Frequency Calibration of the FUNcube Dongle (FCD) Using NAVSPASUR Moon Reflections

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When using the FUNcube Dongle and SDR-Radio software: http://www.sdr-radio.com/Download/tabid/178/language/en-GB/Default.aspx to receive reflected NAVSPASUR moon returns on 216.980 MHz, the frequency calibration or correction factor of the FUNcube Dongle (FCD) is normally accomplished by adjustment of the correction factor number in the FUNcube SDR-Radio frequency column where numerous other adjustments can also be applied that effect its operation.

This procedure will only address the frequency calibration of the unit, including a brief overview of typical NAVSPASUR moon reflections and the software used to record them. The FCD adjustment is made using the very stable and accurate NAVSPASUR signal itself to determine the actual FCD offset or correction factor to match the transmitter frequency.

Since most receiving locations do not normally allow direct reception of the NAVSPASUR carrier frequency due to the distance involved, this method can be used to correct the FCD frequency that should be available at considerable distances limited only by the inability to have a clear line of sight of the moon at both the receive location and at the NAVSPASUR CW transmitter at the same time. In this example, the receiver is ~ 700 + miles from the Texas transmitter source. If your location is close enough to receive the signal directly, you may skip this procedure, measure and set the FCD frequency by comparing it to the very accurate transmitted signal.

By using the NAVSPASUR return moon signal reflected back to the receiver, provides an alternate choice for FCD frequency calibration if no other known reference is equal to or less than 1 ppm accuracy is available, or if there is unknown certainty of a reference signal frequency accuracy that has been used to set the FCD previously.

The adjustment or correction required to the FCD insures accurate frequency calibration assuming a reasonable constant and stable FCD environment temperature, and a minimum FCD on time of 1 hour stabilization time to allow presetting of the excellent low level signal software such as Argo in QRSS mode (FFT bin size of .366Hz bandwidth) is within its limited frequency range total of 170 Hz or (+ - 65 Hz) where the returned NAVSPASUR signal will be located for recording.

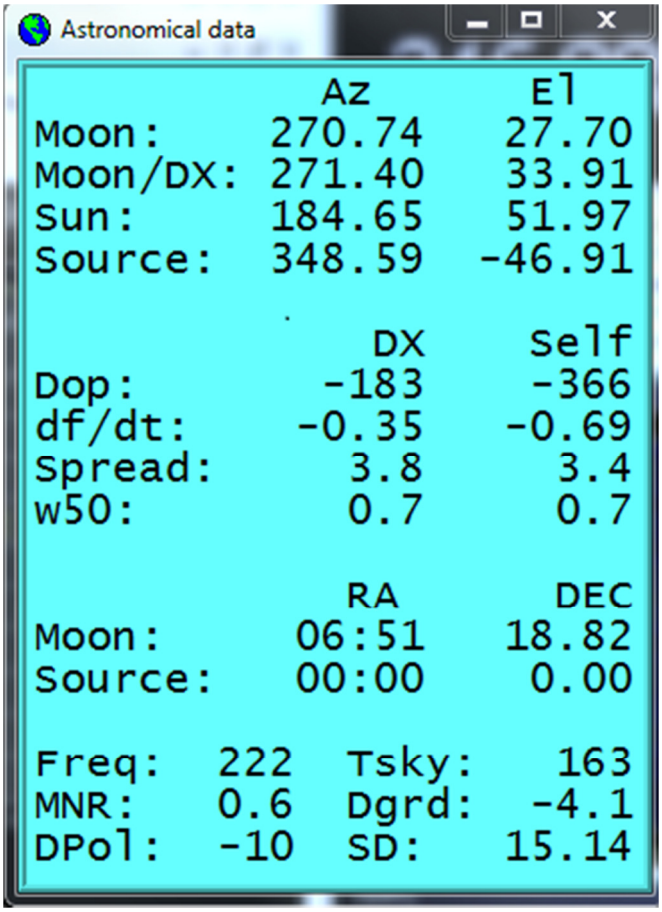
This procedure also assumes in addition to SDR-Radio, the software packages WSJT: http://physics.princeton.edu/pulsar/K1JT/wsjt.html and Argo: http://www.weaksignals.com/ are downloaded on the computer used for FCD NAVSPASUR measurements.

Due to the significant Doppler shift of the returned moon frequency of the NAVSPASUR transmitter (direction dependent if receiving an ascending or descending moon) of + or - several hundreds of Hz, it also must be included in the determination of the actual FCD receive frequency calibration. As demonstrated in the following example, a measurement will have to be made using the current state of the FCD frequency accuracy first using this alternate procedure to determine and correct any FCD frequency accuracy setting error.

There are three known frequencies to work with initially, that being the NAVSPASUR signal itself at 216.980 MHz, the frequency display readout of the SDR-Radio enabled for the FCD that is used, and the known Doppler + or - offset of the received moon reflection at that frequency during the actual time of reception.

The actual moon Doppler offset can be determined from other sources, however in this procedure example, it is conveniently derived from the WSJT software program directly by first setting the NAVSPASUR grid square to EM03ON, or the elevation, longitude and latitude parameters for the Texas site location including your observation site grid square or your elevation, latitude and longitude data, along with the band setting to 222 (the closest frequency band that WSJT provides).

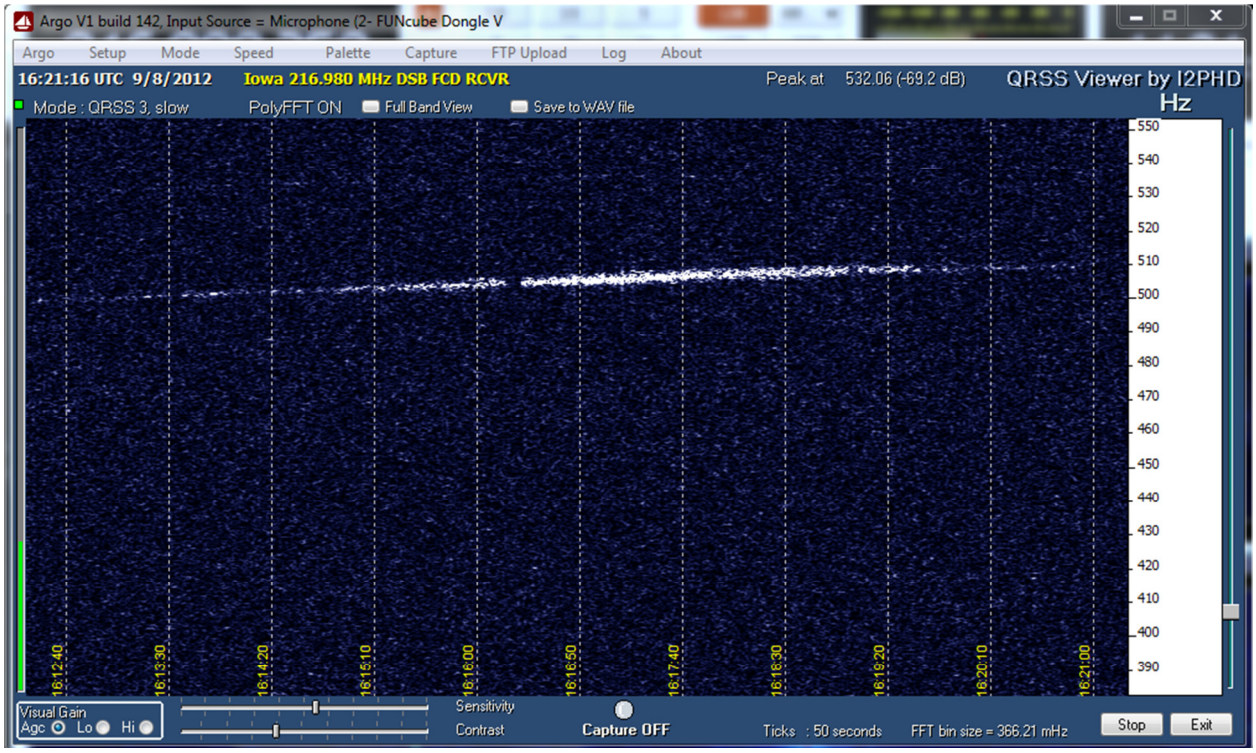
After entering the required position data in SDR-radio and WSJT for both locations, pressing View, Astronomical data, Dop: then reading Self in the WSJT Astronomical data chart will provide at that time, the actual moon Doppler offset in + or – Hz from the 216.980 MHz NAVSPASUR frequency. Under the heading Moon/DX, WSJT will also show the current moon Az and El at the Texas site at that time.



Noteworthy also, at the midpoint (maximum return signal) of the NAVSPASUR transmitter moon reflection occurs when the moon at the NAVSPASUR site is either at azimuth 91.4 (moon ascending) or at 271.4 degrees (moon descending) due to the inherit fixed alignment of the Texas NAVSPASUR transmitting antenna beam.

Noticeable and measurable moon reflected signal levels are also present before and after these maximum azimuths, amounting to several minutes in duration at times when the moon is at the higher elevations relative to the NAVSPASUR site location.

An example of an actual descending FCD NAVSPASUR moon reflected signal frequency measurement is accomplished as follows:



The three frequencies used are: NAVSPASUR at 216.980 MHz, the SDR-Radio display indicating 216.980000 MHz, and the actual moon Doppler frequency data of -366 Hz for this location derived from the WSJT Astronomical data chart.

The moon Doppler offset measured a frequency of -505 Hz is indicated at the beginning of the trace on the Argo spectrum display when the SDR-Radio frequency is set to 216.980000 MHz. Now that all frequency elements are known, the actual FCD error can be calculated by:

1. 216.980000 MHz - .000505Hz = 216.979495 MHz (SDR-Radio display - the measured offset frequency)

2. 216.980000 MHz - .000366 Hz = 216.979634 MHz - 216.979495 MHz = 139 Hz error (NAVSPASUR - moon Doppler - the measured offset frequency)

The FCD calculated frequency error is 139 Hz low when set to 216.980000 MHz when it is actually receiving at 216.979864 MHz (the FCD frequency setting after the above calculations have been applied)

Finding that the FCD receive frequency is 139 Hz low; a correction factor has to be entered in the FUNcube Frequency correction column mentioned previously. The FCD frequency correction is set in ppm and is typically set to ~ -18.00 ppm as in this case. If the correction factor is set to 1ppm further, the FCD frequency will be offset another 216.980 Hz up from 216.979864 MHz, resulting in a small reasonable error of 81 Hz which will set the FCD to a frequency of 216.980081 MHz, a modestly corrected, acceptable FCD frequency accuracy considering it is operating in a relative uncontrolled temperature environment.

Even this 81 Hz error can be negated by applying an additional 139:217 = .64 ppm to the current existing -18.00 FCD correction factor by making it -18.64 by using the up/down arrows should bring it spot on frequency with the NAVSPASUR transmitter. This usually concludes the FCD frequency calibration unless it is desired to obtain further short and long term accuracy by addressing a controlled temperature stabilization of the unit.

There is a remaining additional error however that is not compensated for in this procedure that is an artifact of the WSJT fixed frequency band being set to 222 MHz rather than the operating frequency being considered of 216.980 MHz. Since the FCD is operating at 5 MHz below 222 MHz for this application, the moon Doppler will be less by 2.25 % or 8.235 Hz. For accuracy sake, one could use 358 Hz instead in step 2 for the actual moon Doppler frequency replacing the 366 Hz entry for further calibration accuracy if required.

For FCD in depth frequency stability measurements conducted by George Smart, M1GEO, his findings include short and long term drift characterization at:

http://www.george-smart.co.uk/wiki/FunCube_Dongle_Frequency_Stability

Your FCD receiver is now calibrated by the use of the NAVSPASUR moon reflected signal itself.

DC-REV.006 10-02-12