Enter the Electromagic Spectrum with the USRP

GNU Radio Conference 2018

Nate Temple  nate.temple@ettus.com

Manuel Uhm  manuel.uhm@ettus.com
$ universe --help

**Weak Nuclear Force**
- Converting protons into neutrons
  - When two protons collide and fuse, a disruption in the weak nuclear force emits a positron and neutron, which converts one of the positively charged proton to a neutrally charged neutron. Without the weak nuclear force converting protons into neutrons, certain complex nuclei cannot form.

**Gravity**
- Adding motion to the Universe
  - Gravity forms stars, planets, and moons, and forces these objects to spin on an axis and move along an orbital path. The planets appear to be orbiting the center of the Sun, but the Sun and planets all orbit a shared center of mass. Planets with enough mass can develop orbiting moons or rings of debris.

**Electromagnetic Force**
- Forming atoms and molecules
  - The electromagnetic force pulls negatively charged electrons into bound orbits around positively charged nuclei to form atoms and molecules. As a gas cools, electrons will find their way into the presence of atomic nuclei. Larger nuclei with a greater positive charge pull in more electrons until atoms and molecules have a balance of charges.

**Strong Nuclear Force**
- Binding protons in atomic nuclei
  - Positively charged particles naturally repel each other, it takes an extreme amount of force to hold protons together. The strong nuclear force overcomes the repulsion between protons to hold together atomic nuclei. Without the strong nuclear force, complex nuclei cannot form.

- Breaking the bond
  - Enormous energy is released as gamma rays and neutrons when the strong nuclear force is broken between protons and neutrons.
$ universe --init
$ universe --display earth
$ universe --display earth
$ universe --display earth
$ universe --display earth
$ universe --display earth
$ universe --display earth
$ universe --display earth
$ universe --display modern-world
$ universe --display old-world
$ universe --display modern-world
$ universe --interface wlan0
\[ \int_S \mathbf{E} \cdot d\mathbf{a} = \frac{1}{\epsilon_0} \int \rho \, dV \]

\[ \int_S \mathbf{B} \cdot d\mathbf{a} = 0 \]

\[ \int_{\text{loop}} \mathbf{E} \cdot ds = -\frac{d}{dt} \int_S \mathbf{B} \cdot d\mathbf{a} \]

\[ \int_{\text{loop}} \mathbf{B} \cdot ds = \mu_0 \int_S \mathbf{J} \cdot d\mathbf{a} + \epsilon_0 \mu_0 \frac{d}{dt} \int_S \mathbf{E} \cdot d\mathbf{a} \]
$ universe --flush-rules

What if...
$ pybombs install gr-gravity
$ gr_modtool newmod gravitron
$ python3 gr-gravity/examples/superpowers.py
$ universe --set-time now --where here
$ universe --check-rules

What if...
$ universe --check-rules

What if...

- Gravity
- Weak
- Strong
- Electromagnetic
$ universe --check-rules

What if...

- Gravity
- Weak
- Strong
- Electromagnetic
$ gdb universe --module electromagnetic

![Electromagnetic Spectrum](image-url)
(gdb) next
$ cat gr-magic/requirements.txt
$ uhd_find_devices --args "type=magicwand"
$ uhd_magicwand --help
$ gnuradio-companion ~/magicspells.grc
$ gnuradio-companion gr-magic/apps/qt-magicball.grc
$ gnuradio-companion gr-magic/apps/matrix.grc
$ universe --load matrix --ref external
USRP1
All good things start with a USRP1 and decimation factor of 20
If you want one of them, be one of the first five people to compose a USRP1 Haiku and post it...
USRP1 Haiku

whizzing through the sky

cubesat pass say hi

you-surp on ground try
USRP1 SatNOGS Station

SatNOGS
Automatic Picture Transmission (APT)

- Introduced in the 1960s
- Provides image data to relatively low-cost stations
- Broadcasted by NOAA-15, NOAA-18, NOAA-19
- Data transmitted as a horizontal scan line
- Complete line is 2080 pixels long
- Transmitted at 2 lines per second (4160 baud)
- 8 bit grayscale
- Pixel intensity is AM modulated on a 2.4 kHz tone
- Then FM modulated on 137 MHz carrier
- 4 km/pixel

- wikipedia.org/wiki/Automatic_picture_transmission

Figure 4.2.2-1. APT Frame Format.
Low-Rate Picture Transmission (LRPT)

- Digital transmission system, intended to deliver images and data from weather satellites
- Active on Meteor M2 at 137.9 MHz
- Three spectral channels
- 1km / pixel resolution
- QPSK modulation 72k baud

- Flowgraphs based on Otti’s implementations
  - [https://github.com/otti-soft/meteor-m2-lrpt](https://github.com/otti-soft/meteor-m2-lrpt)
  - Flowgraphs creates .s (soft symbols) file

- Symbols (.s) file can then be processed by `meteor_decoder` utility by artlav
  - [https://github.com/artlav/meteor_decoder](https://github.com/artlav/meteor_decoder)
HRPT

- High-Rate Picture Transmission (HRPT)
- Intended to deliver images and data from an orbital weather satellites

- NOAA-15, NOAA-18, NOAA-19 (USA)
- Meteor M2 (RUSSIA)
- Feng-Yun (CHINA)

- L-Band - 1.7 GHz

- Requires Dish & Tracking Mount
LRIT / HRIT

- Low-Rate Information Transmission
- High-Rate Information Transmission
- LRIT - GOES-13,14,15
- HRIT - GOES-16,17

LEO = Low Earth Orbit (100-1,500 km)
MEO = Medium Earth Orbit (5,000-10,000 km)
GEO = Geostationary Orbit (36,000 km)
HEO = Highly Elliptical Orbit
ADS-B

- gr-air-modes (https://github.com/bistromath/gr-air-modes)
- gr-adsb (https://github.com/wnagele/gr-adsb)
Advanced Television Systems Committee (ATSC) standards are a set of standards for digital television transmission over terrestrial, cable, and satellite networks. Free "Over-The-Air" TV
ATSC Pilot Carrier
ATSC Passive Radar
ATSC Passive Radar
ATSC Passive Radar
ATSC Passive Radar
ATSC Passive Radar
ATSC Passive Radar
ATSC Passive Radar
ATSC Passive Radar
ATSC Passive Radar
ATSC Passive Radar

Parameter
ID: gain
Value: 50
Type: Float

Parameter
ID: freq
Value: 6264 M
Type: Float

Parameter
ID: firs
Value: -1k
Type: Float

Parameter
ID: logi
Value: -70
Type: Float

Parameter
ID: zmsg_addr
Value: tcp://9999
Type: String

Variable
ID: los
Value: finds low point 1.0...

UHD: USRP Source
Device Address: localhost
Sample Rate (Sps): 2M
Ch0: Center Freq (Hz): 6264 M
Ch0: Gain Value: 50
Ch0: Antenna: RX2
Ch0: Bandwidth (Hz): 56 M

Frequency Xlating FIR Filter
Decimation: 30
Taps: 50
Center Frequency: 309k
Sample Rate: 2M

Rational Resampler
Interpolation: 1
Decimation: 50
Taps: 60
Fractional BW: 0

Any Block
Desc: [baz block]
Maker: baz.aver..ffsize:32

Stream to Vector
Num Items: 4,096k

Keep 1 in N
N: 4
Vec Length: 4,096k

FFT
FFT Size: 4,096k
Forward/Reverse: Forward
Window: hann(fftsize)
Shift: Yes
Num. Threads: 2

Complex to Mag
Vec Length: 4,096k

Log10
m: 20
k: -30
Vec Length: 4,096k

Float To Char
Vec Length: 4,096k
Scale: 1

ZMQ PUB Sink
Vec Length: 4,096k
Address: tcp://9999
Timeout (msecs): 100
Pass Tags: No
ATSC Passive Radar
ATSC Passive Radar - Planes
ATSC Passive Radar - Planes
ATSC Passive Radar - Planes
ATSC Passive Radar - Cars
$ ATSC Passive Radar - Planes - Web
ATSC Passive Radar - Planes - Web
ATSC Passive Radar - Planes - Web
$ ATSC Passive Radar - Planes - Web
$ ATSC Passive Radar - Planes - Web
$ ATSC Passive Radar - Planes - Web
ATSC Passive Radar - Planes - Web

[Image: Two screens showing radar data and a map of Las Vegas with aircraft symbols.]
$ ATSC Passive Radar - Planes - Web
$ ATSC Passive Radar - Planes - Web

ATSC Passive Radar

Planes

Web
ATSC Passive Radar - Planes - Web
ATSC Passive Radar - Planes

demo.ettus.com

During GRCon18 Only
Applications include:
- Spectrum sensing/monitoring
- SIGINT
- UAV datalinks
- Drone defense
- TDOA/DF
- UE emulation
- Rapid prototyping
- And many more!

Key features include:
- SWaP friendly
- Standalone operation
- 10GbE to host PC
- 2x2 MIMO
- Remote management/networking
- Xilinx Zynq 7045
- 70 MHz - 6 GHz Frequency Range
- 56 MHz instantaneous bandwidth
- GPSDO

Come see it live at the Ettus booth!
Future Magicwands

Please come talk to me if you have these requirements for future magicwands!

- Phase coherent systems
- Lower latency
- Wider bandwidths
- Lower frequencies (HF)
- Higher frequencies (uWave, mmWave)