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CIVIL APPLICATIONS OF UNDERWATER ACOUSTICS

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POTENTIAL APPLICATIONS AREAS

Research, industry and recreation have become increasingly concerned with the sea and the seabed; in this, the main applications area, the properties of underwater sound have been called upon to circumvent as far as possible the electromagnetic blackout underwater, the useful frequency spectrum extending from a few Hz to several MHz. Other, non-oceanic, applications are possible and exist; the paper excludes cases where the water volume concerned is less than a few m^3.
With this restriction, the research areas in which underwater sound can have applications include: Oceanography, Tidal and hydraulics research, Sedimentology, Geology, Limnology, River research, Fisheries research and Marine biology.
The industrial or other operational applications areas include: Surface shipping, Underwater vehicles, Underwater engineering, Diving, Hydrography and wreck investigation, Marine civil engineering and Fishing operations.

REQUIREMENTS

Requirements in the above areas in which acoustics aids could be applied can be listed as follows:
Surface navigation (oceanic);
Avoidance of ship collision with other vessels, wrecks, sea bed etc;
Inshore and estuarial navigation including dredged channels;
Docking, berthing, especially large and heavy vessels;
Seabed depth measurement, depth profiling;
Sub-bottom profiling;
Seabed topographical survey or local observation;
Obstruction detection and avoidance;
Object identification and delineation;
Location or tracking of marked objects;
Fish or shoal detection, tracking and classification;
Fish catch estimation;
Local frame-of-reference navigation in two or three dimensions;
Homing to marked locations or objects;
Telemetry of data and other signals;
Telecontrol of equipment operations;
Through-water communication, mainly speech;
Passive detection and location of sound sources;
Active direct-sound effects;
Water flow measurement.
Applications in almost all these areas already exist, though in many cases the systems and equipment are in experimental forms or are not in general production.

SYSTEM CATEGORIES

An underwater acoustic system requires a source of sound, a water path and a receiver. In some cases, where the sound already exists, the operational system consists only of a receiver with suitable directional properties and analysis equipment. In others, only a transmitter may be needed. In both types the signals are usually broad-band.

Most applications use both a source and a receiver. The simplest is a link; eg beacons, telemetry and telecontrol devices. An elaboration of this produces the transponder, having a second transmitting source and another water path (or the same used in reverse).

The commonest equipments are echo sonars, operating on signals scattered by underwater objects or other discontinuities.

The available frequency band may be divided on the basis of the different attenuation of sound in the medium, scattering by objects, transducer size/beam-width relationships and other factors. System characteristics depend inter alia on the beam dimensions in both planes, method of scan, system geometry and principle of operation, and types of signal used. Allowing for correlations between some of these, the number of distinguishable systems is in the order of 1000; a large proportion of these have not been used. Some of the reasons are discussed in the paper.

THE INFLUENCE OF THE MEDIUM

The properties of the medium having most significance to practical applications are:

- Absorption loss; generally much lower than for any other form of disturbance in water.
- Low velocity of sound; allowing practical size of equipment for useful angular resolution, but limiting the data rate in echo sonars.
- Refraction (mainly due to temperature gradients); causing significant propagation losses at ranges in the order of 1 km or more, also elevation errors in the order of 1° or more at such ranges.
- Absorption, increasing rapidly with frequency; high angular resolution at long ranges therefore requiring very large equipment.
- Multi-path arrival of signals, often unavoidable; causing correlation loss, fading and broadbanding of signals; effects greatest in shallow waters, at long ranges and with broad beams.

EXISTING TECHNOLOGY

Practical receiving transducers generally are as sensitive as they need to be. Electro-acoustic transmitters, above a few kHz, are convenient and efficient provided they are not required to operate over several octaves of frequency. At lower frequencies coherent sources become large, heavy and inefficient, and may for example be hydraulically powered. Impulse signals such as explosions can be powerful but have less controllable waveforms; air guns and other devices have been improved so that their broadband signals are more repeatable and more convenient for processing. It is usually possible to provide any normal type of transducer polar pattern with the angular dimensions required; there is a wide variety of configurations available. Mirrors, lenses, and transparent arrays (both two- and three-dimensional) are practicable, but very little used.

The electronic handling of signals now offers: Electronic beamforming and beam scanning both for transmission and reception; signal coding, including frequency-sweep; correlation detection, real time spectrum analysis; deconvolution processing of impulse signals. These techniques allow increased flexibility in the design of signalling and sonar equipment; applications requring high angular resolution or narrowband spectrum analysis are not limited to slow scan rates; fine resolution in time or range is not limited to short pulses and a low mean power; and in most cases equipment can be provided with optimum filtering of the desired signals against noise of various kinds.

Amongst techniques still in the research stage are acoustic holography, and the employment of non-linear effects in water. Holography still requires a solution to the problem of suitable

detectors and display; non-linear acoustics, which enables the generation of narrow transmitting and receiving beams at low frequencies with small equipment, appears still to be in search of an application.
Display techniques have shown only minor improvements in the past decade.

PROSPECTS

Long-distance surface navigation is well served by radio and other means; in inshore areas having few navigational aids, Doppler sonar navigation can fill a gap, but there seems little value in extending the performance of the technique to provide trans-oceanic coverage. The conventional echo-sounder still has value, but is of little help to a large vessel in shallow waters; the same may be said of obstruction detection ahead of the vessel. Possible acoustic anti-collision techniques between ships offer no advantage over radar. Local acoustic navigation, eg for dredged channels, while possible, has practical difficulties. Aids to berthing are feasible but are likely to be more limited in value than the corresponding radio techniques.

Underwater navigation for divers and submersibles, together with the location of tagged objects, tracking from a surface vessels, and establishing of construction reference frameworks on the seabed, are available techniques though the systems equipment is not. The necessary underwater items have much in common with communication, telemetry and telecontrol requirements, and an integrated approach is worth consideration. The increasing emphasis on this type of underwater work should be noted.

Hydrographic requirements for rapid seabed profiling, though stringent, can be met, requiring sector-scan or equivalent techniques. Similar equipment can provide forward-scan topographical survey of the seabed, wrecks, obstructions etc for correlation with the profile.

Fish observation and counting techniques based on precise vertical echo sounders have been develped with success. Developments of sector-scan sonar may be expected to improve trawling efficiency. Trawl gear observation, shoal location and movements and warning of seabed snags are possible sources of benefit to the user; fisheries research will continue to use high-resolution sonar for these purposes, for tracking tagged fish, for noise studies etc. The practicability of using Doppler for distinguishing fish by their movement relative to the seabed has yet to be satisfactorily established. Fish detection and location by passive receivers is likely to remain a research tool.

Diving operations and the activities of submersibles would benefit from a pseudo-visual presentation of the underwater scene beyond the visual range which is often only a few metres. Angular resolution of 1° or better is needed; requiring sector scanning, preferably in two planes, at a reasonable refresh rate, and operation within the Rayleigh distance. The technical problems are great; the application is one in which non-linear signal handling may offer significant savings in the electronics. Until such time as this type of equipment is available, single-plane sector-scan equipment is indicated.

In the field of sub-bottom profiling, high-energy acoustic sources and sophisticated signal-handling and data-handling are already employed. The available accounts suggest that further progress is likely to be limited.

CONCLUSIONS

The review indicates that the available armoury of techniques is being applied only slowly; this appears to be true on a world-wide basis. There is still a need for the more extensive application of established techniques in the expanding field of underwater engineering and associated diving and submersibles activities, where there are requirements for positioning, navigation, communication, telemetry and telecontrol. The stimulus for application of the newer techniques arises at present in the fields of hydrography and fishing research, but other fields will become involved. The "eye-in-the-sea" sonar problem presents great difficulties and will require much ingenuity if an economic equipment is to result.