CELESTION INTERNATIONAL LIMITED
DITTON WORKS FOXHALL ROAD IPSWICH SUFFOLK IP3 8JP ENGLAND.
TELEPHONE IPSWICH (0473) 73131. TELEX 98365 CABLES VOICECOIL IPSWICH.

System 6000

Celestion's answer to a BAFFLING PROBLEM!

0. Introduction

It has been generally recognised for some considerable time that the materials used in the construction of a loudspeaker cabinet can markedly affect the overall sound. If this were not enough, we also know that when we have spent a long time producing a loudspeaker of particular merit, then it can be heart-breaking, if not at least embarrassing, only to find it sounds completely different in someone else's listening room. In order to understand these two particular problems Celestion have spent a considerable amount of time researching loudspeaker cabinets as well as the interaction of such loudspeaker cabinets in various room configurations.

1. The Cabinet

In 1982 the SL600 loudspeaker system was developed around two drive units and a crossover that had previously been used in the SL6. It had been recognised that a wooden cabinet was capable of storing energy by the bending modes set up in the various cabinet panels - and if cabinet colouration is caused by such a mechanism then it should be possible to vary this mechanism and observe the results. In order to make a significant change to the mass and stiffness, an experimental cabinet was made from aluminium skinned/aluminium honeycomb panels. Although a number of special techniques have to be used in the construction of such a cabinet, the differences between the two designs are confined to the cabinet and its foam filling.

Figure (1) shows the transmission loss of a typical flat panel that we might want to use in a cabinet wall. The character of the curve will obviously vary for different panels and in particular the resonances depend upon the specific damping mechanisms present in any particular panel used. In the case of Aerolam, which is used for the panels in the SL600, these differ from chipboard in three significant areas.

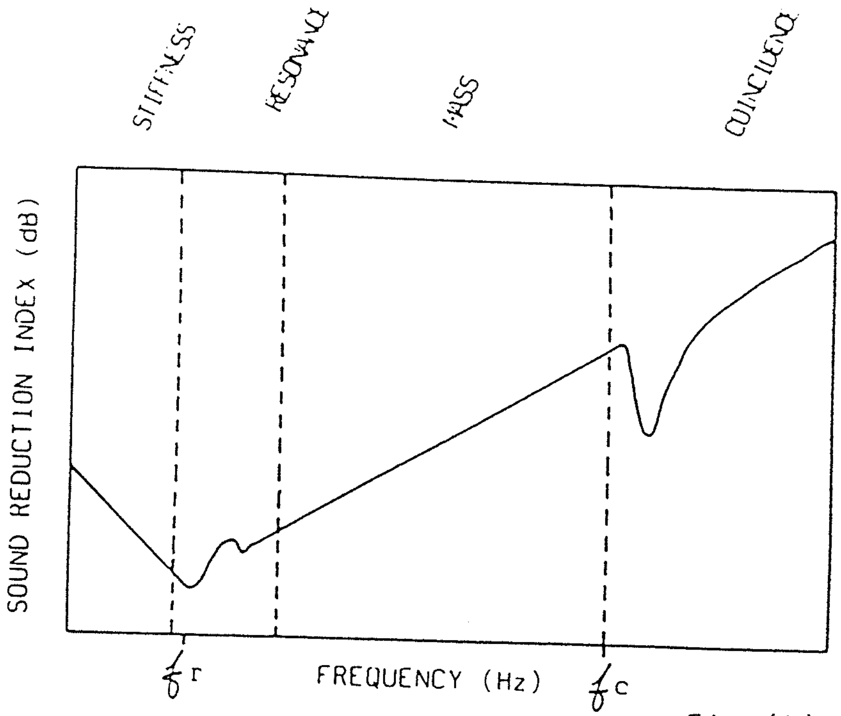


Fig.(1)

(1) A reduction of panel mass per unit area from 7.4kg per sq.metre to 3.12kg per sq.metre.

(2) an increase in stiffness from 15.5 x 10^3 N/m to 32 x 10^3 N/m.

(3) a decrease in critical frequency from 1.3kHz to 660Hz.

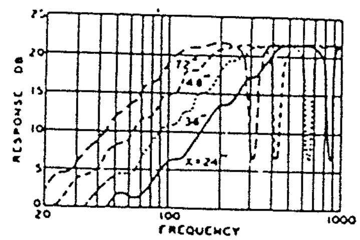
Although these changes may not seem large they do produce a clearly audible difference in listening tests. Having changed all three parameters at once it would be very beneficial to be able to change these parameters one at a time. It is in fact possible to do this to some extent by varying the skin and core Young's modulii as well as the core shear modulus. What might be an ideal cabinet, as a reference, is one in which the panels operate in the stiffness region throughout the whole audible band. Unfortunately such a material has yet to be produced, but to determine the absolute level of performance that MIGHT be achieved, it was decided that a reference transducer would be invaluable.

2. The non-cabinet

The reference transducer should have the ultimate in stiffness to weight ratio. In order to be sure that this would be high enough a loudspeaker without a cabinet at all was postulated. This, by definition, would be a first order source. The advantages of such loudspeakers have been known for quite some time but hitherto have tended to be large area devices (since designers were very conscious of the need to keep a reasonable bass performance). Unfortunately this would change our source size too much for our

The first dipole concept that springs to mind is a large baffle design, and figure (2) shows the sort of frequency responses that have been determined for various sizes of baffle (ref 1). It is this sort of thinking that led to the flat baffle designs popular for some 30 years. In order to maintain a respectable low frequency cut-off very large baffles were often adopted, giving rise to two specific problems.

Fig.(2)



The first is the large acoustical size combined with the irregularities caused by the location of the drive unit in the baffle itself. this problem can be alleviated to some extent by offsetting the drive unit to remove the severe on-axis dip.

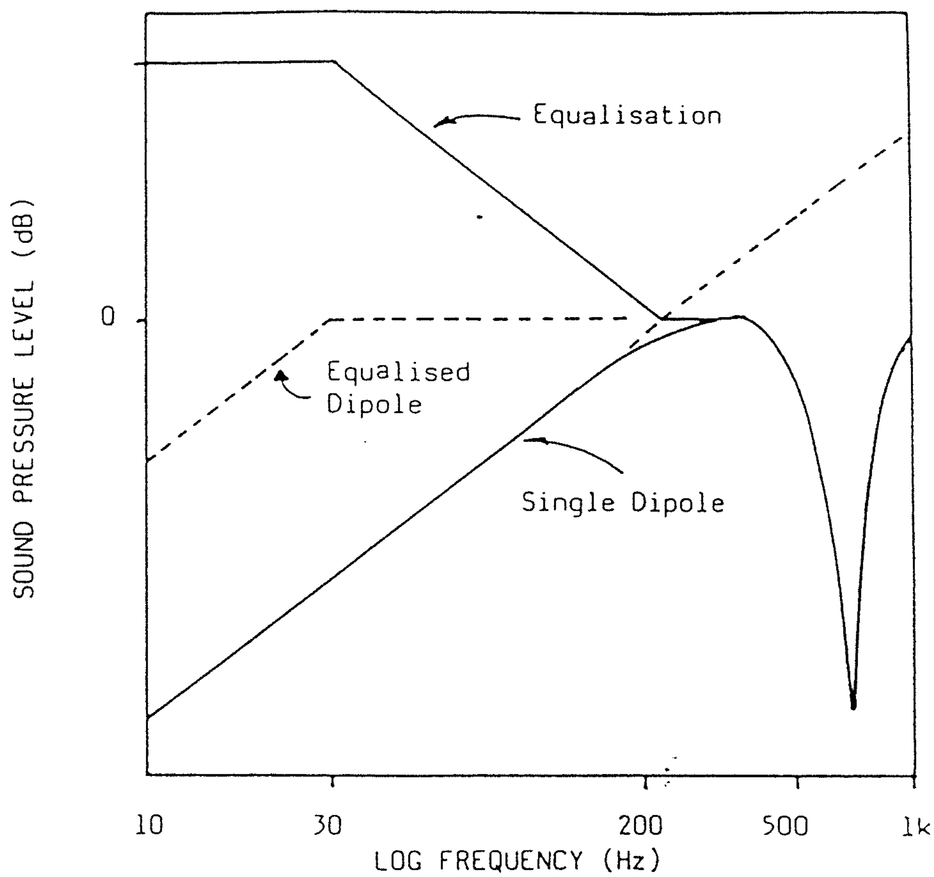
The second problem is that it becomes very easy to induce resonant modes in a large baffle - which is rather ironic, since, if you remember, we introduced the concept of a first order source to stop any cabinet contribution in the first place. However, at first glance there seems to be little one can easily do about the size of the baffle.

Looking back at figure (2) the various response curves show that the only trade-off on baffle size is the -3dB point. If we were to equalise this 6dB per octave response with a simple first order filter which has the inverse characteristic of our dipole then the on-axis sound pressure response would be corrected and at the lower turnover point where the gain becomes constant the dipole would again fall-off at 6dB per octave. From our experience this first order roll-off rate is a very desirable feature since it is most likely to interface to a typical listening room. In fact, choosing different low frequency turnover points for the system is done by simply selecting the lower turnover point, or extension, of the equaliser. It will come as no surprise that reproducing low frequencies places the greatest mechanical demand on any loudspeaker, and the dipole is no exception. With this in mind it was decided to construct a subwoofer system first of all - if we can't get our reference loudspeaker to work at very low frequencies then there would not be very much point in continuing.

We also decided that our source would start as a 12 inch bass unit mounted rigidly on the smallest practical baffle using the appropriate equalisation (figure 3).

A computer model was then developed to determine the low frequency responses possible with different effective path lengths between front and back of the source. However, it soon became clear that a single 12 inch unit on a small baffle acting as a dipole on its own has a limited output capability.

Fig.(3)

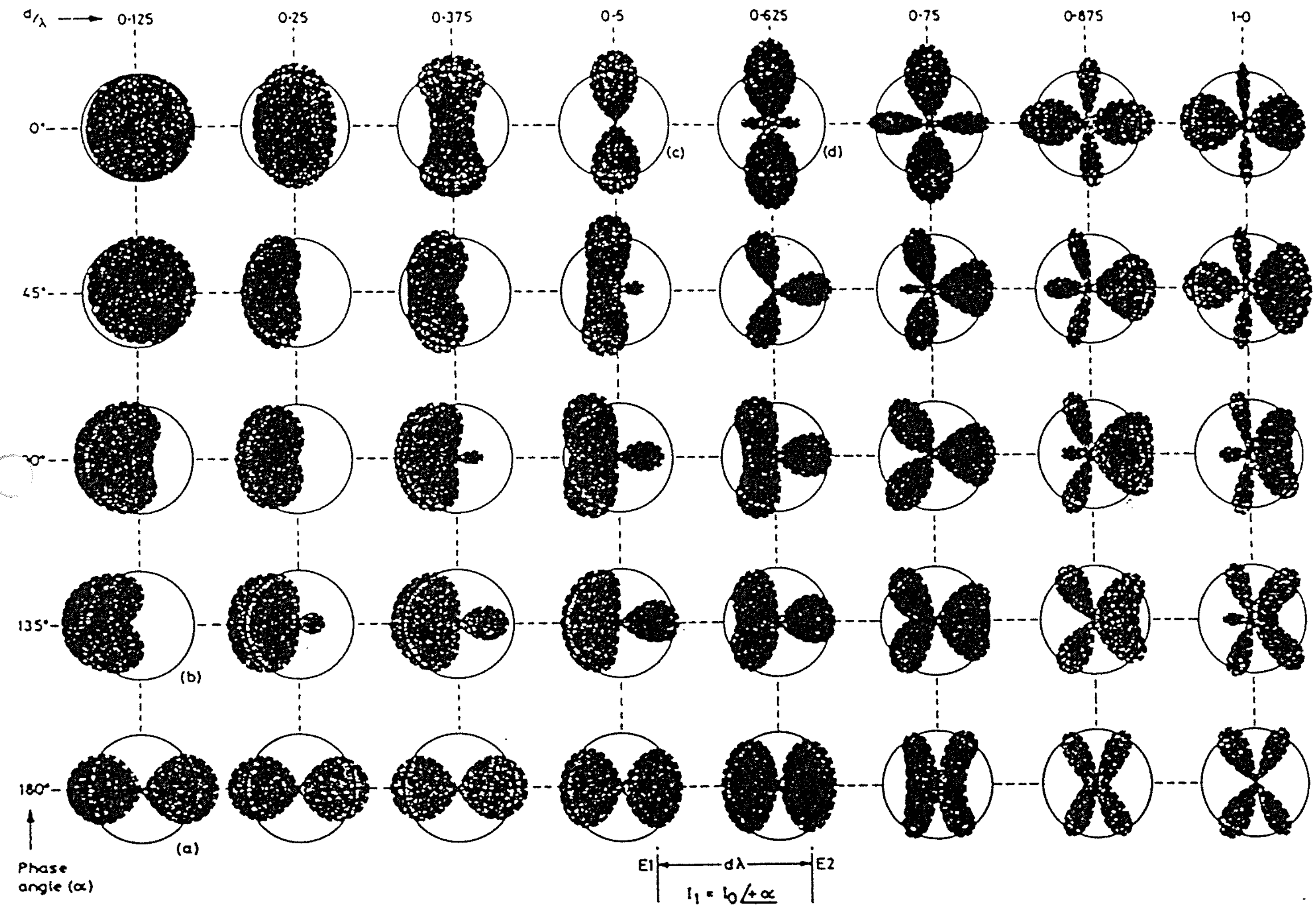


3. The dipole array

The idea of using more than one drive unit to increase output is by no means new, and many designers have used multiple drive units for this purpose, but multiple drive unit systems need large baffles to accommodate them, and you can soon get back to a large acoustical source size as well as big bendy baffles. What we needed was a method of increasing output without a great stack of drive units or enormous baffles.

It then occurred to us that it may be possible to arrange a number of dipoles into a particular array. Figure (4) shows the classic radiation patterns for pairs of monopoles with various spacings and phase relationship (ref 2).

Fig. (4)



The computer model was then further developed to include the possible arrangements and various phase relationships that could be used, including classic broadside and end fire configurations.

By setting two dipoles with specific effective path lengths for each dipole, we can see the effect of the spacing of our two dipoles, as increasing the spacing brings the broadside null lower in frequency.

Incidentally this rather neatly produces an array whose effective source is located, with frequency independence, between the two dipoles. In theory it is possible to use a four dipole or even higher order arrays if even greater output is required.

Fig.(5)

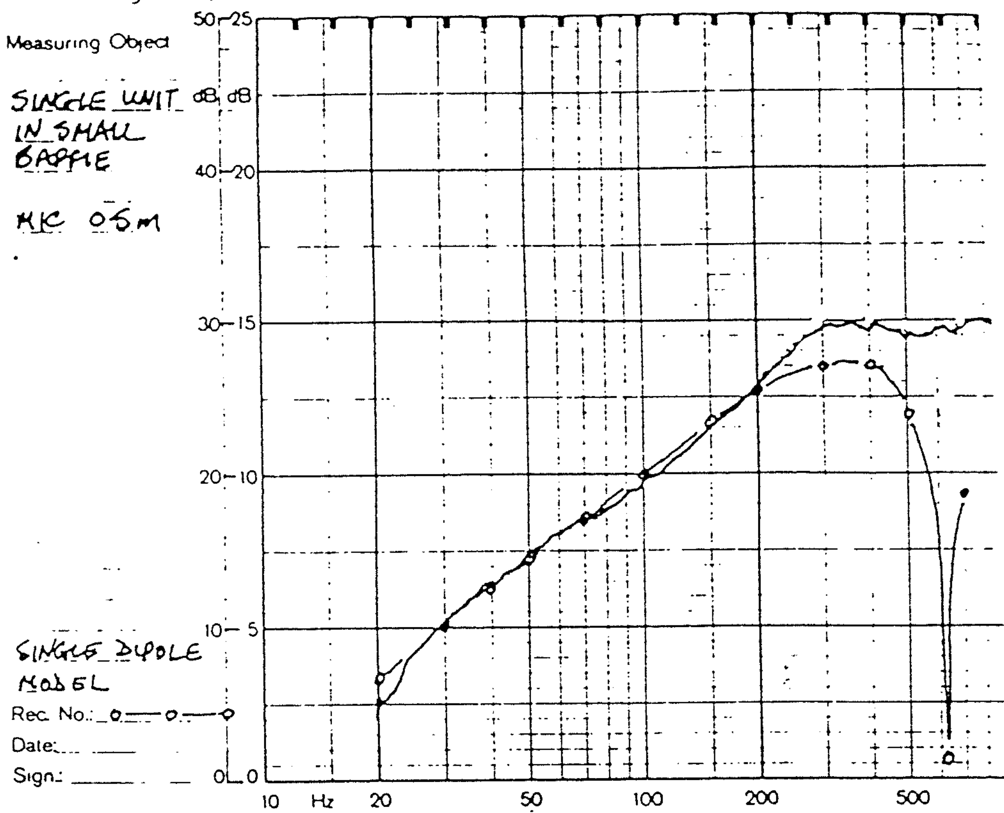


Figure (5) shows an experimental single 12" bass unit with its frequency response when mounted in a small baffle shown by the solid line. The results from the computer model have been transcribed onto the pressure response curve for comparison

No account is taken in the model for the physical size of the bass unit and any possible rise in on-axis output caused by directivety, since we are concentrating on the low frequency performance of the double dipole array.

4. What about the room?

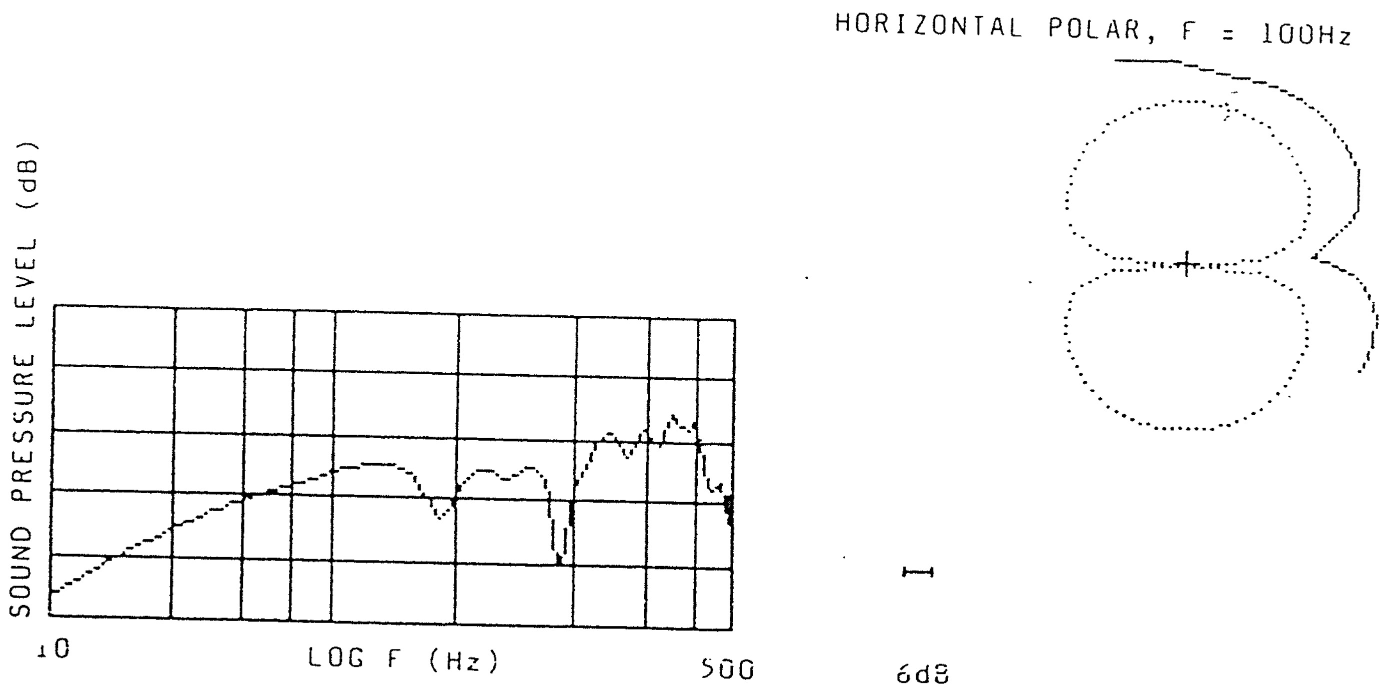
Having decided that we can make a source which is acoustically small, can reproduce low frequencies without the normal cabinet problems associated with such a design - what happens when we take it round to someone else's listening room?

To answer this question a further computer model was generated to determine how the source interacts with room boundaries. This model uses a first order steady state approximation method to construct the polar pattern of a source as determined by an observer in the room. Absorption by all six boundaries can be easily varied in the model, bu ideal reflectivity has been assumed for the cases presented here.

The output format is in the form of both an on axis sound pressure response as well as a horizontal polar response at any selected frequency. This output is used for comparisons between actual sound pressure measurements in a test room and those of the computer model. In this way we can predict the best low frequency extension and dipole/boundary angles to achieve the best stereo presentation combined with suitable room integration.

Previous attempts to look at the interaction between dipoles and boundaries (ref 3) show the radiated power with frequency from a single dipole both normal and parallel to a single boundary, when the source is in a reverberant sound field. To try to relate our results to a typical environment, our technique uses all six room boundaries in a steady state image model.

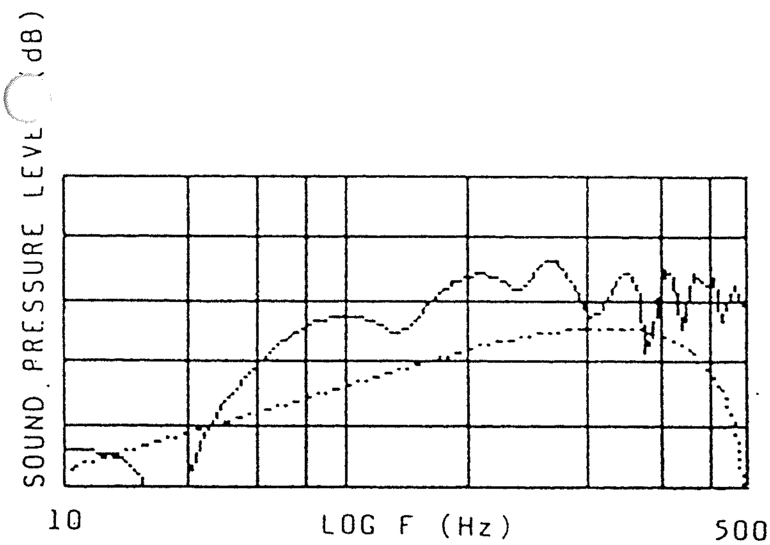
Fig.(6)

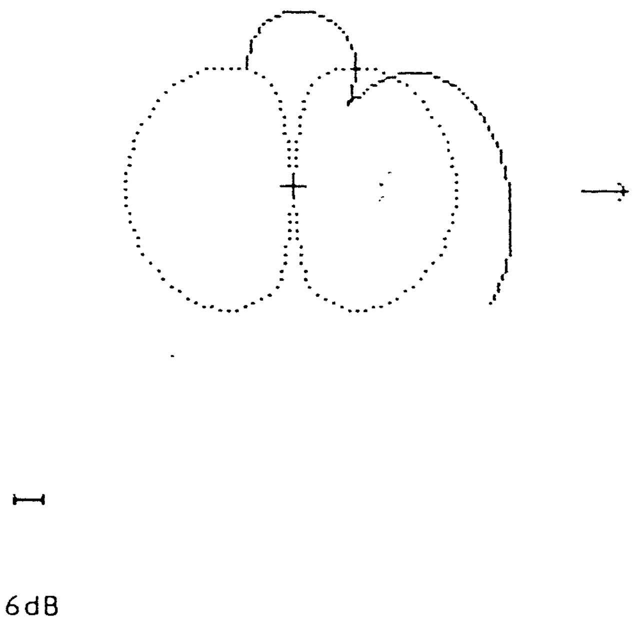


TWO DIPOLE ARRAY, 6 BOUNDARIES,
· SOURCE PARALLEL TO BACK WALL

Fig. (7)

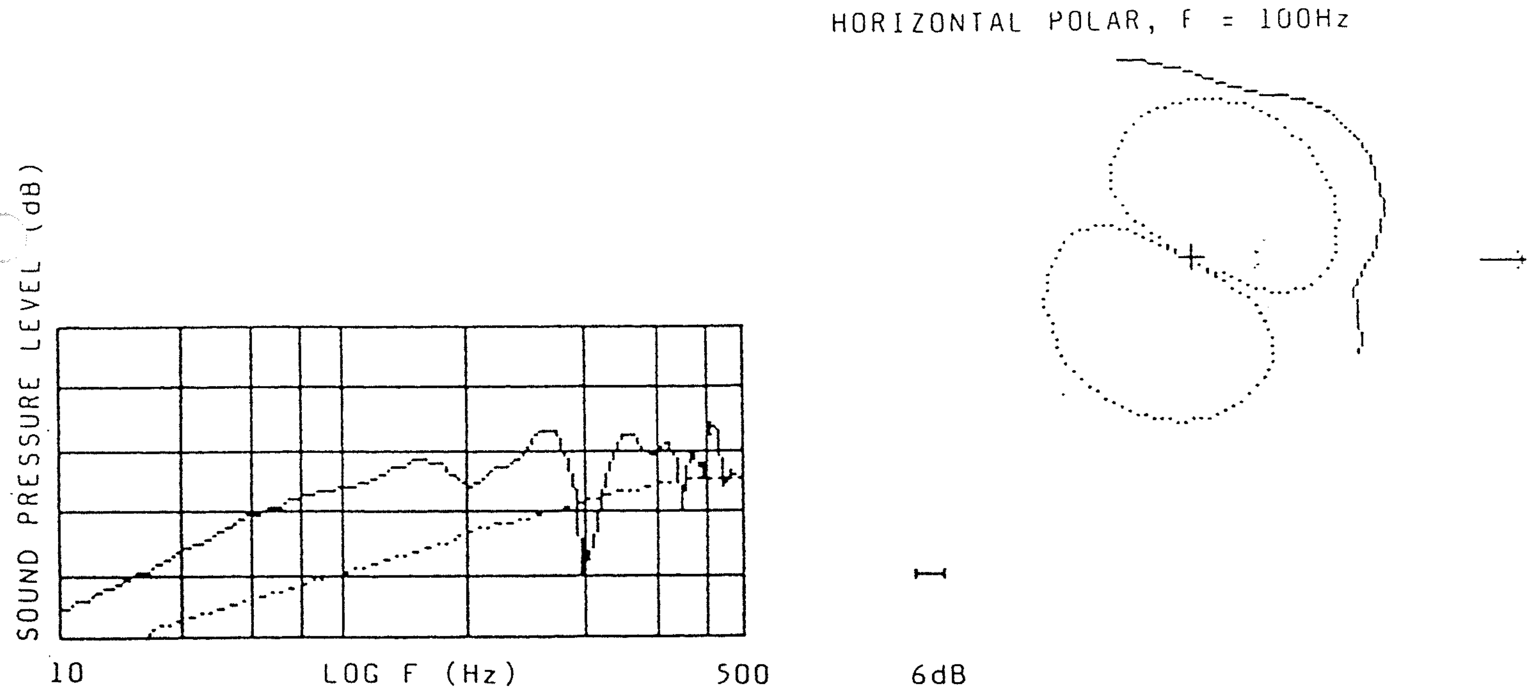
HORIZONTAL POLAR, F = 100Hz





TWO DIPOLE ARRAY, 6 BOUNDARIES
SOURCE SET NORMAL TO BACK WALL

Fig.(8)



TWO DIPOLE ARRAY, 6 BOUNDARIES,
SOURCE SET 60° TO THE NORMAL

If we take a typical case of six boundaries we can see the effect of rotating our double dipole array within the room. By observation you can see that neither the parallel figure (6), nor normal, figure (7), conditions are actually ideal, but by rotating the double dipole array to some intermediate angle, as in figure (8), then both the sound pressure response curve and the polar response curve have an uncanny resemblance to those response curves of the reference unbounded source.

5. CONCLUSION

In this way it is quite feasible to locate a double dipole array in a normal listening room and still retain both the free-field sound pressure and polar responses. A loudspeaker that is sited in a room but gives all the indications that the room isn't there!

References

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