General Principles of Sonar Design

The dry end of modern digital sonar is actually a large, multi-functional digital computer. The design of this computer depends on the configuration of the wet end and on our knowledge and understanding of the ocean environment and the behavior of underwater sound propagation. Therefore, sonar design is a combination of underwater acoustic physics, underwater acoustic engineering, radio electronics and transducer manufacture.

The sonar equation, as a popular tool, is used extensively in sonar theoretical studies and in discussions of technical feasibility. The sonar equation combines the most important concepts in transducers, underwater sound channels, ocean environments (ambient noise, reverberation), target characteristics (radiated noise or signal reflect ability), optimum detection of signal, and signal wave form design.

In this chapter, starting from the sonar equation, the general design principles of sonar design are discussed. Our focus is on the general theory of sonar design rather than on digital or analogue systems. The method for using the sonar equation is introduced and the various parameters appearing in the sonar equation are explained in detail. Some important concepts in underwater acoustic physics are also introduced.

The basic theoretical principles of sonar design and related signal processing techniques can be found in many classical publications in the field of underwater acoustics.\textsuperscript{[1-12]}

4.1 Determination of Sonar System Specifications

Any sonar has its own purpose, and the mission requirements are the most important factor in sonar design. In designing a specific sonar system, it is first necessary to define the main task and tactical mission of the sonar system, and then to define its required performance and specifications. Therefore, the tactical and technical specifications should guide the design and direct the realization of a
sonar system. In this section we will discuss how to define the technical specifications based on the sonar task and tactical mission.

### 4.1.1 Category of Sonar

The general procedure of sonar design is shown in Fig. 4.1. It is divided into four steps: task / mission definition, tactical specifications, functional module and decomposition of technical specifications.

![Fig. 4.1. Procedure of sonar design](image)

The task or mission for a sonar system includes the installation objective, the main performance requirements, the operation environment and the relationship with other equipment already installed in vessels or on platforms. Tactical specifications include the range distance, the accuracy of ranging, the bearing accuracy, the resolution ability of multi-targets and the target recognition ability. For the civil use of sonar, the tactical specifications are often included in the technical specifications. Various functional modules of a sonar system are necessary for the realization of tactical specifications. The fourth step in sonar design is to decompose the technical specifications into a functional module, so that the hardware designer can implement the technical specifications. The technical specifications are the guarantee for the performance of the sonar tactical mission. For example, to reach the ranging accuracy, it is necessary to define the technical requirements for time delay estimation, to realize the reliability specification, and to propose the life test specifications of transducers and electronic components.

There are many different kinds of sonar systems. The technical specification strongly depends on the type of sonar. We will briefly introduce the methods for classifying sonar.