A New Method for Microwave EME Doppler Shift Compensation

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Introduction

A new hardware/software solution for EME Doppler compensation is described, applicable equally to CW/SSB and digital modes. A CAT radio is not required.

On the higher microwave bands, EME signals that are capable of making contacts are often so weak that they are both inaudible and sometimes barely visible on a waterfall display. This makes accurate frequency setting essential, so that signals are tuned with sufficient precision to fall within the decoding tolerance of the software used, or optimum pitch for CW signals. It is highly desirable for the microwave local oscillator to be locked to GPS, or failing that to a high quality OCXO that has been calibrated against GPS. Also, if the main station radio has the capability to be locked to GPS, residual frequency errors will then be very small.

At microwave frequencies, the Doppler shift over the EME path can be very high, typically up to 10-20kHz at 10GHz. The amount of Doppler shift is proportional to frequency, eg is 2.4 times higher at 24GHz compared to 10GHz. While it is possible to make digital EME contacts by manually compensating for the Doppler shift, this has the disadvantages of both not being sufficiently precise, and also requiring almost constant operator inputs. VK7MO pioneered the use of computer controlled Doppler compensation (Ref 1), using software written by VK1XX, which made use of the Doppler shift figures calculated in real time by the WSJT software. WSJT writes a file "azel.dat" every second, which contains the Doppler shift to the specified DX station as well as for the home station, for the selected operating band .

A newly released version of WSJT (WSJT-X 1.6.0) (Ref 2) introduced the possibility for direct Doppler compensation in real time for a wide range of radios with CAT capability, together with two different methods of Doppler compensation. The accuracy of the Doppler calculations in WSJT-X is significantly higher than previous versions of WSJT, so that frequency setting to within a few Hz is now possible at 10GHz.

The most commonly used methods of Doppler compensation are "Full Doppler", where one station adjusts both their transmit and receive frequencies, so that their QSO partner does not have to do any correction (with their transceiver tuned to the "sked" frequency on transmit and receive all the time). This is very useful when one station does not have any automated Doppler compensation capability. If both stations can do Doppler compensation, a second method "Constant Frequency on the Moon" is preferred. In this, both stations adjust their transmit and receive frequencies either side of the "sked" frequency by their own *local* one-way Doppler shift. The advantages of this method are that no knowledge of the other station's grid locator is required (which is good for random operation), and other stations can monitor the QSO if they know only the sked frequency. It also allows use of a "centre of activity" frequency (xxxxx.200 has been proposed) which would promote random CQ operation. A further advantage is that both stations (if they have the system capability) can hear their own echoes at the end of their transmit period, if everything is working correctly.

While WSJT-X, using CAT control, has proved to be very effective for Doppler control, the system described in this paper was primarily developed to overcome the problem where your radio does not allow CAT control during TX. For this reason, and to add Doppler control modes more useful for sked and random CW/SSB operation, a different method of applying Doppler correction has been developed. In this new system, the main station radio is operated on a set frequency (eg 14.225000MHz) and the transverter's local oscillator frequency (eg 130MHz) is adjusted by the computer to allow for the Doppler, with 1Hz resolution. It is desirable, for maximum accuracy, that the controlled oscillator is referenced to GPS.

Implementation

A block diagram of the system is shown in Fig. 1.

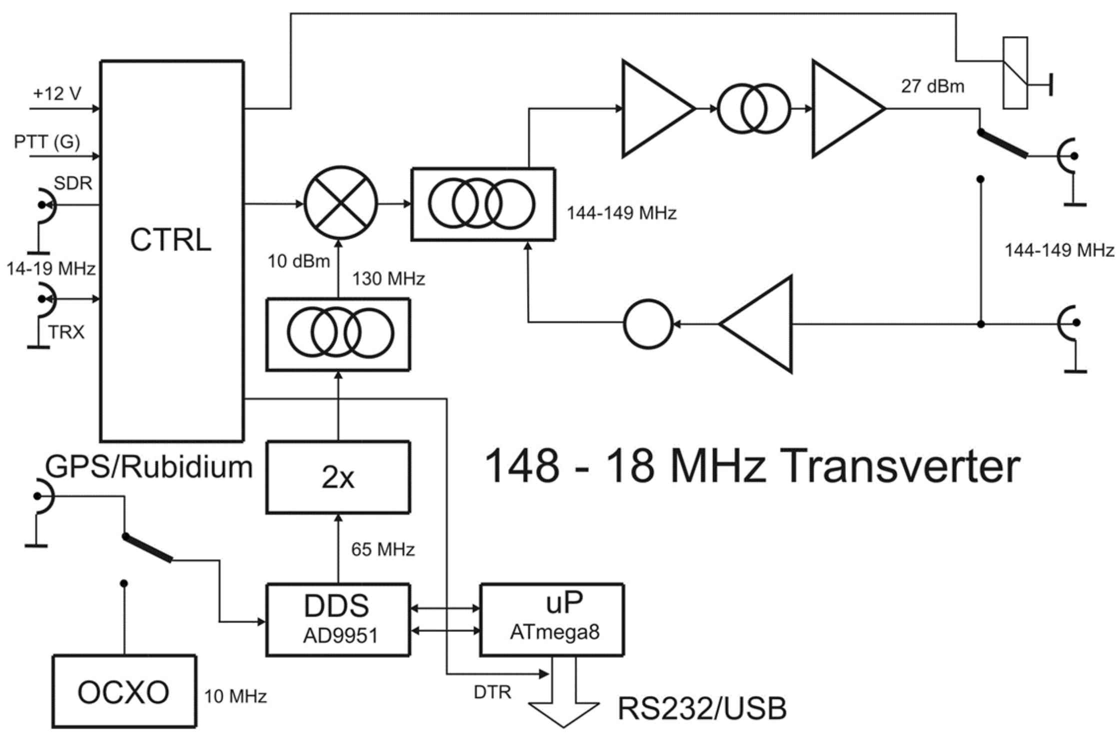

Fig 1 Block diagram of transverter using a DDS as tuneable local oscillator

The local oscillator signal is generated with a Direct Digital Synthesiser (DDS) using an AD9951 chip controlled by a software program called "Dopp", which was written in a MATLAB environment. Fig.2 shows the user interface (GUI) of this application.

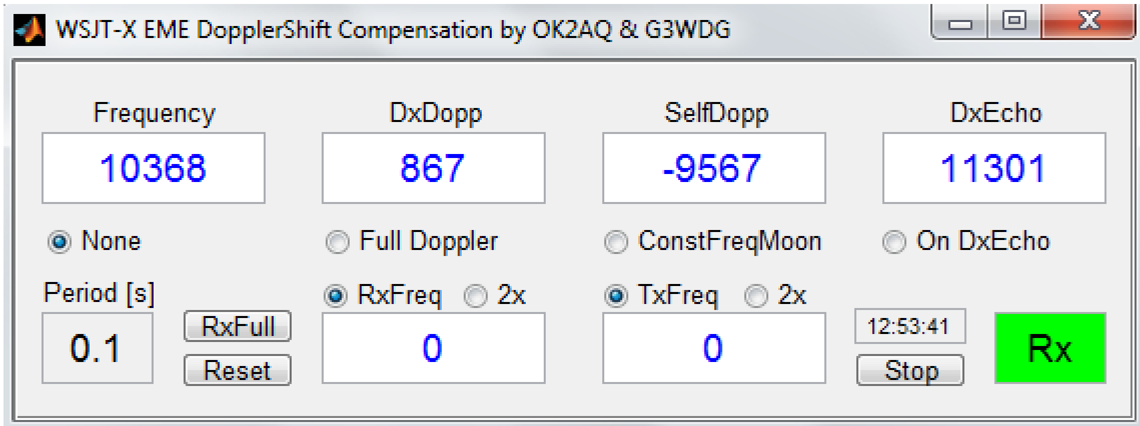

Fig 2 User interface of Dopp program

The frequency band, Doppler shift values (mutual two-way and self-two way), T/R status and time are read from WSJT or WSJT-X's azel.dat file. The DX station's locator needs to be entered into WSJT main window if 'Full Doppler' mode is used, and of course the correct frequency band also needs to be selected in WSJT. The displayed 'DXEcho' is calculated by Dopp as the two-way own-echo Doppler shift for the DX station. 'Period' displays the loop time (see below). 'RX Freq' and 'TX Freq' display the Doppler offsets (in Hz) that are calculated by Dopp and applied in real time in the selected operational modes.

Transmit/receive switching of the main rig is usually done via WSJT's PTT control in the normal way. Dopp can also be configured to switch between transmit and receive frequencies either by WSJT or by an external voltage input to the RS232 DDS interface (DSR line). Options are available to cater for either a positive voltage on RX or on TX. For digital operation Dopp would normally be controlled by WSJT, while for CW/SSB operation, the external option would be used. The external option enables Dopp to follow arbitrary timing of TX/RX sequences, so that when the rig is switched manually between transmit and receive the correct Doppler compensation will be applied by Dopp.

The T/R switching mode is set in a "Settings" window that appears when the program is started – see Fig 3. This window also allows the path to WSJT's azel.dat file to be set to suit local installations of WSJT, the COM port to be used by Dopp, baud rate, Dopp loop time, base DDS frequency, and multiplication factor used if the DDS frequency needs to be multiplied to get to the transverter's LO frequency. Normally 0.5 sec should be sufficiently frequent for the program loop time, but can be reduced can if desired (down to 0.1s), for faster response time, such as for echo testing.

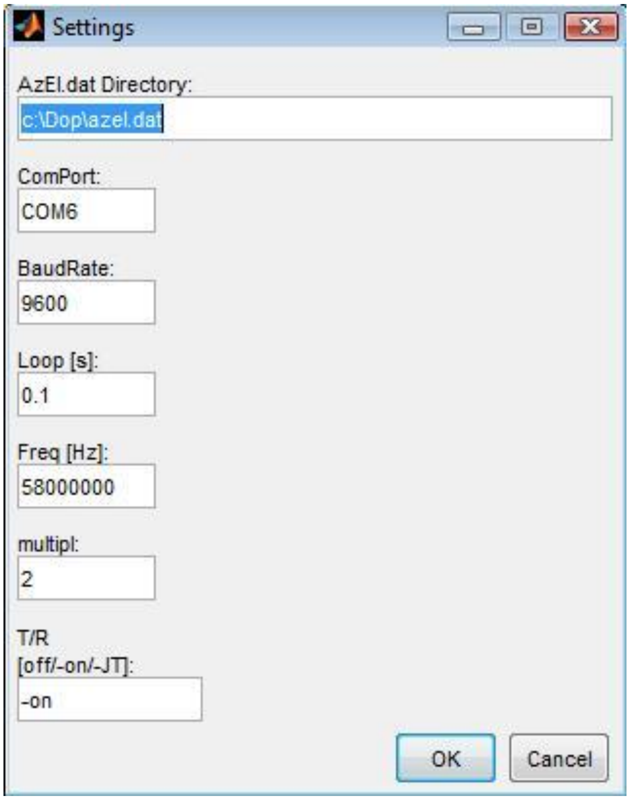

Fig 3 Dopp startup window

Methods of operation

As described above, for digital operation the most common Dopp operating methods are either no compensation, full Dopper or constant frequency on moon. These are selected by the appropriate radio button on the GUI.

The fourth radio button (On DxEcho) is used for other situations. One common scenario is that a station announces on the logger that they intend to call CQ on a specific frequency and listen on their own echo. The station's locator needs to be entered into WSJT. The radio is set to the frequency announced by the CQ station, 'On DXEcho' is selected and 'RXFull' button is pressed. Dopp will then tune and track to the correct frequency to receive the other station, and tune and track your transmit frequency so that the other station will receive you on their own self echo frequency. In addition, you will also receive your own echoes on the same frequency as you hear the other station. The GUI for this mode is shown in Fig 4.

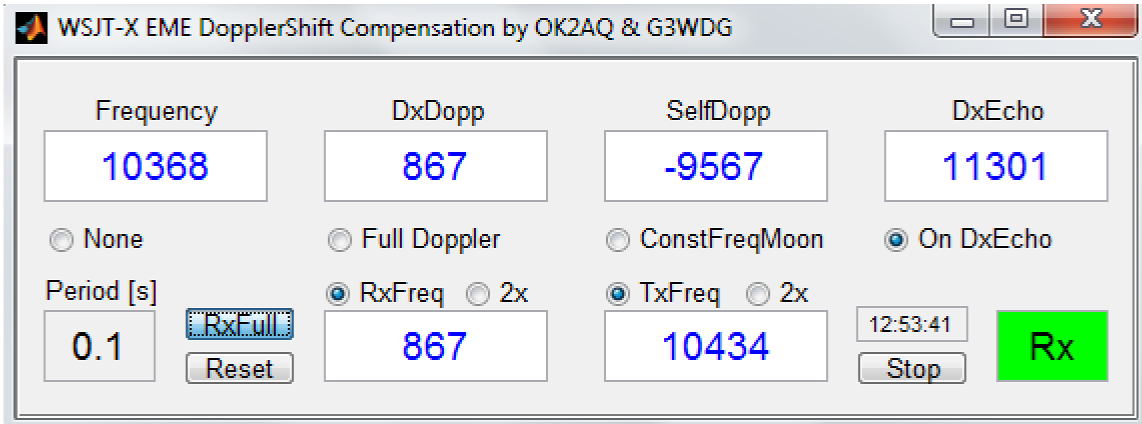

Fig 4 Settings for 'On DXEcho' operation when frequency is known beforehand

Another common situation is where you are tuning the band (with Dopp set to 'None') and identify a station calling CQ. To apply Doppler correction in this case, select 'On DxEcho' and press 'Reset'. These settings will keep your receiver tracking the other station, and will offset and track your transmit frequency so that the other station will find you on their echo frequency. You will also hear your own echoes. The settings for this method of operation are shown in Fig 5.

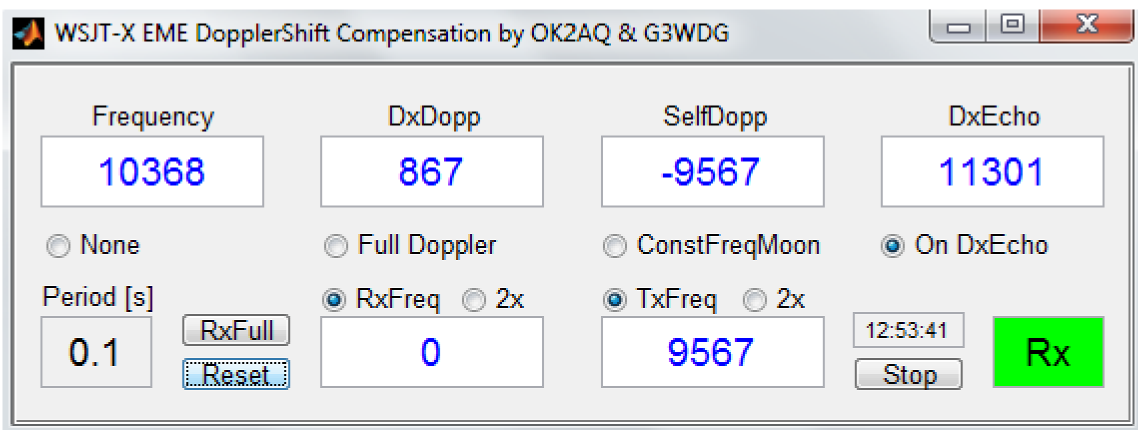

Fig 5 Settings for 'On DxEcho' for random operation after finding a station

In both of the above 'Dx Echo' methods, it is assumed that the other station is not using Doppler tracking.

Hardware

A photograph of the transverter with DDS local oscillator is shown in Fig 6. In this, the DDS and PIC controller (which converts the frequency set commands from Dopp) are on two separate PCBs. These have now been combined on a single board, which will be the subject of a later article.

Fig 6 Photograph of OK2AQ's transverter

On-air tests

Dopp has been tested on-air in all the operational methods described above and performed flawlessly. The authors would like to thank OK1KIR, VK7MO, HB9Q and WA3LBI for helping with these tests. In addition, it was tested in Constant Frequency on the Moon mode at G3WDG for own echoes, and the results are shown in Fig 7.

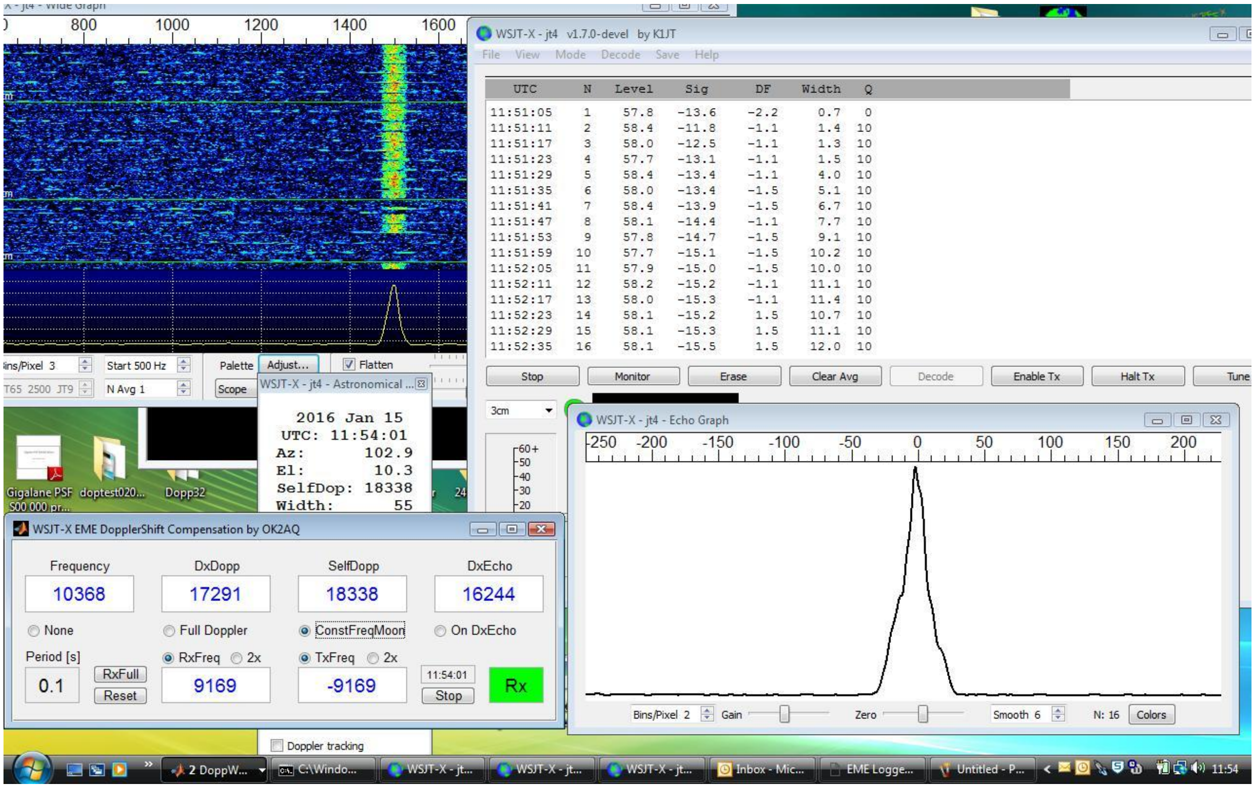

Fig 7 Dopp used on 10GHz in conjunction with WSJT-X Echo mode

In development

A number of other versions of Dopp have been written and are being evaluated. These include a version to control a CAT compatible radio (IC735) with full TX and RX Doppler compensation, using a fixed frequency LO in the 28/144 transverter. This offers no advantage over using WSJT-X for Doppler control for those JT modes that permit Doppler tracking, but does enable some JT modes to be used which do not otherwise have Doppler tracking capability. In addition, the Dopp methods more useful for CW and SSB can be then used.

We have also looked at ways of using CAT radios that do not allow their frequency to be controlled on transmit, by sending a frequency command to the radio during the time when WSJT is decoding the last received transmission (when the radio is still able to receive and process commands). The command sent at that time corresponds to the required transmit frequency midway through the transmit period. This leaves a small uncorrected “drift” during the transmit period but in most cases this is thought unlikely to degrade operational sensitivity to any significant extent.

A third development version of Dopp allows the nominal DDS frequency to set via user input to the GUI. In this way, the Dopp controlled local oscillator (either DDS or LMX2541 fractional N synthesizer) can function both as the primary radio tuning device, as well as applying Doppler correction. An application for this would be to use the controlled oscillator to replace the existing LO in a radio. This would upgrade a simple radio such as an IC202 to function as a computer controlled radio with 1Hz resolution locked to GPS.

The authors would like to thank Rex Moncur VK7MO for reviewing this article and his useful suggestions.

References

1. http://physics.princeton.edu/pulsar/K1JT/small_station_eme.pdf
2. http://physics.princeton.edu/pulsar/k1jt/wsjtx.html

Download links:

User guide: https://drive.google.com/file/d/0B116IwQIUFNTdFNNNUJJaVE5eFU/view?usp=sharing

Software: http://www.urel.feec.vutbr.cz/esl/files/EME/Doc/Dopp32.zip

(400 MB download - after unzipping, install MCRInstaler.exe first and then run Dopp32.exe)

Note: Dopp32.exe may take some time to load and run, especially the first time.

Matlab code: http://www.urel.feec.vutbr.cz/esl/files/EME/Doc/Dopp.m

Note: The Matlab code can be read with a text editor such as Wordpad, either by renaming it as a .txt file, or using Windows “Open with” and selecting Wordpad.