DETECTION OF WEAK ECHOES FROM THE RADAR VIDEO SIGNAL

The original radar video signal contains a lot of information that may be useful to the navigator. This article describes the possibility of detecting weak echoes from original radar video. Two methods for detecting weak radar echoes are presented.

INTRODUCTION

The team of scientists from Polish Naval Academy, for several years has carried out research on usage of radar information for the sake of navigation safety. For many years the successive research projects (mainly the qualification ones) referring to the radar navigation automation assignments, the comparative methods of fixing positions with a use of radar display, radar monitoring of sea traffic and radar detection of watercrafts have been realized at the Maritime Academy in Szczecin, Maritime Academy in Gdynia and Naval Academy in Gdynia. There were published the papers describing the methods of extraction of radar display characteristics, automatic radar navigation system, vector radar map and radar detection of sea surface objects. In a majority of research works mainly the methods of the so-called comparative navigation have been developed and improved. The algorithms of fitting radar images to nautical charts were adapted and worked out; also the neuron methods as well as a potentiality of applying the image identification methods in radar navigation were analyzed. It proves that the above problems draw a great interest; this Project is a natural continuation of the carried out Works. Up till now the experience has indicated a need of further research in this matter. It has been caused by a necessity of acquiring complete and exact radar information, contributing to a growth of navigation safety.

Introducing the new technologies and also the software, capable to analyze visual radar signal, may considerably perfect the echoes detection process, increasing thereby a probability of detecting usable echoes, including those, occurring within the interference area.

1. ANALYSIS OF STRUCTURE OF VISUAL SIGNAL PROCESSED IN RADIOLOCATION EQUIPMENT

The broad-band intermediate frequency amplifier in navigational radars is a logarithmic amplifier, producing a video signal of +1.75V amplitude in the reception line (Downlink). Selection of the reception bandwidth is connected with a scanning pulse length. A composite, integrated receiving signal (Composite Dowlink), transmitted from the receiver to the indicator, is composed of the following items:

- Trigger’s impulse (synchronizer’s),
- Analog visual signal (video),
- 40 bits digital data gate of negative polarization, containing information on the antenna position, tuning etc.

The integrated signal structure is presented in Fig. 1.

![Fig. 1. Integrated visual signal](image)

The structure and the exemplary visual signals are presented in Fig. 2 to Fig. 4. Depending on the applied measurement point the visual signals may be of positive or negative polarization.

![Fig. 2. Visual signal at low amplification level](image)

The time course of 5 μs/scale interval represents a distance of 750 m/dz.

![Fig. 3. Visual signal at normal amplification level](image)
Visual signal processing systems and conversion of analog signal to its digital form are performed through video processors VPA and VPB. The both processors, together with the other systems, form so-called RPU (Radar Processor Unit).

The video processor VPA separates data from the receiving path and converts the analog visual signal to its digital form. In VPA the input signal impedance is selected to match with transmission impedance of data transmission network.

The analog video signal is processed by the amplification and adjustment systems TVG and the discriminator. Using the elements of control, located on the indicator’s front plate, causes dynamic conversion of the visual signal. The first parameter for control of the analog video signal is TVG, which is governed with SEA function and induce reduction of signal amplitude amplification in a time function. A function of atmospheric interference attenuation is selected simultaneously to SEA control and changes the video signal amplitudes' levels. When this mode of regulation is selected, the signal is differential, what causes shortening the analog output signals’ lengths.

The output form of video signal is converted to digital form at a level higher than that of input. A level of analog signal detection is converted to a digital form, depending on the amplification level, and then transmitted further to the automatic echoes tracing systems ARPA.

In the visual VPB processor the digital video signal, received from VPA, is subject to correction and regulation, depending on the switched on operation range and on the selected impulse length. Correction is carried out in the system which performs the function of interference disturbances attenuation.

VPB Processor generates also a train of pulses of regular and movable circles and symbols of automatic acquisition areas.

RSC controller (Radar Scan Converter) is responsible for recording the visual signal in RVM memory (radar video memory) applying rectangular X-Y coordinates, creating thereby an individual address for each cell of the signal. The generated address is necessary for effecting image conversion. The radar video memory RVM is composed of serial memories, wherein the radar signal is stored. After visual signal conversion in VPA and VPB processors, two video levels are transmitted to RVM memory. This video signal contains the radar echoes signal, regular and movable check-marks of distance and ARPA symbols.

The radar signal is saved in the memory at three following levels: low, medium and high. If it appears in an individual pixel for the first time, it is saved at the low level, if it appears again at the next rotation of the antenna, then it is saved at the medium level and on the screen there appears a point of an average brightness. When the signal appears for the third time, it achieves the maximal brightness level. It allows reducing brightness of signals reflected off sea surface.

A synthetic echoes afterglow generator is a part of RVM memory. This function is to enable displaying motion of echo in the screen in a form of so-called “artificial tail”. It has to keep the previous signal locations in specific memory cells with gradual reduction of their brightness level. A time of the afterglow display is adjusted by the user.

A memory system DIA (interface of the indicator - Display Interface“A”) is composed of serial memory systems grouped into cells. This system produces one image presented on the screen, thus it is responsible for the system and organization of all the signals’ display on the indicator’s screen. Output is a logical combination for producing a two-bite signal to send it to the monitor. The standard system requires 4 serial systems; it means two levels of video radar, synthetic memory of true motion and a constant synthetic video image. The radar memory is capable to serve only for 75% of the screen area horizontally, and radar image appears only within the angular scale. Beyond it - it is masked. There were applied two types of synthetic video, constant synthetic and synthetic true motion. It is permanent system, acting between the individual cells in the fixed memory, connected with a pixel on the screen. They account for the course marks, warnings and alarms, a heading line. The true synthetic motion is to effect displaying the image within the radar screen area and it is to operate the radar image, ARPA symbols, marks, symbols, navigational lines etc.

2. DETECTION OF WEAK RADAR ECHOES
USING THE SIGNALS SUMMATION METHOD

Visual signal coming from a superficial object should be characterized with a constant position in relation to the radar antenna location (having assumed that the object is not in motion or moves slowly, and successive signal recordings were carried out at every antenna’s rotation). Noise and disturbances are of random character. A quality of detecting the above mentioned objects against the random disturbances background can be improved applying the method of summation of the images doming from the same position, also making an assumption that the observed objects were motionless or they move inconsiderably.
One of the basic techniques applied to remove the random disturbances is summation of many images of the same object. Assuming that a certain accidental defect is found in every image, then when they are added up there is obtained the object image containing disturbances from all the compound images. Anyhow, a level of these undesired signals, in relation to the usable signal, is much lower than it is originally. Increasing a number of the images added would cause further growing a difference between the desired signal and disturbance.

The presented process of summing images consist in adding values of courses of all the visual signals, conforming to each other, coming from one position. Afterwards the normalization aimed at scaling of the signal level to the admissible values interval is carried out. The summation result is presented below.

3. DETECTION OF WEAK RADAR ECHOES APPLYING THE GRADIENT METHOD

In the following method it was assumed that the hard to detect radar echoes are characterized with not only a low signal level but also its shape.

The signal is obviously at the noise level; anyhow it is slightly "wider" than them. One expects that some sampled values of signal voltage occurring one after another are at a similar level.

\[
U_j = \frac{U_i}{\text{grad}U_{i-1} + \text{grad}U_{i+1}}
\]

where:
- \( \text{grad}U_{i-1} \) - gradient of voltage value changing between \( U_i \) and \( U_{i-1} \)
- \( \text{grad}U_{i+1} \) - gradient of voltage value changing between \( U_i \) and \( U_{i+1} \)

In result of dependence operation, the new visual signal is obtained; it is presented below.

Effects of the method were tested applying the real radar visual signals and the obtained results were satisfactory. The method operates very fast and enables to detect weak radar echoes in true time.

Fig. 7. Summation of visual signals (observation of constant objects of low signal level)

Fig. 8 Weak radar echo of characteristic shape

Fig. 9. Detection of weak radar echo against the noise background applying the gradient method

Fig. 10. Real visual signal and its equivalent processed applying the gradient method
SUMMARY

Application of the digital signal’s filtration methods may provide navigators with information about the objects which remain invisible on the contemporary radars’ indicators. It does happen, as their echo is at a level (or below) of noise and interferences occurring within the radar presentation. When the original visual signal is examined in navigational radar’s receiving block the radar image can be presented applying representation, increasing probability of detecting weak radar echoes.

BIBLIOGRAFIA