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TIME-VARIED GAIN

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Since the early days of medical ultrasonics scanning time-varied gain has been one of the elements of successful systems. The need for its use has been explained and discussed in general terms by many workers. In this paper I will describe our efforts to reach a more specific statement of the requirements in the limited field of obstetrics using a prototype of the Nuclear Enterprises Diasonograph at the Queen Mothers Hospital in Glasgow.

The primary function of time-varied gain is to compensate for tissue absorbtion and thus reduce the dynamic range of received signals from the transducer so that they can be processed and displayed without significant loss of information due to limiting. There is, however, a secondary but important function of suppression arising from the reduction of gain before the detector and display davice thresholds. This is particularly important in contact scanning when considering near range performance where one is contending with considerable reverberation artefacts.

We have for some time used a single time-varied gain, tvg, function of the form shown in Fig. 1. This has been reasonably successful in a large number of cases.However it seemed reasonable to expect that substantial improvements in the ultasonic pictures would be possible if the time-varied gain function could be matched to the patient. The variations in patients are considerable. They range from the obese to the very slim and may appear with any condition of pregnancy or non-pregnancy. We may be attempting to clearly resolve a fetal head a mere 1 to 2cm below the skin surface of a thin patient or looking for retained products of conception in a very fat person. With the objective of picture improvement we started an investigation into the various parameters involved.

The first step was to construct an adjustable calibrated waveform generator which provides a control signal to the R.F. amplifier so that the gain can be increased by up to 36dB during the echo reception time. The waveform is defined by three parameters.

Delay from instant of transmission is adjustable in 1cm steps.

Slope base length is adjustable in 1 or 2cm steps

Change of gain is adjustable in 2dB steps.

After generation the linear waveform is passed through a non-linear function generator to produce a linear dB versus voltage relationship.

In refering to the tvg values I have adopted the convention of stating three numbers refering respectively to delay, slope base length and gain change. For example 2/10/30 meaning 2cm delay, 10cm slope base length,30dB gain change. The rate of compensation in this case would be, of course, 3dB/cm.

There are other ways of selecting the control function and one giving direct control of the slope in dB/cm is probably more generally useful.

Most of our examinations are carried out at 2.5 MHz and the axial characteristics of the transducer used are shown in Fig. 2. This was plotted using four different targets, a ball of 2.5mm diameter, a rectangular face 75cm area and circular flat faces of 0.25cm and 1cm. This is relevant when considering the various targets in the body.

The effect of the slope in the far field can be demonstrated using a simple wire target. Good images are obtained, as would be expected, at slopes close to that which compensates for the transducer. It is more difficult to obtain the ideal compensation in a patient. One does not very often know exactly what the result should be; the time that can be spent obtaining comparitive results is limited and the targets do not remain for long in exactly the same position and orientation. We have therefore tackled the problem in two ways. Firstly to try various settings of tvg in spite of the difficulties, and secondly to record distributions of echo amplitude throughout the range of interest and then to use the results to predict optimum control functions.

The first method of recording that we tried was direct photography of the R.F. signal. This is satisfactory for capturing the echoes along one particular axis but is not very good for obtaining an estimate of the number of echoes which occur at each range.

To overcome this problem we have constructed the signal processing system shown in Fig.3. An echo charges the peak detector and fires the pulse generator. The peak detector output is applied to the Y input of the oscilloscope and the delayed output of the pulse generator is applied to the Z modulation input to brighten up the trace. The time base is triggered by the transmitter. The result is that a dot is displayed indicating the range and amplitude of the echo. The end of the Z modulation pulse discharges the peak detector ready for the next echo. Results obtained using this system are shown from various patients.

The average rates of decay of echo amplitude were estimated by comparison with curves of known dB/cm and some typical results are presented in Fig.4. The initial slopes are in the range 6 to 10dB/cm between 0 and 6cm followed by a more gradual slope of about 1dB/cm. When the the result is considered in conjunction with the transducer characteristecs we find that there is a very rapid drop in echo strength, about 8 to 12 dB/cm, followed by an apparent increase in reflectivity with the range in the deeper regions. The explanation of this would appear to be that the near range echo complex contains considerable reverberations occuring between the uterine wall, fetal skull the layers in the abdominal wall and the transducer. These will decay at a rate determined by the spacing and the reflectivity of the interface. The deeper regions contain week reflectors interspersed with low absortion tissues with the somewhat more solid structures especially the maternal spine, giving strong echoes which tend to raise the average. Using the estimate of the echo amplitude/range distribution we have applied this to a number of cases where we were measuring BPD. In these cases it is important to obtain clear echoes of the fetal skull and falx both on section scan, so that the BPD is easily and quickly located, and on A scan so that the measurment can be made quickly and confidently. The tvg was set so that the gain increased from tx time to max gain just short of the range of the falx using a slope of about 6dB/cm. This approach has produced some improvement over our standard tvg as will be shown with slides taken from a number of patients.

Another important effect of tvg in making BPD measurements is that it helps to keep the amplitudes of the skull echoes approx. equal. With out tvg they can be 20/30dB different which results in significant errors when measuring growth rates.

In the examination of early pregnancy we are trying to record weak echoes from small objects within the uterus and one would expect that the exactcompensation would be possible and valuable. An example will be shown of a case of twins. The picture with zero compensation in the uterine region contains cosiderable clutter. Slight reduction of sensitivity and the application 1.5dB/cm compensation yeilds a more useful result.

The object of this investigation, which is by no means complete, was to examine one of the factors affecting the ultrasonic picture and to determine what part tvg plays in easily achieving clear reliable results. We have obtained some improvement inresolving the fetal skull during BPD measurements and shown that clarification of gestation sacs is possible. We have stil l to tackle the important questions of improving the image of the placenta and defining settings which can be relied on to produce correctly interpretable results. It seems that we may reach the conclusion that time varied gain is not a critical factor but that good results can be obtained if it is set in fairly broad limits.

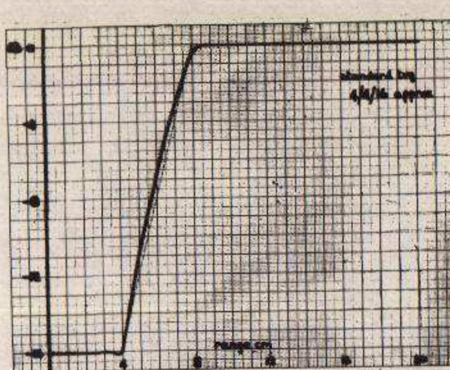

fig. 1

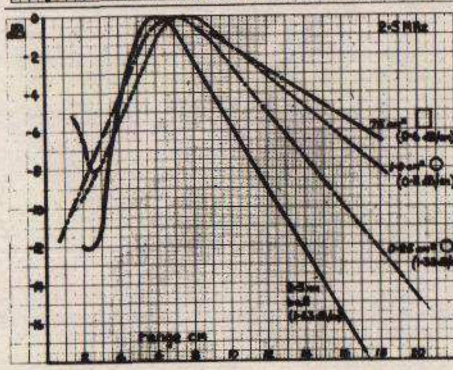

fig. 2

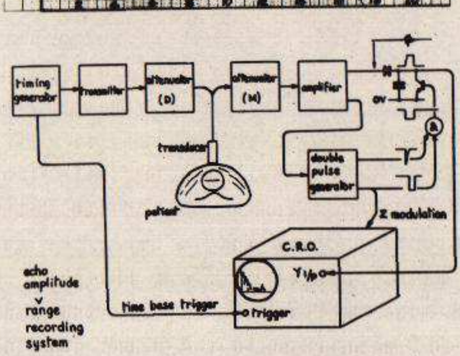

fig. 3

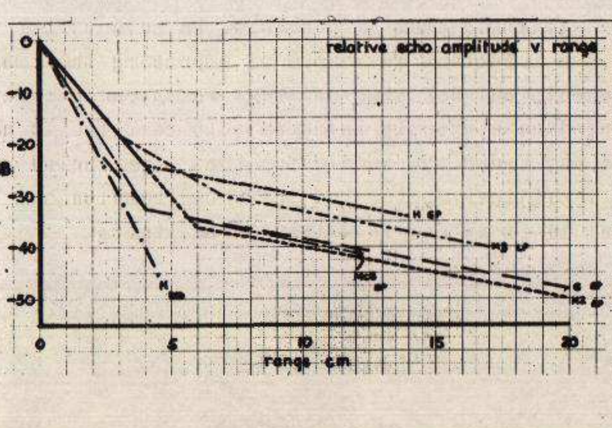

fig. 4