B-Type Imaging with Coded Signals

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ABSTRACT

We have used a pseudorandom (PN) coded signal to investigate the improvement of the signal to noise ratio (SNR) in B-type echography. With $N \approx 10^3$ bits of code the experimental value of SNR is about 55 dB for PN sequence, close to the theoretical value of 20 log N $\approx$ 60 dB.

In order to assess the respective advantages of the classical echo images and those obtained with coded signal, we present some B- type images obtained from objects of elementary geometry with application to non destructive testing and medical imaging. We show that the SNR improvement obtained with PN sequence allows the observation of details which would remain invisible with classical echographic techniques.

BACKGROUND

Pulse echo reflection techniques used for ultrasonic boundary location in non-destructive testing instruments and in diagnostic medicine are often limited in average transmitted power by peak power constraints. In the case of medical ultrasound devices for example, the power limit arises from the risk of causing tissue damage rather than from signal emission limits of the instrument. Obviously, the energy in reflected signals depends on the transmitted energy which determines also to SNR limit.

To overcome such problems a general technique has been proposed [1-7] which includes matched filtering in an ultrasonic system via correlation between the received signal perturbed by noise, and the emitted signal. In our correlation based system we have used a circular maximal length sequence of N = 1023 binary digits which displays a number of randomness approximating that of white noise. Its autocorrelation function consists of a series of triangular peaks of height $1+N^{(-1)}$. Elsewhere the function has a constant value of $-N^{(-1)}$. and the SNR = 20*logN = 60 dB. Since the coded signal is emitted continuously, the system needs at least two transducers operating respectively in emission and reception mode.

EXPERIMENTAL SET UP

In the experimental results presented here the central part of an annular array is used as an emitter, whereas the first ring is operated in receiver mode. The central frequency is f = 7.5 MHz and the bandwidth at -20 dB is B = 7 MHz. In this configuration the lateral resolution is rather poor : ±0.5 mm at -6 dB. Nevertheless it still allows interesting comparisons between classical and correlation echography .

For a maximum energy transmission, a phase shift keying modulation was chosen. The binary code was phase modulated to the center frequency of the transducer. For a good resolution, the duration of each bit of coding sequence should be as short as possible since after the demodulation and correlation, the signal output will have a triangular shape with a basewidth of 2τ. With a 7,5MHz transducer bandwidth $\tau \approx 0{,}28$ ms. In the receiving unit the local carrier was derived from the same source as the transmitted carrier so that synchronous detection can be achieved. The return echoes were then split into two channels and demodulated by the same function used for initial modulation but separed from one another by 90° in phase. The output from both channels is correlated with delayed replicas of the transmitted sequence. Each of the correlated results were squared and added together. The final result was displayed on the screen. In our system, the demodulated signal was first digitalized by 8 bit A/D converter and stored in the scope memory. The acquired data were then transferred to the memory of the microcomputer where they were correlated with the stored reference.

EXPERIMENTAL RESULTS

In figure 1 we present a classical A type line obtained from a small tip 13 mm high and 0.2 mm in diameter, located in the front of a stainless steel used as a mirror. The observed value of SNR = 50 dB, instead of

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the expected 60 dB value, is due to the limited bandwidth B of our transducer; with f = 7.5 MHz and B = 2MHz (at - 4.3 dB) it can be shown that the decrease in SNR should be ≈ 6 dB.

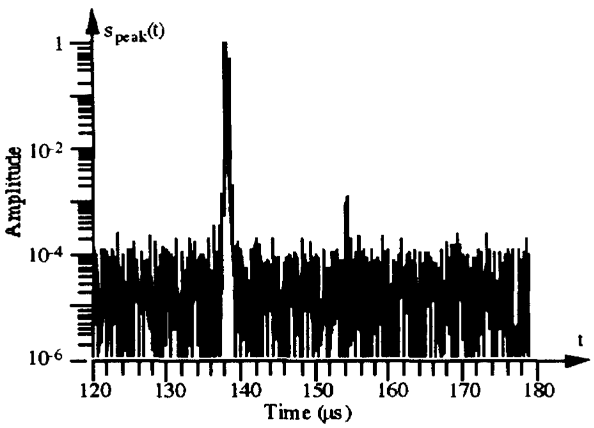


Fig.1 : A type echogram. Correlation with a m-sequence.

With the same very broad ultrasonic beam we have obtained some preliminary B type images of very simple objects . In fig 2.a we present two echograms of a single hole (3 mm in diameter and 10 mm in depth) drilled in AGAl4 (dural). The transducer was moved along the diameter. The absence of a sharp discontinuity on the upper horizontal line of the echogram indicates a beamwidth of the hole diameter order.

When m-sequences are used (fig 2.b) the walls of the drilled hole are clearly visible. This effect never observed by us in classical echography, is observable in correlation techniques because the local dynamic is improved by band compression.

The local SNR improvement is also observable in the two last echograms of a longitudinal section of a gel phantom (width 40 mm, depth 50 mm and $\alpha = 1$ dB cm^{-1}MHz^{-1}) that contains two steel threads located near the top (diameter 0.3 mm) and two more near the bottom (diameter 0.1 mm). When the transducer is operating in the classical pulse mode, two echoes corresponding to 0.3 mm targets located near the sonicated front plane of the phantom appear clearly, as well as a single echo from the 0.1 mm target located in the lower right part of the gel phantom. (fig 3a). Using classical echography, it should be pointed out that due to the high attenuation of the gel, the acoustic speckle remains buried in electronic noise; this also holds for the most distant target echo. In contrast, both appear when a coded emission is used (fig 3b).

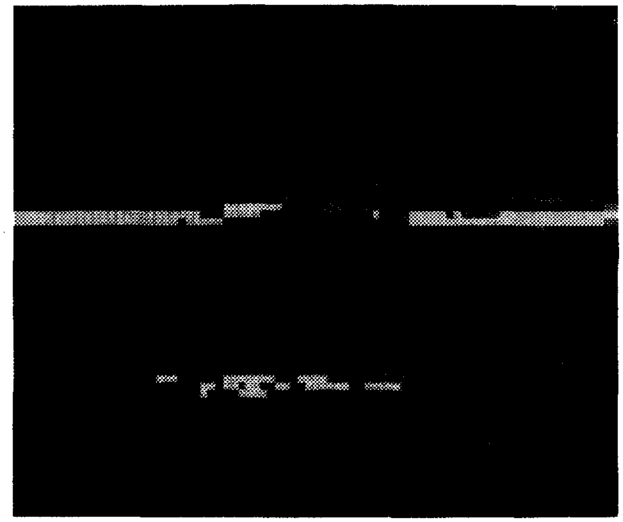


Fig. 2.a : Echogram of a single hole drilled in AGAl4 (dural), sonicated from above.Pulse method

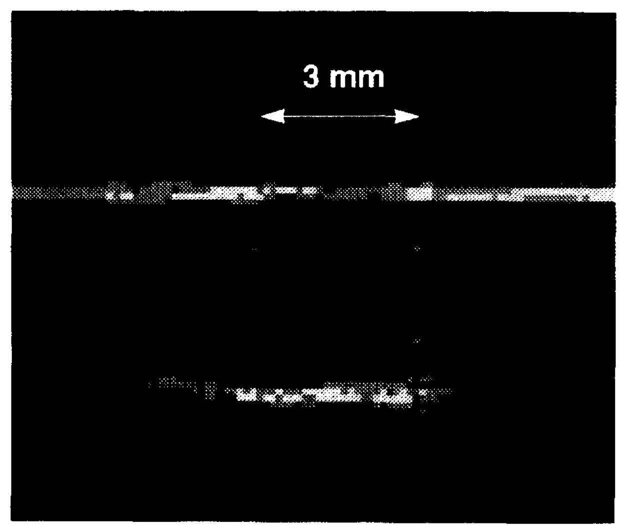
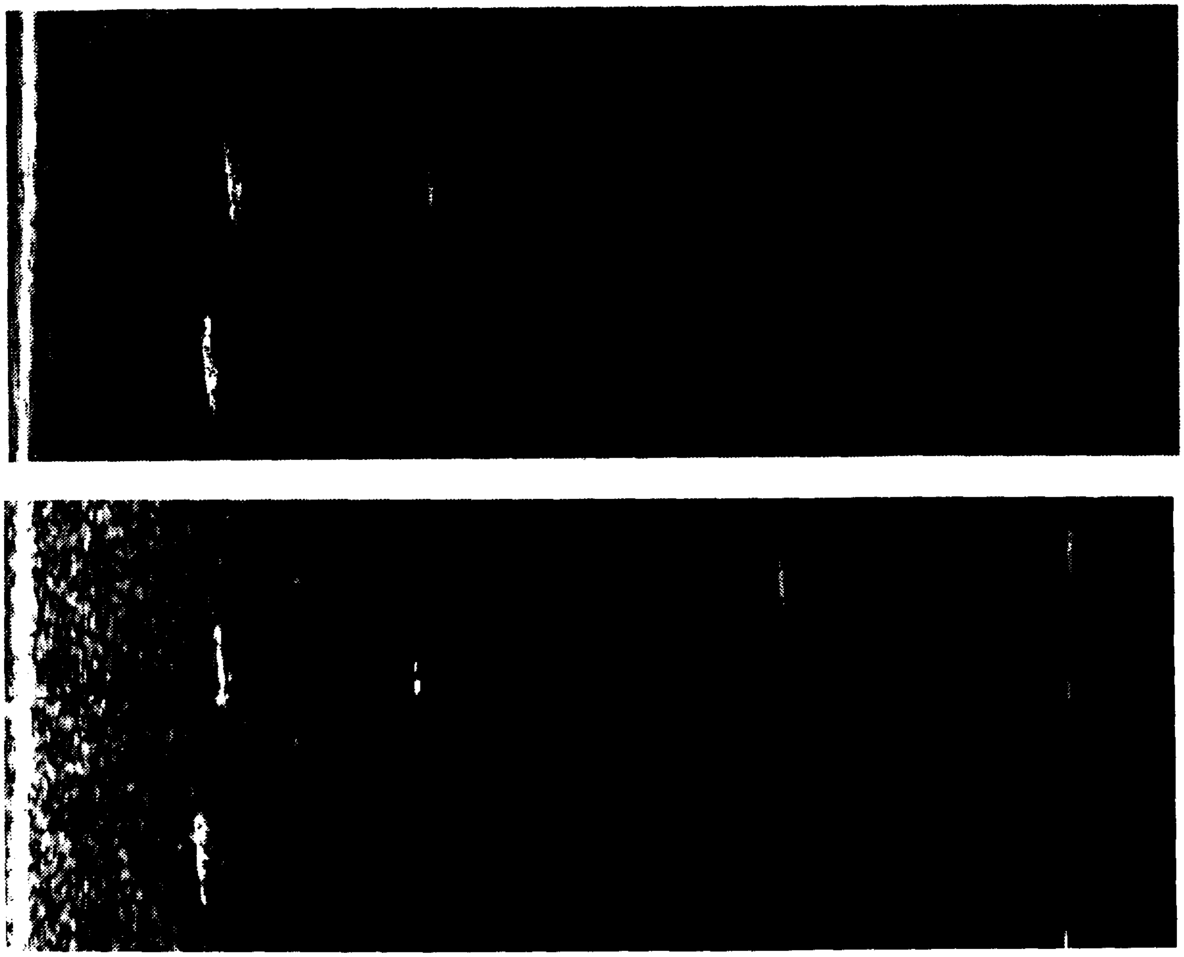


Fig. 2.b:correlation with a m-sequence : the side walls of the hole appear clearly.

CONCLUSION

The result presented here indicate clearly that by transmitting a continuous coded signal and then by compressing it into a short high resolution pulse at the receiver, the signal to noise ratio of B-types images of strongly echogenic targets is improved. In media where the signal attenuation at fixed depth is proportional to the frequency, the SNR improvement allows the use of higher frequencies and leads to an improved resolution.



a)

b)

Fig 3: Echograms of a gel phantom sonicated from the left side. (see text).

ACKNOWLEDGMENTS

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