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Underwater communications using acoustic parametric arrays

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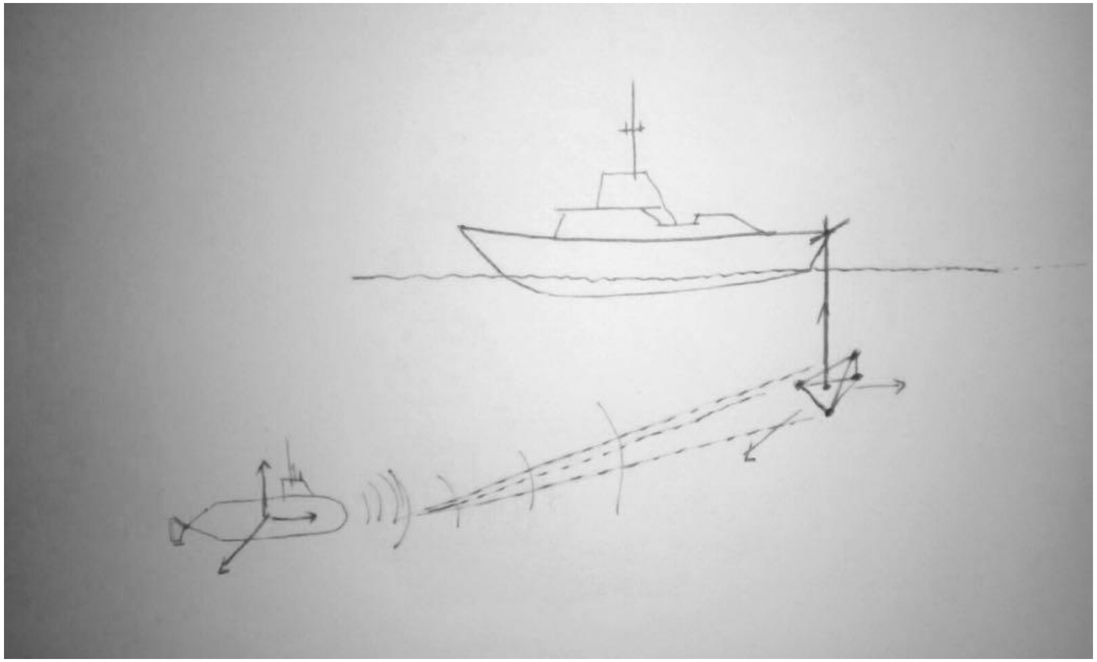
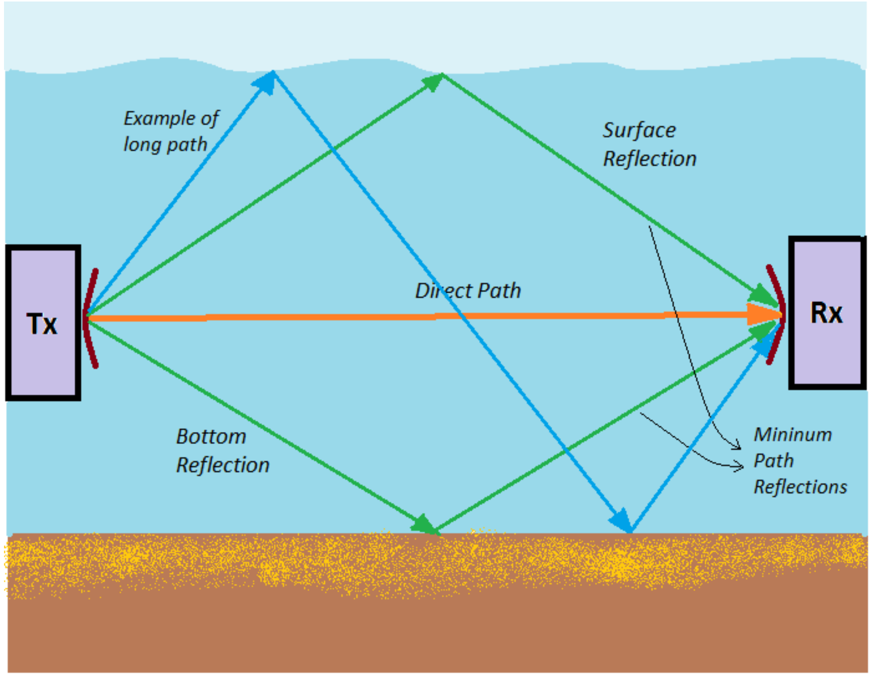
CONTENIDO

I. INTRODUCTION



Communications in underwater environments have become a field of research of great interest in recent years. Therefore, the development of submarine sensors have experienced a significant increase in transmission technologies in underwater communication systems. The transmission of information in underwater media can be based on acoustic systems.

I. INTRODUCCIÓN



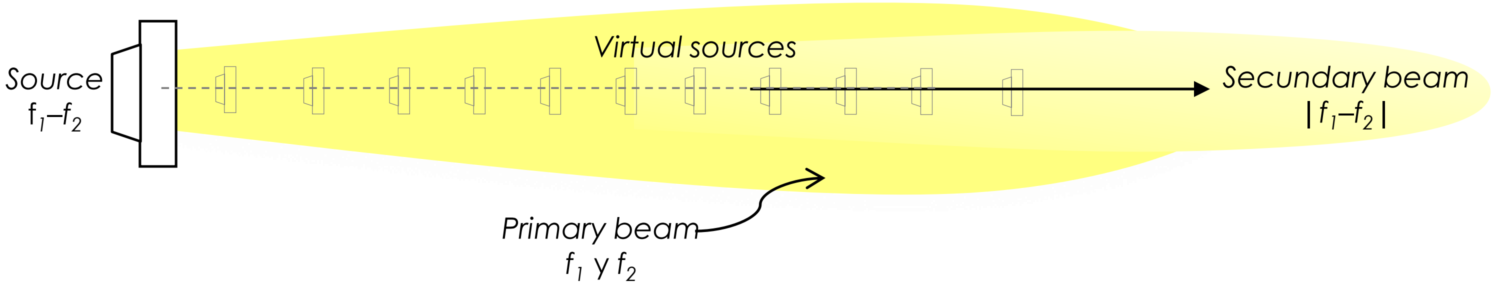
The propagation of the waves in the underwater acoustic channel has important limitations:

- Limited bandwidth.
- Extended multipath
- Severe fading, and refractive properties of the medium.

News methods of communication are proposed based on non-linear propagation effect that allows directive communication by using directive high frequency transducers to produce a low-frequency secondary beam in the medium used for the communication application. With this, several advantages are foreseen:

- ***To communicate just in the desired direction, so being more robust against unwanted dissemination of information, or avoiding reflections or multi-path effects that could worsen the quality of the communication.***

II. Parametric effect



$$p(x,t) = \left(1 + \frac{B}{2A}\right)\frac{p^2 S}{16\pi\rho c^4 \alpha x}\frac{\delta^2}{\delta t^2}\left[f\left(t - \frac{x}{c}\right)\right]^2 \sim \frac{\delta^2}{\delta t^2} f^2$$

Where:

B/A	Nonlinearity parameter of the medium.
P	Primary beam pressure amplitude [V].
S	Area of the vibrating surface of the transducer $[\mathrm{m}^2]$.
ρ	Density $[\mathrm{kg/m}^3]$.
c	Velocity of sound [m/s].
α	Absorption coefficient in the medium [Np/m].
x	Distance to the source [m].
t	Time[s].
$f(t\text{-}x/c)^2$	Envelope of modulation.

Therefore, the resulting wave p (x, t) will be proportional to the second derivative of the square envelope of the emitted signal.

III. HARDWARE CONSIDERATION

The formulations are presented below for the level of the secundary beam signal Bertay and Leahy.

As an ***example***, these equations are applied to the emitter transducer studied in this paper Airmar P19 with a ceramic diameter of 0.033 m, the results are presented for a 1 kHz bandwidth in the next Table 1.

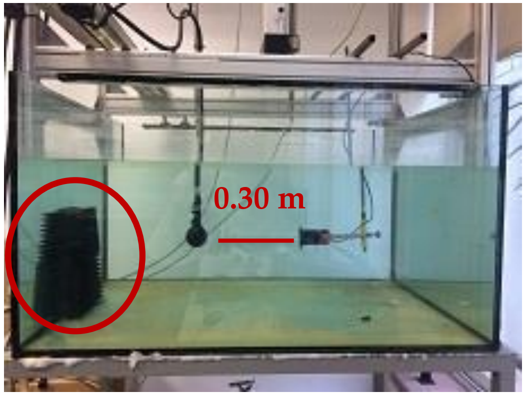
fs [kHz]	Power [W]	TL [20km]	NL [dB/uPa @1m]	DI [dB]	SLp [dB]	SLc [dB]	SLs [dB]	SNR [1kHz]
40	182	111	33	9	216	225	179	60

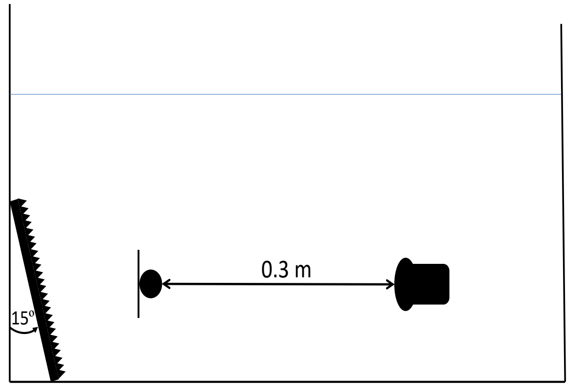
Fs (kHz)	Secondary beam frequency.
Wo	Transducer power
TL(20km)	Transmission noise.
NL (dB/uPa)	Noise.
DI (dB)	Directivity.
SLp	Primary beam pressure level.
SLc	Critical source level.
SLs (dB/ uPa @ 1m)	Secondary beam pressure level.
SNR (1kHz)	Signal-to-noise-ratio.

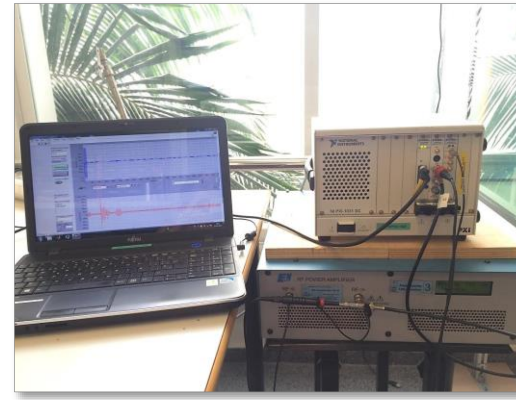
It was observed in the table that for our transducer, the value for SNR is very high, this is because it is difficult assumptions on noise level (may be considerably higher) on transmission loss. Even so, with this example we can show the potential of the parametric array concept serving as the basis for the design not of a transducer but of a array in question.

the experimental setup where the distance between the emitter and the receiver is 0.30 m with an absorbent inclined ~10° panel located on the rear wall

IV. Experimental Setup







- Water tank of size 1.12 x 0.96 x 0.51 m^3.
- Transmitter: the Airmar P19 plane transducer.
  - Resonance frecuency 200 kHz = Carrier frecuency (fp).
  - Transmitting voltaje response (TVR) 167 dB re μPa/V @ 1 m.

- Receiver: transducer ITC 1032.
  - Resonance frecuency 33 kHz.
  - Receiving sensitivity (RVR) -194 dB re 1V/μPa.

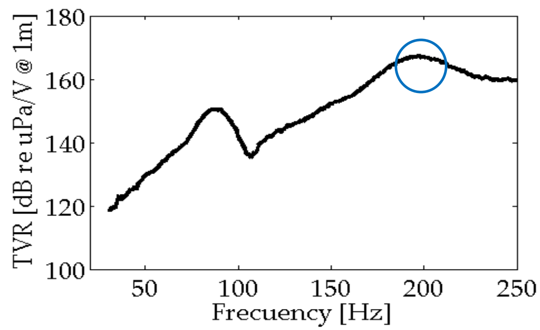
- Sampling frecuency $f_s = 20$ *MHz*.

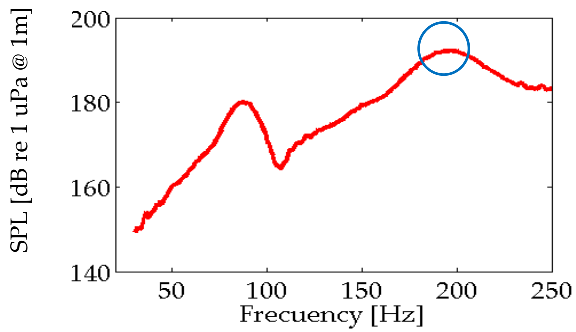
The figure in the middle shows the experimental setup where the distance between the emitter and the receiver is 0.30 m with an absorbent inclined ~10° panel located on the rear wall of the ITC 1032 receiver transducer in order to avoid certain reflections.

the experimental setup where the distance between the emitter and the receiver is 0.30 m with an absorbent inclined ~10° panel located on the rear wall

IV. EXPERIMENTAL SETUP

- Technical especification for Airmar P19 plane transducer





- Black figure: transmitting voltaje response (TVR) 167 dB re µPa/V @ 1 m.
- Red figure: the sound pressure level is presented, with a value for the frequency of 200 kHz of 195 dB re mµPa @ 1m.

V. Results

- Parametric sweep:

  - Frequency bandwidth of 4 to 40 kHz
  - Duration: 1 ms
  - Carrier frequency fp = 200 kHz.

The intention is to generate a 16 bit = 1010010110010110, string of ones and zeros with this signal.

- bit 1 → sweep of 4 to 40 kHz
- bit 0 → sweep of 40 to 4 kHz

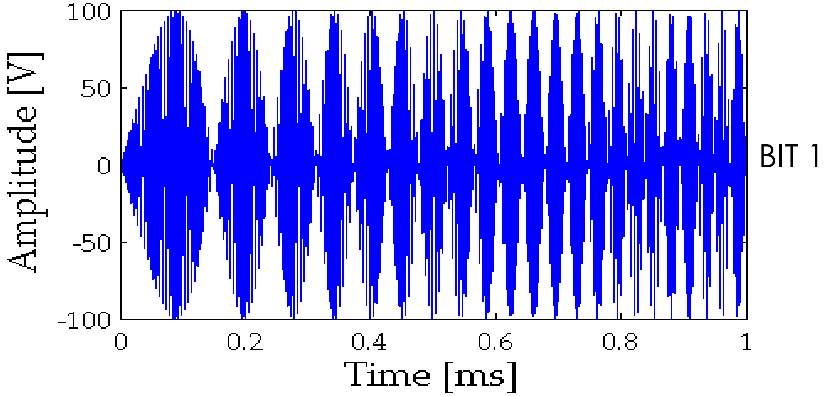
} Through cross correlation this bits are detected in time.

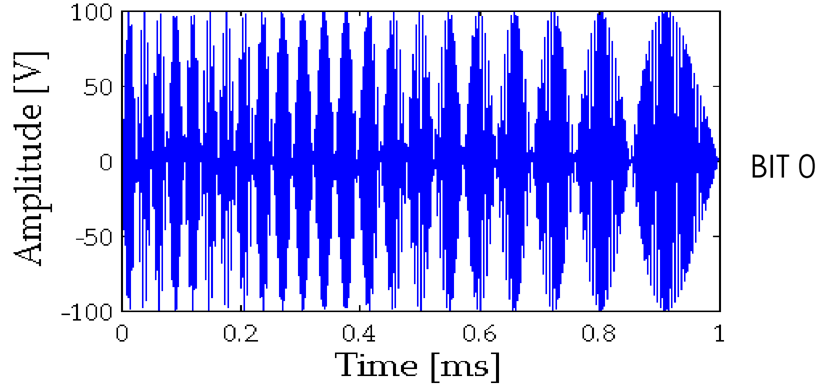
All of this, in order to be able to send messages in acoustic communications at low frequencies with high directivity.

The signals sent for bit 1 and bits 0, and the resulting signal received for each of them, are shown below.

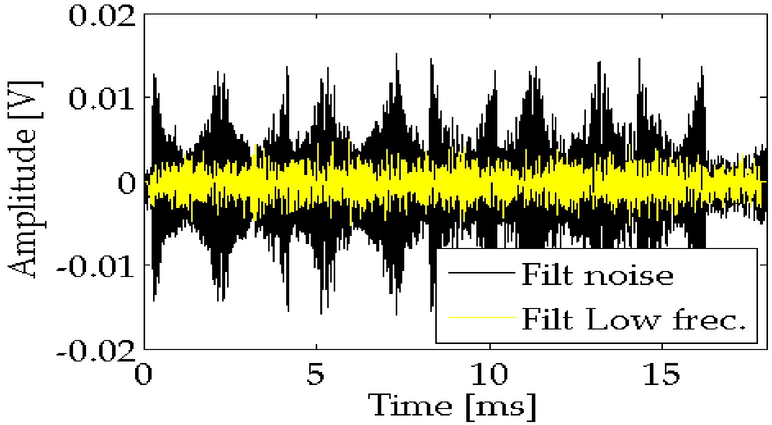
V. RESULTS

- Parametric sweep sent





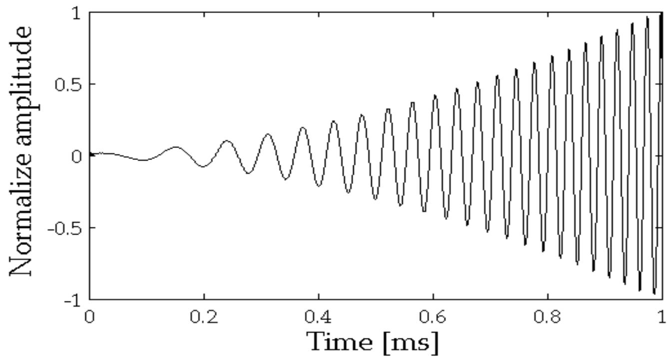
- 16-bits received signal and filtered



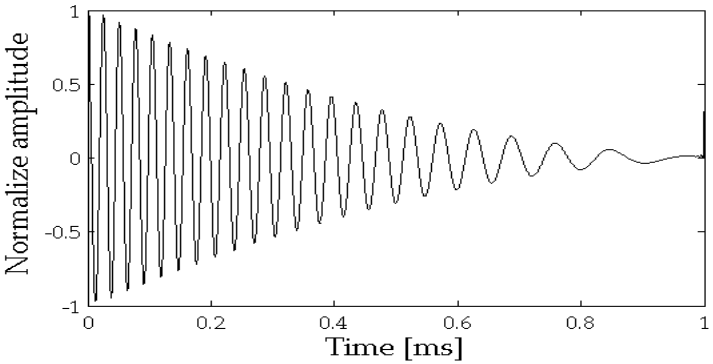
the received signal is filtered at low frequencies, → low pass filter of 2 to 60 kHz being applied so as to be able to correlate such signal with the second derivative of the envelope to the square of the signal sent to obtain the secondary beam.

V. Results

- The correlation of the received signal with the second derivative of the envelope to the square of the sent signal (the secondary beam) for each bit is shown:

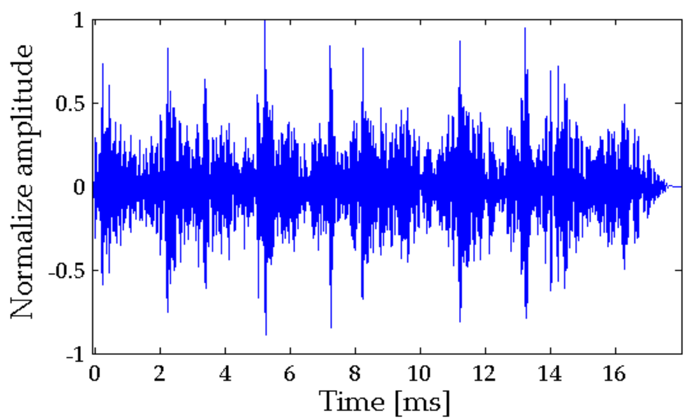


2^{nd} time derivative of envelope – upward sweep

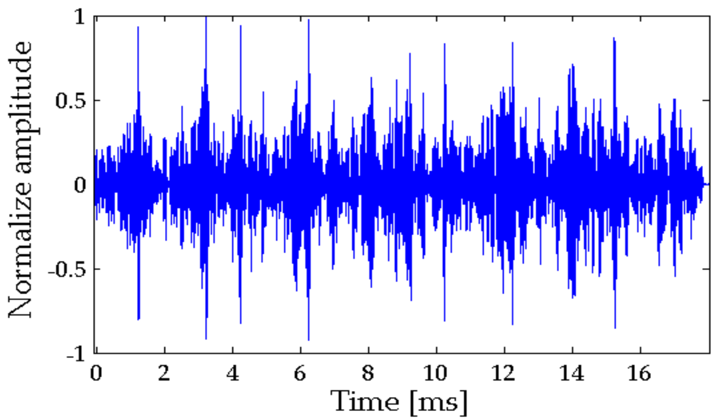


2^{nd} time derivative of envelope – down sweep

CORRELATION



Correlated signal, detection bit 1



Correlated signal, detection bit 0

V. Results

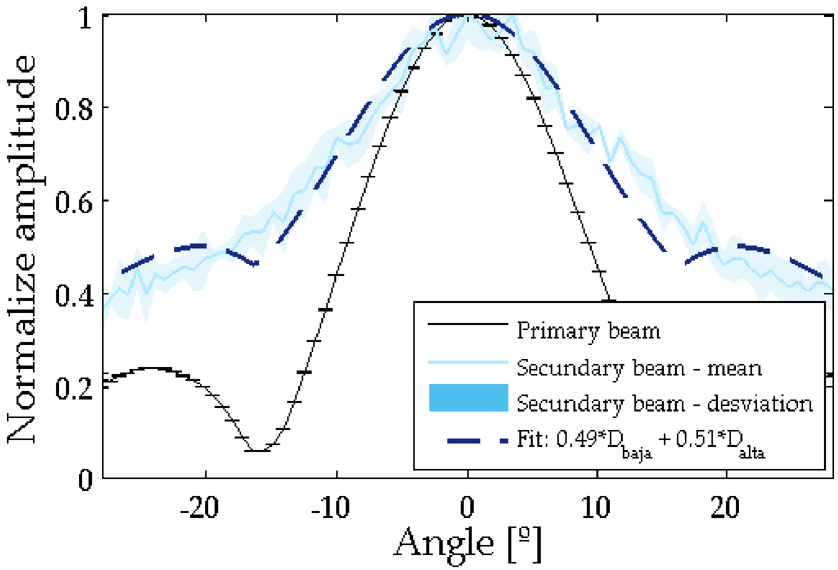
- Parameters of the detection and interpretation of the 16-bit signal received

Detection time [ms]	Amplitude Bit 1	Amplitude Bit 0
0.22	0.69	0.12
1.22	0.17	0.93
2.22	0.82	0.15
3.22	0.17	1
4.22	0.25	0.94
5.22	1	0.16
6.21	0.25	0.97
7.21	0.83	0.20
8.22	0.82	0.18
9.22	0.37	0.77
10.22	0.22	0.83
11.22	0.84	0.23
12.22	0.23	0.83
13.22	0.95	0.18
14.22	0.72	0.24
15.22	0.17	0.88
Mean	0.83	0.89

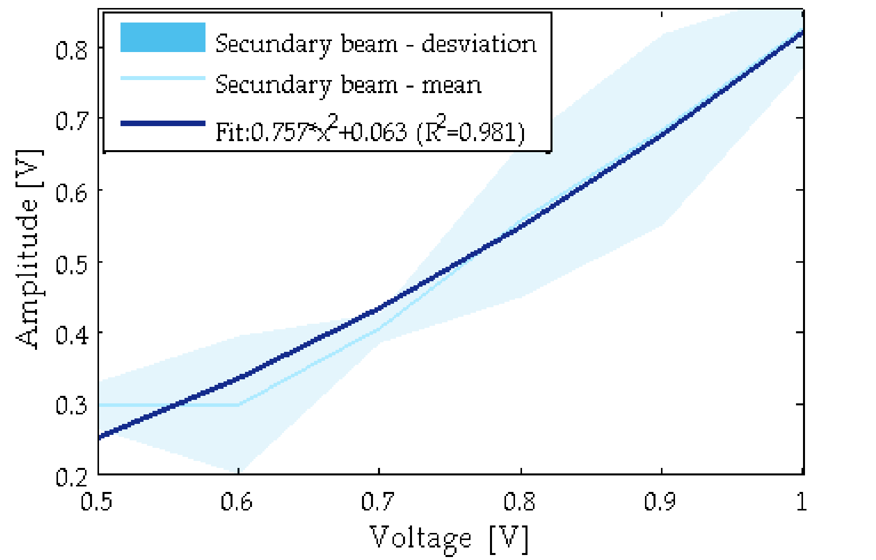
- In this table, the detection times for a direct flight time of 0.2 ms, the relative amplitudes obtained after the cross-correlation and the assigned bit is presented, showing that the information could easily be extracted.

V. Results

- Finally, the directivity for the signal generated together with the voltage variation is presented



Directivity



Voltage variation

- The directivity pattern for both signals clearly shows the evidence of the parametric effect of the secondary beam, presenting a directivity similar to that of the primary beam with an opening angle of 15 ° and 9 ° respectively.

- A non-linearity for the secondary beam is presented as the voltage is increased. Both effects agree that the signal has been generated parametrically and thus, this technique could be used for acoustic underwater communications in circumstances that highly directive beams are preferable.

VI. CONCLUSIONS

- The formulations presented to optimize the design of an array according to the model of Bertay and Leahy, lay the foundations for developing the design of a parametric array.

- The generation and analysis of parametric signals for a plane emitter transducer has been discussed in order to apply it to underwater acoustic communications. With respect to this, we can conclude that the parametric generation allows a better use of the communication channel which allows to transmit in a more defined region, in addition to improving the resistance against possible background noise and interference.

- On the other hand, the rapid absorption of high frequencies in the medium allows the low frequencies (secondary beam) to propagate at greater distances with a rather narrow directivity angle of the order of 15 ° for a frequency bandwidth between the 4 and 40 kHz presented in this study, comparing it with conventional transducers with a directivity angle of ~60 °.

THANK YOU