AIR BUBBLE SCREEN NOISE SUPPRESSION TEST IN LAKE MARACAIBO

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RESUMEN

Entre 1994 y 1997, SVA y Western Geophysical han llevado a cabo una investigación detallada de los ruidos asociados a los disparos sísmicos que se observan en el Lago de Maracaibo. Un análisis de aquellos ruidos y las técnicas de procesamiento para eliminarlos fue publicada en el Congreso de la SOVG en 1996. En el mismo ano procedimos a realizar ensayos en el campo con Cortinas de Burbujas de Aire, disenados para suprimir los ruidos causados por Ondas Guiadas. Aunque este metodo esta todavia en su etapa experimental, conseguimos algunos resultados muy alentadores. En un ensayo inicial se logro una supresion de 12 dB del tipico ruido sismico de la Costa Oriental, asociado con la capa de barro. Todavia quedan sin ensayar una serie de posibilidades para mejorar el metodo.

INTRODUCTION

In the period 1994 to 1997, SVSA and Western Geophysical have conducted an extensive investigation of the shot generated noises observed in Lake Maracaibo. An analysis of the noise and processing techniques to deal with them were presented at the SOVG conference in 1997. In the same year, field tests were performed with Air Bubble Screens aimed at suppressing the shot generated noises in the recording stage. Although this method is still in an experimetal stage, some very encouraging results have been obtained. 12 dB suppression of the seismic noise typical of the E coast of Lake Maracaibo has been achieved in a first field experiment, whiel there appears to be ample scope for further improvement of the technique.

SHOT GENERATED NOISE IN LAKE MARACAIBO

Lake Maracaibo constitutes a classical poor seismic data area, due to high levels of shot generated noise asociated with the shallow (<35m) water and, in places, a low velocity mud layer on the Lake bottom.

The noises commonly observed can be classified in two distinct types:

"HF noise": High frequency noise appearing as a strong waterbreak and subsequent backscattering, as seen in fig. A. The HF noise has a starting frequency of 30 - 70 Hz (depending on water depth) and has a flat spectrum beyond this cut off frequency.

"LF noise": Very monochromatic noise in the 20 - 40 Hz range as shown of Fig. G.

Both types of noise have high amplitudes (some 30 dB above most other events on the records), with very little tie decay after application of the spherical spreading correction.

The HF noise is typical for the NW part of the Lake, were there is no low velocity mud on the hard Lake bottom. The LF noise, baptised "Lake Maracaibo Singing" by the early explorers, is typical for the E coast of the Lake in the Bachaquero, Tia Juana and Cabimas areas, where the mud layer is 10-30 m thick. The HF noise is sometimes observed in the mud covered area also.

The HF noise is clearly identified with a normal mode propagating guided wave, as documented in ref. 5 and graphically illustrated in fig. B. The wave is supported b repeated critical reflection between the hard water botton and the free water surface and propagates with only circular spreading attenuation.

For the LF noise, Burg ea. And Levin (refs. 1 and 3) propose a leaking mode propagating wave or reverberation, assuming a very high reflection coefficient of the low velocity mud. The Burg-Levin theory does, however, not fully explain the near constant amplitudes of the LF noise.

SPERCRITICAL SCREENING HYPOTHESIS

In 1996 we postulated the Supercritical Sreening Hypothesis (ref. 5):

Screening off the supercritical energy leaving a seismic source, will eliminate the Normal Mode Waves that would otherwise be generated by this source in shallow water.

Fig. B shows the proposed screening in cross section.

The hypothesis in intuitive and unfortunately the Guided Wave phenomenon is too complex to corroborate it with theory or though finite difference modellin. Expensive, experimetal field testing is needed to verify it's validity.

Many methods have been considered to produce the required screening, but turned out to be impractical. Injecting massive amounts of air into the water, however, proves to be effective and operationally feasible.

SUPPRESION OF ACOUSTIC ENERGY BY AIR BUBLES

It is well know that small amounts of gas in solution will reduce the P wave velocity in a fluid. When larger amounts are included as free gas in bubbles, the velocity effect becomes more pronounced and in addition, the gas - fluid mixture will absorb acoustic energy. Domenico studied these affects in the seismic frequency band and includes a number of useful references in his report (ref. 2). He absorption of acoustic energy for a given bubble size is weak for low frequencies, up to a resonance frequency, where the effect becomes dramatic. To reach resonance at 40 Hz, a bubble size of about 7 cm is needed. Formula's for the absorption and the resonance frequency as a function of bubble size, gas saturation and fluid properties have been derived on theoretical grounds and appear to compare well with experimental data.

We repeated some of Domenico's experiments in a Western Geophysical test facility near Houston. Fig. C shows the results of measuring the signal from a single airgun source, with and without an air bubble screen between the source and the receiver. As predicted by theory, there is little absorption up to a starting frequency (about 20-26 Hz. in case) and good (12-18 dB) absorption beyond this point. We found it quite easy to obtain 18-24 dB suppression above 60 Hz. To produce the larger bubbles needed to reach lower cut off frequencies required careful engineering and the result shown in Fig. C is about the best we have been able to achieve so far. Fortunately the filter response shown in Fig. C is fit for the purpose of suppressing the HF noise, which only starts at about 40 Hz.

IMPLEMENTATION OF AIR BUBBLE SCREENS

After some encouraging small scale testing, we equipped the source vessels Western Shore with two Air Bubble Screens for full scale field testing during a seismic survey for SVSA in the Urdaneta West block in 1997. The schematic lay out of the screens in shown in Fig. D.

Five air compressors (750 scf/m) were mounted on the helideck of the vessels. The screen generators consisted of 4 inch flexible pressure hoses with nozzles every 30 cm. These were towed from the A frame to achieve the lateral separation from the gun array, at an average depth of 12 m. The length of hose equipped with nozzles was 50 m, but due to the slow rise time of the bubbles (approx. 3 sec/m) the actual Air Bubble Screen in the water is a lot longer than this.

A far field signature test was recorder in deep water off Aruba and under those conditions there was negligible interference from the screens, provided they were kept more than 6 m away from the airgun array. The towing characteristics of the screen were good and their operation did not present any serious problems.

Numerous difficulties had to be overcome to produce the required Air Bubble size, but towards the end of the survey good experimental evidence was obtained in support of the Supercritial Screening Hypothesis. However, contrary to what was observed in deep water, in the shallow water of Urdaneta West (<22 m), the screens did cause unacceptable interference with the signal.

RESULTS FROM BACHAQUERO TEST LINE

Just before the seismic crew was demobilised, a testline was recorded in the Lagoven Bachaquero area, to investigate the response of the LF noise to the Air Bubble Screens. The testline was shot W-E, perpendicular to the coastline, starting in 34 m and ending in 12 m water depth. The results of this testline were quite exciting.

The first, encouraging surprise was that in the deeper water (34-24 m) there was no evidence of interference with the downgoing signal. Strong interference, as observed in the Urdantea West area, developed quickly once the shooting vessels crossed the 24 m water line. In both areas the Screens were deployed at an average depth of 12 m. This leads us to believe that the damaging interference may be avoided by keeping the screen deployment depth less than half the water depth. Unfortunately, we did not have the opportunity to test this as the crew had left Lake Maracaibo when this possibility was realized. If this indeed is the case, it may yet prove possible to suppress the HF noise inn the shallower waters of the Urdaneta area, by careful control of the screen depth.

Secondly, good suppresion of the HF noise was observed Fig. E and F show a record without and with the Air Bubble Screens.

Last, but no least, the LF noise is also reduced by at least 12 dB. Fig G shows a record with strong LF noise and Fig. H the same record with the Air Bubble Screens operating, The spectral plot of these two records (Fig I) show a 12 dB reduction on the sharp spectral peak at 30 Hz representing the LF noise.

Note that in the case of this LF noise, we have to assume the (narrow, vertical) screens are intercepting reverberations with nearly vertical travel paths, while the screens used were designed to intercept subhorizontal supercritical rays! The Air Bubble Screens are about two meters wide when they reach the surface. However, they impose the zero pressure boundary condition for a free surface, so the actual area where the acoustic propagation is impaired is several meters wider. Thus they will constitute an approximately 10 m wide and 12 m high obstacle for the vertical rays of the reverberations.

Several modifications could be easily made to the screen geometry, to produce better and repeated interception of vertical ray paths and we therefore consider it quite likely that the 12 dB suppression achieved in this first test can bi significantly increased.

Even though the LF noise was reduced by some 12 dB on the field records, the sharp noise peak in the spectrum remains some 18 dB above the signal, which is far to much to present processing techniques to deal with. Consequently, the stacks of the line with and without the Air Bubble Screens operating show little difference. A further noise reduction of at least 12 dB on the field records would be needed to produce stacks which are not degraded by this very damaging noise.

CONCLUSIONS

- We have collected good evidence in support of the Supercritial Screening Hypothesis.
- Air Bubble Screens can attenuate the HF guided wave noise, but severe interference with the signal was observed in less than 24 m water depth. This interference may be avoided with shallower screen deployment, but this remains subject to testing.
- Air bubble screens are an effective tool to reduce the LF noise typical of the Lake Maracaibo E. Coast. 12 dB suppression has been demonstrated and it is considered quite feasible to improve this performance significantly.
- Air Bubble Screens are effective in reducing the horizontally travelling acoustic energy leaving a seismic source. This could be beneficial in areas where a negative environmental impact (e.g. disturbance of dolphins and other cetaceans) of the use of airguns is suspected.

ACKNOWLEDGEMENTS

The authors thanks PDV, SVSA and Western Geophysical for their support for this research and their permission for publishing the results.

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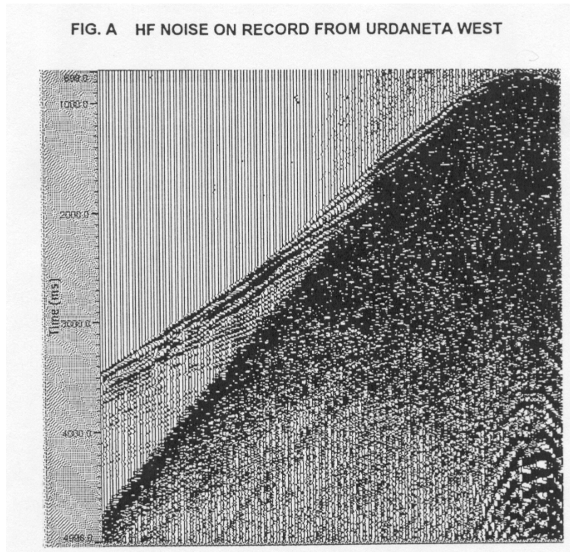

FIG. A HF NOISE ON RECORD FROM URDANETA WEST

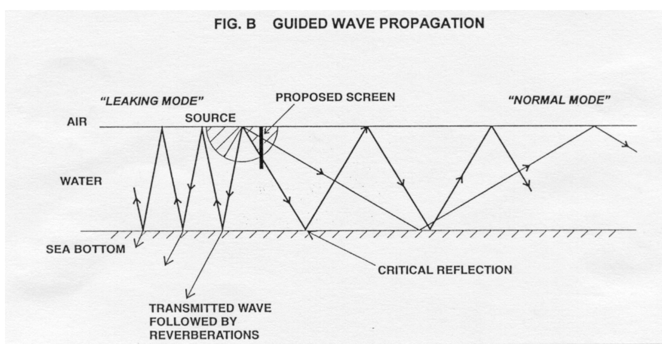

FIG. B GUIDED WAVE PROPAGATION

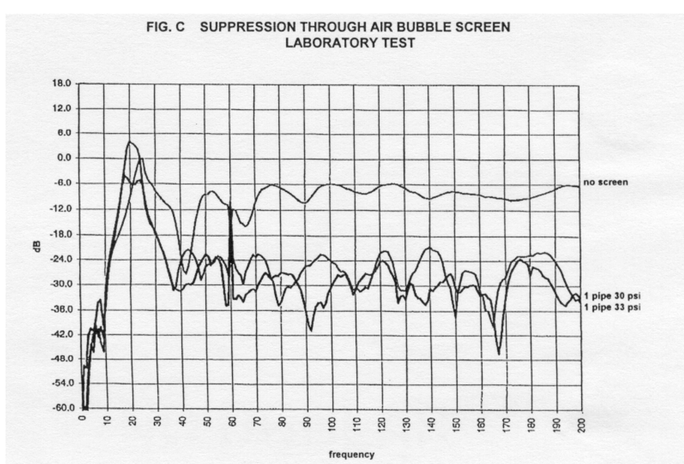

FIG. C SUPPRESSION THROUGH AIR BUBBLE SCREEN LABORATORY TEST

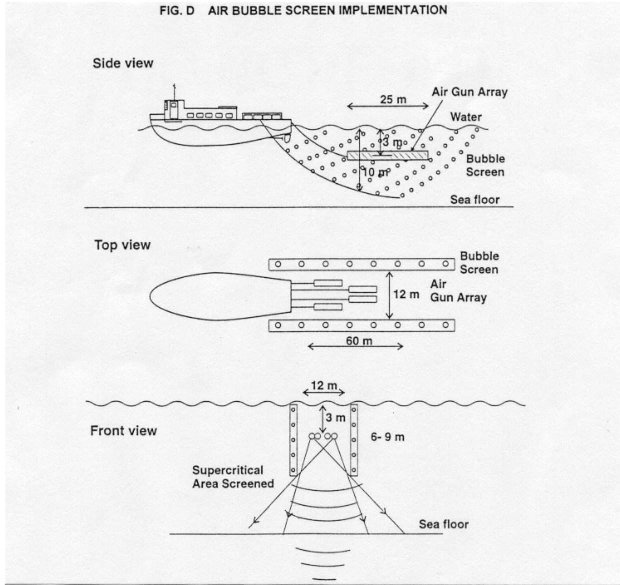

FIG. D AIR BUBBLE SCREEN IMPLEMENTATION

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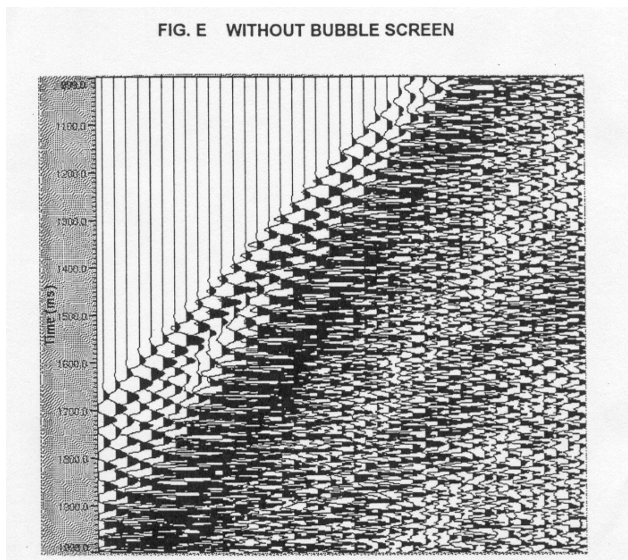

FIG. E WITHOUT BUBBLE SCREEN

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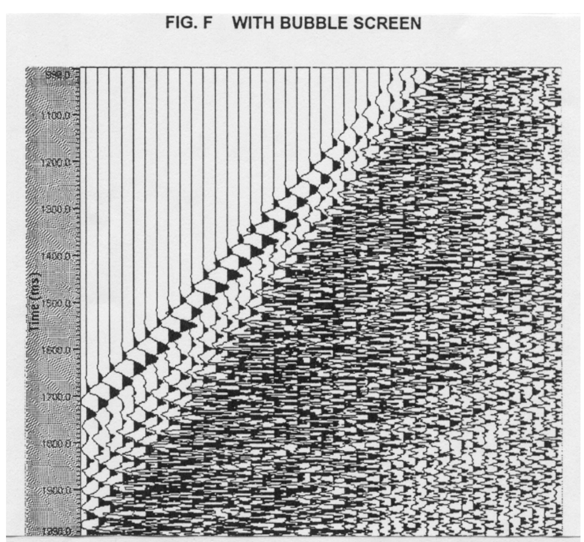

FIG. F WITH BUBBLE SCREEN

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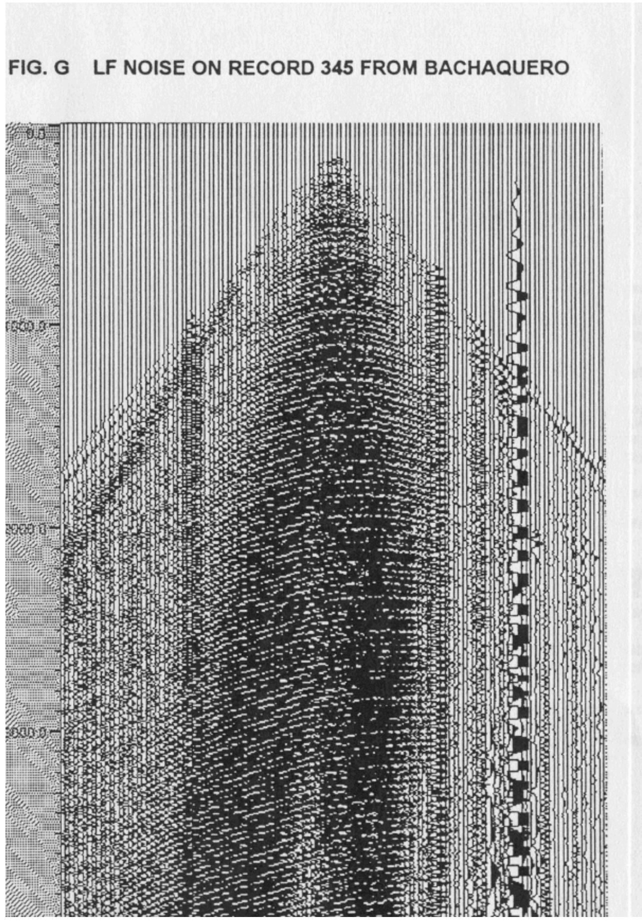

FIG. G LF NOISE ON RECORD 345 FROM BACHAQUERO

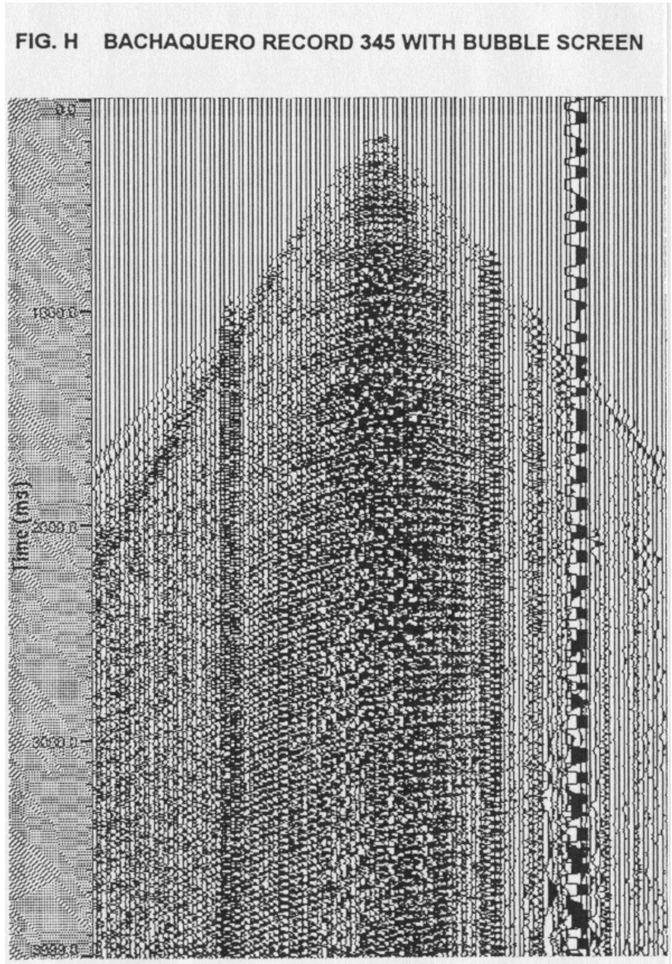

FIG. H BACHAQUERO RECORD 345 WITH BUBBLE SCREEN

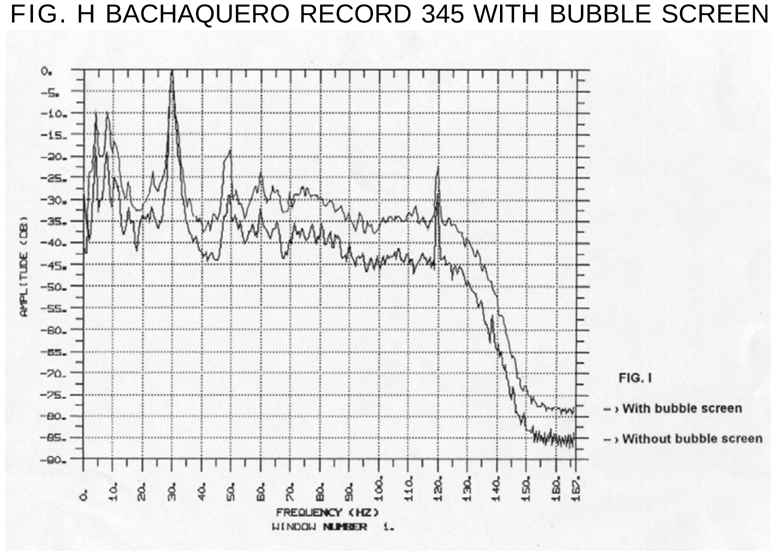

FIG. I -> WITH BUBBLE SCREEN

-> WITHOUT BUBBLE SCREEN