

5

10

ULTRASOUND TRANSDUCER AND METHOD FOR GENERATING
ULTRASOUND SIGNALS FOR DIGITAL COMMUNICATION VIA ULTRASOUND
TRANSMISSION

TECHNICAL FIELD

20 The present disclosure relates to an ultrasound transducer, an ultrasound communication device comprising the ultrasound transducer and related methods. More specifically, the invention as herein claimed relates to the subject matter set forth in the appended claims.

25

BACKGROUND OF THE DISCLOSURE

Wireless underwater communication is a field of significant interest.

30 Electromagnetic waves, in particular in frequency ranges suitable for radio transmission, are strongly absorbed in water, and hence radio communication

through water is not suitable. In contrast, acoustic waves are very well transmitted through water. While in particular infrasound signals can be usefully transmitted over several hundred or even thousand kilometers, the information bandwidth, when transmitting digital signals via infrasound transmission is very limited.

- 5 Ultrasound signals yield a lower useful transmission distance, but are generally able to transmit significant more data per time unit.

Certain documents known in the art describe the use of underwater communication by ultrasound transmission. Various documents, like e.g.

- 10 US 2012/0213034, US 2012/0180788, WO 2012/154679, US 5,530,682 or EP 2 666 710 deal with communication between divers by ultrasound signals. Other documents, like e.g. EP 4 265 193 and WO 2016/037912, deal generally with the use of ultrasound signals propagating through a body in medical diagnostic and medical device control. Still further documents known in the art
15 generally deal with digital ultrasound data transmission under water, like e.g. EP 1 056 223 and GB 1,447,547.

An important part of any underwater ultrasound communication are transducers which are suitable to receive electric signals, convert the electric signals into
20 ultrasound oscillations and transmit the oscillations into water to generate the ultrasound waves propagating through the water, and of course, transducers which are suitable to receive the ultrasound waves and convert them into electric signals for a receiver. Various documents known in the art suggest the use of piezoelectric elements for generating ultrasound signals in water. Such

- 25 suggestions are found in e.g. WO 2023/213479, EP 1 056 223 or CN 117176261. US 2023/0142881 suggests to use a piezoelectric layer in a membrane suspended over a cavity. Tomoya Hirata *et al.*, in "Sub-terahertz photoacoustic effect enabling broadband ultrasound generation for underwater communication" in APL Photonics, 20230919, American Institute of Physics, Vol. 8 No. 9 suggest to use
30 the photoacoustic effect instead of piezo transducers to generate ultrasound waves in water.

OUTLINE OF THE SUBJECT MATTER OF THE PRESENT DISCLOSURE

5 An object of the present disclosure is the subject matter set out above. In aspects, drawbacks of the art shall be mitigated. According to more specific aspects, a compact and/or robust ultrasound transducer shall be suggested. In still other aspects, efficient ways of generating signals for efficient digital ultrasound communication are desired.

10

This is achieved by at least embodiments of the subject matter set forth below.

Further effects and advantages of the disclosed subject matter, whether explicitly mentioned or not, will become apparent in view of the disclosure provided below.

15

Disclosed is an ultrasound transducer configured for converting AC electric signals into ultrasonic vibrations and for receiving ultrasonic vibrations and convert the ultrasonic vibrations into an AC electric signal. The ultrasound transducer comprises a piezoelectric layer. The piezoelectric layer comprises a ply of a piezoelectric material and two conductive plies, wherein one of the conductive plies is disposed on each of the two opposed faces of the ply of piezoelectric material. A conductive ply is a ply of a conductive material having, e.g., a resistivity, or specific electrical resistance, of $10^{-2} \Omega\text{m}$ or less or $10^{-4} \Omega\text{m}$ or less. The two conductive plies may in particular be electrically isolated from each other, apart from being connected to the common piezoelectric ply, which enables to measure or apply a voltage between the two conductive plies. For instance, the electric resistance between the two conductive layers is $1 \text{ M}\Omega$ or more. The piezoelectric layer is embedded in a non-conductive liquid-proof sheath. The material of the liquid-proof sheath may for instance have a resistivity of $1 \text{ M}\Omega\text{m}$ or more. The liquid-proof sheath may consist of a rigid or an elastic material. However, the material, and geometry, of the liquid-proof sheath need to be

- provided such that ultrasonic vibrations form ultrasound waves in a surrounding medium are transmitted to the underlying piezoelectric layer. The surrounding medium, in particular, may comprise water comprising a range from fresh water to salt water at least in a range found in oceans, seas and lakes on the earth, and
- 5 may comprise the range of salinity found in any surface water on the earth. Each ply of conductive material disposed on one side of the ply of piezoelectric material is electrically connected to a separate terminal which is accessible from outside the sheath.
- 10 It is noted that within the framework of the present disclosure the use of the indefinite article “a” or “an” does in no way stipulate a singularity nor does it exclude the presence of a multitude of the named member or feature. It is thus to be read in the sense of “at least one” or “one or a multitude of”.
- 15 The liquid-proof sheath, which will also be referred to as simply the “sheath” below, may in embodiments be an integral, one-piece, seamless member. In particular, the sheath is provided so as to seal liquid-tight with any element extending through or out of the sheath.
- 20 The skilled person will readily appreciate that the herein disclosed subject matter enables bidirectional communication via one single transducer: On the one hand, AC electric signals may be provided to the transducer via the terminals and excite the piezoelectric ply of the piezoelectric layer to vibrate in line with the AC electric signals, which emits ultrasound waves through the sheath to a surrounding fluid.
- 25 On the other hand, ultrasound waves in the surrounding fluid are transmitted through the sheath to the piezoelectric ply, which, in response, generates AC voltage between the two conductive plies, which in turn may be tapped at the terminals.
- 30 In the context of the present disclosure, the terms conductive and isolating, or non-conductive, respectively, shall relate to electrical conductivity. The definitions

commonly found in literature for the definition of electrically conductive or non-conductive, electrically isolated, electrically connected and so forth shall apply. More specifically conductive materials refer to materials having a resistivity of $10^{-2} \Omega\text{m}$ or less or, in even more specific embodiments, $10^{-4} \Omega\text{m}$ or less. Non-
5 conductive or electrically isolating materials refer to materials having a resistivity of $1 \text{ M}\Omega\text{m}$ or more. Connected or electrically connected shall refer to connections having a resistance of 1Ω or less, in more specific embodiments 0.1Ω or less and in even more specific embodiments $10^{-2} \Omega$ or less, and isolated shall refer to a resistance of $1 \text{ M}\Omega$ or more.

10

In particular, the herein suggested transducer is a solid transducer, i.e., it consists of solid materials being arranged directly adjacent and contacting each other. The transducer may be considered a solid body transducer. The transducer does not contain or comprise or enclose any internal, enclosed functional cavities which
15 may be filled with or fillable with a gas and/or liquid and which are functionally connected with the piezoelectric layer. That is, in other words, the piezoelectric layer is fully supported by and enclosed in solid material. Small openings like, e.g., a conduit for passing a wire or other conductive element therethrough, and, when assembled, at least essentially filled with said wire of other conductive element,
20 shall not be considered a cavity, and the transducer shall still be considered a solid transducer.

The solid body design of the herein suggested transducer yields in compact and robust embodiments. In particular, the dispensation of enclosed functional hollow
25 spaces results in a compact design, which moreover yields robustness. In some respect the herein suggested transducer resembles of an antenna, while designs known in the art follow more speaker-like designs. The herein disclosed transducer may thus be referred to as an ultrasound antenna.

30 Moreover, the herein disclosed subject matter may easily and inexpensively be manufactured. The beneficial properties of the herein suggested ultrasound

transducer render it also suitable for applications in underwater sensors and model sports. For instance, underwater sensors may communicate via ultrasound with each other and/or a hub, whereby communication may be unidirectionally or bidirectionally, wherein the herein suggested transducer constitutes a robust,
5 compact and at least in embodiments inexpensive component enabling effective underwater data transmission via ultrasound. Likewise, e.g. underwater drones or submergeable drones may be equipped with the herein suggested transducer as a robust, compact and at least in embodiments inexpensive device for generating and emitting as well as receiving ultrasound signals which may be used for control
10 and communication with the underwater drone. The above-mentioned applications are, of course, not comprehensive, and abundant other application may readily be conceived by a person having skill in the art.

The piezoelectric layer may comprise or consist of a piezoelectric film element. It
15 is understood that also the piezoelectric film element comprises a piezoelectric ply sandwiched between two conductive plies. The material of the piezoelectric ply, in more specific embodiments a piezoelectric ply of the piezoelectric film element, may be a polymer. The polymer may be polyvinylidene fluoride, abbreviated as PVDF.

20 At least one of the conductive plies of the piezoelectric layer may contain silver or, in more specific embodiments, may be a silver layer. In other embodiments, at least one of the conductive plies may comprise or consist of at least one of copper, a zinc-nickel-alloy, tin, gold or other suitable conductive materials.

25 The sheath may consist of a cured resin, in particular a cured epoxy resin. It will be appreciated that the use of a resin to manufacture the sheath may largely facilitate manufacturing of the transducer: A "core" of the transducer may essentially simply be dipped into a bath of resin or be overmoulded with the resin
30 and the resulting layer subsequently be cured. It is understood that with some resins a cured resin may still yield highly elastic properties, as may be the case

with, for instance, while not being limited to, flexible epoxies or silicone sealants. The used resin may for instance, while not limited to, be an epoxy resin.

The material of the sheath may in embodiments be selected to have a density which deviates by no more than 60%, or, in more particular embodiments, no more than 50% or no more than 40%, from the density of the material of the material of the piezoelectric ply, wherein the relative difference is related to the density of the material of the piezoelectric ply. If the sheath consists of a resin, the density of the material refers to the density in the cured state. For instance, the density of a PVDF piezoelectric material is 1.28 g/cm^3 and the density of a typical cured epoxy resin is 1.78 g/cm^3 . The comparatively low difference in density, and the relative proximity of the respective density values to the density of water, facilitate the transmission of ultrasonic vibrations from the piezoelectric ply through the sheath into surrounding water and vice versa.

In some embodiments, the transducer may consist simply of the piezoelectric layer embedded in the sheath, and the terminals connected to the conductive plies of the piezoelectric layer. Said embodiments may be realized, for instance, as a rod-shaped transducer, wherein the piezoelectric layer is provided as a strip of material, or a disc-shaped transducer, wherein the piezoelectric layer is provided as a disc of material. The disc may be circular but may also be differently shaped. Also, an annular geometry is conceivable. Other embodiments comprise a center body, or core, of a non-conductive material, wherein the piezoelectric layer is provided on and around the center body, with one of the conductive plies adjacent and contacting the center body. The sheath is provided on and around the piezoelectric layer. It shall be noted, in this respect, that "provided around" shall not be construed such that a body is in any case entirely covered by another element or member, while this is not excluded. The center body may in particular be a solid center body. The solid center body may also be considered a solid center body if the center body has a conduit for passing a wire or other conductive element therethrough.

In one embodiment comprising a center body, the ultrasound transducer comprises, or in more specific embodiments is, a rod-shaped transducer. The non-conductive center body has a longitudinal extent and a lateral surface. The lateral
5 surface extends circumferentially around a longitudinal axis of the center body. The center body may be a cylindrical center body, and may more in particular have a circular cross-section. An inner conductive element extends through the interior of the center body and provides a first terminal accessible at a back side of the center body. The piezoelectric layer is disposed circumferentially around the
10 center body, at least along a portion of the longitudinal extent of the center body, whereby the piezoelectric layer provides a radially inner conductive ply and a radially outer conductive ply. The radially inner conductive ply is electrically conductive connected to the inner conductive element, and hence the first terminal, and the radially outer conductive ply is electrically connected to a second
15 terminal accessible at the back side of the center body. The sheath extends over a front end of the ultrasound transducer and at least a front portion of an outer circumference of the ultrasound transducer, or constitutes the outer surface of at least a front portion of the ultrasound transducer, respectively. The second terminal may be provided by a sleeve which circumferentially encloses a back
20 portion of the piezoelectric layer and is in electric contact with the radially outer conductive ply. The sheath extends over at least a front portion of the sleeve. The first terminal may be provided radially inside the sleeve.

In respect of the aforementioned embodiments of rod-shaped transducers, the
25 piezoelectric layer may extend longitudinally beyond the center body at least in the front portion of the ultrasound transducer so as to form a cylindric space circumferentially enclosed by the extending portion of the piezoelectric layer in a front portion of the ultrasound transducer. The inner conductive element longitudinally extends through the center body and from the center body at least in
30 the front portion of the ultrasound transducer into the cylindric space circumferentially enclosed by the extending portion of the piezoelectric layer. The

cylindric space circumferentially enclosed by the extending portion of the piezoelectric layer contains, or, in embodiments, is filled with a conductive material to establish an electric connection between the radially inner conductive ply and the inner conductive element, and consequently the electric connection between
5 the radially inner conductive ply and the first terminal. The conductive material contained in the cylindric space may in embodiments be a cured electrically conductive resin. The sheath extends over the conductive material contained in the cylindric space circumferentially enclosed by the extending portion of the piezoelectric layer, which includes a front face of the transducer. A longitudinal
10 extent by which the inner conductive element longitudinally extends from the center body in the front portion of the ultrasound transducer may be smaller than a longitudinal extent by which the piezoelectric layer extends longitudinally beyond the center body in the front portion of the ultrasound transducer.

15 In a rod transducer as set forth above a free length of the piezoelectric layer by which the piezoelectric layer extends axially and is covered by the sheath only, e.g. the length by which the piezoelectric layer extends from a sleeve terminal, may be used to optimize the transducer for communication at a specific preferred ultrasound frequency. Said free length of the piezoelectric layer may in particular
20 correspond to the half of the wavelength of ultrasound waves in the surrounding fluid at the preferred frequency, or an integer multiple thereof.

In further embodiments, the ultrasound transducer may be a branched transducer comprising at least two branches, wherein each branch extends from a common
25 root of all branches to a respective front end and wherein the branches include a non-zero angle with each other. Each branch includes a piezoelectric layer extending in a direction along a longitudinal extent of the respective branch, which is defined from the common root towards a respective front end of the branch. The conductive ply on a first side of each piezoelectric layer is electrically connected to
30 a first common terminal and the conductive ply on a second side of each piezoelectric layer is electrically connected to a second common terminal. At least

one branch of the at least two branches may be a rod-shaped transducer as outlined above. In some embodiments, all branches of the branched transducer may be rod-shaped transducer as outlined above. The first terminal of the rod-shaped transducer, or of each rod-shaped transducer, is connected to the first
5 common terminal of the branched transducer, and the second terminal of the rod-shaped transducer, or of each rod-shaped transducer, is connected to the second common terminal of the branched transducer. In certain embodiments, a free length of each piezoelectric layer arranged in a branch may be at least essentially equal. That is, all branches are optimized for communication at the same preferred
10 ultrasound frequency. The branched arrangement may serve, for instance, to provide specific spatial emission and/or receiver sensitivity characteristics. In other embodiments, however, a free length of the piezoelectric layer arranged in a first one of the branches may differ from the free length of the piezoelectric layer arranged in a second one of the branches. The branched transducer may thus
15 comprise branches being optimized for communication at different preferred wavelengths, such that the branched transducer in its entirety may be suitable for communication in a broader ultrasound frequency range or at different ultrasound frequencies.

20 In still further embodiments, the ultrasound transducer may be a cone transducer, wherein the piezoelectric layer is shaped as a conical shell and the sheath is shaped as a hollow conical shell embedding the piezoelectric layer. The terminals are arranged at the convergent, or narrow, end of the cone transducer. A cone transducer may comprise a hollow-conical center body inside the sheath and on
25 which the piezoelectric layer is provided, or not.

In yet further embodiments of an ultrasound transducer comprising a center body, in particular a solid center body, the center body may be provided as a round body of revolution, e.g. an ellipsoid or a spheroid, wherein the piezoelectric layer is
30 disposed around the center body and the sheath is provided around the piezoelectric layer. In said embodiments, the terminal to which a radially outer one

of the two conductive plies is electrically connected may be a sleeve extending through the sheath, wherein an interior of the sleeve may be free from the sheath, and the terminal which is electrically connected to the radially inner one of the two conductive plies may be provided within the sleeve. In embodiments, the terminal
5 which is electrically connected to the radially inner one of the two conductive plies may extend through the center body along a diameter of the center body.

Further disclosed is an ultrasound communication device configured for emitting and/or receiving ultrasound signals. The ultrasound communication device
10 comprises a receiver electronics and/or an emitter electronics and at least one ultrasound transducer of any type herein claimed or otherwise disclosed. The ultrasound transducer is functionally connected or selectively functionally connectable to at least one of the receiver electronics and/or emitter electronics. In a more particular aspect, the terminals of the ultrasound transducer may be
15 functionally connected or selectively functionally connectable to at least one of the receiver electronics and/or emitter electronics. Generally, a functional connection might be construed in a way that signals may be transmitted between the ultrasound transducer and the receiver electronics and/or the emitter electronics. In other aspects, a functional connection might be construed in a way that the
20 terminals of the ultrasound transducer are electrically connected to signal input terminals of the receiver electronics and/or signal output terminals of the emitter electronics. A switching device may be provided between the terminals of the transducer and the respective terminals of at least one of the receiver electronics and/or the emitter electronics and allow to selectively connect or disconnect the
25 transducer and the respective electronics. Such switching devices might be found useful to switch the communication device between a sending mode and a receiving mode. The input terminals of the receiver electronics may thus be isolated from output signals of the emitter device. In other aspects, a switching device which is configured to selectively open and close a functional connection
30 between an AC voltage generator of the emitter electronics and at least one of the at least one ultrasound transducer may be found useful to perform a method of

generating ultrasound signals for digital ultrasound signal transmission, which is set forth below.

Accordingly, a method of generating ultrasound signals for digital ultrasonic signal transmission comprises operating an AC voltage generator to continuously
5 generate a continuous AC output in an ultrasound frequency range. Generally, sound at frequencies of 20 kHz or more is considered ultrasound. This definition is used in the context of the present disclosure. The frequency range may in particular reach from 20 kHz to 2 Mhz. The emitter electronics may in
10 embodiments be operated at a constant output amplitude. The method further comprises selectively connecting an output of the AC voltage generator to an ultrasound transducer and disconnecting the output of the AC voltage generator from the ultrasound transducer. The selective connection and disconnection between the emitter electronics and the transducer, while the emitter electronics is
15 constantly operated, may allow to generate significantly sharper defined digital output signals than the switching the emitter electronics itself on and off.

Data transmission applying said method may comprise compiling a bit sequence to be transmitted into a sequence of time spans in which the AC voltage generator
20 is connected to the ultrasound transducer or disconnected from the ultrasound transducer, and further selectively connecting and disconnecting the output of the AC voltage generator to and from the ultrasound transducer in a temporal sequence according to the sequence of time spans. According to this particular method, each transmitted bit corresponds to a predefined unit of time, and the
25 connection between the AC voltage generator and the ultrasound transducer is switched on or off during the predefined unit of time dependent of the value of the bit, and successively according to the sequence of bits. If two or more bits of identical value are to be transmitted in direct succession, switching between each bit might not be required, as the number of successive bits may be identified by
30 the duration of the generated constant amplitude signal output. In other aspects, modulation methods like e.g. amplitude modulation, frequency modulation, phase

modulation or the spread spectrum method may be applied. The ultrasound transducer used in the method may be an ultrasound transducer of any type set forth above.

- 5 In this respect, the present disclosure also relates to the use of a transducer of any type set out above in a method of generating ultrasound signals for digital ultrasonic signal transmission set out above.

In still a further aspect, disclosed is a method of localizing a device, in particular
10 under water, e.g., determining a position of the device, which comprises emitting an ultrasound signal from the device, receiving the ultrasound signal by at least two ultrasound receivers and determining a time difference between the reception of the signals by each of the at least two ultrasound receivers. This method makes it possible to determine a direction of the device relative to the at least two
15 ultrasound receivers. In particular, at least one of the ultrasound receivers may comprise a transducer of any type set out above. Emitting the ultrasound signal may comprise emitting an ultrasound sequence representing a time stamp characterizing an emission time. Said time may for instance be a time of transmission start, a time of transmission end, or any time between. It is, however,
20 important in evaluating the signals to know which point of the transmission is referred to. The receiver may then determine the corresponding receipt time and, accordingly, the signal propagation delay, and thus determine the distance of the device from the receiver. Thus, an absolute position of the device relative to the at least two receivers may be determined.

25 Still further aspects of the herein disclosed subject matter address the different needs for wireless communication through air and water. Hence, disclosed is a communication system for transmitting data between a land-based transceiver and a target object located submerged in water. The communication system comprises
30 the transceiver, a translation platform and the target object. The translation platform may in particular be a floating translation platform. It is understood that

the translation platform is intended to be provided in the same volume of water as the target object. The position of the translation platform may be fixed by a suitable anchoring means. The transceiver and the translation platform are configured for bidirectional wireless transmission of electromagnetic waves between the

5 transceiver and the translation platform above the water surface. The translation platform comprises an ultrasound transducer arranged and configured to be located under the water surface and in the water when the translation platform floats, and converter means configured for converting electromagnetic wave signals received from the transceiver into ultrasound frequency electric signals and

10 for converting ultrasound frequency electric signals into electromagnetic wave signals for transmission to the transceiver. The converter means and the ultrasound transducer are functionally connected to each other such that electric signals are transmittable between the converter means and the ultrasound transducer. The target object has an ultrasound transducer configured to receive

15 ultrasound signals from surrounding water and convert the received ultrasound signals into ultrasound frequency electric signals and to convert ultrasound frequency electric signals into ultrasound signals and emit the ultrasound signals into surrounding water. The target object further comprises means for evaluating ultrasound frequency electric signals generated by the ultrasound transducer of

20 the target object in response to receiving ultrasound signals from the water, and/or for generating ultrasound frequency electric signals to be converted into ultrasound signals via the ultrasound transducer of the target object. Said means is operatively connected to the ultrasound transducer of the target object, such that electric signals can be bidirectionally transmitted between said means and the

25 ultrasound transducer of the target object. It is understood that said system is configured to transmit data for instance between a land-based controller and a submerged object, whereby along a portion of the transmission path which extends through air electromagnetic waves are suitably used for the transmission, while along a further portion of the transmission path which extends under water

30 ultrasound waves are suitably used for the transmission. The ultrasound

transducer may be an ultrasound transducer as herein claimed or otherwise disclosed.

Accordingly, a method for transmitting data between a land-based transceiver and
5 a target object submerged in water as herein suggested comprises at least one of two sequences set forth below.

A first sequence comprises transmitting an electromagnetic wave signal from the land-based transceiver to a floating translation platform. The electromagnetic wave
10 signal received from the transceiver is converted into an ultrasound frequency electric signal, which, in turn, is transmitted to an ultrasound transducer of the translation platform. The ultrasound transducer of the translation platform converts the ultrasound frequency electric signal into an ultrasound signal and emits the ultrasound signal into the water. The ultrasound signal is received by an
15 ultrasound transducer of the target object and the ultrasound signal received by the ultrasound transducer of the target object is converted into an ultrasound frequency electric signal by the ultrasound transducer of the target object.

The second sequence comprises generating an ultrasound frequency electric
20 signal by the target object. Said ultrasound frequency electric signal generated by the target object is transmitted to an ultrasound transducer of the target object, where it is converted into an ultrasound signal by the ultrasound transducer of the target object, which in turn are emitted into the water by the ultrasound transducer of the target object. The resulting ultrasound signal is received by the ultrasound
25 transducer of the floating translation platform and converted into an ultrasound frequency electric signal. The resulting ultrasound frequency electric signal is then converted into an electromagnetic wave signal, which is transmitted to the land-based transceiver.

30 It is understood that the features and embodiments disclosed above may be combined with each other. It will further be appreciated that further embodiments

are conceivable within the scope of the present disclosure and the claimed subject matter which are obvious and apparent to the skilled person by virtue of the present disclosure.

5

BRIEF DESCRIPTION OF THE DRAWINGS

The subject matter of the present disclosure is now to be explained in more detail by means of selected exemplary embodiments shown in the accompanying
10 drawings. The figures show

- | | |
|-----------|--|
| Fig. 1 | a first exemplary embodiment of an ultrasound transducer; |
| Fig. 2 | an exemplary embodiment of an ultrasound transducer comprising a center body which is shaped as a rod-shaped transducer; |
| 15 Fig. 3 | an exemplary embodiment of a branched transducer; |
| Fig. 4 | an exemplary embodiment of a conical transducer; |
| Fig. 5 | an exemplary embodiment of a transducer shaped as a spherical transducer; |
| Fig. 6 | an exemplary embodiment of a communication device as herein
20 suggested; |
| Fig. 7 | an exemplary embodiment of an ultrasound transmitted for transmitting digital signals; |
| Fig. 8 | a diagram explaining an exemplary method of generating and/or transmitting digital signals; and |
| 25 Fig. 9 | an exemplary embodiment of a system enabling communication between a land-based controller station and a submerged object. |

It is understood that the drawings are schematic and not necessarily to scale. Details not required for instruction purposes may have been omitted for the ease
30 of understanding and depiction. It is further understood that the drawings show

only selected, illustrative embodiments, and embodiments not shown may still be well within the scope of the herein disclosed and/or claimed subject matter.

5

EXEMPLARY MODES OF CARRYING OUT THE TEACHING OF THE PRESENT DISCLOSURE

Figure 1 shows a first embodiment of an ultrasound transducer as herein
10 described. Ultrasound transducer 1 comprises piezoelectric layer 2 embedded in a sheath 3 of non-conductive material. Sheath 3 is liquid-proof and seals liquid-tight with any element extending through or out of liquid-proof sheath 3. Sheath 3 may be a cured resin sheath. Piezoelectric layer 2 consists of a piezoelectric ply 21 and two conductive plies 22 and 23, which are provided on the opposed faces of
15 piezoelectric ply 21. Each conductive ply is electrically connected to a terminal 4 or terminal 5, respectively. Terminal 4, in the exemplary embodiment, essentially is provided by a wire 41 extending through an isolating bushing 31 to conductive ply 22. Isolating bushing 31 prevents contact between wire 41 and conductive ply 23. Via a washer-shaped head 42, electrical contact between wire 41, or
20 terminal 4, respectively, and conductive ply 22 is established. Terminal 5 consists essentially of sleeve 51, which is electrically connected to conductive ply 23. Sleeve 51 has an internal thread 52, by which it may be securely attached to a counter plug. Both terminals 4 and 5 extend through liquid-proof sheath 3. Liquid-proof sheath seals liquid-tight with wire 41 and sleeve 51. For instance, sheath 3
25 may be manufactured by first assembling piezoelectric layer 2 with wire 41 and sleeve 51 and subsequently either casting non-cured resin over the resulting unit or dipping the resulting unit into a bath of resin and curing the resulting resin layer. As outlined above, on the one hand an AC voltage may be applied between terminals 4 and 5. Said AC voltage is accordingly also applied between conductive
30 plies 22 and 23, and accordingly piezoelectric layer 2 is excited to oscillate with the frequency of the applied AC voltage, and the resulting mechanical oscillation is

transmitted through sheath 3 to a surrounding fluid, like e.g. water, where the oscillations result in ultrasound waves propagating through the fluid. On the other hand, ultrasound waves propagating through the surrounding fluid and meeting transducer 1 are transferred through sheath 3 to piezoelectric layer 2, whereby a
5 voltage is generated between conductive plies 22 and 23, which may be tapped at terminals 4 and 5 and be further processed.

Figure 2 shows a transducer 1 which is rod-shaped. Transducer 1 comprises a non-conductive center body 6 having a longitudinal extent. Piezoelectric layer 2,
10 provided as a piezoelectric film, is wrapped around a circumference of center body 6. Conductive ply 23 is provided on a radially inner side of piezoelectric film 2, and, along a portion of the axial extent of transducer 1, adjacent to and contacting center body 6, while conductive ply 22 is provided at a radially outer side and adjacent to and contacting liquid-proof sheath 3 along a portion of the
15 axial extent of transducer 1. Radially outer conductive ply is further adjacent and electrically connected to sleeve 51, and, accordingly, terminal 5. In a front portion of transducer 1, piezoelectric layer 2 extends axially beyond center body 6. The resulting space radially inside piezoelectric layer 2 and adjacent a front end of center body 6 contains a conductive filler material 7, which may for instance be a
20 cured conductive resin. Wire 41, which constitutes an inner conductive element and forms terminal 4 on a back side of rod-shaped transducer 1, extends axially through center body 6 and extends beyond the front end of center body 6 and into the space formed radially inside piezoelectric layer 2 and adjacent the front end of center body 6, and consequently into conductive filler 7. Conductive filler 7 is in
25 contact with radially inner conductive ply 23 and with wire 41, and consequently establishes electric connection between radially inner conductive ply 23 and terminal 4. Liquid-proof sheath 3 extends integrally on radially outer conductive ply 22 between a front end of piezoelectric layer 2 and a front end of sleeve 51, and further extends over a front end of sleeve 51 and over front end 11 of
30 transducer 1. Sleeve 51 of terminal 5 may, via internal threads 52, be connected to a counter connector, whereby the connection between sleeve 51 and the counter

connector may be liquid-proof sealed. Hence, piezoelectric layer 2 is protected from contact with e.g. water if transducer 1 with a counter connector connected to the back side of transducer 1 is submerged into water. In the present embodiment, the distance by which wire 41 extends beyond the front end of central body, or
5 core, 6 is smaller than the distance by which piezoelectric layer 2 extends beyond the front end of center body 6. Conductive filler 7 terminates flush with the front end of piezoelectric layer 2. Thus, a front end of wire 41 is covered by conductive filler 7 and is thus protected against damages and also protected against
damaging sheath 3.

10

Figure 3 shows an embodiment of a transducer 1 which is shaped as a branched transducer. Two branches 1a and 1b of branched transducer 1 are visible. A branched transducer may, in essence, comprise any number of branches equal or greater than two, extending from a common root 1c. The branches may include
15 equal angles between any two neighboring branches, or different angles. For one instance, the arrangement of branches may serve to generate specific directional emission and receiving characteristics of transducer 1. The longitudinal extent of the piezoelectric layers 2a and 2b in the individual branches, measured from common root 1c, may be equal in all branches, or may be different in at least one
20 branch compared to at least one other branch. The branches may then be optimized for emitting of receiving ultrasound at different frequencies. A piezoelectric layer 2a, 2b is arranged in each of the two exemplarily shown branches 1a and 1b. Each of piezoelectric layers 2a and 2b comprises, respectively, piezoelectric ply 21a, first conductive ply 22a, and second conductive
25 ply 23a, and piezoelectric ply 21b, first conductive ply 22b, and second conductive ply 23b. Terminal 4 is electrically connected, via conducting elements 41a and 41b, respectively, to conductive plies 23a and 23b of the piezoelectric layers 2a and 2b, respectively. Terminal sleeve 51 forming second terminal 5 is electrically connected to conductive plies 22a and 22b of the piezoelectric layers 2a and 2b,
30 respectively, at the common root 1c of transducer 1. At least one of branches 1a and 1b may be provided as a rod-shaped transducer as essentially shown in and

set out in connection with figure 2, wherein the respective piezoelectric layer is wrapped around the circumference of a longitudinal center body of the respective branch.

- 5 Figure 4 depicts an embodiment of transducer 1 which is shaped as a conical transducer. Piezoelectric layer 2 is shaped as a hollow cone, or truncated hollow cone, and is embedded in liquid-proof sheath 3, which is also shaped as a hollow cone or truncated hollow cone. Terminals 4 and 5 are provided at a convergent, or narrow, end of cone transducer 1, wherein terminal 4 is, via conductive
10 element 41, electrically connected to conductive ply 23 and sleeve-shaped terminal 5 is electrically connected to conductive ply 22.

- The exemplary embodiment of transducer 1 shown in figure 5 comprises a center body 6 shaped as a round body of revolution, wherein the piezoelectric layer 2 is
15 disposed around center body 6 and sheath 3 is provided around piezoelectric layer 2. Center body 6 in the shown exemplary embodiment is a spherical solid body, but it will be appreciated that it may in other embodiments be, for instance, an ellipsoid of revolution. Radially inner conductive ply 23 is arranged adjacent and in contact with center body 6, while radially outer conductive ply 22 is covered
20 by and in contact with sheath 3. Piezoelectric ply 21 is arranged between conductive plies 22 and 23. Wire or conductor 41 extends through center body 6 along a diameter of center body 6 and establishes electric connection between radially inner conductive ply 23 and terminal 4. Terminal sleeve 51 is electrically connected to radially outer conductive ply 22 and hence provides electric
25 connection between radially outer conductive ply 22 and terminal 5.

- Above, various exemplary embodiments of ultrasound transducers as herein suggested have been presented. Other embodiments, however, are conceivable by a person having skill in the art. They all share a common working principle:
30 They may for instance be submerged in a liquid, like water, due to the liquid-proof sheath 3. Sound waves in the water, or other fluid surrounding the transducer, is

transmitted, through sheath 3, to piezoelectric layer 2. An AC voltage having a frequency equal to that of the sound, and having an amplitude at least essentially proportional to the sound amplitude, is generated in piezoelectric ply 21 and can be measured between conductive plies 22 and 23 of piezoelectric layer 2, and
5 may be tapped at terminals 4 and 5. Likewise, an AC voltage may be applied between terminals 4 and 5 and transmitted to piezoelectric layer 21 via conductive plies 22 and 23 of piezoelectric layer 2. Piezoelectric ply 21 is excited to vibrate at a frequency equal to that of the applied AC voltage and an amplitude at least essentially proportional to the amplitude of the AC voltage. Said vibration is
10 transmitted as sound waves to a surrounding medium. For the intended communication and data transmission purpose, sound waves in a frequency range of 20 kHz or more shall be applied. For the present purpose, sound waves up to a frequency of about 2 MHz were found useful. The ultrasound frequency can on the one hand be controlled by the frequency of the applied AC excitation voltage. On
15 the other hand, certain dimensions of the transducer may be optimized for specific ultrasound wavelengths in the surrounding medium, and thus specific frequencies. For instance, in the embodiment of figure 2, it may be desirable if the free length of piezoelectric layer 2, from the front end of sleeve 5 to the front end of piezoelectric layer 2, at least essentially corresponds to half the wavelength of the sound waves
20 in the surrounding fluid at the desired frequency, or an integer multiple thereof. Likewise, in the embodiment of figure 3, the length of the piezoelectric layer inside a branch from common root 1c to a distal end of the respective piezoelectric layer may be chosen to at least essentially correspond to half the wavelength of the sound waves in the surrounding fluid at the desired frequency or an integer
25 multiple thereof. For any given frequency, the skilled person will be readily able to determine the preferred dimensions for a specific preferred sound frequency by computations or experiments.

Referring to figure 6, shown is an ultrasound communication device, or ultrasound
30 emitter and receiver device, 100. Communication device 100 comprises ultrasound transducer 1, emitter electronics 110, receiver electronics 120, and

selector 130. As indicated by arrows, signal flow between ultrasound transducer 1 and selector 130 generally is bidirectional, whereas signal flows from emitter electronics 110 to selector 130 and from selector 130 to receiver electronics 120 are unidirectional. Selector 130 is configured to selectively functionally connect
5 ultrasound transducer 1 to either emitter electronics 110 or receiver electronics 120. AC voltage in an ultrasound frequency range from emitter electronics 110 may thus be routed to ultrasound transducer 1, where it is converted to vibrations at a frequency corresponding to that of the AC voltage and transmitted as ultrasound waves to a fluid surrounding ultrasound transducer 1.
10 On the other hand, ultrasound signals received from the surrounding fluid may be converted to an AC voltage in ultrasound transducer 1 and the AC voltage be routed to receiver electronics 120, where it may be further processed.

An embodiment of emitter electronics 110 and a beneficial communication method
15 for which the exemplarily disclosed emitter electronics is suitable are outlined in connection with figures 7 and 8. Emitter electronics 110 comprises AC voltage generator 111, which is configured to generate an AC voltage output 200 of constant frequency and amplitude. Binary signal modulator 112 is operated to generate a binary modulation signal 300 representing a succession of bits. For
20 instance, high output level of binary modulation signal 300 may correspond to a "1" bit, while low level of binary signal 300 may correspond to a "0" bit. Each bit may be represented by a predefined output duration, as becomes apparent below. Modulator switch 113 is configured to selectively open and close a functional connection between AC voltage generator 111 and transducer 1, i.e., to selectively
25 forward AC voltage signal 200 to transducer 1 or not, in response to the input of binary modulation signal 300 from binary signal modulator 112. Any device suitable to selectively open and close a functional connection between AC voltage generator 111 and transducer 1 may be used as modulator switch 113. Referring now to figure 8, the thus realized method is illustrated. AC voltage generator 111,
30 as indicated above, continuously generates AC voltage signal 200 of constant frequency and amplitude. Emitter signal 400, which is transmitted to ultrasound

transducer 1, comprises AC voltage signal 200 modulated by means of binary modulation signal 300, according to which AC voltage signal 200 is transmitted to transducer 1 or not. In the present embodiment, a single bit is represented by a duration T. Assuming that modulator switch 113 shown in figure 7 functionally connects the output of AC voltage generator 111 to transducer 1 if modulation signal 300 is high, and disconnects the output of AC voltage generator 111 to transducer 1 if modulation signal 300 is low, modulation signal 300 is, in succession, high for a duration 2T, low for a duration 2T, high for a duration 4T, low for a duration 5T, and high for a duration 2T to send the bit sequence “110011110000011” through emitter signal 400, which is transmitted to transducer 1, and from transducer 1 as an ultrasound signal into a surrounding fluid. It is appreciated that in modulating AC voltage signal 200 by binary modulation signal 300 in modulator switch 113, as outlined in connection with figures 7 and 8, the switch-over between “high” and “low” states, or bit values, might be performed faster than if the output amplitude of AC voltage generator needed to be directly modulated. Duration T, representing one bit, might be chosen such that duration T corresponds to a certain number of oscillations of AC voltage signal 200. Assuming that this number is four, and the frequency of AC voltage signal 200, and, accordingly, the ultrasound frequency used for communication, is 100 kHz, then duration T would correspond to 40 μ s, and accordingly 25 kBit/s could be transmitted.

Figure 9 shows an exemplary embodiment of a system enabling communication between e.g. a land-based control station and a submerged object, for instance underwater drone 530 submerged in water 500. The controller station comprises a transceiver 510 configured to emit and receive electromagnetic wave signals 511. Electromagnetic wave signals 511 emitted by transceiver 510 are transmitted through air and above a water surface 501 and may be received by floating translation platform 520. Floating translation platform 520 converts the received electromagnetic wave signal into an ultrasound frequency electric signal, which is transmitted to ultrasound transducer 521 of floating translation platform 520.

Ultrasound transducer 521 of floating translation platform 520 converts the ultrasound frequency electric signal into ultrasonic vibrations and emits ultrasound waves 522, which in turn are received by ultrasound transducer 531 of underwater drone 530. Ultrasound transducer 531 of underwater drone 530 converts the

5 received ultrasound waves into an ultrasound frequency electric signal, which may be processed in underwater drone 530 for instance as control signals. Underwater drone 530 may use ultrasound transducer 531 of underwater drone 530 to generate ultrasound waves for transmission via translation platform 520 to transceiver 510 and the land-based control station, for instance for the

10 transmission of sensor signals. In view of the explanations above, the skilled person readily understands the transmission process from underwater drone 530 to the land-based control station. Communication between the land-based control station and submerged underwater drone 530 is preferably via digital signals.

15 While the subject matter of the disclosure has been explained by means of exemplary embodiments, it is understood that these are in no way intended to limit the scope of the claimed invention. It will be appreciated that the claims cover embodiments not explicitly shown or disclosed herein, and embodiments deviating from those disclosed in the exemplary modes of carrying out the

20 teaching of the present disclosure will still be covered by the claims.

CLAIMS

1. An ultrasound transducer (1) configured for converting AC electric signals
5 (400) into ultrasonic vibrations and for receiving ultrasonic vibrations and
convert the ultrasonic vibrations into an AC electric signal, wherein the
ultrasound transducer comprises a piezoelectric layer (2), the piezoelectric
layer comprising a piezoelectric ply (21) of a piezoelectric material and two
conductive plies (22, 23) of a conductive material, wherein one of the
10 conductive plies (22, 23) is disposed on each of the two opposed faces of
the piezoelectric ply (21),
wherein the piezoelectric layer is embedded in a non-conductive liquid-
proof sheath (3), and wherein each conductive ply (22, 23) disposed on one
side of the piezoelectric ply (21) is electrically connected to a separate
15 terminal (4, 5) which is accessible from outside the sheath.
2. The ultrasound transducer of claim 1, wherein the piezoelectric layer (2) is a
film element.
- 20 3. The ultrasound transducer according to any preceding claim, wherein the
piezoelectric ply (21) is a polyvinylidene fluoride ply.
4. The ultrasound transducer according to any preceding claim, wherein at
least one conductive ply (22, 23) of the piezoelectric layer contains at least
25 one of silver, copper, a zinc-nickel-alloy, tin and/or gold.
5. The ultrasound transducer according to any preceding claim, wherein the
sheath (3) consists of a cured resin, in particular a cured epoxy resin.
- 30 6. The ultrasound transducer according to any preceding claim, wherein the
material of the sheath (3) is selected to have a density which deviates by no

more than 60% from the density of the material of the piezoelectric ply (21) of the piezoelectric layer.

- 5 7. The ultrasound transducer according to any preceding claim, wherein the ultrasound transducer comprises a non-conductive center body (6), the piezoelectric layer (2) being provided on and around the center body and the sheath (3) provided around the piezoelectric layer.
- 10 8. The ultrasound transducer according to claim 7, the ultrasound transducer comprising a rod-shaped transducer, wherein the non-conductive center body (6) has a longitudinal extent and a lateral surface, the lateral surface extending circumferentially around a longitudinal axis of the center body, an inner conductive element (41) extending through the interior of the center body and providing a first terminal (4) accessible at a back side of the center body,
- 15 wherein the piezoelectric layer (2) is disposed circumferentially around the center body (6) whereby the piezoelectric layer provides a radially inner conductive ply (23) and a radially outer conductive ply (22), wherein the radially inner conductive ply (23) is electrically connected to the inner conductive element (41) and the radially outer conductive ply (22) is electrically connected to a second terminal (5) accessible at the back side of the center body,
- 20 and wherein the sheath (3) extends over a front end (11) of the ultrasound transducer and at least a front portion of an outer circumference of the ultrasound transducer.
- 25
- 30 9. The ultrasound transducer according to the preceding claim, wherein the second terminal (5) is provided by a sleeve (51), wherein the sleeve circumferentially encloses a back portion of the piezoelectric layer (2) and establishes electric contact with the radially outer conductive ply (22), and

wherein the sheath (3) extends over at least a front portion of the sleeve (51).

10. The ultrasound transducer according to any of the two preceding claims,
5 wherein
 the piezoelectric layer (2) extends longitudinally beyond the center body (6)
 at least in the front portion of the ultrasound transducer so as to form a
 cylindric space circumferentially enclosed by the extending portion of the
 piezoelectric layer,
10 the inner conductive element (41) longitudinally extends from the center
 body (6) at least in the front portion of the ultrasound transducer and into
 the cylindric space circumferentially enclosed by the extending portion of
 the piezoelectric layer (2),
 wherein the cylindric space circumferentially enclosed by the extending
15 portion of the piezoelectric layer contains (*is filled with*) a conductive
 material (7) to establish an electric connection between the radially inner
 conductive ply (23) and the inner conductive element (41),
 and wherein the sheath (3) extends over the conductive material contained
 in the cylindric space circumferentially enclosed by the extending portion of
20 the piezoelectric layer.
11. The ultrasound transducer according to the preceding claim, wherein a
 longitudinal extent by which the inner conductive element (41) longitudinally
 extends from the center body (6) in the front portion of the ultrasound
25 transducer is smaller than a longitudinal extent by which the piezoelectric
 layer (2) extends longitudinally beyond the center body (6) in the front
 portion of the ultrasound transducer.
12. The ultrasound transducer according to any of claims 1 through 7, wherein
30 the ultrasound transducer (1) is a branched transducer comprising at least
 two branches (1a, 1b), wherein each branch extends from a common

- root (1c) of all branches to a respective front end, the branches including a non-zero angle with each other,
wherein each branch (1a, 1b) includes a piezoelectric layer (2a, 2b) extending in a direction along a longitudinal extent of the respective branch
5 which is defined from the common root towards the respective front end of the branch,
wherein the conductive ply (23a, 23b) on a first side of each piezoelectric layer (2a, 2b) is electrically connected to a first common terminal (4) and the conductive ply (22a, 22b) on a second side of each piezoelectric layer is
10 electrically connected to a second common terminal (5).
13. The ultrasound transducer according to the preceding claim, wherein at least one branch (1a, 1b) of the at least two branches is provided as a rod-shaped transducer according to any of claims 8, 10 or 11, wherein the first
15 terminal of the rod-shaped transducer is connected to the first common terminal (4) of the branched transducer and the second terminal of the rod-shaped transducer is connected to the second common terminal (5) of the branched transducer.
- 20 14. The ultrasound transducer according to any of claims 12 or 13, wherein a free length of each piezoelectric layer arranged in a branch (1a, 1b) is at least essentially equal.
- 25 15. The ultrasound transducer according to any of claims 12 or 13, wherein a free length of the piezoelectric layer arranged in a first one of the branches is different from the free length of the piezoelectric layer arranged in a second one of the branches.
- 30 16. The ultrasound transducer according to any of claims 1 through 7, wherein the ultrasound transducer is a cone transducer, wherein the piezoelectric layer (2) is shaped as a conical shell and the sheath (3) is shaped as a

hollow conical shell embedding the piezoelectric layer, wherein the terminals (4, 5) are arranged at the convergent end of the cone transducer.

- 5 17. The ultrasound transducer according to claim 7, comprising a center body (6) shaped as a round body of revolution, wherein the piezoelectric layer (2) is disposed around the center body and the sheath (3) is arranged around the piezoelectric layer.
- 10 18. The ultrasound transducer according to the preceding claim, wherein the terminal to which a radially outer one (22) of the two conductive plies is electrically connected is a sleeve (51) extending through the sheath (3), and the terminal which is electrically connected to the radially inner one of the two conductive plies is provided within the sleeve.
- 15 19. The ultrasound transducer according to any of the two preceding claims, wherein the terminal (4) which is electrically connected to the radially inner one (23) of the two conductive plies extends through the center body (6) along a diameter of the center body.
- 20 20. An ultrasound communication device (100) configured for emitting and/or receiving ultrasound signals, the ultrasound communication device comprising a receiver electronics (120) and/or an emitter electronics (110) and at least one ultrasound transducer (1) according to any preceding claim, wherein the ultrasound transducer is functionally connected or
- 25 selectively functionally connectable to at least one of the receiver electronics and/or emitter electronics.
- 30 21. The ultrasound communication device according to the preceding claim comprising an AC voltage generator (111) and a switching device (113) configured to selectively open and close a functional connection between an AC voltage generator and at least one of the at least one ultrasound

transducer.

22. A method of generating ultrasound signals for digital ultrasonic signal transmission, the method comprising operating an AC voltage generator
5 (111) to generate a continuous AC output (200) in an ultrasound frequency range, the method further comprising selectively connecting an output of the AC voltage generator to an ultrasound transducer (1) and disconnecting the output of the AC voltage generator from the ultrasound transducer.

10 23. The method according to the preceding claim, comprising compiling a bit sequence to be transmitted into a sequence of time spans in which the AC voltage generator (110) is connected to the ultrasound transducer (1) or disconnected from the ultrasound transducer and selectively connecting and disconnecting the output of the AC voltage generator (111) to and from
15 the ultrasound transducer in a temporal sequence according to the sequence of time spans.

24. The method according to any of the two preceding claims, wherein the method comprises selectively connecting and disconnecting the output of
20 the AC voltage generator to and from an ultrasound transducer according to any of claims 1 through 19.

25. Use of an ultrasound transducer according to any of claims 1 through 19 in a method according to any of claims 22 through 25.

25 26. A method of localizing a device, the method comprising emitting an ultrasound signal from the device, receiving the ultrasound signal by at least two ultrasound receivers and determining a time difference between the reception of the signals by each of the at least two ultrasound receivers.

30

27. The method according to the preceding claim, wherein emitting the ultrasound signal comprises emitting an ultrasound sequence representing a time stamp characterizing an emission time.

5 28. A communication system for transmitting data between a land-based transceiver (510) and a target object (530) submerged in water (500), the communication system comprising the transceiver (510), a translation platform (520), the translation platform being in particular a floating translation platform, and further comprising the target object (530), wherein
10 the transceiver and the translation platform are configured for bidirectional wireless transmission of electromagnetic waves (511) between the transceiver and the translation platform above the water surface (501), wherein the translation platform comprises an ultrasound transducer (521) arranged and configured to be located under the water surface and in the
15 water when the translation platform floats, and converter means for converting electromagnetic wave signals received from the transceiver into ultrasound frequency electric signals (522) and for converting ultrasound frequency electric signals into electromagnetic wave signals for transmission to the transceiver, wherein the converter means and the
20 ultrasound transducer are functionally connected to each other such that ultrasound frequency electric signals are transmittable between the converter means and the ultrasound transducer (521) of the translation platform (520), and wherein further the target object (530) has an ultrasound transducer (531) configured to receive ultrasound signals (522)
25 from surrounding water (500) and convert the received ultrasound signals into ultrasound frequency electric signals and to convert ultrasound frequency electric signals into ultrasound signals and emit the ultrasound signals into surrounding water,
and further means for evaluating ultrasound frequency electric signals
30 generated by the ultrasound transducer of the target object in response to receiving ultrasound signals from surrounding water, and/or for generating

ultrasound frequency electric signals to be converted into ultrasound signals via the ultrasound transducer of the target object, which means is operatively connected to the ultrasound transducer of the target object.

- 5 29. The communication system according to the preceding claim, wherein at least one of the ultrasound transducer (521, 531) of the translation platform and the ultrasound transducer of the target object is an ultrasound transducer of any of claims 1 through 19.
- 10 30. A method for transmitting data between a land-based transceiver (510) and a target object submerged in water, the method comprising at least one of the following sequences, namely
- 15 a first sequence comprising transmitting an electromagnetic wave signal (511) from the land-based transceiver to a floating translation platform (520), converting the electromagnetic wave signal received from the transceiver into an ultrasound frequency electric signal, transmitting the ultrasound frequency electric signal to an ultrasound transducer (521) of the translation platform (520), converting the ultrasound frequency electric signal into an ultrasound signal (522) by the ultrasound transducer of the translation platform and emitting the ultrasound signal into the water (500)
- 20 by the ultrasound transducer of the translation platform, and receiving the ultrasound signal (522) by an ultrasound transducer (531) of the target object (530) and converting the ultrasound signal received by the ultrasound transducer of the target object into an ultrasound frequency electric signal by the ultrasound transducer of the target object, and/or
- 25 a second sequence of generating an ultrasound frequency electric signal by the target object, transmitting the ultrasound frequency electric signal generated by the target object to the ultrasound transducer (531) of the target object (530), converting the ultrasound frequency electric signal generated by the target object into an ultrasound signal (522) by the
- 30 ultrasound transducer of the target object and emitting the ultrasound signal

into the water by the ultrasound transducer of the target object, receiving the ultrasound signal (522) by the ultrasound transducer (521) of the floating translation platform (520), converting the ultrasound signal into an ultrasound frequency electric signal by the ultrasound transducer of the floating translation platform, converting the ultrasound frequency electric signal into a electromagnetic wave signal (511), and transmitting the electromagnetic wave signal to the land-based transceiver.