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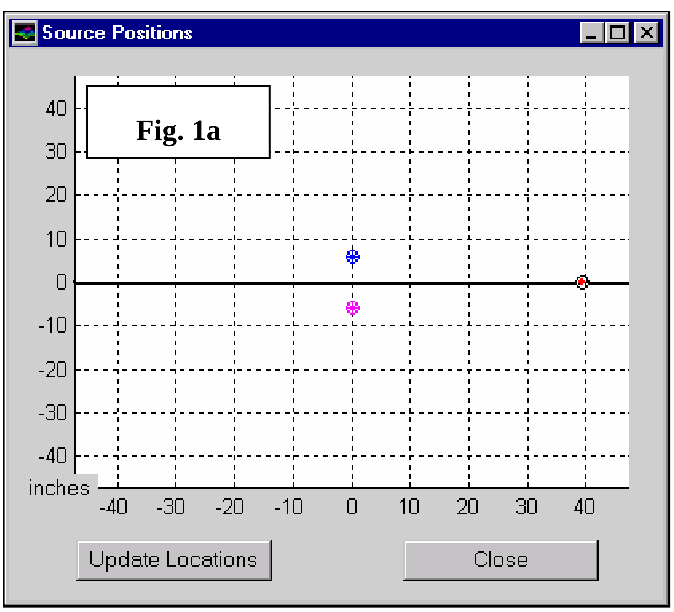
Alternative Ways of Viewing Polar Data

by Charlie Hughes

The inclusion of phase information in loudspeaker polar data represents the next milestone in simulation accuracy for the loudspeaker array designer. A respected loudspeaker engineer shares his work with our readers.

Several years ago I read an AES paper (pre print # 3750 from the 95th Convention, October 1993) by Andrew Rimell and Dr. Malcolm O. Hawksford, of the University of Essex, on crossover design strategy. The crossover filter concept they covered was interesting. However, I was very intrigued by some of the illustrations they used to display level vs. frequency vs. radiation angle. Most of the displays I had seen up until that time were balloon type graphs displaying full 3D data of a given level (say -6 dB) at a particular frequency or averaged band of frequencies, basically a 3D polar plot. In contrast, the Rimell and Hawksford displays were 3D Cartesian in form. They consisted of a series of frequency response curves at different radiation angles within the same plane, very similar to a TEF waterfall plot of polar data. The main difference from the TEF display was that 0° was in the middle & 180° was on each end. Furthermore, color gradients are used to help denote level differences.



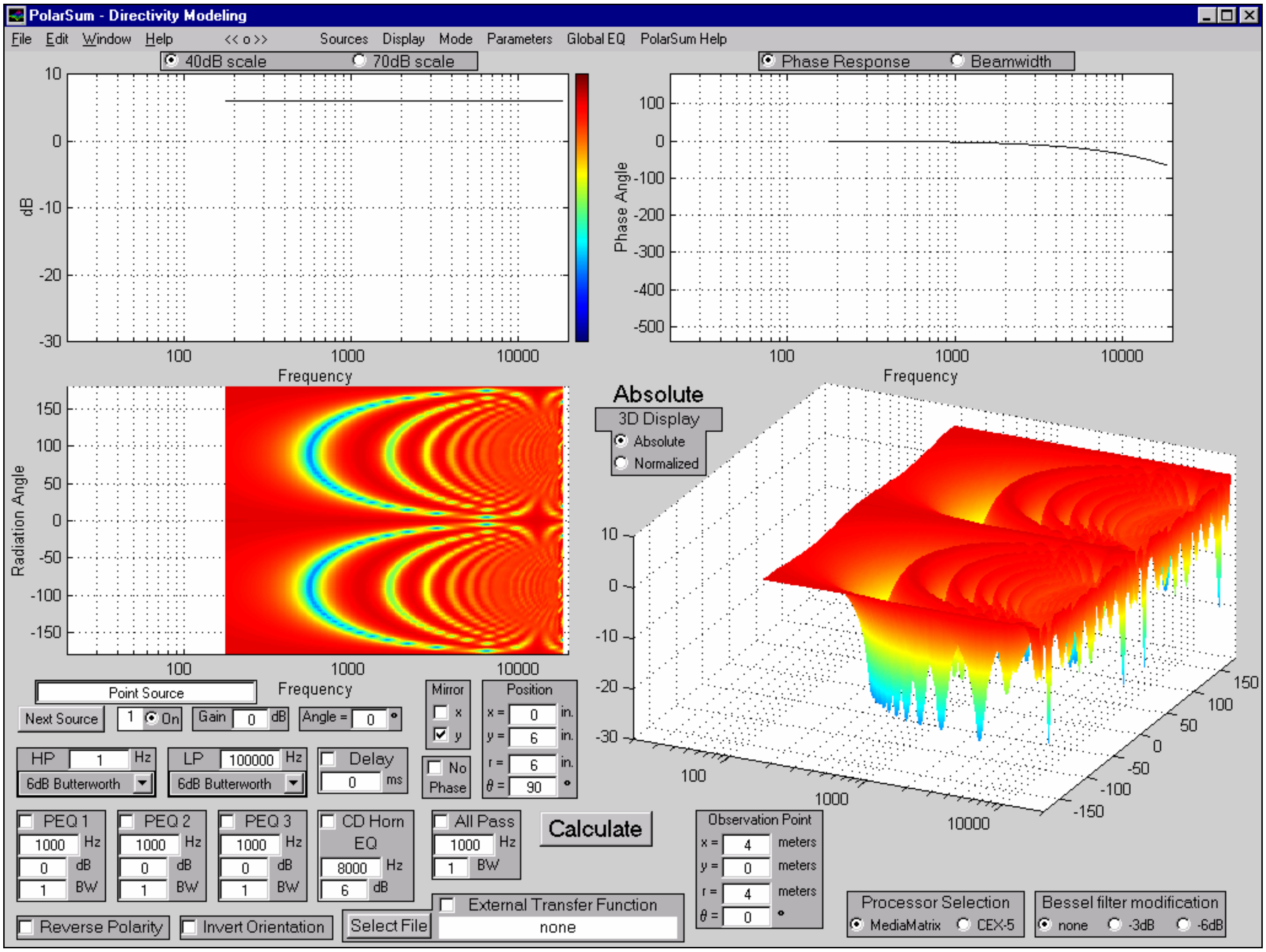
Source & observation locations

About the same time I read this paper I had begun playing around with MATLAB. There are several very useful features of MATLAB. One is that it can operate on an entire matrix of data in a single operation as opposed to processing each element individually. This gives it fast processing time when operating on large quantities of data. The other is its capability for data visualization. It has nice built-in graphing routines so that a lot of time need not be spent on this low-level function.

I soon realized that accurate models of loudspeaker systems could be constructed and their performance viewed using MATLAB to crunch the numbers and display the data in the above format. All that is required is that very accurate data of individual components be entered into database files that the program could access. By applying the principle of superposition, the radiated sound field of a loudspeaker system, or an array, could be accurately calculated.

To test the waters I began with simple point sources and piston sources. Once I was able to get these to sum properly I could proceed to working with measured data from real devices.

As the program, PolarSum™, evolved many features



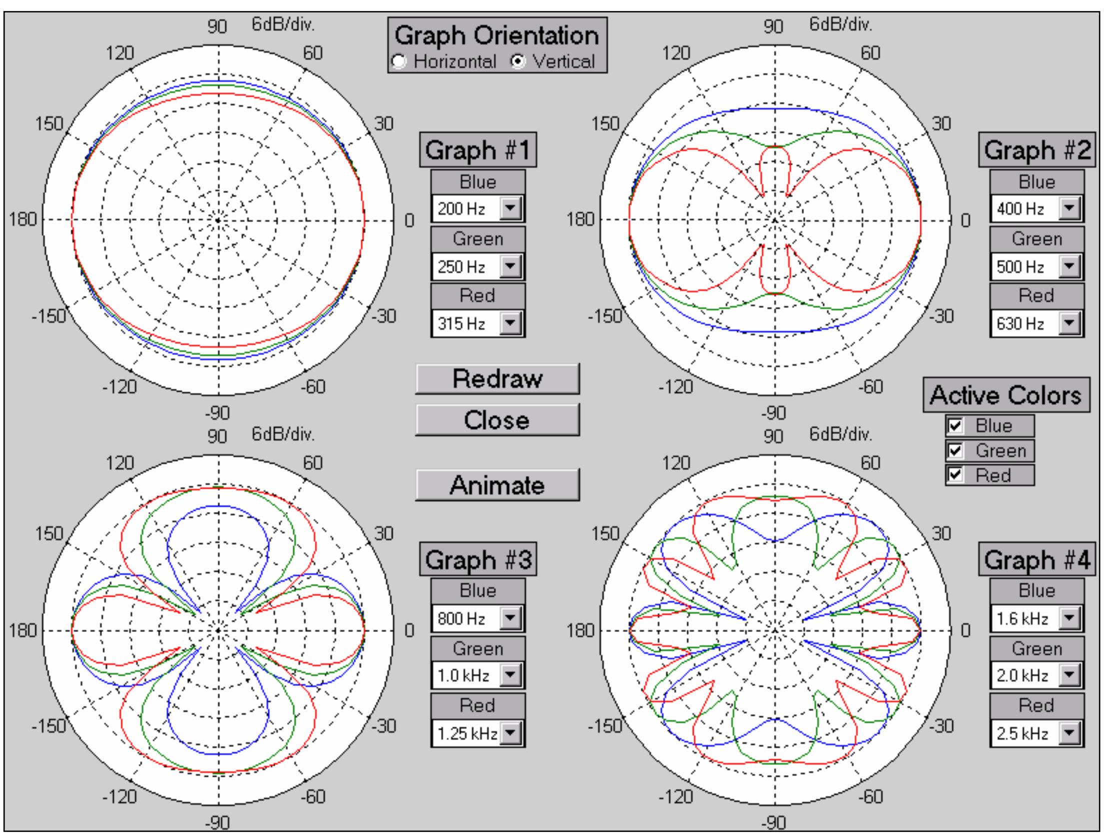


Fig. 1b

Fig. 1c

Figure 1a shows the source & observation locations.

Figure 1b shows the radiated directivity for two point sources each spaced 6 inches from the observation axis.

Figure 1c is a more familiar polar plot of the same data at 1/3 octave center frequencies.

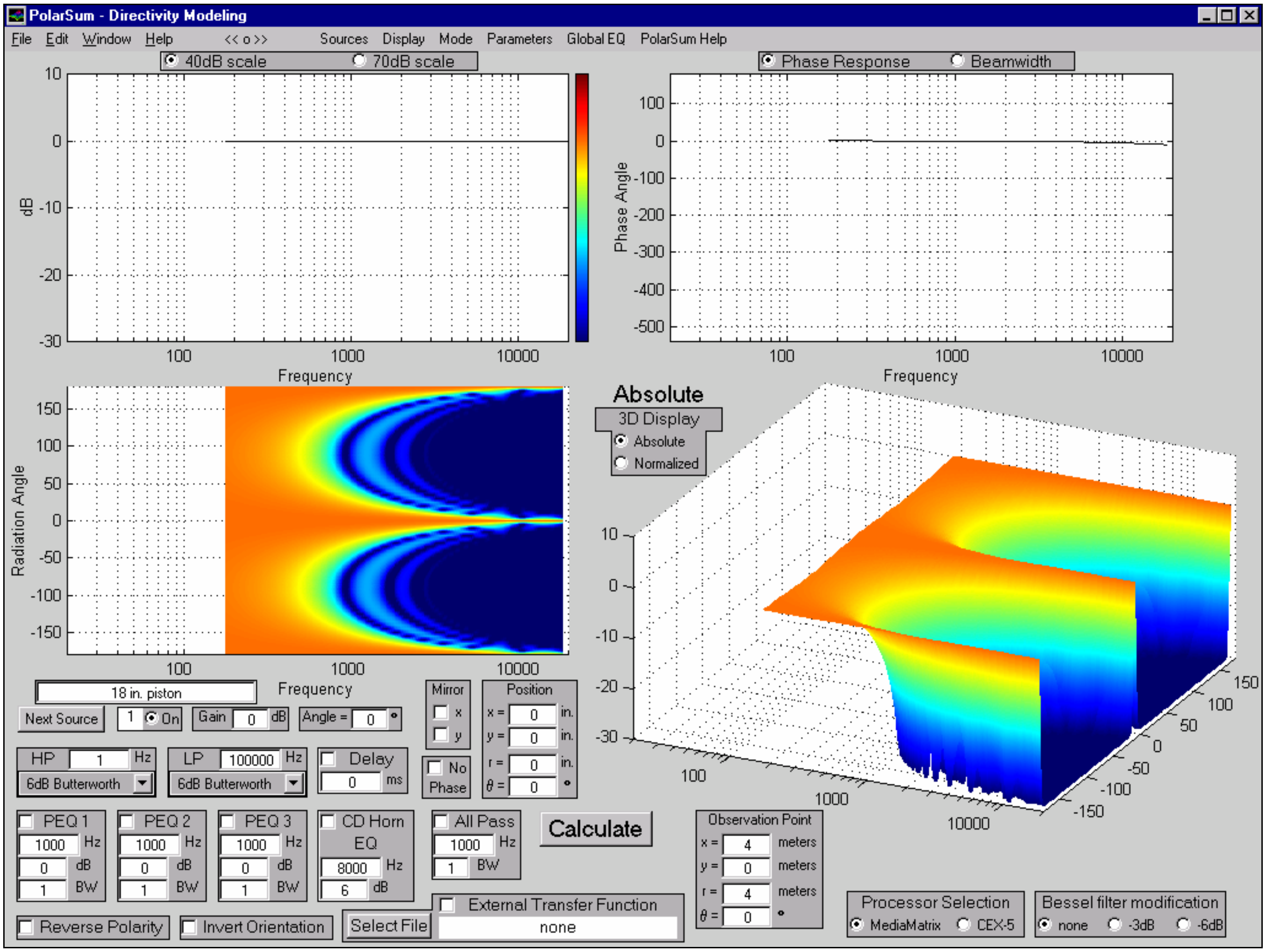


Fig. 2a

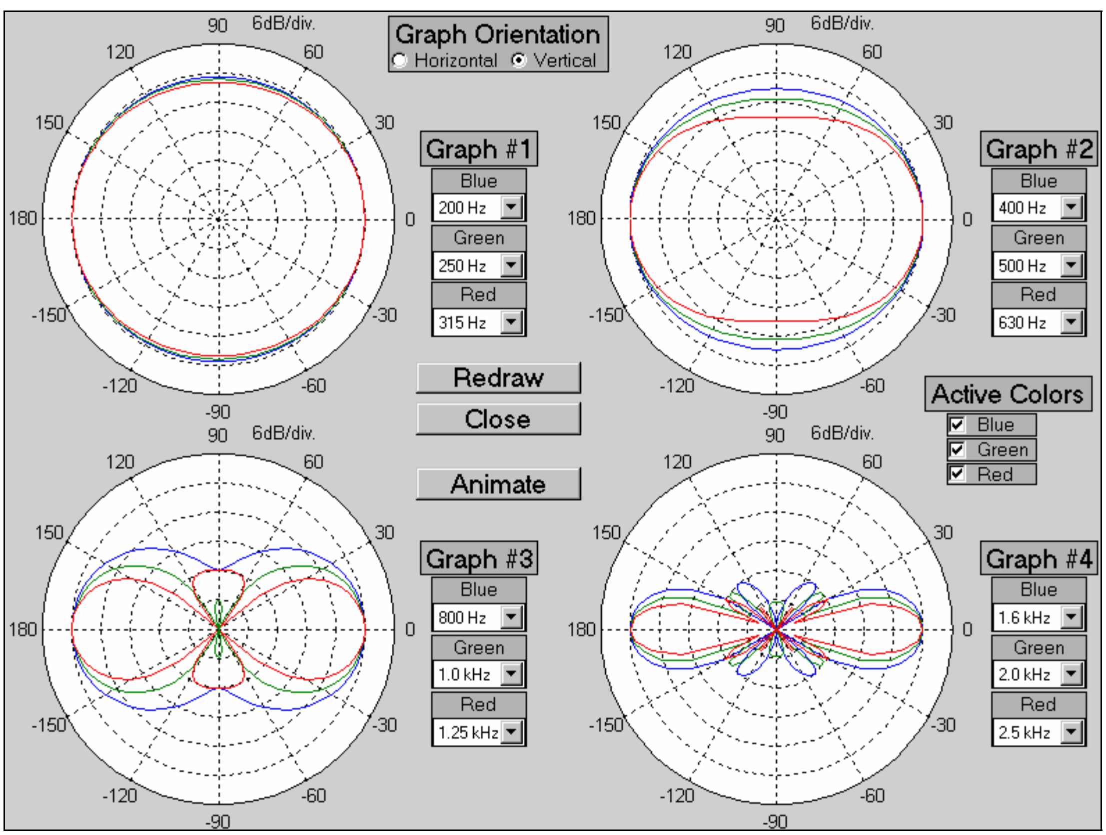


Fig. 2b

Figure 2a is the radiation pattern for a single 18-inch piston. Again figure 2b shows the same data as a polar plot.

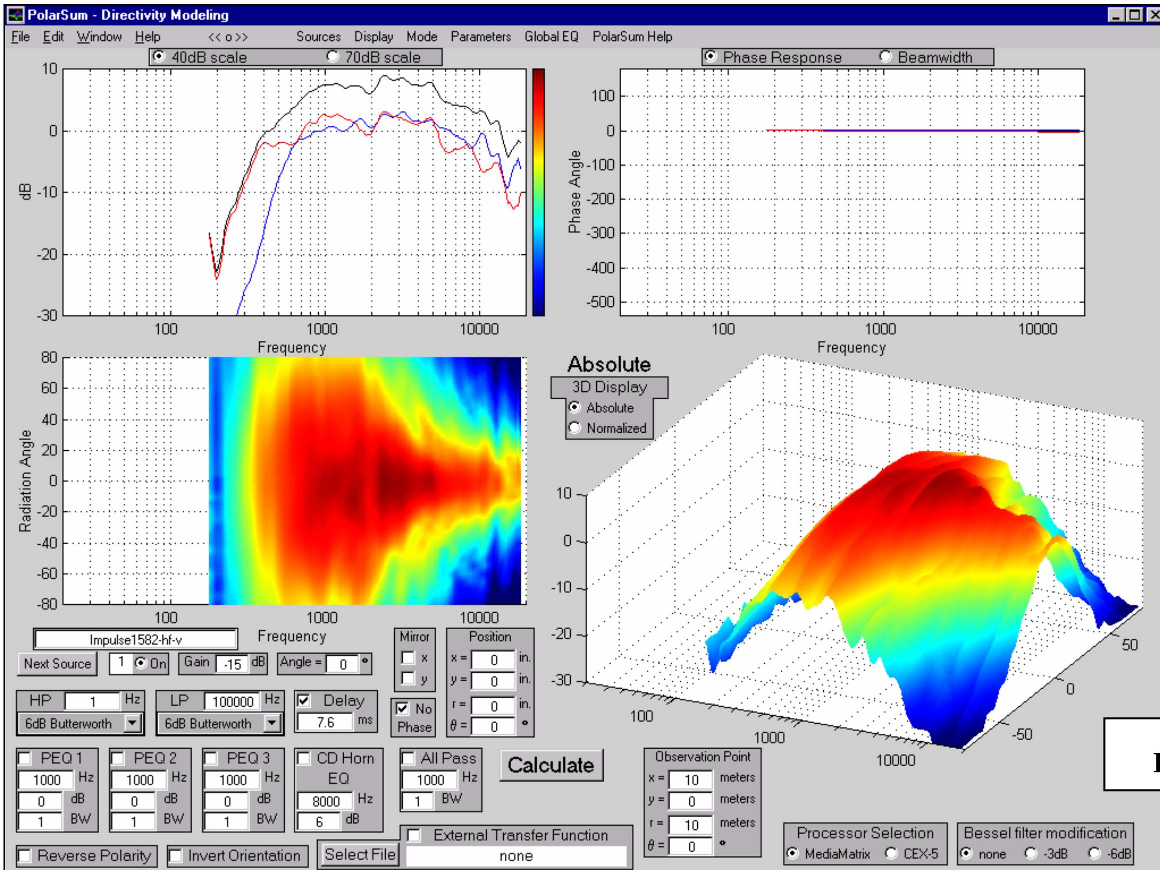


Fig. 3a

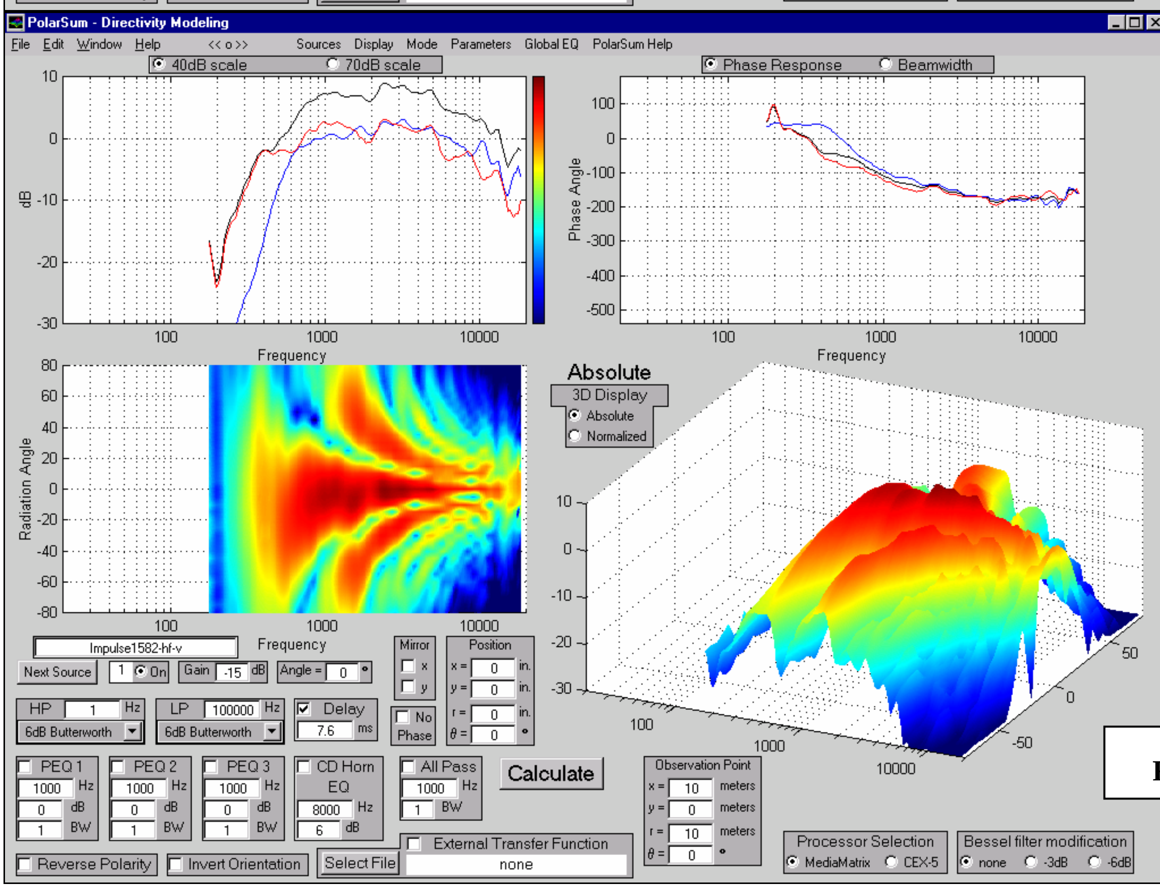


Fig. 3b

Figures 3a and 3b show the summation of the measured data (in the vertical plane) of two different horns. For this summation both horns are located at the same point in space. While this is physically impossible, it does help illustrate how not taking into account the source phase data leads to less than accurate results in the summation. The angular limits of the graph have been confined to +/-80° in order to concentrate the display within the coverage angle of the horns. In figure 3a the phase data of the sources is eliminated, while figure 3b includes this phase data in the summation.

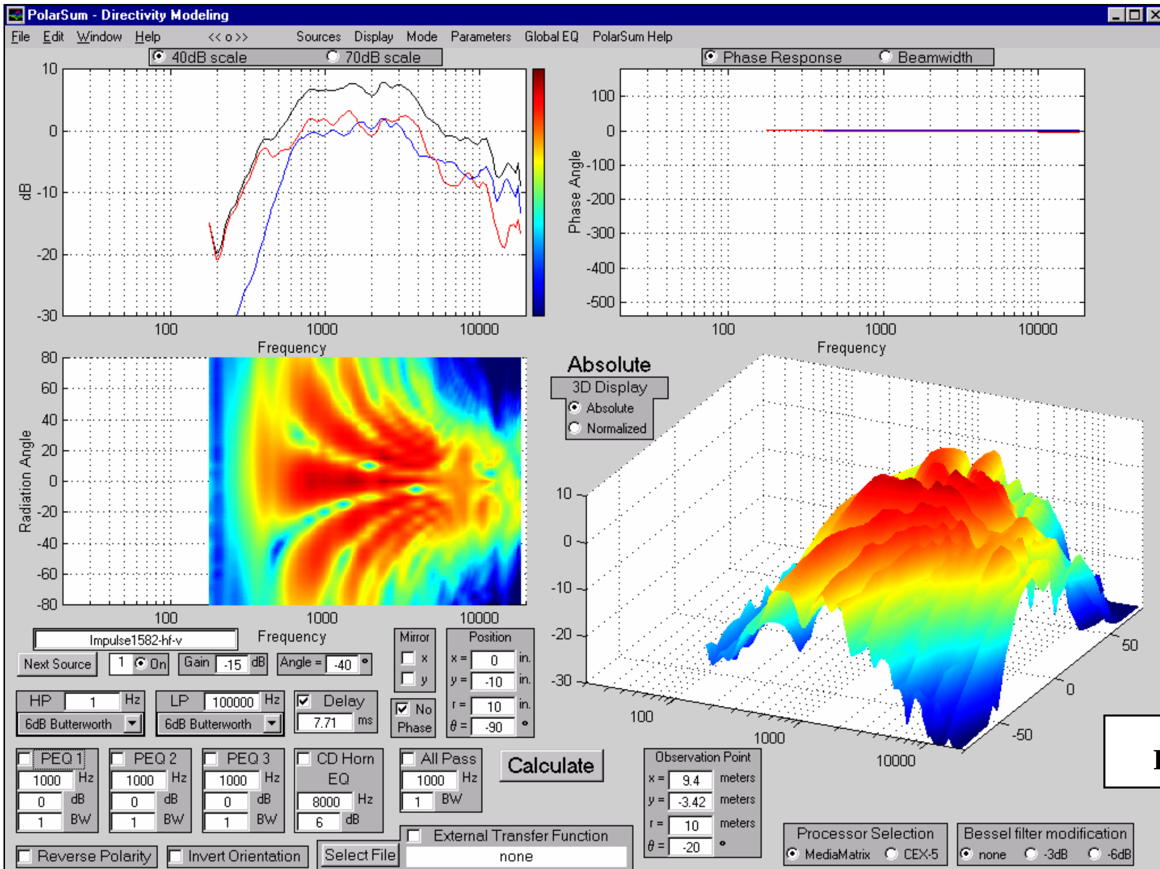


Fig. 4a

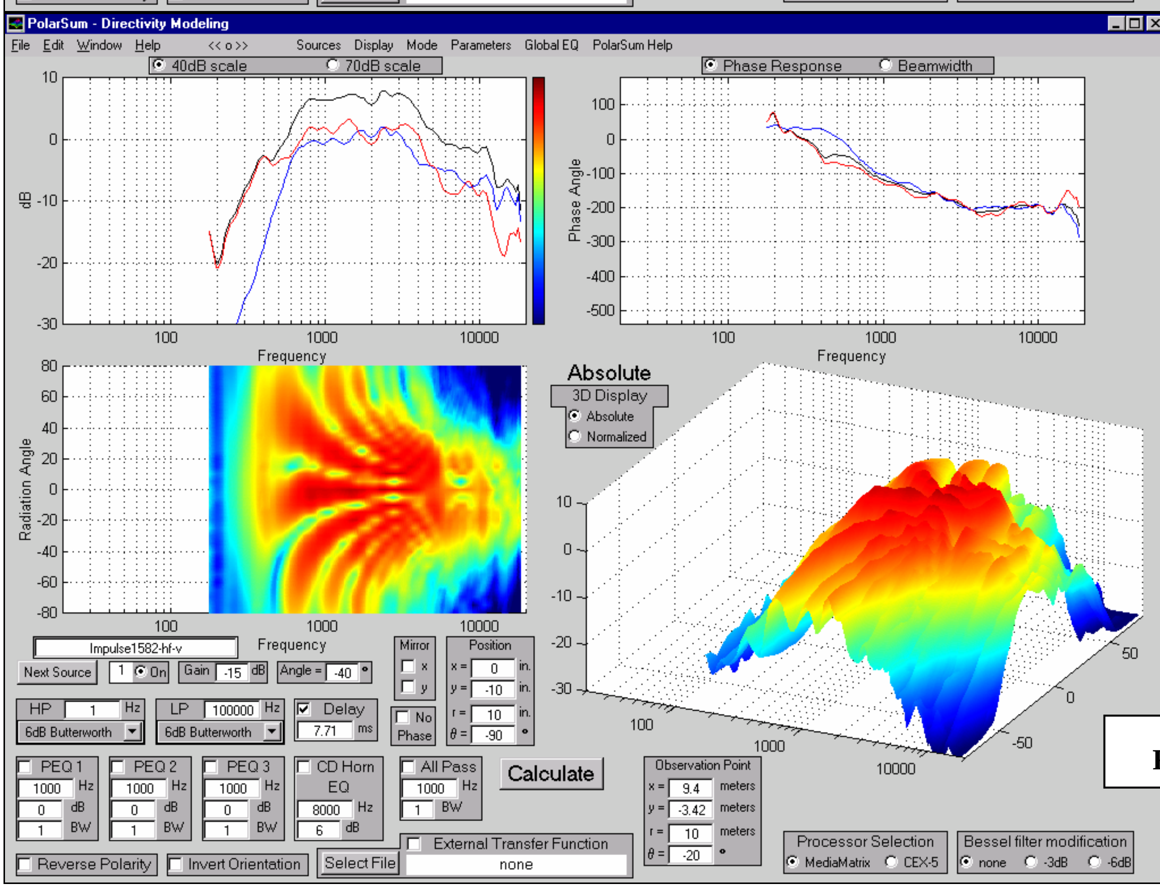


Fig. 4b

Figure 4 shows the summation of the same devices used in figure 3 but with them separated in space much as they would be used in a typical application. The mouths are 20 inches apart. The lower device (a 90°x40° horn) is aimed at -40° to the horizontal. The upper device (a 60°x40° horn) is at 0° to the horizontal. The observation point is 10 meters from the array at a point in the overlap zone of the two devices. Figure 4a has the source phase data eliminated while figure 4b includes this phase data in the summation. Note the change in location (frequency & radiation angle) of the nulls. Figure 4c shows the source locations and orientation along with the observation point.

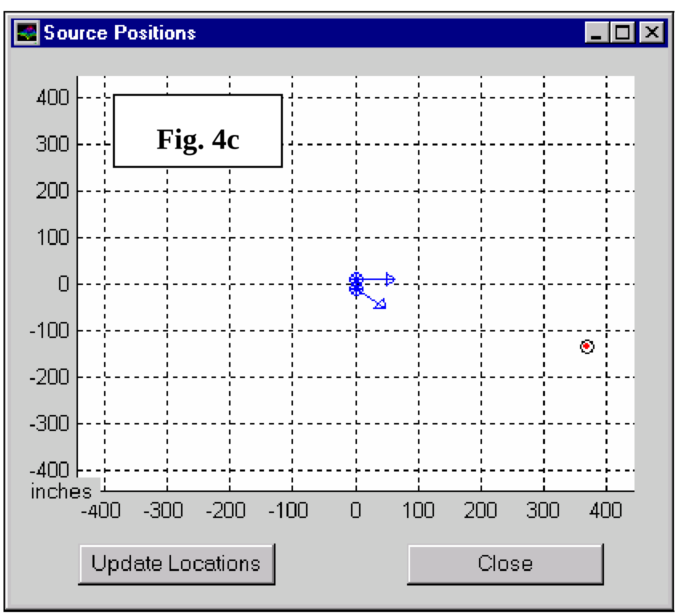
were added. In its current form measured directivity data from multiple devices may be combined while applying high pass, low pass, all pass, delay and equalization functions to each device. Measured transfer functions may be imported to apply to the directivity matrices as well. What this has enabled is a quick way to investigate the directivity characteristics of systems with the measurement of only the base components (called devices). Up until this time MANY hours were spent finalizing the crossover design for a loudspeaker system. It would require approximately 30 minutes to take one plane of 5° resolution polar data on a system. If the results were not satisfactory a change in the crossover might be made. Then another 30-minute measurement must be taken, et cetera, et cetera, et cetera. With PolarSum the same results are obtained in about 10 seconds, after the initial measurement of the individual components of course.

After acclamation to the displays, much more information can be discerned at a glance than pouring over multiple polar plots. One is able to view the frequency response of an entire plane at once. To help correlate to the traditional polar plots a routine is included which will calculate and display polars. It will even perform an animation of the change in polar response as frequency increases.

Once a loudspeaker system is modeled from its base components the system may be saved as a single device. This device may then be combined with other devices, of the same or different types to construct an array. The directivity of this array may then be calculated. This part does have some inaccuracies. As the model is based solely on the principle of superposition, diffraction effects from non-measured object orientations are not represented in the model.

The array calculation seems to work well. It allows reasonably accurate summation of unlike devices. This is only possible because of the inclusion of phase data for each device. For like devices the phase data need not be considered, as it is the same for each device. Knowledge of the geometry of the array is all that is necessary. For dissimilar devices with non-identical phase responses, accurate phase data and vector summation must be used to yield an accurate representation of the combined directivity response.

While PolarSum™ is not well suited to mapping the coverage in rooms, it will calculate what an array is doing in the free field. *ch*



Source & observation locations

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