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(71) Applicant *(for CA only)*: **SCHLUMBERGER CANADA LIMITED** [CA/CA]; 525-3rd Avenue Southwest, Calgary, alberta T2P 0G4 (CA).

(71) Applicant *(for IS only)*: **SCHLUMBERGER TECHNOLOGY CORPORATION** [US/US]; 300 Schlumberger Drive, Sugar Land, Texas 77478 (US).

(71) Applicant *(for FR only)*: **SERVICES PETROLIERS SCHLUMBERGER** [FR/FR]; 42 rue Saint Dominique, F-75007 Paris (FR).

(71) Applicant *(for JP, NL only)*: **SCHLUMBERGER HOLDINGS LIMITED** [GB/GB]; P.O. BOX 71 Craigmuir Chambers, Road Town, Tortola, Virgin Islands, British, GB, Virgin Islands Virgin Islands 1110 (GB).

(71) Applicant *(for AL, AM, AU, AZ, BF, BG, BJ, BY, CF, CG, CI, CM, CO, CZ, DE, DK, GA, GN, GQ, GR, GW, HU, ID, IE, IL, IT, KG, KP, KR, KZ, LT, MD, ML, MR, MX, MY, NE, NO, NZ, OM, PL, RO, RU, SI, SK, SN, TD, TG, TH, TJ, TM, TN, TR, TT, UZ, ZA only)*: **SCHLUMBERGER TECHNOLOGY B.V.** [NL/NL]; Parkstraat 83-89, 2514 JG The Hague, NL-2514 The Hague (NL).

(71) Applicant *(for all designated States except AM, AU, AZ, BF, BG, BJ, BY, CA, CF, CG, CI, CM, CO, CZ, DE, DK, FR, GA, GB, GN, GQ, GR, GW, HU, ID, IE, IL, IT, JP, KG, KP, KR, KZ, LT, MD, ML, MR, MX, MY, NE, NL, NO, NZ, OM, PL, QA, RO, RU, RW, SI, SK, SN, TD, TG, TH, TJ, TM, TN, TR, TT, US, UZ, ZA)*: **PRAD RESEARCH AND DEVELOPMENT LIMITED** [GB/GB]; P.O. Box 71, Craigmuir Chambers, Road Town, Tortola, Virgin Islands, British, GB, 1110, Tortola Virgin Islands 1110 (GB).

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(54) Title: ULTRASONIC TELEMETRY AND POWER TRANSMISSION THROUGH SUBSEA RISER CASING WALL

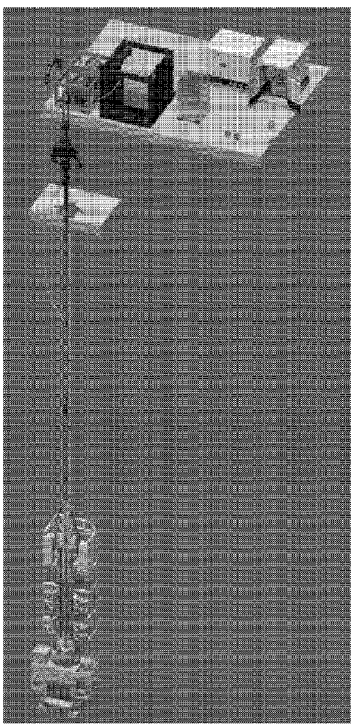

Figure 1

(57) Abstract: A method and apparatus for providing communication and/or power through a medium including a transmitter comprising a surface configured to send a signal at a controlled angle a receiver comprising a surface configured to receive the signal from the transmitter a medium between the transmitter and receiver, wherein the medium comprises a pipe, and wherein the controlled angle can be less than or greater than 90 degrees. In some embodiments, the controlled angle is tailored to allow only the first direct arrival to reach the receiver and to prevent multiple reflections from reaching the receiver. In some embodiments, the transmitter surface steers a beam to deliver the controlled angle. In some embodiments the medium is exposed to a temperature of up to 200°C and/or a pressure of up to 30,000 psi. In some embodiments the receiver surface receives a signal that comprises a frequency of 1-20 MHz or a frequency of about 5 to about 15 MHz.

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(72) **Inventor; and**
(75) **Inventor/Applicant** *(for US only)*: **LIANG, Kenneth** [GB/US]; One Hampshire Street, Cambridge, MA 02139, Canbridge, Massachusetts 02139 (US).

(74) **Agents**: **GREENE, Rachel** et al.; 10001 Richmond Avenue, Houston, Texas 77042 (US).

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ULTRASONIC TELEMETRY AND POWER TRANSMISSION THROUGH SUBSEA RISER CASING WALL

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

This invention relates broadly to wireless communication through a structure such as a metal or plastic wall of a pipe or tube, a containment vessel, a fuselage, well casing, hull, structure or similar embodiment.

BACKGROUND

[0001] In current information gathering and control systems for oil field services marine equipment, an umbilical is deployed inside the marine riser fixed to the inner landing string with a series of clamps positioned every 45 feet to 90 feet apart for the entire length of the subsea landing string. In addition to the umbilical clamps, large centralizers must be installed in the landing string to permit passage of the umbilical across any landing string valves or inner diameter restrictions. Deployment of the umbilical is typically a delicate and cumbersome operation requiring many additional equipment and environmental conditions such as weather often introduce unforeseen complications in its execution.

Ultrasonic inspection is a well-established technique for non-destructive testing and evaluation of various components of oil field infrastructure. Typically, ultrasonic waves are generated to probe the condition and integrity of targeted objects. The health of the probed objects can be assessed based on specific signatures in the returned waves from the objects. In this disclosure, however, ultrasonic waves are used specifically utilized to transmit and receive data at a distance. A range of methods to circumvent certain practical difficulties that can impair the speed and accuracy of data communication is needed.

SUMMARY

Embodiments relate to a method and apparatus for providing communication and/or power through a medium including a transmitter comprising a surface configured to send a signal at a controlled angle, a receiver comprising a surface configured to receive the signal from the transmitter, a medium between the transmitter and receiver, wherein the medium comprises a pipe, and wherein the controlled angle can be less than or greater than 90 degrees. In some embodiments, the pipe is a riser. In some embodiments, the transmitter or receiver surface comprises a fluid. In some embodiments, the controlled angle is tailored to allow only the first direct arrival to reach the receiver and to prevent multiple reflections from reaching the receiver. In some embodiments, the transmitter surface steers a beam to deliver the controlled angle. In some embodiments, the medium is exposed to a temperature of up to 200°C and/or a pressure of up to 30,000 psi. In some embodiments, the receiver surface receives a signal that is more selective than if the transmit beam is not selectively aimed or directed. In some embodiments, the receiver surface receives a signal that comprises a frequency of 1-20 MHz or a frequency of about 5 to about 15 MHz.

FIGURES

Figure 1 is a schematic of a riser system.

Figure 2 is a schematic of multiple acoustic reflections between two parallel surfaces.

Figure 3 is a waveform of multiple acoustic arrivals due to multiple reflections between two parallel surfaces.

Figure 4 is a schematic of a collimated acoustic beam steered at a specific angle from a transmitting transducer array.

Figure 5 is a schematic of a sectional view of receiver and transmitter arrays transmitting through a riser wall.

Figure 6 is a schematic of a sectional view of a system for electronic beam-forming.

DETAILED DESCRIPTION

[0002] Ultrasonic waves can be generated in a propagation medium, such as structural media, and can propagate from one physical location to another. Wireless telemetry through the metal casing wall of a subsea riser using ultrasonic waves and phased array techniques are provided. Historically, simple single-element transducers are used as the transmitter and the receiver. These transducers are positioned or aligned so that they are squarely facing each other, often with the least distance between the two, that is, the distance between the two is often at right angle to the surface of the riser wall or other surface to which the transmitter face is affixed. The purpose of this alignment geometry is to maximize the received signal. However, such a geometric configuration tends to trap multiply reflected ultrasonic energy between the transducers. The resulting received signal at the receiver consists in general of not just the primary arrival, but a series of later, periodically spaced arrivals corresponding to the multiple reflections.

[0003] In the context of data communication, whereas the primary arrival signal is the desired data, the subsequent arrivals signals are redundant and unwanted. The presence of unwanted arrival signals interferes with how rapidly new data can be sent. This phenomenon is well known in Communications Theory as Inter-Symbol-Interference. It is desirable to at least adequately suppress, if not totally eliminate, the later arrival signals in order to increase data rate and to enhance the fidelity of the data. Embodiments described herein achieve these performance improvements by purposefully offsetting the positioning of the transmitter and the receiver, by deviating substantially from the normal practice of "bore-sight" alignment, so that the receiver only sees the primary arrival and the subsequent unwanted arrivals are steered away from it. Embodiments utilize phase-array technique to optimize the transmission and reception of the ultrasonic beam that facilitates the communication link such that the communication process is highly directional and selective.

[0004] In accordance with one embodiment, waves may propagate through primarily metallic structural media such as a subsea riser casing. Numerous alternative examples exist, wherein these examples may be of various shapes, sizes, compositions and may further have a variety of suitable physical characteristics such as a metal or plastic wall of a pipe or tube, a containment vessel, a fuselage, well casing, hull, structure or similar embodiment. Although Figure 1 illustrates a riser-containing system, other equipment may benefit from embodiments described herein. The following discussion of a metallic subsea riser pipe is not intended to be limiting in scope, as embodiments of this may be readily practiced using metallic components, non-metallic (i.e. such as composite and/or polymer) components and any suitable combination thereof. Any structure that can propagate acoustic waves may benefit from embodiments of this.

[0005] ~~In contrast,~~ the transmitter and the receiver may be positioned in a tailored offset manner to prevent multiple reflections (reverberations) from reaching the receiver (the primary should land totally and completely on the receiver, but the subsequent multiple reflections should necessarily and entirely miss the receiver), which would otherwise severely limit the resulting data bandwidth. Figure 6 illustrates how the angle of propagation between the transmitter and riser surfaces may be implemented. Ultrasonic phased array technique is used to beam the transmit signal at an oblique angle to the receiver which is simultaneously set up to listen at the same angle (if the surfaces are not parallel, the technique still works by aiming the transmission and reception to the same direction), thus forming a highly directional communication channel insensitive to reverberations. For a specified angle as shown in Figure 4, the steering of the ultrasonic beam is accomplished by applying progressively increasing time advances as indicated to the array elements across the array from right to left. The exact requirements pertaining to the spatial size of the array and the number of array elements are well known to those conversant in the art of Phased Array Antenna Theory. The overriding objective is to fashion a transmit beam that is highly collimated and aimed towards the receiver, with minimal energy contained in side-lobes and grating-lobes that does not reach the intended receiver target.

[0006] In the simplest case where the transmit and receive surfaces are parallel to each other, the problem of reverberation is solved by transmitting and receiving at off-normal incidence. As shown in Figure 5, the "transmitter" is mounted on the insider surface of the riser wall whereas the "receiver" is mounted on the outside surface. The positions of the transmitter and the receiver are deliberately offset to avoid reverberation problems. One possible solution to the positional offset required is given by: $\Delta x > W/2$ where W is the shared identical width of the transmitter and receiver arrays, or equivalently a steering angle given by: $\theta >> tan^{-1}(W/(2*T))$. Other solutions may exist depending on the degree of suppression of secondary undesirable effects such as shear wave conversion in the propagation media. Solutions for general cases where the transmit and receive surfaces are not parallel to each other, and/or the transmitter and receiver sizes are not the same can readily be calculated based on straightforward geometric considerations.

[0007] Due to the position offset, the transmitter needs to transmit signal at an angle in order to send data to the receiver, utilizing the methodology described in Figure 2, the time advances applied to the individual transmitter array elements increase from left to right in this case. Similarly the receiver needs to receive at an angle, again utilizing the same methodology described in Figure 2, where the time advances applied to the individual receiver elements increase from left to right in the same manner as for the transmitter array. The appropriately time-shifted waveforms from all the receiver elements are then summed to generate the receive signal. Only an incoming ultrasonic beam at an angle consistent with the applied time advances (listening/steering angle) will sum coherently to yield a large signal at the receiver. Incoming beams at angles inconsistent with the steering angle will sum destructively to yield a diminishing output.

[0008] In accordance with one embodiment of the present invention, such transmit/receive operation at a non-normal angle can be provided by a phase array transducer. The individual elements of the array may be time-adjusted (phase-shifted) to steer the acoustic beam at a desired angle to make the transmitter signal highly directional. Multiple reflections between the inner and outer surfaces of the riser do occur but they are directed away from the transducers themselves, thus circumventing the reverberation problem. An embodiment is illustrated by the Figure 3 schematic.

[0009] In the general case where the transmit and receive surfaces are not necessarily parallel to each other, the transmitting transducer array may be "tuned" to aim the transmit beam so that the beam ultimately arrives intersecting the receiving transducer array. The actual beam pattern is not necessarily a straight line, subjected in general to Snell's Law refraction at intervening interfaces and ray bending due to velocity dispersion in the propagation media. The receiving transducer array is similarly "tuned" to "listen" specifically in the direction of the incoming ultrasonic beam. This results in a highly angularly selective communication channel between the transmit/receive pair. This angular selectivity helps to reject spurious signals and modes propagating at angles different from the line-of-sight between the transmitting and receiving transducers. Phase array techniques provide a high degree of angular selectivity to the communication channel, with good immunity to multiple reflections and spurious wave modes.

[0010] Also, because acoustic transducers are bi-directional devices, each can act as both a transmitter and a receiver in accordance with the present invention. The roles of transmit and receive can be reversed to allow bi-directional communications. In the present invention, each transducer array may have built-in (on-board) smarts such that the "broadcast" and the "listen" angle can be fine-tuned in real-time to accommodate changes in acoustic velocity in steel due to temperature effects for example. In the simplex mode of operation, the present invention can also "handshake" with its "partner" transducer array to assign "talker" versus "listener" roles to start communication, and to reverse roles when the information flow goes the opposite way. The system can also be set up to carry out full duplex communication: using different operating frequencies for the two communication directions.

[0011] In one embodiment, the ultrasonic transducer arrays used for the transmitter and the receiver may be fabricated using piezocomposite technology. The resulting devices are relatively low-cost and can accommodate the surface curvature of propagation medium. For example, these devices can be readily affixed to the curved surface of a cylindrical casing. The transducer acoustic impedance can be matched to that of the casing metal to obtain large frequency bandwidth operation. Irregular surfaces may also benefit from using devices containing piezocomposite materials. Conforming to unusual surface topology may be a benefit of using piezocomposite materials.

[0012] Often, the transmitters may be positioned along the surface of a riser wall. In some embodiments, the transmitter surface may be positioned away from the surface of a wall such that a fluid such as water, brine, completion fluids (drilling mud, fluids tailored for drilling or completions, etc.) or other material such as cement may exist between the transmitter surface and the riser wall or other solid surface. In an embodiment of an operational configuration, the ultrasonic devices do not have to be in direct contact with the riser wall (internal and/or external). The ultrasonic devices can be stood off from the riser wall surfaces. Such a configuration has several practical advantages: (1) ease of setup, the ultrasonic devices just need to be moved into position, there is no post-positioning complication of attaching the devices to the riser surfaces, (2) the ultrasonic devices do not have to be shaped to conform to the curvature of the riser surfaces. The presence of a liquid medium is sufficient to allow the propagation and transmission of ultrasonic waves from one device, through the inner liquid medium, the riser wall thickness, then the outer liquid medium, to the other device, and likewise in the opposite direction. The physics remains substantially the same as in the case where the ultrasonic devices are in direct contact with the riser wall.

[0013] The operating frequency of the transducers should be high enough so that the reverberation signals would be attenuated by losses in the propagation medium and they would not return to interfere with the initial single-path signal. This frequency is in the 10 MHz or higher range.

[0014] Additionally, high data-rate is provided by the high center frequency of operation and the bandwidth of ultrasonic transducers, wherein these transducers are well matched in acoustic impedance to the propagation medium. Assuming a transducer bandwidth of 50%, which is reasonable for a piezoceramic transducer coupled directly to steel, one can have substantial bandwidth (MHz) available for data communication.

[0015] In accordance an additional embodiment, one may convey power from one surface of the riser to the other and a higher data rate as compared to traditional techniques may be provided. The capability to convey power and transfer digital data wirelessly using an ultrasonic link would provide considerable operational and cost benefits for the subsea landing string equipment. Because both power and communications are provided by an umbilical line which is strapped to the drill pipe located within the riser pipe, an ultrasonic link between an ultrasonic transducer device mounted on the external surface of the riser and another transducer device mounted on the tool mandrel would replace this umbilical line inside the riser.

[0016] Embodiments will eliminate the need for power and communications to be provided from surface via an umbilical for operation/monitoring the subsea landing string. By eliminating the umbilical in-riser, we remove the need for burdensome equipment and the associated logistical challenges. That is, high-speed communication from the inside surface of a subsea riser casing, through the wall thickness, to the outside surface of the riser, without the benefit of a connecting wire which necessarily has to be installed in a drill-hole in the casing is provided. The immediate benefits are: topside footprint reduction, optimum operational efficiency, and reduced rig time.

WHAT IS CLAIMED IS:

1. An apparatus for providing communication or power or both through a medium, comprising:

a transmitter comprising a surface configured to send a signal at a controlled angle;

a receiver comprising a surface configured to receive the signal from the transmitter; and

a medium between the transmitter and receiver;

wherein the medium comprises a pipe, and

wherein the controlled angle is less than or greater than 90 degrees.

2. The apparatus of claim 1, wherein the pipe is a riser.

3. The apparatus of claim 2, wherein the transmitter surface comprises a fluid.

4. The apparatus of claim 2, wherein the receiver surface comprises a fluid.

5. The apparatus of claim 1, wherein the controlled angle is tailored to allow only the first direct arrival to reach the receiver and to prevent multiple reflections from reaching the receiver.

6. The apparatus of claim 1, wherein the transmitter surface steers a beam to deliver the controlled angle.

7. The apparatus of claim 1, wherein the medium is exposed to a temperature of up to 200°C.

8. The apparatus of claim 1, wherein the medium is exposed to a pressure of up to 30,000 psi.

9. The apparatus of claim 1, wherein the receiver surface receives a signal that is more selective than if the transmit beam is not selectively aimed.

10. The apparatus of claim 9, wherein the receiver surface receives a signal that is more selective than if the transit beam is not selectively directed.

11. The apparatus of claim 1, wherein the receiver surface receives a signal that comprises a frequency of 1-20 MHz.

12. The apparatus of claim 1, wherein the signal comprises a frequency of about 5 to about 15 MHz.

13. A method for providing communication or power or both through a medium, comprising:

sending a signal from a transmitter at a controlled angle;

receiving the signal with a receiver comprising a surface configured to receive the signal from the transmitter; and

tailoring the controlled angle to allow only the first direct arrival to reach the receiver and to prevent multiple reflections from reaching the receiver,

wherein the sending comprises sending the signal through a medium between the transmitter and receiver,

wherein the medium comprises a pipe, and

wherein the controlled angle is less than or greater than 90 degrees.

14. The method of claim 13, wherein the pipe is a riser.

15. The method of claim 14, wherein the transmitter surface comprises a fluid.

16. The method of claim 14, wherein the receiver surface comprises a fluid.

17. The method of claim 13, wherein the transmitter surface steers a beam to deliver the controlled angle.

18. The method of claim 13, wherein the medium is exposed to a temperature of up to 200°C.

19. The method of claim 13, wherein the medium is exposed to a pressure of up to 30,000 psi.

20. The method of claim 13, wherein the receiver surface receives a signal that comprises a frequency of 1-20 MHz.

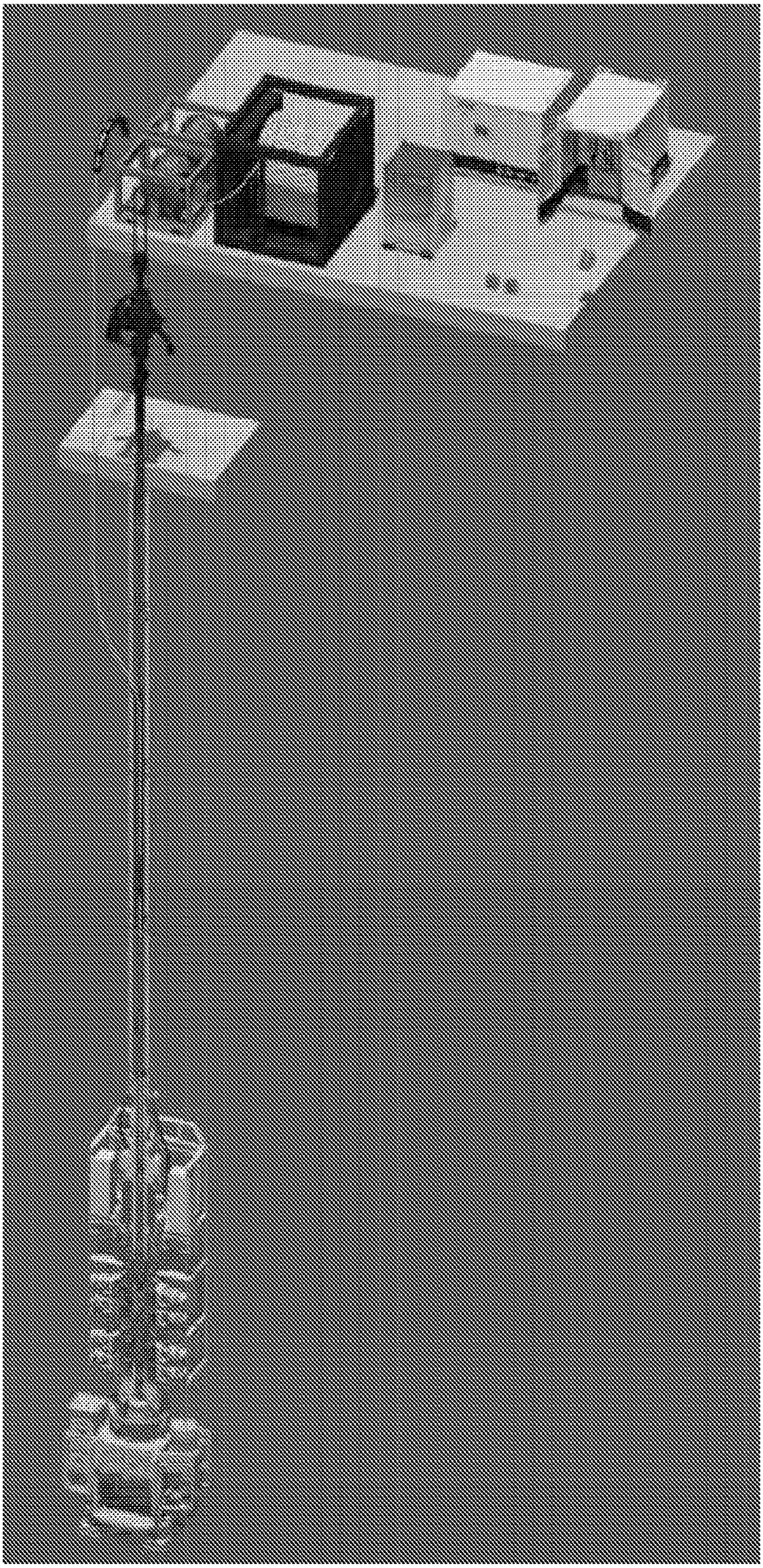


Figure 1

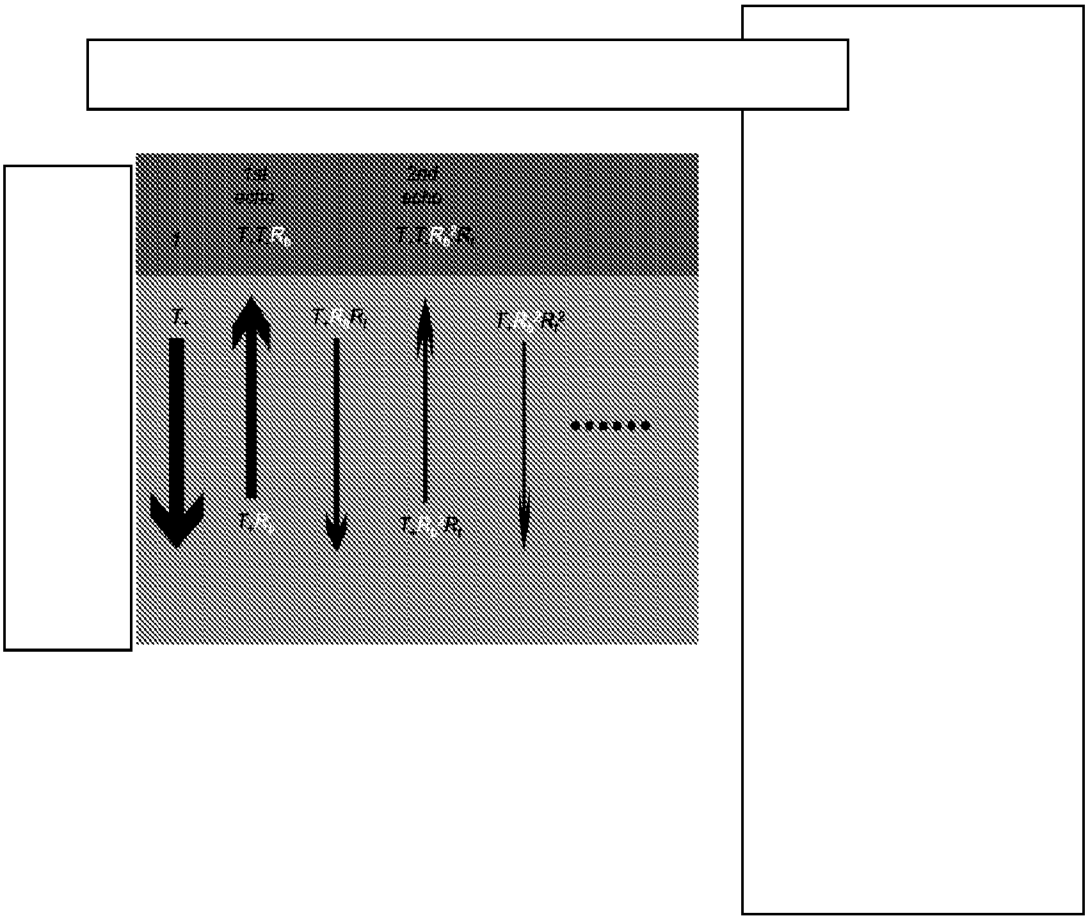


Figure 2

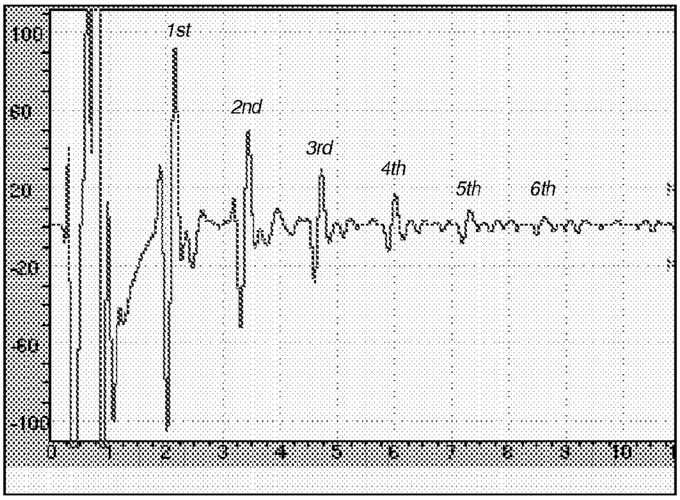


Figure 3

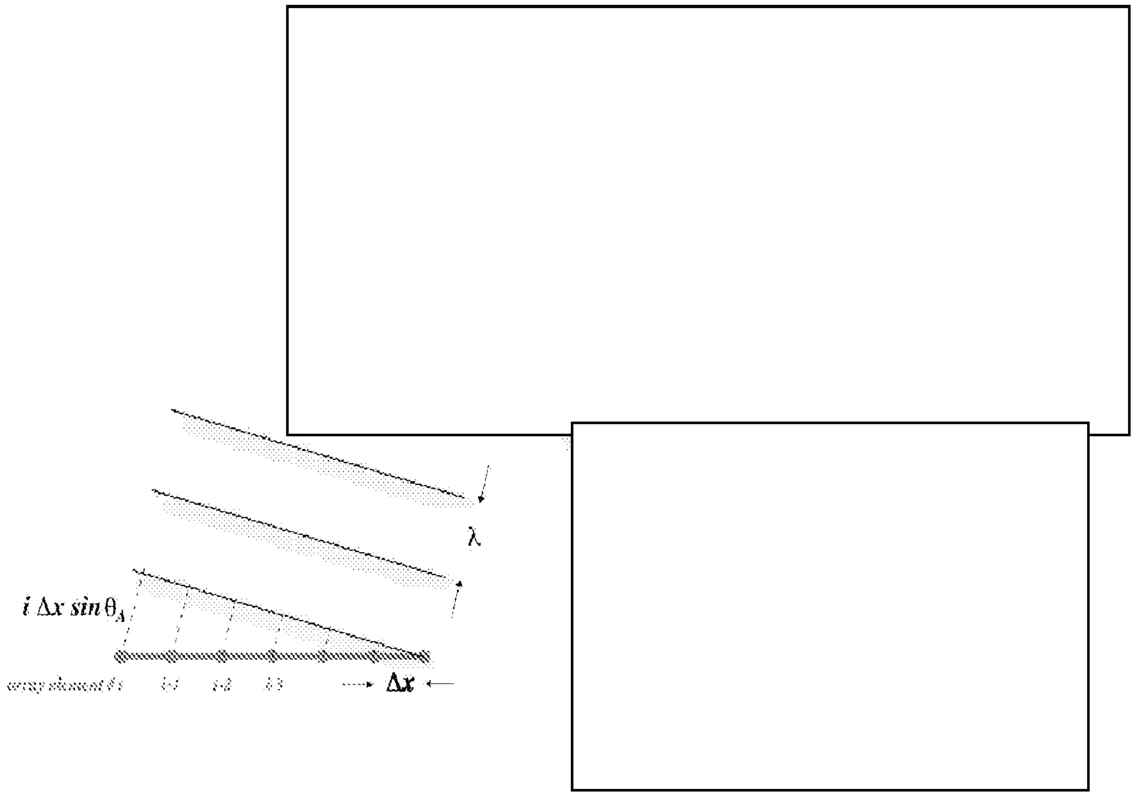


Figure 4

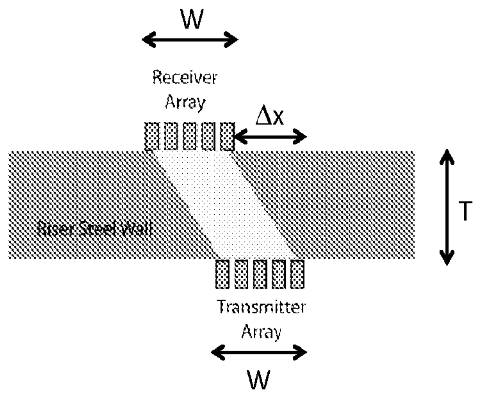
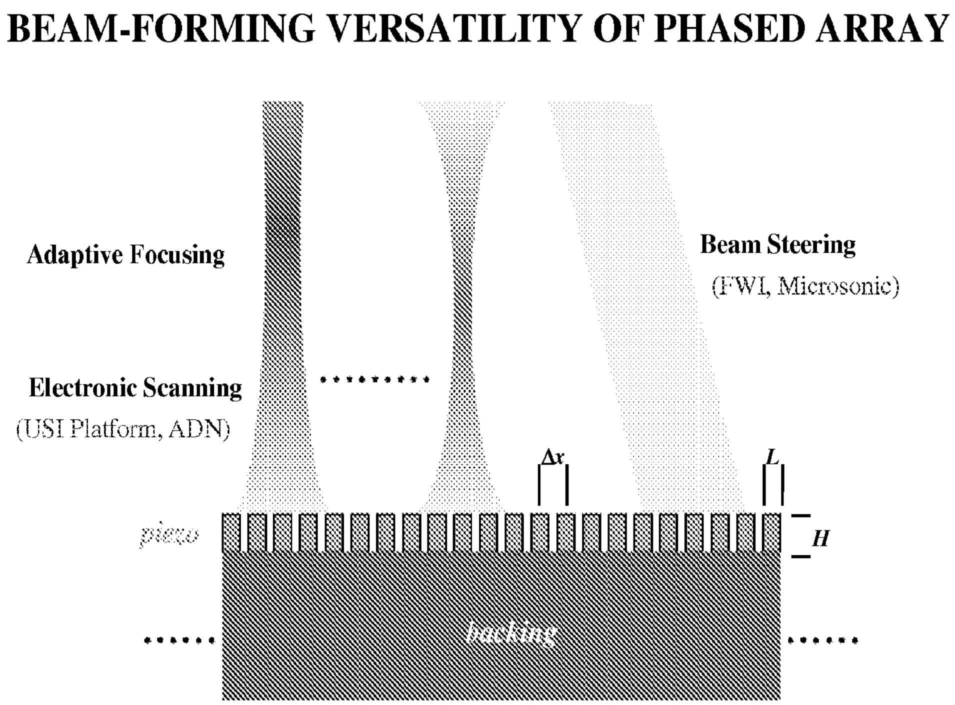


Figure 5


BEAM-FORMING VERSATILITY OF PHASED ARRAY
Adaptive Focusing
Electronic Scanning
(USI Platform, ADN)
Beam Steering
(FWI, Microsonic)
Δx
L
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piezo
backing

Figure 6