Ionospheric Ranging for the Amateur

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There have been tools for studying the ionosphere for many years, perhaps the most important, from a Amateur point of view, being the Doppler technique, using '**SBSpectrum**' software by Peter G3PLX. Many of you will be familiar with this, as many tests transmissions have been made over the last few years for this fascinating study. Slow, but fascinating.

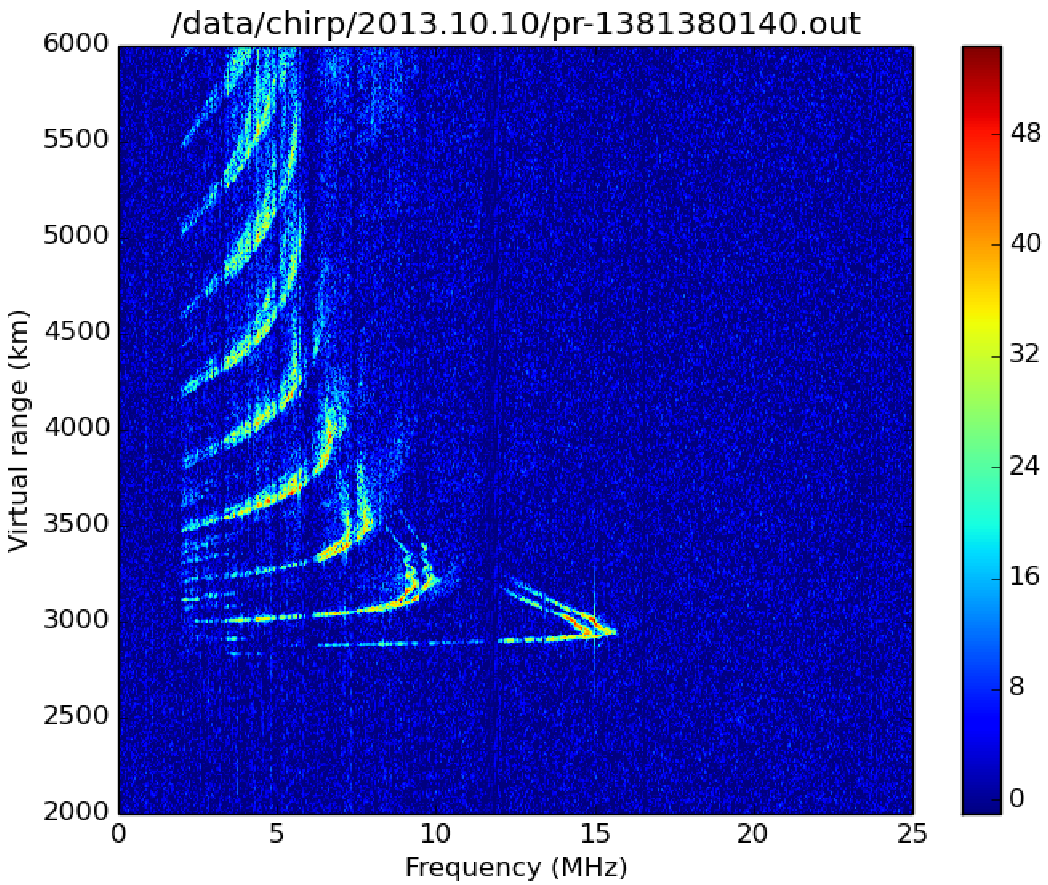
But this analysis is not by any means simple, and requires very stable gear and considerable experience. This technique also has its limitations, principally that, while it shows ionospheric movement in exquisite detail, it does not provide a means to measure the height of ionospheric layers, only their movement. So identification of each return relies on significant experience.

For height or range measurement, and to study propagation delay, a 'Radar' type tool is required. Unfortunately (even if permitted) simply transmitting narrow pulses (on HF at least) is not practical, as the transmission and reception equipment is narrow-band, inevitably has group-delay issues (principally caused by filters), and the result is broad, smeared pulses and insufficient resolution. We know that the difference in height of various layers can be quite small, so we need to differentiate 'reflections' as little as 1 ms apart. After all, the vertical heights of the E, F1 and F2 layers are say 50, 200 and 300 km, and 300 km represents 1 msec up and 1 ms down again.

So for 60 years now, radar developers have relied on a technique called 'Pulse Compression', where through one means of coding or another, a broad pulse can be given a means of timing that can be much sharper. The business of 'un-compression' at the receiving end also results in the benefit that all the energy of a longer pulse is concentrated in a narrow solution, thus not only sharpening the response, but improving sensitivity because all the energy is concentrated.

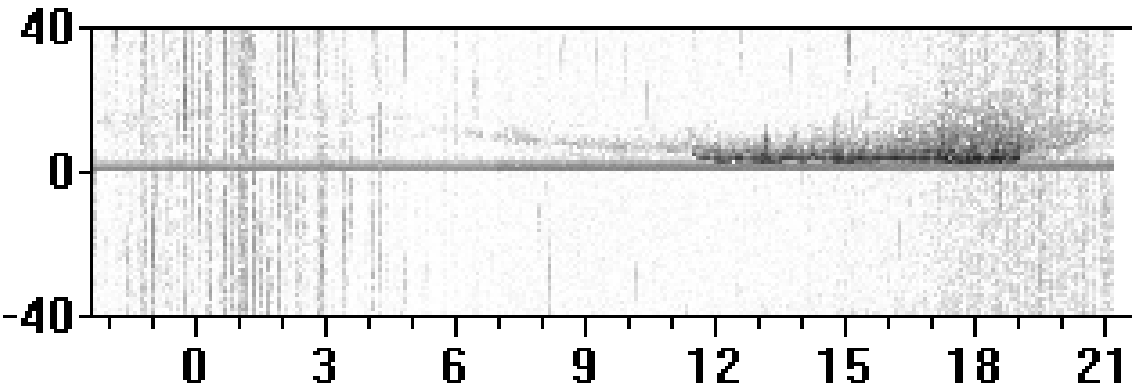
Chirped Transmissions

There are two techniques used for Pulse Compression. One is the Chirp technique, where the transmission (which can be several minutes long) changes frequency at a fixed rate, typically 100 kHz/sec. This is how commercial and military ionospheric sounders work. They are typically locked to GPS, so remote receivers can track them, and any variation in frequency noted will be as a result of a change in the reflection height.

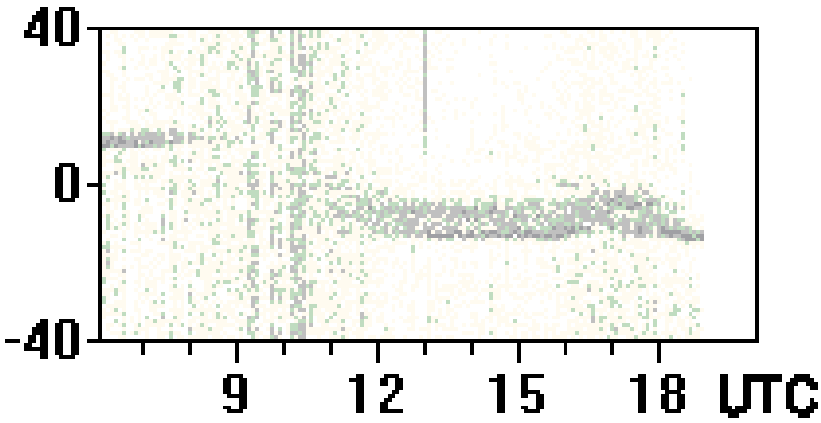


A typical Chirp Sounder example

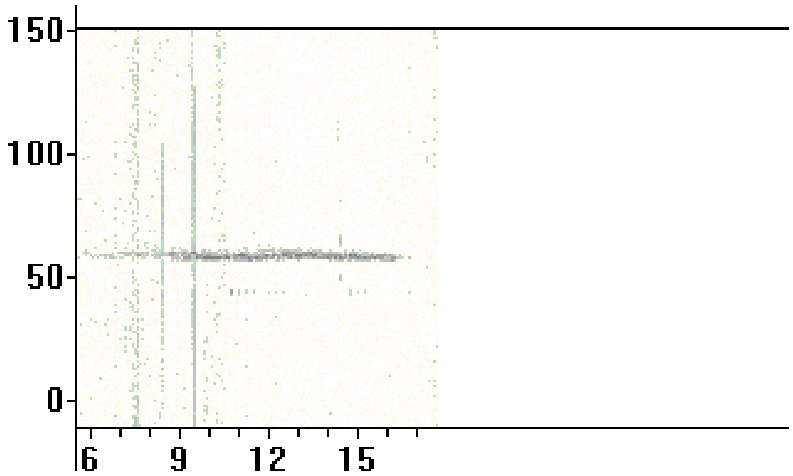
Back in about 1997, Peter G3PLX developed a technique called 'passive sounding' whereby a receiver could sit on one frequency, and wait for the pulses of one (or more) of these chirped sounders to come by. The idea worked well, although a GPS 1pps source was essential, and at the time, the '**EVMChirp**' software required a specialised decoder board, the Motorola 56002 EVM.



Ground wave range recording of the Inskip (UK) sounder by G3PLX.
Here you can see ground wave, E-layer and scattered F-layer returns.



Recorded in NZ showing long and short-path returns from Cyprus



A short-path return, with the graph is calibrated in virtual height (km).

This last example is from the public domain '**Chirpview**' Windows software, available here:

https://www.andrewsenior.me.uk/chirpview

Pulse Transmissions

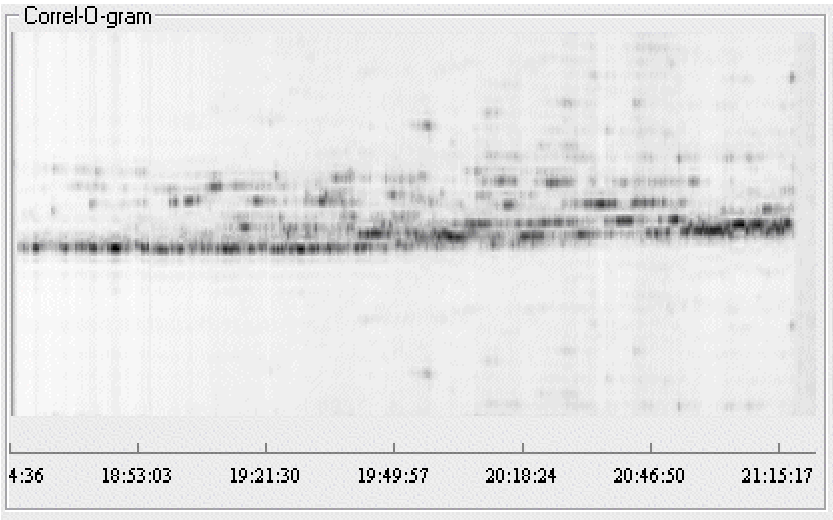
The second technique commonly used for Pulse Compression is a digital one. Rather that transmit a wide signal (in order to study large parts of the spectrum), a relatively narrow transmission of pulses is made, but the pulses are digitally coded, typically with PSK modulation. The P-N sequence header in STANAG 4285 military transmissions such as we frequently hear on HF (try 9910.6 kHz USB) is this type of thing. Most Over-the-Horizon Radars (OTHR), ever since the first 'woodpeckers' also have had coded pulses; the technique is also used for aircraft ground radar and even ultrasonic measurement of blood flowing through the body.

The trouble with all these techniques is that they are reliant on transmitting stations over which you have no control: either they are in a place of no interest, or they don't transmit when you want them to! The first Amateur

effort to use digital pulse compression was by Con ZL2AFP, who developed '**PSKSounder**' in 2008, based on the STANAG 4285 specification. This was based on an idea by Peter G3PLX, who had developed a passive ranging receiver for STANAG 4285 ('**SBStanag**', 2003). The important difference with 'PSKSounder' is that for the first time a ***transmit program*** was also offered, so Amateurs could do ranging measurements over a path of their choice.

https://www.qsl.net/zl1bpu/SOFT/PSKSounder.htm

Unfortunately 'PSKSounder' has two significant drawbacks: it requires considerable skill to use and interpret; and it requires very stable equipment, transmitter, receiver and computers. While it didn't need GPS, had a range of 9 ms (2700 km), and a resolution of about 1 ms (300 km), unless you could see the ground wave (which is very rare), you would not be able to measure total flight time of the signal, only *relative* flight time between products. It remains a really sensitive and useful tool, but not for the beginner.



A 'Correlogram' from PSKSounder, showing E-layer and several F-layer returns.

New Development

Which brings me to a ***brand new development***, which you will soon hear more about. Based on all this past history, and recent discussions between me (doing the documentation), Peter G3PLX (who has kindly offered to be our consultant), and Con ZL2AFP, (who is writing the code), we have come up with a new pulse-ranging technique based on much shorter P-N sequences than those used by STANAG 4285 (and PSKSounder).

Shorter sequences make for better time resolution, and ease the tuning issues, perhaps at the expense of signal clarity and sensitivity, which we will work on. The pulses used are PSK modulated 'Barker Codes', which have been used for radar for several decades.

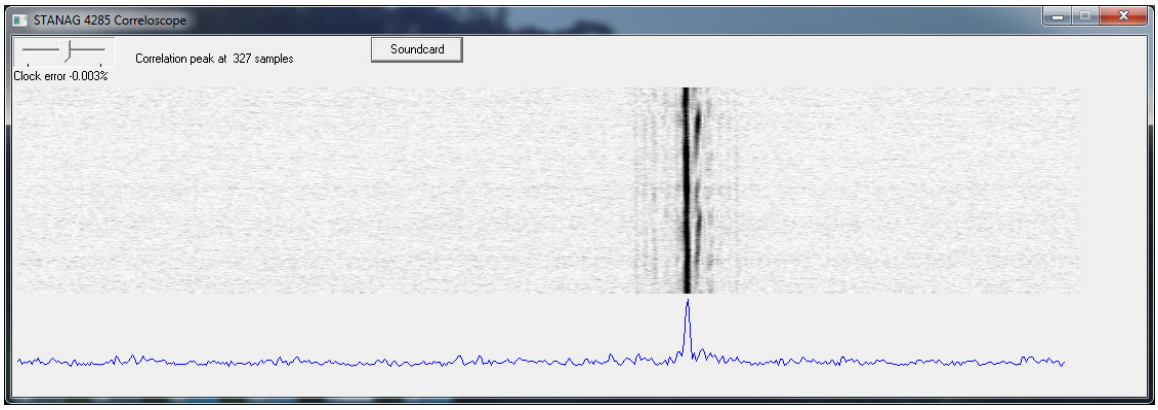
While the design is in the very early stages, some transmissions were made last night on 80 metres, using this new technique, and they show significant promise. Here are some details of last night's transmissions, and some examples will follow.

Modulation:	PSK
Subcarrier:	1500 Hz
Sample rate:	8000 Hz
Pulse rate:	7.8125 pps
Pulse period:	128 ms
Pulse width:	6.5 ms
TX duty cycle:	5%
Samples/frame:	1024
TX bandwidth:	2.4 kHz (300 - 2700 Hz)
Resolution:	<1ms
Chart width:	128 ms
Tuning tolerance:	about ± 50 Hz

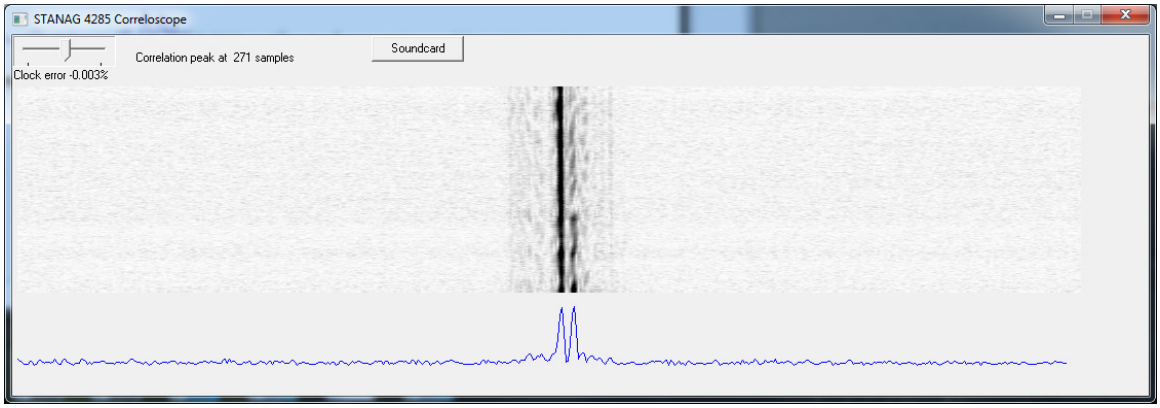
Note the low transmitter duty cycle: the signal sounds not unlike a clean version of a 'Woodpecker', since the bandwidth is limited by a special post-modulation filter, and of course also by the transceiver SSB filter. Also note the relaxed tuning tolerance compared with PSKSounder: an error of even 50 Hz will result in a timing shift, but will not severely smear the pulse returns.

The equipment required to take part in this study of the ionosphere is in virtually every ham shack: a modern stable SSB transceiver and a modest PC computer with sound card. Nothing specialised is necessary.

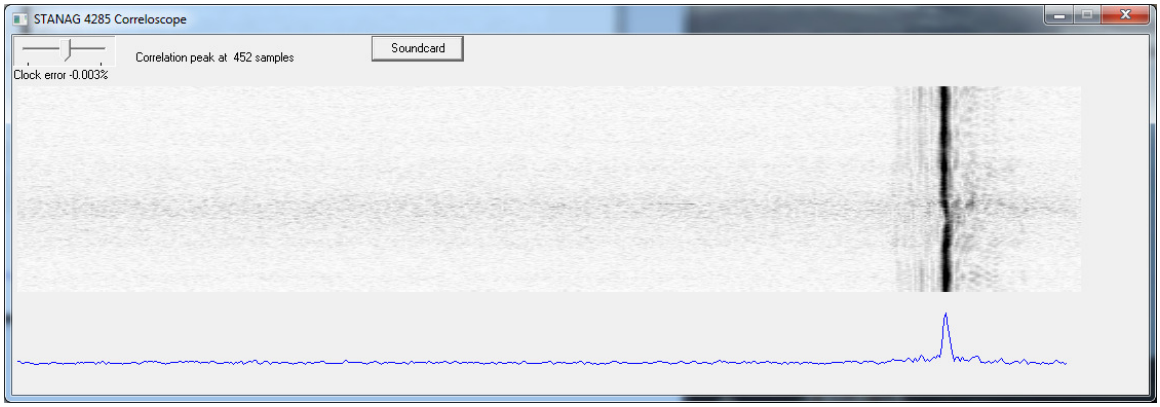
The following pictures were recorded in Waiuku, of transmissions from Gisborne, a 300 km path.



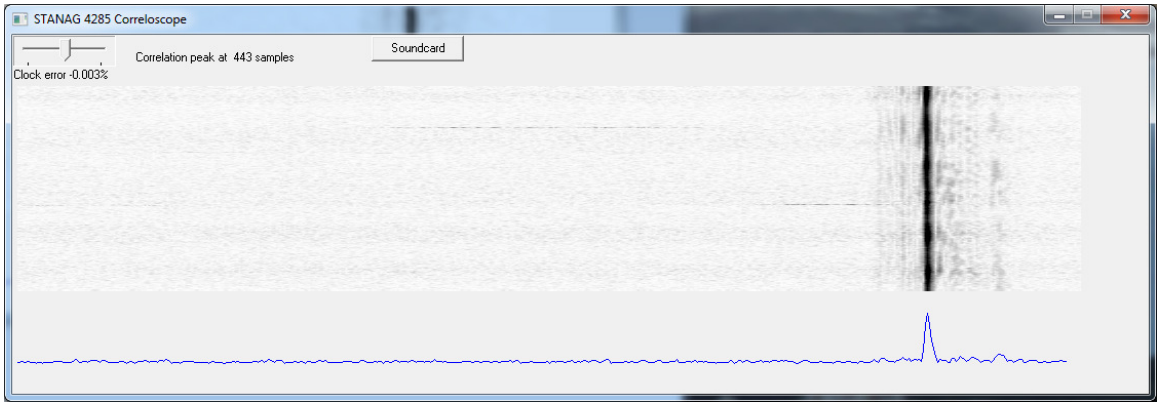
1716 NZST: (before sunset), showing E layer and short segments of F layer returns.



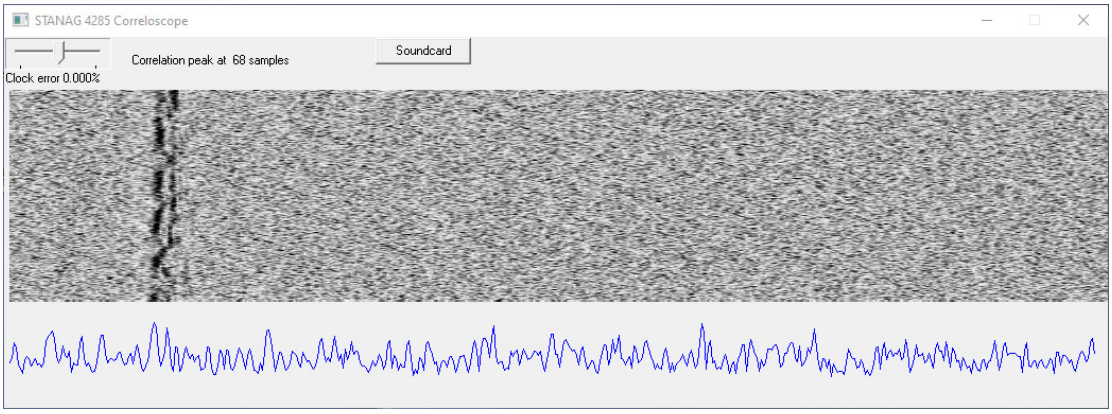
1728 NZST: Example of Barker-Coded ionospheric sounding showing E-layer and F-layer returns 2 ms apart.



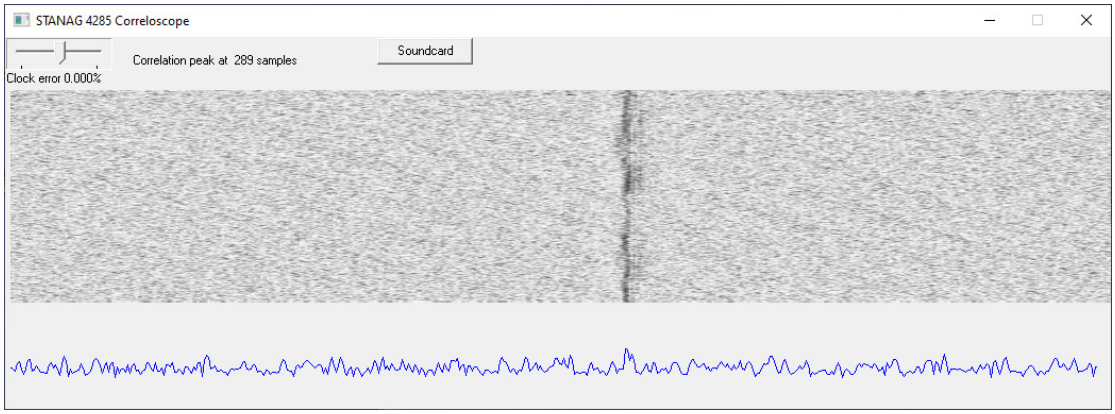
1755 NZST: Example showing a clear fade, accompanied by a timing shift of nearly 1 ms.



1758 NZST: Example showing F-layer return with significant scatter (no doubt well off-path), with at least 10 ms delay.



1746 NZST: Gisborne to Christchurch path (~1000 km)



0839 NZST: Daytime, Waiuku to Christchurch, principally E-layer

Apart from the last two, these pictures are from the 300 km path Gisborne - Waiuku. As you can see, the timing resolution is all we could hope for (< 1 ms resolution, chart width 128 ms), and the sensitivity is more than adequate.

Several things are still to be accomplished. Here are the most obvious:

(a) we need a time and/or distance scale
(b) We need to know where the transmission time was relative to the return, to enable accurate time-of-flight measurements. This will probably mean GPS timing, although I'm hoping that PC time along with a good SNTP service will suffice.
(c) We need to better suppress the 'ghosts' seen in some of these pictures, which are caused by insufficient suppression of Barker Code cross correlations.

But considering that this idea is less than 24 hours old, we've made great progress. Virtual fist-bumps and high-fives for Con ZL2AFP!

I will report further as the technique develops.

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03 May 2020