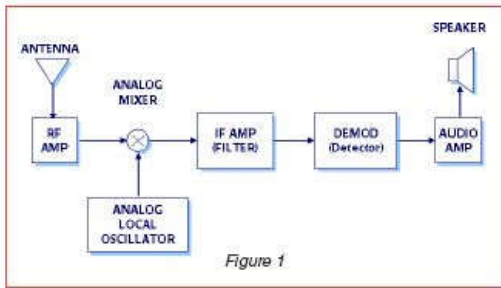


PRIN MRI 19F
Proposta di utilizzo della tecnica
software defined radio (SDR) e direct digital synthesis (DDS).

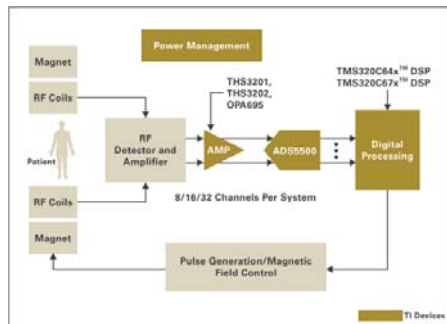
Valerio Bocci
Francesco Iacoangeli

INFN Roma

Il ricevitore delle MRI è sostanzialmente un ricevitore Radio le frequenze in gioco sono le stesse



Versione Analogica

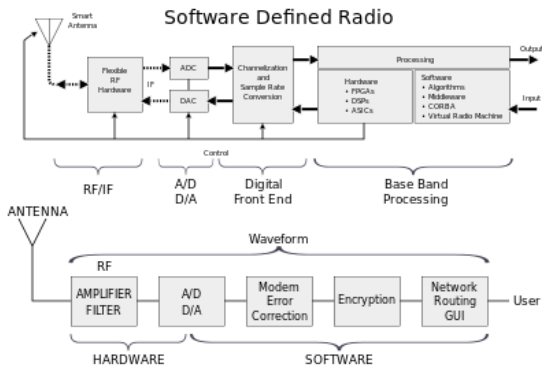


Versione nelle MRI moderne con utilizzo di FPGAs e DSP.

Lungo sviluppo, impossibilità di avere i sorgenti (tutto proprietario)

poco flessibile in fase di studio, sicuramente ottimizzato in una ipotetica soluzione finale. Esiste un progetto **open** di MRI basato su FPGA ma non sembra in stato avanzato

K. Takeda **OPENCORE NMR**: open-source core modules for implementing an integrated FPGA-based NMR spectrometer



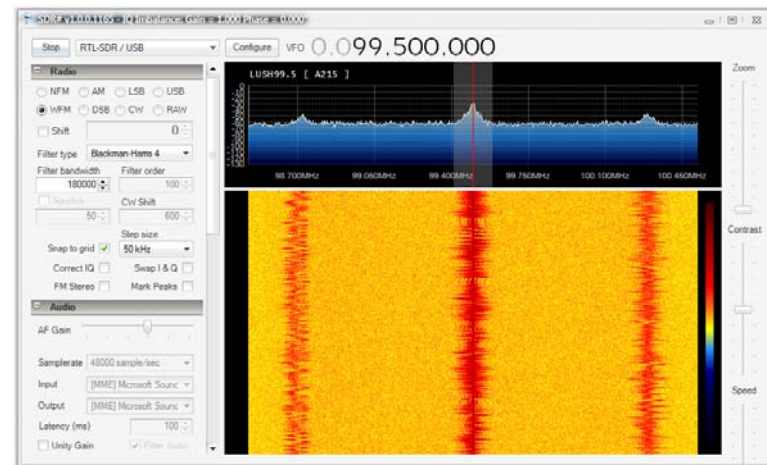
Versione SDR: la demodulazione del segnale è fatta via software su PC.
I sorgenti sono liberi (Gnu Radio)

Software defined Radio (SDR)

Software-defined radio (SDR) is a [radio communication](#) system where components that have been traditionally implemented in hardware (e.g. [mixers](#), [filters](#), [amplifiers](#), [modulators/demodulators](#), [detectors](#), etc.) are instead implemented by means of software on a personal computer or [embedded system](#).^[1] While the concept of SDR is not new, the rapidly evolving capabilities of digital electronics render practical many processes which were once only theoretically possible.

....

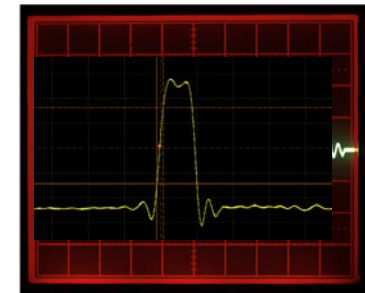
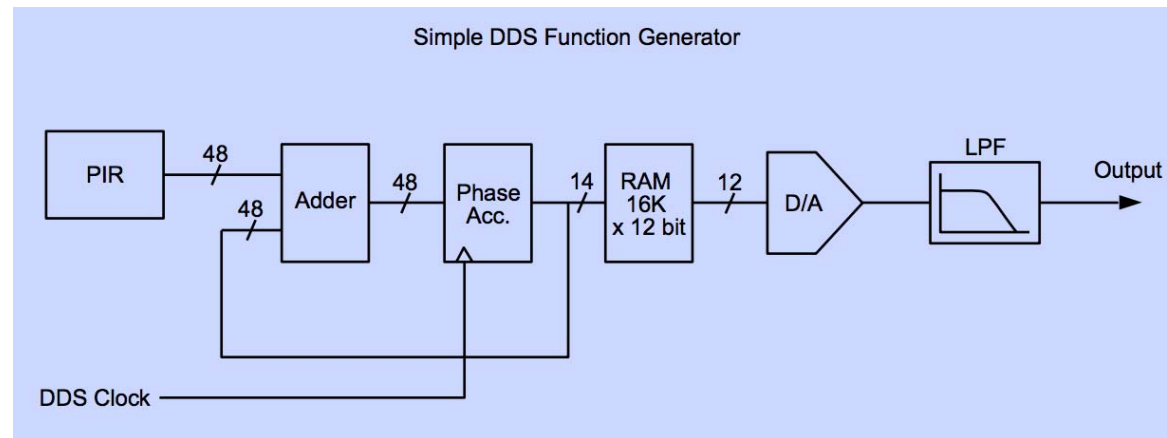
A basic SDR system may consist of a [personal computer](#) equipped with a [sound card](#), or other [analog-to-digital converter](#), preceded by some form of [RF front end](#). Significant amounts of [signal processing](#) are handed over to the general-purpose processor, rather than being done in special-purpose hardware ([electronic circuits](#)). Such a design produces a [radio](#) which can receive and transmit widely different radio protocols (sometimes referred to as waveforms) based solely on the software used.



Direct Digital Synthesis (DDS)



Software designed Waveform



Arbitrary waveforms

Analog Output

Direct digital synthesizer (DDS) is a type of [frequency synthesizer](#) used for creating arbitrary [waveforms](#) from a single, fixed-frequency reference clock. Applications of DDS include: [signal generation](#), [local oscillators](#) in communication systems, [function generators](#), mixers, [modulators](#),^[1] [sound synthesizers](#) and as part of a digital [phase-locked loop](#).^[2]

GNU RADIO a free SDR radio software

<https://www.gnuradio.org/>
<https://github.com/gnuradio/gnuradio>

GNU Radio è un progetto di **Software Defined Radio (SDR)** lanciato circa dieci anni fa da Eric Blossom, un ingegnere elettronico. L'idea principale che sta alla base di questo progetto è quella di convertire tutti i problemi hardware in problemi software, cioè spostare la complessità relativa alla progettazione di un apparato radio dal livello hardware a quello software, e portare il software più vicino possibile all'antenna.

GNU Radio Blocks

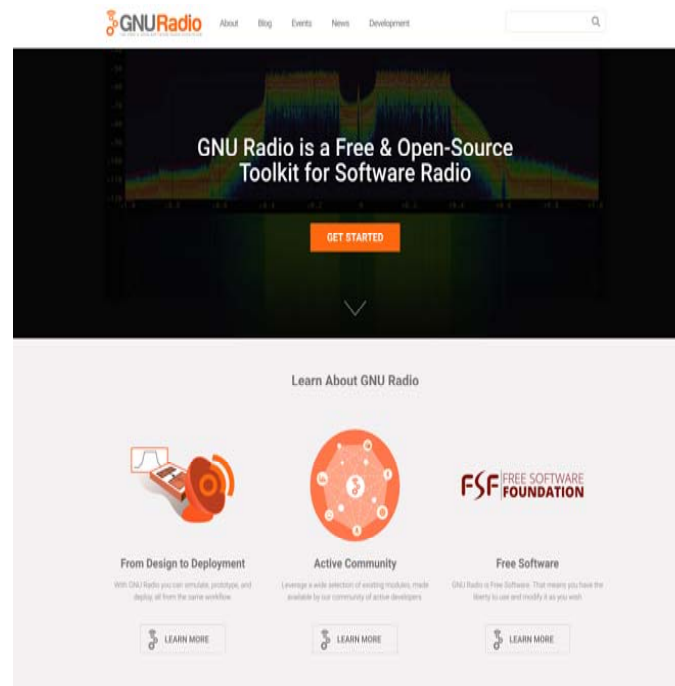
GNU Radio uses discrete signal processing blocks that are connected together to perform your signal processing application. This manual contain a list of all GNU Radio [C++ Blocks](#), sorted by category.

(....)

In-tree components

All our in-tree components have their own top-level documentation:

- [Analog Modulation](#)
- [Audio Interface](#)
- [Standard GNU Radio Blocks](#)
- [Channel Model Blocks](#)
- [ControlPort](#)
- [Digital Modulation](#)
- [Packet Communications](#)
- [FunCube Dongle Source](#)
- [Forward Error Correction](#)
- [FFT Signal Processing Blocks](#)
- [Filter Signal Processing Blocks](#)
- [QT Graphical User Interface](#)
- [UHD Interface](#)
- [Voice Coders and Decoders \(Vocoders\)](#)
- [ZeroMQ](#)



- ▼ GNU Radio C++ Signal Processing Blocks
 - Top Block and Hierarchical Block Base Classes
 - Audio Signals
 - Boolean Operators
 - Byte Operators
 - Channel Models
 - Channelizers
 - Information Coding and Decoding
 - ControlPort
 - Debug Tools
 - Deprecated
 - Equalizers
 - Error Coding and Decoding
 - FCD Interface
 - File Operators
 - Filters
 - Fourier Analysis
 - Instrumentation Tools
 - Level Controllers
 - Math Operators
 - Measurement Tools
 - Message Tools
 - Miscellaneous
 - Modulators and Demodulators
 - Networking Tools
 - NOAA Blocks
 - OFDM Blocks
 - Packet/Frame Operators
 - Peak Detectors
 - Pager Blocks
 - QT Graphical Interfaces
 - Resamplers
 - Streams Operators
 - Stream Tag Tools
 - Symbol Coding
 - Synchronizers
 - Trellis Coding
 - Data Type Converters
 - UHD Interface
 - Waveform Generators
 - Wavelet Transforms
 - WX Graphical Interfaces
 - Base classes for GR Blocks
 - Digital Filter Design
 - Miscellaneous
 - Implementation Details
- ▼ Applications
 - ATSC
 - Pager
 - Misc Hardware Control

Hardware per il Software Defined Radio

Comparisons with other common Wideband Commercial Software Defined Radios

SDR	Tune Low (MHz)	Tune Max (MHz)	RX Bandwidth (MHz)	ADC Resolution (Bits)	Transmit? (Yes/No)	Price (\$USD)
RTL-SDR (R820T)	24	1766	3.2	8	No	~20
Funcube Pro+	0.15 410	260 2050	0.192	16	No	~200
Airspy	24	1800	10	12	No	199
SDRPlay	0.1	2000	8	12	No	149
HackRF	30	6000	20	8	Yes	299
BladeRF	300	3800	40	12	Yes	400 & 650
USRP 1	DC	6000	64	12	Yes	700

Very low cost home version



RTL SDR

Commercial DVB Tv:
USB receiver + PC running GNU Radio

Professional version: Including DDS (Ettus Research)

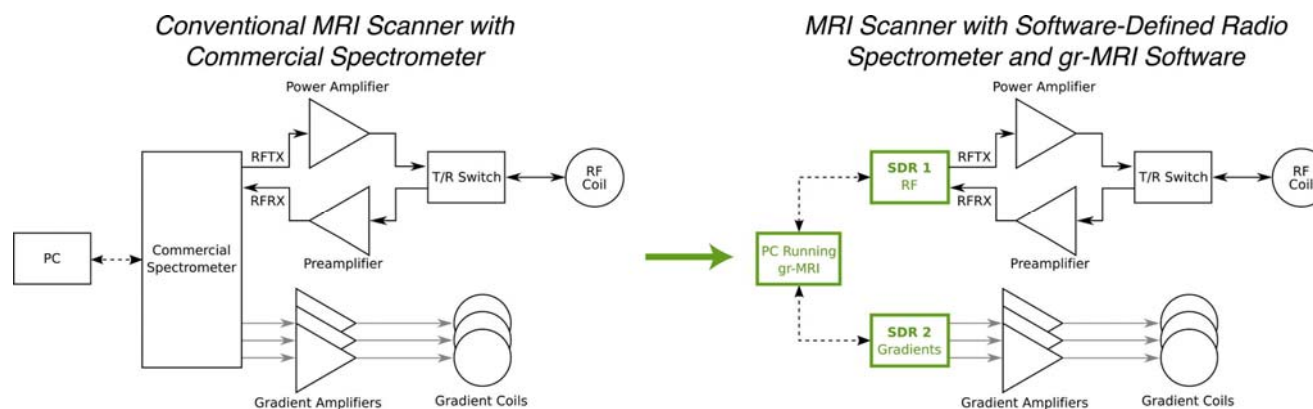


https://en.wikipedia.org/wiki/Universal_Software_Radio_Peripheral

Valerio Bocci

Nel campo dei ricevitori radio l'idea delle SDR basate su Gnu Radio ha avuto un grosso sviluppo, utilizzarla in MRI è sicuramente accattivante, ricercando in letteratura ho trovato che ad altri gruppi è venuta la stessa idea e hanno iniziato ad utilizzarla.

- **Asfour et al. Software Defined Radio (SDR) and Direct Digital Synthesizer (DDS) for NMR/MRI Instruments at Low-Field (2013)**
Grenoble Electrical Engineering Lab (G2E-Lab) <http://www.mdpi.com/1424-8220/13/12/16245>
- Christopher J.Hasselwander et al (Department of Biomedical Engineering, Vanderbilt University, Nashville)
gr-MRI: A software package for magnetic resonance imaging using software defined radios (2016)
<https://www.sciencedirect.com/science/article/pii/S1090780716300994>



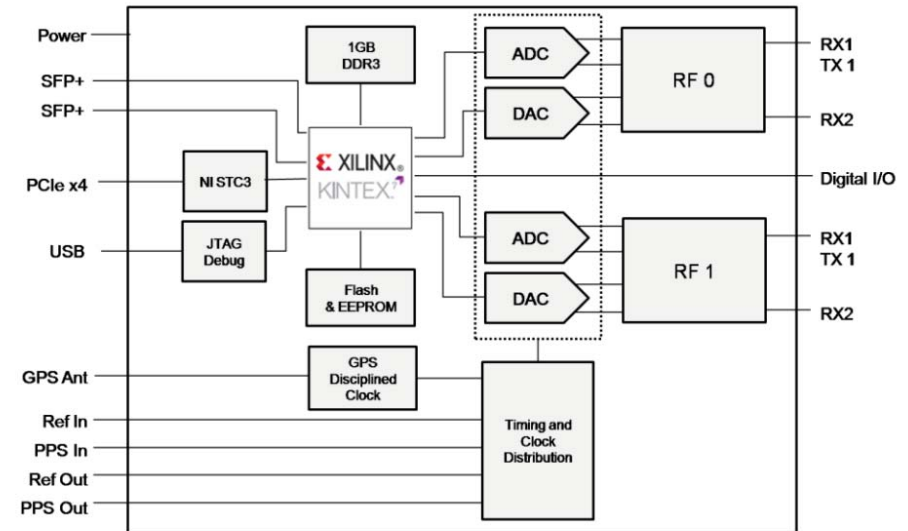
USRP-X310

- Two wideband RF daughterboard slots
 - Up 120MHz bandwidth per channel
 - Selection covers DC to 6 GHz
- Large, customizable Kintex-7 FPGA
 - USRP X300 - XC7K325T
 - USRP X310 - XC7K410T
- UHD architecture provides compatibility:
 - GNURadio
 - C++ API/Python
 - Other third-party frameworks & applications
- Multiple high-speed interfaces
 - Dual SFP(+) ports for 1/10 Gigabit Ethernet
 - PCIe x4
- Flexible clocking architecture
 - Configurable sample clock
 - Optional GPS-disciplined OCXO
 - Coherent operation with 10 MHz/1 PPS
- Compact and rugged half-wide 1U form factor

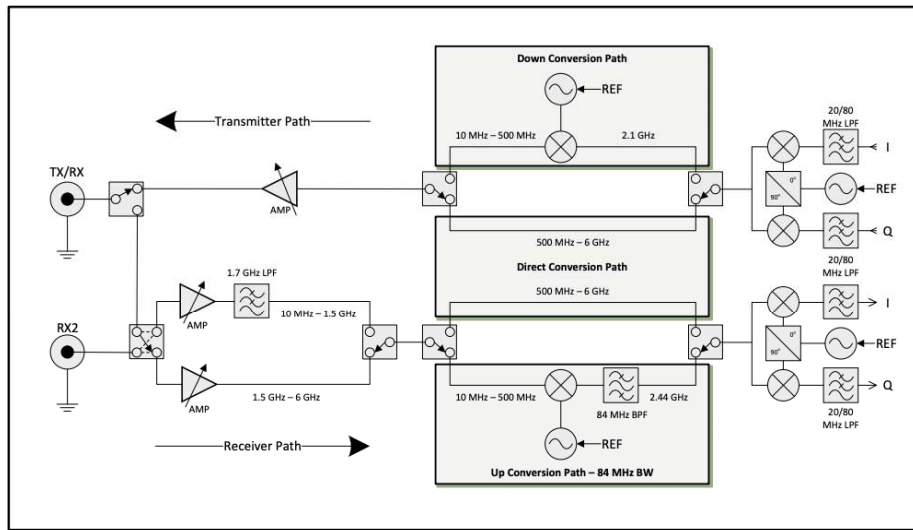


SAMPLE APPLICATIONS

- Advanced Wireless Prototyping (WiFi/Cellular)
- Massive MIMO Testbeds
- Passive RADAR
- Signals Intelligence



UBX 10-6000 MHz Rx/Tx (160 MHz BW)



1 The UBX 160 transmitter path has 160 MHz of bandwidth throughout the full frequency range of the device; the receiver path has 84 MHz of bandwidth for center frequencies from 10 MHz to 500 MHz.

2 UBX phase-aligned operation is only supported on USRP X Series devices.



Features

Wide RF Coverage

- 10 MHz to 6 GHz

Wide bandwidth

- UBX 160: up to 160 MHz¹
- UBX 40: 40 MHz

USRP Compatibility

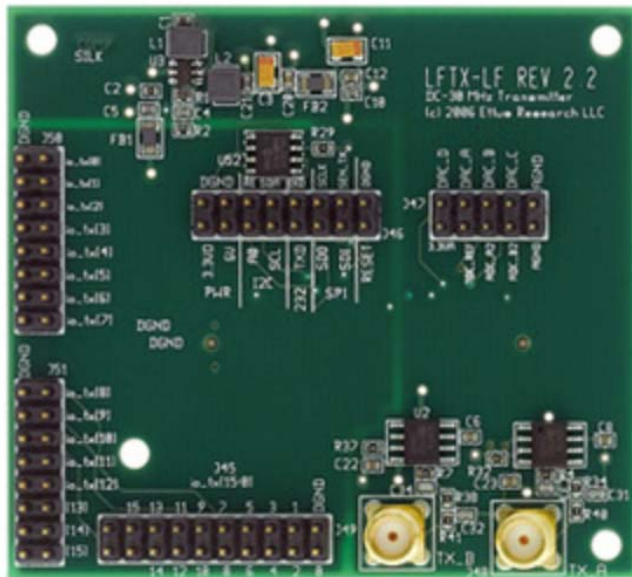
- UBX 160: X Series and N Series
- UBX 40: N Series

Full-Duplex Operation

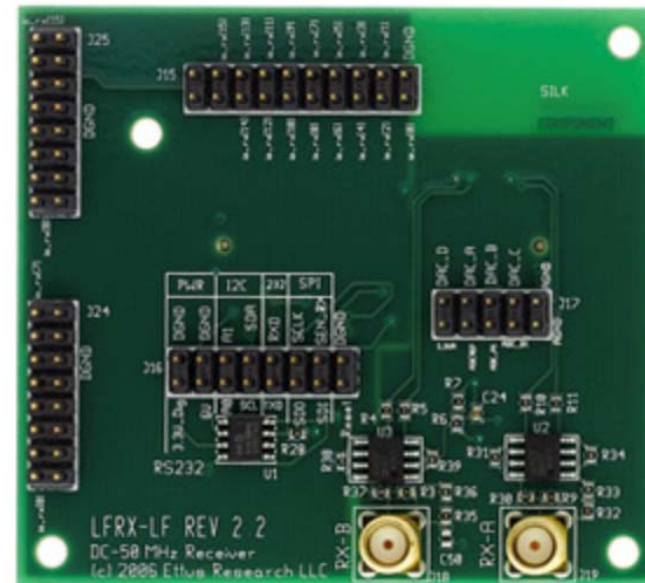
RF Shielding

Coherent and phase-aligned² operation

LFRX Daughterboard 0-30 MHz



LFTX Daughterboard 0-30 MHz Tx



LFRX Daughterboard 0-30 MHz Rx

Conclusioni

- La differenza chiave nell'utilizzo di un sistema SDR/DDS è l'abilità di cambiare gli algoritmi stessi (...uso wavelet) non solo i parametri di un algoritmo prestabilito.
- Le singole componenti non sono costose, possibilità di utilizzare migliaia di linee di codice di software open source e di ottimizzare solo le parti necessarie.
- NI Universal Software Radio Peripheral (**USRP**) è sicuramente il top del mercato. Al momento esistono diverse versioni USRP X310 ha 160 MHz banda base con all'interno anche un FPGA con firmware open core, frequenze maggiori possono essere esplorate in configurazione Supereterodina. Esistono altre board più performanti ma l'interfaccia con Gnu Radio va scritta.