HYDROACOUSTICS
4, 213-216 (2001)

VISUAL REPRESENTATION OF THE EFFECTS OF SPATIAL AND FREQUENCY FILTERS APPLIED IN PASSIVE SONARS

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The operator of a passive sonar should be able to discern the direction (bearing) of a submerged, noise-producing object. Interference to bearing comes from reverberations, noise from the sea, man-made noise and noise generated by other objects. The article presents methods of spatial and frequency filtration designed to provide various forms of display of those fragments of the spectrum that are of interest to the operator. The operator makes his selection on the basis of many spectrograms that are produced during the successive listening cycles, displayed on the monitor. The amplitudes of spectral lines in the spectrograms are presented as lines of various lengths and colours. The summation spectrum of the displayed listening cycles is presented, too. The lines from a selected spectral range are shown on the panoramic amplitude graph in the function of the bearing angle. Thanks to that the determination of the location of the source of sound is significantly improved. The source of sound can also be discerned by using a reverse technique whereby a group of spectral lines is determined on the basis of a selected sector of angular observation.

INTRODUCTION

The job of the operator of a passive sonar is to detect and establish the direction (bearing) of a submerged, noise-emitting object. This job, in particular establishing the bearing, is made more difficult by reverberations, noise from the sea, man-made noise and noise generated by other objects. The article presents methods that help to improve the detection capability and bearing determination of the passive sonar whose design and special signal processing are discussed in detail in [1]. This particular sonar uses a small size space oriented antenna (10 ÷ 100 times smaller than the wavelength of signals) to receive low frequency, broadband signals. This crossed frame, gradient antenna is built of four hydrophones placed in the corners of a square. The sonar's receiver uses spectral analysis (FFT) of signals and interference which constitutes the basis for further spatial and time filtration activities that the operator undertakes using a specially arranged visual representation of the effects of listening as seen on the sonar's monitor.

1. THE DISPLAY

The sonar's display is shown in Fig. 1. It is a windows-based display as known from the system WINDOWS with windows that can be enlarged or moved as needed. It also has dynamic and static dialogue boxes outfitted with various controls such as keys, lists, selection fields, etc. What is by nature a user-friendly set-up has been simplified even further by limiting the number of keys and allowing the use of a pointing device so that the operator can concentrate on the information rather than the operation.

The signals received are displayed in four windows – three of which present the spectral distributions of the signals (and interference) in various forms and the fourth one called "Passive visual representation" showing a panoramic view of the directions of where the particular lines (of various amplitudes) of the signal's spectrum originate.

2. SPECTRAL DISTRIBUTION WINDOWS

In the window "Signal spectrums" the operator can see several (the maximum of ten) spectral distributions of signals that appear one after another in a regular succession. The appearance of a "new" brightly illuminated spectrogram causes "older" and fainter images to move upward with the "oldest" one removed from the picture. This gives the operator the opportunity to analyse the shape of the successive spectrums and detect any changes in the distributions that earlier showed the ship's own noise and other recurring noises. New lines mean that an additional source of signal has been detected. The procedure follows a time filtration pattern.

The window "Summation spectrum" shows the result of summed up spectral distributions presented in the window "Signal spectrums". If we assume that a source we are interested in emits quasi-stationary signals (having a similar spectrum all through the recorded period), then the result of summing up the source's lines will be higher than that of summing up accidental lines in the spectrums of non-stationary signals. With these conditions fulfilled, the sonar's detection performance will be improved.

Because of the screen's size, only a limited number of spectrograms can be displayed at the same time in the typical form. To display historical data of listening a window is provided where the amplitude of a line is represented by the colour of a pixel. Thanks to that, a single spectrogram occupies only one line of the window "History" which the operator can use to keep track of dynamic changes of signal spectrum distributions over long periods of time. This arrangement also allows the operator to draw conclusions as to the parameters of the source's movements. The possible meaning of changes in the amplitudes of lines may be that the source is moving closer or further away while lines moving on the frequency scale may represent changes in the revolutions of the screw propeller, i.e. the object being tracked is speeding up or slowing down.

3. "PASSIVE VISUAL REPRESENTATION" WINDOW

This window shows points, which represent lines of spectrums depicted in right-hand windows. The colour and degree of brightness of these points matches the colour and brightness of the lines in the spectrograms. The line's amplitude is denoted by how far away it is from the circle's centre while its angular position is denoted by the direction from which the analysed signal was received.

The screen shows both the points related to the signals emitted by objects and the hydroacoustic noise. If the signal to noise ratio is big enough, then the points related to the useful signal will be near the outer circle concentrated on a small area. Points related to noise are found near the circle's centre. This allows a high degree of bearing accuracy on the detected object. With a low signal to noise ratio, the area of noise overlaps with the concentration of points related to the useful signal which makes bearing determination difficult or impossible. To counteract that, two methods of filtration were developed: frequency and sector scanning which enable the identification of the useful signal in a noise signal.

In frequency scanning the operator, having found interesting lines in displayed spectrums, can impose a digital "window" type filter on the frequency scale. The operator can select any mid-band frequency and bandwidth of the filter. With the filter switched on, the visual effect is that the colour of the lines from the selected band changes (into yellow) both in the spectrogram windows and the panoramic view (see Fig. 1). If the filter's band covers noise lines only (Fig. 1a), and then the bright points will be scattered randomly in the picture. If, however, the filter's band covers the lines of the signal generated by the object (Fig. 2b), then the bright points will become concentrated on a smaller or bigger area whose position will be determined by the bearing on the detected ship.

In sector scanning a red angular frame (sector) is placed on the panoramic display. Its angular width covers the width of the concentration of points that are thought to be related to the object being scanned. The points within the sector are matched by spectral lines in the spectrograms marked in red (Fig. 2c). If the red lines appear in a single spectral frequency or appear periodically (less frequent), we are sure that the concentration of points within the frame comes from a single object. If the red lines are randomly distributed in the spectral charts, then it is highly likely that they are generated by noise. If the red lines are lined up at regular intervals, this means that the same bearing probably covers two objects (or more).

4. CONCLUSION

When seen formally, the methods presented in the article could be treated as a form of a frequency and spatial processing that aims to improve the detection and bearing performance of the passive sonar. It is difficult to see these methods in quantitative terms, e.g. by stating the filtration gain, because they involve training, experience and psychophysical features of the operator's vision supported with listening on low frequency signals headphones moved to the band around 1kHz to improve the hearing conditions. The experiments show a spectacular increase in the effectiveness of detecting and establishing the bearing on objects compared with the performance of "classic" visual representation methods used in passive sonars.

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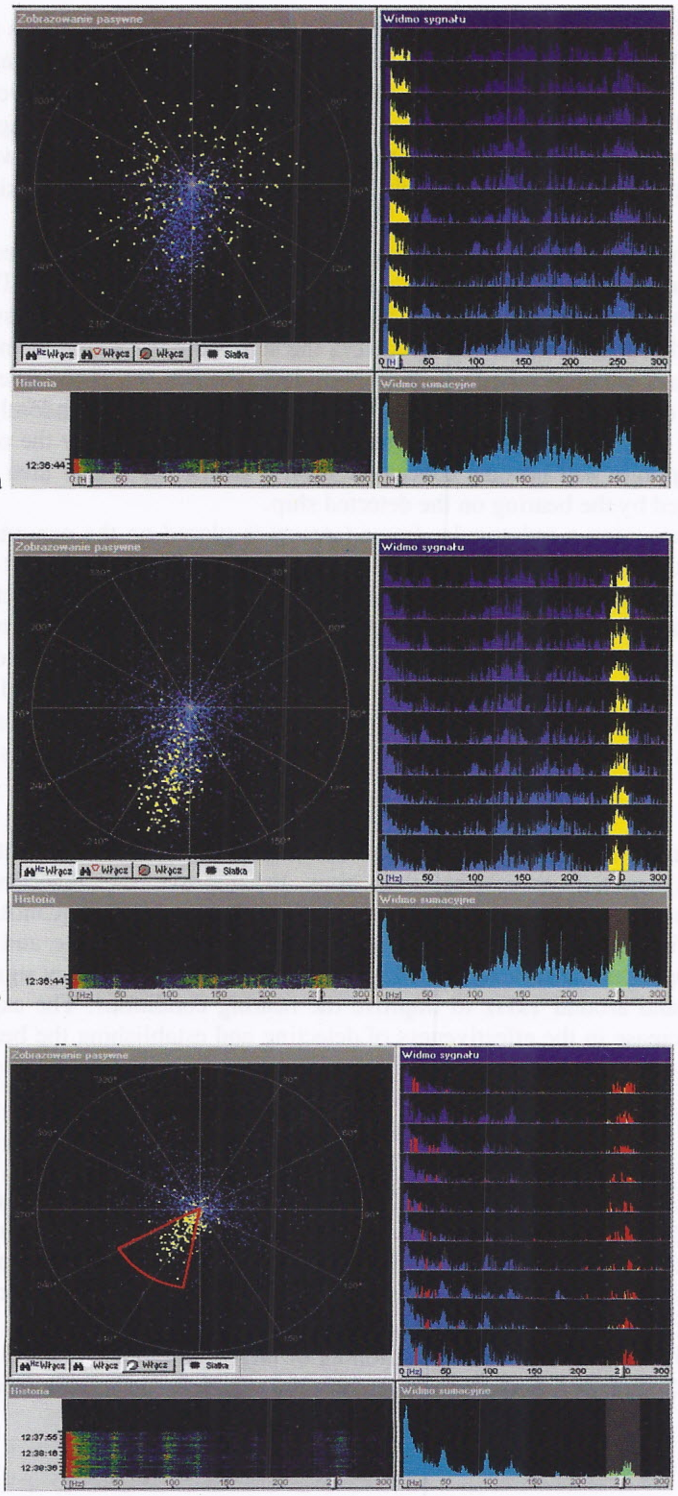

a b c

Fig.1. Types of visualisations on the monitor of the passive sonar.