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# An Adaptive Noise Cancellation System for the HF Bands

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Noise cancellation prior to the antenna socket of a receiver is a well-established technique with several commercial devices available including the MFJ-1026, the NCC-2 from DX Engineering and the ANC-4 from Timewave. This method needs an auxiliary antenna, and means to match the noise amplitudes from the auxiliary and main antennas and alter the phase so that at a combiner the two noise components are 180˚ out of phase.

I've described a manual passive noise canceller using a switched attenuator and tapped delay line[1]. Results were encouraging, with noise reduction of 12dB possible on 7MHz. However, the optimum settings changed through the day, and from day to day. Those changes provided the motivation for this adaptive version currently configured to be compatible with WSPR reception.

### Key features

- Fully adaptive using closed-loop feedback control of delay and attenuator settings based on measured noise in a defined audio band.
- Usable from 80–10m. (40–15m in prototype).
- Delay and attenuator step size to give over 20dB noise reduction for a single source of small spatial extent.
- Front panel display of delay and attenuator settings.
- Compact aluminium case approx. 160x210x60mm.
- User interface with 3D display of noise with delay and attenuation, time-stamped .csv log file for diagnostics including noise levels, noise notch depth and width.

### System Overview

The diagram in Fig.1 shows the main components of the adaptive noise cancellation system. In this prototype:

- Both antennas are shallow inverted V dipoles.
- The motivation is to improve SNR for WSPR reception hence the receiver[2] output is fed to a USB audio interface connected to a Raspberry Pi 3. The Pi runs standard *WSJT-X* software and a custom set of Python and Bash shell scripts to implement adaptive noise cancellation.
- The relay-switched attenuator and delay lines are configured with powers-of-two steps: 0–7dB in 1dB steps, and 0–77.5ns in 2.5ns steps. Delay and attenuation values are set over the I2C bus from the Pi via I2C to 8-bit IO expanders. Simple front panel LED bargraph displays show the current settings in binary.
- WSPR transmissions last 110.6s starting 1s after an even minute within a two-minute frame, making available a 9.4s gap with no transmissions (in theory) within which noise measurements can be made. Currently it takes the gaps over three two-minute WSPR frames to step through all the delay and attenuator settings.
- Each measurement cycle comprises setting the relays, waiting 6ms for contacts to settle, acquiring 200ms of audio, an FFT analysis to find the noise amplitude within the 1400–1600Hz band and the discard of the top 20% amplitudes (a transmission may have over-run or started early, or there may be a non-WSPR signal present).
- Once a set of noise levels at the complete set of delays and attenuator settings has been gathered (currently every six minutes) the filtered noise profiles are updated, the optimum delay and attenuator settings found, ready to be applied for the next three acquisition cycles

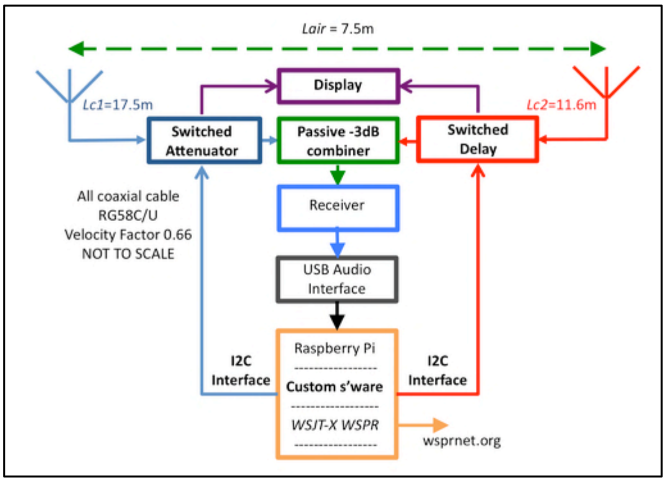


*Fig. 1. Block diagram of the main components of the G3ZIL adaptive noise cancellation system as applied to WSPR reception, September 2018.*

- The current filtered delay and attenuation profiles are stored as a .csv file and a Python program can plot a 3D representation from which the noise level and the depth of cancellation can be seen, Fig. 2. With experience of the local noise environment, one can infer direction from the delay setting and the spatial extent of the noise source(s) from the width and depth of the cancellation notch.
- While there is some interaction between the delay and attenuation settings, e.g. with coaxial cable delay lines longer delays mean greater attenuation in that path, the intersection of the minima for the delay and attenuator settings in Fig. 2 is a very good combined minimum.
- A notch width of 10ns or less between 3dB points is often seen at G3ZIL's location on 40m, implying a delay step size of 5ns (about 12˚ in phase) or less is needed to deliver the 20dB noise cancellation that is possible. On this basis, a step size of 1.25ns should be fine for operation to 10m.

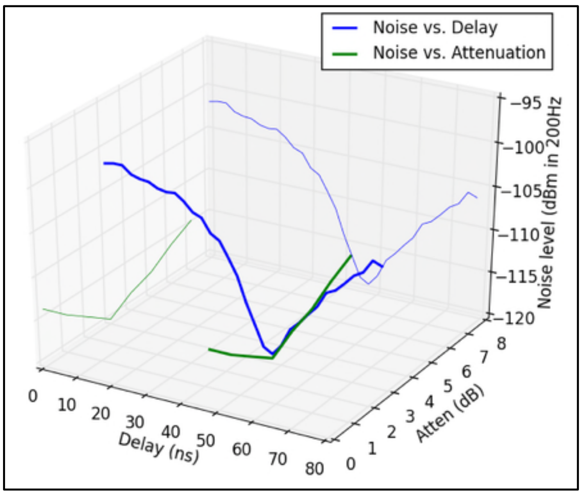


*Fig. 2. 3D representation of the noise levels with delay and attenuator settings. Here there was a single, spatially narrow noise source.*

[1] Griffiths, G., 2018. HF band passive noise cancellation, Practical Wireless, 94(9): 12-15.

[2] Griffiths, G., 2016. A Direct Conversion WSPR Receiver for 30, 40 or 60 metres. *Practical Wireless* 92(4): 30-35.

### Daily noise environment and noise canceller data

Filtered noise level profiles are appended to a .csv file suitable for post-processing, e.g. using Excel as here. Fig. 3 shows the wealth of useful information from the data logged by the adaptive noise canceller. Interpretation comes with experience of using the system, and each location may well be different, but the caption shows what can be gleaned from a day of data.

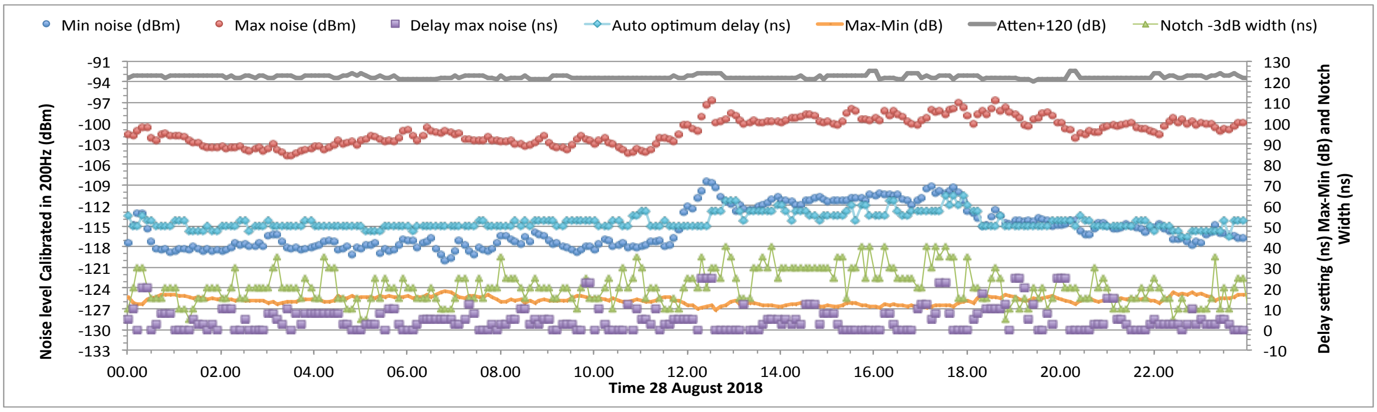


*Fig. 3. Example of a very good day's noise record: until ~1130 noise level after cancellation (blue) is as low as has been achieved so far at around -118dBm in 200Hz, the noise direction is steady, inferred from the delay setting (cyan), and the noise cancellation (orange) averages 14.9dB. After 1130 the pre-cancellation noise level is higher (red), as the noise level rises from 1130–1230 the notch width (green) increases, implying a greater angular extent, and the notch depth (orange) decreases, hence the post-cancellation noise (cyan) increases by more than the noise level has increased. While the noise level (red) is much the same from 1730–2000, there is a narrowing of the angular distribution after 1730 (green) resulting in a deeper notch (orange) and a ~6dB reduction in post-cancellation noise.*

### The longer-term noise environment

Fig. 4 shows another form of presentation, a form of contour plot of noise level with time and delay setting over a nine-day period. This shows a regular, approximately daily, pattern to the minimum noise obtainable and periods of high noise that have a relatively sudden onset and end. The wider spectrum available on an RSP1 SDR shows many of these high noise events to slowly drifting interference with bandwidths of 10s of kHz. Only on few occasions does the noise canceller fail to reduce the noise to less than-110dBm in 200Hz. It is intriguing that the most extensive period of low noise in this record, 26–27 August, was during and immediately following a G3 geomagnetic storm. It is possible that "band noise" was lower during that period.

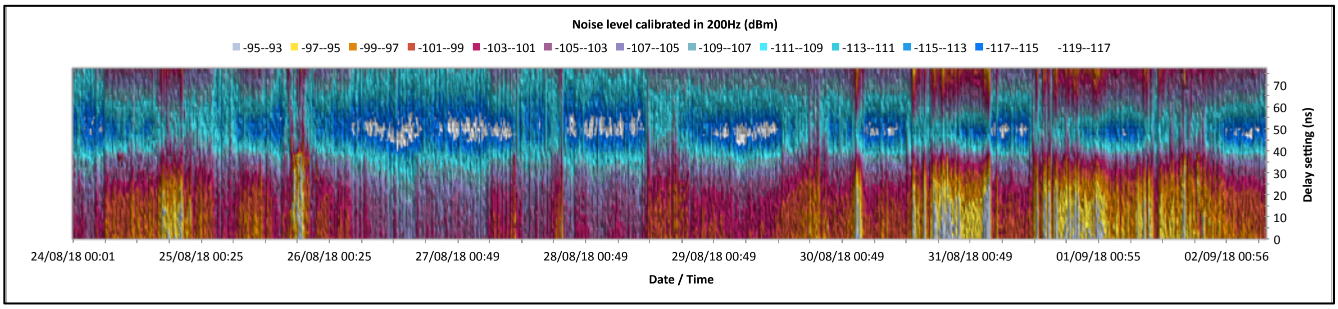


*Fig. 4. Nine days of noise level variation with delay setting shown as a contour chart. There is a regular, approximately daily, pattern to the noise minima around 50ns and the maximum around 0-10ns. Note that there was a G3 geomagnetic storm on 26 August, with Kp at 7 between 0300–0900.*

### Using the system to drive reductions in local noise level

With the consistent measurement capability of this system, Fig 5 shows the improvements in noise cancellation and average position in the 40m WSPR Challenge[3] for the following changes:

- Until 27 July (blue), manual noise cancellation with fixed delay and attenuator settings, 11m separation between the two antennas, first antenna 4m from the house.
- 29 July–3 August (red), same antenna arrangement, but now with adaptive noise cancellation.
- 4–23 August, adaptive noise cancellation but antenna spacing 7.5m, first antenna 7.5m from the house. Increased noise reduction probably due to smaller angular extent as first antenna further from the house.
- 24 August – 2 September, as previous but with my 60m dipole and its feeder into the house taken down. Increased noise reduction from less house-originating noise coupled to the outside.

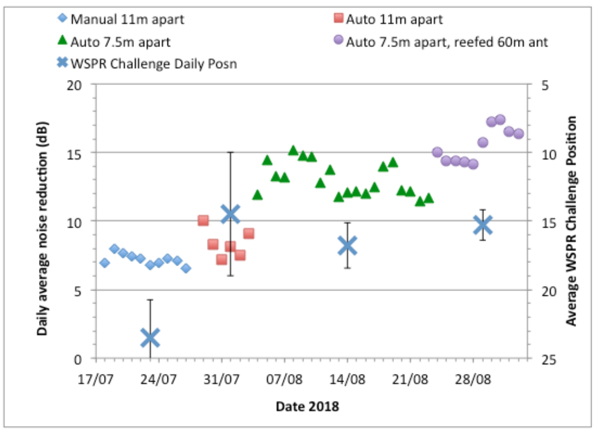


*Fig. 5 Daily average noise reduction for four configurations with average WSPR challenge positions for each configuration with standard error bars.*

[3] http://wspr.pe1itr.com/