Recovering the weak and lost sources in the Sea Acoustic

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Sea Acoustic is a nonlinear Function for the sound and Ultrasound Perception.
All types of unwanted signals are considered as noise.
Contrary to the common believes, the noise is never added to the information.
The information is "correlated" with noise. And the information is never lost, regardless of how weak or small, even when the signal level is below noise level it is never lost and can be recovered by "de-correlation". Two kind of Noise are predominant in the sea acoustic domain: Multi path received signals and Multi source received signals.
These two groups of signals are correlated or modulated with the desired signals and will generate a reshaped signal that can be very different from the original signal. As described above, even in the case of the two known acoustical sources, their correlation is too complex to be analyzed theoretically by known mathematical formulas. Now if one of the known sources is replaced by noise (RANDOM and UKNOWN), the complexity of the equations is even higher. Our solution is the recognition and extraction and distinction of all the sources included the lost or buried sources under noise inside this concert.

1 Introduction

However, the reality of sea acoustic is drastically different from our wishes!

First, with the linear methods we can answer to the linearly treated signals and not the nonlinear conditions. In the classical digital approach, that considers the affected signal and the treating function linear in a reduced time or sampling period the outcome is not relevant.

Even if we take in consideration the nonlinearity, we should define a variable nonlinearity or a dynamic nonlinearity.

In the digital and adaptive method, the static nonlinearity can be treated if the nonlinearity function is known.

In the sea acoustic the nonlinearity function is a variable nonlinear function inside a variable nonlinear function. On the other hand, the intermodulated signals correlated with each other, which are double time variants.

By taking in consideration all these parameters, we find the reason why the current digital methods are not the right tools to treat the sea acoustic.

2 Our approach

The Intermodulation, is a Gaussian function in it's reduced simplest schematically study. The Correlation is a multi-order function

The theoretical way of treating this kind of signal is:

- To decompose it or de-correlate it with a time variant complementary function,
- To apply it to a complementary Gaussian function that is variable in time.

With this method we have succeeded to recover the signals lost under the noise, our improved SIGNAL TO NOISE ratio is better than 30 dB for the very weak signals.

3 We solved the problem

3.1 Mathematical form

The simplified mathematical form of the complex concert of the signal can be presented as:

$$\text{Complex } S = S(a)*S(b)*S(c)*,,,,,,,,,,,,,S(n) \qquad (1)$$

Where S(a) to S(n) are the individual acoustic or ultrasound sources which compose the complex signal.

The problem becomes more complicated when we look at each individual source and we find that each one of these sources is composed of a chain of frequencies with their appropriate arrangements or shapes, which determines their identities.

The individual form of each source can be presented as:

$$S(n) = \sum\{kn(Fn)\} \qquad n = F0 \text{ to } Fn \qquad (2)$$

Where, Kn is the level of each frequency.

In the experimental laboratory conditions that we can limit the test dimensions by reducing the number of sources to a single source, we can observe the inter-modulation of the source when it is transmitted in a bulk of water, in fact the perceived sound inside the water is completely altered regarding the original source and the source has lost its identity.

This is due to the inter-modulation of the individual frequencies of the source by each other in the nonlinear environment of water.

In the real sea acoustic, when we encounter multiple sources simultaneously that each source is already inter-modulated and the altered source is correlated with the other intermodulated sources, we can imagine the very complex situation and formulas that we have to resolve.

In Fact, inside our complex sound we have a good part of noise that can be subdivided on these following parts just for a theoretical study:

A – Static noise:

- All kind of unwanted sources.

B – Dynamic noise:

- Due to Nonlinearity
- Intermodulation noise
- Correlation noise
- Echo

At the receiving point or the perception point, the good signal or source is buried inside these noises enumerated above.

If the mathematical relationship between these sources and the individual frequencies of a single source were the linear functions, the overall sound could be studied and the targeted source could be distinguished with a linear analysis.

3.2 Sound and ultrasound measurements

The following graphs and tests are the examples that can be observed with our technology.

The blue line shows the square signal without our technology. The red line shows the output with our technology in the circuit.

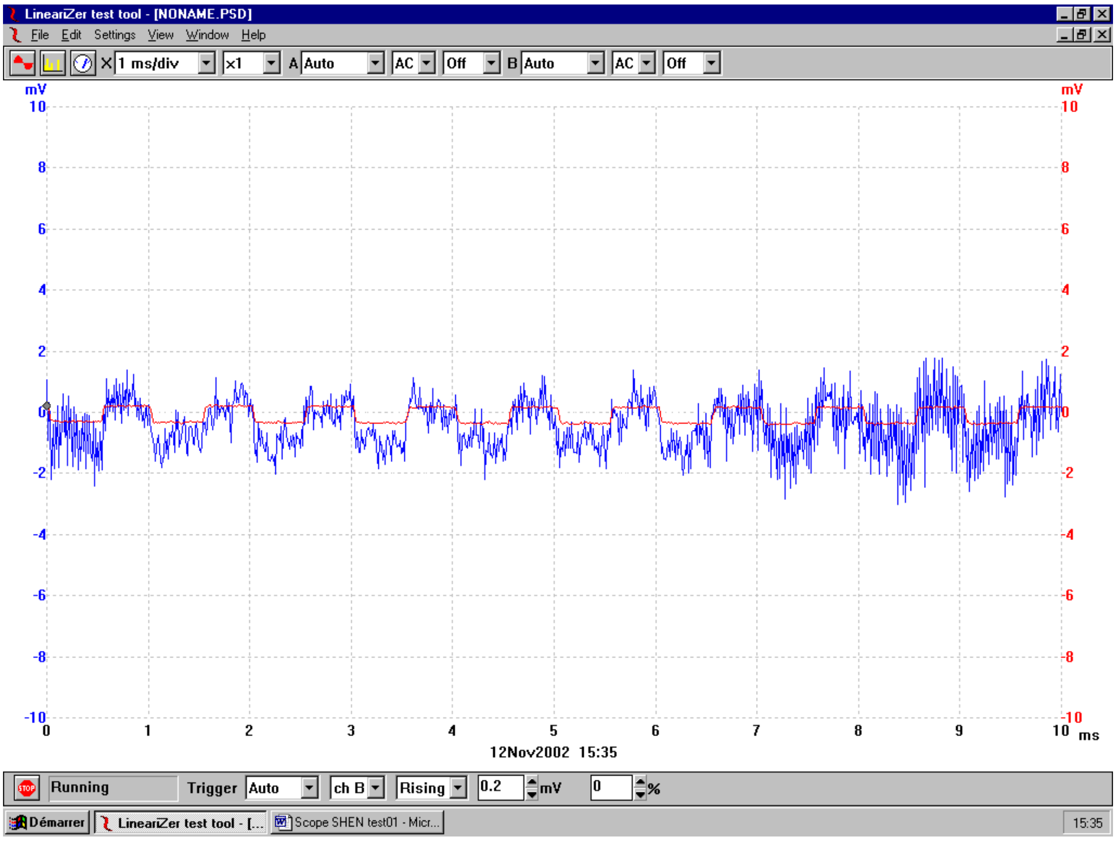

Figure 1, Recovering One KHZ Square Wave

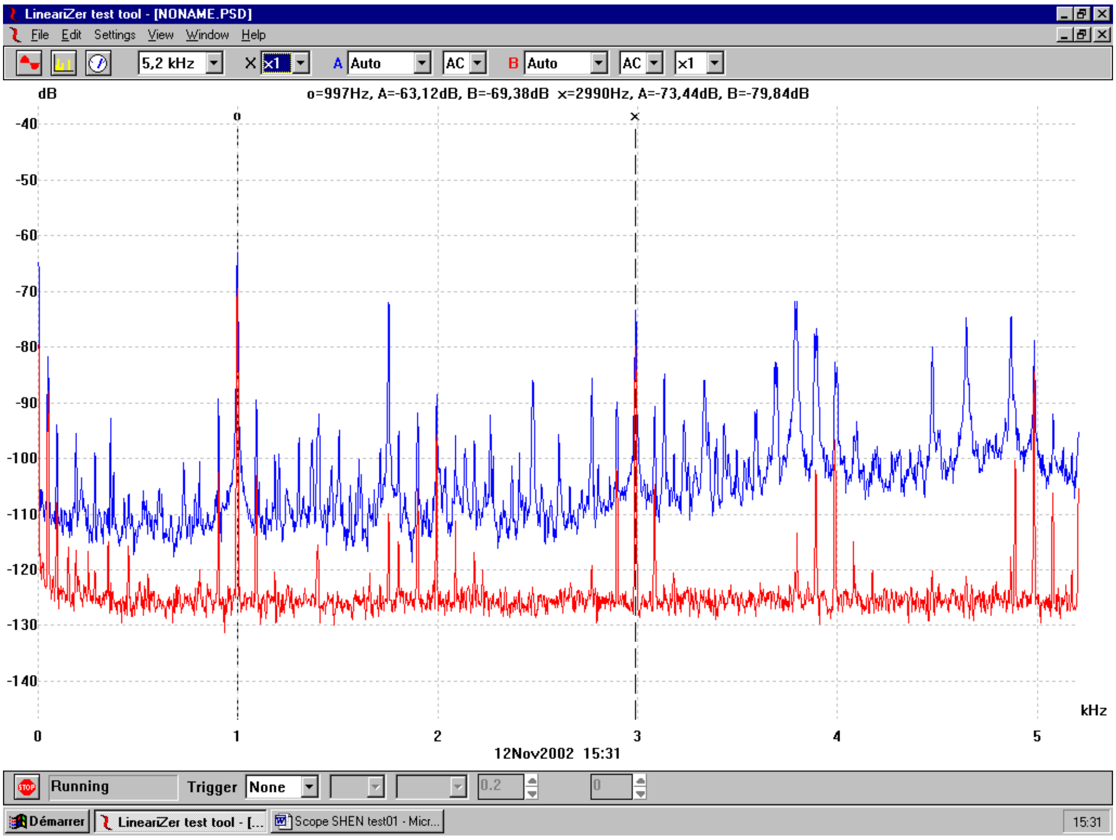

Figure 2, Frequency domain of the Square wave of Figure 1

Notice that without our technology (blue), the theoretical Fourier transform is shifted. The harmonics are not at the right frequencies. This effect is due to the jitter generated by the noise in the non-linear media. Our technology is able to cancel this jitter. You can see that all the harmonics are at the right place. This test is done with natural dynamic noises.

The Figures 3 and 4 show the Single source INTERMODULATION and DEMODULATION.

The blue line is without our technology, the Red line is with our technology

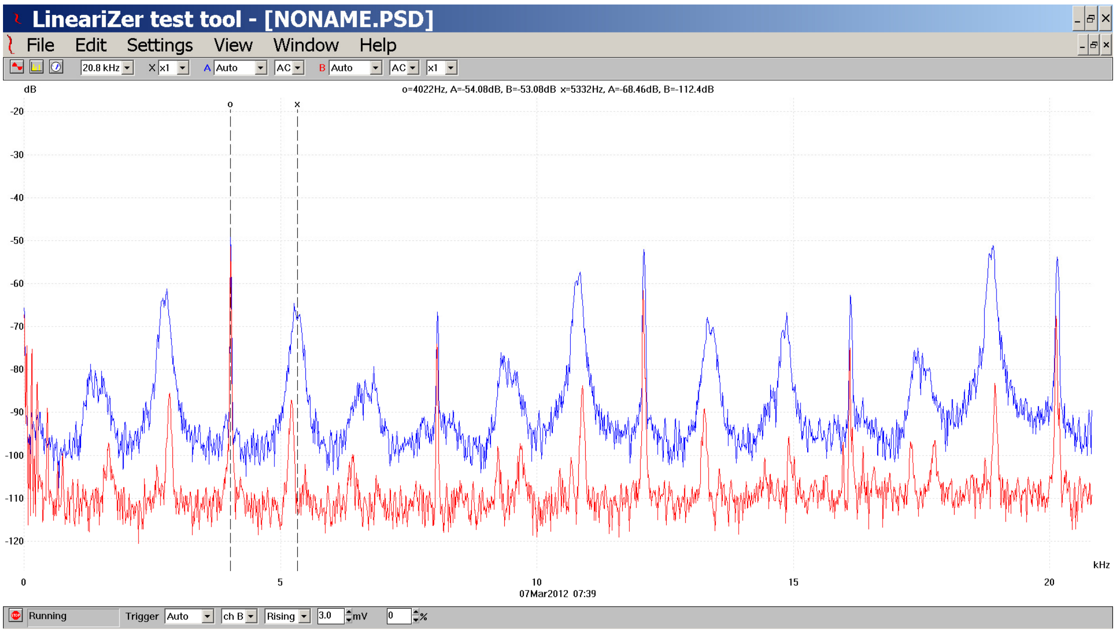

Figure 3: In frequency domain, ultra-Sound test /4 kHz square wave
O is the main frequency = 4022HZ, X is the noise axis; improved S/N = 45dB.

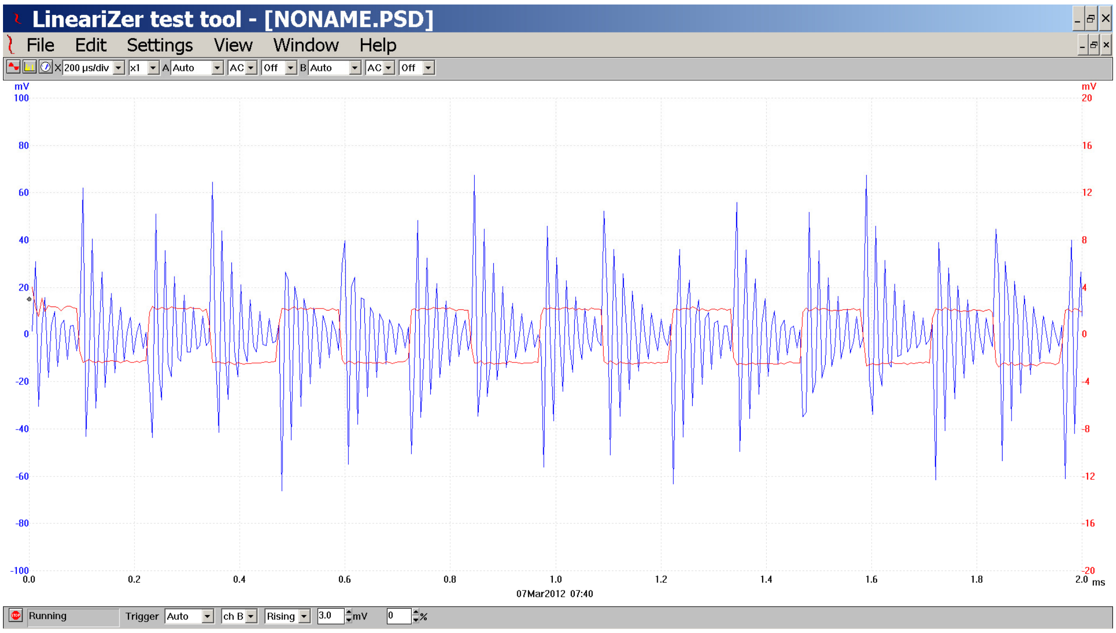

Figure 4: In time domain, ultra-Sound test / The same 4022HZ Square wave on time domain

The following test at 35 kHz is corresponding to very deep water ultrasound transmission (Fig 5 and Fig 6)

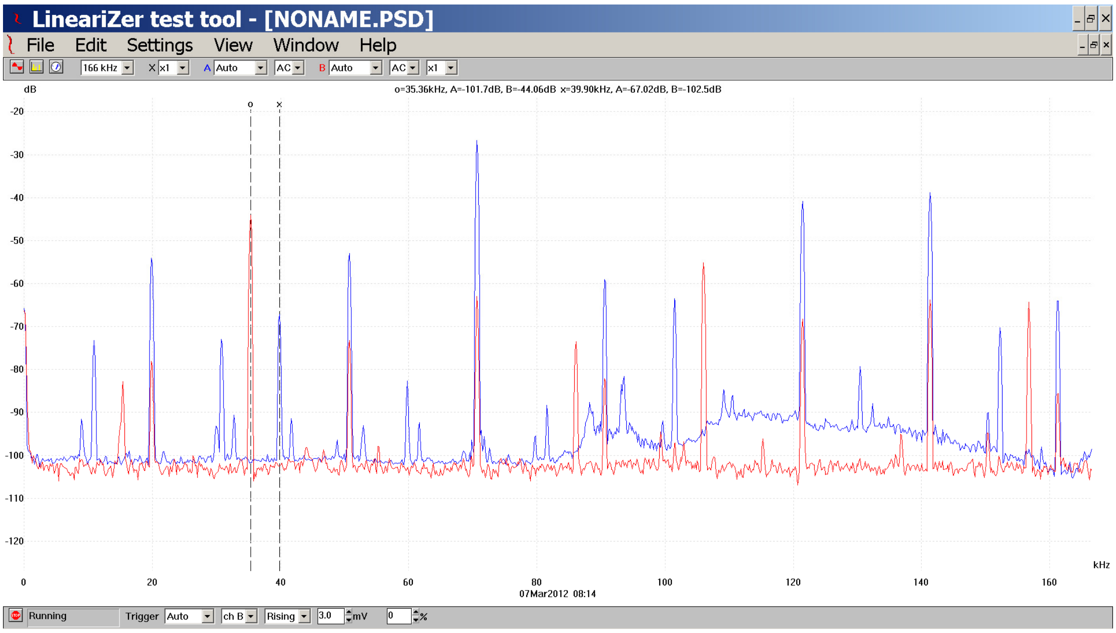

Figure 5: 35,36 kHz square wave
O is the main frequency = 35,36KHZ, X is the noise axis; improved S/N = 90dB.

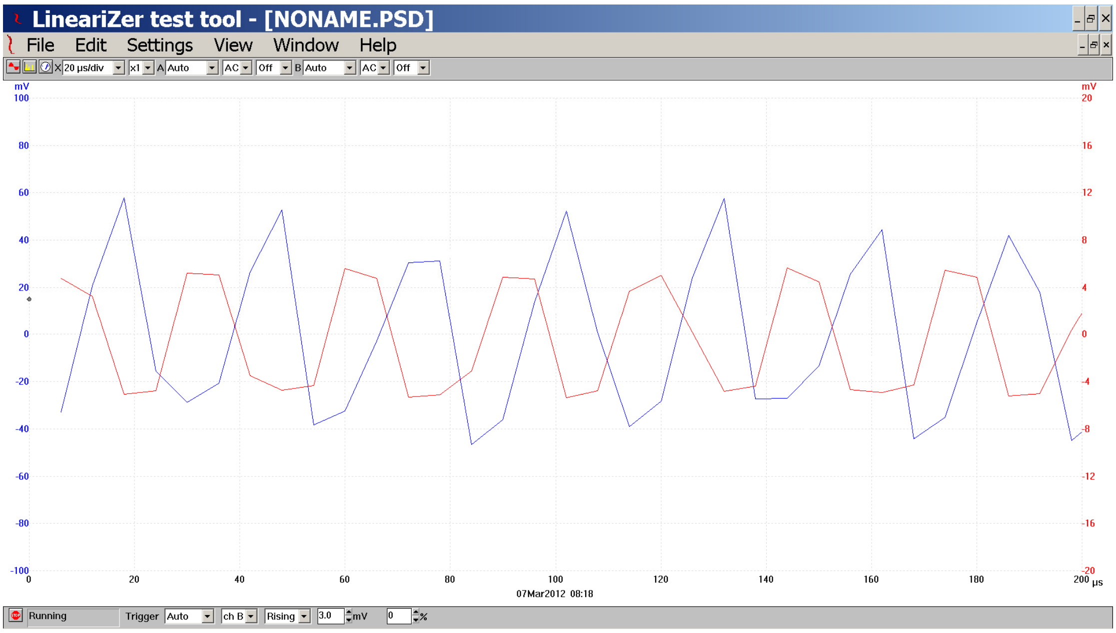

Fig 6: The same 35,36KHZ Square wave on time domain

3.3 Performance of our technology

Today, in a natural environment, we improve to 30 dB the SNR of the reception signal in a band of 0.7 Hz to 2 MHz regardless of the conditions of dynamic noise. In this same environment, we separate all components of the signal, all individually to find the sources and the original information. We cancel all the phenomena of echoes and reflections (multi-path and multi-source). We also cancel the jitter in the channel that we treat (perfect group delay).

3.4 The characteristics of our technology

Our technology is operating in real time. The processing time is lower than 20 nanoseconds (square wave). This technology does not use any filter, does not change the spectrum, and does not use external sensor and any sampling or digital processing. Our technology can be used independently or as a pretreatment to reduce the workload of digital processors.

4 Conclusion

This technology is a bridge between the real non-linear analog world of sea acoustic and the linear digital world of measurement and detection.

If we do not take in consideration the principals and laws of physics we will never arrive to resolve the problem.

The fundamental research is the base of our work.

A simple example of a single source on the Figures 3, 4, 5, 6 exposes clearly the importance and exactitude of our analysis.

Figures 5 and 6 are the ultrasound tests of the BLACK BOXES when they are lost in the shallow waters and why the success of finding them after the air accidents is minimum.

In this particular example of BLACK BOX pilot Signal of 35,36KHZ, we observe that the main frequency is shifted because of the Intermodulation of the main 35,36KHZ SQUARE WAVE.

But, after demodulation that lost signal, we recover it.

This "BLACK BOX" test was done in a nonlinear media without any other source and without environmental noise to show the effect of the Intermodulation of the components of a single source.

If we repeat the same test with multiple sources, we will have the correlation of the intermodulated sources that will make impossible the detection of the target signal with the primitive and non-adapted methods of DSP.

The major reason of the poor results of the SONARS is due to this hard reality, when the SONARS of the sophisticated Military Submarines are not able to detect each other and collide with each other, or the Magnetic Mines are not detected with any kind of SONARS the hard reality of the real SEA ACOUSTIC becomes evident.