VOL. 10, NO. 18, OCTOBER 2015 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

SONAR PROJECTOR CELL DESIGN FOR SUBMARINE DETECTION

Syamsu Ismail, Deni Permana, Tauffiqurrachman, Eko Joni Pristianto and Hana Arisesa
Research Centre For Electronics and Telecommunications Indonesian Institute of Sciences, Indonesia
E-Mail: ismailsamsu@gmail.com

ABSTRACT

Sound Navigation and Ranging (SONAR), is a detection technique using acoustic waves. One part in the SONAR system is subsystem transmitter with the projector as an electrical signal converter into acoustic waves. Designing a SONAR system begins with Link Budget underwater transmission and propagation referring to predetermined specifications. In the Link Budget calculated intensity acoustic power needs at the hydrophone, thus acoustic power projected by the projector on the transmitter can be determined. This paper discusses the design of the projector cell acoustic submarine detection sonar crystal based on Zirconate Lead Titanate, or PZT, which is relatively easy to obtain in the market. Submarine sonar detection system is an early warning underwater detection. Therefore, the acoustic output power must be large enough to be able to work as needed. Cell projector is designed in the form of a vertical array consisting of several pieces of PZT crystals with a specific interconnection between the chip to obtain maximum acoustic radiation. Cell projector is the basic element of a projector. An acoustic projector with high transmit power, directivity, radiation pattern, beam steering applications, composed of a number of cells projector.

Keywords: cell-projector, PZT-crystal, linkbudget, transmitter.

INTRODUCTION

Characteristics projector to be used is an important factor in the design of sonar systems [1-3]. Efficiency and gain of the projector determines the applied electric power in order to radiate required acoustic power [4], [5], [7]. This cell design refers to the design of sonar transmitters and the link budget of sonar calculations for submarine detection [3], [8]. For sonar transmitter with a total level of 208 dB, the power of 37.2 dBW in frequency 28KHz [10].

Increasing the applied power to the projector has consequences increasing acoustic pressure at the front surface. The acoustic pressure should have not exceeding the threshold of hydrostatic pressure, so the cavitation that in the surface of the projector is not formed. Therefore, must take into account the maximum acoustic power limit [1], [5], [11], [12]. For higher acoustic power projector, the total acoustic pressure can be distributed onto some cells in the array construction [10].

BASIC THEORY

The basic principle of the electro-acoustic transducer is the interaction between the mechanical and electrical systems. If the system is simple, only two pairs of variables, then only two equations are required to determine two variables [4]. Kinsler's simplified diagram for electro-acoustic transducer is shown in Figure-1 [1].

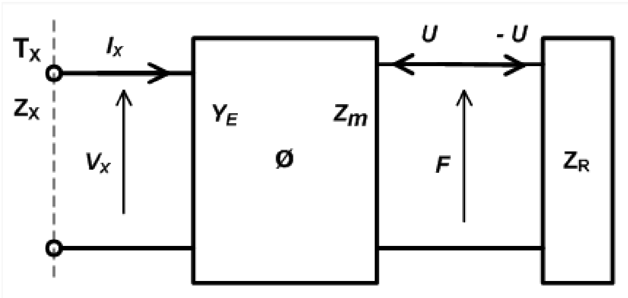

Figure-1. The scheme of electro-acoustic transducer system [1].

Kinsler's explanation gives the first equation for transducer impedance [1]. If the alternating voltage (V_X, from T_X) is applied to the input terminals, with the electrical admittance Y_E, then the current (I_X) will flows to the network

$$\boldsymbol{I_X = Y_E V_X + \emptyset U} \tag{1}$$

Where $Y_E = R_o^{-1} + Y_c^{-1}$ corresponding to U = 0, and Ø is a transformating factor relating the piezoelectric generated current in the short-circuited electrical side of the transducer (for V_X=0) the generating velocity (U) in the mechanical side. The second equation is found if an alternating force is applied to the mechanical side of the transducer, then

$$F = \emptyset V_X + Z_m U \tag{2}$$

Where Z_m is the input short-circuited mechanical impedance (V_X = 0).

The applied voltage (V_X) generates mechanical force (F) on the transducer face area (A) and must be related to the particles motion velocity (U) in the adjacent fluid medium (sea water) by the equation

$$Z_r = \frac{F}{-U} \tag{3}$$

Where Z_r is the mechanical radiation impedance. Combination of equations (1), (2) and (3) yield the electrical admittance of the transducer Y_T

$$Y_T = Y_E + \frac{\phi^2}{R_r + R_m + J(\omega m - A/\omega)} \tag{4}$$

where m is the effective mass of the transducer. The equivalent circuit for equation4 is depicted in figure2

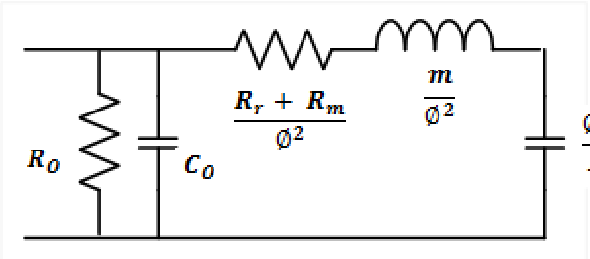

Figure-2. The equivalent circuit of equation 4 [1].

Piezoelectricity is defined as a change in electric polarization with a change in applied stress; it is called direct piezoelectric effect. Conversely a change of strain or stress in a material due to an applied electric field is called converse piezoelectric effect [13]. The projectors work based on the converse effect. Piezoelectric chip, in the design of these projectors, supplied by the electric power amplifier on the axis of vibrating so as to produce vibration modes-33, Figure-3 is the scheme of electrical feeding on a piezoelectric crystal chip.

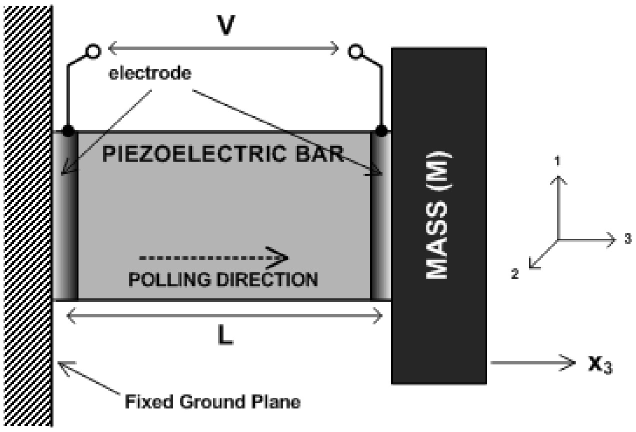

Figure-3. The scheme of electrical-feeding on a piezoelectric for mode-33 [16].

The structure of PZT crystal pieces in a stack with distributed mechanical model, and also a particular electrical connection between their electrodes allow the generated amplitude acoustic greater at a lower driving voltage [2]. Polarization each pairs of the PZT element in the stack are made face to face each other and form a pair of PZT-chips, bringing the total number of chips is always even.

THE PROJECTOR DESIGN

Methods of design of the high-power sonar projector, we start with the determination of operating frequency, bandwidth, acoustic peak power, and the physical dimensions of PZT crystal element to be used, then the cell design projector. Operating frequency and sonar source level is a reference of the projector cell design. Data obtained from the link budget [3], [8], [10] specifications are found as follows:

- Pulse Repetition Period: 16s, or PRF: 0.0625 p/s.
- Operating Frequency: 28 KHz ± 1KHz.
- Signal Mode: Pulsed CW.
- Pulse Duration: 5 – 10 ms, with ID-code of 1mS if any.
- Acoustic Peak Pulse Power in order of 10 KW.

According to the size of the targets, generally, the sonar system must have an overall bandwidth at least of the order of the ratio of speed of sound and the length of the target[10], equation (5) expressed the minimum bandwidth.

$$BW_T = \frac{c}{L} \tag{5}$$

According to the signals, the required bandwidth, if the identity code width t is included, can be found by equation (6).

$$BW_S = \frac{1}{t} \tag{6}$$

For code with time duration (t) of 1mS, then the required bandwidth is 1 KHz. Piezoelectric ceramic transducer gives maximum practical bandwidth of about half the resonance frequency [12], so the PZT crystal resonance at about 60 KHz must be selected.

Active sonar, with projector, rely on electro acoustic transducer (K) to project acoustic wave into the water. One type of transducer is piezoelectric. Piezoelectric has wide range of linear characteristic for stress versus electric field [7]. The structure of an acoustic projector is depicted in Figure-4. The structure consists of 3-parts, namely Front Mass with the end cones shaped (M1), Vibrator (K), and Back Mass (M2). The projector will be designed to operate at the sonar frequency below 30KHz with using piston-type transducers, Tonpilz, with cylindrical on the Front Mass cone- shaped [4], [7], [12]. To generate an acoustic wave radiation toward the front, then the back mass is made of iron and heavier than the front mass (M1 > M2).

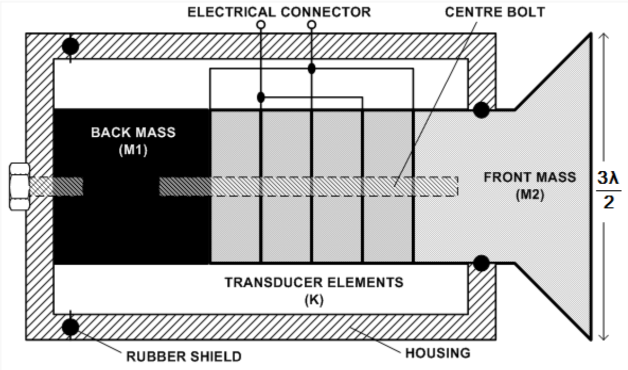

Figure-4. The structure of the acoustic projector [16].

The transducers element, Figure-4, is a stack assembled of a number of piezoelectric ring made of plumbum zirconate titanate crystals. The stack is an apparatus to convert electrical to mechanical energy at the same frequency [16]. The data from link budget shows that the acoustic power is 10 KWs peak. The vibrator, in this design, consists of four PZT Rings 30*07*10, with Rm = 22Ω, Co = 3300 pF, resonance frequency is 68 KHz, and maximum drive Voltage is greater than 5000V. If the total impedance Z_T, equ-4, is approximately 450Ω at 28 KHz, then working voltage projector is 1060 Volts. The Drive voltage is distributed in parallel to all block of PZT, Figure-4, so as to obtain a higher power not necessary to increase the voltage. The transducers for high power projector, according to the requirement, are selected hard piezoelectric crystal chip, PZT-8, 10 mm thickness. The material might be equivalent to the Navy Type III, EC-67 and EC-69 with Q=900 high maximum positive field 800V/mm [17]. The housing is made of hard thick polyvinyl chloride pipe. At the front end, ring rubber shield is mounted as a free running water shield. The rear cap is bolt tightened to the back mass (M1) and a ring rubber shield also inserted.

CONCLUSIONS

Underwater acoustic cell projector is designed using 4 rings of piezoelectric vibrator which are cemented together. A back mass is a massive iron rod of 1500 grams weight, and the front mass is a 1.5 λ face cones shape aluminium rod of 350 grams weight, (M1>M2). These three parts are tied together with a centre bolt.

ACKNOWLEDGEMENT

The work design was fully supported by Research Centre For Electronics And Telecommunications, Indonesian Institute of Science. The authors would like to thank to the reviewers for the valuable observations.

REFERENCES

[1] Kinsler Lawrence E., Austin R. Frey, Alan B. Coppens, James V. Sand-ers. 1982. Fundamentals of Acoustics. 2nd Edition, John Wiley and Son, New York.

[2] Tucker D. G., D. Sc., B. K. Gazey, Ph.D. 1966. Applied Underwater Acous-tics. Pergamon Press, Oxford.

[3] Ismail Samsu dan Deni Permana, ’ Underwater Propagation Link Bud-get as a Basis to Determine The Transmitted Power of Sonar for Submarine Detection’ Journal, IJET-IJENS Vol:14 No:05 2014.

[4] Wilson Oscar Bryan. 1988. Introduction to Theory and Design of Sonar Transducers. Expanded and Corrected Edition, Peninsula Publishing, California.

[5] Urick Robert J. 1983. Principles of Underwater Sound’ 3rd Edition. McGraw-Hill Book Company, New York.

[6] Merhaut Josef. 1981. Theory of Electro-acoustics. McGraw Hill International Book Company, New York.

[7] Sherman Charles H., and John L. Butler. 2010. Transducers and Arrays for Underwater Sound. Springer, New York.

[8] Ismail Samsu,dkk, Sonar Trans-mitter Design for Submarines Detection System’ Proceeding of National Seminar for Insentif Riset Sinas, Jakarta 29-30 September 2012.

[9] Waite A. D. 2005. SONAR for Practising Engineers. 3rd Edition John Wiley and So, Ltd, West Sussex.

[10] Ismail S., and team. 2012.Log Book Underwater Electronics research, PPET_LIPI Bandung.

[11] Hodges Richard P. 2010. Underwater Acouatics Analysis, Design and Performance Of Sonar. John Wiley and So, Ltd, West Sussex.

[12] Stansfield D. 1991. Underwater Electro-acoustic Transducers. Peninsula Publishing, California.

[13] Hutagalung. Sabar D. 2015. Dr. ‘Piezo-electric Ceramic. Power Point Presentation School of Materials and Mineral Resources Engineering, Universiti Sains Malaysia 2007, www.aast.edu accessed on May 4th.

[14] Rienstra S. W. and A. Hirschberg. 2015. An Introduction to Acoustics. Ein-dhoven University of Techno-logy 26 Jan 2015, http://www.win.tue.nl/~sjoerdr/papers/boek.pdf, accessed on April 30th.

[15] The International Association of Oil and Gas Producers.2015. Fundamentals for underwater sound, Report No: 406 May 2008, http://www.ogp. org.uk/pubs/406.pdf accessed on April 30th.

[16] Fischer F. A. 1955. Fundamentals of Electroacoustics. Inter science Publishers, Inc., New York.

[17] Exelis Acoustic Systems Ceramic Products Materials and Specifications Electro Ceramic Products Material Specification, www.exelisinc.com, Salt Lake City, http://www.ex
http://www.exelisinc.com/capabilities/piezoelectrics/
Documents/electroceramic%20products%20and%20
material%20specification.pdfelisinc.
com/capabilities/piezo
electrics/Documents/electroceramic%20products%20
and%20material%20specification.pdf accessed on May 4th 2015.