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(54) ELECTROACOUSTIC UNIT FOR GENERATING HIGH SONIC AND ULTRASONIC INTENSITIES IN GASES AND INTERPHASES.

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(56) References cited :
EP-A- 0 327 486
WO-A-86/02058
US-A- 4 779 243
US-A- 4 868 445
Ultrasonics International 85, London, 2-4 July 1985, Conference Proceedings, et al:"High power ultrasonic equipment for industrial defoaming", pages506-511
Ultrasonics International 87, London, 6-9 July 1987, Conference Proceedings, G. Rodriguez-Corral et al.:"Focused high power ultrasonic transducer with stepped-plate radiator for industrial application in gases", pages 794-799.

(73) Proprietor : **CONSEJO SUPERIOR DE INVESTIGACIONES CIENTIFICAS**
Serrano, 117
E-28006 Madrid (ES)

(72) Inventor : **GALLEGO JUAREZ, Juan Antonio**
Inst. de Acustica del CSIC
Serrano 114 E-28006 Madrid (ES)
Inventor : **RODRIGUEZ CORRAL, Germán**
Instituto de Acustica del CSIC
Serrano 144 E-28006 Madrid (ES)
Inventor : **SAN EMETERIO PRIETO, José Luis**
Instituto de Acustica del CSIC
Serrano 144 E-28006 Madrid (ES)
Inventor : **MONTOYA VITINI, Fausto Instituto de Teledeteccion y Telecomunicaciones del CSIC**
Serrano 144 E-28006 Madrid (ES)

(74) Representative : **Ungria Lopez, Javier et al**
Avda. Ramon y Cajal, 78
E-28043 Madrid (ES)

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Description

The object of this patent application is an electroacoustic unit for efficient generating of high acoustic intensities in gas media and in interphases (gas-solid, gas-liquid.)

Generating high intensity ultrasonic sonic waves in gases involves outstanding difficulties that are basically connected to the low acoustic impedance of the medium (product of the intensity by the propagation velocity) and the high absorption of the same. Therefore, in order to obtain efficient transmitting of acoustic energy a good coupling between the transmitting system and the gas is necessary. Besides, in order to reach high intensities high vibration amplitudes are required and the acoustic beam must be very directional or focalized.

There are different types of sonic and ultrasonic generators for use in gases. Most of them are aerodynamic systems, such as whistles and sirens, in which the energy is supplied by a stream of gas. The acoustic powers reached with these systems may be high, however, the yields that are obtained are generally low. Acoustic signals transmitted are complex and have difficulties in reaching ultrasonic frequencies. Besides, aerodynamic systems have the disadvantage that, along with acoustic radiation, a large amount of gas coming from the transmitter is propagated.

Other high intensity acoustic wave generators are of the electromagnetic, magnetostrictive or piezoelectric type, working with solid transmitters vibrating longitudinally whereby they have outstanding limitations in geometry (to prevent transversal modes), as well as to attain high yields and high displacements. The most recent attempts try to use flat radiators vibrating flexionally. This makes it possible to increase the radiating surface, increasing the radiation impedance (which is proportional to the radiator surface), and attain high displacements. However, the big problem of these systems comes from the phase cancellation that is produced as a result of the areas that vibrate in counterphase on both sides of a nodal line. There are some attempts to avoid this effect by covering those internodal areas that vibrate with the same phase with absorbent materials and leaving the alternate areas that vibrate in phase opposition to the previous ones free. Other more effective structures try to take advantage of all the vibrating areas by covering the internodal areas with materials that serve as medium impedance adaptors and with a thickness such that it is possible to correct in the radiation the phase displacement that is produced in vibration. These systems, though they are more effective than the above cited ones, have outstanding practical problems coming from the connections between the flat plate and the additional materials that are placed on the internodal areas.

The present invention refers to an electroacoustic unit that consists of a transducer system and an electronic feed device. In the transducer system which may be piezoelectric or magnetostrictive, the radiating element is a flexional type, but it has a structure having a discontinuous profile. With this special design, the vibration amplitude and the radiation phase are modified in such a way that all the vibrating areas directly contribute to the construction of the acoustic field with a configuration that may be predetermined. Besides, with the same radiatingelement it is possible to obtain two different configurations of the acoustic field, in correspondence with the different profile of each one of the surfaces of the same. Particularly prototypes for frequencies of approximately 20 KHz have been developed which achieve, with a single transducer, a directional field of a beam width (at 3 db) less than 3 degrees by one of the surfaces of the radiating element, and a strongly focalized field in an axial cylindric volume some 10 cm long and less than 2 cm wide on the other surface. Figure 1 shows the directivity diagram of the transducer radiating at its directional surface, while Figure 2 shows the axial and transversal distribution (in the focus) of the acoustic field transmitted by the focalizing surface. P represents the acoustic pressure amplitude and D the distance in centimeters. Figure 3 shows a transducer System according to the invention, and Figure 4 shows a general block diagram of an electronic generator according to the invention, which includes the transformation, power amplification, generation, automatic frequency control and power control steps.

The transducer system (Figure 3) consists essentially of a transducer element (1) that can be piezoelectric or magnetostrictive, a mechanical vibration amplifier (2), which may be exponential, stepped, conical or catenoid, and a radiator which is a plate having a discontinuous profile on the two surfaces (3) thereof. The longitudinal vibration generated by the transducer element and amplified by the mechanical amplifier, serves to excite the radiating element in one of its flexional modes. Although in general it is useful to use circular shapes and axysymmetric modes, obtaining directional fields is achieved by displacing alternatively internodal crowns by a half radiation wave length in the medium, for the purpose of putting the entire beam in phase. Likewise, focalized fields are obtained by displacing the internodal crowns in such a way that the distance from the center of said areas to the focal point is such that the radiation arrives in phase said point situated in the field close to the radiator. It is obvious that by varying the length of displacement of the internodal crowns adequately practically any distribution of the acoustic field that is desired can be achieved.

The construction of radiators with a double discontinuous profile, aside from the usefulness that is represented by having two configurations of the acoustic field, favors in general lines a more homogeneous distribution of the vibration amplitudes, in comparison with a flat radiator, as a result of the mass distribution. This results in a greater power capacity of the transducer systems which, in the structure that is presented here, is produced by the maximum vibration amplitude which the radiator can develop without breaking. For this purpose the radiators that are presented here must be made out of metals or metal alloys which, like the ones of titanium, have good vibratory features and high mechanical resistance.

In order to obtain a maximum yield in the transducer system, the three basic parts that form it have to be well tuned to the work frequency. As a result, the system turns out to be highly resonant and, given that the conditions of the medium or by heating the frequency can vary with time, an electronic excitation device with very specific requirements is necessary.

Therefore, the generating system, aside from producing in each instant a signal whose frequency is situated within a very narrow band (corresponding to the resonance margin of the transmitter used), is capable of automatically correcting the value of said frequency by adapting it to the slipping produced in the resonance band of the transmitter, as the reactive mechanical load associated to the latter varies for different conditions of the radiated medium and of the transmitter device itself.

The presently used systems for excitation of this type of transducer are based on analogic type oscillator assemblies, formed by a power amplifier refed by the ultrasonic transducer itself by means of a tuned bridge circuit, a phase shifter, a limiter and a band pass filter. This type of system has a rather critical performance above all in the initial instants of transmission, also requiring the use of components having a very high precision, as well as including several adjustment points, that have to be adjusted individually for each different ultrasonic transmitter that is connected.

The generator object of the present patent application introduces a new process for following up the resonance frequency of the transmitter, which does not need the transducer to be introduced in the refeed (feedback) loop of the oscillating circuit.

The process is based on the fact that a sonic or ultrasonic transmitter of the piezoelectric type has a purely resistive electric impedance when it vibrates in the central point of its resonance band (assuming that there has been a compensation of the reactive component associated with the interelectrodic capacity of the transducer.) When the operating point moves away (though slightly) from the resonance, a considerable reactive component rapidly appears. As a result thereof, only the voltage and intensity signals in the transducer will have a negative phase displacement at the resonance frequency.

Therefore, it will suffice that the generator accomodates the frequency of the signal at the point in which said phase displacement is cancelled so that resonance is produced.

This method presents a series of advantages over the above cited ones:

a) It is not necessary to introduce the transducer in the refeed (feedback) chain of the system, which leads to a greater stability of the amplitude of the exciting signal.

b) The manufacturing of the electronic device does not require the use of high precision components.

c) Finally, the operating of the system in the resonance points turns out to be very stable, adapting accurately to the band slippings caused by variations of the features of the medium in which the transmitter radiates.

Such a method is described in:

Ultrasonics International 85, London, 2-4 Julio 1985, Conference Proceedings, G. Rodriguez et al.: "High power ultrasonic equipment for industrial defoaming", páginas 506-511

Sonic and ultrasonic transducers also have considerable resistance variations in terms of the temperature of the ceramics, which changes extensively during operation due to heating. The described system also includes a circuit which measures the power delivered by the transducer to the load and which permits stabilization thereof.

Just as is put forth in the block diagram of Figure 4, the generating system consists of the following basic components:

a) An impedance transformer that reduces the impedance of the transducer to 50 Ω.

b) A compensation reactor of the spurious capacity of the transducer.

c) A suitable power amplifier to excite loads of 50 Ω.

d) A channel to take a sample of the current signal in the load.

e) A channel to take a sample of the output voltage of the power amplifier.

f) A PLL (Phase Looked Loop) circuit to generate the exciting signal of the power amplifier, with a frequency equal to the resonance frequency of the transducer.

g) A circuit measuring the power delivered to the load.

h) A circuit controlling the power delivered to the load.

Hereinafter the operation of each one of these steps is described individually as well as their interrelationship:

a) Transformer T1 has a band much wider than the resonance frequency margin in which the transducer moves, introducing a negligible phase displacement. The transformation ratio is such that the impedance that the primary has is 50 Ω, when it is loaded with the cold transducer. The impedance of 50 Ω has been chosen to be able to adapt to the impedance of ordinary transmission lines of 50 Ω, which join the transformer and the amplifier. Depending on the use, it may be necessary that the transducer and main unit are very separated from each other, and therefore, they have to be joined by an adapted transmission line.

b) The compensation reactor L1 resonates at the work frequency of the transducer with the spurious electric capacity of the transducer, compensating the detrimental phase displacement that the latter could introduce.

c) The power amplifier is capable of delivering a power suitable to each use. The design thereof is common and it should be adapted to excite loads of 50 Ω. The phase displacement introduced between the input and output signals has to be zero.

d) The channel for taking a sample of the current in the charge signal is formed by the resistor R1 which is series connected with the load of the amplifier and which is of a value much less than 50 Ω, in such a way that it does not appreciably modify the load impedance and the voltage that appears in the terminals thereof is proportional to the current intensity in the load. The signal obtained serves to control the frequency as well as to control the power.

e) The channel for taking a sample of the output voltage of the power amplifier is formed by a voltage divider that takes a small fraction thereof, made out of resistors R2 and R3. The signal obtained servies to control the power.

The PLL (Phase Locked Loop) circuit is of a common type. It is made up of a VCO (voltage controlled oscillator), a four -quadrant multiplier acting as a M1 phase and low pass filter comparator, consisting of resistor R6 and capacitor C3. The VCO has two outputs, one in the form of a square wave to attack the phase comparator and another in the form of a sinewave to attack the amplifier, both outputs are out of phase by $\pi/2$ radians. The other phase comparator input is the signal of sample of output current. The phase comparator is a four-quadrant multiplier in such a way that the PLL hooks up to the frequency at which the phase difference between the two inputs is $\pi/2$, since the phase difference between the two VCO outputs is also $\pi/2$, it turns out that it will be maintained at the frequency at which the phase between the voltage and current at the power amplifier output is zero.

The central operating frequency of the VCO is adjusted by means of resistor R4 and capacitor C1.

g) The circuit measuring the power delivered to the load is formed by a four-quadrant multiplier M2 whose inputs are the voltage and current samples taken at the output of the power amplifier, the product signal is low pass filtered by means of resistor R5 and capacitor C2 in such a way that the filter output is proportional to the effective power in the load.

h) The circuit controlling the power delivered to the load consists of a comparator COM1 and a four-quadrant multiplier M3, functioning as an attentuator controlled by voltage. The comparator finds the difference of magnitude between the effective power in the load and a reference signal REF, the difference between them serves to control the attenuation introduced by the multiplier M2.

Claims

1. Electroacoustic unit for generating high sonic and ultrasonic intensities in gases and interphases consisting of an electromechanical transducer system and an electronic device for controlled generation of the electric power signal in which the electroacoustic unit includes a transducer system which consists of three parts:

   a transducer element, a mechanical vibration amplifier and a radiator shaped like a plate having a discontinuous profile on both surfaces and is characterized in that the three parts that make up the transducer system are tuned in order to resonate at the operating frequency; and in that the electronic generator is made up of a power amplifier, a PLL (Phase Locked Loop) circuit, a circuit measuring the power delivered to the transducer and a circuit controlling the power.

2. An electroacoustic unit according to claim 1 in which the transducer element may be piezoelectric or magnetostrictive and causes a longitudinal vibration.

3. An electroacoustic unit according to the above claims in which the shape of the mechanical amplifier is substantially exponential, stepped, conical, or catenoid, and amplifies the vibration generated by the transducer element, exciting the radiator in one of its flexional modes of vibration.

4. An electroacoustic unit according to the above claims, in which the radiating element is made up of a plate that may have any geometric shape (circular, rectangular, square) and whose two surfaces have a discontinous profile which is obtained by displacing some internodal areas in the direction perpendicular to the medium plane of the plate.

5. An electroacoustic unit according to the above claims in which the number and position of the internodal areas that are displaced as well as the height or depth of the displacements depends on the configuration of the acoustic field that is desired.

6. An electroacoustic unit according to the above claims in which two acoustic fields can be generated with a different configuration with a single radiator, in correspondence with the two different profiles on each one of the radiator surfaces.

7. An electroacoustic unit according to the above claims in which the obtaining of directional fields is achieved, in the case of circular radiators by vibrating in one of the axysymmetric modes thereof, alternately displacing the internodal crowns by a half wave length of radiation in the medium.

8. An electroacoustic unit according to the above claims in which the obtaining of focalized fields is achieved, in the case of circular radiators by vibrating in one of the axysymmetric modes thereof, displacing the internodal crowns in such a way that the distance from the center of said areas to the focal point is such that the radiation arrives in phase at said point situated in the field close to the radiator.

9. An electroacoustic unit according to the above claims in which the electronic generating device produces in each instant a signal whose frequency is situated within the resonance band of the transducer system, and automatically corrects the value of said frequency to adapt it to the slipping that can be produced in the resonance band of the transmitter.

10. An electroacoustic unit according to the above claims in which the electronic generator has a power amplifier in which the phase displacement introduced between the input and output signals is zero.

11. An electroacoustic unit according to the above claims in which the electronic generator comprises a channel for taking the sample of the load current signal is formed by a resistor in series with the load of the amplifier with a value that does not appreciably modify the load impedance, the voltage in the terminals thereof being proportional to the current intensity in the load.

12. An electroacoustic unit according to the above claims in which the electronic generator takes a sample of the output voltage of the power amplifier by means of a voltage divider to control the power.

13. An electroacoustic unit according to the above claims in which the electronic generator includes a PLL (Phase Locked Loop) circuit comprising a voltage controlled oscillator, a four-quadrant multiplier acting as a phase comparator and a low pass filter.

14. An electroacoustic unit according to the above claims in which the voltage controlled oscillator of the electronic generator has two outputs, one supplying a square wave which feeds the phase comparator and another supplying a sinewave that feeds the amplifier, which are both out of phase by $\pi/2$ radians, the other input of the phase comparator being the output current sample signal.

15. An electroacoustic unit according to the above claims in which the circuit of the electronic generator measuring the power delivered to the load is formed by a four-quadrant multiplier whose inputs are the voltage and current samples taken at the output of the power amplifier, the product signal being low pass filtered to obtain a signal proportional to the effective power in the load.

16. An electroacoustic unit according to the above claims in which the circuit of the electronic generator controlling the power delivered to the load is made up of a comparator and a four quadrant multiplier operating as an attenuator controlled by voltage.

Patentansprüche

1. Elektroakustische Einheit zum Erzeugen von Hochintensitätsschall und -ultraschall in Gasen und Zwischenphasen, bestehend aus einem elektromechanischen Übertragersystem und einer elektronischen Vorrichtung zur gesteuerten Erzeugung des elektrischen Leistungssignals, wobei die elektroakustische Einheit beinhaltet:
ein Übertragersystem, welches aus drei Teilen besteht, einem Übertragerelement, einem Verstärker für mechanische Vibration und einem Radiator, der wie eine Platte geformt ist mit einem diskontinuierlichen Profil auf beiden Oberflächen, und
dadurch **gekennzeichnet** ist, daß
die drei Teile, die das Übertragersystem bilden, abgestimmt sind, bei der Betriebsfrequenz eine Resonanz zu haben; und
der elektronische Generator aus einem Leistungsverstärker, einer phasenstarken Schaltung (PLL = Phase Locked Loop - Schaltung), ei-

ner Schaltung zum der an den Übertrager gelieferten Leistung und einer Schaltung zum Steuern der Leistung besteht.

2. Elektroakustische Einheit nach Anspruch 1, wobei das Übertragerelement piezoelektrisch oder magnetostriktiv sein kann und eine Längsvibration verursacht.

3. Elektroakustische Einheit nach den obigen Ansprüchen, wobei die Gestalt des mechanischen Verstärkers im wesentlichen exponentiell, gestuft, konisch oder katenoid ist, und die Vibration verstärkt, die durch das Übertragerelement erzeugt wird, zum Erregen des Radiators in einen seiner flexionalen Vibrationsmodi.

4. Elektroakustische Einheit nach den obigen Ansprüchen, wobei das Radiatorelement aus einer Platte besteht, welche jegliche geometrische Gestalt (kreisförmig, rechteckig, quadratisch) haben kann und deren zwei Oberflächen ein diskontinuierliches Profil haben, welches erhalten wird durch Versetzen einiger Zwischenknotenbereiche in der Richtung senkrecht zur Mittelebene der Platte.

5. Elektroakustische Einheit nach den obigen Ansprüchen, wobei die Anzahl und Position der Zwischenknotenbereiche, welche verschoben sind, sowie die Höhe oder Tiefe der Verschiebungen abhängt von der Konfiguration des akustischen Feldes, welches erwünscht ist.

6. Elektroakustische Einheit nach den obigen Ansprüchen, wobei zwei akustische Felder erzeugt werden können mit einer verschiedenen Konfiguration mit einem einzelnen Radiator, in Übereinstimmung mit den zwei verschiedenen Profilen auf jeder der Radiatoroberflächen.

7. Elektroakustische Einheit nach den obigen Ansprüchen, wobei das Erhalten der Richtungsfelder erzielt wird in dem Fall der kreisförmigen Radiatoren durch Vibrieren in einem der axial-symmetrischen Modi davon, alternierend verschiebend die Zwischenknotenkronen um eine halbe Wellenlänge der Strahlung in dem Medium.

8. Elektroakustische Einheit gemäß den obigen Ansprüchen, wobei das Erhalten der fokussierten Felder erzielt wird im Fall der kreisförmigen Radiatoren durch Vibrieren in einem der axial-symetrischen Modi davon, verschiebend die Zwischenknotenkronen in solch einer Art und Weise, daß der Abstand von dem Zentrum der Bereiche zum Brennpunkt so ist, daß die Strahlung in Phase ankommt an dem Punkt, der gelegen ist in dem Feld nahe des Radiators.

9. Elektroakustische Einheit nach den obigen Ansprüchen, wobei die elektronische Erzeugungsvorichtung in jedem Augenblick ein Signal erzeugt, dessen Frequenz innerhalb des Resonanzbandes des Übertragersystems liegt, und automatisch den Wert der Frequenz korrigiert, um ihn an das Verrutschen anzupassen, das erzeugt werden kann in dem Resonanzband des Übertragers.

10. Elektroakustische Einheit nach den obigen Ansprüchen, wobei der elektronische Generator einen Leistungsverstärker hat, in dem die Phasenverschiebung, die zwischen dem Eingabe- und Ausgabesignal eingeführt ist, Null ist.

11. Elektroakustische Einheit nach den obigen Ansprüchen, wobei der elektronische Generator, einen Kanal umfaßt zum Nehmen des Abtastwertes des Laststromsignals, welcher gebildet ist durch einen Widerstand in Reihe mit der Last des Verstärkers, mit einem Wert der nicht wesentlich die Lastimpedanz modifiziert, wobei die Spannung an den Anschlüssen davon proportional ist zur Stromintensität in der Last.

12. Elektroakustische Einheit gemäß den obigen Ansprüchen, wobei der elektronische Generator einen Abtastpunkt nimmt von der Ausgabespannung des Leistungsverstärkers mittels eines Spannungsteilers zum Steuern der Leistung.

13. Elektroakustische Einheit nach den obigen Ansprüchen, wobei der elektronische Generator eine phasensstarre Schaltung (PLL-Schaltung) enthält mit einem spannungsgesteuerten Oszillator, einem Vier-Quadranten-Vervielfacher, agierend als ein Phasenkomparator, und einem Tiefpaßfilter.

14. Elektroakustische Einheit nach den obigen Ansprüchen, wobei der spannungsgesteuerte Oszillator des elektronischen Generators zwei Ausgänge hat, einen zum Zuführen einer Rechteckwelle, welche in den Phasenkomperator eingespeist wird, und

einen weiteren zum Zuführen einer Sinuswelle, welche in den Verstärker eingespeist wird, welche beide um pi/2 Radian außer Phase sind, wobei der andere Eingang des Phasenkomparators das Ausgabestromabtastsignal ist.

15. Elektroakustische Einheit nach den obigen Ansprüchen,
wobei die Schaltung des elektronischen Generators zum Messen der Leistung, welche an die Last geliefert wird, gebildet ist durch einen Vier-Quadrant-Vervielfacher, dessen Eingänge die Spannung und Stromabtastwerte sind, die genommen werden an dem Ausgang des Leistungsverstärkers, wobei das Produktsignal tiefpaßgefiltert ist zum Erhalten eines Signals proportional zur effektiven Leistung in der Last.

16. Elektroakustische Einheit nach den obigen Ansprüchen,
wobei die Schaltung des elektronischen Generators zum Steuern der Leistung, die geliefert wird an die Last, aus einem Komparator und einem Vier-Quadrant-Vervielfacher besteht, der als ein Abschwächer, gesteuert durch eine Spannung, agiert.

Revendications

1. Unité électroacoustique, pour la génération de hautes intensités soniques et ultrasoniques dans des gaz et des interphases, constituée d'un système électromécanique de transducteur et d'un dispositif électronique pour une génération commandée du signal électrique de puissance, unité électroacoustique comprenant un dispositif de transducteur constitué de trois parties, c-à-d un élément de transducteur, un amplificateur de vibrations mécaniques et une plaque en forme de radiateur présentant un profil discontinu sur chaque face,
unité caractérisée en ce que les trois parties constituant le dispositif de transducteur sont accordées de façon à résonner à la fréquence de fonctionnement et en ce que le générateur électronique est constitué d'un amplificateur de puissance, d'un circuit PLL (Boucle à Blocage de Phase), d'un circuit mesurant la puissance délivrée au transducteur et d'un circuit commandant la puissance.

2. Unité électroacoustique selon la revendication 1, dans laquelle l'elément de transducteur peut être piézoélectrique ou magnétostrictif et crée des vibrations longitudinales.

3. Unité électroacoustique selon les revendications précédentes, dans laquelle la forme de l'amplificateur mécanique est pratiquement exponentielle, étagée, conique ou caténoïde et amplifie les vibrations générées par l'élément de transducteur, excitant le radiateur dans un de ses modes de vibrations en flexion.

4. Unité électroacoustique selon les revendications précédentes, dans laquelle l'élément de radiateur est constitué d'une plaque pouvant avoir une quelconque forme géométrique (circulaire, rectangulaire ou carrée) et dont les deux surfaces présentent un profil discontinu qui est obtenu en déplaçant certaines zones internodales dans une direction normale au plan médian de la plaque.

5. Unité électroacoustique selon les revendications précédentes, dans laquelle le nombre et la position des zones internodales déplacées ainsi que la hauteur ou la profondeur déplacements dépendent de la configuration du champ acoustique recherché.

6. Unité électroacoustique selon les revendications précédentes, dans laquelle deux champs acoustiques peuvent être générés avec une configuration différente pour un seul radiateur selon les deux profils différents sur chacune des surfaces de radiateur.

7. Unité électroacoustique selon les revendications précédentes, dans laquelle l'obtention des champs directionnels est obtenue, dans le cas de radiateurs circulaires, par un mise en vibration dans un des modes symétriques par rapport à l'axe, déplaçant, de façon alternée, les couronnes internodales d'une moitié de longueur d'onde de rayonnement dans le milieu.

8. Unité électroacoustique selon les revendications précédentes, dans laquelle l'obtention des champs focalisés est obtenue, dans le cas de radiateurs circulaires, par mise en vibration dans un des modes symétriques par rapport à l'axe, déplaçant les couronnes internodales de telle façon que la distance du centre desdites zones au point focal soit telle que le rayonnement arrive en phase sur ledit point situé dans le champ près du radiateur.

9. Unité électroacoustique selon les revendications précédentes, dans laquelle le dispositif de génération électronique produit, à chaque instant, un signal dont la fréquence se trouve dans la bande de résonnance du dispositif de transducteur et corrige automatiquement la valeur de ladite fréquence pour l'adapter au glissement pouvant être produit dans la bande de résonnance de l'émetteur.

10. Unité électroacoustique selon les revendications précédentes, dans laquelle le générateur électronique possède un amplificateur de puissance dans lequel le décalage de phase introduit entre les signaux d'entrée et de sortie est nul.

11. Unité électroacoustique selon les revendications précédentes, dans laquelle le générateur électronique comprend un canal d'échantillonnage du signal de courant de charge formé d'une résistance montée en série avec la charge de l'amplificateur avec une valeur ne modifiant pas, de façon appréciable, l'impédance de charge, la tension aux bornes de la résistance étant proportionnelle à l'intensité du courant dans la charge.

12. Unité électroacoustique selon les revendications précédentes, dans laquelle le générateur électronique prélève un échantillon de la tension de sortie de l'amplificateur de puissance au moyen d'un diviseur de tension pour commander la puissance.

13. Unité électroacoustique selon les revendications précédentes, dans laquelle le générateur électronique comprend un circuit PLL (Boucle à Blocage de Phase) comprenant un oscillateur commandé en tension, un multiplicateur à quatre quadrants servant de comparateur de phase et de filtre passe-bas.

14. Unité électroacoustique selon les revendications précédentes, dans laquelle l'oscillateur commandé en tension du générateur électronique possède deux sorties, une fournissant une onde carrée alimentant le comparateur de phase et une autre fournissant une onde sinusoïdale alimentant l'amplificataur, sorties qui sont toutes les deux en décalage de phase de $\pi/2$ radians, l'autre entrée du comparateur de phase constituant le signal d'échantillonnage du courant de sortie.

15. Unite électroacoustique selon les revendications précédentes, dans laquelle le circuit du générateur électronique mesurant la puissance délivrée à la charge est formé d'un multiplicateur à quatre quadrants dont les entrées sont les échantillons de tension et de courant pris à la sortie de l'amplificateur de puissance, le signal produit étant filtré en passe-bas pour obtenir un signal proportionnel à la puissance effective dans la charge.

16. Unité électroacoustique selon les revendications précédentes, dans laquelle le circuit du générateur électronique commandant la puissance delivrée à la charge est constitué d'un comparateur et d'un multiplicateur à quatre quadrants fonctionnant comme atténuateur commandé par la tension.

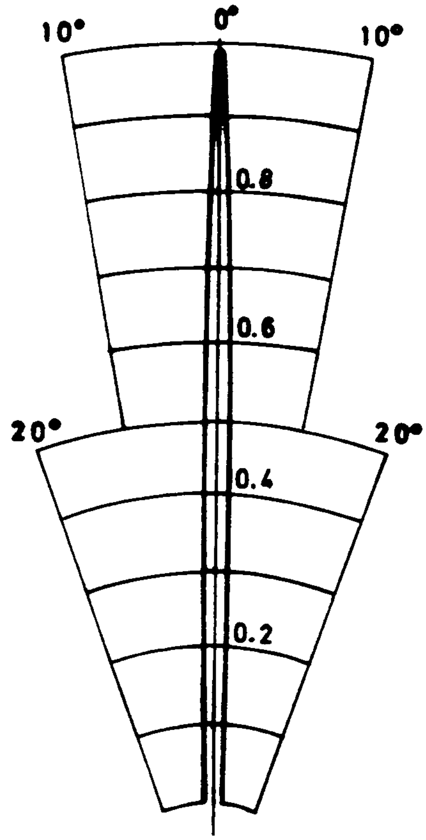

Fig.1

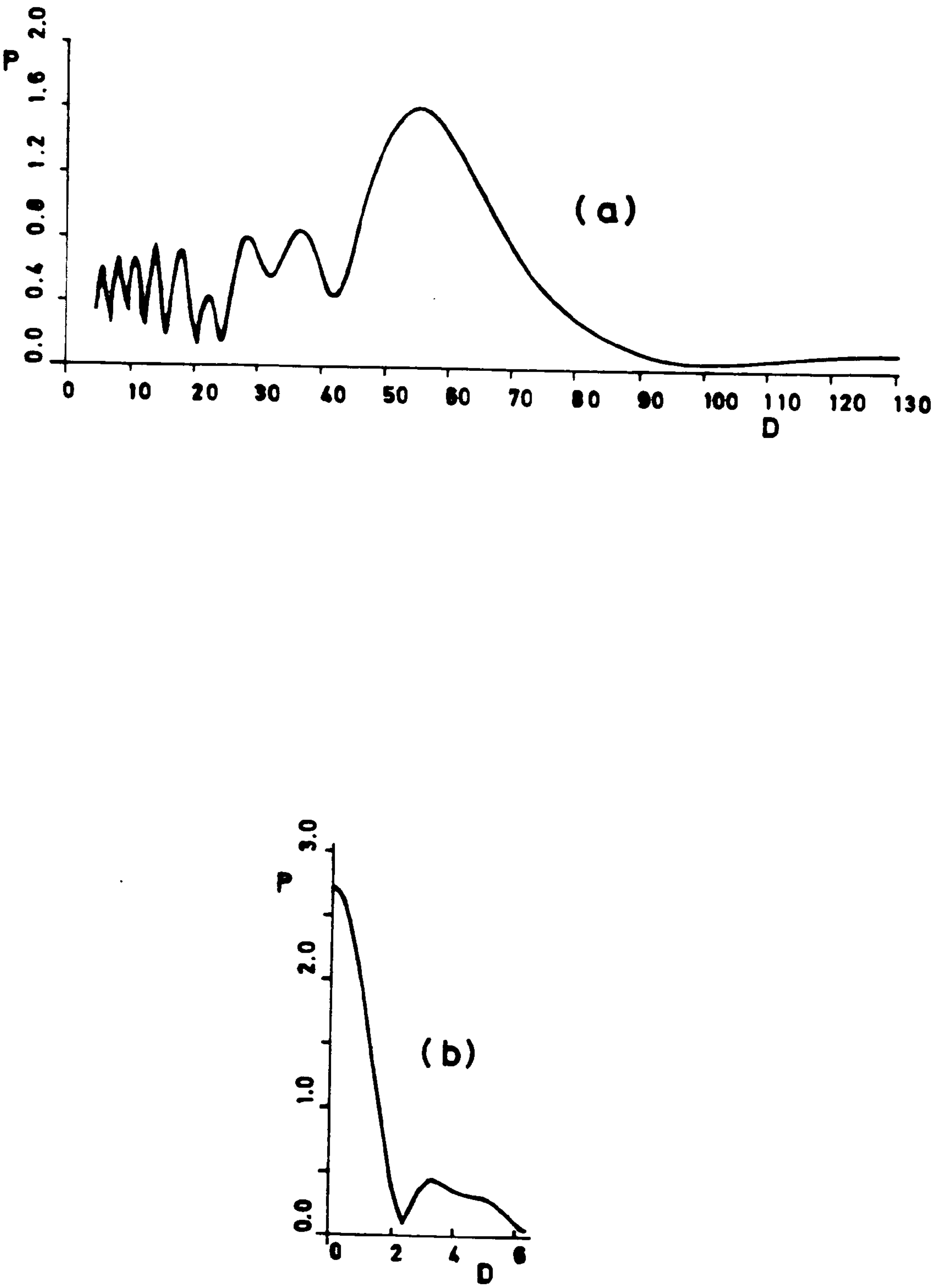
P
2.0
1.6
1.2
0.8
0.4
0.0
0
10
20
30
40
50
60
70
80
90
100
110
120
130
D
(a)
P
3.0
2.0
1.0
0.0
0
2
4
6
D
(b)

Fig.2

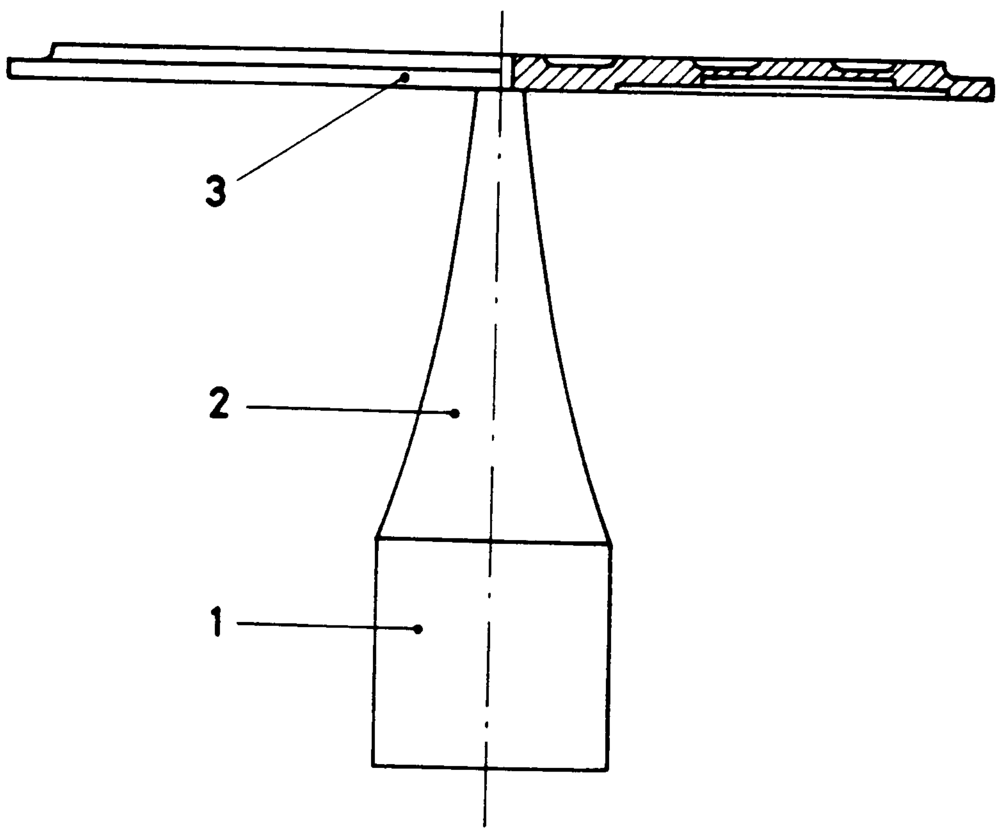

Fig. 3

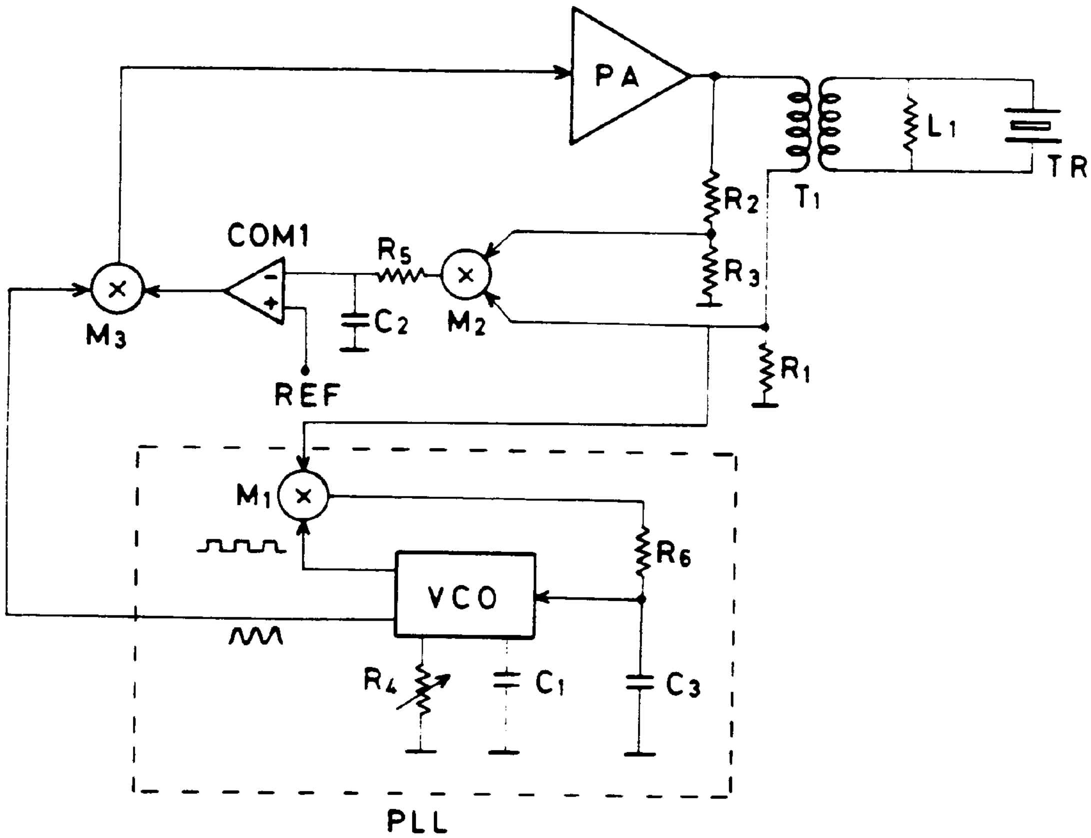

Fig. 4