AN EXPERIMENTAL SYNTHETIC APERTURE SONAR SYSTEM

Meng Z., Griffiths J.W.R., Curtis T.E. and Wood W.J.

Loughborough University of Technology, Sonar Group
Department of Electrical and Electronic Engineering, Loughborough, U.K.

1. INTRODUCTION

The concept of the synthesis of an aperture by sampling as an array or element moves along a given path dates back many years but unfortunately the variability of the medium has restricted the application of the concept in sonar. However a similar technique, side scan sonar which does not require phase coherence from sample point to sample point, has been in use for many years producing excellent results (e.g., ref 1.).
Over recent years there has been a resurgence of interest in Synthetic Aperture Sonars (refs 2,3) and this paper describes some laboratory experiments on such a system. The main emphasis of the work described in this paper is on the signal processing and a practical almost realtime synthetic aperture system has been constructed based on the Motorola 56001 DSP. Some early results using the system are presented.

2. BASIC CONCEPT

The principle of the synthetic aperture system is based on the fact that in a stationary system it does make any difference whether a set of samples at different points in space are observed at the same time or in sequence. Thus the performance of the synthetic aperture system will be the same as a normal array which has the same length as the synthetic aperture.
Normally the length of the aperture is limited by the time over which the system can be assumed stationary, together with the speed of the vehicle towing the sensor, the rate at which samples can be taken (depends on the range required) and the wavelength (since samples should be taken at half wavelength intervals). However the size of the aperture may also limited by the dimension of the sampling transducer since the beam pattern of this will control the total range of angles over which signals can be received.
Considering the passive case if the receiving transducer is d metres across then the beam angle (at 3db) is $\frac{\lambda}{d}$ radians. This restricts the length of the aperture to $R \cdot \frac{\lambda}{d}$ approximately. The 3db beam width of the synthesised aperture will be $\frac{\lambda}{R \cdot \frac{\lambda}{d}}$ i.e. $\frac{d}{R}$. Thus at range R the resolution will be d.
A similar argument for the active case when the same transducer is used for transmission and reception gives the limit of resolution as d/2. It should be noted that although this argument is based on a far field assumption, the limit of resolution still applies in the near field provided the processing is focussed, i.e., a range dependent phase correction is used.

3. DESCRIPTION OF APPARATUS

The sketch in fig.1 shows the tank and the experimental apparatus. The transducer is mounted on a computer-controlled moving platform set on the rails across the tank. The motion is controlled by software run on a 386 PC and data is captured and stored in the memory of a 56001 DSP board plugged into the PC.
Fig.2 shows the schematic diagram of the system.
The frequency of operation was 40kHz and the transducer is one wavelength i.e., 37.5mm wide.

4. EXPERIMENTAL RESULTS

Fig.3 shows a typical data file before processing.
Fig.4(a) shows the reconstruction of a single source and Fig.4(b) shows a single scan along one range gate. The 3db width is 38mm as shown.
Similarly in Fig.5(a) and 5(b) reconstruction for two sources spaced at a distance of 100mm is shown.
In Fig.6(a) and 6(b) the reconstruction for one target using the same transducer for sending and receiving is shown. The 3db width is 20mm. Similarly Figs 7(a) and 7(b) show the reconstruction for two targets spaced at a distance of 25mm.
In all of these measurements the aperture length was 2m and samples were taken at 20mm intervals.

5. CONCLUSIONS

The resolution achieved in the practical system is approximately that predicted from theory and the processing time for a small aperture is almost in real time. The time taken for the sweep along the aperture far exceeds the time taken for the processing.

6. REFERENCES

1 M.L.Somers and A.R. Stubbs "Side-Scan Sonar" IEE Proc. Part F Vol. 131 No.3 pp. 243-256 Jan. 1984

2 P.T.Gough and M.P.Hayes "Test Results Using a Prototype Synthetic Aperture Sonar" J.A.S.A. Dec. 1989 Vol. 86 No. 6 pp. 2328-2333

3 M.E.Zakharia, J Chatillon and M.E.Bouhier "Synthetic Aperture Sonar; A Wide Band Approach", I.E.E.E. Ultrasonics Symposium, Honolulu Hawaii, U.S.A. Dec. 1990 pp. 1133-1136

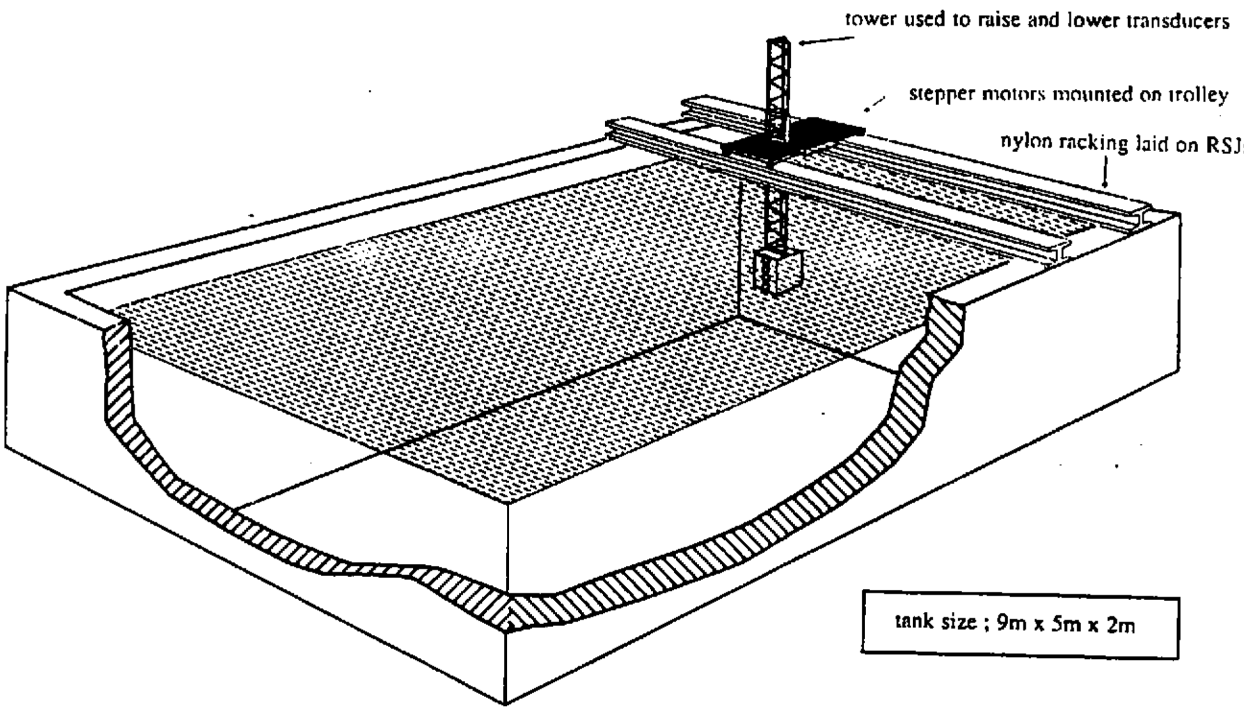

Fig.1 Tank and the Experimental Apparatus

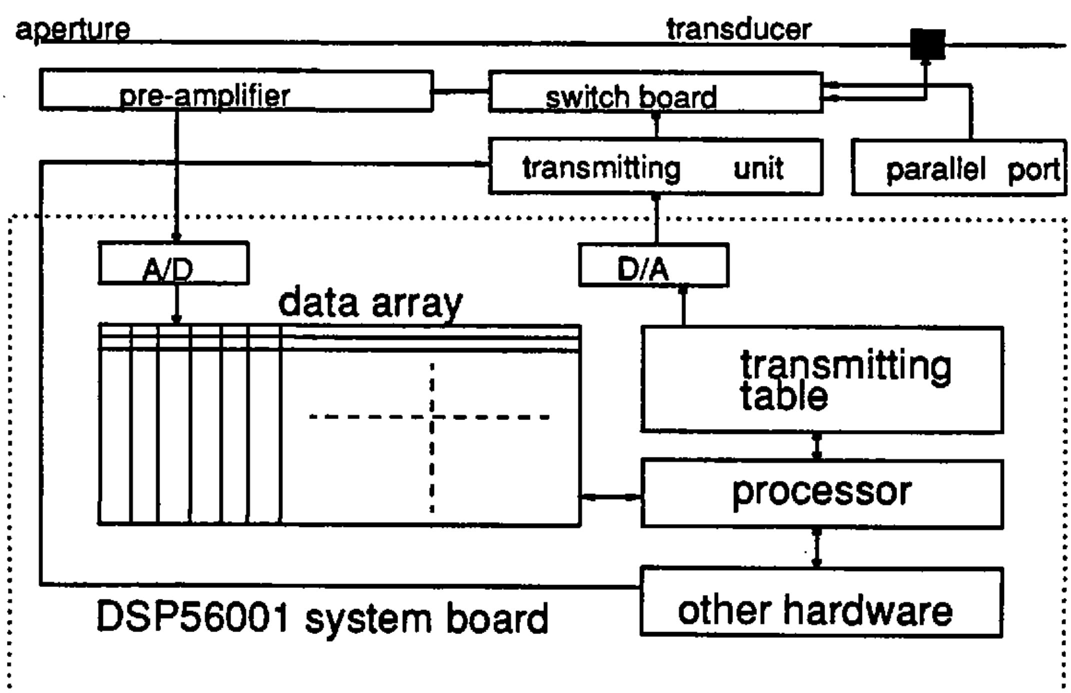

Fig.2 Schematic Diagram of the System

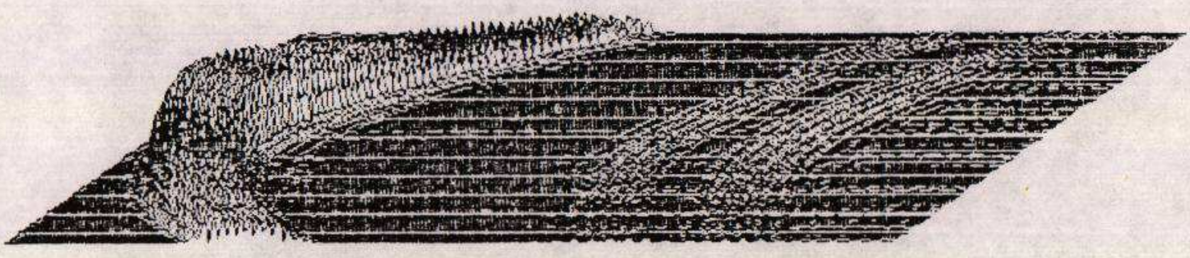

Fig.3 A Typical Data File Before Processing

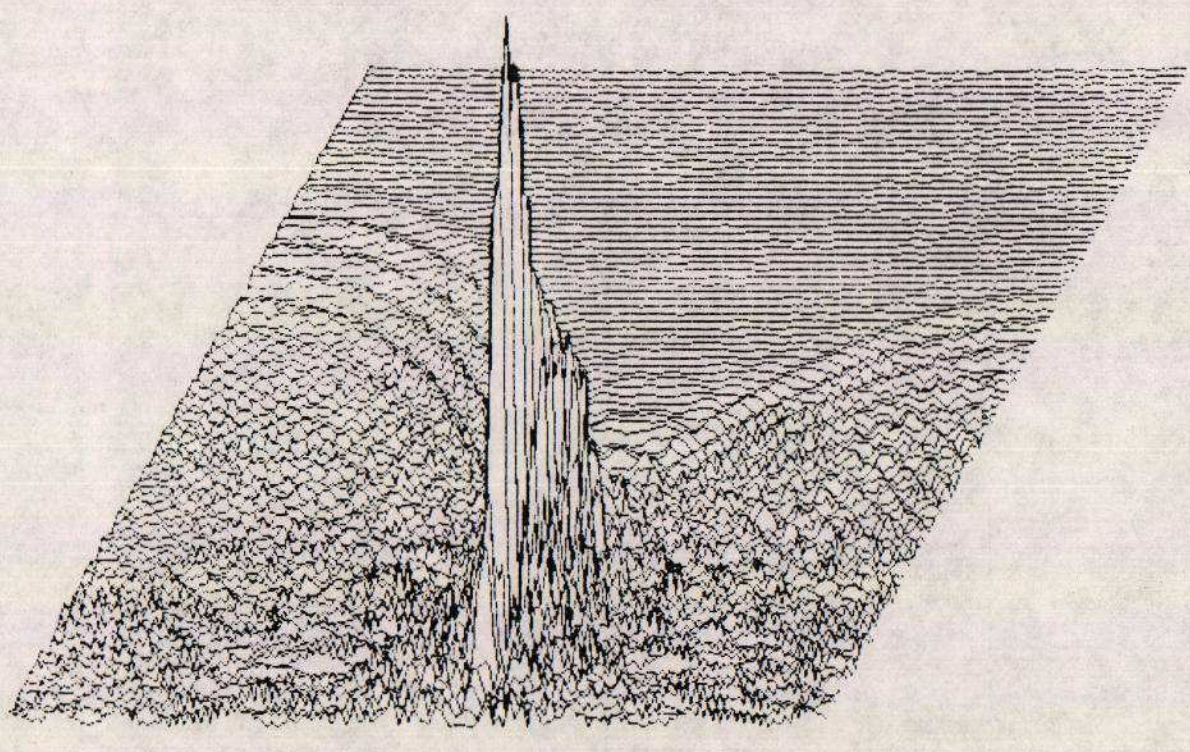

Fig.4(a) The Reconstruction of A Single Source

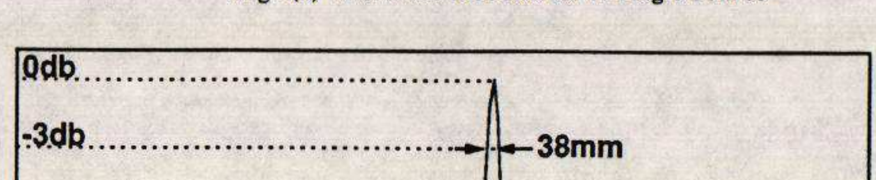

Fig.4(b) A single scan along one range gate

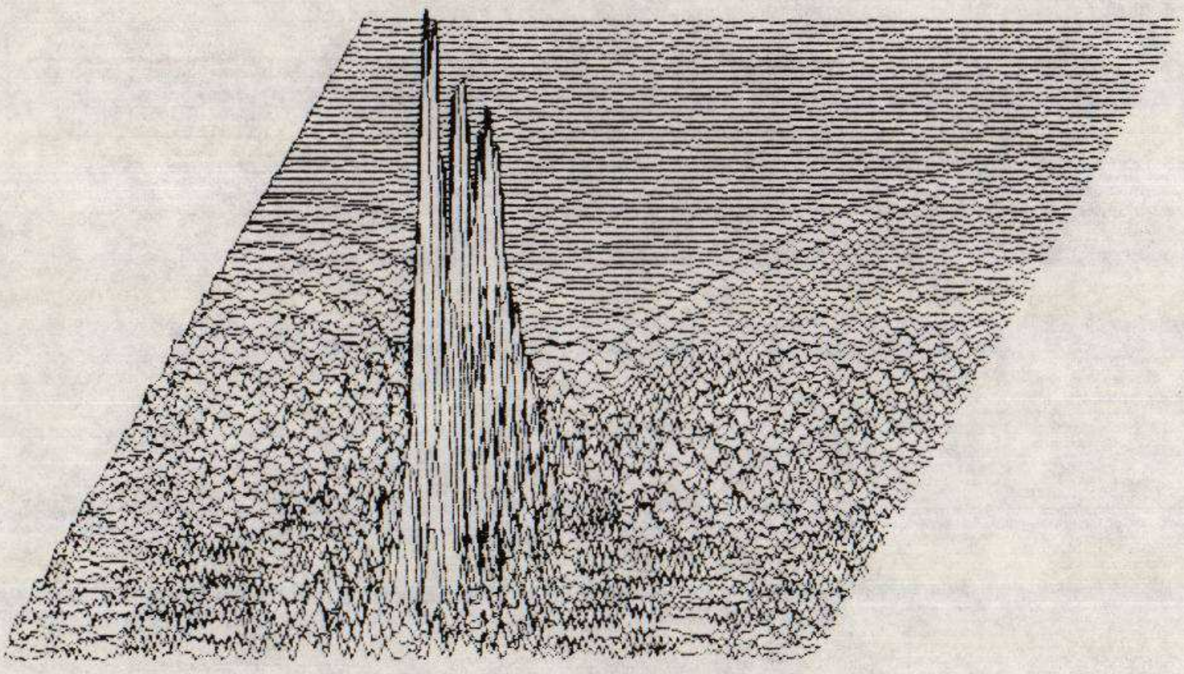

Fig.5(a) The Reconstruction of Two Sources

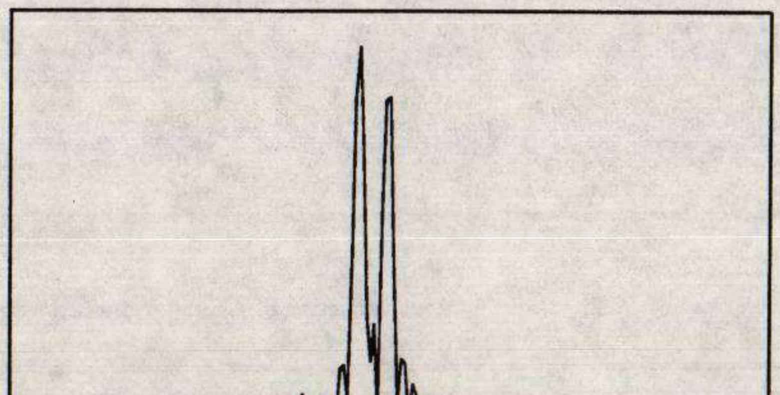

Fig.5(b) A single scan along one range gate

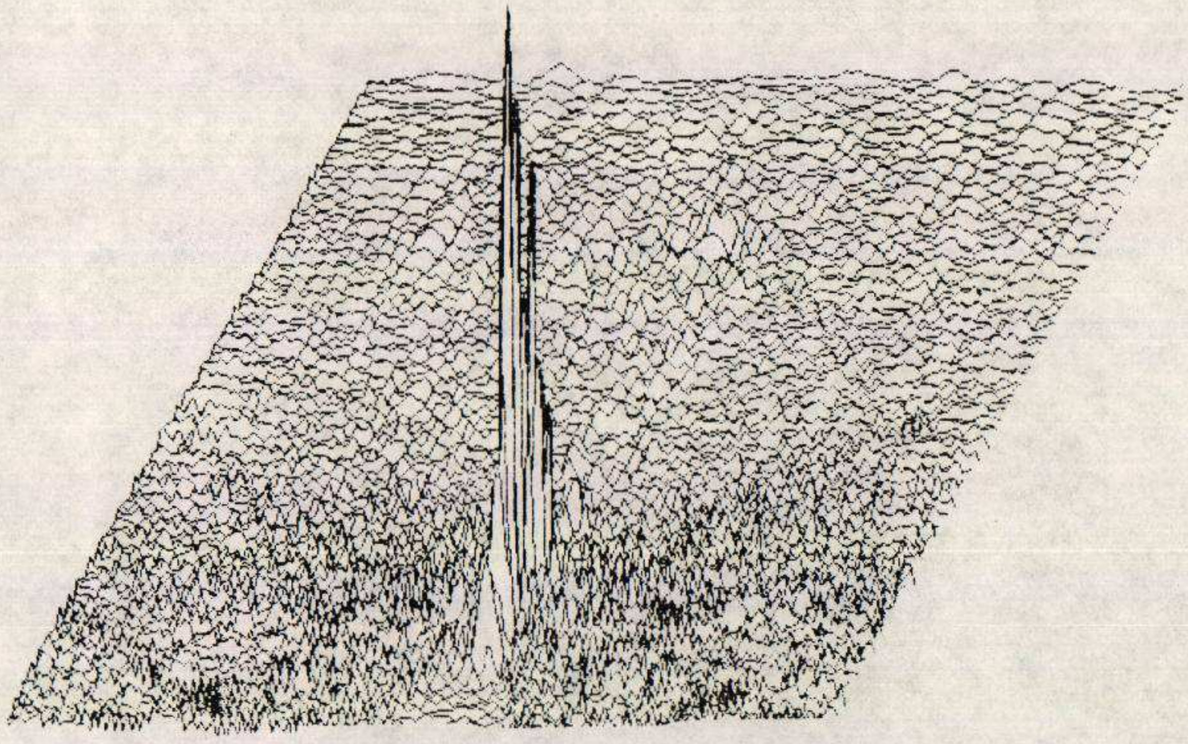

Fig.6(a) The Reconstruction of A Single Target

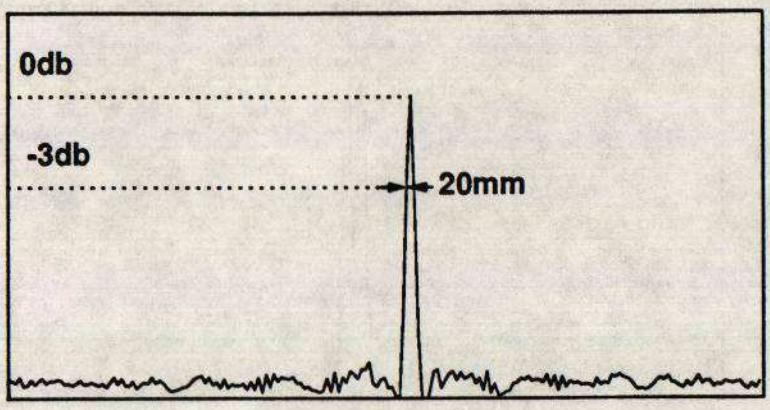

Fig.6(b) A single scan along one range gate

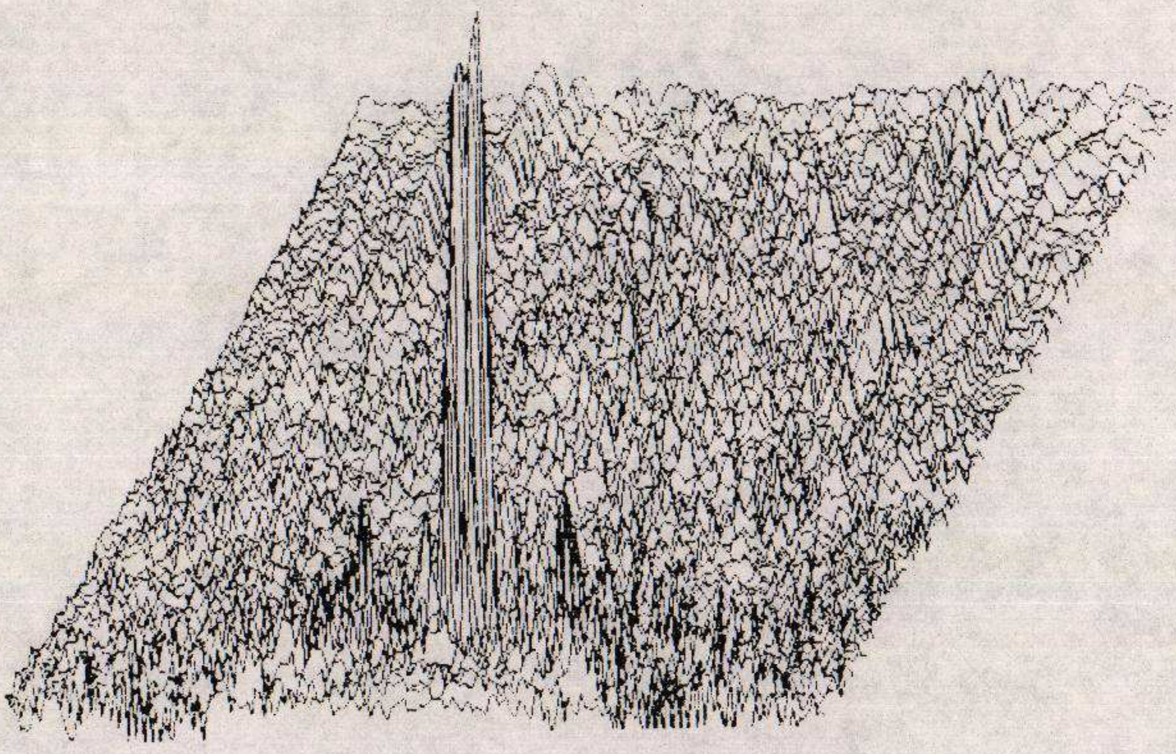

Fig.7(a) The Reconstruction of Two Targets

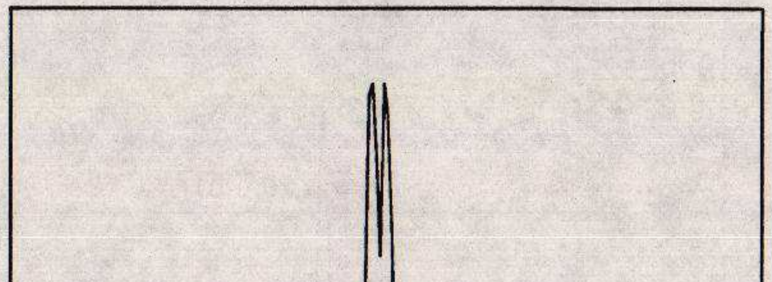

Fig.7(b) A single scan along one range gate