United States Patent [19]

Hunter et al.

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[45] **Jan. 29, 1974**

[54] **DIVER COMMUNICATION SYSTEM**

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[73] Assignee: **The United States of America as represented by the Secretary of the** Navy, Washington, D.C.

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[52] **U.S. Cl.** .... **340/5 T,** 179/1 UW, 325/28, 340/6 R

[51] **Int. Cl.** **G01s 3/80**

[58] **Field of Search** .... 340/3 R, 5 T, 6 R, 16 R; 325/16, 28; 179/1 UW

[56] **References Cited**

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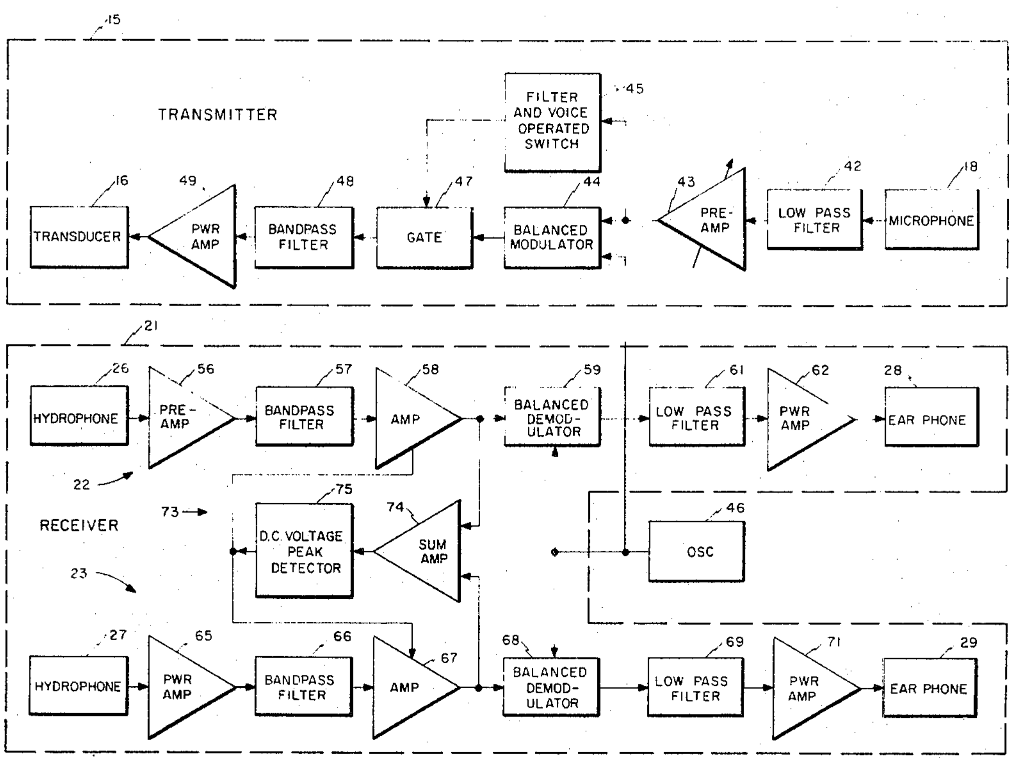
[57] **ABSTRACT**

An underwater diver communication system is disclosed as including a voice actuated transmitter for broadcasting speech signals throughout an ambient subaqueous environmental medium combined with a two-channel, binaural, speech signal receiver by means of a common local oscillator connected therebetween which, in turn, effects relative phase enhancement in the channels thereof. In addition, the two channels of said binaural receiver incorporate substantially identical adjustable gain amplifiers, respectively, the gains of which are identically regulated by a single control signal from a unique feedback type of signal amplitude enhancement circuit that is effective to further distinguish the amplitudes of the speech signals being processed within one receiver channel relative to those being processed within the other receiver channel, to thereby facilitate the localization of the speech signals received by said diver from said ambient subaqueous environmental medium.

16 Claims, 4 Drawing Figures



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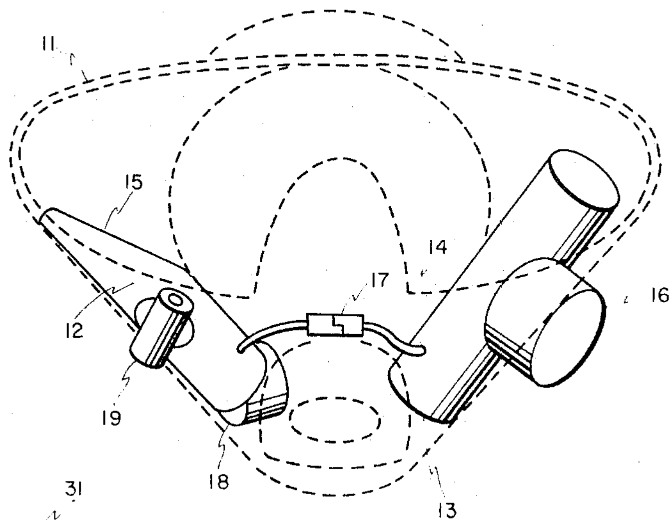
SHEET 1 OF 2

FIG. 1



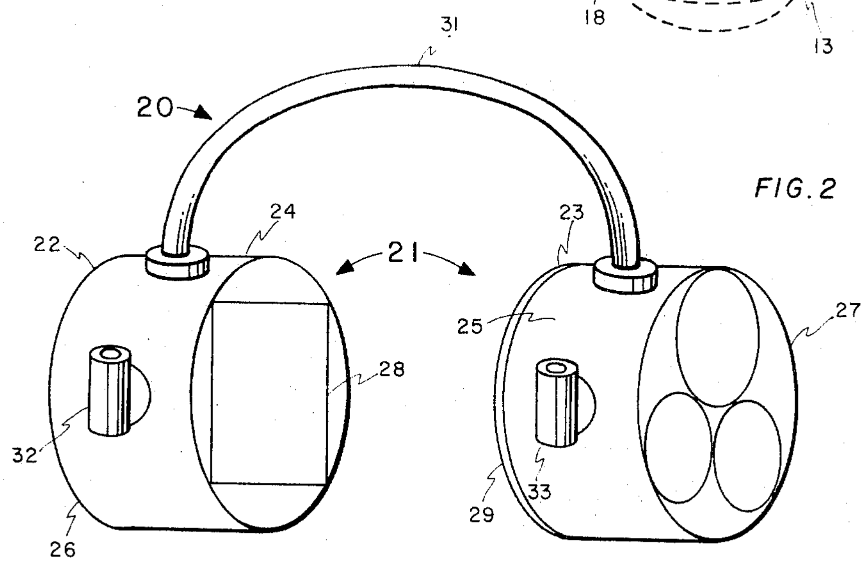


FIG. 2

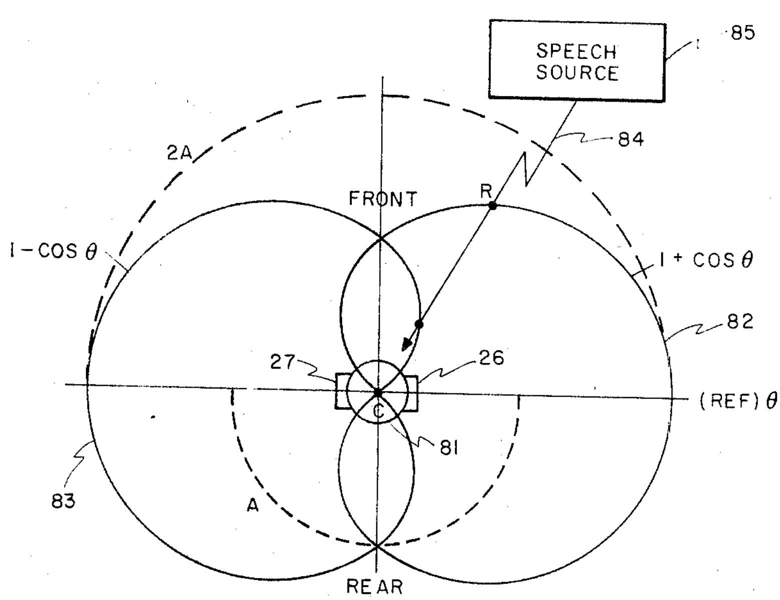
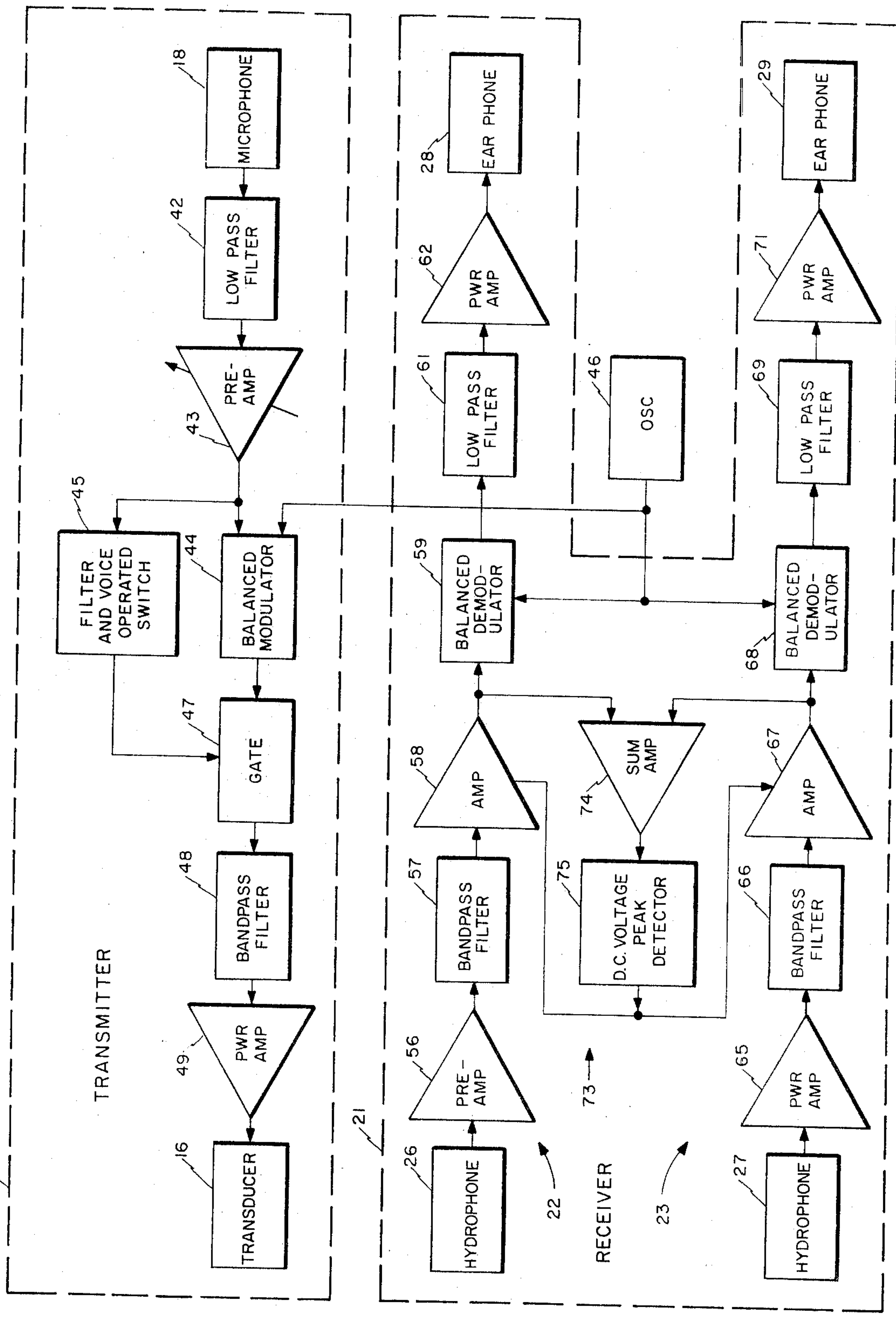


FIG. 4


TRANSMITTER
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LOW PASS FILTER
PRE-AMP
FILTER AND VOICE OPERATED SWITCH
BALANCED MODULATOR
GATE
BANDPASS FILTER
PWR AMP
TRANSDUCER
EAR PHONE
PWR AMP
LOW PASS FILTER
BALANCED DEMOD-ULATOR
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BANDPASS FILTER
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HYDROPHONE
OSC
SUM AMP
D.C. VOLTAGE PEAK DETECTOR
RECEIVER
EAR PHONE
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FIG. 3

DIVER COMMUNICATION SYSTEM

STATEMENT OF GOVERNMENT INTEREST

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

FIELD OF THE INVENTION

The present invention relates, in general, to communication systems, and, in particular, it is a sonar system for communicating and navigating within a subaqueous medium. In even greater particularity, the invention is a binaural sonar system combined with a face mask in such unique manner that it facilitates the communication, target search, navigation, and homing operations of swimmers and divers operating within waters which would otherwise constitute adverse environmental conditions.

DESCRIPTION OF THE PRIOR ART

Heretofore, numerous sonar and underwater communication systems have been employed by swimmers, divers, and various and sundry manned and unmanned underwater vehicles. For some purposes, they have proven to be quite satisfactory; however, for swimmer-diver communication, homing, and navigation purposes, they usually leave a great deal to be desired.

SUMMARY OF THE INVENTION

The instant invention overcomes many of the disadvantages of the prior art, in that it enables underwater swimmers to communicate intelligibly in a manner that is somewhat similar, as far as psychological and physiological experiences are concerned, to normal talking and hearing in an atmospheric environment by a human being.

It is, therefore, an object of this invention to provide an improved underwater sonic communication system.

Another object of this invention is to provide an improved echo-search-ranging system.

Still another object of this invention is to provide an improved sonar system in which the output thereof is produced as enhanced binaural signals which provide bearing information of received acoustical energy when listened to by human ears.

A further object of this invention is to provide an acoustical communication system having an improved signal-to-noise ratio.

Another object of this invention is to provide an improved underwater communication and face mask combination which will essentially free a swimmer-diver from the burden of large, heavy, cumbersome, communication apparatus, thereby allowing said swimmer-diver considerably greater freedom of movement and complete freedom of hand use within sea water or the like.

A further object of this invention is to provide an improved method and means for localizing the source of various and sundry underwater sounds.

Still another object of this invention is to provide a method and means for improving the binaural capabilities as a result of incorporating both amplitude and phase discrimination techniques in an underwater communication system.

Another object of this invention is to provide restoration of binaural hearing and acoustical signal localization abilities to an individual operating in an otherwise acoustical signal diffusing environmental medium, such as pressurized helium, sea water, or the like.

Another object of this invention is to provide an improved voice activated underwater communication system.

Another object of this invention is to provide an underwater communication system that is easily and economically manufactured, operated, and maintained.

Other objects and many of the attendant advantages will be readily appreciated as the subject invention becomes better understood by reference to the following detailed description, when considered in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a schematic elevational view of the transmitter portion of the subject invention mounted in and in cooperative association with a swimmer-diver face mask;

FIG. 2 is a schematic perspective view of headset and earphone arrangements employed which constitutes the receiver portion in the subject invention;

FIG. 3 is a block diagram of the swimmer-diver underwater communication system of this invention; and

FIG. 4 is a graphical representation of the acoustical response patterns of the receiving hydrophones of the instant invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to FIG. 1, there is shown a face mask 11 of the type which is typically worn by swimmers and divers. Obviously, many different face masks, diver's helmets, etc., are commercially available, and anyone thereof may be employed as a component of this invention, as long as it allows freedom of lip and jaw movements, has sufficient room in it to allow emplacement of the transmitting and/or receiving apparatus therein, and meets the physiological requirements of the swimmer-diver.

Preferably, the acoustic frequency response of the speaking cavity of face mask 11 should be determined under all environmental conditions, so that it may be frequency compensated — both electronically and mechanically — so that the overall system will have as flat a frequency response as possible and, thus, enhance communication intelligibility. As a general rule, however, it has been found that most conventional face masks have a 6 db per octave signal attenuation or downslope, with a resonant peak somewhere between 500 and 1,000 Hz. Therefore, it is necessary to compensate for such downslope, if optimum operation is to be obtained. Such compensation is accomplished within the transmitter electronics portion 12 of the invention, as will be discussed more fully subsequently.

So as to make the subject system self-contained, a rechargeable battery pack 13 is deployed within mask 11 and is connected to encased electronics portion 12 by means of intercabling 14. Intercabling 14, in addition to supplying power to the electronic circuitry, also transmits electrical signals from a transmitter 15 — a part of said electronics circuitry 14 — to a broadcasting electroacoustical transducer **16** located on the other side of the face mask, in this particular instance. Disposed in cable **14** is a connector **17**, which enables transmitter **15** to automatically be turned off merely by breaking the electrical circuit thereat. It is preferably an Electro Oceanics 59F2F–1 connector that can be connected and disconnected underwater.

All of the foregoing elements **12** through **17** are housed in such manner in any suitable containers as would be necessary to provide water and pressure proofness. Details of such housing or containers are not disclosed specifically herewith because it would be well within the purview of one skilled in the art having the benefit of the teachings presented herein to make and use whatever ones thereof would be required for any given operational circumstances. Of course, they may be epoxy coated to insure waterproofness, if desired.

A microphone **18** is also included within face mask **11.** It, too, must be both pressure and waterproof. In this particular instance, it has been found, for example, that a three-quarter inch diameter ceramic bimorph connected in series, potted in any suitable potting compound, such as, for example, a self-leveling silicone rubber compound, and encased in a neoprene cup is quite satisfactory as microphone **18,** inasmuch as such element has approximately a 6 db per octave upslope and will, thus, help compensate for the aforementioned downslope of mask **11.** Also, it is relatively distortion free from 300 Hz to 6,000 Hz, thereby having a bandwidth that is the minimum allowable to capture optimum speech intelligibility, especially when the speech spectrum is upshifted in frequency, due to a high pressure water or helium gas ambient environment. Of course, any other suitable microphone may be employed as microphone **18,** if so desired by the artisan or the swimmer-diver.

An external connector **19** provides a preamplified speech output for use by voice recorders, wire communication systems, and other external and/or remote systems, requiring voice input (not shown and not a part of this invention).

FIG. 2 shows a headset **20** which preferably includes the receiver circuitry **21** of the subject system, the electronics of which will be discussed more fully below. Disclosed is a pair of receiver channels which are signal processors for the ears of the swimmer-diver, respectively. Hence, headset **20** contains a right ear receiver channel **22** and a left ear receiver channel **23,** each of which includes substantially similar receiver channel components that are interconnected by a unique binaural amplitude enhancement circuit that may be physically disposed in the housing of either one thereof (or optionally within the electronics portion of the aforesaid face mask **11,** if so desired). Said receiver channels will be discussed in greater detail in conjunction with FIG. 3.

Receiver channels **22** and **23** are, in this particular embodiment, respectively encased in any suitable pressure proof, waterproof housings **24** and **25.** They include receiving hydrophones **26** and **27,** respectively, which are mounted on the outer sides thereof for diametrically opposed response to incoming acoustical energy which, thus, effectively impacts thereon from opposite directions, just as the ears do for any given human being. As will be explained in better detail subsequently, such opposite directional response characteristics play an important part in enabling the swimmer-diver to localize and determine the direction from which a sound is coming within water, sea water, or the like — something which, in actual practice is exceedingly difficult to do.

The inside surfaces of receiver channels **22** and **23** constitute earphones **28** and **29,** respectively, and, of course, they are adapted for fitting firmly against the ears of the swimmer-diver.

A headpiece **31** interconnects both receiver channels both electrically and physically and enables the receiver to be properly — and conventionally — mounted on the swimmer's head. As will be discussed more fully in conjunction with FIG. 3, a unique binaural enhancement circuit (not shown in FIG. 2) is appropriately connected between the receiver channels; consequently, it may be physically located anywhere in headset **20** that would be structurally and electrically convenient.

A pair of external connectors **32** and **33** are optionally mounted on the receiver channels, in order to connect external and perhaps remote recording equipment thereto.

Referring now to FIG. 3, wherein the elements disclosed are indicated by the same reference numerals as employed in the disclosure thereon in FIGS. 1 and 2, insofar as it is possible and practical. Disclosed is the aforesaid single sideband transmitter **15** which, of course, may be incorporated as a portion of electronics **12** in swimmer-diver face mask **11.** Included therein and also preferably mounted in face mask **11** is the aforementioned microphone **18,** the output of which is connected to the input of a 6,000 Hz low pass filter **42,** employed for the purpose of eliminating external noise above the desired human speech band of, say, from 300 to 6,000 Hz and to provide approximately a 6 db per octave signal upslope or enhancement, to fully compensate for the 6 db per octave signal attenuation or downslope inherently caused by the face mask.

The output of low pass filter **42** is connected to the input of an adjustable gain preamplifier **43,** which is preferably designed in such manner that a flat frequency response occurs within the transmitter portion of the invention. The output of preamplifier **43** is connected to one of the inputs of a balanced modulator **44** and the input of an input signal actuated switch which, in this particular case, effectively operates as a selective activator filter and voice operated switch (VOX) **45.**

As would be obvious to one skilled in the art, voice operated switch **45,** as it is presently connected to its associated components, is, in fact, actuated by the electrical signal equivalent of the human voice after it has been properly filtered and amplified. Such arrangement has been employed for two reasons: (1) spurious ambient signals will not pass through low pass filter **42,** which prevents inadvertent transmission by the transmitter from being effected by signals other than the diver's voice; and (2) the transmitter will not be actuated by changes in ambient pressure, in the event the diver changes water depths. Of course, the voice operated switch should be conventionally designed to be inoperative below a given threshold or voice volume and selective to only diver voice signatures, thereby preventing the broadcasting of such undesirable and noise producing signals as diver breathing and movement signals and water bubble sounds. Any commercially available or conventional voice operated switch means having the above mentioned operational characteristics may be employed as voice operated switch **45** in the subject invention.

The other input of balanced modulator **44** is connected to the output of an 8.087 KHz local oscillator **46**, which may or may not be considered as being part of transmitter **15**. Since local oscillator **46** is used as the heterodyning signal generator for both the transmitter and the receiver in this preferred embodiment, it is considered as being separate from each thereof. However, it should be understood that both the transmitter and the receiver may have their own individual local oscillator, if so desired, as long as the signal frequencies thereof are identical.

On the other hand, local oscillator **46** alone is incorporated in this disclosed preferred embodiment of the invention because it has been determined that so doing enhances the phase aspect of the binaural characteristics produced thereby as a result of using a common carrier frequency in both demodulators which cause the demodulated output signals therefrom to retain any phase differences between the receiver channels.

The output of balanced modulator **44** is connected to the data signal input of a gate **47**, the control input of which is connected to the output of voice operated switch **45**. In this particular instance, gate **47** is a voltage controlled gate which is normally closed but is opened whenever a predetermined voltage signal is supplied to the control input thereof as a result of switch **45** being effectively opened by the speech of the swimmer-diver. Of course, switch **45** is actually opened by the filtered and amplified electrical signal that is proportional to the acoustical speech signal supplied to microphone **18** minus any spurious signals, such as, for instance, breathing sounds, and the like. But when it is opened thereby, the actuating signal also effectively passes through switch **45** and then becomes the gate control signal which, in turn, effects the opening thereof, so that the output signal from balanced modulator **44** can pass therethrough. Obviously, such switch and gate operations occur simultaneously and instantaneously, for all practical purposes.

The output of gate **47** is connected to the input of a bandpass filter **48**, in order to eliminate the lower sideband output signals effectively supplied thereto from modulator **44**, and the output of filter **48**, in turn, connected with a power amplifier **49** to the input of electroacoustical transducer **16** adapted for broadcasting the aforesaid modified speech signals throughout the subaqueous medium, such as water, sea water, or the like, within which the swimmer-diver is submerged or throughout any other predetermined suitable environmental medium. Of course, said modified speech signals are, in fact, the communication signals which allows one diver to talk to another diver having similar transmitting and receiving apparatus while both are under water.

A receiver system **21** is used to receive the talk signals of substantially comparable frequencies and qualities from other divers, as suggested above. It contains the aforementioned pair of signal processing channels **22** and **23** which are adopted for supplying said speech signals to the ears of a diver, respectively. However, as will be explained in greater detail subsequently, they do it in such manner as to uniquely improve the binaural characteristics thereof and, thus, enable a diver to localize and determine the direction from which talk signals are coming, even though the entire communications system constituting this invention may have been miniaturized or compacted by the employment of solid state or other suitable manufacturing techniques to the extent that it is combined with the diver's face mask and be in proximity with his head and ears.

Receiver channel **22** includes the aforesaid electroacoustical hydrophone **26**, the output of which is connected through a preamplifier **56** to the input of bandpass filter **57** of the type that is similar to the aforesaid bandpass filter **48** in transmitter **15**. The output of filter **57** is connected to the data signal input of an adjustable gain amplifier **58**, the gain of which is adjusted in proportion with whatever voltage signal is supplied to the gain control input thereof.

The output of amplifier **58** is connected to one of the inputs of a demodulator **59**, with the other input thereof being connected to the output of the aforementioned local oscillator **46**. Again, as previously suggested, if so desired, receiver **21** may be self-contained and have its own local oscillator, as long as the signal frequency thereof is identical to that supplied to balanced modulator **44** in transmitter **15**. Of course, as will be explained more fully below, demodulator **59** heterodynes the incoming modified speech signal down to its original frequency range of between 300 and 6,000 Hz, so that it will be intelligible when received by the diver's ear. For effecting such processing, a low pass filter **61** is connected to the output of demodulator **59**, in order that said diver only receives the lower side band output — that is, said 300 to 6,000 Hz talk signals — therefrom. The output of low pass filter **61** is connected through a power amplifier **62** to the input of the aforesaid earphone **28**, which, as previously indicated, is physically disposed in contiguous relationship with one of the divers ears, so that the diver may hear the talk signals emanating therefrom while he is working in an underwater environment.

In every respect, receiver channel **23** should be as identical as possible to receiver channel **22**; therefore, the components thereof are substantially identical to the above described components of said channel **22**, respectively. As a result of such arrangement, the aforesaid hydrophone **27**, a preamplifier **65**, a bandpass filter **66**, a variable gain amplifier **67**, a balanced demodulator **68**, a low pass filter **59**, a power amplifier **71**, and the aforesaid earphone **29** are connected in series in the same manner as the components comparable thereto were series connected in channel **22**.

The aforementioned binaural characteristics are considerably improved in the subject invention by a simple but unique binaural enhancement circuit **73** which is connected to receiver channels **22** and **23**. Said binaural enhancement circuit **73** includes a summing amplifier **74** having a pair of inputs which are connected to the outputs of the aforesaid variable gain amplifiers **58** and **67** of receiver channels **22** and **23**, respectively. The output of summing amplifier **74** is connected to the input of a direct current (DC) voltage peak detector **75**, the output of which is connected to the gain control inputs of said variable gain amplifiers **58** and **67**.

FIG. 4 depicts schematically the top of the head of a diver **81** (otherwise not shown), with right and left hydrophones **26** and **27** physically located in association therewith in such manner that the respective response patterns are oppositely directed cardioid patterns **82** and **83**, mathematically defined by the expressions $1 + \cos \theta$ and $1 - \cos \theta$, respectively. Also, in this particular embodiment, said hydrophones are preferably designed so that the outer cardioid radius (2A), as measured from the center of diver head **81**, is twice the distance (A) of their radius of intersection, likewise measured from the center of diver head **81.** As will be explained more fully below, such structural arrangement and dispositions of receiving hydrophones further enhance the discernment of the diver, as far as the direction of incoming sound is concerned. Thus, in conjunction with signal enhancement circuit **73** discussed above, the listening characteristics of a swimmer-diver working underwater are more nearly the same as they would be if he were working in the atmosphere with only his ears as the sound receptors.

At this time, it would perhaps be noteworthy that the subject invention is primarily intended to facilitate the operation of a diver within water and within considerable depths thereof; however, it should be understood that it may also be used to an advantage in other environmental mediums — such as, for instance, pressurized helium — if so desired and designed therefor by one skilled in the art having the benefit of the teachings presented herewith.

It should also be understood that all of the various and sundry components of this invention are well known and conventional per se, and some thereof may have been patented in their own right at some time in the past. Therefore, it is their interconnection and interactions that effect the new combinations of elements constituting this invention and cause the stated improved results and objectives to be achieved thereby.

MODE OF OPERATION

The operation of the invention will now be discussed briefly in conjunction with all of the figures of the drawing.

A swimmer-diver wears the face mask and headset disclosed in FIGS. **1** and **2.** Hence, he can speak into the transmitter and hear from the receiver portions thereof without carrying additional apparatus or without requiring the use of his hands. This, of course, is very advantageous, because the diver is not handicapped by the unwieldy burden of an undue load and, furthermore, has his hands free to do whatever work he desires to do. Moreover, even though he is working in an underwater environment that is, at least, unnatural and perhaps hostile to him, he is considerably less disoriented and can, thus, navigate more easily therein than he otherwise could without the benefit of the subject invention. In addition, this arrangement allows complete and natural feedback of the diver's voice to occur and, hence, facilitates improved speech formation which, in turn, further enhances intelligibility.

Perhaps, at the outset, the significance of the unique transmitter and receiver systems **15** and **21** depicted in FIG. **3** should again be mentioned. As may readily be seen from inspection thereof, as a result of both thereof using the same local oscillator **46** — and, hence, being heterodyned with the same frequency signal having the same polarity at any given instant — transmitter **15** and receiver **21** are effectively interconnected and are, hence, perfectly synchronized, and may thus be considered to be a unique transmit-receive system in the disclosed preferred embodiment. However, if they are identical, two independent local oscillators may be employed, if so desired. In such case, both transmitter **15** and receiver **21** could be considered as being self-contained units.

As seen from FIG. **1,** microphone **18** is located in proximity with the diver's mouth, so that he may speak into it without undue effort. Microphone **18** conventionally converts the acoustical energy of the diver's voice into a proportional electrical speech signal that is processed by 6,000 Hz low pass filter **42** to remove all external noise above the speech band, as well as other spurious and feedback signals. Then, the output is amplified by preamplifier **43** to provide a 6 db per octave upslope for face mask downslope compensation purposes, thereby effecting a substantially flat frequency response which enhances signal intelligibility. The filtered and preamplified speech signal falls within approximately the 300 to 6,000 Hz frequency band and is then heterodyned with an 8.087 KHz signal from oscillator **46.** At the same time, a predetermined frequency signature portion thereof passes through selective filter and VOX **45** and opens gate **47** to let the heterodyned output signal from balanced modulator **44** pass therethrough. The output from modulator **44** consists of the upper and lower side bands having frequencies of 8–14 KHz and 2–8 KHz, respectively. In order to provide improved intelligibility, a 6,000 Hz speech bandwidth is maintained throughout the subject system; therefore, only the 8–14 KHz upper side band is passed through band pass filter **48,** after which it is amplified by power amplifier **49** and braodcast or projected into the ambient water by transmitting transducer **16.**

Obviously, speech transmission is primarily intended for receipt by another diver, but because receiver **21** remains "on" constantly — so as to require no external cabling or controls — the speaking diver receives his own speech signals, which he can hear as a result of the processing thereof by his own receiver, namely, in this particular instance, receiver **21.** Of course, it should also be obvious that all of the communicating divers must wear one of the subject communication systems, if actual communication of the speaking-hearing type is to occur.

Receiver **21,** as illustrated in FIG. **3,** receives the incoming speech signals by means of hydrophones **26** and **27** of receiver channels **22** and **23,** respectively. Because both of said receiver channels internally process the received signals in the same manner, only channel **22** will be described, in order to keep this disclosure as simple as possible.

When the 8–14 KHz acoustical speech signals are received from within the ambient water environment, they are transduced into electrical signals proportional thereto by hydrophone **26** (say, the right hydrophone, in this case), after which they are amplified to a more useful level by preamplifier **56.** After such amplification, they are filtered by 8–14 KHz bandpass filter **57,** in order to delete spurious signals outside the 8–14 KHz band that may exist therein, thereby improving the signal-to-noise ratio thereof. The filtered output speech signals from filter **57** are then amplified an appropriate amount — as determined by signal enhancement circuit **73,** to be explained shortly — by variable gain amplifier **58** before being heterodyned down to the original speech frequency range of from 300 to 6,000 Hz by balanced demodulator **59** and oscillator **46.** Then said original speech frequency output signals from demodulator **59** are filtered by 6,000 Hz low pass filter to insure passage of audible speech signals only before being amplified to a more useful level by power amplifier **62** and supplied to the diver's ear — say, the right ear, in this particular instance — by earphone **28.** The aforesaid power amplifier **62** is preferably designed to compensate for any signal attenuation caused by the downslope of frequency response inherently introduced by the aforementioned earphone **28** and the human ear being immersed in water.

Due to certain acoustic considerations, a human ear immersed in water loses some of its ability to localize the source of underwater sounds. This invention restores such ability to the swimmer-diver by means of signal amplitude enhancement and discrimination techniques which, in effect, improve the binaural aspects thereof. In this invention such binaural effects are improved by two separate and distinct structural entities, which, although operative individually, combine associatively to produce results that are superior to either one used alone or both thereof merely added together.

One such entity is signal enhancement circuit **73** in combination with adjustable gain amplifiers **58** and **67** of receiver channels **22** and **23.** As mentioned previously, channels **22** and **23** are substantially identical in structure and operation; therefore, the analysis of channel **23** will not be belabored herein. However, it would appear to be noteworthy at this time (for purpose of emphasis) that the amplification characteristic curves of amplifiers **58** and **67** should be as identical as possible, if optimum performance is to be obtained from the overall invention. The outputs of adjustable gain amplifiers **58** and **67** are supplied to the inputs of summing amplifier **74** which, in turn, produces a composite output signal that is proportional to the addition of the voltages thereof. This composite signal is then peak detected, so as to produce a direct current (DC) control voltage signal that is proportional to peak thereof, and such peak DC control signal is supplied to the control inputs of amplifiers **58** and **67** for appropriate regulation of the gain thereof. In this particular case, amplifiers **58** and **67** should be designed by the artisan to be decreased in gain for an increase in the composite gain control signal and vice versa.

From the foregoing, it may readily be inferred that if the incoming speech signal originates at a point directly in front of the diver, it will be amplified the same amount in amplifiers **58** and **67** and the diver's ears will hear signals of equal intensity and of the same phase. On the other hand, in the event the source of the incoming speech signals is to the right or left of the diver, the speech signals received by the divers right or left ear will be stronger and a phase difference will exist proportional to the degree of offset from center of the source and its frequencies, depending upon which direction they come. For example, if the sonic signal source — say, another diver **85** that is speaking — is to the right of the receiving or hearing diver, hydrophone **26** (as best seen in FIG. **4**) will receive a higher power signal than hydrophone **27** because it is closer thereto and because said hydrophones are directionally oriented for acoustical response in diametrically opposed directions. In such instance, if, for example, after cardioid response pattern compensation a 6 volt signal **84** were sensed by hydrophone **26** and the same signal had attenuated to a 5 volt signal by the time it was sensed by hydrophone **27,** then, when both signals were amplified an equal amount — say, for example, by **11** — the right ear would hear a signal proportional to a 66 volt signal and the left ear would receive a signal proportional to a 55 volt signal, with the voltage difference therebetween being 11 volts instead of 1 volt. Such increase in intensity in the right ear of the diver would immediately alert him that the speech signals that he was receiving were coming from his right. Accordingly, binaural enhancement is achieved in water, in proportion to the addition of the received signals which facilitates ascertaining the signal source direction or bearing. This, in turn, makes it easier for a diver to retain his orientation, even though he and the person or persons with whom he is communicating may be working in the dark in deep or turbid water.

As previously suggested, whenever incoming speech or other signals arrive from the left or the right of the listening diver, the phase thereof is delayed at the hydrophone that receives it last, as a result of their greater travel distance in an aqueous medium. In addition, the effective intensity differences of the received signals are enhanced by the respective hydrophone cardioid response patterns which, in turn, are arranged in diametrically opposed dispositions as a result of the opposite orientations of the hydrophones themselves on the head of the diver, as previously mentioned. Such arrangement and evidence of response patterns can best be seen in FIG. **4,** wherein response pattern **82** of hydrophone **26** is depicted graphically and is mathematically defined by the expression $1 + \cos \theta$, where θ is the angle measured around the center (C) of diver head **81,** and wherein response pattern **83** of hydrophone **27** is depicted graphically and is mathematically defined by the expression $1 - \cos \theta$, where θ is again the angle measured around the center (C) of diver head **81.** Thus, it may be seen that if speech signals **84** are being received from a speech source **85** to the right of the front of diver **81,** hydrophone **26** would produce an output signal that is proportional in intensity to RC, while hydrophone **27** would produce an output signal that is proportional in intensity to LC, and because RC is greater than LC, the output signal voltage from right hydrophone **26** would be greater than the output signal voltage from left hydrophone **27.** Such voltage differences, of course, enhance the binaural aspect of the invention, thereby effectively simulating the normal hearing characteristics of a human being.

In view of the foregoing, ostensively it should be evident that the instant swimmer-diver communications system constitutes an advancement in the art and that, to some extent, it achieves objectives heretofore unattainable. Accordingly, it is a new and exceedingly useful method and means for enabling intelligible communication to occur between people and/or other beings response to human speech or other transmitted sound.

Concomitantly with the above, as previously suggested, it would perhaps be noteworthy that it is possible to use the invention as an active or passive sonar system, wherein the transmitter broadcasts certain speech or other signals as target search signals that are received as target echo signals by the receiver, which, in turn, are then interpreted by the diver as to whether or not a target has been acquired and, if so, the relative bearing thereof, or he may merely listen to or home on an incoming sonic signal.

Obviously, other embodiments and modifications of the subject invention will readily come to the mind of one skilled in the art having the benefit of the teachings presented in the foregoing description and the drawings. It is, therefore, to be understood that this invention is not to be limited thereto and that said modifications and embodiments are intended to be included within the scope of the appended claims.

What is claimed is:

1. A communications system, comprising in combination:

a heterodyne transmitter for broadcasting a first signal within a first predetermined frequency range throughout a predetermined environmental medium;

means connected to said transmitter for effecting the actuation thereof in response to a second signal within a second predetermined frequency range;

a heterodyne receiver, having a pair of receiving channels, each of which includes a voltage controlled amplifier, contiguously disposed with said heterodyne receiver, for receiving signals within said first predetermined frequency range and heterodyning them back within said second frequency range; and

means connected between the outputs and control inputs of the voltage controlled amplifiers of said pairs of receiving channels for regulating the respective amplifications thereof in proportion to the peak of the sum of the output signals from said voltage controlled amplifiers.

2. The device of claim **1**, wherein said communication system is a binaural underwater communication system, and wherein said predetermined environmental medium is water.

3. The device of claim **1**, wherein said communication system is a binaural underwater communication system, wherein said predetermined environmental medium is water, and wherein said second signal within a second predetermined frequency is a signal that is generated by and proportional to the sonic energy produced by the human voice.

4. The device of claim **1**, wherein said heterodyne transmitter comprises:

a microphone;

a low pass filter connected to the output of said microphone;

a balanced modulator having a pair of inputs and an output, with one of the inputs thereof effectively connected to the output of said low pass filter;

a normally closed gate having a data signal input, a control signal input, and an output, with the data signal input thereof connected to the output of said balanced modulator, and with the control signal input thereof adapted for effecting the opening thereof in response to a control signal within a predetermined frequency range;

a band pass filter connected to the output of said normally closed gate; and

a transmitting transducer effectively connected to the output of said band pass filter.

5. The device of claim **1**, wherein said heterodyne transmitter comprises:

a microphone;

a low pass filter connected to the output of said microphone;

a balanced modulator having a pair of inputs and an output, with one of the inputs thereof effectively connected to the output of said low pass filter;

a normally closed gate having a data signal input, a control signal input, and an output, with the data signal input thereof connected to the output of said balanced modulator, and with the control signal input thereof adapted for effecting the opening thereof in response to a control signal within a predetermined frequency range;

a band pass filter connected to the output of said normally closed gate;

a transmitting transducer effectively connected to the output of said band pass filter; and

a local oscillator connected to the other input of said balanced modulator.

6. The device of claim **1**, wherein said heterodyne transmitter comprises:

a microphone;

a low pass filter connected to the output of said microphone;

a balanced modulator having a pair of inputs and an output, with one of the inputs thereof effectively connected to the output of said low pass filter;

a normally closed gate having a data signal input, a control signal input, and an output, with the data signal input thereof connected to the output of said balanced modulator, and with the control signal input thereof adapted for effecting the opening thereof in response to a control signal within a predetermined frequency range;

a band pass filter connected to the output of said normally closed gate;

a transmitting transducer effectively connected to the output of said band pass filter;

a local oscillator connected to the other input of said balanced modulator; and

means effectively connected between the output of said low pass filter and the voltage control input of the aforesaid normally closed gate for effecting the opening thereof in response to the signal received from the output of said low pass filter.

7. The device of claim **1**, wherein said heterodyne transmitter comprises:

a microphone;

a low pass filter connected to the output of said microphone;

a balanced modulator having a pair of inputs and an output, with one of the inputs thereof effectively connected to the output of said low pass filter;

a normally closed gate having a data signal input, a control signal input, and an output, with the data signal input thereof connected to the output of said balanced modulator, and with the control signal input thereof adapted for effecting the opening thereof in response to a control signal within a predetermined frequency range;

a band pass filter connected to the output of said normally closed gate;

a transmitting transducer effectively connected to the output of said band pass filter; and

means effectively connected between the output of said low pass filter and the voltage control input of the aforesaid normally closed gate for effecting the opening thereof in response to the signal received from the output of said low pass filter.

8. The device of claim **1**, wherein said means connected between the outputs and control inputs of the voltage control amplifiers of said pairs of receiving channels for regulating the respective amplifications thereof in proportion to the peak of the sum of the output signals from said voltage controlled amplifiers comprises:

a summing amplifier having a pair of inputs and an output, with the inputs thereof respectively connected to the outputs of said voltage controlled amplifiers; and

a direct current peak detector connected between the output of said summing amplifier and the control inputs of said voltage control amplifiers.

9. The invention of claim **1**, further characterized by a face mask means surrounding said communication system for the housing thereof therein when said face mask means is worn by a swimmer-diver.

10. The invention of claim **1**, further characterized by a face mask means surrounding the transmitter and transmitter actuation means of said communication system for the housing thereof therein when said face mask means is worn by a swimmer-diver.

11. The invention of claim **1**, further characterized by a local oscillator connected to said heterodyne transmitter and each of said pair of receiving channels of said heterodyne receiver for supplying a predetermined heterodying signal thereto.

12. The device of claim **1**, wherein each of said pair of receiving channels of the aforesaid heterodyne receiver comprises:

a receiving hydrophone;

a band pass filter effectively connected to the output of said receiving hydrophone;

a voltage controlled amplifier having a data signal input, a control input, and an output, with the data signal input thereof connected to the output of said band pass filter, and with the control input responsive to a voltage control signal;

a balanced demodulator having a pair of inputs and an output, with one of the inputs thereof connected to the output of said voltage controlled amplifier;

a low pass filter connected to the output of said balanced demodulator; and

an earphone effectively connected to the output of the aforesaid low pass filter.

13. The device of claim **12**, wherein the hydrophones of said pair of receiving channels are physically disposed in such diametrically opposed manner as to be responsive to acoustical energy arriving thereat from predominantly opposite directions.

14. The device of claim **12**, wherein the hydrophones of said pair of receiving channels are physically disposed in such manner as to be responsive to acoustical energy arriving thereat from within similar oppositely directed cardioid response patterns.

15. An underwater communication system, comprising in combination:

a microphone;

a first low pass filter connected to the output of said microphone;

a first preamplifier connected to the output of said low pass filter;

a balanced modulator having a pair of inputs and an output, with one of the inputs thereof connected to the output of said first preamplifier;

a gate having a data signal input, a control input, and an output, with the data signal input thereof connected to the output of said balanced modulator;

a voice operated switch connected between the output of the aforesaid first preamplifier and the control input of said gate;

a first band pass filter connected to the output of said gate

a first power amplifier connected to the output of said first band pass filter;

a transmitting transducer connected to the output of said first power amplifier;

a first hydrophone;

a second preamplifier connected to the output of said hydrophone;

a second band pass filter connected to the output of said second preamplifier;

a first voltage controlled amplifier having a data signal input, a control input, and an output, with the data signal input thereof connected to the output of said second band pass filter;

a first balanced demodulator having a pair of inputs and an output, with one of the inputs thereof connected to the output of said first voltage controlled amplifier;

a second low pass filter connected to the output of said first balanced demodulator;

a second power amplifier connected to the output of said second low pass filter;

a first earphone connected to the output of said second power amplifier;

a second hydrophone;

a third preamplifier connected to the output of said second hydrophone;

a third band pass filter connected to the output of said third preamplifier;

a second voltage controlled amplifier having a data signal input, a control input, and an output, with the data signal input thereof connected to the output of said third band pass filter;

a second balanced demodulator having a pair of inputs and an output, with one of the inputs thereof connected to the output of said second voltage controlled amplifier;

a third low pass filter connected to the output of said second balanced demodulator;

a third power amplifier connected to the output of said third low pass filter;

a second earphone connected to the output of said third power amplifier;

an oscillator connected to the other inputs of said first and second balanced demodulators and the aforesaid balanced modulator;

a summing amplifier having a pair of inputs and an output, with the inputs thereof respectively connected to the outputs of said first and second voltage controlled amplifiers; and

a direct current voltage peak detector having an input and an output, with the input thereof connected to the output of said summing amplifier, and with the output thereof connected to the control inputs of the aforesaid first and second voltage controlled amplifiers.

16. The invention of claim **15**, further characterized by means for housing said underwater communication system in a waterproof manner and in contiguous disposition with the mouth and ears of an underwater swimmer-diver.

* * * * *

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,789,353 Dated January 29, 1974

Inventor(s) Earl K. Hunter and Don G. Smith

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

In the Specification

Column 2, line 11, delete the word --and--.

Column 2, line 11, after the word "maintained" and before the period, insert the term --, and transported--.

Column 2, line 38, between the words "and" and "anyone", insert the term --,thus,--.

Column 4, line 6, delete the term "receiver channels 22 and 23" and substitute the term --housings 24 and 25-- therefor.

Column 4, line 8, between the words "the" and "ears", insert the term --right and left--.

Column 4, line 9, between the term "swimmer-diver" and the period, insert the term --, respectively--.

In the Drawing

In FIG. 3., change the legend of element 65 from "PWR AMP" to --PRE-AMP--.

In FIG. 4, near the intersection of cardioid response pattern 83 and speech signal 84, insert an --L--.

Signed and sealed this 3rd day of December 1974

(SEAL)
Attest:

McCOY M. GIBSON JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents

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