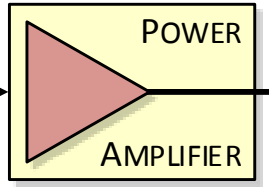
Ultrasound attenuation

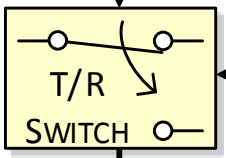
Ultrasound attenuates by 1 dB/cm/MHz during propagation.
Example:
- for a 10 MHz probe, echoes reflected by a target at 6 cm depth are attenuated by 60 dB

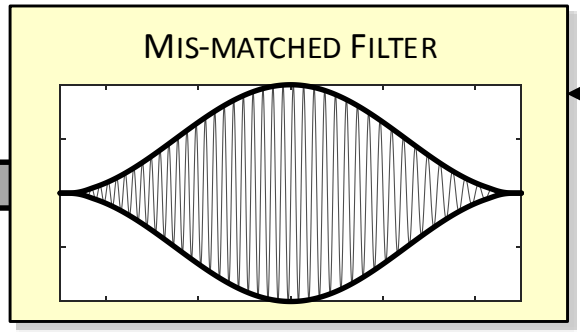
Classic solutions:
- Increasing the TX power (*safety issues*)
- Decreasing the TX frequency (*spatial resolution issues*)

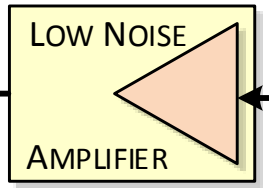
SOLUTION: Coded imaging/Doppler

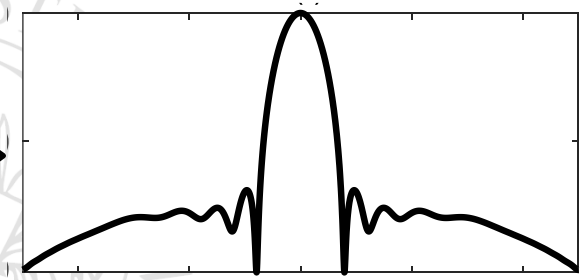












ADOPTED CODE:

LINEAR FREQUENCY MODULATION

TIME DURATION (T): 2-10 µs

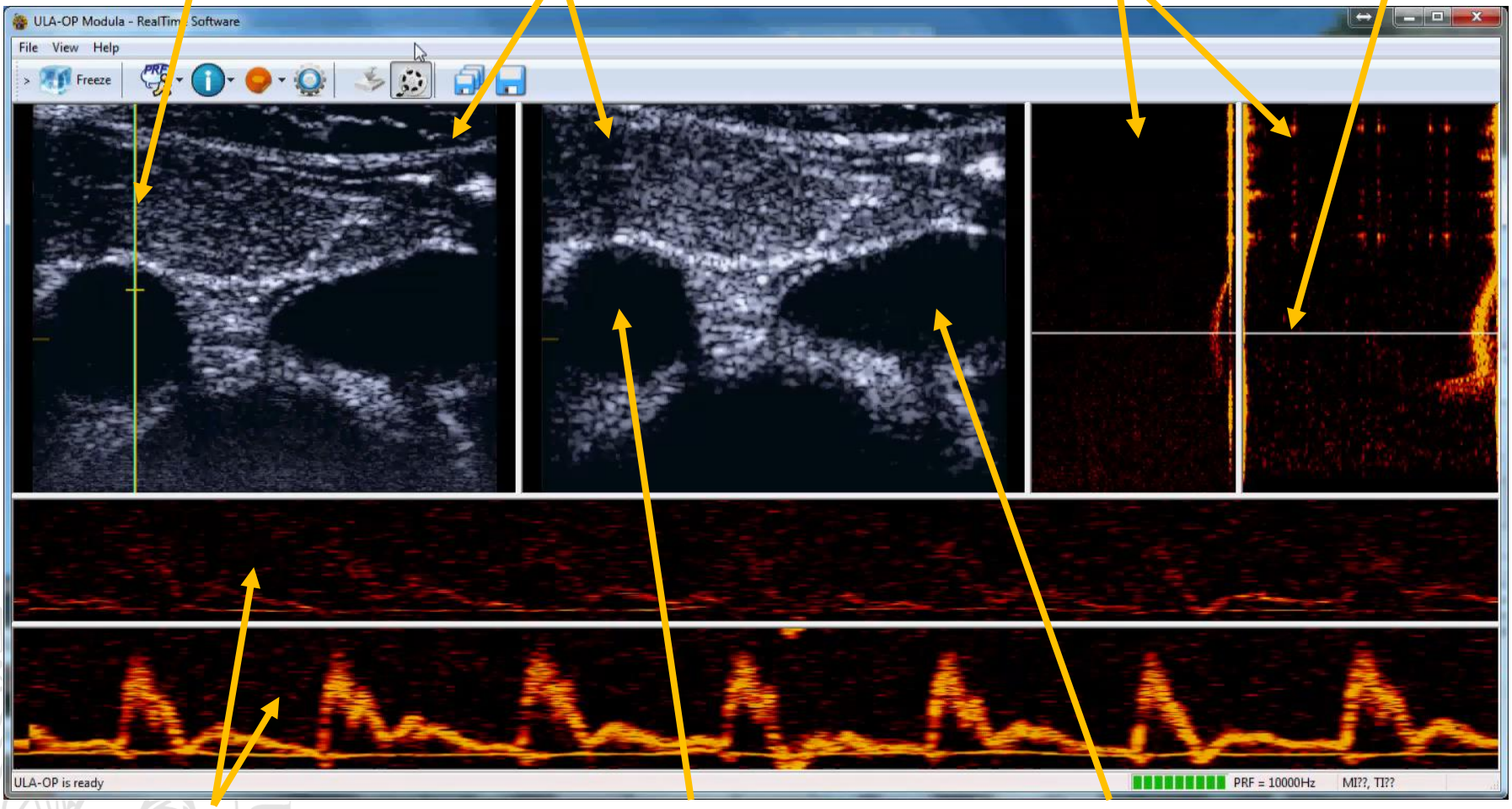
BANDWIDTH (B): 1-5 MHz

COMPRESSED PULSE

GSNR = B·T

RESOLUTION = 1/B

In-vivo Example



ULA-OP network