DYNAMIC CONTROL OF THE RECEIVING BEAM HORIZONTAL CROSS-SECTION IN THE SIDE SCAN SONAR

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A decade old side scan sonars are now being modernised by way of dynamically controlling the width of the receiving beam in the horizontal cross-section. The result is a quasi-constant linear resolution of the sonar (replacing constant angular resolution), when it picks up echo signals as it moves further away from the targets. The advantage of the treatment is that the ship using the side scan sonar can increase its speed without risking the loss of near targets' echo. The articles describes how the system of dynamic control was implemented. Special TVG systems were introduced to control dynamic signal gain from several separate sections of the sonar's acoustic array, which was divided symmetrically into unequal sections. The location of these systems in the sonar's receiver is presented. Examples are given of curves that control TVG and of the effects of dynamic horizontal stabilisation of the sonar's linear resolution as it receives signals.

INTRODUCTION

Designed by the authors about a dozen years ago, the side scan sonars are now being modernised by way of dynamically controlling the width of the receiving beam in the horizontal cross-section.

For a constant horizontal angular resolution of the sonar, as the towed medium is moved along, it is quite likely that some sectors near the medium will not be scanned. These sectors tend to grow along with the speed of towing and the sounding pulses are less frequent (the longer the sonar range). This effect is not very strong, because of the imprecisely conical beams. Before the modernisation, however, two angular resolutions were used, making it possible to choose a higher speed of the sounding ship at the cost of a lower resolution (4 º beam) or a lower speed with more precise sounding results (1º beam).

When the width of the beam's horizontal cross-section is controlled dynamically as it receives echo signals, the result is a constant (or quasi-constant) linear resolution of the sonar in that cross-section, which eliminates the above risk. What is important is that this treatment helps to increase the sounding ship's speed without the risk of losing near targets' echo.

For a sonar range of 300m, the duration of a single transmission, from the moment the sounding signal is emitted until the echo from the far end of the range is received is (with some margin) 0.5s. When the ship's speed is 6 knots, it will cover about 3 meters in 1s. If modernised, the sonar's horizontal constant linear resolution of 3m will produce two echoes from each target for this range (for a 150m range, when transmission time is twice as short, there will be four echoes). In theory the speed of the ship and a 300m range of sounding per one side could be 12 knots (with one echo off each target). In practice, to make target detection reasonably likely, the number of echoes should be as high as possible. Consequently, the speed of a sounding ship should be minimised.

1. THE PRINCIPLE OF CONTROL

The block diagram below shows how dynamic control of the beamwidth was implemented on the example of a single (on one ship's side) channel of the sonar's receiver placed in the tow-fish. The antenna transducers array is divided into 32 elements, forming the sections as shown in Figure1. As a result, beamwidth can be controlled using fragments or the entire antenna for receiving echo signals.

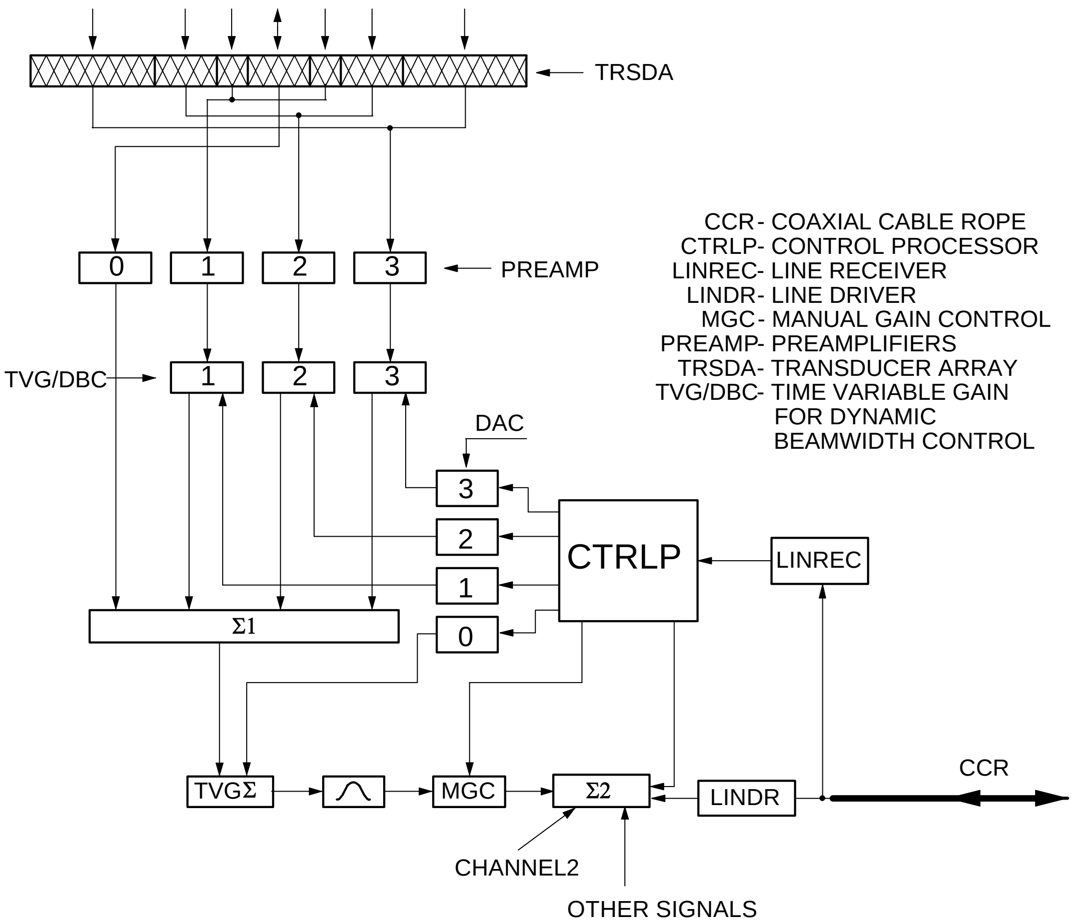

Fig.1 Block diagram of the receiver (1 channel) of the side scan sonar with dynamic control of the beamwidth

The pulses received are sent to the middle section (it is short because it has four elements beamwidth can be controlled). As a result, they are emitted into a wide (about 8 º) beamwidth, which means that a sufficiently large area has been scanned.

In the initial phase of listening – up to some 25m – echo signals should be received from this section only. What it means is that all amplifiers with time variable gain for dynamic beamwidth control TVG/DBC should be set at the minimum value. As we move beyond 25 m, TVG/DBC 1 should increase to reach its maximum at 50 m. The full range is scanned from four sections (eight elements) of the transducer's array, with a four stage resolution of the beamwidth. From 50 m onwards, TVG/DBC 2 should start (for two consecutive four element sections) to reach the maximum at 100 m. The beamwidth angular resolution is then 2º. From this range onwards, TVG/DBC 3 is introduced, with full gain reached at 200 m, at which point all the sections (32 elements) receive at 1º resolution. The proposed division into control sections was optimised to some degree. It ensures that control is transparent and that, as will be shown later, the beamwidth is stable at -3 dB up to 150 m range, with a slight widening in the 150 – 300 m section.

Echo signals from sections of the array are amplified in PREAMP pre-amplifiers. Their amplitudes are controlled by TVG/DBC. They must then be added in Σ1. It is only at its output that the echo signals have dynamic beamwidth control. Please note, that as the signals from array sections are added in the Σ1 adder, the result is an unintentional increase in sensitivity (signal level) by two, three and four times. This effect needs to be compensated in TVG systems, as shown below.

Controlled from the CTRLP processors, digital to analogue converters (DAC) produce the necessary values to control TVG.

When it is added, the signal undergoes time variable gain TVG Σ (with special shapes in side scan sounding). The signals are filtered and sent to manual gain control MGC, which is set from the CTRLP processor on the operator's control panel.

After the manual gain control amplifier, echo signals from both sides in their natural form (with different carrier frequencies) are sent to an onboard system (operator's control panel). This is done following another summation (with the other signals) in the Σ2 adder and via the line driver LINDR to the coaxial cable rope.

2. CONTROL WITHOUT TVG/DBC AMPLIFIERS

The simplest way to achieve quasi-stabilisation of the beamwidth is to add signals as the sections are activated with no preliminary TVG/DBC. Figures 2, 3, 4 and 5 show the effects of this operation.

Figure 3 shows that up to a distance of 1.5 m signals oscillation does not exceed 3 dB, suggesting that the desired stability has been attained, i.e. the results are satisfactory. When the process is irregular the images show areas of rapid gain. Using TVG/DBC will help to significantly reduce the oscillation and irregularities.

In practice TVG systems are controlled attenuators, which is why Figure 5 shows the gain on a scale of 0 to 1. The saw tooth-like shape of the control is the result of having to compensate for the increase in signal level, as new array sections are activated. After the compensation, the level of the output signals increases in proportion to the range (20 log r type control).

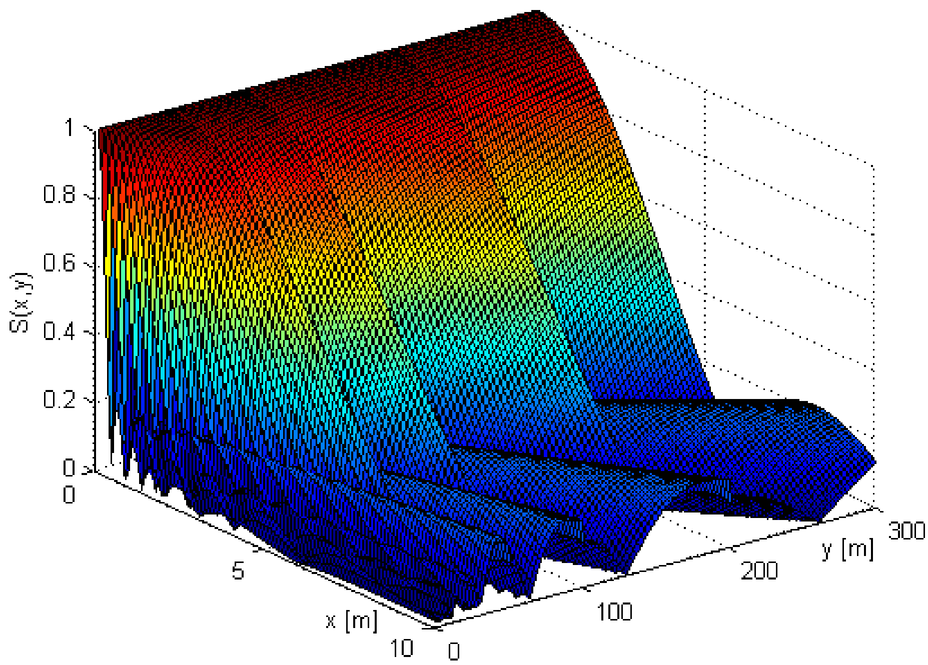

Fig.2 Spatial distribution of echo signal levels at a distance of *x* from the acoustic array's axis from range *y* without TVG/DBC

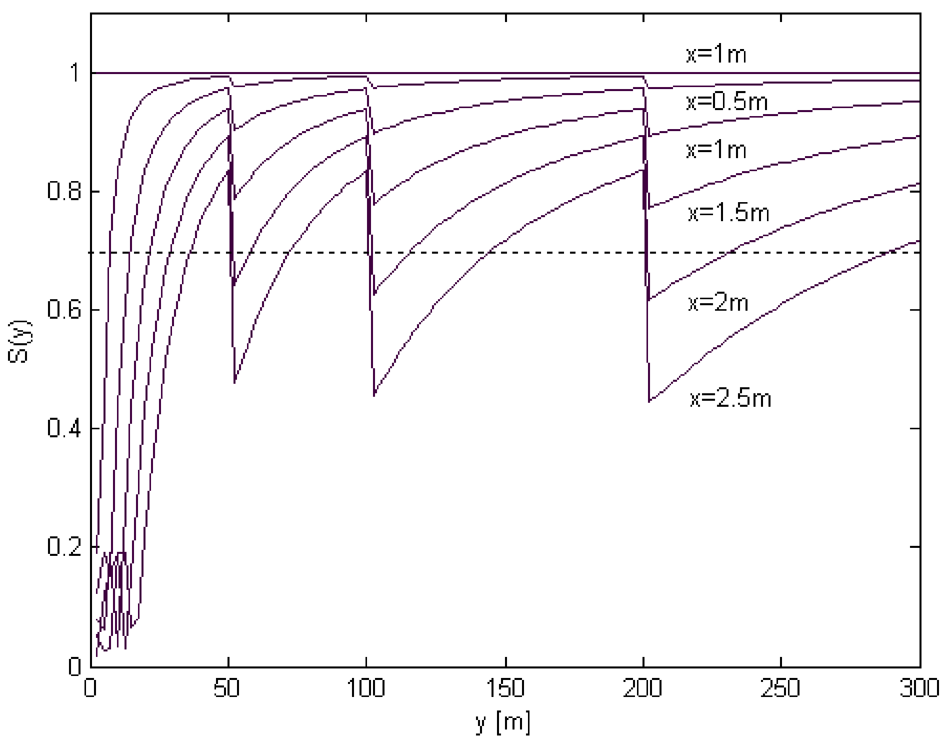

Fig.3 Examples of echo signals distribution at distance *x* from the acoustic array's axis from range *y* (the spatial distribution is shown in Figure 2) without TVG/DBC

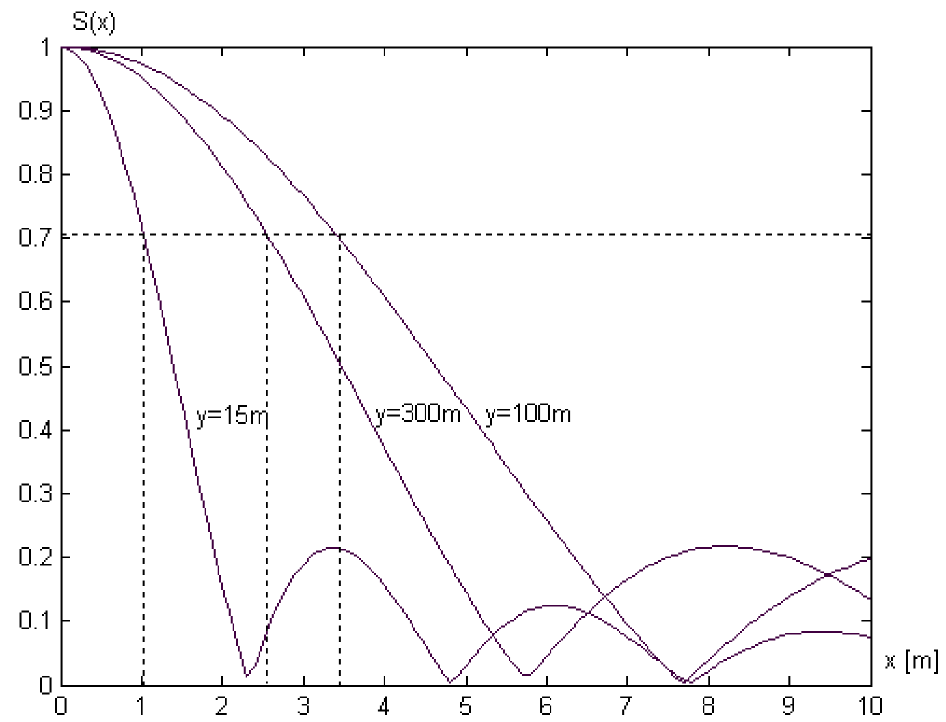

Fig.4 Examples of horizontal sections of the array's beam pattern for different sonar ranges y without TVG/DBC

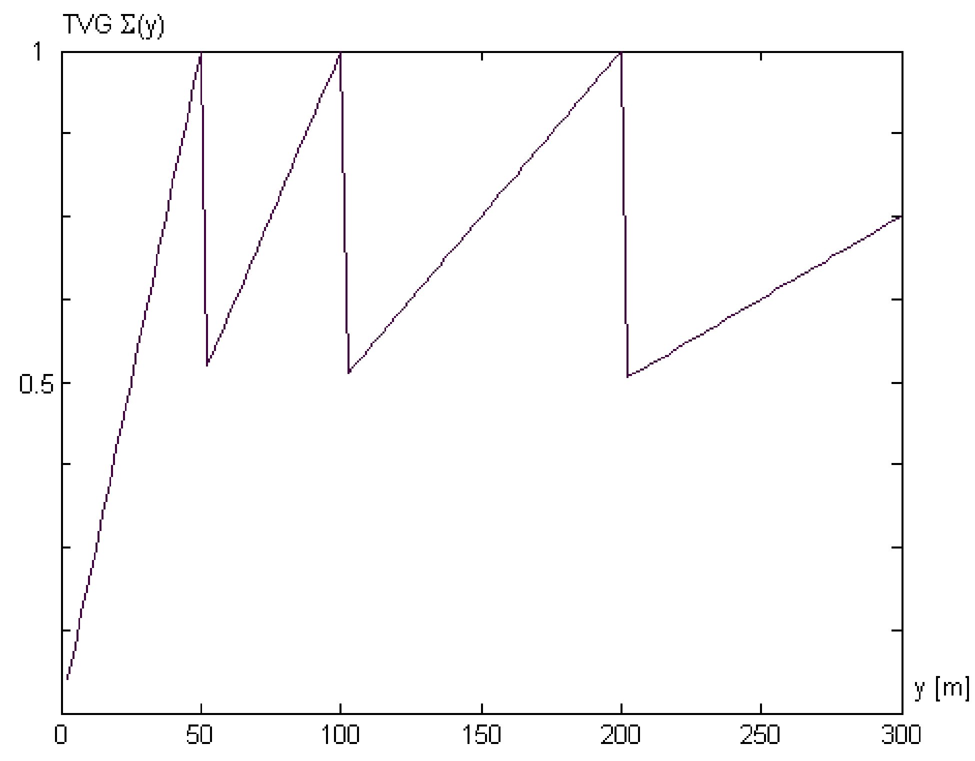

Fig.5 The necessary form of TVG Σ without TVG/DBC

3. CONTROL WITH TVG/DBC

Figures 6, 7, 8 and 9 (matching Figures 2 – 5 respectively) show the improved effects of control as a result of linearly de-attenuated TVG/DBC amplifiers. The improvement is the clearest in Figure 7, which shows that signal levels variations are of the order of a decibel fraction.

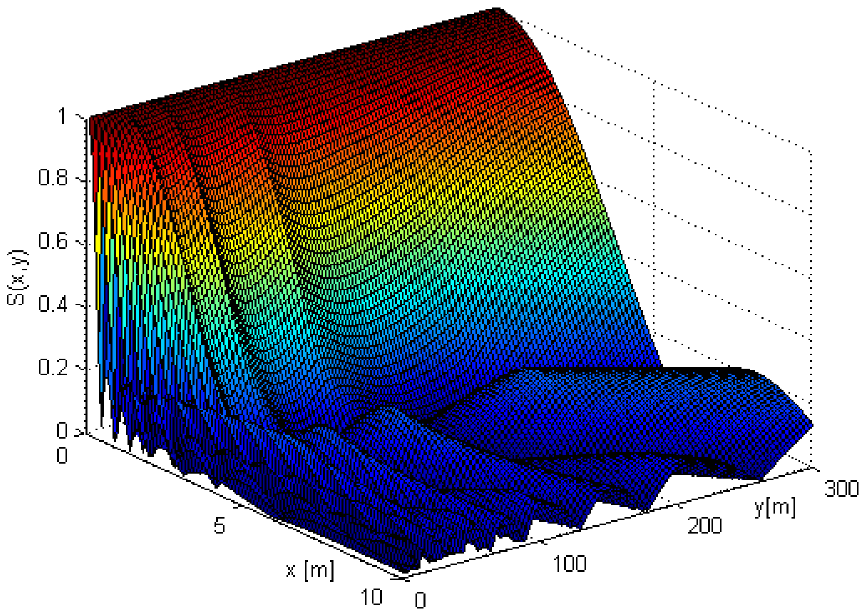

Fig.6 Spatial distribution of echo signals at distance *x* from the acoustic array's axis from range *y* from TVG/DBC as depicted in Figure 9

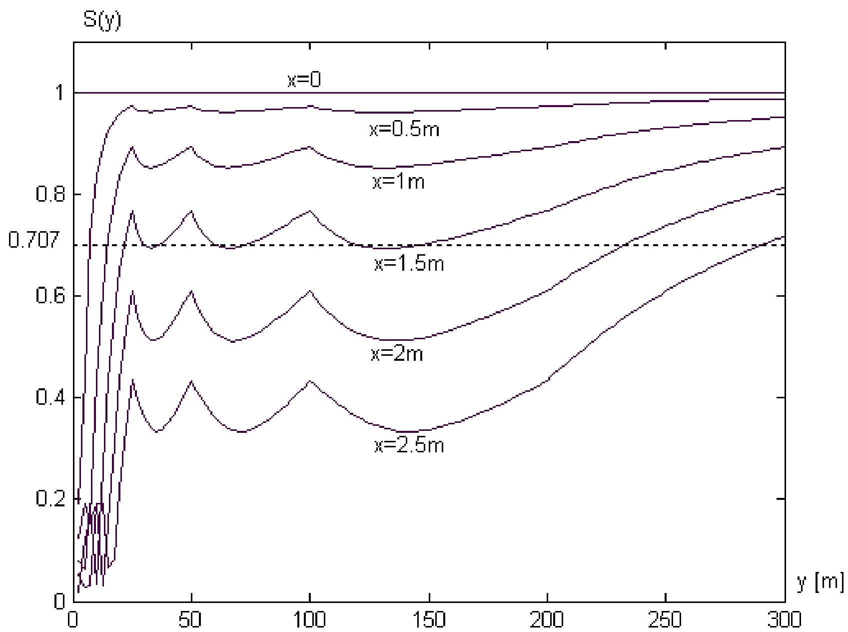

Fig.7. Examples of echo signal level distribution at distance *x* from the acoustic array's axis from range *y* (the spatial distribution is shown in Figure 6) from TVG/DBC as depicted in Figure 9

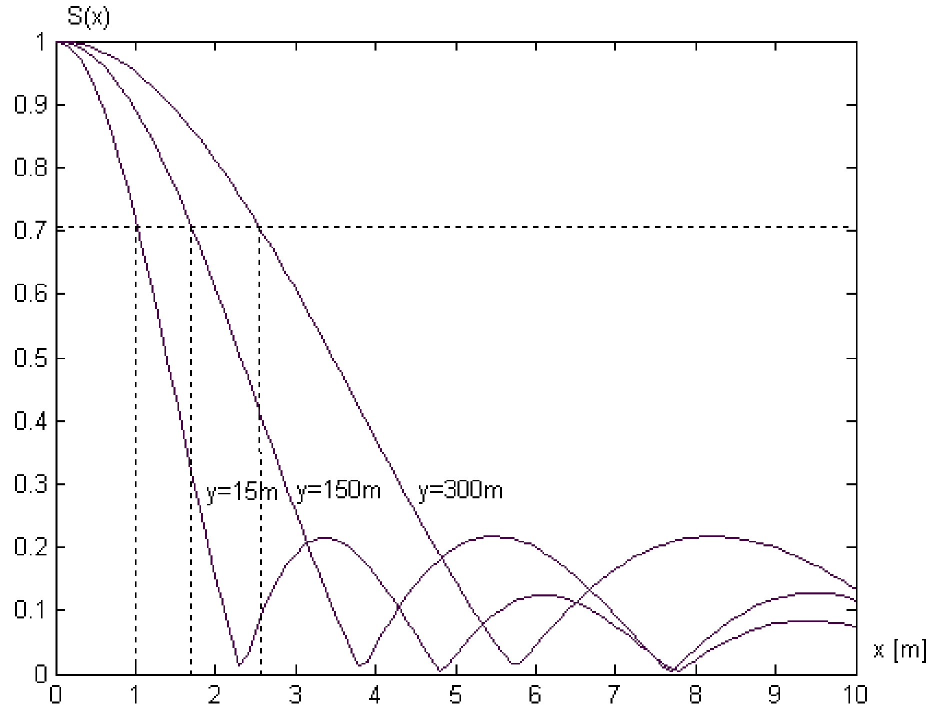

Fig.7 Examples of horizontal sections of the array's beam pattern for different sonar y ranges from TVG/DBC as depicted in Figure 9

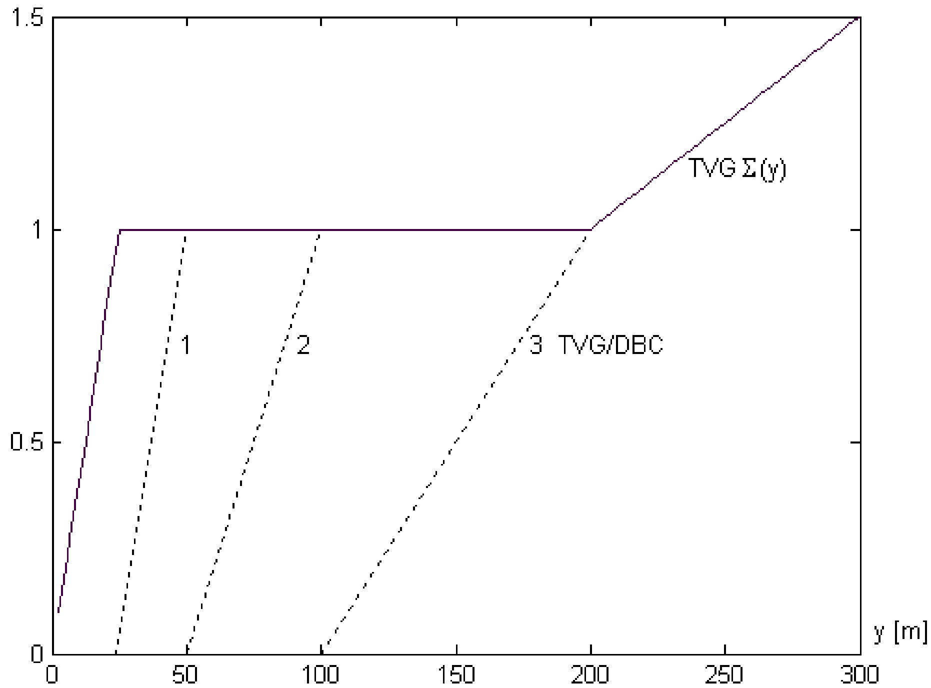

Fig.8 TVG/DBC and TVG Σ which give results shown in Figures 6, 7 and 8

Following the control as shown in Figure 9, the level of the output signal increases in proportion to the range, i.e. just as in the case depicted in Figure 5.

4. CONCLUSIONS

The presented method and design of dynamic beamwidth control is universal and can be used in different active sonars. Because of how easy it is to generate practically any shapes of processes that control TVG/DBC, control optimisation can go to different lengths (naturally, some technical moderation is required). As an example, optimisation should be used to smoothen out the distinct edges to avoid the ringing reaction from the other amplifiers, which come up on images as stripes.

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