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SONAR PANORAMIQUE TEMPS REEL HYPSON 400

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Le sonar panoramique temps réel est un outil indispensable chaque fois que les conditions optiques imposent des limites à l'intervention d'un ROV ou d'un opérateur sous-marin.

On présente ici une technologie qui satisfait ce besoin, en apportant une formation de voie instantanée, temps réel, sans balayage, avec une ouverture large, en utilisant une technique de formation de voies hybride permise par les nouvelles technologies de composants.

Le principe de la formation de voie est analysé en détail, montrant en particulier l'emploi de composants analogiques et digitaux qui assurent le déphasage et l'addition des signaux d'entrée en 31 signaux de voies. La tête acoustique est bâtie autour d'un réseau linéaire de 64 éléments. Les diverses étapes du traitement (amplification, échantillonnage, conversion analogique/digitale) ainsi que le traitement d'image sont présentés prenant en compte la contrainte de maintenir un taux de rafraîchissement élevé de l'information. Enfin, l'architecture du système est décrite.

Globalement, on forme jusqu'à 7 images par seconde à une distance de 100 mètres, et plus à faible distance, comme le permet la vitesse de propagation du son, donnant ainsi le taux de renouvellement maximum permis, et requis par les opérations en mer. Les applications typiques en sont : l'anti-collision pour ROV/AUV, la protection et l'intrusion en site portuaire et les levés hydrographiques multifaisceaux.

HYPSON 400, A REAL TIME PANORAMIC SONAR

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ABSTRACT

The search for a panoramic, real-time, high frequency sonar has been a major goal for operating ranges where optical systems have established limitations.

HYPSON 400 meets such requirements and provides a simultaneous and continuous beam-forming, no-scanning, wide opening system, using a hybrid beam-forming technique allowed by new component technologies.

Up to seven images per second can be formed at a range of 100 meters, and more at shorter distances, as allowed by the speed of sound, thus providing the highest possible rate of information renewal required by operations at sea.

PRINCIPLE OF BEAM FORMING

The basic principle of beam-forming on a multi-elements, linear array is well documented: given a plane wave front, incoming from a direction θ, the reception of signals in that direction will be achieved by time delaying and summing the elementary signals received on each element of the array.

Given the monochromatic, sinusoidal structure of the signal, a time delay can be achieved through a change of phase. If M transducer elements are present and N beams are to be formed, a total of M*N delaying or phasing devices must be used.

Delaying systems (RC lines, LC lines, SAW/ surface waves or data storage techniques) are expensive and need volume or computation power. Hence, sonars using this technology will usually form a limited number of beams (1 to 4) and will be associated with a mechanical (i.e. slow) scanning device.

In HYPSON 400, a new technique is used for the generation of properly phased signals. Multiplying the incoming signal $S.\cos(2\pi Ft)$ with a properly selected auxiliary frequency, $\cos(2\pi F't + \varphi)$ will result in a sum of two signals: $\cos(2\pi(F-F')t + \varphi)$, the low frequency component, + $\cos(2\pi(F+F')t - \varphi)$, the high frequency component. If we keep the low frequency component, we get a signal that has a phase shift relative to the main signal. This classical method will generate the phased signals through the use of a frequency generator and a series of multipliers.

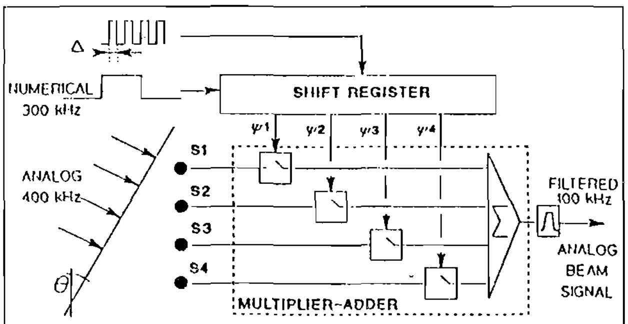


FIG 1. PLANE WAVE, POSITIVE ANGLE BEAM FORMATION

The technological implementation, in the HYPSON 400, requires the use of a numerical shift register, under a 36 Mhz clock, to generate a series of blocking logical signals that will control an analog gate at a rate of 300 kHz. This logical control of the analog signal results in a multiplication, combined with a phase shift according to the selected register output.

The analog signals issued from the gates are then added and filtered, to keep the lower frequency part, carrying the total analog signal incoming from a particular direction.

The beams are formed according to the narrowest possible width that can be achieved, using transducer elements that are distributed at $\lambda/2$ intervals, i.e. 1.9 mm for 400kHz. The beam width will thus be around 1.8 degrees, allowing a coverage of 60 degrees with 31 beams (1 central and 15 beams on each side). A proper selection of the auxiliary frequency and beam axis allow the use of symmetries, and instead of 31 times 64 shift signals, a total of 115 signals allows the complete beam-forming.

The specific interest of this technique is to combine:

- the low price of analog gates (instead of analog multipliers)
- the accuracy of logical signals, generated by a high frequency clock.

- the real-time efficiency of analog signals, which are processed continuously with no delay or computational bottle neck.

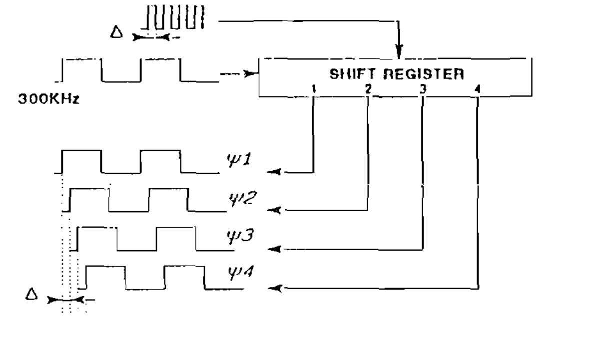


FIG 2. PRINCIPLE OF A NUMERICAL SHIFT REGISTER

This beam-forming technique, known as hybrid due to the combination of numerical and analog signals, gives its name to the sonar, as:

H Y brid Panoramic S O Nar 400 kHz

or HYPSON 400

As will be seen later, the use of Surface Mounted Components permits the integration of all 31 beam forming circuits on 5 standard electronic cards.

EMISSION AND RECEPTION - ARRAY DESIGN

HYPSON 400 has been designed for an operating frequency of 400 kHz, as an appropriate compromise between array size and detection range.

The emitting system is a classical, single ceramic transducer with a 210 dB (ref 1uPa, 1m) output, a horizontal opening of 60 degrees and a vertical opening of 20 degrees. It is mounted on top of the receiving array. Pulse duration is 50 to 100us.

The receiver is designed for high resolution and wide aperture. This combination requires a spacing between elementary ceramics of a half wavelength, i.e. 1.9 millimeters, in order to avoid exceedingly high side lobes that are common in similar designs. A series of 64 square transducer elements is lined on a plane, and integrated on the front side of a pressure resistant housing.

Inside, 64 pre-amplifiers are mounted, also with a half wavelength spacing, thus permitting to be directly plugged on the back side of the ceramics. The gain factor is 4 and a particular attention is kept on phase preservation. A cable consisting in 64 micro coaxes, with a length of up to several tens of meters, links the receiver head to the sonar rack.

SIGNAL PROCESSING

Amplification

Amplification at the input stage of the processing system includes:

- a time variable gain (TVG), which restores signal dynamic in spite of a continuous attenuation of signal level due to the propagation loss with distance.
- a dynamic compression which prevents saturation and is controled by level on one of the central receiver ceramics.

Beam forming

Beam-forming is achieved following the principles described above. A clock generates a source frequency at 36 MHz, that is used to generate associated frequencies, that are used throughout the sonar:

- the shift register frequency (36 MHz)
- the auxiliary frequency (around 300 MHz)
- the pulse repetition frequency (4 to 10 Hz)
- the sampling rate (3 MHz).

Sixty four shifted auxiliary signals are generated using shift registers and the control frequency. These signals are used to control the analog signals issued from the amplification stage, through quad-multipliers and adders. The 16 output signals are then added using standard analog components, resulting in a particular beam signal.

In order to allow a compact integration of these components, the technology combines several simplifications or levels of integration:

- all components are "Surface Mounted Components"
- all cards are standard 3U (110x200 mm) format with 8 layers
- all beam-forming cards are identical and can generate 128 control frequencies. Thanks to a variety of symetries and periodicities, issued from a proper selection of the auxiliary frequency, the total number of required control frequencies is 115.
- all multipliers and adders are placed on pseudo-hybrid macro components, with a size of 12x35 or 12x20 mm, that are mounted perpendicularly to the board.

- a specific beam is formed by hard-wiring the proper control signals between the shift registers and the multipliers.
- a particular attention was payed to the shielding of signals on the cards, due to the risk of cross-talk between analog channels.

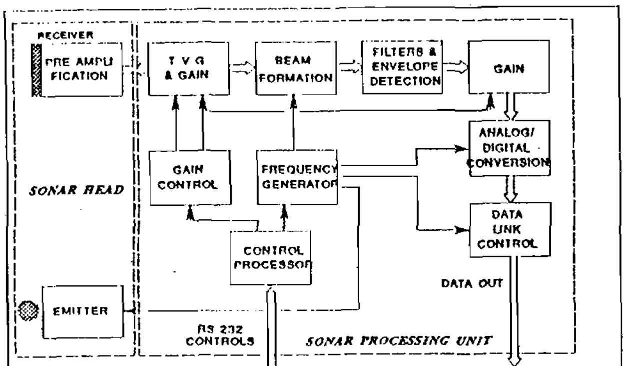


FIG 3. HYPSON 400 GENERAL LAYOUT

Filters

All 31 beam signals are filtered using fourth-order band pass filters centered on 100 kHz. The outputs of these filters are directed on envelope detection circuits, in order to allow direct sampling.

Samplers and numerizers

A 31-inputs multiplexer, associated with an 8 bits analog to digital flash converter, is used to numerize the signal under the control of a sampling clock and the emission trigger. Data are stored in a dual flip-flop 16K RAM that allows the transfer of an image while sampling is going on.

Given the 31 beams, that are always sampled at a rate of 512 time gatings, on the user selected range (i.e. 512 values on 10 meters, if this 10m range has been selected), a total amount of 31x512 bytes (8-bit words), or approximately 16Kbytes, are generated for each emitted pulse. When the range allows it, the emission rate reaches 10 pulses per second, thus providing over 160 000 bytes per second.

Data link

The standard output is an 8-bit parallel line to the image processor, as can be implemented in situations where the sonar unit and the imaging unit are located in the same environment. Other options are available, under a coding scheme, such as:

- a PCM (Phase Coded Modulation) radio link
- a PCM optical fiber
- a PCM coaxial cable link

in order to transmit all available information.

Control unit

A microprocessor-based card within the sonar unit allows the control by the user of gain and range. Ranges are selected in a series of pre-programed values: 5, 10, 25, 50, 75 and 100 meters. Gain control is used to set up the gain level and the shape of the TVG (Time Variable Gain) inside a choice of 5 values. In addition, the control unit has a variety of ancillary tasks such as initial autotest, periodic checks, and maintenance purposes.

IMAGE PROCESSING

Image generation

Given the remarkable achievment consisting in processing, in real time, with both high resolution and wide opening, the acoustical information to a range of 100 meters, the image processor had to be at the same quality level. Although a TV video-type image could have been generated with a simple system, the choice was made on a more sophisticated fully numerical image processing system.

Using a VME-bus MOTOROLA 68020 based graphics system, with the appropriate graphic processor, this user-oriented terminal allows the complete control of sonar operation.

First, data are received, their X-Y coordinates are used to locate the pixel position using a lookup table. Values for adjacent pixels are then interpolated using image processing algorithms, in order to create the full, 256 color viewing sector achieved by the sonar.

A particular attention has been payed to the organization of this pixel generation, in order to avoid image flicker.

Image control

The imaging system is used also to control the operation, through the use of menu driven functions and a light pen (or a similar joystick, trackball interface).

In addition to sonar controls that have been discussed above, and are passed to the sonar unit through a serial interface, the user can select a variety of image and mission controls

Image controls include zooming and color scales. Mission controls allow the user to carry out target pinpointing and relative / absolute locating. A variety of sensors can be interfaced to the HYPSON 400 sonar, including:

- X Y location of the sonar head
- speed, heading and attitude sensors

These values, in addition to being continuously displayed, are used for target location: the target is located using the light pen, its relative (bearing and distance) and absolute (X Y) positions are computed and displayed.

Finally, if the acoustic head has been set on a dual axis orientable mount, pan and tilt parameters can be displayed.

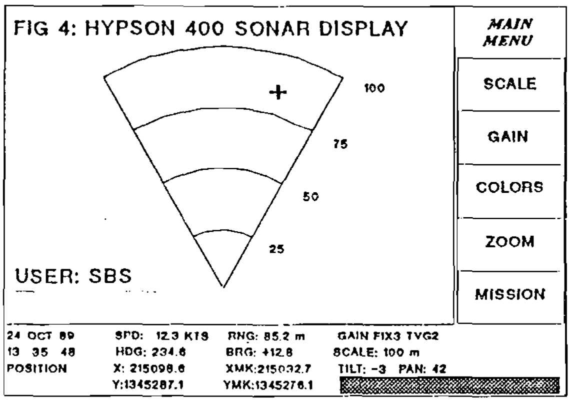


FIG 4: HYPSON 400 SONAR DISPLAY

THE EQUIPMENTS

There are four main parts in the sonar equipment:

- the sonar head, a 220 x 100 x 120 mm unit, including the emission transducer, the receiver array with a preamplification card and a 3m cable. The standard depth rating is 300 meters.

- the sonar processing unit, a standard 4U, 19 inch rack, which includes:
  . power emission
  . 4 amplification cards
  . 5 beam-forming cards
  . 1 filter, envelope detection card
  . 1 frequency generation card
  . 1 sampling, A/D conversion card
  . 1 control unit card
  . power supply
  . an 8-bit parallel data output
  . a RS 232 serial control link

  and an optional data link. Approx. weight: 15 kg.

- the image processing unit, a standard 3U 19 inch rack, which includes:
  . CPU MOTOROLA 68020 card
  . 2 graphic cards
  . 1 memory card

  and an optional recording hard disk. Approx. weight: 12 kg.

- the 13 inch color, high resolution screen.

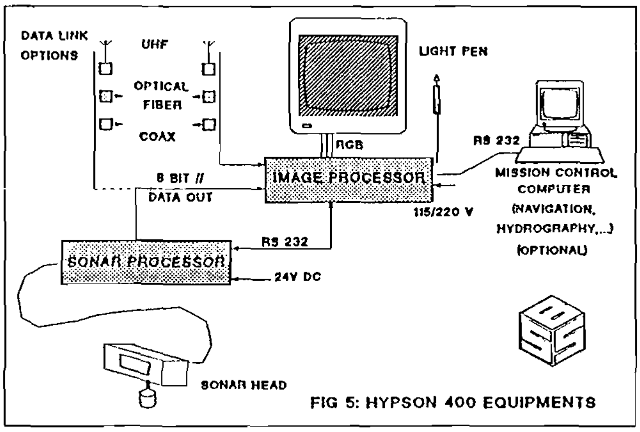


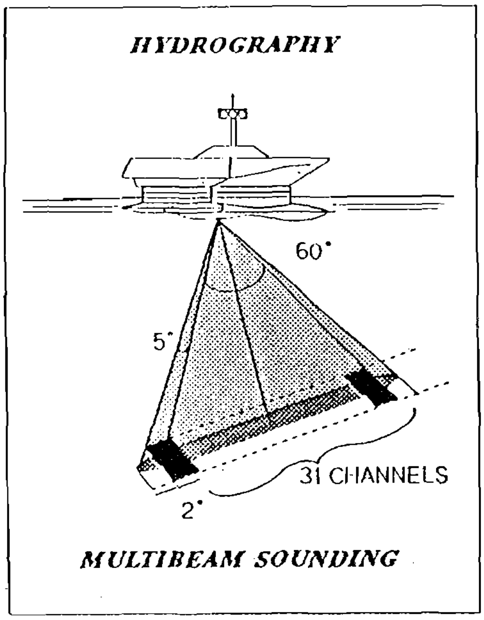
FIG 5: HYPSON 400 EQUIPMENTS

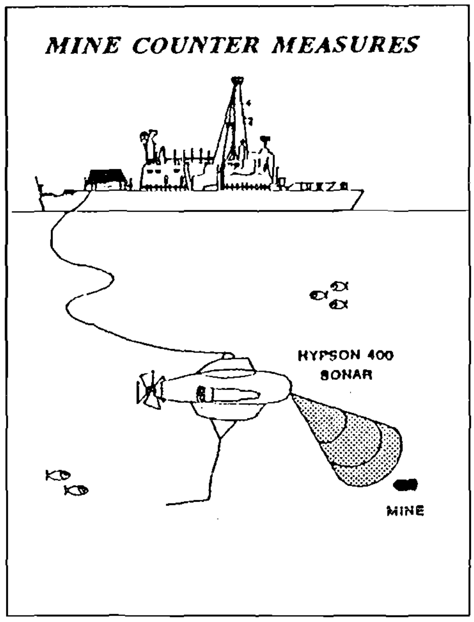
APPLICATIONS

Given the real-time capability of HYPSON 400, a variety of applications can be retained, in an environment where fast movements of the carrier and/or the target are expected.

Fixed carrier:
- harbour, dam, offshore facility intrusion detector.

Moving carrier:
- horizontal setting: obstacle avoidance sonar, fishing sonar
- oblique setting: bottom inspection, mine detection, mine localization, bridge and pier inspection.
- vertical setting: hydrographical multi beam echo-sounder (harbours and rivers)





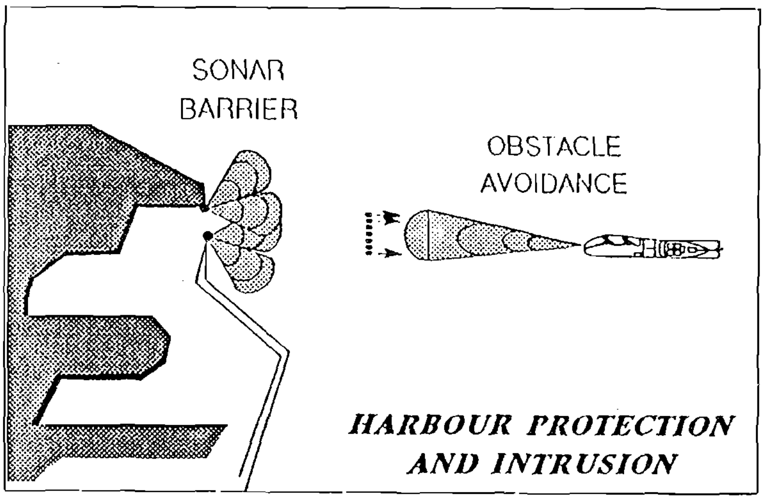


FIG 6: APPLICATIONS OF HYPSON REAL TIME SONAR