

RTL-SDR TUTORIAL: How to receive Meteor-M N2 LRPT Weather Satellite images in VHF with an RTL-SDR dongle.

On July 8, 2014, Russia orbited its latest version of a weather-forecasting and remote-sensing satellite, known as Meteor-M No. 2 (NORAD ID: 40069/Int'l Code: 2014-037A).

The Meteor-M-2 satellite is a Roskosmos/Roshydromet/Planeta (Moscow, Russia) follow-on polar-orbiting meteorological mission prior to Meteor-M-1 (launch Sept. 17, 2009).

Overall objectives of the Meteor-M-2 mission are to provide global observations of the Earth's surface and its atmosphere.

Designed lifetime to operate in orbit are five years.

The 2,778-kilogram Meteor-M No. 2-1 satellite was designed to watch global weather, the ozone layer, the ocean surface temperature and ice conditions to facilitate shipping in polar regions and to monitor radiation environment in the near-Earth space.

The payload package onboard Meteor-M No. 2 includes:

Multi-channel imaging scanner, MSU-MR

Multi-channel imaging complex, KMSS

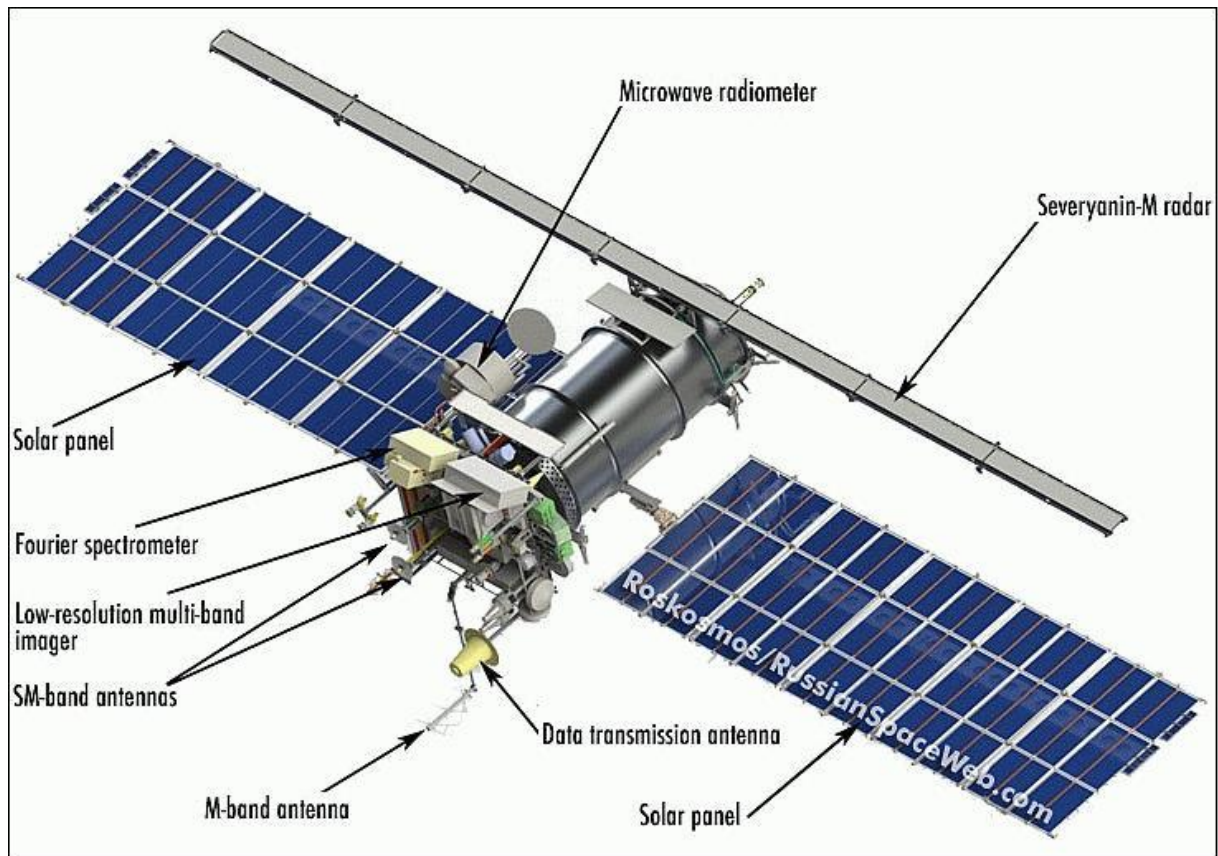
Ultra-high frequency temperature and humidity radiometer, MTVZA-GYa

Infrared Fourier spectrometer, IKFS-2

Radar complex, BRLK Severyanin

Heliophysics instrument complex, GGAK-M

Radio relay complex, BRK SSPD



So far it has been active only with a digital Lrpt downlink on 137 MHz band, not compatible with Analog Automatic Picture Transmission APT signal (NOAA) because it is a QPSK digital signal with a speed of 72 or 80 Kilo symbols per second.

Thanks to the wonderful input of these following people: Raydel Abreu Espinet (Guide), Oleg (LRPToffLineDecoder), Martin Blaho (Linux Scripts), Paul from Australia (LrptRx).

It's possible during the commissioning test phase of Meteor to receive with a rtl-sdr dongle (combined with a good antenna) , SDRSharp and a few decoding programs used to display a live weather image of your area!

Guide By Raydel Abreu Espinet.

Antenna:

RTL-SDR dongles has commonly poor sensitivity and usually suffer from out-band de-sense due to strong signals causing saturation on ADC.

A good antenna like a QFH or a crossed dipole is recommended.

A narrowband tuned pre-amp for 136-138 MHz will help to overcome the low signal and attenuate out-band interference, but may be worst if in-band interference exists.

Receiver:

An SDR device capable of handling at least 150KHz wide signals is required to handle the 72KSymb/s or 80 KSymb/s QPSK image.

However the scope of this text is focused on cheap USB dongles based on RTL2832U chipset.

Other SDR devices or professional satellite modems may work.

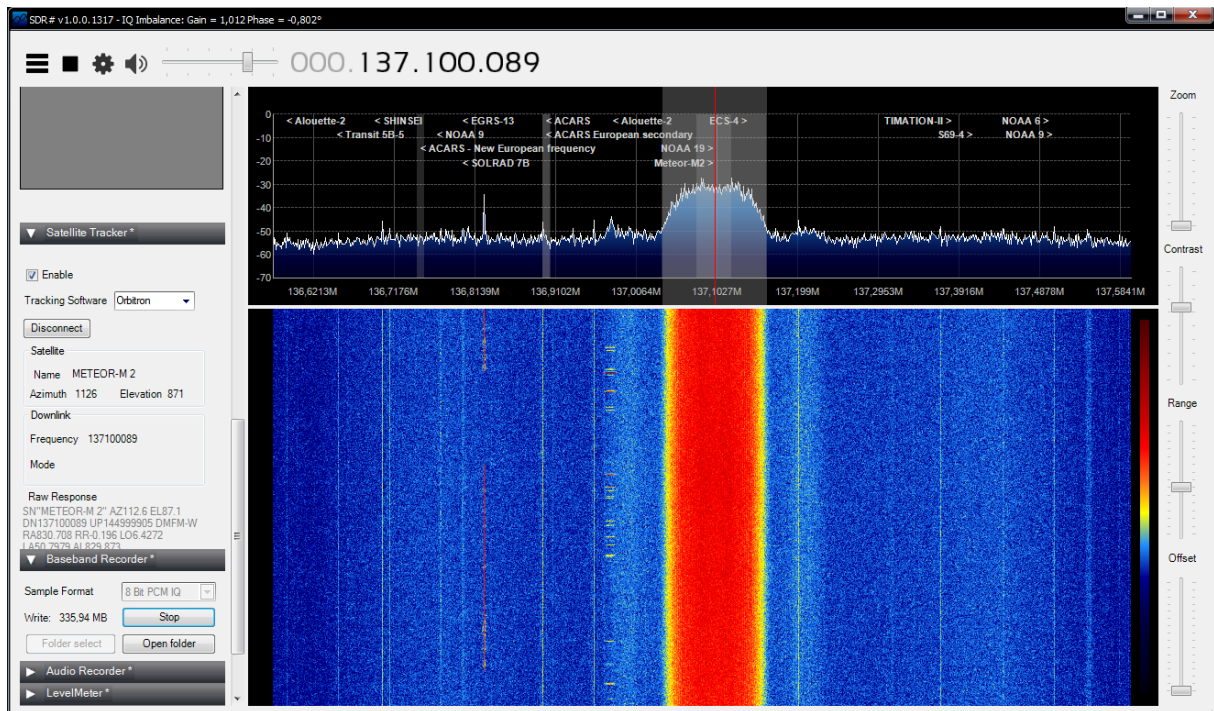
Two different dongles were tested an Ezcap 645 with an FC0013 tuner and a generic RTL2832 with an R820T tuner both produced excellent imageries, but R820T may required more external amplification due to USB bus noise.

A “Windows only” procedure (Offline decoding)

In order to view imagery, first we need to record a baseband I/Q WAVE file.

It is recommended to use a 0.900 MSPS sample rate at the RTL2832U dongle and maximum (192 KHz) for the Funcube Dongle (FCD), or something near 130 or 150 KHz if you use a different SDR.

You may use your favorite SDR program but I prefer SDRSharp (<http://sdrsharp.com/>).



The satellite downlink frequency 137.100 or 137.900 has to be chosen as center frequency (137.100 MHz / 72K Symbolrate is currently in use).

It doesn't matter what audio mode, volume or VFO frequency is chosen,

because we are recording base-band data centered on the main downlink there is no need neither to do Doppler tracking.

Always use "Correct IQ" and off-set tuning if available.

To improve constellation quality a lesser bandwidth is recommended if you are using an RTL.

In order to do it we can use the free audio handling software Audacity (<http://audacity.sourceforge.net/>).

Open the recorded WAV file with it, and then at the left-bottom side change the sample rate to 130000 (130 KHz).

We can also remove and crop sections at the beginning and end of the recording where signal was low if required.

To save the file, proceed to the File menu, hit Export, select WAV as format, and save it.

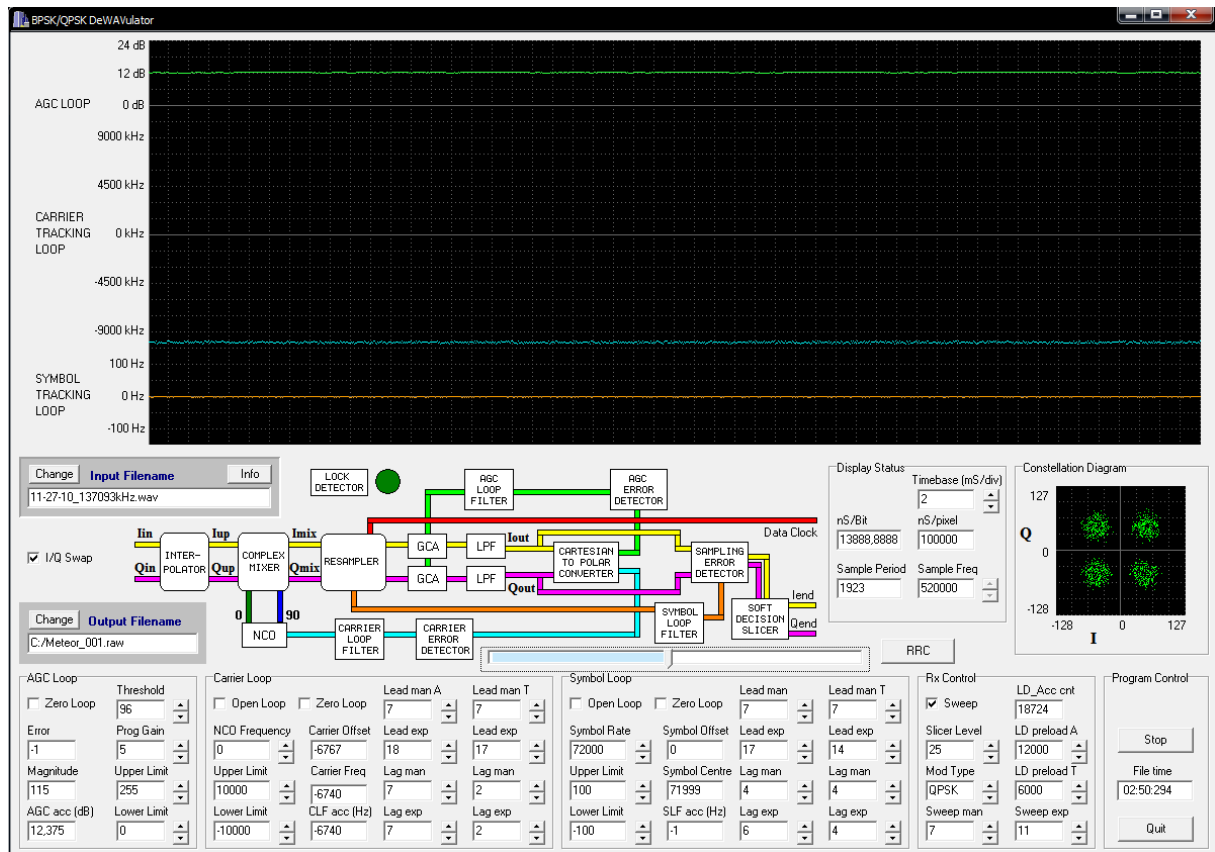
We can then delete the original file to save space on hard disk (a 12 minute pass at 900 KHz sample rate takes more than 1GByte of space).

This step is not needed for the FCD, or other SDR with a sample rate lower than 200 KHz.

To process the WAV file we need to download this file:
<https://www.dropbox.com/s/qq1fjyitpa3j14o/software.zip>

Now we open LrptRx.exe (the other two programs are not needed*), load the new wav file (insome cases Swap I/Q should be selected, at least when recording with SDRSharp it has been always required).

We hit run and manually move the progress slider to the center where signal should be the best.



If we obtain a well defined 4 dots constellation, everything is OK, close the program, re-open it and process the entire file.

If at the middle the constellation looks like an X or a square, try changing symbol rate from 72000 to 80000, if constellation is achieved with 4 dots, then the satellite is on 80K mode and therefore no decoding can be done with Paul's programs.

It is important to know that when reached the end of the file LrptRx will run forever, unless we manually stop it, so keep an eye on the progress slider.

We can change the destination and name of the RAW file if desired; otherwise the program will save it on hard disk letter C:

To extract image from the RAW data we need Oleg's decoder version 6 or higher and it can be found here: <http://meteor.robonuka.ru/soft/>

Oleg's program produces superb color images that can be saved in high resolution !

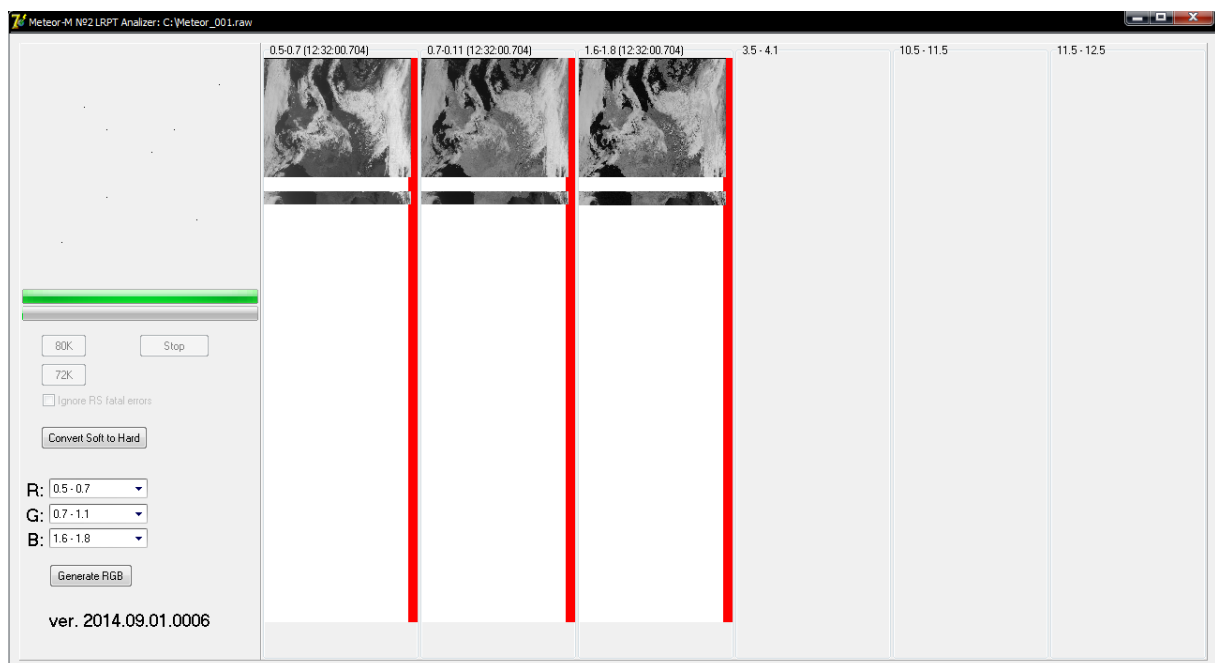
(Under some conditions it may be a good idea to check the "Ignore RS fatal error" option).

Then hit 72K or 80K button depending of the received symbol rate.

Browse for the RAW file and open.

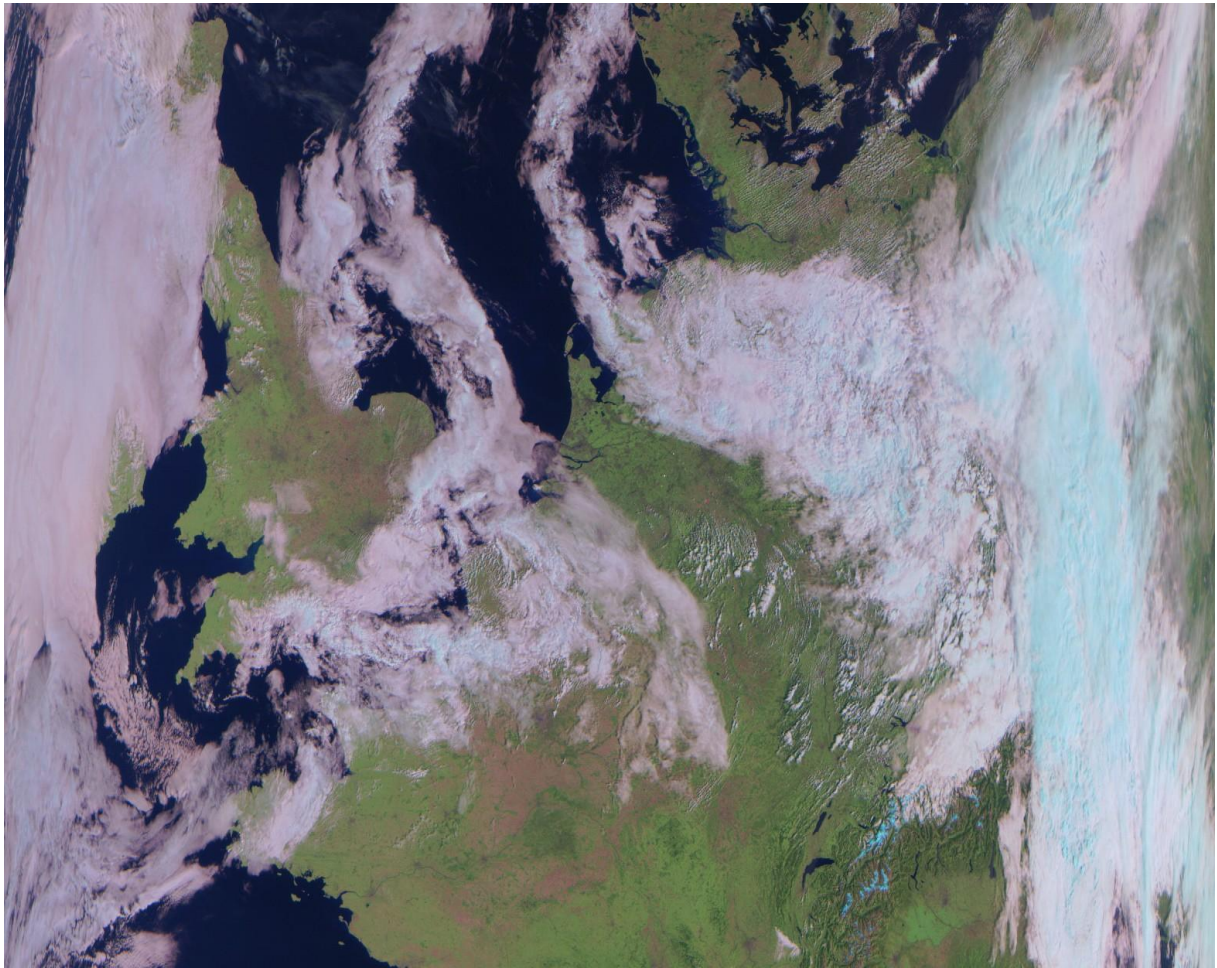
If you don't find the file, you can select "All (*.*)" in the file type filter.

Now the program will begin to process the file.

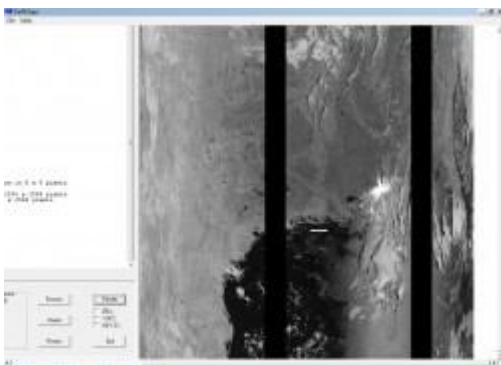


After finish the processing, you can click on the "Generate RGB" button to see the result.

In the new window hit "Save" to keep the image, it will be stored in the same folder that contains the raw file.



*Paul's software was made for Meteor-M N1 (not active) which has different image structure than N2 so several image artifacts like two black rows, and others are visible when used to decode N2 imagery, but some pictures can be obtained.



But the programs were designed for experimental and learning purposes so there is no method to save the image or see it entire in full resolution.

Also it is only compatible with the 72K mode, so the 80K mode cannot be decoded.

However, this process can be slow and take some time because there are multiple steps.

First record the entire pass into a WAV file (10 to 15 minutes).

Second, re-sample if using an RTL (7 minutes, or not needed if using less than 200 KHz bandwidth).

Third, extract symbols, which take around half the length of WAV file (usually 7 minutes).

And finally process imagery (up to 5 minutes).

If you want to remove some steps and proceed direct to real-time reception and store symbol data you can use a simple Linux based receiving program.

The process takes much less time because steps of recording, re-sampling and symbol extraction are done at the same time during the satellite pass.

A “Linux/Windows” procedure (fast):

First we need a Linux version that already has all the required libraries pre-installed:

<http://downloads.gnuradio.org/releases/gnuradio/iso/>

After downloading the ISO file we need to install it into a 4GB or bigger flash drive with this program:

<http://www.pendrivelinux.com/universal-usb-installer-easy-as-1-2-3/>

It is recommended to add a persistence file to store and save the changes; otherwise the configurations will be lost every time we boot.

Calculate the size of the file depending of your flash drive capacity and the fact that Linux will take at least 2.5GB.

Then copy the .PY files contained on this ZIP to your hard drive or a different flash drive.

https://www.dropbox.com/s/par34n42m1r68k3/meteor_rx.zip

Connect the Linux flash, and reboot computer, command your PC to boot from the USB and wait for Ubuntu to load.

It will said after booting that some error was detected, just click cancel and proceed to the indicated steps in the readme.txt file found inside the meteor_rx.ZIP

After running the app you should see a spectrum in the window showing data, if no signal or spectrum is shown, probably the RTL or FCD was not recognized.

The programs are my own edited version from a script written originally by Martin Blaho, I changed some parameters and things to adapt it to my station conditions, so in case of

problems it is my fault, but I guess that it should run equally good in other stations.

Unfortunately some users have reports that the Linux script for FunCubeDongle (FCD) doesn't work.

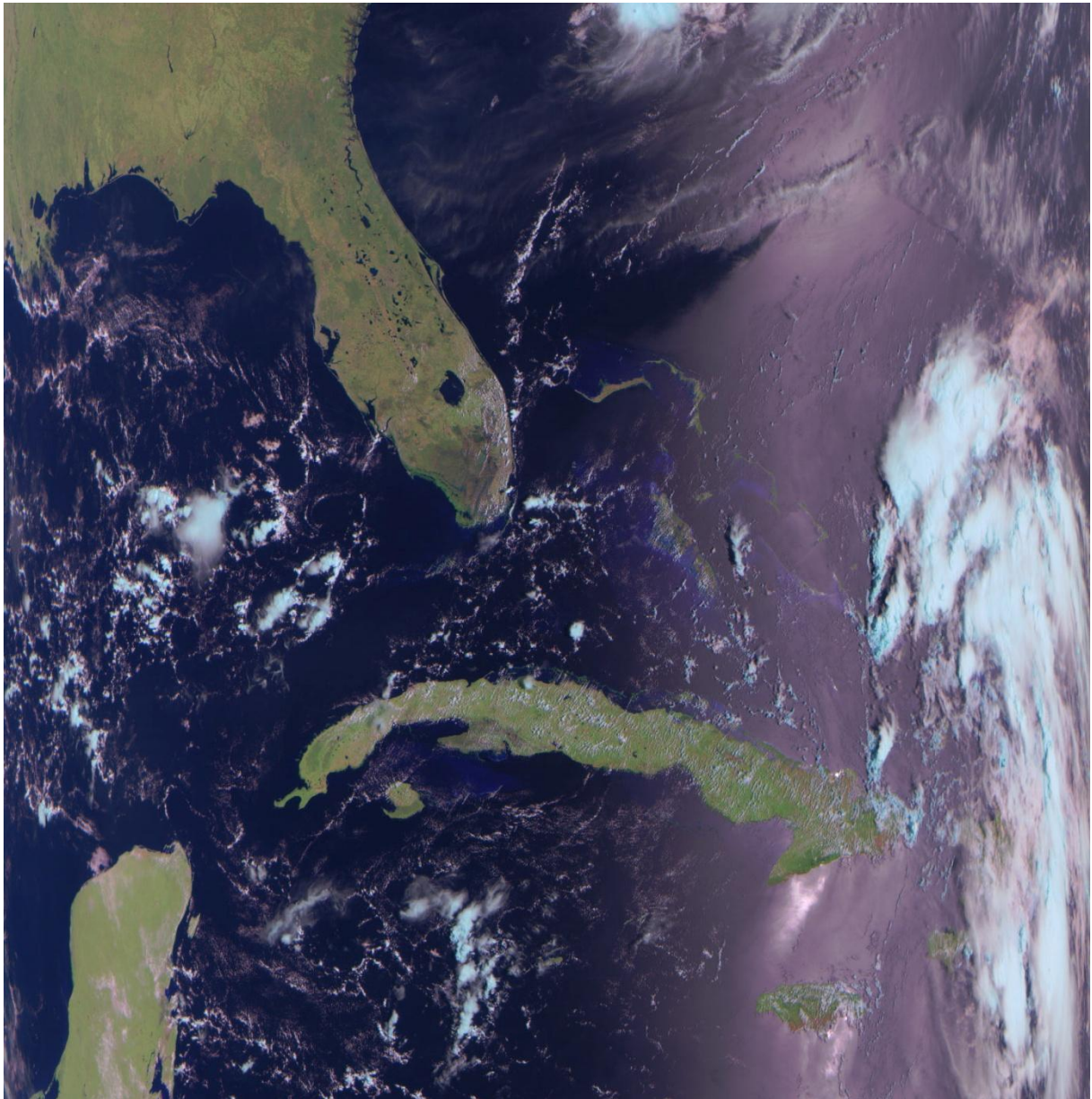
Main concern is regarding the frequency correction ppm value of each RTL dongle and proper gain value for FCD, so probably in other people computer, the downlink frequency can be 5 to 10

KHz up or down the nominal, or a different gain should be needed.

When the signal to noise ratio in the spectrum from Meteor satellite transmission is above 5dB, go the second panel and look at the constellation, if it looks like a circle, increase PLL alpha, as soon as it is formed by four dots (even if spread), reduce the PLL alpha until reach value "1m", if you suddenly lose lock and it become a circle again then increase it, but always try to keep it as low as possible. There is no need to change Clock alpha. Keep receiving until the end of the pass, and then close the program.

The soft-decision symbol file and a WAV file (only needed for debugging and testing purposes) are saved in Linux desktop.

To be able to open the file, we have to copy the .s file to our hard disk or second flash drive, and then we can re-start the computer without Linux flash and open Oleg's program decoder to extract the images and build the color composite.



In the first icon at the top left section we can search other installed Linux programs.

You can look for “gpredict” which is a satellite tracker, after downloading a fresh set of keplers and updating our coordinates and adding Meteor-M N2 satellite to the list we will be able to see the time of satellite pass as well as its current position.

All of these steps will be lost if we didn’t created a persistence file.

Note The Meteor satellite has 3 visual channels and 3 IR channels, but LRPT only supports 3 channels each time.

The satellite has to be commanded to change from visual to IR after passing the terminator line (day/night), but at the moment only black images are during night.

But in a very very clear cloud free evening you can take the black picture and open it with an image editor program to change bright/contrast and with a lot of luck you may be able to see some brighter points from the city lights!!!

To track Meteor-M N2 in windows:

Orbiton <http://www.stoff.pl/>

Heavensat - program for visual observing of artificial satellites.

Also available some additional tasks: passes prediction, calculation of satellites.

<http://www.heavensat.ru/english/>

The file: <http://www.celestrak.com/NORAD/elements/weather.txt>

Online trackers:

http://www.satview.org/?sat_id=40069U

<http://www.n2yo.com/satellite/?s=40069>

Raydel's How to receive Meteor-M N2 LRPT Weather Satellite images in VHF with an RTL-SDR dongle (Windows/Linux) PDF File - https://www.dropbox.com/s/4l44gftmc770gvj/meteor_rx_guide_v2.pdf

Operator - http://planet.iitp.ru/english/index_eng.htm

Weather satellite/Discussion - <https://groups.yahoo.com/neo/groups/weather-satellite-reports/info>

Weather satellite status reports <http://homepage.ntlworld.com/phqfh1/status.htm>

Meteor M2 Technical details:

<https://directory.eoportal.org/web/eoportal/satellite-missions/m/meteor-m-2>

<http://www.spaceflight101.com/soyuz-2-1b--meteor-m-2-launch-updates.html>

http://www.russianspaceweb.com/meteor_m2.html

Note - During the commissioning test phase its possible that Meteor M N2 is transmitting with 80 KiloSymbols and not 72K (International Mode) using an unique word inserted (ecnrypted system only can decode) or broadcasting fill packets, no image data, and only a bytes values of zero is being sent..

Planeta can only receive data within the range off its network of stations, and they are very excited to have reports of other area's of the world which can be submitted to the,

Meteor-M N2 LRPT Gallery, images from all over the world collected - <http://meteor.robonuka.ru/>

Thanks fly out to Raydel Abreu Espinet CM2ESP (Guide), Oleg (LRPToffLineDecoder), Martin Blaho (Linux Scripts), Paul from Australia (LrptRx)!

