63. Distance and Proximity experiments and discussion about the possible application of the cross correlation method **DRAFT 2**

UFO Doctor, April 29th, 2013

Introduction and Measuring Principle

Miru wrote with Duc075 a program for measuring the Distance (D) from Baby Duck to Mama Duck, the Angle to Mama Duck and the Proximity (P) Baby Duck to any obstacle.

The new FSK parameter features in program Duc075 are:

```
#define     FSKDDUR   MS2TIC(1.0) /* [ms] D FSK shift duration */
#define     FSKDHLD   MS2TIC(1.0) /* [ms] D FSK signal output after shift back */
#define     FSKPDUR   MS2TIC(0.5) /* [ms] P FSK shift duration */
#define     FSKPHLD   MS2TIC(0.1) /* [ms] P FSK signal output after shift back */
```

The ultrasonic signals (Distance: Speaker at Mama Duck, Proximity: Speaker at Baby Duck) are FSK sound signals 41/38 kHz and processed by the PLL of Baby Duck. Measured are the delays of the first negative PLL slopes to the global system clock, given by the RC frame signal of the aileron channel.

The Mama Speaker radiates the sound omnidirectional in the horizontal plane. The Baby Mics show a receiving angle of about +/-20 degree. They need to be turned to the sound source (by servos or Baby rotation) for reliable operation.

The distance measuring system is perfect; however the angular measurement suffers from a +/- 18usec jitter of the left and right distance signals (see Fig. 3.2.) At an ear distance of 40mm the maximum angular resolution is about +/- 8 degrees only.

1. Test Setup

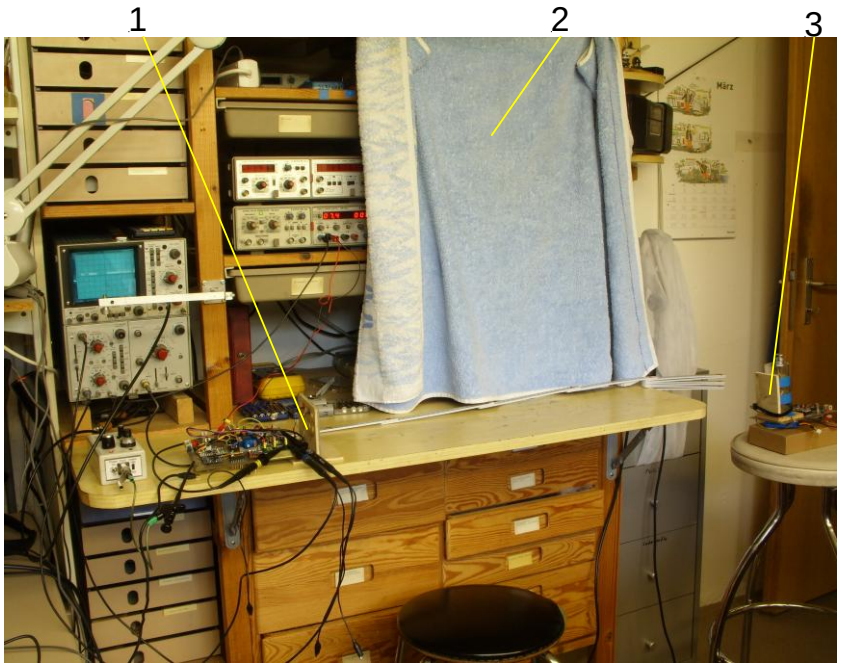


Fig. 1: Test Setup

1: Baby Duck with 2 ears at distance of 40mm (Proximity: left Mic operates as a speaker)

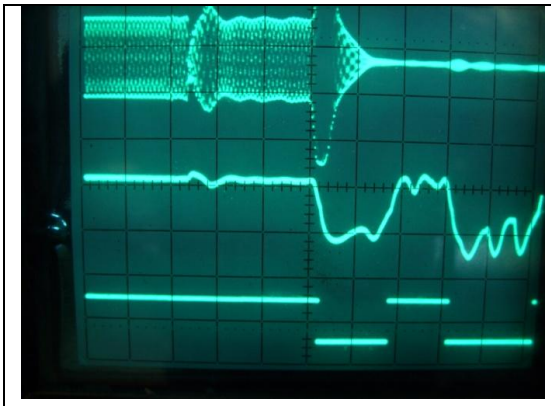
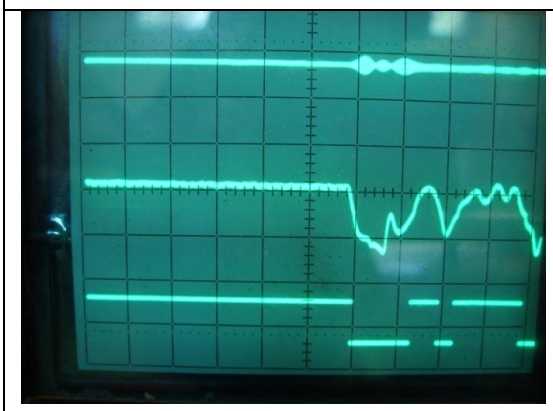
2: Turkish Towel for reduction of acoustic reflections

3. Mama Duck with omnidirectional speaker in the horizontal plane (Proximity Target 70x90 mm)

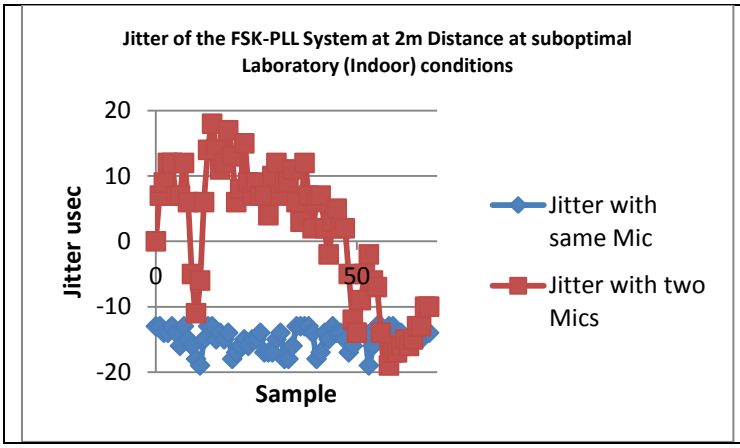
2. Test Procedure

Mama Duck approaches to Baby Duck from 2m slowly to 1m, proceeds to 0.6m and walks with 0.1 m steps from 0.6m to 0.0m

3.1. Proximity and Distance Signals measured with delayed Trigger

	Fig. 3.1.a: Proximity Signals Trigger Delay about 63 msec Target at 0.5 m Scope: 1msec/Div Top: BP-Out RIGHT, 0.5V/Div Middle: PLL Analog Out RIGHT, 2V/Div Below: PLL Digital OUT RIGHT, 5V/Div Response time about 3 msec, ok Clear first negative PLL slope, ok
	Fig. 3.1.b: Distance Signals Trigger Delay about 130 msec Mama position at about 2m Scope: 1msec/Div Top: BP-Out RIGHT, 0.5V/Div Middle: PLL Analog Out RIGHT, 2V/Div Below: PLL Digital OUT RIGHT. 5V/Div Response time about 6msec, ok Clear first negative PLL slope, ok

3.2. Jitter of the distance measuring FSK-PLL system, ear distance 40mm

	Fig. 3.2:Jitter of the System (Indoor conditions) - The Jitter of the distance measuring system for optimal acoustic conditions is about +/-3 usec, ok - The Jitter of the distance measuring system for real acoustic conditions is about +/-18 usec, not perfect

Comments:
- The FSK-PLL distance measuring principle works fine.
- The Jitter is mainly an acoustic pathway problem
- More work is needed to improve the Mic Signal Pathway Quality! But How?

4. HyperTerminal Data

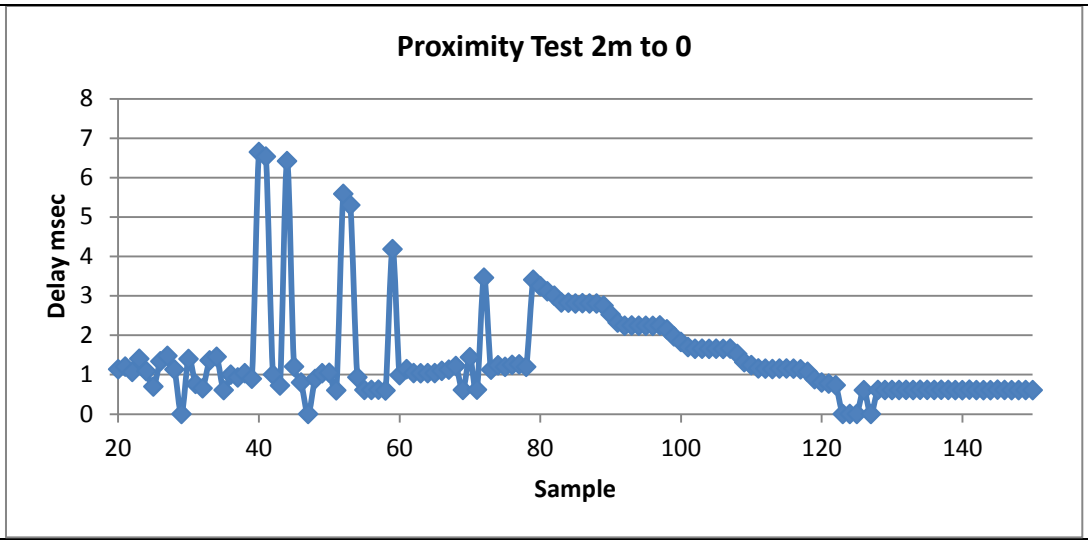


Fig. 4a: Proximity Signals
Good data from 0.6m to about 0.2m, quite ok!

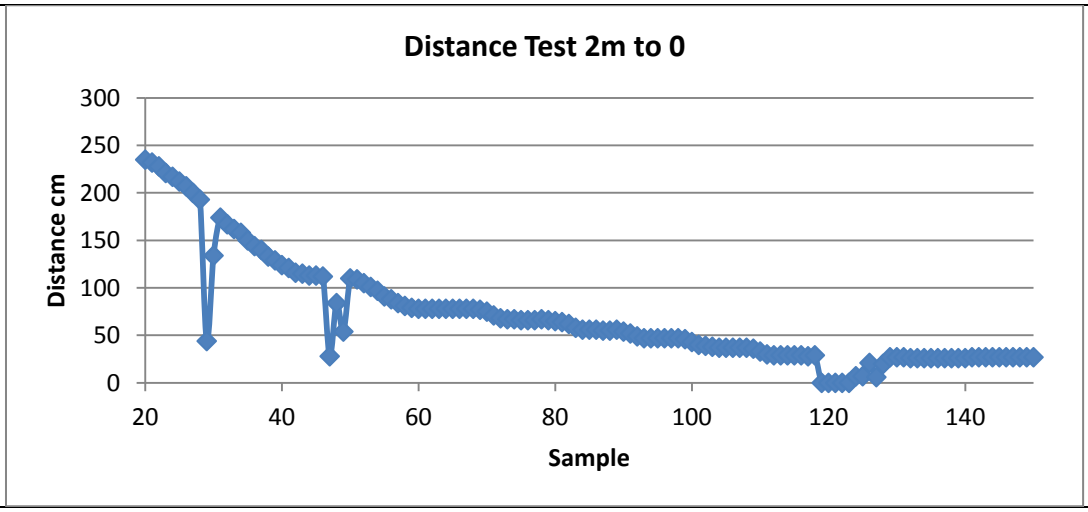


Fig. 4b: Distance Signals
Good data (with some disturbance due to reverberation in laboratory conditions) from 2m to about 0.3m, ok

6. Details about Proximity Signals

(Same scope settings as given in Fig. 3a, 1msec/Div)

Fig. 6a: Proximity 0.6m, ok

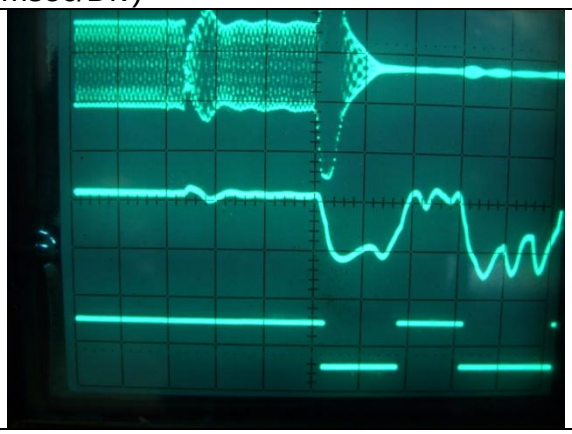


Fig. 6b: Proximity 0.5m, ok

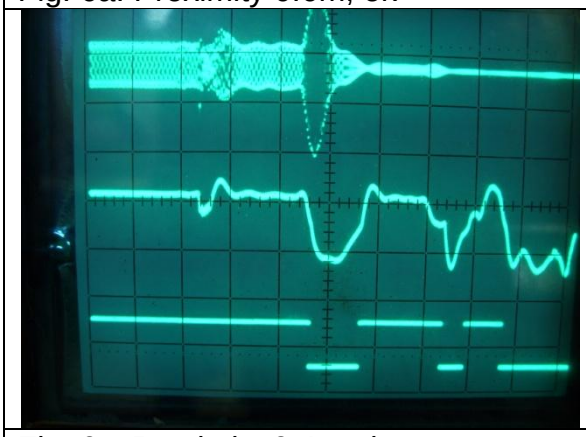


Fig. 6c: Proximity 0.4m,ok

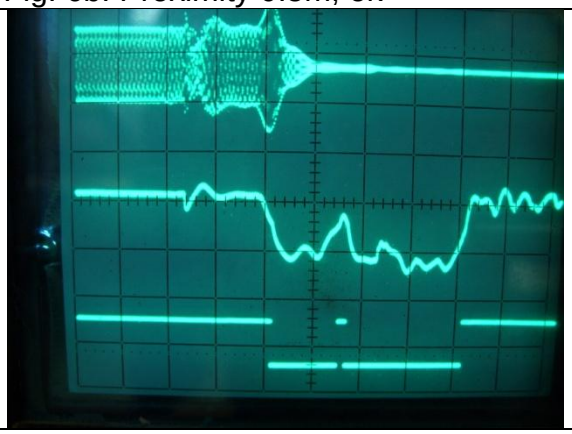


Fig.6d: Proximity 0.3m, ok

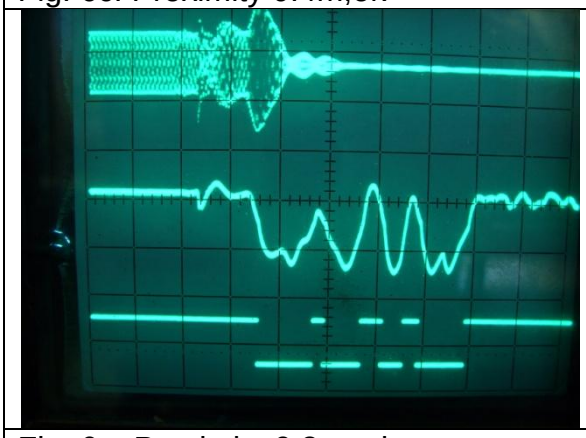


Fig. 6e: Proximity 0.2m, ok

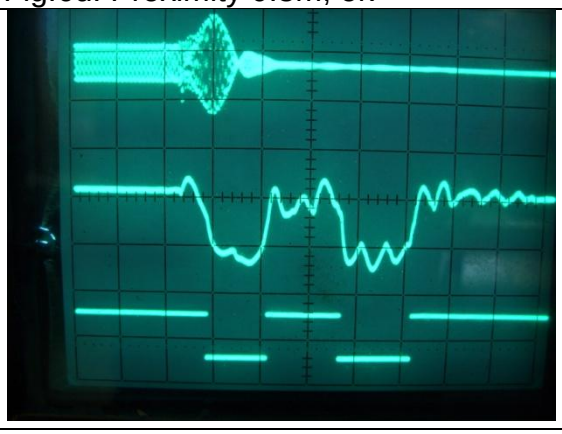


Fig. 6f: Proximity 0.1m, ok

Fig. 6g: Proximity 0.0m, NOK

Comment:
There is an acoustic crosstalk between Baby Speaker and Baby Mic.

Thus, we need to mask the PLL signals data processing during the time period from 0 to about 1msec!

7. Detail Distance and Direction Signals

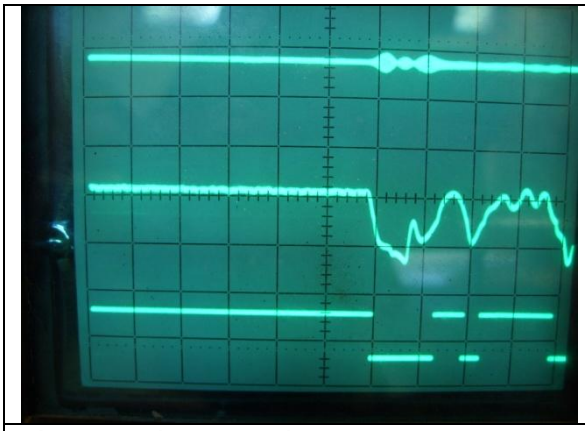


Fig. 7a: Distance about 2m

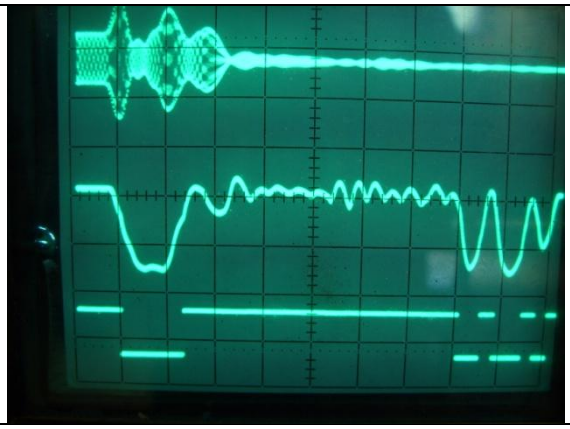


Fig. 7b: Distance about 1m

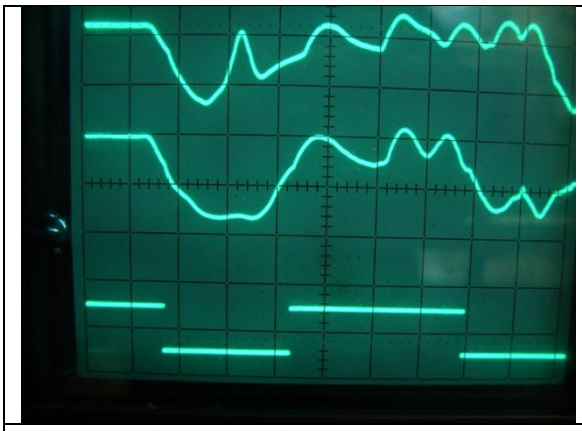


Fig. 7c: Distance about 2m
Delay about 145msec
Scope 0.5msec/Div
Top: Analog PLL RIGHT Out, 2V/Div
Middle: Analog PLL LEFT, Out, 2V/Div
Below: Digital PLL RIGHT Out, 5V/Div

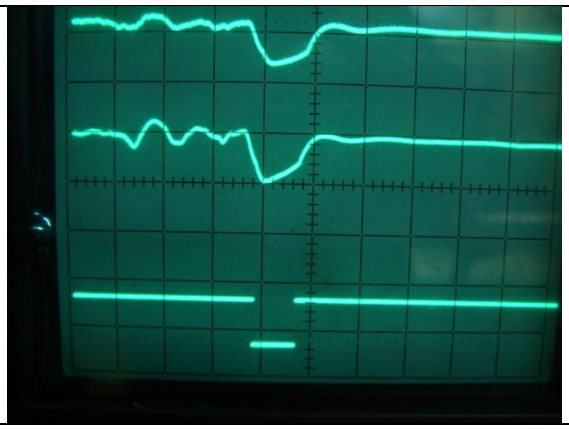


Fig. 7d: Distance about 1m
Delay about 90msec
Scope 0.5msec/Div
Top: Analog PLL RIGHT Out, 2V/Div
Middle: Analog PLL LEFT, Out, 2V/Div
Below: Digital PLL RIGHT Out, 5V/Div

8. Discussion

Both Distance and Proximity Data, measured by the negative slope of the (analog) PLL signals, providing digital signals to the Arduino, are quite ok.

There is a slight jitter of the negative slope of about +/- 15usec. This does not harm the distance discrimination, but affects the angle measurement!

IMPORTANT NOTE

After the first negative PLL slope, it may happen that the PLL signal jumps for a short time to positive and back, see fig 7c.

This happens in realistic acoustic conditions due to reflections and reverberation and must be accepted in real life situations!

9. Discussion about the Application of the Cross Correlation Technology

9.1. Introduction to Cross Correlation

We used up to here the reliable FSK/PLL technology which works quite fine for distance measurement, but is not so perfect for precise angular detection.

A sophisticated technology such as the Cross Correlation (proposed by Daniel von Grünigen, BFH) looks very promising to improve the angular resolution sensitivity.

The paper ELEC 499 from the University of Victoria describes a system for localizing a speaker in an auditorium:

http://www.ece.uvic.ca/~elec499/2011-spring/group09/Final_Report.pdf

The result was not perfect (due to reverberation effects), but is interesting for further investigations.

9.2. Minimum Sampling ADC Rate for Cross Correlation

A first estimation for our application with an ear distance of 40 mm tells us that the minimum sampling rate of the ADC should be at least 100 kHz:

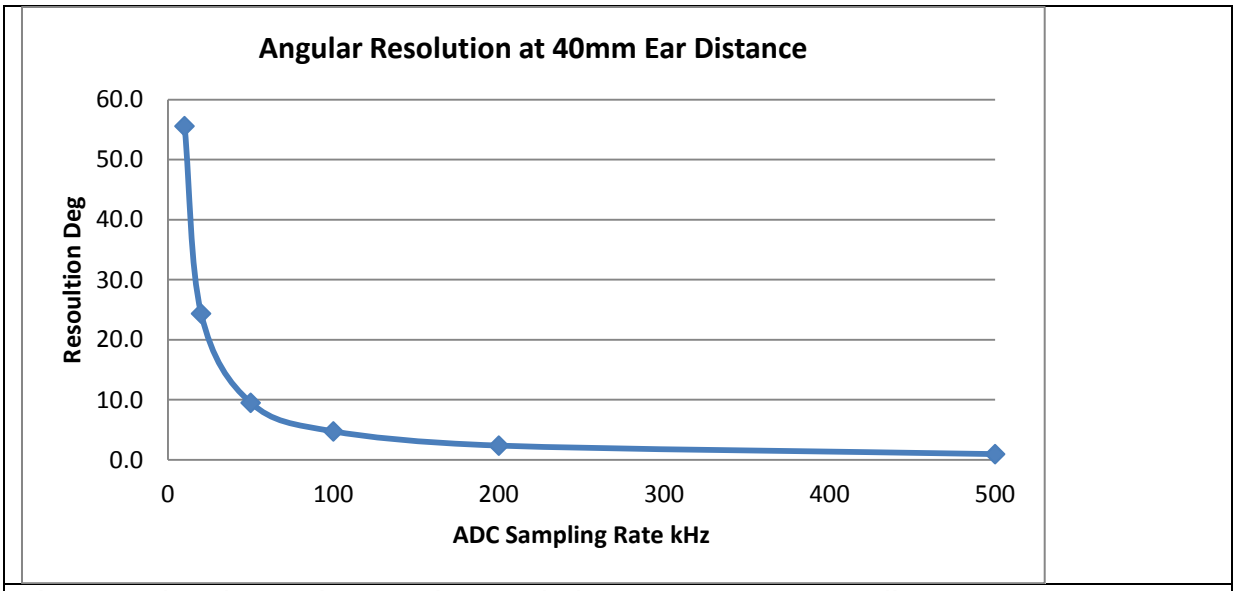


Fig. 9: Estimation of the angular resolution versus ADC sampling rate (calculated by formulae mentioned in the paper ELEC499)

At 100 kHz ADC sampling rate the Angular Resolution is about 5 Degrees, this is ok for our Duck application.

9.3. Cross Correlation signal detection capability

9.3.1 Input Signals

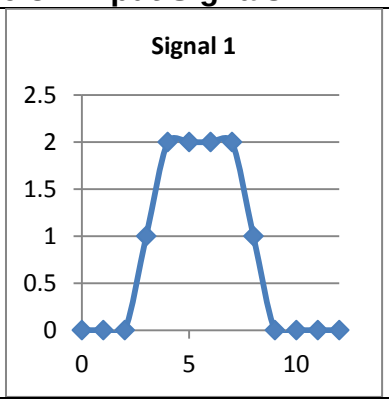


Fig.10a: PLL Signal 1
Optimal Acoustic
Conditions, 1 step=100usec

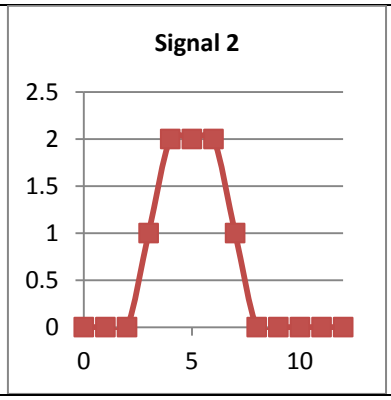


Fig.10b: PLL Signal 2
Good Acoustic
Conditions

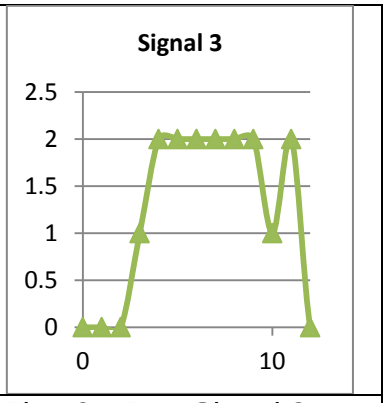


Fig.10c: PLL Signal 3
Realistic Acoustic
Conditions, see Fig. 7c

9.3.2. Peak Cross Correlation Results

(m=Shift Parameter, see Cross Correlation Theory)

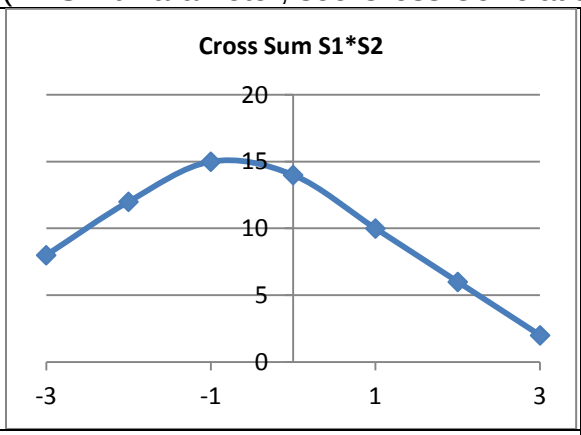


Fig. 11a: Cross Sum S1with S2
Parameter: -3<m<+3
Maximum at -1, not at 0!

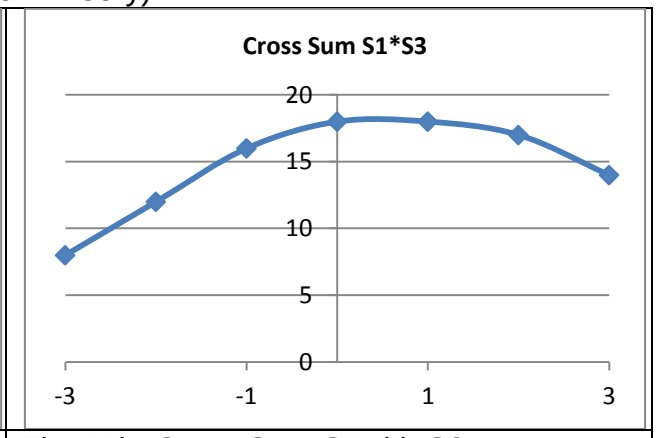


Fig. 11b: Cross Sum S1with S3
Parameter: -3<m<+3
Maximum at +1, not at 0!

9.3.3. Discussion about the Cross Correlation Method

The source signals are the PLL outputs, discriminating the FSK sound signals.
The first f1 to f2 change is well recognized, but the later received acoustic signals are disturbed by reflections and reverberation.

The current signal processing applied up to now discriminates the first f1 to f2 change only. Later PLL signals are not treated. The current jitter is about +/- 18usec.

The Cross Correlation Method processes the PLL signals f1 to f2 and back to f2.
All PLL signals after the first f1 to f2 change are treated, too.
This means that the expected jitter will be about +/-100usec.

At first glance the Cross Correlation Method is less good for our practical application!

Kind regards from the old UFO Doctor