(54) Title: ACTIVE ACOUSTIC DEVICES COMPRISING PANEL MEMBERS
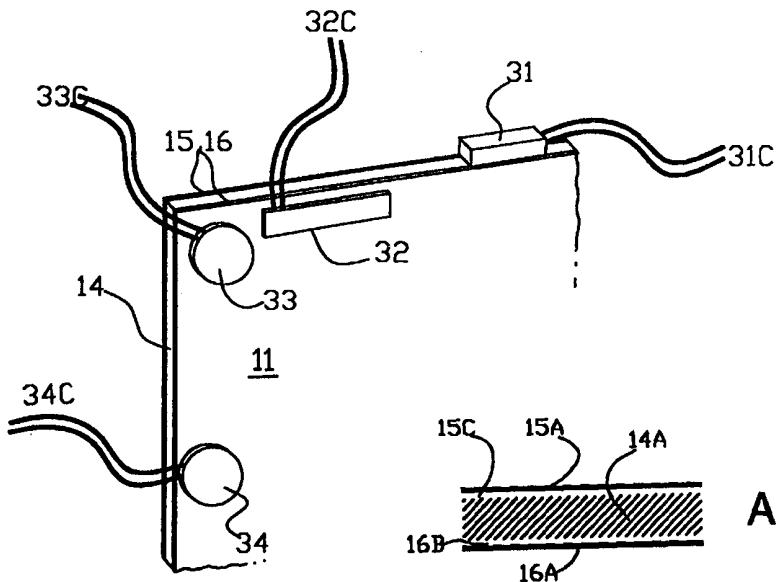
(57) Abstract

Active acoustic device comprises a panel member (11) having distribution of resonant modes of bending wave action determining acoustic performance in conjunction with transducer means (31–34). The transducer means (31–34) is coupled to the panel member (11) at a marginal position. The arrangement is such as to result in acoustically acceptable action dependent on said distribution of active said resonant modes. Methods of selecting the transducer location, or improvement by location of localised marginal clamping, rely on assessing best or better operative interaction of said transducer means (31–34) and the panel members (11) according to parameters of acoustic output for the device as an acoustic radiator.

5   ACTIVE ACOUSTIC DEVICES COMPRISING PANEL MEMBERS

10   <u>DESCRIPTION</u>

15 FIELD OF THE INVENTION

This invention relates to active acoustic devices and more

particularly to panel members for which acoustic action or

performance relies on beneficial distribution of resonant

modes of bending wave action in such a panel member and

20 related surface vibration; and to methods of making or

improving such active acoustic devices.

It is convenient herein to use the term "distributed

mode" for such acoustic devices, including acoustic

radiators or loudspeakers; and for the term "panel-form"

25 to be taken as inferring such distributed mode action in a

panel member unless the context does not permit.

In or as panel-form loudspeakers, such panel members

operate as distributed mode acoustic radiators relying on

bending wave action induced by input means applying
mechanical action to the panel member; and resulting
excitation of resonant modes of bending wave action
causing surface vibration for acoustic output by coupling

5 to ambient fluid, typically air.   Revelatory teaching
regarding such acoustic radiators (amongst a wider class
of active and passive distributed mode acoustic devices)
is given in our International patent application
WO97/09842; and various of our later patent applications

10 concern useful additions and developments.

BACKGROUND TO THE INVENTION

Hitherto, transducer locations have been considered as
viably and optimally effective at locations in-board of
the panel member to a substantial extent towards but

15 offset from its centre, at least for panels that are
substantially isotropic as to bending stiffness and
exhibit effectively substantially constant axial
anisotropy of bending stiffness(es).   Aforementioned
WO97/09842 gives specific guidance in terms of optimal

20 proportionate co-ordinates for such in-board transducer
locations, including alternatives; and preference for
different particular co-ordinate combinations when using
two or more transducers.

Various advantageous applications peculiar to the

25 panel-form of acoustic devices have been foreshadowed,
including carrying acoustically non-intrusive surfacing
sheets or layers.   For example, physically merging or
incorporating into trim or cladding is feasible, including

as visually virtually indistinguishable. Also, functional
combination is feasible with other purposes, such as
display, including pictures, posters, write-on/erase
boards, projection screens, etc. The capability
5 effectively to hide in-board transducers from view is
enough for many applications. However, there are
potential practical applications where it could be useful
to leave larger, particularly central, panel regions
unobstructed even by hideable transducers. For example,
10 for video or other see-through display use, pursuit of
translucence, even transparency, of panel members is not
worthwhile with such in-board intrusions of transducers,
though a panel-form acoustic device would be highly
attractive if it could afford large medial areas of
15 unobstructed visibility.

SUMMARY OF THE INVENTION

According to one device aspect of this invention, there is
provided a panel-form acoustic device comprising a
distributed mode acoustic panel member with transducer
20 means located at a marginal position, the arrangement
being such as to result in acoustically acceptable
effective distribution and excitement of resonant mode
vibration. Existence of suitable such marginal positions
is established herein as locations for transducer means,
25 along with valuable teaching as to judicious selection or
improvement of one or more such locations. Such judicious
selection may advantageously be by or as would result from
investigation of an acoustic radiator device or

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loudspeaker relative to satisfactorily introducing vibrational energy into the panel member, say conveniently by assessing parameters of acoustic output from the panel member concerned when excited at marginal positions or

5 locations. At least best results also apply to microphones.

From the relevant background teaching as of the time of this invention, availability of successful such marginal locations is, to say the least, unexpected.

10 Indeed, main closest prior art cited against WO97/09842, is the start-point for its invention and revelatory teaching, namely WO92/03024 from which progress was made particularly in terms of departing from in-corner excitation thereof. Such progress involved appreciating

15 that distributed resonant mode bending wave action as required for viable acoustic performance results in high vibrational activity at panel corners; as is also a factor for panel edges generally. At least intuitively, and as greatly reinforced by practical success with

20 somewhat off-centre but very much in-board transducer locations, such high vibrational activity compounds strongly with panel margins self-evidently affording limited access, thus likely available effect upon, panel member material as a whole; this compounding combination

25 contributing to previously perceived non-viability of edge excitation.

For application of this invention, a suitable acoustic panel member, or at least region thereof, may be

transparent or translucent. Typical panel members may be
generally polygonal, often substantially rectangular.
Plural transducer means may be at or near different edges,
at least for substantially rectangular panel members.

5 The or each transducer may be piezo-electric,
electrostatic or electro-mechanical. The or each
transducer may be arranged to launch compression waves
into the panel edge, and/or to deflect the panel edge
laterally to launch transverse bending waves along a panel

10 edge, and/or to apply torsion across a panel corner,
and/or to produce linear deflection of a local region of
the panel.

Assessment of acoustic output from panel members may
be relative to suitable criteria for acoustic output

15 include as to amount of power output thus efficiency in
converting input mechanical vibration (automatically also
customary causative electrical drive) into acoustic
output, smoothness of power output as measure of even-ness
of excitation of resonant mode of bending wave action,

20 inspection of power output as to frequencies of excited
resonant modes including number and distribution or spread
of those frequencies, each up to all as useful indicators.
Such assessments of viability of locations for transducer
means constitute method aspects of this invention

25 individually and in combination.

As aid to assessment at least of smoothness of power
output, it is further proposed herein to use techniques
based on mean square deviation from some reference. Use

of the inverse of mean square deviation has the benefit of
presenting smoothness for assessment according directly to
positive values and/or representations.   A suitable
reference can be individual to each case considered, say a
5 median-based, such as represented graphically by a
smoothed line through actual measured power output over a
frequency range of interest. It is significantly helpful
to mean square deviation assessment for the reference to
have a be normalised standard format;   and for the
10 measured acoustic power output to be adjusted to fit that
standard format. The standard format may be a graphically
straight line, preferably a flat straight line thus
corresponding to some particular constant reference value;
further preferably the same line or value as found
15 naturally to apply to a distributed mode panel member at
higher frequencies where modes and modal action are more
or most dense.

In this connection it is seen as noteworthy that
whatever function is required for such normalising to a
20 substantially constant reference is effectively also a
basis for an equalisation function applicable to input
signals to improve lower frequency acoustic output. It is
the case that viable distributed mode panel members as
such, and with preferential aspect ratios and bending
25 stiffness(es) as in our above patent application, may
naturally have acoustic power output characteristics
relative to frequency that show progressive droops towards
and through lower frequencies where resonant modes and

modal action are less dense - but, as their frequency distribution as such is usually beneficial to acoustic action in such lower frequency range, such equalisation of input signal can be useful. This lower acoustic power 5 output at lower frequencies is related to free edge vibration of the panel members as such, and consequential greater loss of lower frequency power, greater proportion of which tends to be poorly radiated and/or dissipated, including effectively short-circuited about free adjacent 10 panel edges.   As expected, these lower frequency power loss effects are significantly greater for panel members with transducer locations at or near their edges and/or lesser stiffnesses - compared with panel members using in-board transducer locations.   However, and separately from 15 any input signal equalisation, significant mitigation of these effects is available by mounting the panel members surrounded by baffles and/or by clamping at the edges of the panel members.   Indeed, spaced localised edge clamps can have usefully selectively beneficial effects relative 20 to frequencies with wavelengths greater than the spacing of the localised edge clamps.

Interestingly, for specific panel members of quite high stiffnesses, viable marginal transducer locations include positions having edge-wise correlation with 25 normally in-board locations for transducer means arising as preferred by application of teachings or practice such as specifically in our above patent applications.   When using transducer means in pairs, a first preference was

found for marginal transducer locations with said correlation as corresponding to notionally encompassing greatest area. For a substantially rectangular panel member, said correlation can be by way of correspondence

5 with orthogonal or Cartesian co-ordinates, with said first preference represented by associating transducer means with diagonally opposite quadrants. However, this was in relation to a particularly high stiffness/high-Q panel member, and is not always true, even for quite (but less)

10 stiff panels, see further below showing promising operation with association in some or adjacent quadrants. For an elliptical panel member said correlation/ correspondence can be according to hyperbolic resonant mode related lines as going edge-wards through the in-

15 board locations. Other variously less good, but feasibly viable, pairs of edge locations for transducer means were found by investigation based on rotating orthogonal vectors about in-board preferential transducer locations, including close to or at corner positions of panel

20 members. Another inventive aspect regarding corner or near-corner excitation involves suitably mass-loading or clamping substantially at a known in-board optimal or preferential drive location, where it appears that such mass-loaded optimal drive location(s) effectively

25 behave(s) to some useful extent as "virtual" source(s) of bending wave vibrations in the member. This latter may not avoid central intrusion by the mass loading but is clearly germane to successful marginal excitation at

corners.

Further investigations have been made, including of panel members having different stiffnesses, specifically again quite high but also much lower and intermediate

5 stiffness panels, in each case of usual substantially rectangular configuration with aspect ratios and axial bending stiffnesses generally as in WO97/09842.

For the higher stiffness panel member, assessment based on smoothness of power output for single transducer

10 locations along longer and shorter edges were generally confirmatory of above preferential coordinate positions, i.e. peaking as expected for best locations for single transducer means. However, additionally, longer edges had promising spreads of smoothness measure within about 15%

15 of peak at transducer locations between the co-ordinate positions in each half of the edge and beyond those coordinate positions to about one-third length from each corner; and within about 30% along to at least the quarter length positions. For the shorter edges, spreads

20 of smoothness measure were within about 10% between the co-ordinate positions, and within about 25% at quarter length positions. The shorter edges actually showed a better power smoothness measure than the longer edges showed at quarter length positions right through to within

25 about one-tenth length of the corners.

Investigation of combinations of two transducers has also been extended particularly for same and adjacent quadrants with one transducer, for one on each of longer

and shorter edges.   One transducer can be at one best
position along one of the edges for a single transducer,
with the other transducer varied along the other edge.
For variation along the shorter edge, above preference for
5 one of positions according to co-ordinates of in-board
preferential transducer locations is confirmed by best
smoothness measure at about six-tenths length.   There are
also near as good positions at three-quarter length and
only a little less good at quarter and third length
10 positions.   Moreover, most positions other than below
about one-tenth from a corner are better, similar, near as
good, or not much worse, than for association with co-
ordinates of preferred in-board locations in the same
quadrant.   For variation along the longer edge, the
15 shorter edge transducer was located at about preferred
near six-tenths position, there was then actually marked
preference for combinations of transducer locations in
adjacent quadrants, with best at just under one-fifth, and
slightly better than the 0.42 position at the one-third
20 length position with only a little worse at the one-tenth
length position.   The quarter length position is actually
about the same as for the mid-length position and the
adjacent quadrant position of the co-ordinate of preferred
in-board location.   Self-evidently, these procedures may
25 be continued on an iterative basis, and may then reveal
more favourable combinations.

    Investigations of much lower stiffness panel members
on the basis of smoothness of power output have shown

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peaking for marginal transducer locations also at about the in-board co-ordinate position, but near as good at quarter length of panel edges, and generally markedly less criticality as to position along the edges in terms of

5 actual achieved modal distribution. This is seen as explicable by interaction between the lower panel stiffness and compliance within the used transducer itself. It appears that the resonant modal distribution of the panel is affected and altered by the transducer

10 location, at least to some extent going with such location. Higher panel stiffnesses substantially avoid such effects. However, such in-transducer compliance and possible interaction with panel stiffness/elasticity is clearly another factor to be taken into account, including

15 exploited usefully.

Investigations of panel members with quite high and much lower stiffnesses clearly reveal rather different cases for application of marginal excitation, including as to more and less criticality as to transducer locations,

20 whether singly or in pairs, and as to less or more interaction with in-transducer compliance. It is thus appropriate to consider a panel member of intermediate stiffness.

For such intermediate stiffness panel member, and

25 much as expected, differences relative to the much lower stiffness panel member include increase in acoustic power output available by edge clamping, markedly increased power for mid-range frequency modes, and stronger modality

or peakiness for lower-frequency modes. Tendency towards characteristics of the higher stiffness panel member include stronger preference as best single transducer locations for edge positions on a co-ordinate of optimal in-board transducer locations, also promising feasibility for through the mid-point, but perhaps also at about one-tenth in from corners. For two marginally located transducer means, marked preference resulted for the co-ordinate related position of optimal in-board transducer location, with less good but likely viable spread to middle and two-thirds length positions and equality of same quadrant co-ordinate related and two-thirds length positions.

It is evident that differences in materials parameters of panel members beyond basic capability to sustain bending wave action are significant in determining marginal transducer locations; and that use of two or more such transducer locations produces highly individual solutions requiring experimental assessment such as now enabled by teachings hereof.

Also, at least specifically for tested substantially rectangular panel members, it has been found that many if not most, probably going on all, of edge or near-edge locations for transducer means that are unpromising as such can be significantly improved (as to bending wave dependent resonant mode distribution and excitement into acoustical response of the member) if associated with localised mass-loading or clamping at one or more selected

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other marginal position(s) of the panel member concerned. Inventive aspects thus includes association of a said drive means position with helpful other mass-loading or clamping position marginal of the panel member.

5   Regarding use of two or more transducer means, exhaustive investigation of combinations of marginal locations is impractical, but teaching is given as to how to find best and other viable marginal locations for second transducer means for any given first transducer 10 marginal location.   Indeed, yet further marginal transducer locations could be investigated and assessed according to the teaching hereof. Somewhat likewise, use of localised marginal damping for improving performance for any given transducer marginal location is 15 investigatable and assessable to any extent and number using the teaching hereof, whether for enhancing or reducing contributions of some resonant mode(s), otherwise deliberately interfering with other resonant mode(s), or mainly to increase output power.

20   It believed to be worthwhile generally to take into account the fact that lowest resonant modes are related to length of the longest natural axis of any panel member, thus that longer edges of substantially rectangular panel members are sensibly always favoured for location of 25 transducer means, including doing so wherever feasible at the best position for operation with single transducer means. It is sensible to see this as applying even where use of another transducer means is encouraged or intended,

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again whether for enhancing some resonant mode(s),
deliberately interfering with other resonant mode(s) or
mainly to increase output power.

Also relevant as a general matter is the fact that
5 the operating frequency range of interest should be made
part of assessment of location for transducer means, and
may well affect best and viable such locations, i.e. could
be different for ranges wholly above and extending below
such as 500 Hz. Another influencing factor could be
10 presence of an adjacent surface, say behind the panel
member at a spacing affecting acoustic performance.

It is inferred or postulated that the nature of
preferred said edge or edge-adjacent position(s) tend
towards what is fore-shadowed in our above PCT and other
15 patent applications, typically viewed as affording
coupling to more approaching most frequency modes, and
doing so more rather than less evenly, perhaps typically
avoiding dominance of up to only a few frequency modes.

Such suitability may be for lower rather than higher total
20 actual vibrational energy locally in the panel member, but
high as to population by frequency modes, i.e. rather than
"dead" in the sense of little or no coupling to any or few
modes.

BRIEF DESCRIPTION OF THE DRAWINGS
25 Specific implementation for the invention is now
diagrammatically illustrated and described in and with
reference to by way of example, in the accompanying
drawings, in which:-

Figure 1 shows a distributed mode acoustic panel with a fitted transducer as generally described in the above PCT application;

Figure 2 shows outline indication of four different
5 ways of marginal or edge excitation an acoustic panel;

Figure 3 shows possible placements of transducers marginally of an acoustic panel to achieve actions shown in Figure 2, and Figure 3A shows transparent such panel;

Figure 4 shows four favoured marginal locations for
10 transducers shown in outline, relative to an in-board location of Figure 1 shown in phantom;

Figure 5 shows the same four favoured locations relative to another preferential in-board drive location and favoured pair of the complementary or phantom in-board
15 drive location;

Figure 6 indicates how any pairs and all four drive transducers at such favoured locations were connected for testing;

Figure 7 shows viable if less favoured pairs of
20 marginal drive transducer locations;

Figure 8 shows corner drive position and helpful mass-loading at an in-board preferential drive location;

Figures 9 and 9A show four normally unfavoured marginal drive transducer locations together with many
25 marginal mass-loading or clamping positions and how test masses and drive transducers were associated with the panel; and

Figure 10 shows in-board area unobstructed within

marginal positions for drive transducer(s), clamp termination(s) and resilient suspension/mounting.

Figures 11A, B are graphs of output power/frequency for a substantially rectangular panel member of quite high 5 stiffness and single transducer positions along longer and shorter edges;

Figures 12A, B are related bar charts for measures of smoothness of output power;

Figures 13A, B are graphs of output power/frequency 10 for two transducer positions with one varied along shorter or longer edges;

Figures 14A, B are related bar charts for measures of smoothness of output power;

Figures 15A, B are output power/frequency graphs and 15 related power smoothness bar chart for a panel member of much lower stiffness and single transducer positions along the longer edge;

Figures 16A, B are output power/frequency graphs and power smoothness bar chart for second transducer positions 20 along the shorter edge;

Figure 17 shows comparison of power outputs with transducers located preferentially in-board and at edge for the low stiffness panel member;

Figures 18A, B, C show effects of baffling, three-25 edge clamping and both;

Figures 19A, B are output power/frequency graphs and related power smoothness bar chart for the low stiffness panel member clamped along on three edges and transducer

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positions on the fourth edge;

Figures 20A, B are output power/frequency graphs and related power smoothness bar chart for the low stiffness panel member clamped on two parallel edges sides and 5 transducer positions on another edge;

Figures 21A, B are output power/frequency graphs and related power smoothness bar chart for the low stiffness panel member with localised clamping at corners/mid-edges and transducer positions on other longer edge;

10   Figure 22 is a power smoothness bar chart for the low stiffness panel member with further localised clamping between other corner/mid-point clamping;

Figures 23A, B are bar charts for power assessment without normalisation for the low stiffness panel member 15 with three edge clamping of seven-point and full edge nature, respectively, and for position of another local clamp along the other edge at which transducer means has an unfavourable position;

Figures 24A, B are power output/frequency graphs and 20 related power smoothness bar chart for the three-edge clamped case assessed with normalisation;

Figures 25A, B are power output/frequency graphs and related power smoothness bar charts for a panel member of intermediate stiffness and single transducer positions 25 along the longer edge with normalisation;

Figures 26A, B are output power/frequency graphs and power assessment bar chart for the intermediate stiffness panel member with seven point localised clamping assessed

without normalisation;

Figures 27A, B are similar but with normalising for power smoothness assessment;

Figures 28A, B are power output graph and power

5 smoothness bar chart for the intermediate stiffness panel member and a second transducer position along shorter edge;

Figure 29 indicates seven- and thirteen- point localised clamping as applied above;

10   Figure 30 is a schematic diagram useful in explaining impact of in-transducer compliance, and

Figures 31A-E are power efficiency bar charts for the lower stiffness panel member for different edge conditions.

15 DESCRIPTION OF ILLUSTRATED EMBODIMENTS

In Figure 1, distributed mode acoustic panel loud-speaker 10 is as described in WO97/09842 with panel member 11 having typical optimal near- (but off-) centre location for drive means transducer 12. The sandwich structure

20 shown with core 14 and skins 15, 16 is exemplary only, there being many monolithic and/or reinforced and other structural possibilities. In any event, normal in-board transducer placement potentially limits clear area available, e.g. for such as transmission of light in the

25 case of a transparent or translucent panel.

Mainly transparent or translucent resonant mode acoustic panel members might use known transparent piezo-electric transducers, e.g. of lanthanum doped titanium

zirconate. However these are relatively costly, hence the
alternative approach thereof by which it is possible to
leave the resonant mode acoustic panel member 10 mainly
clear and unobstructed by optimising loudspeaker design
5 from a choice of four types of excitation shown in Figure
2 directed to the margins or perimeter of the panel, and
labelled as types T1 - T4, as follows:-

T1 - launching compression waves into an edge (shown along
        18A) of the panel member 11 - as available by
10   inertial action or reference plane related drive
        transducers

T2 - launching transverse bending waves along an edge
        (also shown along 18A) of the panel member 11 - as
        available by laterally deflecting the panel edge
15   using bender action drive transducers

T3 - applying torsion to the panel member 11 as shown
        across a corner between edges 18A, B - available by
        action of either of bender or inertial type drive
        transducers

20 T4 - producing linear deflection directly at an edge of
        the panel member 11 as shown at edge 18B - available
        at local region of contact by inertial action drive
        transducers.

        Figure 3 is a scrap view of composite panel 11
25 showing high tensile skins 15, 16 and structural core 14
with drive transducers/exciters 31 - 34 for the above-
mentioned four types T1 - T4 of edge/marginal drive. In
practice, fewer than four drive types might be used at the

same time on a panel which can usefully be acoustically

and mechanically optimised for the desired bandwidth of

operation and for the particular type of drive employed.

Thus, an optimised panel may be driven by any one or more

5 of the different drive types.

A transparent or translucent edge-driven acoustic

panel could be monolithic, e.g. of glass, or of skinned

core structure using suitable translucent/transparent core

and skin materials, see Figure 11. Interpretation with a

10 a visual display unit (VDU) may enable the screen also to

be used as a loudspeaker, can have suitably high bending

stiffness along with low mass if comprising a pair of

skins 15A, 16A sandwiching a lightweight core of aerogel

material 14A using transparent adhesive 15B, 16B. Aerogel

15 materials are extremely light porous solid materials, say

of silica. Transparent or translucent skin or skins may

be of laminated structure and/or made from transparent

plastics material such a polyester, or from glass.

Conventional transparent VDU screens may be replaced by

20 such a transparent acoustic radiator panel, including with

acoustic excitation outside unobstructed main screen area.

A particular suitable silica aerogel core material is

(RTM) BASOGEL from BASF. Other feasible core materials

could include less familiar aerogel-forming materials

25 including metal oxides such as iron and tin oxide, organic

polymers, natural gels, and carbon aerogels. A particular

suitable plastics skin laminates may be of polyethylene

terephthalate (RTM) MYLAR, or other transparent materials

with the correct thickness, modulus and density. Very high shear modulus of aerogels allow extremely thin composites to be made to suit miniaturisation and other physically important factors and working under distributed 5 mode acoustic principles.

If desired, such transparent panel could be added to an existing VDU panel, say incorporated as an integral front plate. For a plasma type display the interior is held at low gas pressure, close to vacuum, and is of very 10 low acoustic impedance. Consequently there will be negligible acoustic interaction behind the sound radiator, resulting in improved performance, and the saving of the usual front plate. For film type display technologies, again the front transparent window may be built using a 15 distributed mode radiator while the display structures behind may be dimensioned and specified to include acoustic properties which aid the radiation of sound from the front panel. For example partial acoustic transparency for the rear display structures will reduce 20 back wave reflection and improve performance for the distributed mode speaker element. In the case of the light emitting class of display, these may be deposited on the rear surface of the transparent distributed mode panel, without significant impediment to its acoustic 25 properties, the images being viewed from the front side.

A transparent distributed mode loudspeaker may also have application for rear projection systems where it may be additional to a translucent screen or this function may

itself be incorporated with a suitably prepared surface for rear projection. In this case the projection surface and the screen may be one component both for convenience and economy but also for optimising acoustic performance.

5 The rear skin may be selected to take a projected image, or alternatively, the optical properties of the core may be chosen for projection use. For example in the case of a loudspeaker panel having a relatively thin core, full optical transparency may not be required or be ideal,

10 allowing the choice of alternative light transmitting cores, e.g. other grades of aerogel or more economical substitutes. Special optical properties may be combined with the core and/or the skin surface to generate directional and brightness enhancing properties for the

15 transmitted optical images.

Where the transparent distributed mode speaker has an exposed front face it may be enhanced, for example, by the provision of conductive pads or regions, visible, or transparent, for user input of data or commands to the

20 screen. The transparent panel may also be enhanced by optical coatings to reduce reflections and/or improve scratch resistance, or simply by anti scratch coatings. The core and skin for the transparent panel may be selected to have an optical tint, for colour shading or in

25 a neutral hue to improve the visual contrast ratios for the display used with or incorporated in the distributed mode transparent panel speaker. During manufacture of the transparent distributed model panel, invisible wiring,

e.g. in the form of micro-wires, or transparent conductive films, may be incorporated together with indicators, e.g. light emitting diodes (LED) or liquid crystal displays (LCD) or similar, allowing their integration into the

5 transparent panel and consequent protection, the technique also minimising impairment to the acoustic performance. Designs may also be produced where total transparency is not required, e.g. where one skin only of the panel has transparency to provide a view to an integral display

10 under that surface.

The transducers may be piezo-electric or electro-dynamic according to design criteria including price and performance considerations, and are represented in Figure 3 as simple outline elements simply bonded to the panel by

15 suitable adhesive(s). For above T1 type drive excitation, inertial transducer 31 is shown driving vertically directed compression waves into the panel 30. For above T2 type of drive excitation, bending type of transducer 32 is shown operative for directly bending regionally to

20 launch bending waves through the loudspeaker panel 30. For above T3 type of drive excitation, inertial transducer 33 is shown serving to deflect the panel corner in driving into the diagonal and thence into the whole loudspeaker panel 30. For above type T4 drive excitation another

25 inertial transducer 34 is shown of block or semi-circular form serving to deflect an edge of the loudspeaker panel 30.

Each type of excitation will engender its own

characteristic drive to the panel 30 which is accounted
for in the overall loudspeaker design including parameters
of the panel 30 itself. The placement of the transducers
31 - 34 along the panel edge is in practice iterated with
5 the panel design parameters for optimum or at least
operationally acceptable modal distribution of bending
waves. It is envisaged that, according to the panel
characteristics, including such as controlled loss for
example, and the location(s) and type(s) of marginal edge
10 or near-edge drive, more than one audio channel may be
applied to the panel 30 concerned, e.g. via plural drive
transducers. This multi-channel potential may be
augmented by signal processing to optimise the sound
quality, and/or to control the sound radiation properties
15 and/or even to modify the perceived channel-to-channel
separation and spatial effects.

Particularly satisfactory drive transducer locations
along edges of a substantially rectangular panel member
are at edge positions reached by orthogonal side-parallel
20 lines or co-ordinates through an in-board optimal or
preferential drive transducer position according to our
above PCT application, see dashed at 42 to 45 - 48 in
Figure 4. It is actually practical to use drive
transducers at at least two such co-ordinate related edge
25 locations 45 - 48. Figure 6 shows in-phase serial and
serial/parallel connections for two and four drive
transducers at A and B. Other driver connections are
feasible, and may often be preferred, including directly

one-to-one to each transducer means; and any desirable signal conditioning may be applied, e.g. differential delay(s), filtering etc, say to suit reduction of undesirable interaction between transducers and/or with

5 electrical signal source and favoured drive transducer positions CP1 - CP4 in Figure 5 relative to in-board preferential location PL. Pairing can be one from each co-ordinate, i.e. CP1 and CP2, CP2 and CP3, CP3 and CP4, CP4 and CP1, and a first favoured pairing is the one

10 notionally defining included area that is greatest, indeed, contains the geometrical centre X. Such notional area will, of course, further pass through or contain other usual optimal or preferential in-board drive transducer position, see complementary location CL and

15 indication at CP5 and CP6 for the first favoured pairing of drive transducer locations.

It has been interesting to note for a very high Q panel that preferred and most preferred pairs of orthogonal co-ordinate related drive locations can produce

20 low frequency output that may be more extended and uniform even than prior preferential in-board much nearer centre positions, albeit with some moderate variation in the higher frequency range. Off-axis response is similar at higher frequencies but actually somewhat more symmetrical

25 at lower frequencies.

Figure 7 shows select results of an experiment where pairs of transducers for which orthogonal angular relative relation is maintained centred on above normal inboard

preferential transducer location, specifically most
beneficial for co-ordinate related marginal drive
locations SP1 and SP4, but the transducers are tested at
positions relatively translated round the panel edge.

5 Most viable/promising pairs of locations are indicated at
pairs of positions 1a, 1b to 6a, 6d. Figure 7 actually
also shows results of another experiment where pairs of
transducers were at opposite ends of straight lines
through the preferential in-board drive location SP1, 2.

10 Fewer viable/promising locations were found at positions
2a, 2d and 3a, 3d. More experimental work may well be
worthwhile relative to other pairs or more of edge-drive
positions, and theoretical/systematising work is being
attempted. It will be appreciated from dimensions quoted

15 and as measured at pairs of positions giving
viable/promising measured/assessed results that Figure 7
is not strictly to scale.

Figure 8 shows a panel 70 of core 74 and skins 75, 76
structure, and having near-corner-mounted transducer 72

20 with mass loading 78 substantially at an otherwise normal
in-board preferential transducer, actually the one or in
the group furthest away from the corner of excitation by
the transducer 72, which is found to be particularly
effective in appearing to behave as a "virtual" source of

25 bending wave vibrations. It can be advantageous for the
transducer to avoid or at least couple outside a position
with a co-ordinate location substantially centred at 5% of
side dimensions from the corner as such, where it has been

established that many resonant mode(s) have nodes, i.e.
low vibrational activity.

Turning to Figure 9, outline is indicated for an
investigation involving select single positions for one
5 edge or edge-adjacent transducer mounting, see at ST1 -
ST4 for in-corner, half-side length, quarter-side length
and three-eighths side-length, respectively; and select
positions for edge-clamping/mass-loading at edge positions
about the panel. An exciting transducer was used, see 92
10 in Figure 9A relative to panel 90, along with loads/clamps
by way of panel flanking/gripping 93A/B magnets.

Performance using the corner exciting transducer
position ST1 was aided by mass-loading as in Figure 9A at
positions Pos. 13, 14, 18, 19 - including in further
15 combination with other positions. For exciting transducer
position ST2, good single mass-loading positions are Pos.
6, 7, 8 perhaps 9, 11 particularly, 12, 15 - again
including combinations with other positions. Combinations
5 = 11 and 6 + 11 were of particular value, including in
20 further combinations. For exciting transducer position
ST3, good single mass-loading positions are Pos. 5, 6, 7,
13, especially the combinations 5 + 13 and 10 + 13, the
combination 6 + 18, and combinations/further combinations.

For exciting transducer position ST4, best positions
25 appear to be 6, 18 but neither was as good as those for
the other exciter positions ST1 - ST3.

Figure 10 shows a panel-form loudspeaker 80 having an
in-board unobstructed region 81 extending throughout and

beyond normal in-board preferential drive transducer locations, and a marginally located transducer 82. The region 81 may serve for display purposes directly, or represent something carried by the panel 80 without

5 affecting acoustic performance, or something behind which the loudspeaker panel 80 passes, say in close spacing and/or transparent or translucent. Both of loudness and quality are readily enhanced, the former by additional drive transducers judiciously placed (not shown), and

10 quality by localised edge clamping(s) 83 beneficially to control particular modal vibration points effectively as panel termination(s). The panel 80 is further indicated with localised resilient suspensions 84 located neutrally or even beneficially regarding achieved acoustic

15 performance. High pass filtering 85 is preferred for input signals to drive transducer(s) 82, conveniently to limit to range of best reproduction, say not below 100Hz for A4-size or similar panels. Then, there should not be any problematic low-frequency panel/exciter vibration.

20   It is advantageous in terms for acoustic performance to control acoustic impedance loading on the panel 80, say to be relatively low in the marginal or peripheral region, especially in the vicinity of the drive transducer(s) 82 where surface velocity tends to be high. Beneficial such

25 control provision includes significant clearance to local planar members (say about 1 - 3 centimetre) and/or slots or other apertures in adjacent peripheral framing or support provision or grille elements.

29

It is further feasible and advantageous deliberately to arrange for such as mechanical damping to result in acoustic modification including loss in the area 81, or even also marginally thereof, not to be obstructed, at

5 least for higher frequencies. This may be done by choice of materials, e.g. monolithic polycarbonate or acrylic and/or suitable surface coating or laminated construction. Resulting effective concentration of acoustic radiation to marginal regions about plural drive transducers

10 particularly facilitates reproduction of more than one sound channel, at least for near-field listening as for playing computer games or like localised virtual sound stage applications. Further away, merging even of multiple as-energised sound sources need not be

15 problematic when summed, at least for such as audio visual presentations.

The following Table gives relevant physical parameters of actual panel members used for investigation to which Figures 11-28 relate.

20

25

	Lower Stiffness Panel	Higher Stiffness Panel	Intermediate Stiffness panel
Core material	Rohacell	Al honeycomb	Rohacell
Core thickness	1.5mm	4mm	1.8mm
Skin material	Melinex	Black glass	Black glass
Skin thickness	50 μm	102 μm	102 μm
Panel Area	0.06m2	0.06m2	0.06m2
Aspect ratio	1:1.13	1:1.13	1:1.13
Bending stiffness	0.32 Nm	12.26 Nm	2.47 Nm
Mass density	0.35 kgm-2	0.76 kgm-2	0.6 kgm-2
Zm	2.7 Nsm-1	24.4 Nsm-1	9.73 Nsm-1

Figures 11-14 relate to the higher stiffness panel member of the first column, Figures 15-24 to the much 5 lower stiffness panel member of the second column, and Figures 25-28 to the intermediate stiffness panel member of the third column.

All of the graphs have acoustic output power (dB/W) as ordinate and frequency as abscissa, thus show measured 10 acoustic output power as a formation of frequency, typically as a truly plotted dotted line. Most of the graphs also show an upper adjustment of the true power line. As mentioned in the preamble, this adjustment is by way of applying functions that normalise to a flat 15 straight line, and allows assessment of resonant modality free of often encountered effects of fall-off of power at

lower frequencies. It is found that smoothness of power
makes significant contribution to quality of sound. From
such normalised value of the actual power output, it is
advantageous to produce assessment of smoothness by
5 inverse of mean square deviation, and most of the bar
plots are of that type.

The higher stiffness panel member for Figures 11-14
is actually somewhat less stiff than that used for
previous Figures 7 and 9, but does clearly show preference
10 for single transducers to be located at positions
corresponding to co-ordinates of in-board transducer
locations previously established as optimal, i.e. at about
3/7, 4/9 length from any corner or about 0.42-0.44.
However, there are substantial spreads of promising
15 potential location between and beyond such positions for
each edge, actually within about 10% and 15% in the mid-
regions of shorter and longer edges, respectively, and
further within 28% and 30% at quarter-length positions.

At least for the most part, trial positions for
20 transducer edge or near edge location are based on spacing
substantially corresponding to the difference between the
preferential co-ordinate value of 0.42 for in-board
transducer location and the mid-point (0.5) of the edge,
albeit with alternate spacings increased to 0.09. Usual
25 trial locations are thus 0.08, 0.17, 0.28, 0.33, 0.42,
0.50.

In the main, it is believed that the illustrated
graph and bar charts are substantially self-explanatory as

to showing best and presumably promising locations for transducers, and for localised clamping as feasible for improving less promising transducer locations, see Figures 23.

5   As far as single transducer edge or near-edge location is concerned, the other two tested panel members of much lower and intermediate stiffnesses also show the same in-board co-ordinate preference on a smoothness of power basis, see Figures 15 and 25. However, the lower

10 stiffness panel member shows another band of nearly as promising locations ranging from about quarter to below tenth length from corners. Interestingly, if assessment is based on efficiency, i.e. amount of power output - as would be the case for a median line through the true

15 output power plot being the basis used for mean square deviation - the above band becomes skewed to emphasise the quarter length position and is mostly preferential to the in-board coordinate related position, see inverse mean square deviation bar chart of Figure 31A. The

20 intermediate stiffness panel member veers towards the characteristic of the higher stiffness panel member in showing a promising spread between the in-board preferential coordinate positions, but also shows promise at about the one-tenth length positions.

25   It will be appreciated from inspection of true output power plots by those skilled in the art that there are differences between indicated best and viable transducer edge locations in terms of impact on expected quality of

sound reproduction - for which modality is normally taken as a significant factor, i.e. number and evenness of excitation of resonant modes. If characteristics such as modality are seen as more promising for locations
5 indicated as preferential on the basis of assessing smoothness of output power, it is, of course, feasible to process input signals towards what is shown after above normalising - specifically selectively to amplify low frequency in a form of signal conditioning or equalising.
10 This would achieve, indeed exceed, power available using locations optimised on efficiency basis; but obviously not the efficiency itself as more input power has to be used.

Accordingly, other ways of increasing lower frequency
15 power were investigated as foreshadowed above, namely baffling and/or selectively spaced local clamping or full edge clamping. Figures 18A, B, C give indication of generally beneficial raising of lower frequency output for surrounding baffling with an area over 60% greater than
20 the low stiffness panel, rigid clamping of all three edges not affording transducer location, and both of such baffling and clamping. Such baffling tends to maintain modality but may not always be feasible in specific applications. Accordingly, full investigation of clamping
25 seemed worthwhile for alternative transducer edge locations for the lower stiffness panel member. Results showed that assessment on an efficiency basis tended to emphasise the quarter length point for both of full edge

clamping at true parallel edges or three edges, and 7-point local edge clamping at corners and mid-points as at 'X' in Figure 29, with the edge of transducer location unclamped along its length, see bar charts of Figures 31B, 5 C and D, respectively. However, 13-point clamping as at 'X' + 'O' in Figure 29 shifted emphasis strongly to the in-board preferential coordinate position. Assessment of panel members with clamping on the basis of power smoothness produces much the same results for indication 10 of best transducer locations, see bar charts of Figures 19A, 20B, 21B and 22, but with considerable differences as to next favoured positions, as is generally confirmed by inspection of true output power plots.

Indeed, particularly strong general correlation is 15 found between preferences based on skilled inspection and assessment according to smoothness of power output. In turn, this tends to confirm at least slight preference for such assessment unless there are practical factors that lead to preference for efficiency rather than quality - 20 though that may not be much different anyway.

Another application for localised edge clamping is in relation to improving an unpromising transducer edge location, see bar charts Figures 23A, B showing right hand rather than left hand sides of the edge concerned as 25 otherwise in the drawings. The cases concerned relate to the lower stiffness panel member, and are full clamping of three edges and seven point clamping, with a localised clamp varied along the same edge as the transducer means.

In both cases, useful improvement results at about the
quarter length position from the corner more remote from
the exciter - see reference bar at right hand side of
Figure 23B for no clamping condition. The spread is
5 greater for the full edge clamping case, see Figure 23A.

Where there is disagreement between assessments based
on power efficiency and power smoothness, it is worth
bearing in mind that any panel member with clamping of
corners to the edge with which the transducer is
10 associates effectively has forced nulls at the corner.
There thus must be up to half wavelengths distance for
resonant modes concerned before vibrational activity can
reach anti-nodal peaks. If preference for a close-to-
corner transducer location is indicated by power
15 smoothness assessment, it should be treated with caution
as it could be of low power/efficiency, even though smooth
by reason of coupling to all resonant mode waveform
concerned at may be quite small rises in their waveforms.
Checking with the corresponding power/efficiency
20 assessment is thus recommended. Indeed, best is always
likely to be where there is substantial agreement between
the two bases of assessment, or some compromise
particularly suited to a specific application; and
preferably further taking account of skilled inspection of
25 power/frequency graphs perhaps advantageously with as well
as without any normalisation for assessment purposes.

For the investigated panel members with higher and
intermediate stiffnesses, there is a considerable measure

of consistency as to best transducer edge locations, but with quite marked difference as to other promising locations. The much lower stiffness panel member is markedly less critical as to promising transducer edge

5 locations.

This position is yet more apparent when considering use of more than one transducer means associated with edges of the same panel member. The position for increased coupling to the resonant modes of a panel member

10 is accompanied by complexity of their inevitable combined interaction with the natural distributed resonant vibration pattern of the panel member, and compounded by such distributed vibration pattern being available only at panel edges. There are notable variations from simple

15 rules such as based on coordinates of established preferential in-board transducer location. However, the assessment procedures hereof afford valuable tools for finding good combinations of edge-associated transducer locations.

20   For the higher stiffness panel of the above Table, Figures 13A, 14A one transducer means is located at a position within the tolerance range of about 0.38-0.45 for the 0.42 preferred position for single transducer means along the longer edge. Second transducer means is varied

25 along the closest shorter edge and Figure 14A shows marginal preference for the furthest 0.42 preferred position, i.e. centred at 0.58, compared with several other positions at about quarter, third and two-thirds

lengths from the common corner. Interestingly, fixing the second transducer means at such about 0.58 preferred position along the shorter panel edge, and varying the other transducer along the longer pane edge (see Figures 13B, 14B), produced best and next best preferences at about the one-fifth (0.17) and quarter length positions along the longer panel edge, both showing better than the start position (about 0.42) for power smoothness. This is a procedure clearly capable of further application in an iterative manner, though it is recommended that either or both of power/efficiency assessment and skilled inspection be deployed, particularly if there is no convergence of location in the procedure or any indicated good position is less good in practice than hoped (or was before in the procedure).

Figures 16A, B show results of investigation of the much lower stiffness panel member with the preferred about 0.42 transducer location used for the longer edge and a second transducer varied along the nearest shorter edge. There were no great differences in power smoothness increase, the best three approaching corners and the nearest 0.42 preferential position, with some otherwise general preference for associations being in some quadrant.

The same investigation for the intermediate stiffness panel member showed strong preference for the adjacent quadrant preferential 0.42 transducer location (actually 0.58), see Figures 28A, B.

Reverting to the case of the much less stiff panel member, two effects are seen as contributing to much less well-defined best/near best exciter position. One is that the panel modes for the range of frequencies of the

5 optimisation are higher than for stiffer panel members. The panel member is therefore a closer approximation to a continuum, and smoothness of output power is less dependent on transducer position, particularly second transducer positions.

10   The other effect concerns the much lower mechanical impedance of the panel member, which leads to a less strong dependence on transducer position for energy transfer. The mechanism involved is now explained.

The mechanical impedance (Zm) of a panel member

15 determines the movement resulting for an applied point force, see 100, 101 in Figure 30. An object associated with the panel with a mechanical impedance put very much less than, even approaching comparable to, the panel impedance will strongly offset panel motion where the

20 object is located. Associating an exciting transducer of moving coil type with the panel is equivalent to connecting the panel to a grounded mass (the magnet cup of the transducer, see 102) via a spring (the voice coil suspension of the transducer, see 108). When the

25 impedance of such spring is too close to the panel impedance, it will in some part determine the panel motion at the transducer. In the limit of this spring wholly determining the point motion at the transducer, there

would be no dependence of input power on exciter position.
In practice the ratio of spring impedance to panel
impedance can so profoundly affect best transducer
location, and results are no longer so clear for best/near
5 best transducer locations.

This low mechanical impedance has more effect for
edge transducer location than for in-board transducer
location as mechanical impedance is yet lower at the panel
edge, which means that a transducer, voice coil suspension
10 has a larger effect. Specifically, for the lower
stiffness panel of the above Table:

mechanical impedance in the body of the panel is

$Zmbody=2.7 Nsm-1$

mechanical impedance at the panel edge is approximately
15 half Zmbody, i.e.

$Zmedge=1.3 Nsm-1$

Compliance of the voice coil suspension of the transducer
used is:

$Cms=0.52x10-3 mN-1$

20   The mechanical impedance at each of modal frequencies
can be an order of magnitude lower than the average
impedance, Zmedge. It is therefore feasible to estimate a
typical frequency, below which the exciter has a strong
effect on the panel member, say where impedance of the
25 voice coil suspension is about one-fifth of the average
impedance at the panel edge. Then,

$$\frac{1}{} \qquad \frac{1}{}$$

40

$$= \quad \text{x Zmedge}$$

$$\omega \text{ x Cms} \qquad 5$$

and gives an estimate of 1200 Hz, below which the transducer and panel are intendedly coupled, which is
5 within the frequency range of optimisation.

Considering the transducer and such low mechanical impedance, panel member as one coupled system the transducer in part determines the impedance of the panel member, and smoothness of the output power is less
10 dependent on the position of the transducer.

Repeating such analysis for the high stiffness panel gives a corresponding frequency of 130Hz, which is outside the frequency range of the optimisation.

CLAIMS

1.   Active acoustic device comprising a panel member having distribution of resonant modes of bending wave action determining acoustic performance in conjunction
5   with transducer means coupled to the panel member, wherein the transducer means is located at a marginal position of the panel member, the arrangement being such as to result in acoustically acceptable action dependent on said distribution of active said resonant modes.

10 2.   Active acoustic device according to claim 1, wherein said marginal position has been selected for best or better operative interaction of said transducer means as located thereat with said panel member as to numbers and frequencies of said resonant modes involved in operation
15 of said transducer means in conjunction with said panel member.

3.   Active acoustic device according to claim 1 or claim 2, wherein said marginal position has been selected for best or better operative interaction of said transducer
20 means as located thereat with said panel member as to power of acoustic output as an acoustic radiator or loudspeaker.

4.   Active acoustic device according to claim 1, 2 or 3, wherein said marginal position has been selected for best
25 or better operative interaction of said transducer means as located thereat with said panel member as to smoothness of acoustic output power as an acoustic radiator or loudspeaker.

5. Active acoustic device according to any preceding claim, wherein said panel member has edge clamping means.

6. Active acoustic device according to claim 5, wherein said edge clamping means is localised.

5 7. Active acoustic device according to claim 6 with claim 1, wherein said arrangement includes said localised edge clamping means being located to improve acoustic operation of the device in conjunction with said transducer means located at a said marginal position not 10 itself selected for best operative interaction with said panel member.

8. Active acoustic device according to claim 6, having plural said localised edge clamping means.

9. Active acoustic device according to claim 7, wherein 15 mutual spacing of said plural localised edge clamping means is related to wavelengths of lower frequency resonant modes so as to raise their contribution to acoustic action of the device.

10. Active acoustic device according to claim 7, 8 or 9 20 wherein said panel member is of plural-sided form with said localised edge clamping means associated with more than one side.

11. Active acoustic device according to claim 10 with claim 8, wherein said panel member is substantially 25 rectangular with said plural localised edge clamping means associated with three sides not associated with said transducer means.

12. Active acoustic device according to claim 11, wherein

said plural localised edge clamping means are at each corner and at mid-points of said three sides.

13. Active acoustic device according to claim 5, wherein said edge clamping means extends along said panel member.

14. Active acoustic device according to claim 13, wherein said panel member is of plural sided form and said edge clamping means extends along at least one side not associated with said transducer means.

15. Active acoustic device according to claim 14, wherein said panel member is substantially rectangular and said edge clamping means extends along two parallel sides.

16. Active acoustic device according to claim 14, wherein said edge-clamping means extends along three sides.

17. Active acoustic device according to any preceding claim, wherein said panel member has at least two said transducer means in edge association therewith.

18. Active acoustic device according to claim 17, wherein said panel member is of plural sided form with said transducer means associated with at least two side edges.

19. Active acoustic device according to claim 17 or claim 18, wherein said panel member is substantially rectangular with said transducer means associated with longer and shorter sides.

20. Active acoustic device according to any preceding claim, wherein at least one said marginal position has correlation with in-board transducer location known to be viable.

21. Active acoustic device according to any preceding

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claim, further comprising baffle means extending about and beyond said panel member.

22. Active acoustic device according to any preceding claim, wherein said panel member is at least partially

5 transparent or translucent.

23. Active acoustic device according to any preceding claim, wherein said transducer means is of electro-mechanical type.

24. Active acoustic device according to any preceding

10 claim, wherein said transducer means is operative to launch compression waves into edge of said panel member and/or to deflect edge of said panel member laterally to launch transverse bending waves along said panel member and/or to apply torsion across a corner of said panel

15 member and/or to produce linear deflection of a local edge region of said panel member.

25. Method of making an active acoustic device to include a panel member having distribution of resonant modes of bending wave action beneficial to acceptable acoustic

20 performance in conjunction with transducer means suitably coupled to the panel member, the method comprising assessing acoustic performance resulting from locating the transducer means at a number of different marginal positions of the panel member, and selecting a said

25 marginal position for acceptable acoustic performance.

26. Method for making an acoustic device to include a panel member having distribution of resonant modes of bending wave action beneficial to acceptable acoustic

performance in conjunction with transducer means suitably coupled to the panel member, the method comprising adding localised clamping means to improve said acoustic performance resulting from some particular marginally

5 located said transducer means, the method further comprising assessing acoustic performance resulting from locating said localised clamping means at a number of different marginal positions of the panel member, and selecting a said marginal position for acceptable acoustic

10 performance.

27. Method according to claim 25 or claim 26, wherein said assessing of said acoustic output is limited to a frequency range germane to intended use and acceptable performance of said active acoustic device.

15 28. Method according to claim 1, 25, 26 or 27, wherein said assessing is of the active acoustic device operative as a sound radiator or loudspeaker and in relation to its acoustic output using said different marginal positions.

29. Method according to claim 28, wherein said assessing

20 of said acoustic output is or includes in relation to its content corresponding to said resonant modes as to number of such resonant modes and/or their frequencies or distribution and/or evenness of their contributions to said acoustic output.

25 30. Method according to claim 28, or claim 29,, wherein said assessing of said acoustic output is or includes in relation to amount of power in said acoustic output thus efficiency in conversion of input mechanical vibration

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(thus customary causative electrical drive) into said acoustic output.

31. Method according to claim 28,29 or 30, wherein said assessing of said acoustic output is or includes in relation to smoothness of power of said acoustic output thus evenness of contributions from said resonant modes.

32. Method according to claim 30 or claim 31, wherein said assessing includes relating said acoustic output to some reference and producing an assessment measure according to deviation from said reference.

33. Method according to claim 32 with claim 30, wherein said reference is a single substantially median value over a particular frequency range of said acoustic output.

34. Method according to claim 32 with claim 31, wherein said reference comprises a succession or continuum of substantially median values throughout said acoustic output over a particular frequency range of said acoustic output.

35. Method according to claim 34, wherein said assessing includes adjusting measured said acoustic output selectively to levels consonant with said reference having meaningful a single value.

36. Method according to claim 35, wherein said single median value corresponds with what applies at higher frequencies where said resonant modes are relatively dense.

37. Method according to claim 35 or claim 36, wherein said adjusting involves raising levels of lower

frequencies where said resonant modes are less dense.

38. Method according to any one of claims 32 to 37, wherein said assessment measure involves mean square deviation from said reference.

5 39. Method according to claim 38, wherein said assessment measure comprises inverse mean square deviation from said reference.

40. Method according to any preceding method claim, wherein application of a method according to any one of

10 claims 5, 6 and 7 is followed or accompanied by application of at least one other method of claims 5 to 7 to the same said acoustic outputs from the same said number of different positions.

41. Method according to any preceding method claim, as

15 applied to a said panel member with three or more sides or edges, wherein each of stages of said assessing is applied to said number of different positions spaced along the one and the same edge of said panel member.

42. Method according to claim 41 with claim 25, wherein a

20 said assessing stage is applied with a first transducer means already at one marginal location of said panel member, the assessing stage serving to locate any other marginal position for a second transducer means to be satisfactorily operative together with the first

25 transducer means.

43. Method according to claim 42, wherein said one marginal location of said first transducer means is as indicated best or viable by an earlier stage of said

assessing.

44. Method according to claim 43, wherein said first and second transducer means are marginally located relative to different edges of said panel member.

5 45. Method according to claim 44, wherein said different edges are longer and shorter edges of a substantially rectangular panel.

46. Method according to claim 45, wherein said first transducer means is marginally located relative to said 10 longer edge.

47. Method according to claim 46, wherein longer and shorter edges of a substantially rectangular panel member are subject to said assessing individually in separate said assessing stages.

15 48. Method according to any preceding method claim, wherein spacings of said different positions along said one edge are related to difference between the mid-point of said one edge and a point orthogonally related to a known successful transducer location in-board of said 20 panel member.

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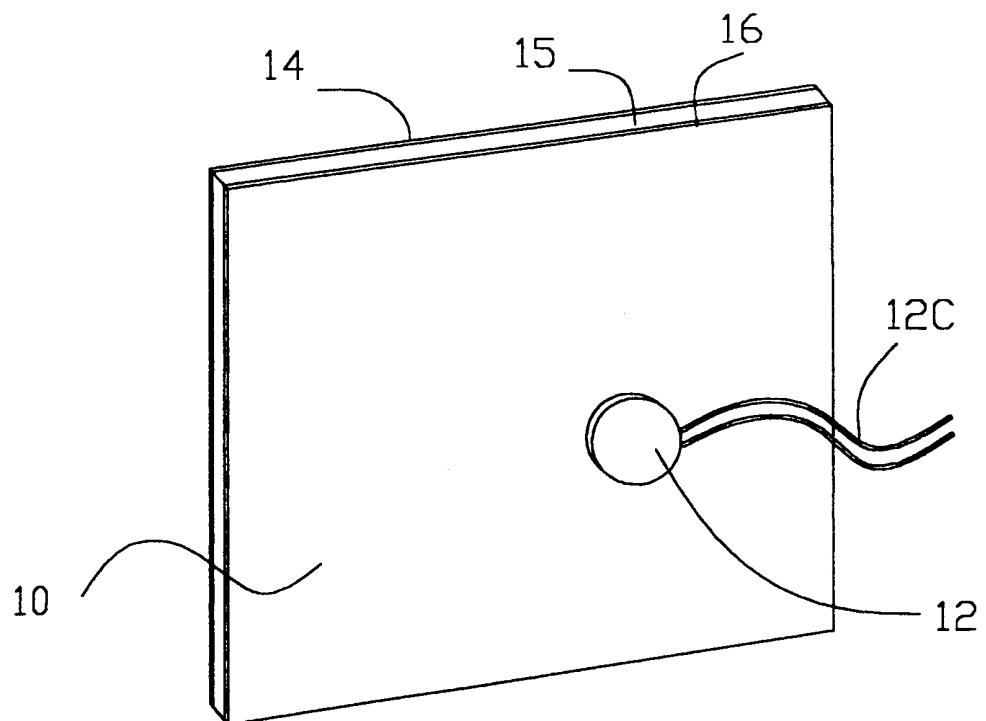
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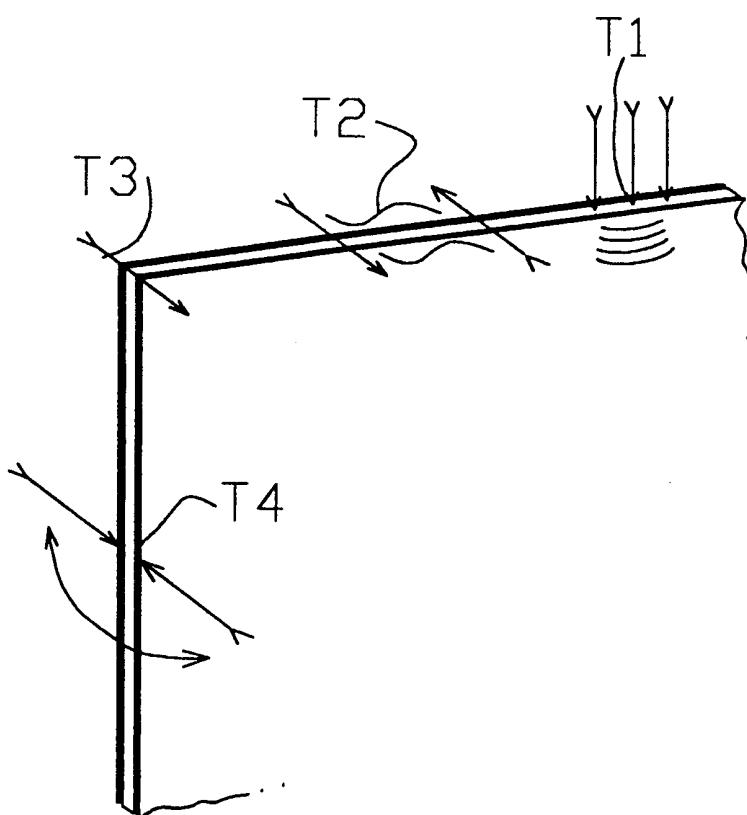
FIG.2
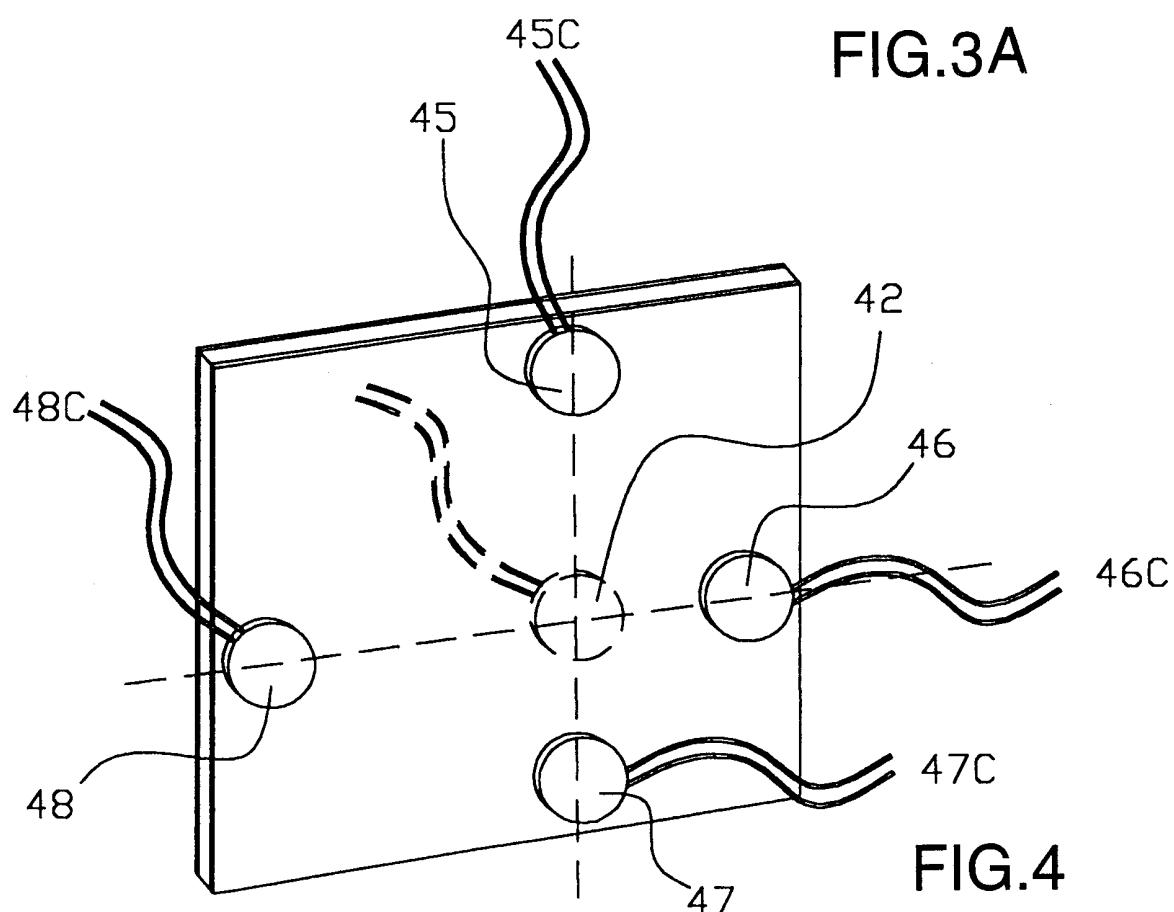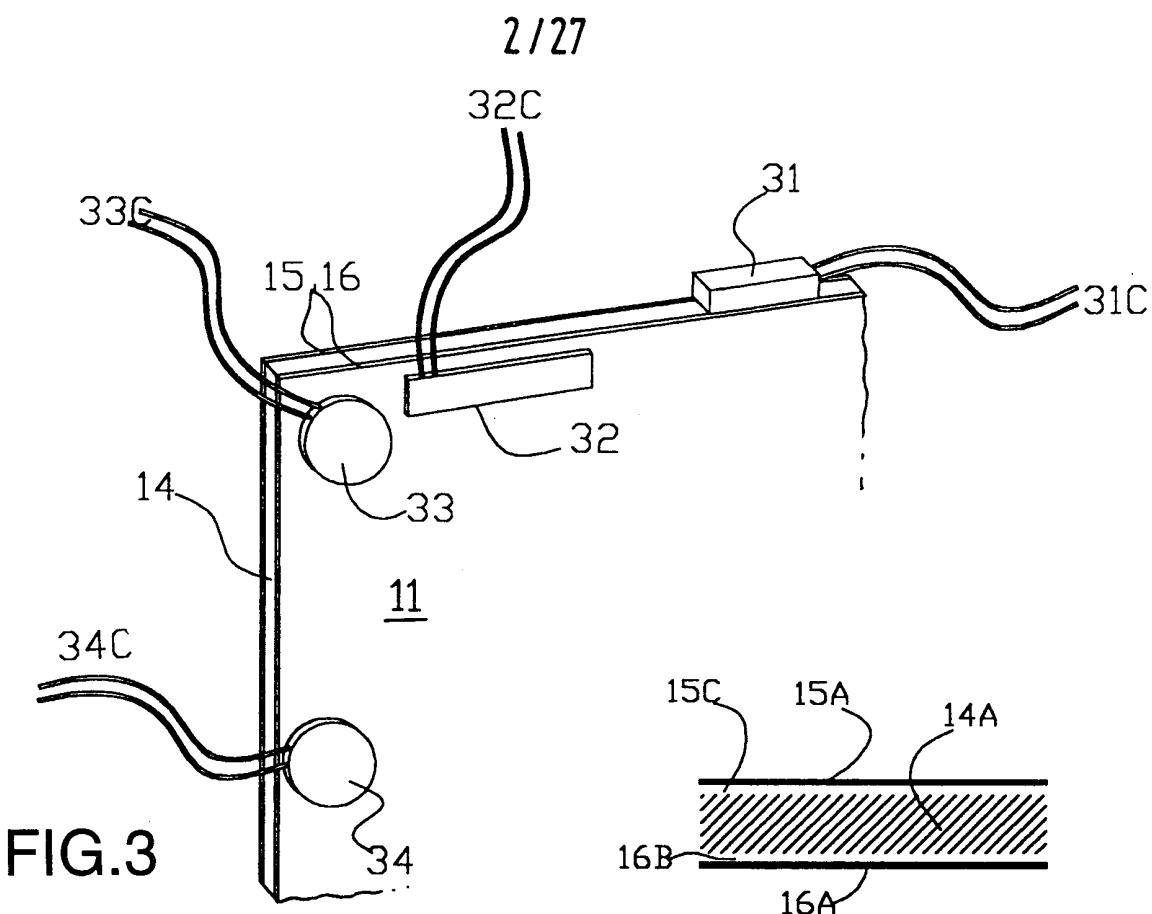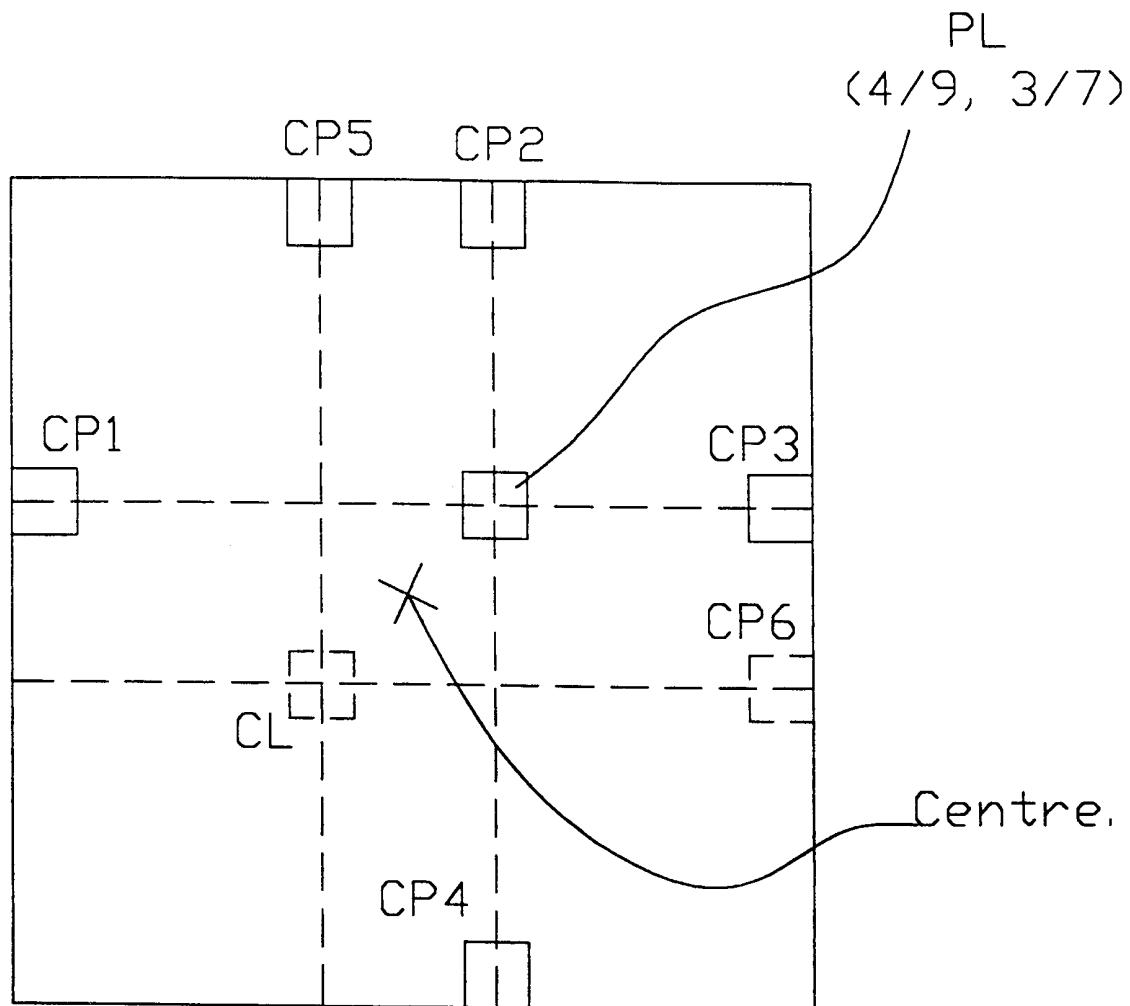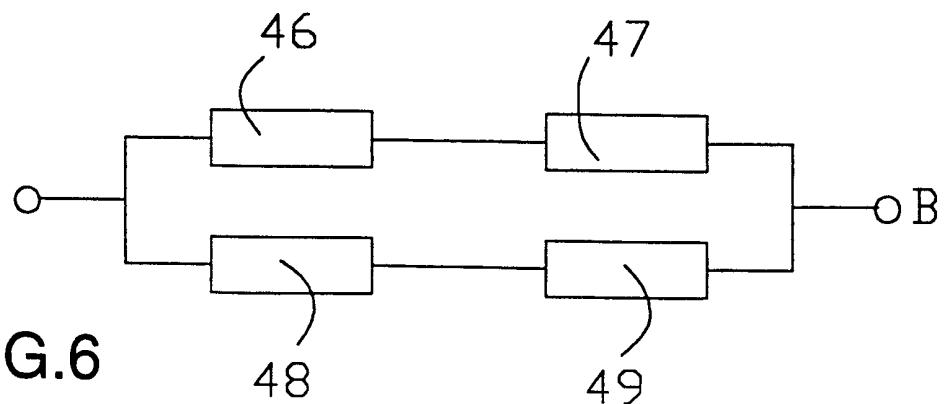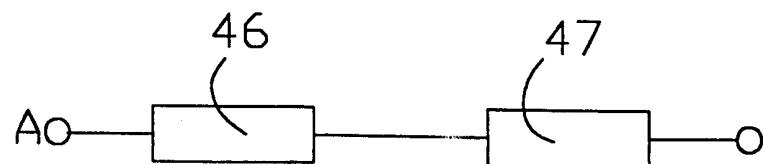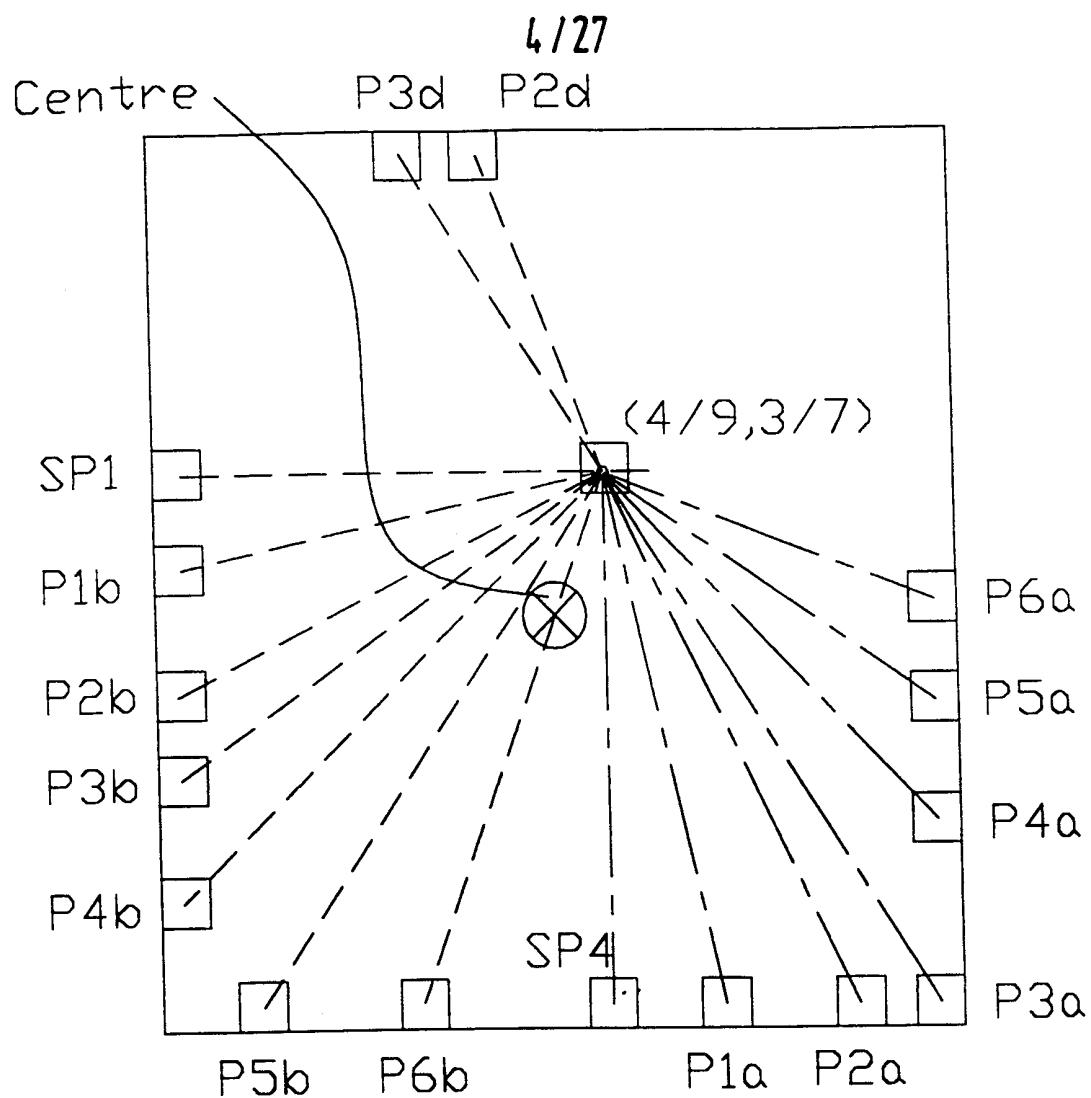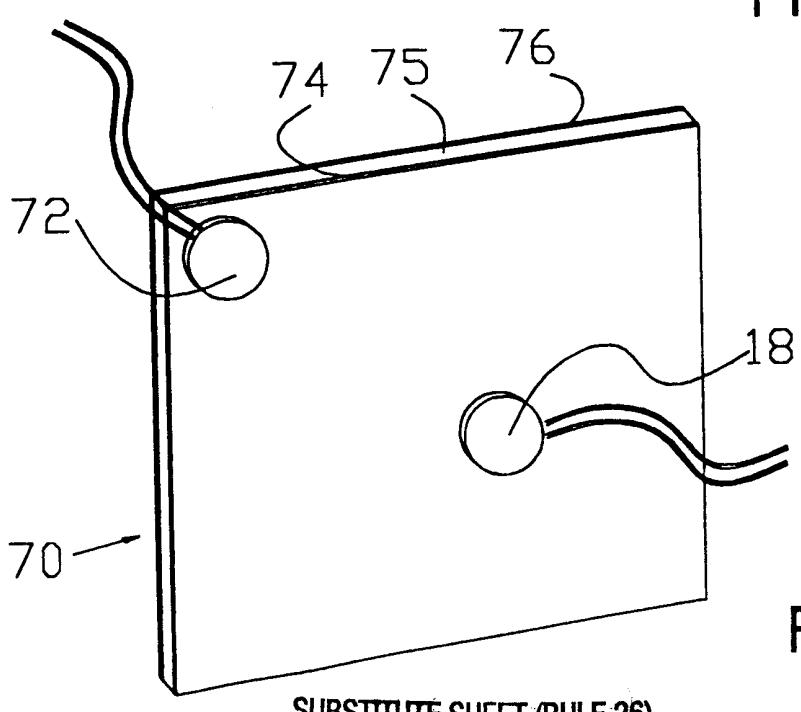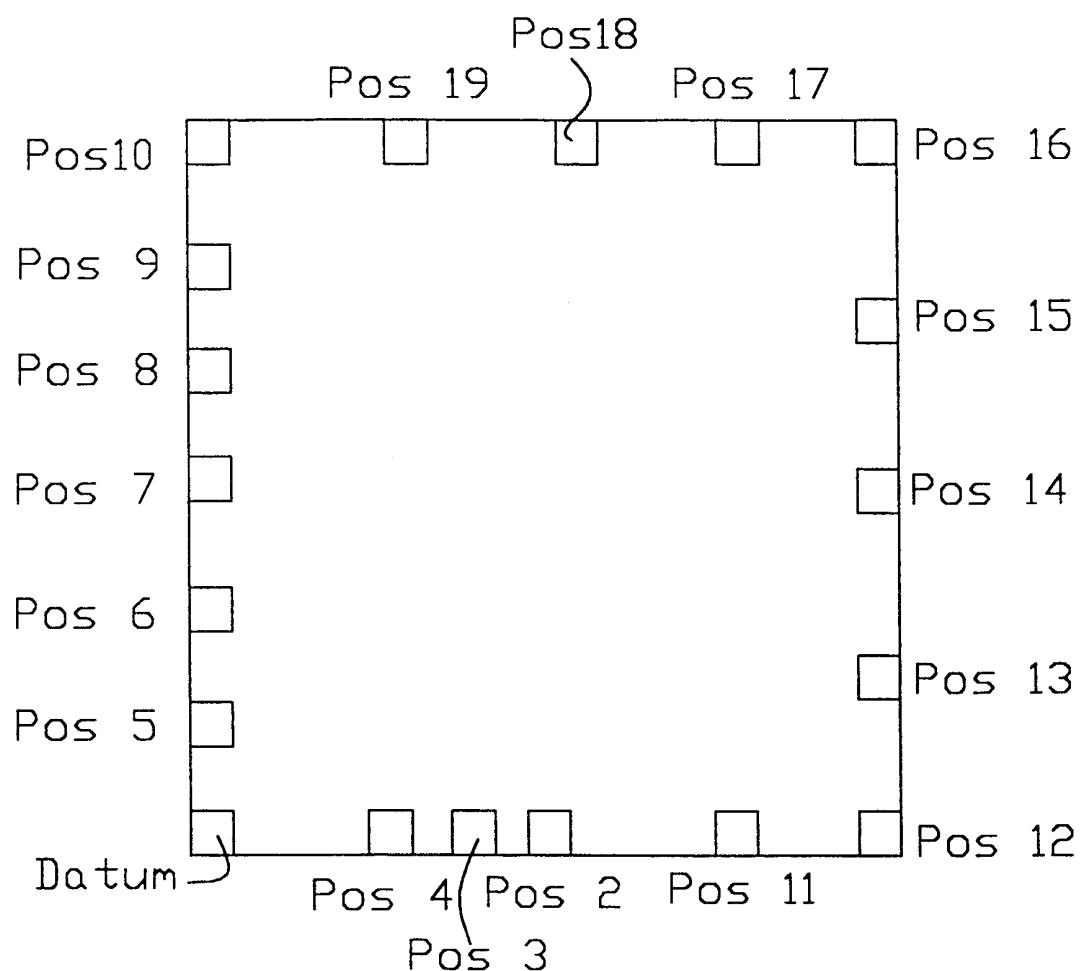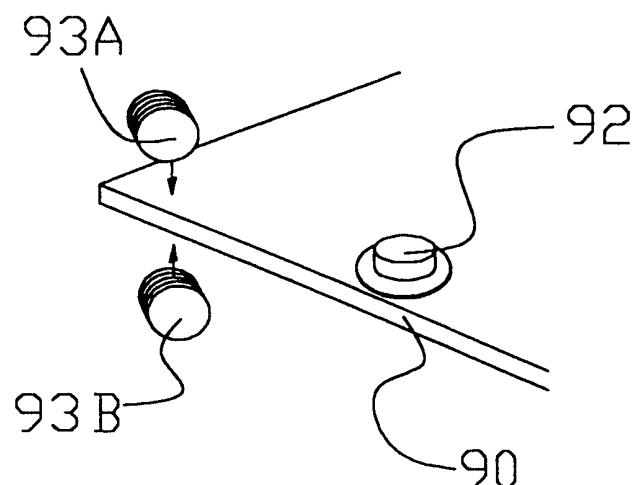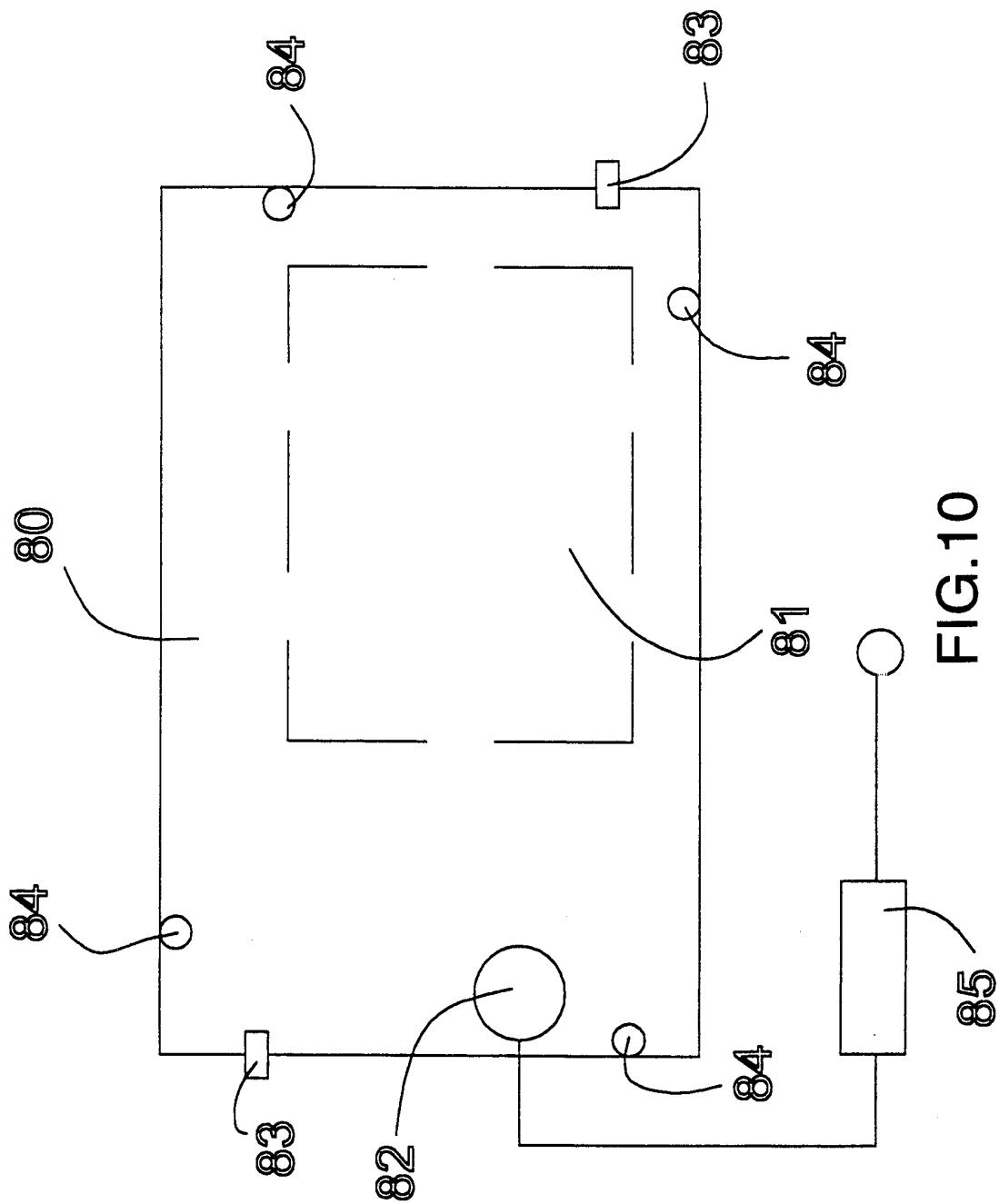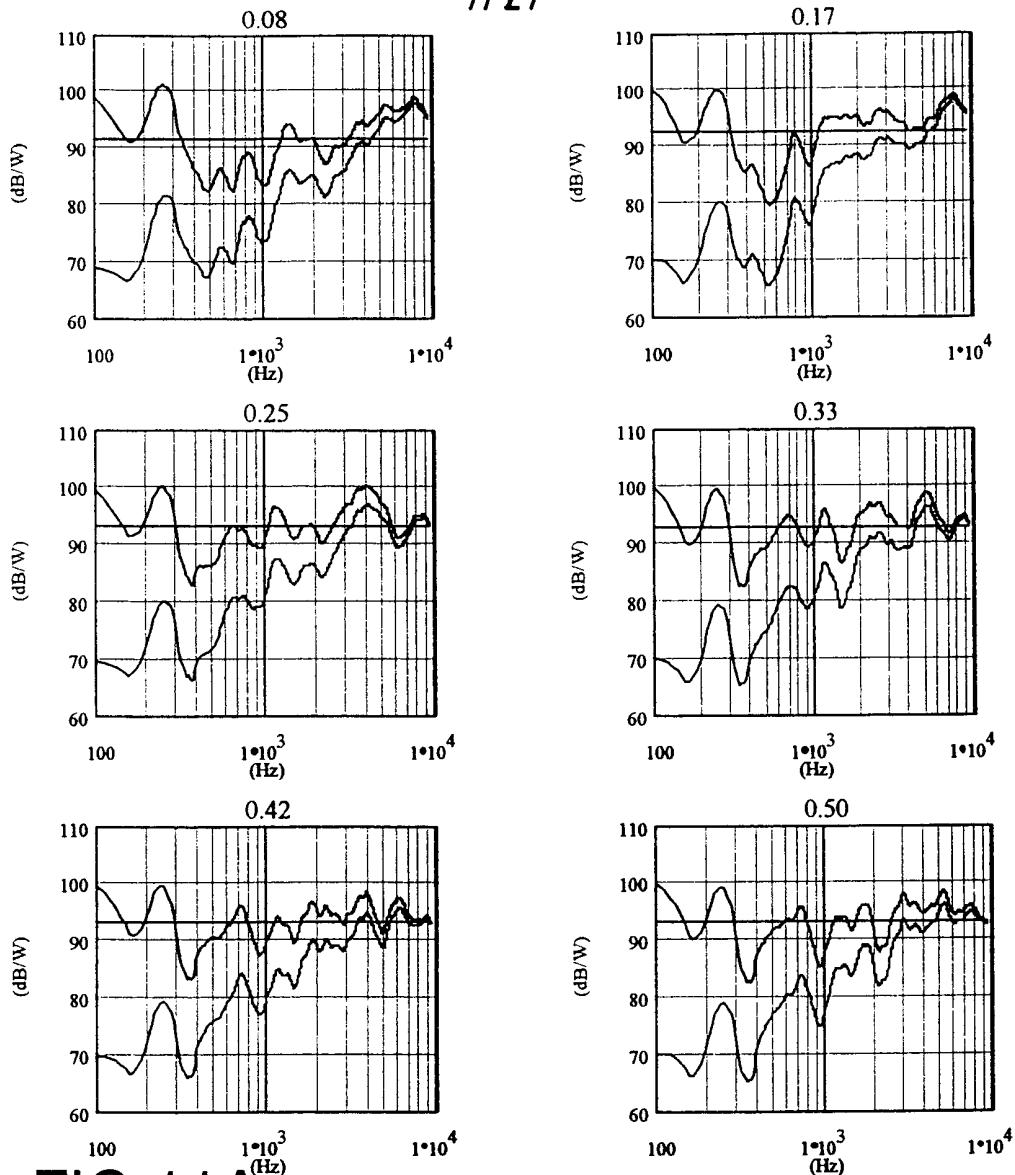
2/27

FIG.3

FIG.3A

FIG.4

FIG.5

FIG.6

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FIG.7

FIG.8

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Pos18

Pos 19   Pos 17

Pos10 □   □   □   □   □ Pos 16

Pos 9 □   □ Pos 15

Pos 8 □

Pos 7 □   □ Pos 14

Pos 6 □

Pos 5 □   □ Pos 13

Datum—□   □ □ □   □ Pos 12

        Pos 4 Pos 2   Pos 11

        Pos 3

FIG.9

93A

                              92

93B

                    90   **FIG.9A**

FIG.10

FIG.11A

FIG.12A

FIG.11B

FIG.12B

FIG.13A

FIG.13B

FIG.14A

FIG.14B

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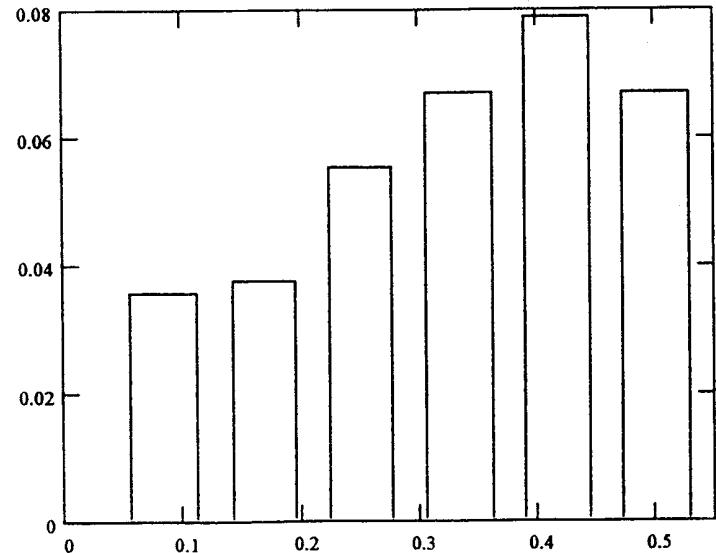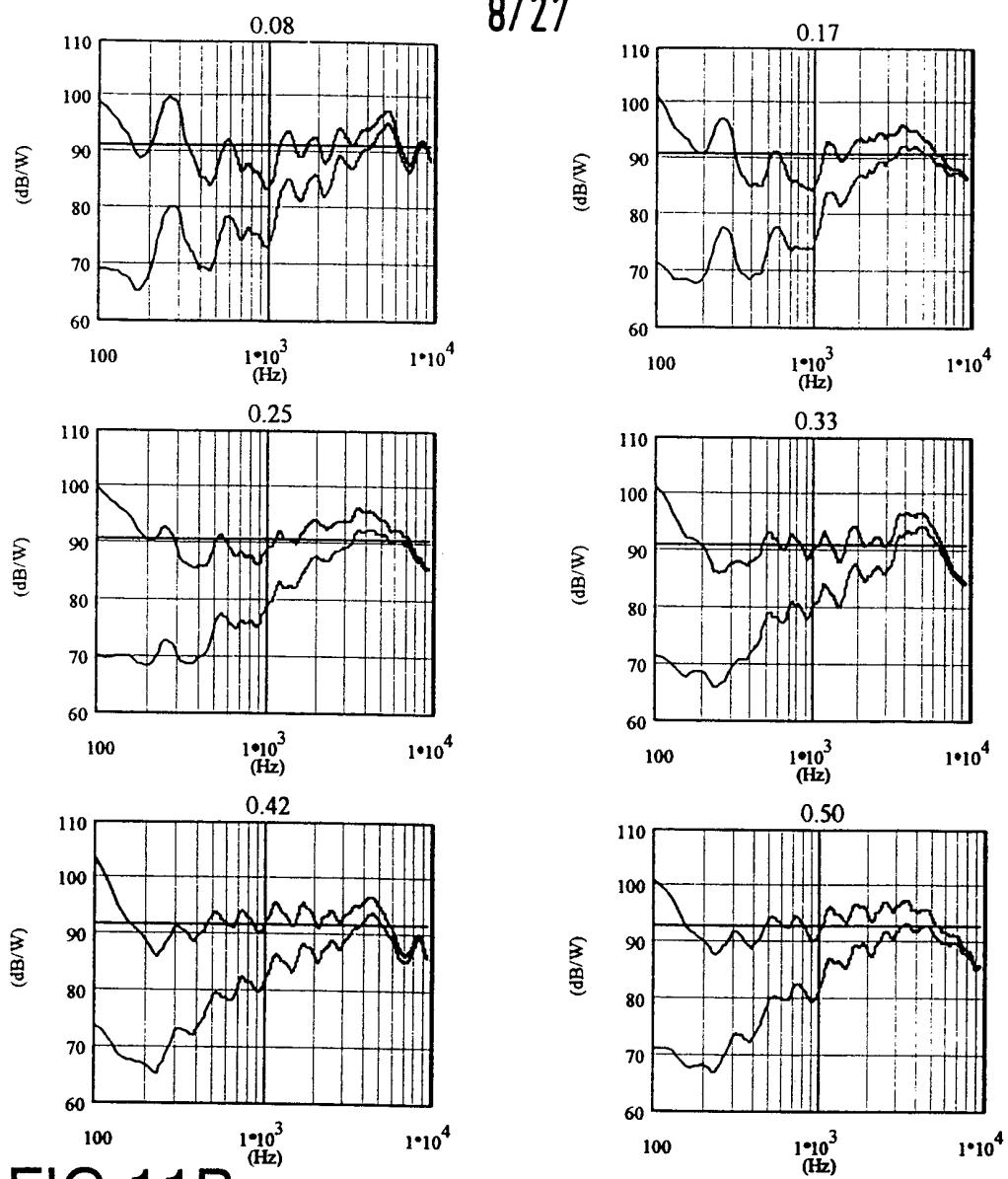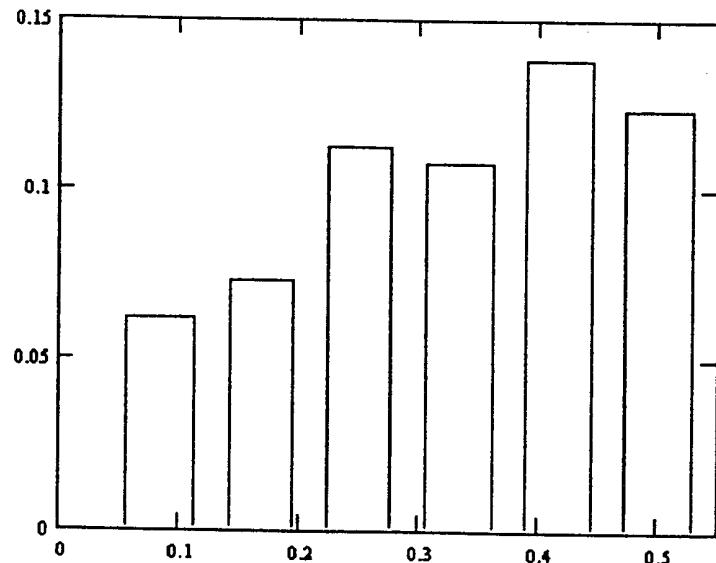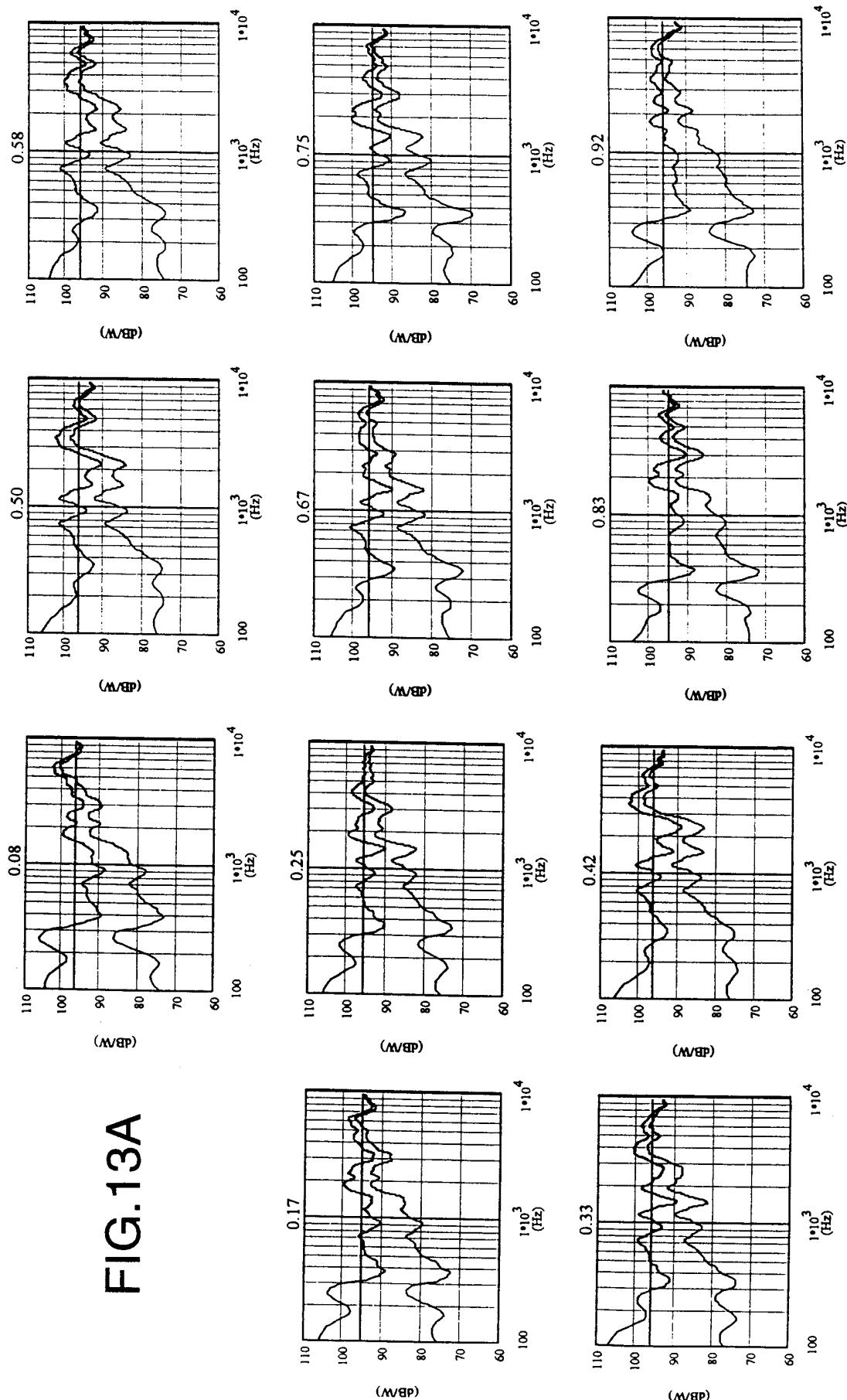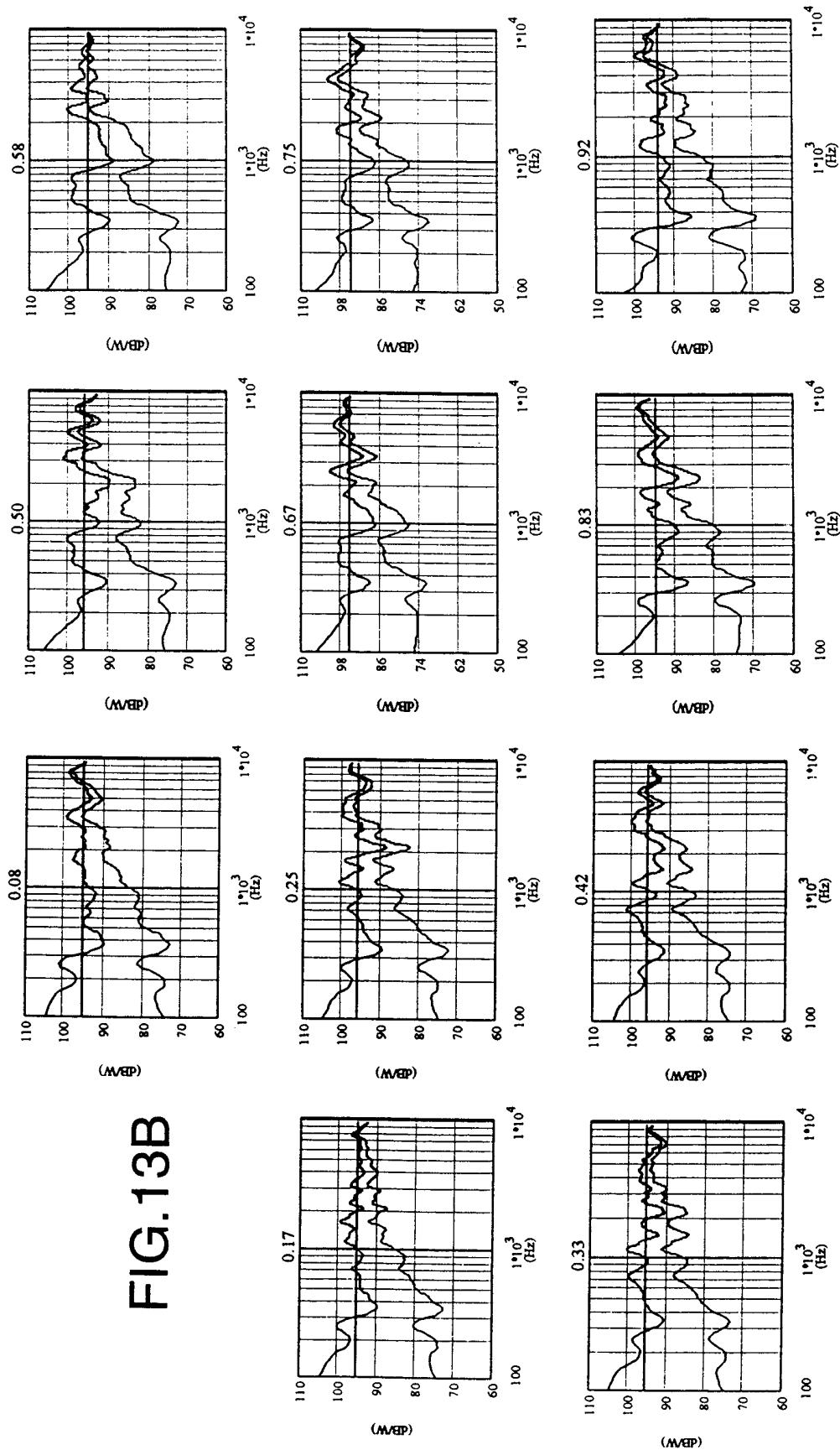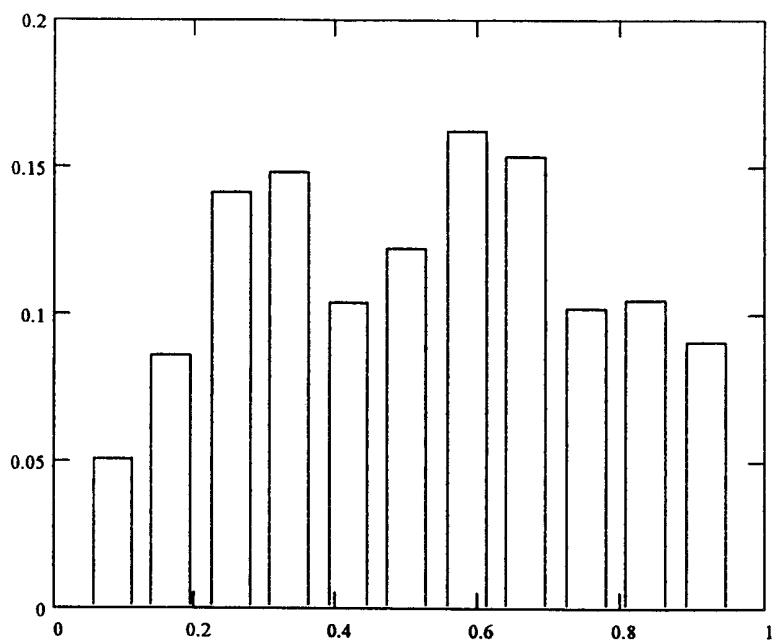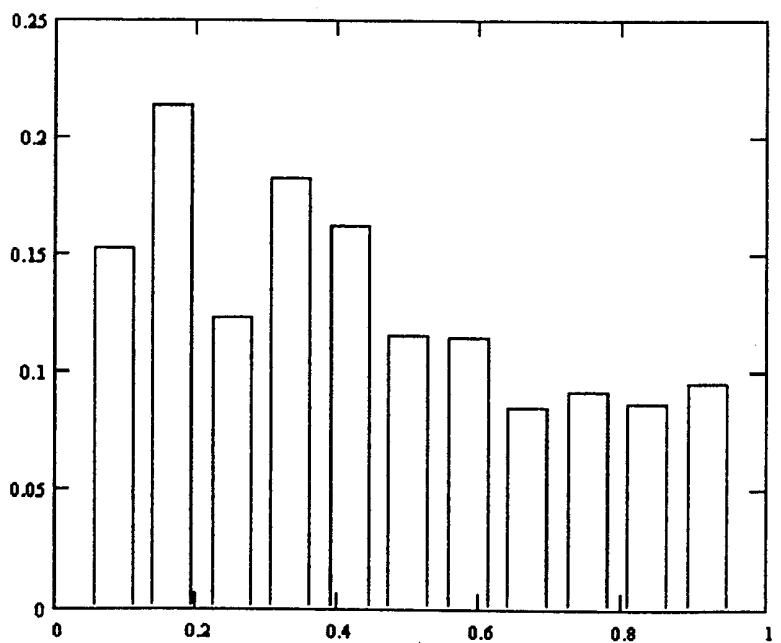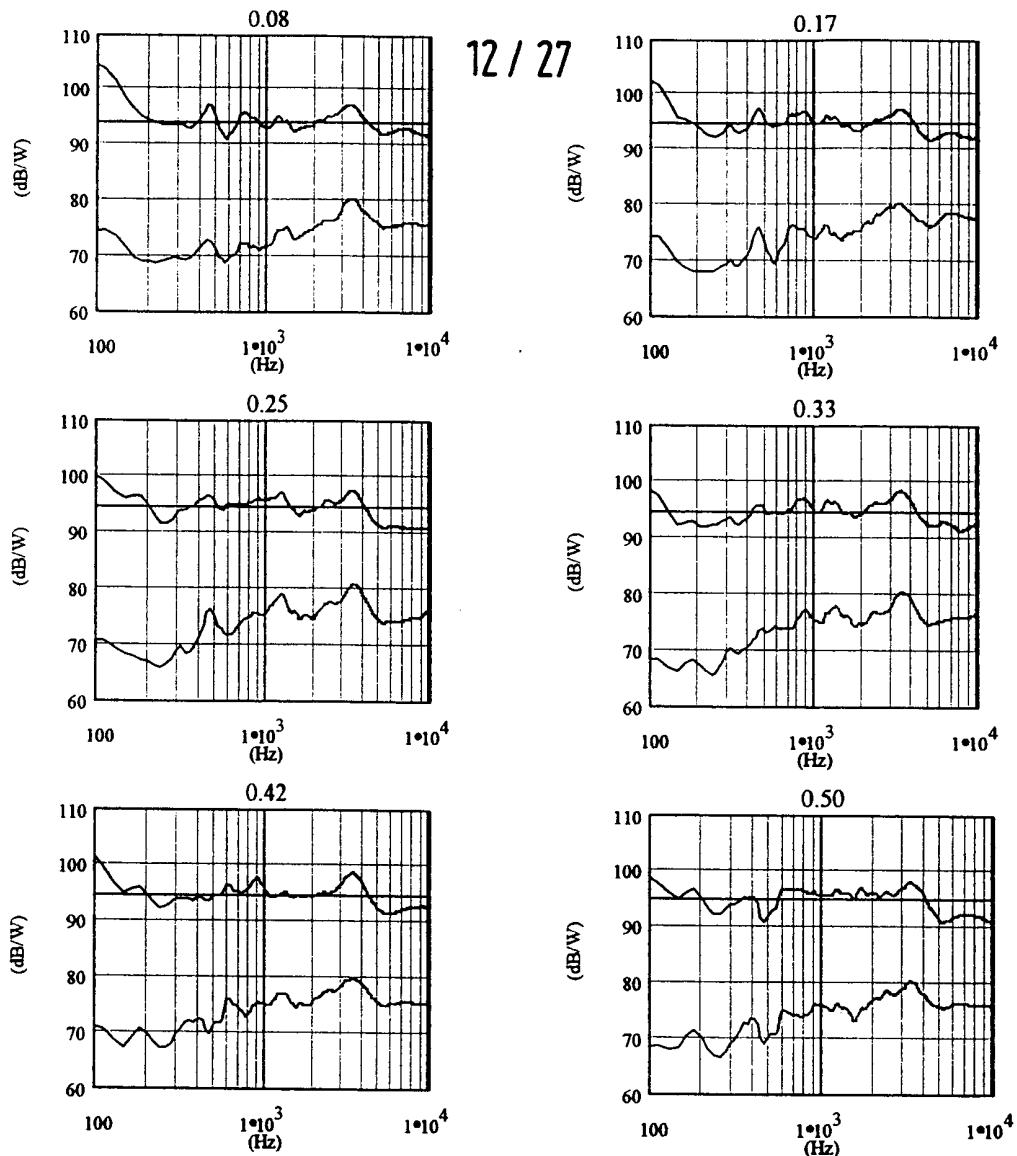
FIG.15A

FIG.15B
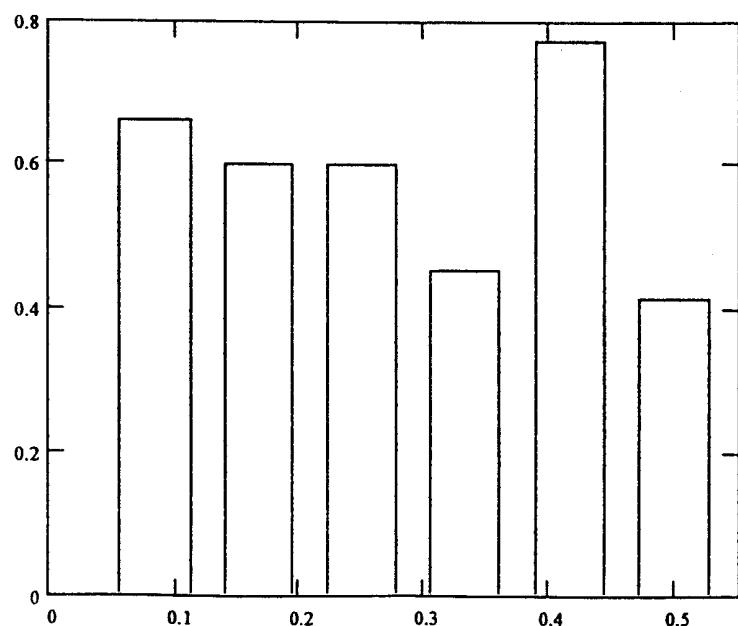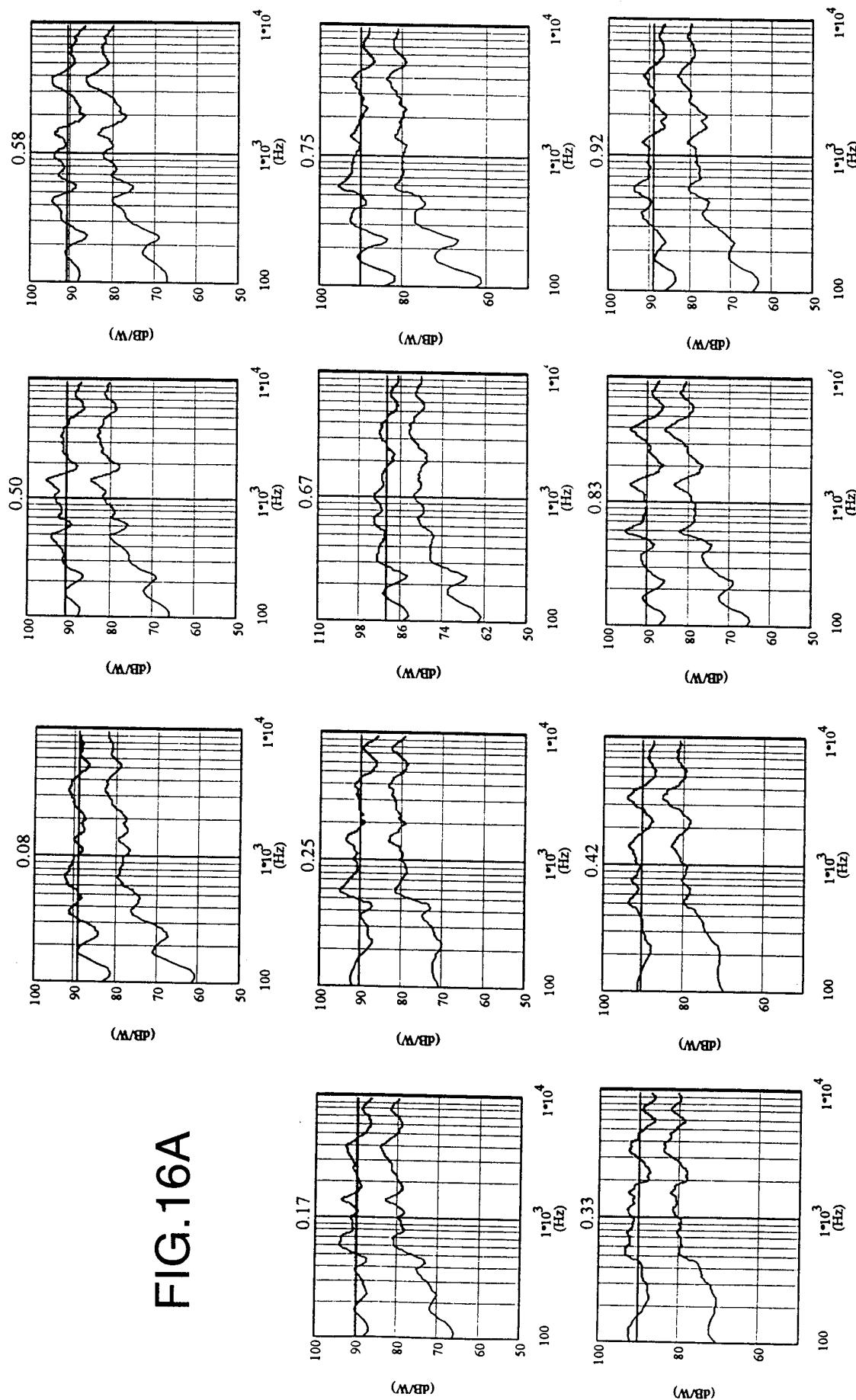
FIG.16A

200Hz-10kHz

FIG.16B
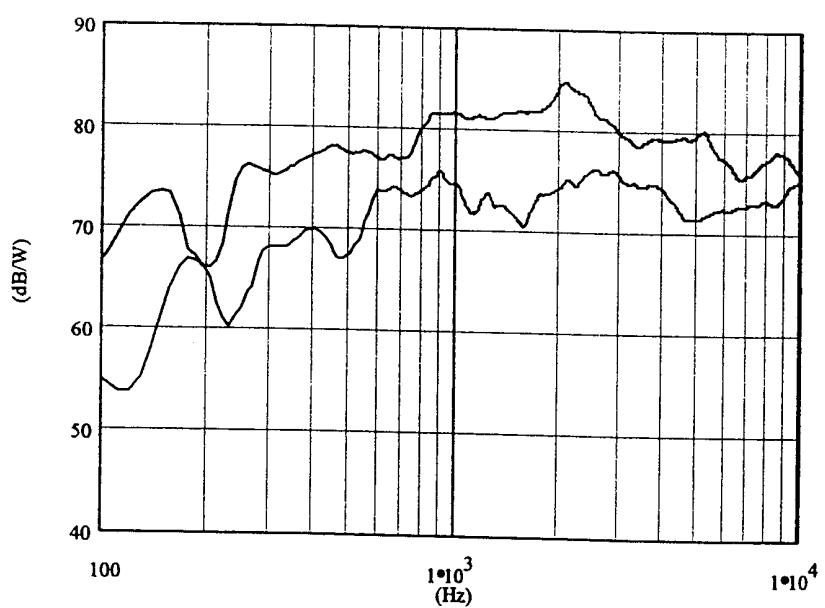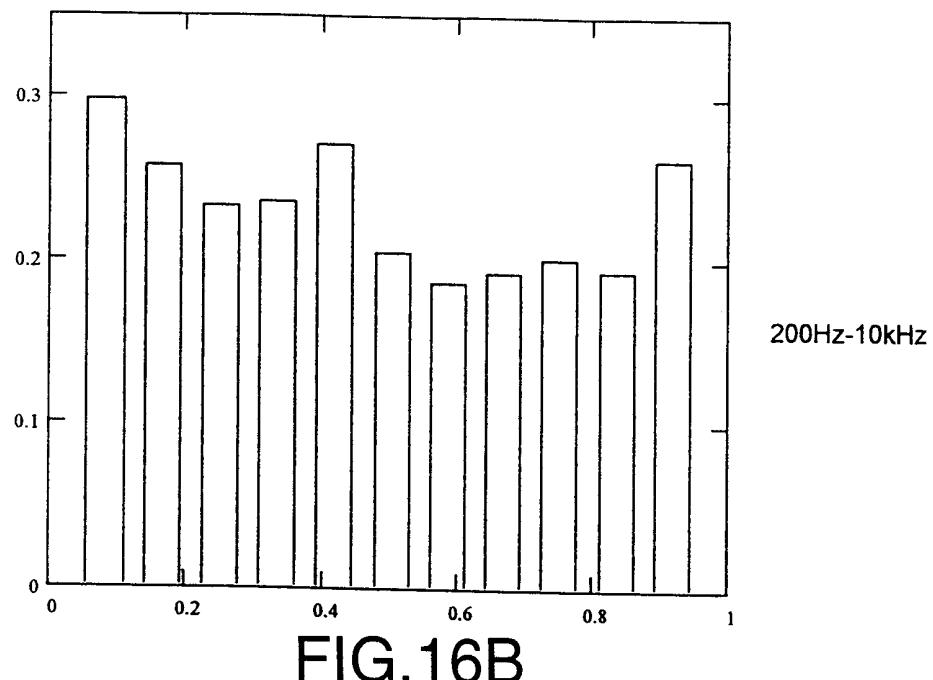
FIG.17

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FIG.18A

FIG.18B

FIG.18C

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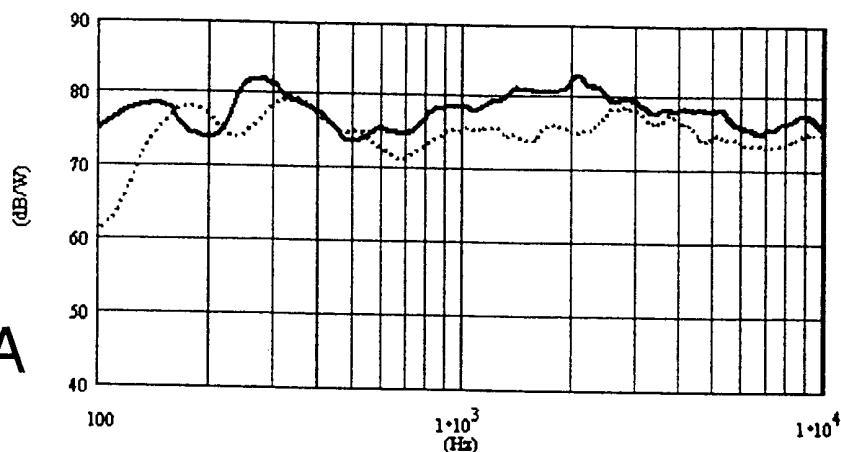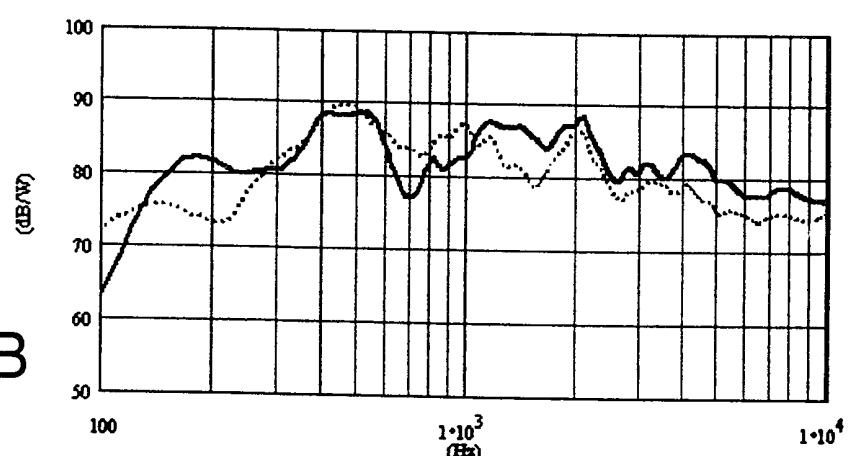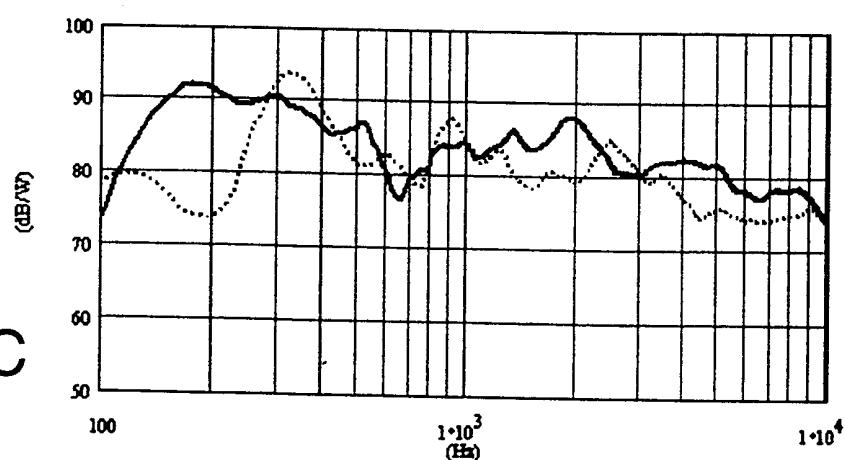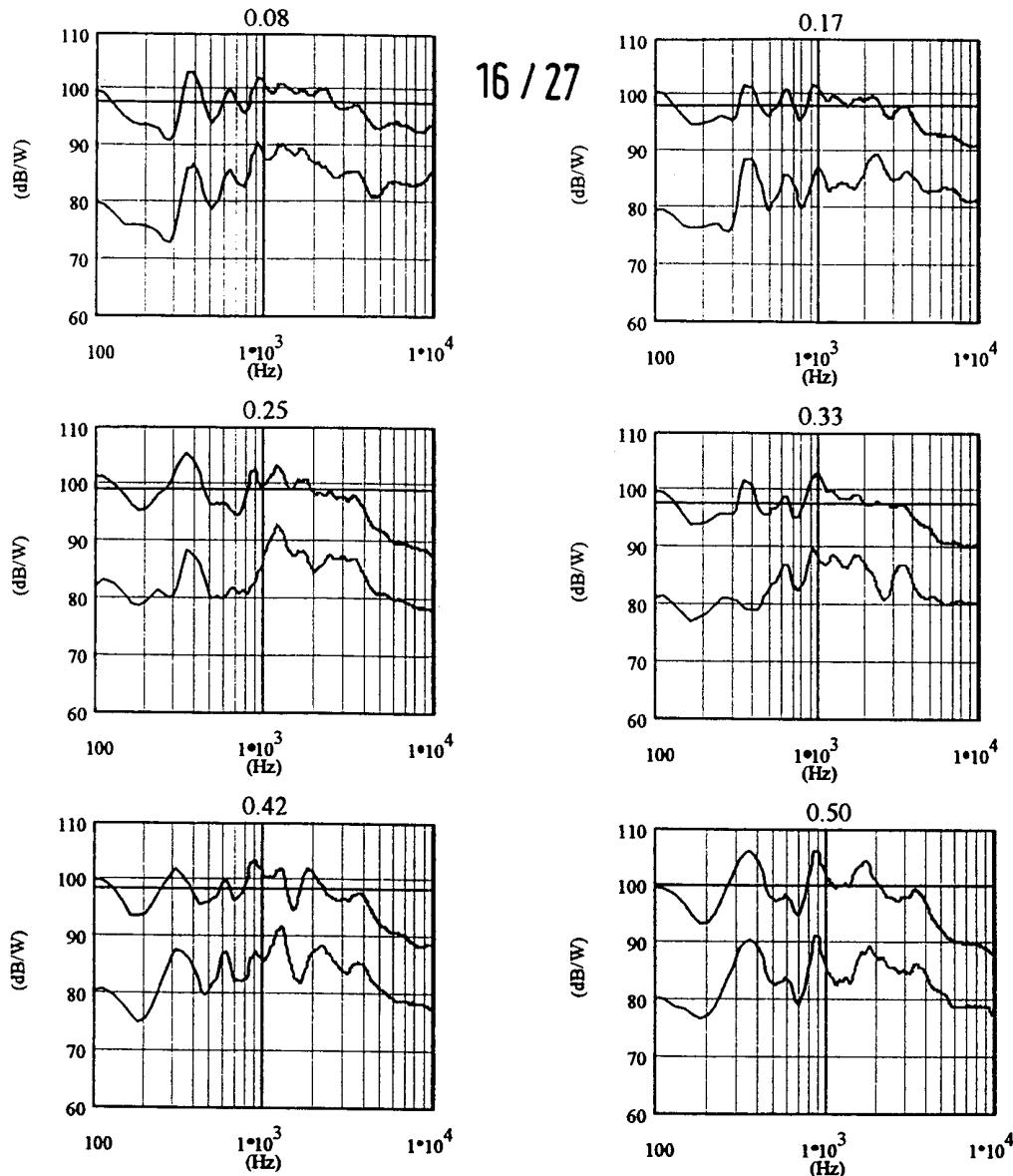
FIG.19A

FIG.19B

200Hz-4kHz
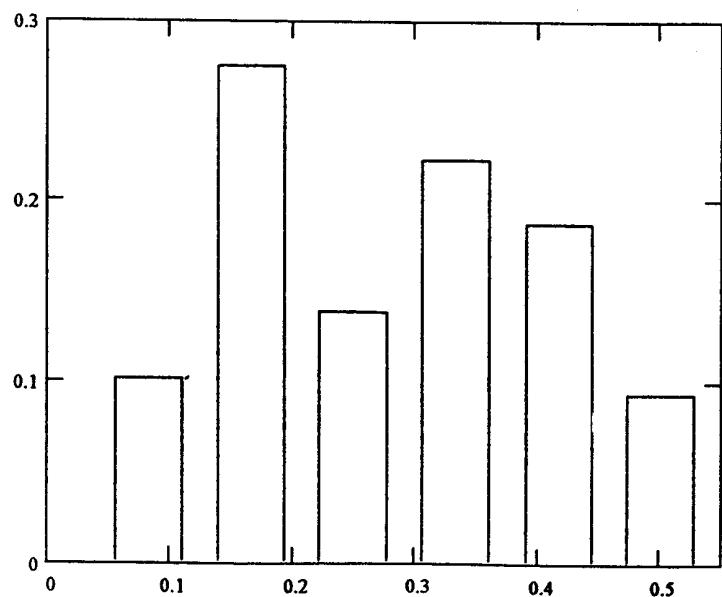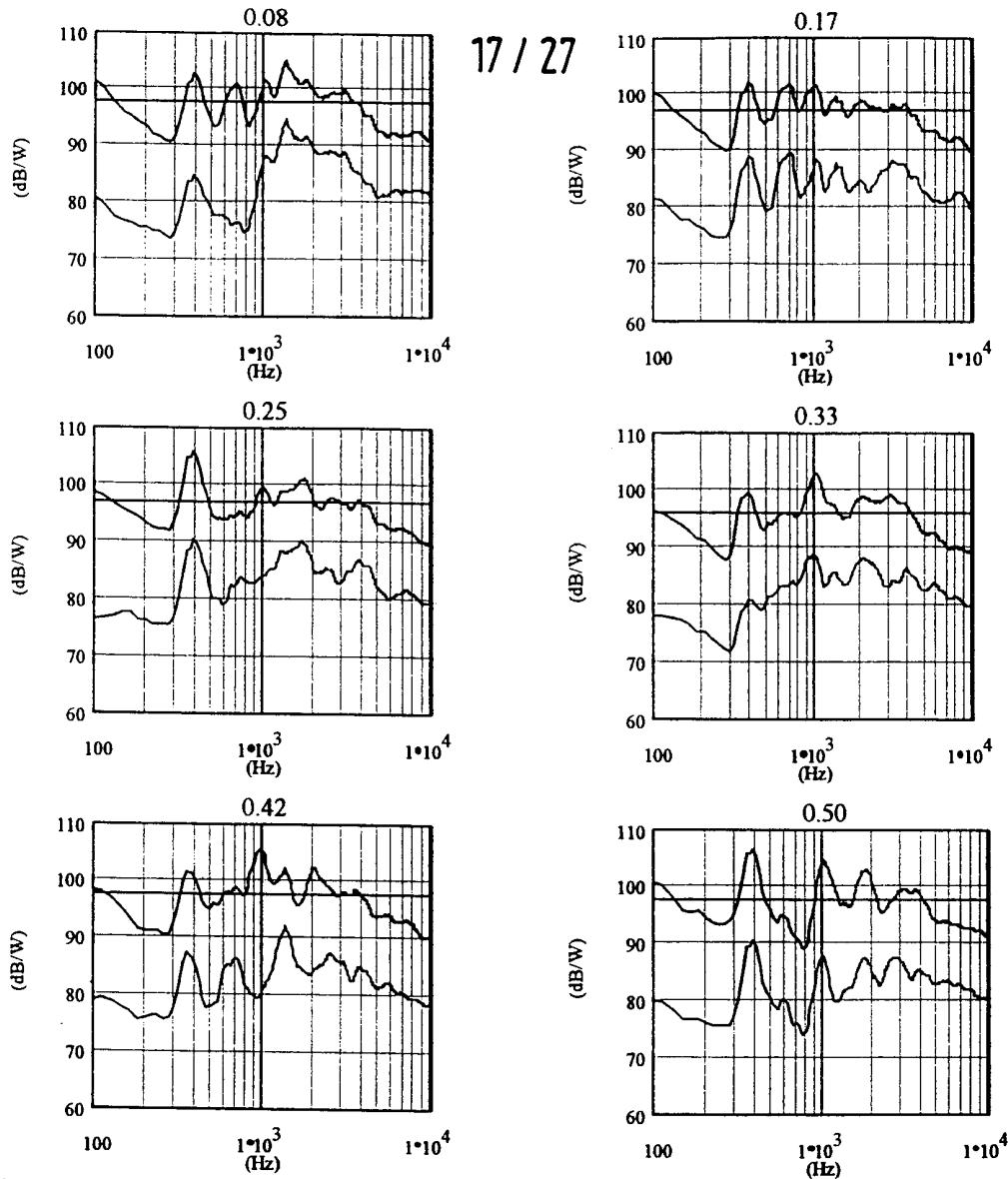
FIG.20A

FIG.20B

200Hz-4kHz
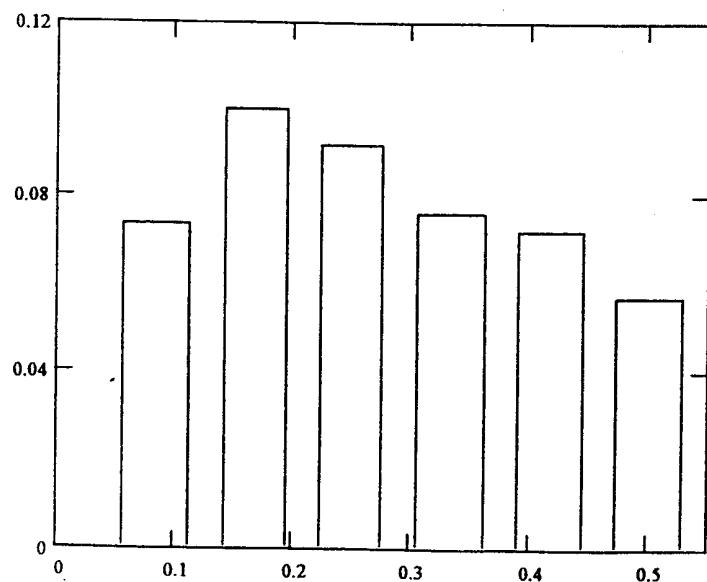
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FIG.21A
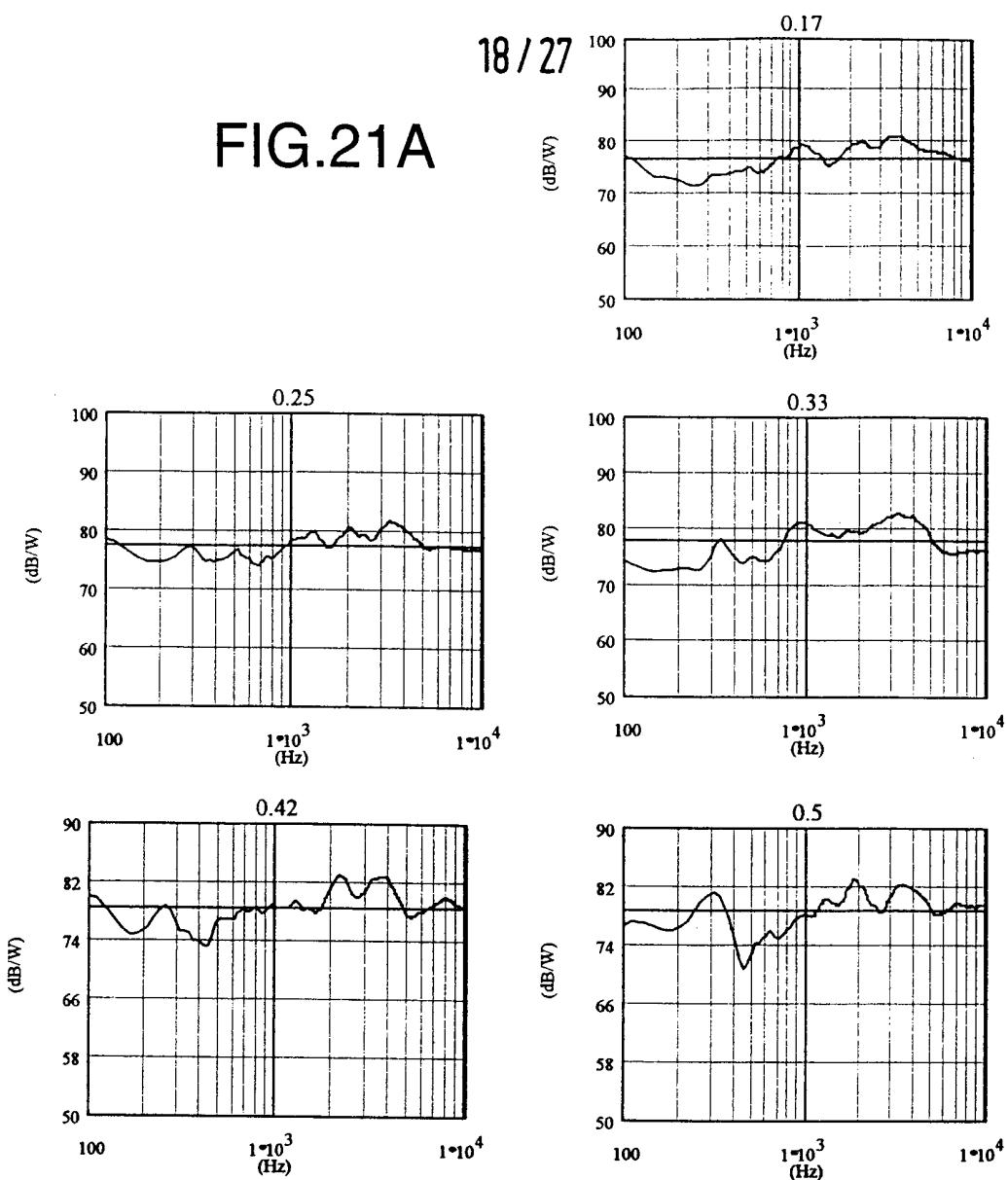
FIG.21B

200Hz-10kHz
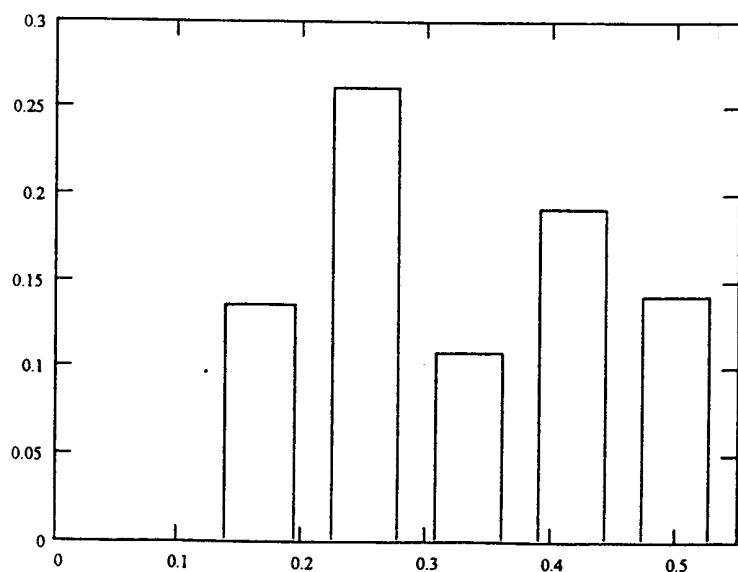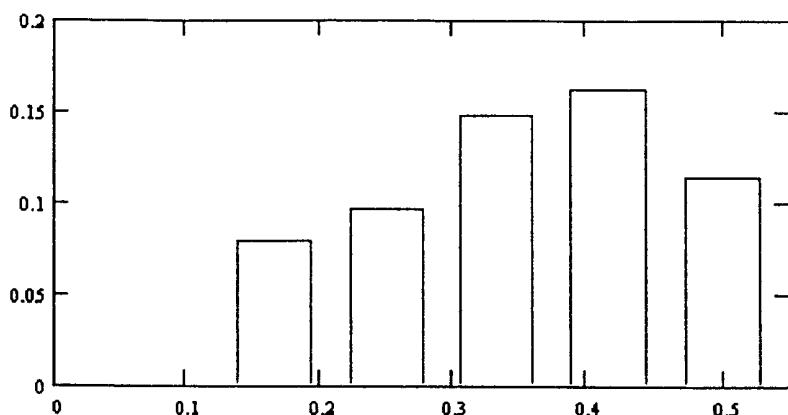
FIG.22
300Hz-3kHz
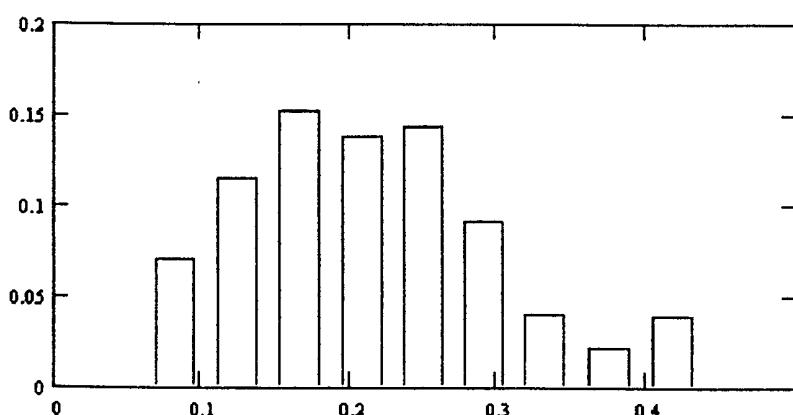
FIG.23A
300Hz-3kHz



FIG.23B
300Hz-3kHz

FIG.24B

FIG.24A
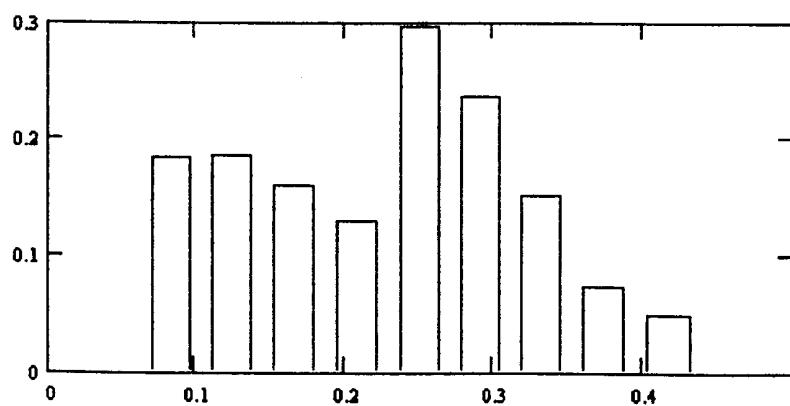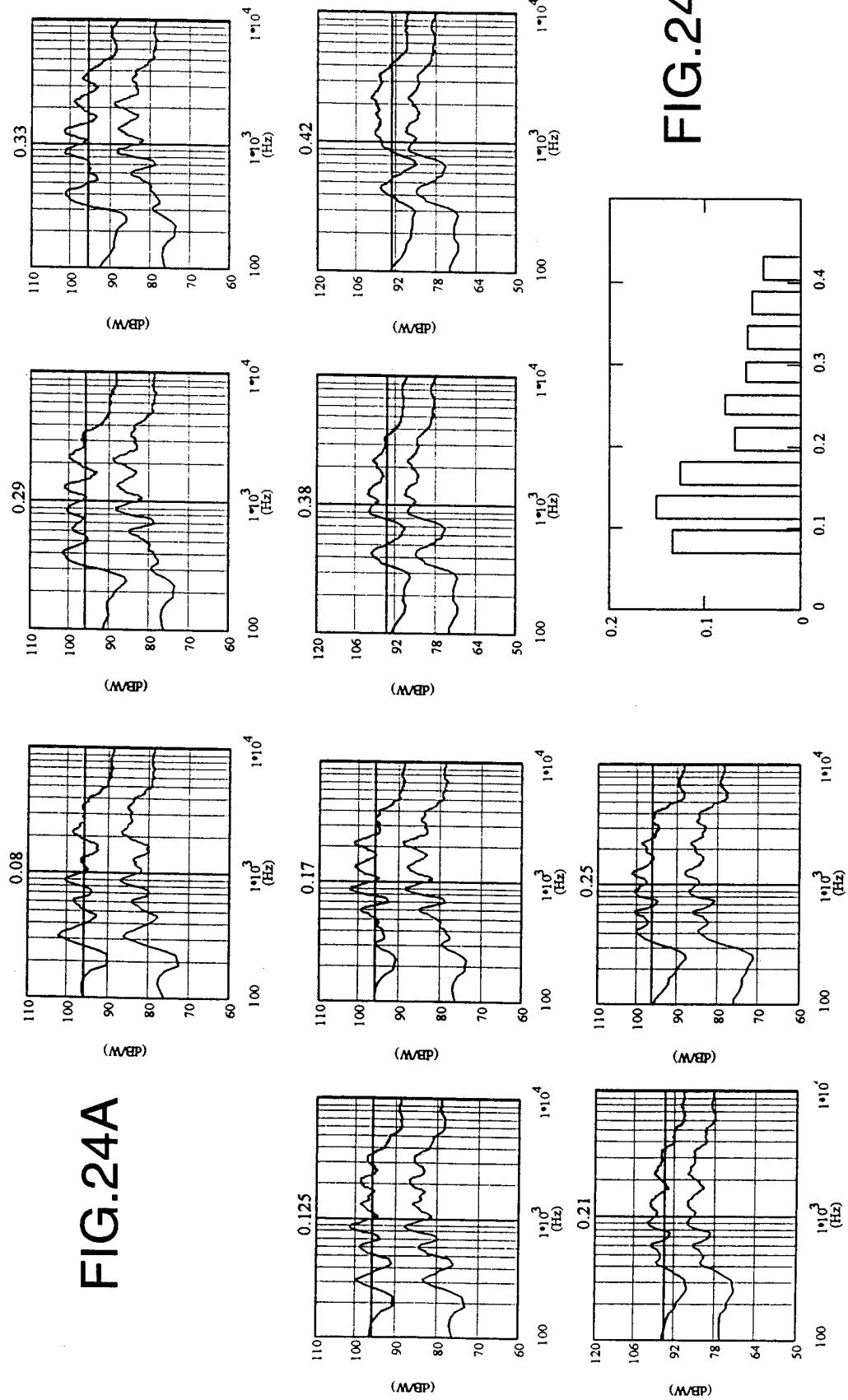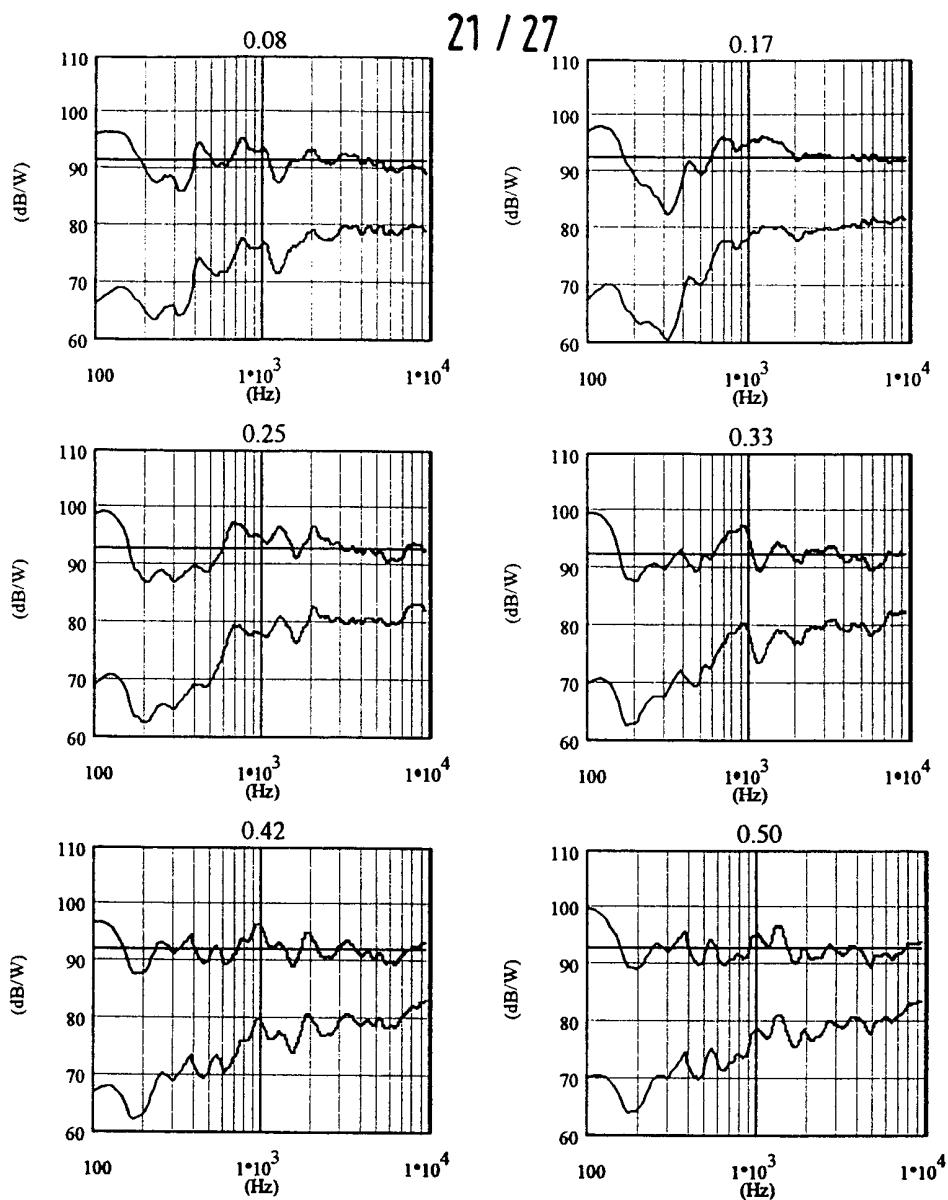
FIG.25A

FIG.25B
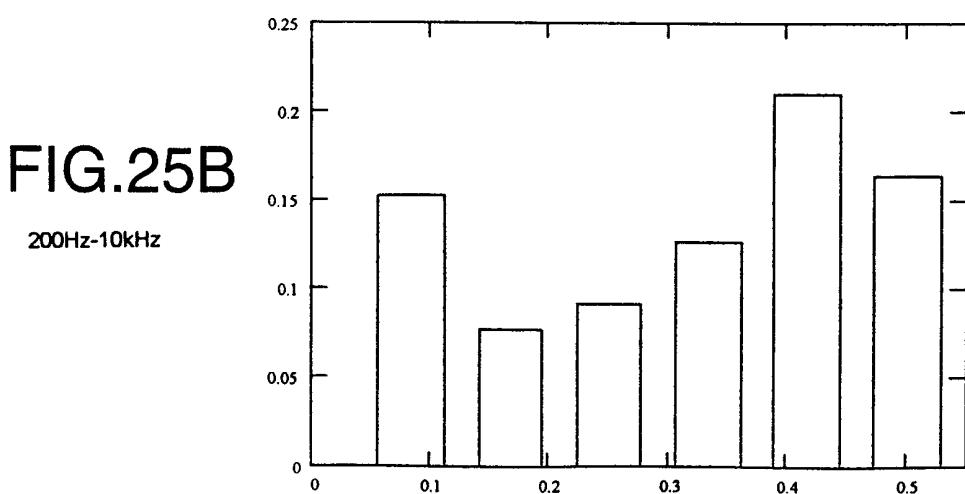
200Hz-10kHz

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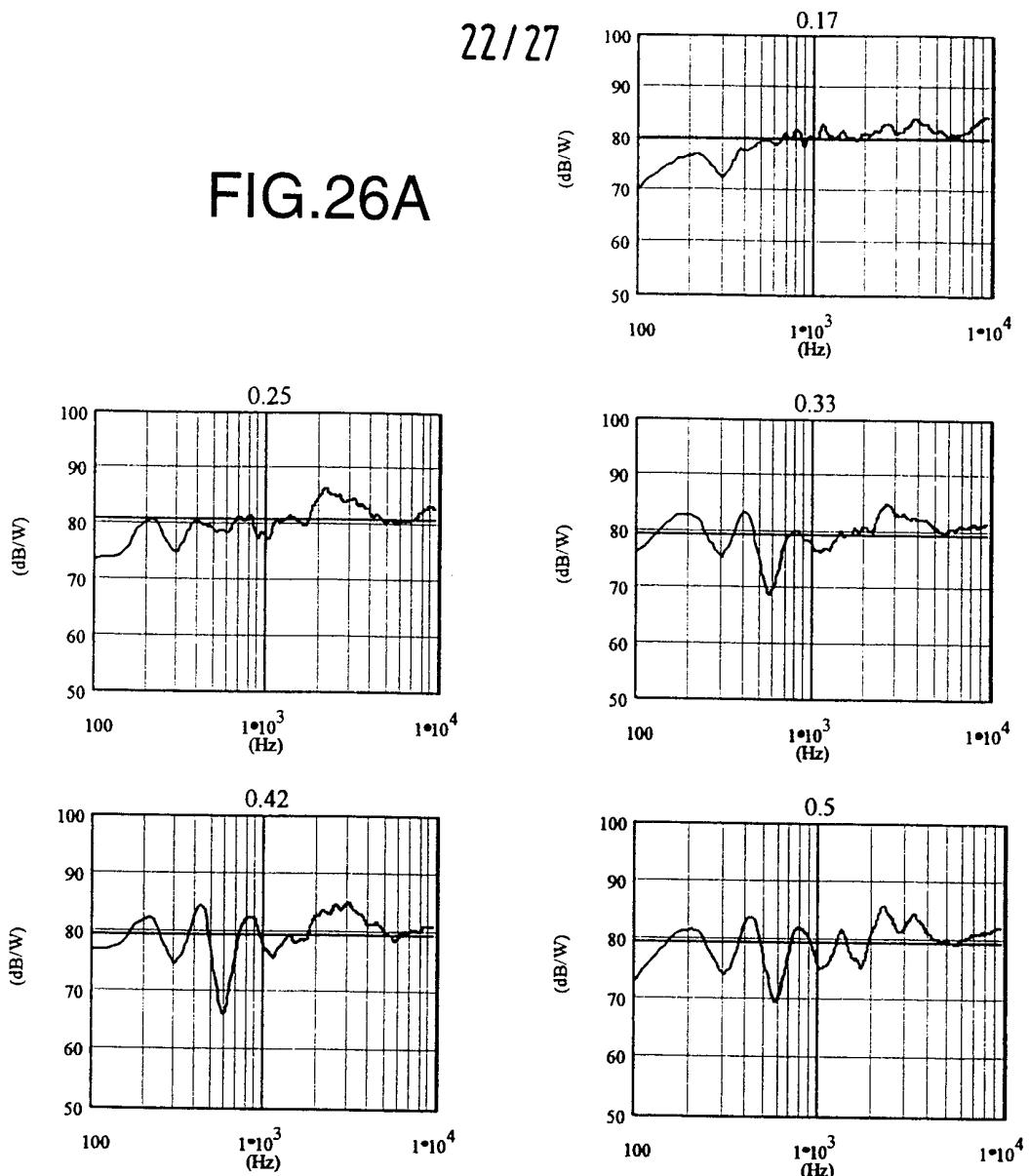
FIG.26A

FIG.26B

200Hz-10kHz
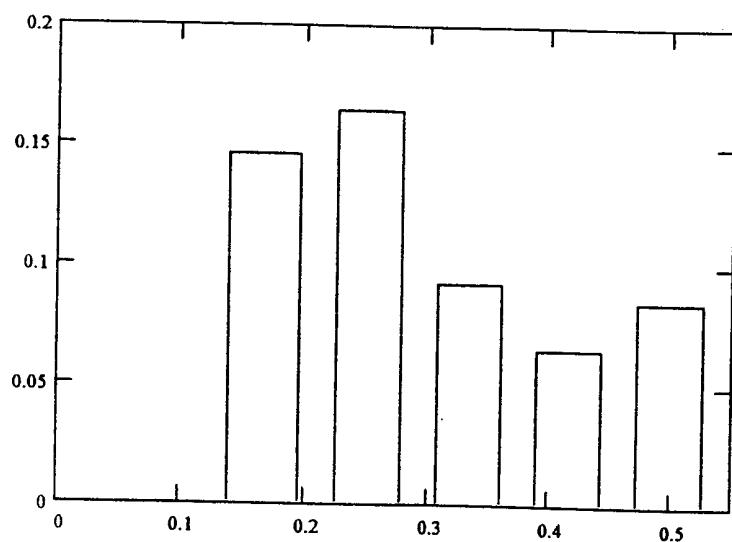
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FIG.27A
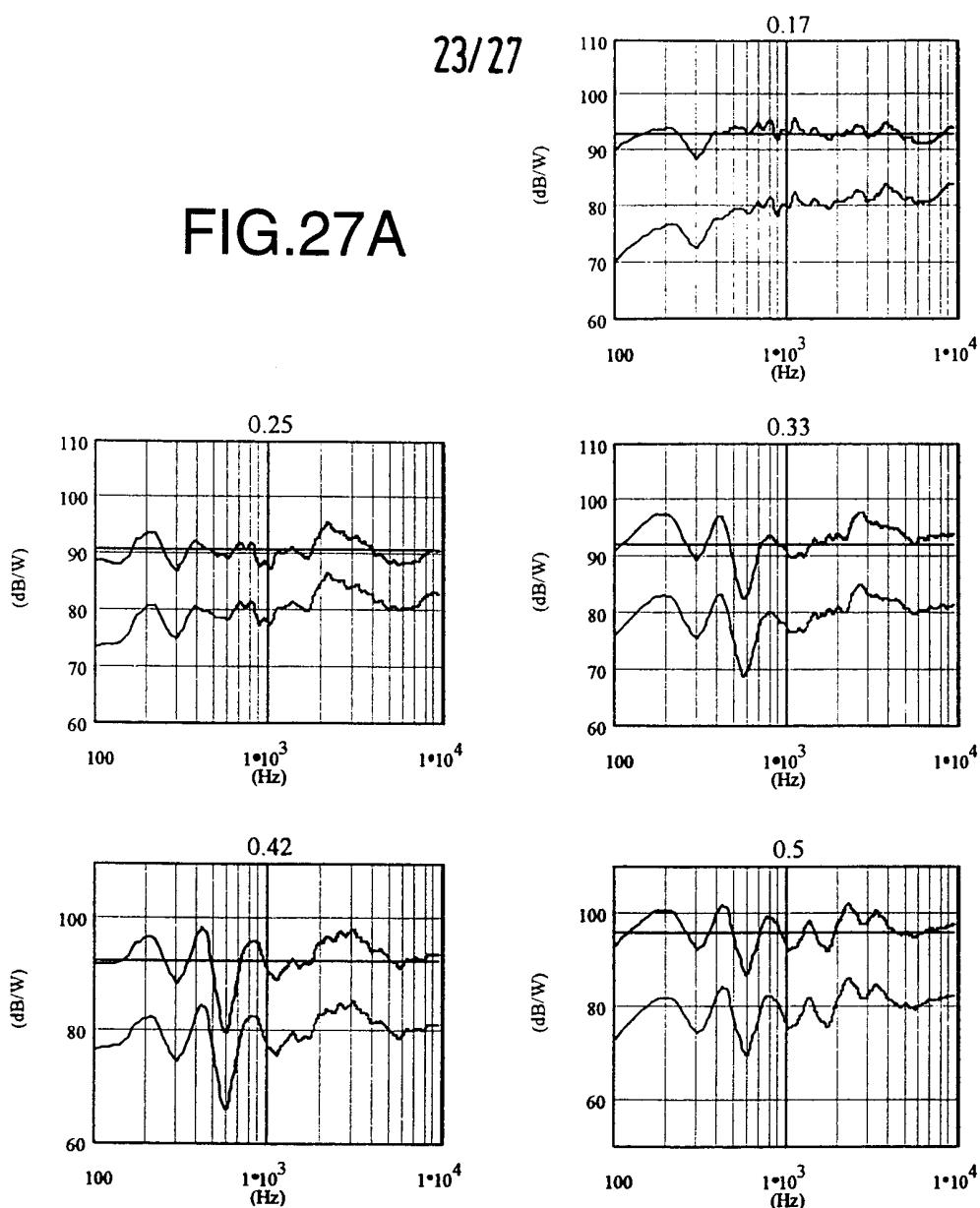
FIG.27B

200Hz-10kHz
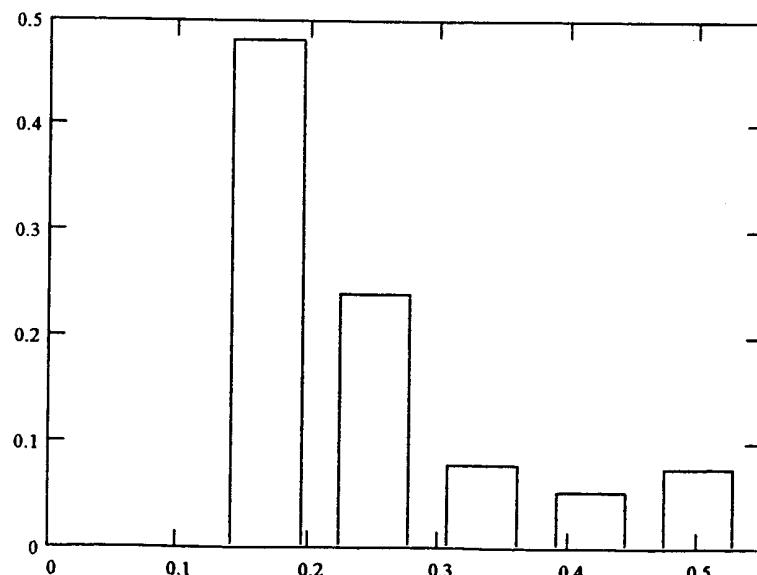
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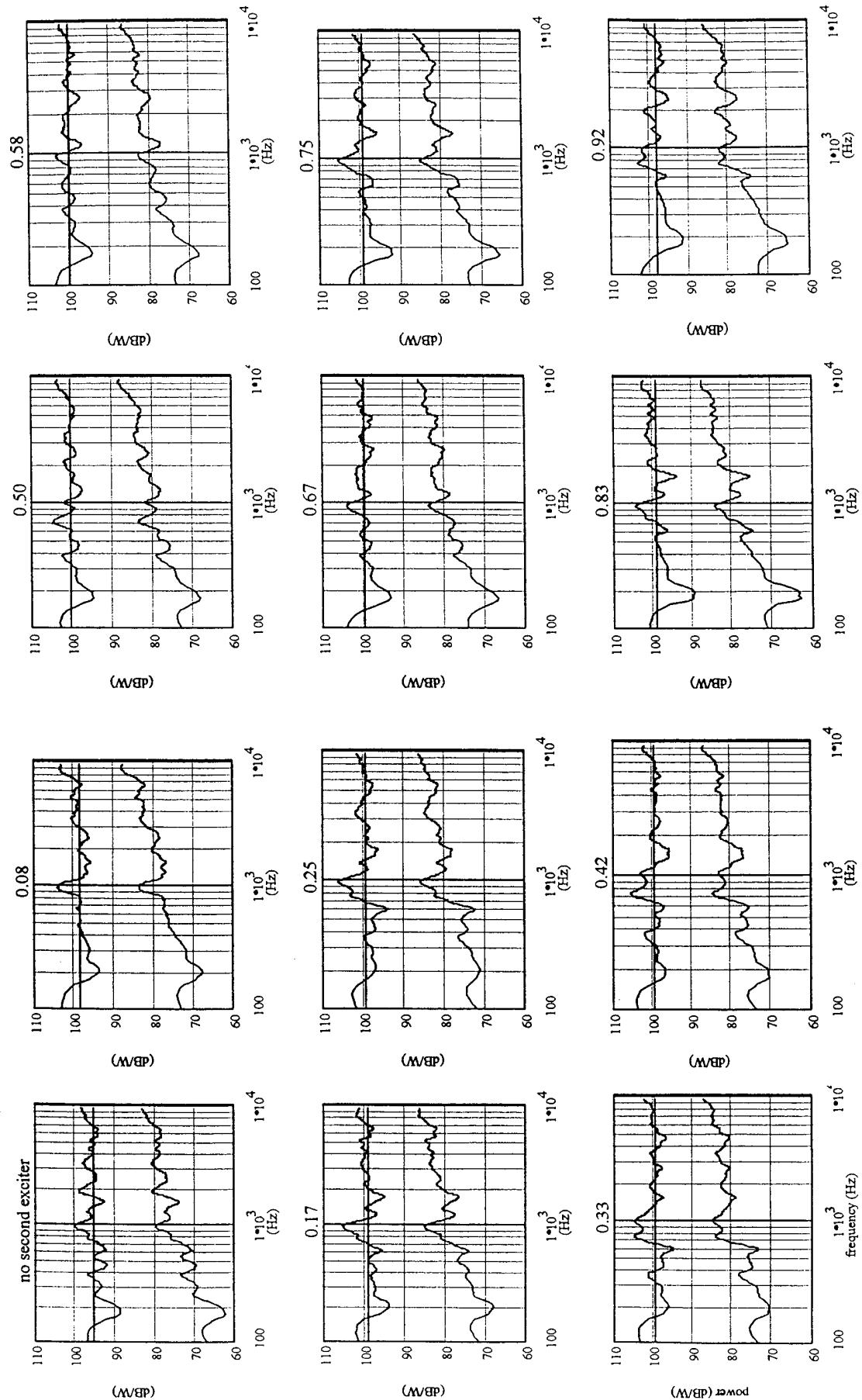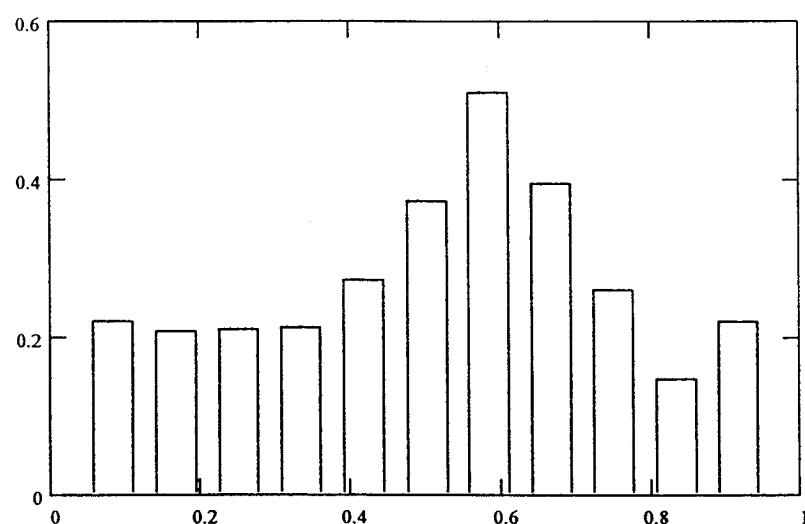
FIG.28A

FIG.28B 200Hz-10kHz

Panel.

FIG.29

Point force.

100

101

103

102
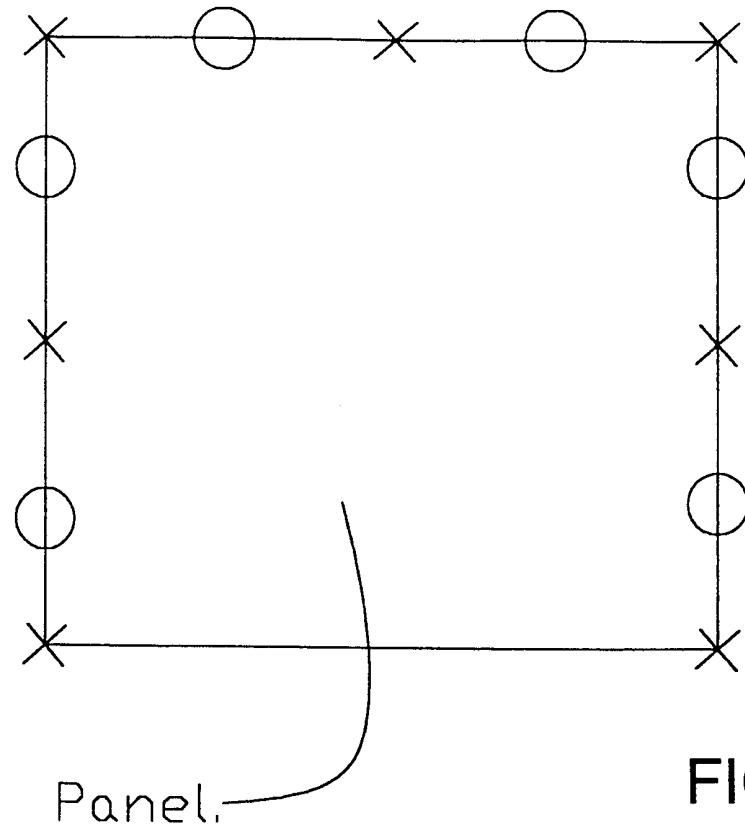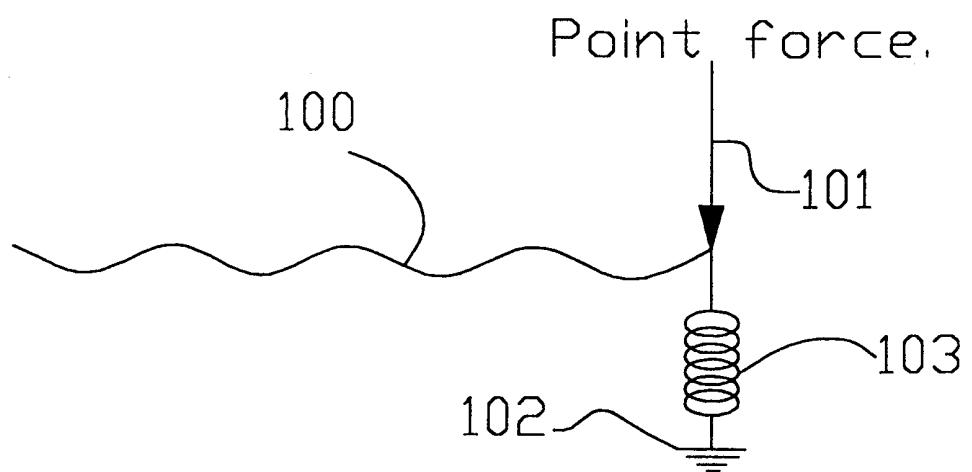
FIG.30
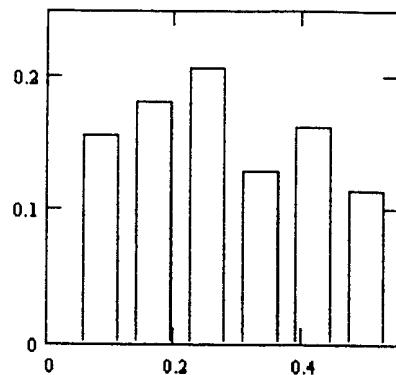
FIG.31A
300Hz-3kHz
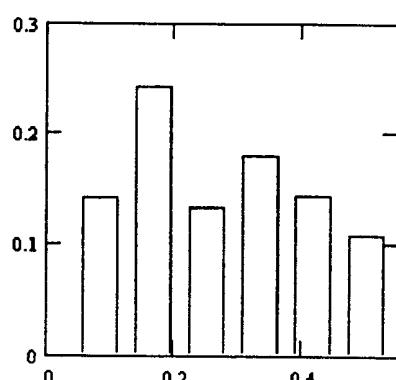
FIG.31B
300Hz-3kHz

FIG.31C
300Hz-3kHz
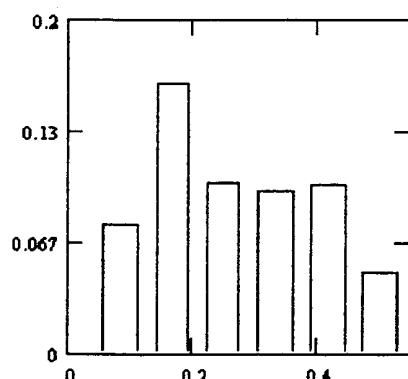
FIG.31D
300Hz-3kHz
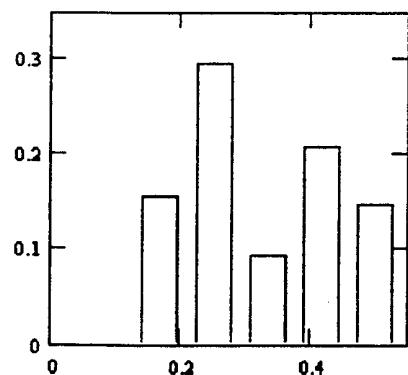
FIG.31E
300Hz-3kHz

INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6   H04R7/06   H04R7/10

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6   H04R

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 92 03024 A (SECR DEFENCE BRIT) 20 February 1992 cited in the application	1-5,25
Y	see page 5, line 6 - line 23; figures	26
A	WO 97 09842 A (AZIMA HENRY ;HARRIS NEIL (GB); COLLOMS MARTIN (GB); VERITY GROUP P) 13 March 1997 cited in the application	1,17-24, 27,28, 40,41,48
Y	see abstract; figures 50-55 see page 80, line 22 - page 82, line 27	26
X	US 3 347 335 A (BILL G. WATTERS) 17 October 1967 see column 2, line 50 - column 3, line 13; figures	1-5,25

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| X | Further documents are listed in the continuation of box C. | | X | Patent family members are listed in annex. |

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Date of the actual completion of the international search	Date of mailing of the international search report
14 June 1999	21/06/1999

Name and mailing address of the ISA	Authorized officer
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INTERNATIONAL SEARCH REPORT

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category°	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	US 3 247 925 A (GLENN E. WARNAKA) 26 April 1966 see the whole document ---	1-5
A	PATENT ABSTRACTS OF JAPAN vol. 010, no. 228 (E-426), 8 August 1986 & JP 61 061598 A (MATSUSHITA ELECTRIC IND CO LTD), 29 March 1986 see abstract ------	17-24

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/GB 99/00143

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