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Progress Report No. 7

Project Title: "Measurement of Damping of Graphite Epoxy Material"

Sponsor: NASA George C. Marshall Space Flight Center, Huntsville, AL 35812

Period: April 1, 1985 - April 30, 1985

During this period damping measurements were made on the cylindrical graphite epoxy specimen using the forced-vibration test method. Thus the work performed during this period is a continuation of that reported in the last progress report.

The specimen was carefully mounted directly on the shaker through the supporting ring and the impedance head. This was done to simulate an idealized free-free boundary condition at the two edges. The damping ratio value and the natural frequency (first mode) obtained in this experiment were 0.13% and 508.75 Hz respectively. In order to check the damping induced by the supporting ring, measurements were made with the top half of the ring removed. The specimen then was supported only by the bottom half of the ring (half ring). It was observed that the natural frequency of the specimen (first mode) increased to a value of 552.5 Hz due to the influence of the reduced mass of the supporting ring. But the damping ratio value obtained was the same as that obtained with the full supporting ring, namely 0.13%. This gave more confidence in the measured value of the damping ratio of the specimen. The frequency response (velocity/force) curves of the specimen as obtained with the full supporting ring and with the top half of the supporting ring removed (half ring) are shown in Figures (1a) and (1b).

The next set of experiments was conducted on the cylindrical tube specimen using the half ring support in order to study the variation of the damping ratio values with different modes of vibration. Fig. 2 shows the frequency response curve of the specimen in the frequency range of 450Hz to 3050Hz. The first six resonance frequencies of the specimen can be observed from the peaks of the curve. The numerical value of the resonance frequency of each mode of vibration of this specimen cannot be accurately estimated from this plot due to its large frequency range and hence poor frequency resolution. To offset this problem two techniques may be used a) to reduce the frequency range of analysis or b) to zoom the frequency response plot at the natural frequency of interest.

Figures 3 and 4 show the effect of reducing the upper limit of frequency of interest to 1.6kHz and 700Hz respectively. It is seen that the first and second resonance frequencies can be clearly identified from Fig. 3 but only the first from Fig. 4. In all these figures the amplitude of vibration is not the same since random input signal was used for excitation which is different for different frequency range of measurement.

The resonance frequency and damping estimated from the plots obtained through zoom analysis for the first six modes of the specimen are tabulated in Table I. It is seen from the table that the damping ratio value increases with the mode number. However further investigation is being carried out to study this aspect in more detail.

In all the experiments conducted so far, the cylindrical tube specimen was excited using random input signal. In order to study the effect of other types of excitation the cylindrical tube specimen with the half ring was excited using two other types of excitation namely: (a) pseudo-random input signal (b) and swept sine input signal. A random input signal is a non-deterministic signal which can be characterized by a probability density function and a power spectral density function. A pseudo-random input signal is a deterministic signal which is always periodic within the sample window. A swept sine input is a non periodic signal where a periodic sine wave is swept up or down through the frequency range of interest. Figures 5, 6, and 7 show the frequency response curves obtained for the specimen with these three different types of excitation. It is observed that the random noise excitation produced the best response curve with a sharp peak, when compared to the response curves obtained with other two types of excitation. However, all the three methods, gave the same resonance frequency estimate for the first mode of vibration. The damping ratio values as estimated from the three curves are as follows.

Random Noise excitation	ζ = 0.13%
Pseudo Random Noise excitation	ζ = 0.27%
Swept Sine Wave excitation	ζ = 0.36%

The discrepancy in the value of the damping ratio can be attributed to the following reasons. A random input signal gives the best linear approximation for any nonlinearities present in the system. It is by far the best input signal. One of the main disadvantages of pseudo-random excitation is that nonlinearities in the system under investigation, will generate periodic noise signals which cannot be averaged out of the data. Due to this condition the overall quality of a pseudo-random measurement is generally lower than that made by any other technique. Regarding the swept sine input, the sweeping in the present case was performed manually which is not uniform. A more uniform sweeping can be obtained by using an excitation control system. The damping ratio values reported using these three types of excitation were from preliminary experiments. Further experiments will be conducted to investigate the discrepancy in the measured value of damping ratio with the above three types of excitation.

Figs. 8 and 9 show the real and imaginary parts of the mobility function ($\frac{\text{velocity}}{\text{force}}$) for the tube specimen when it is vibrating in its 1st mode and excited by random noise. The real part of the mobility function has a maximum value when the frequency of excitation is at the resonance frequency of the specimen and correspondingly the imaginary part has a zero value at this frequency. Further work is in progress to develop a curve fitting algorithm to estimate the real and imaginary parts of the mobility function. This would then enable us to estimate the values of the damping ratio and resonance frequency more accurately.

Table I

Mode #	Nat. frequency (Hz)	Δf (Hz)	Damping ratio (ζ)%
1	552.5	1.5	0.135
2	1514	7.5	0.267
3	1873	12.5	0.336
4	2204.5	15.5	0.351
5	2232	16.0	0.358
6	2841.75	20.5	0.360

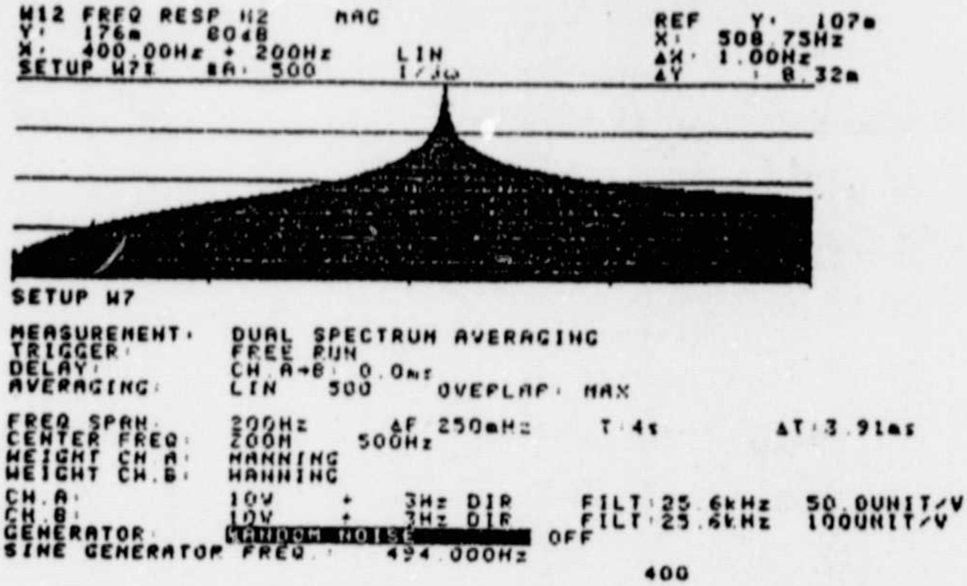

Fig. 1a. Frequency Response curve for Free-Free Tube with Full ring. (Random input signal)

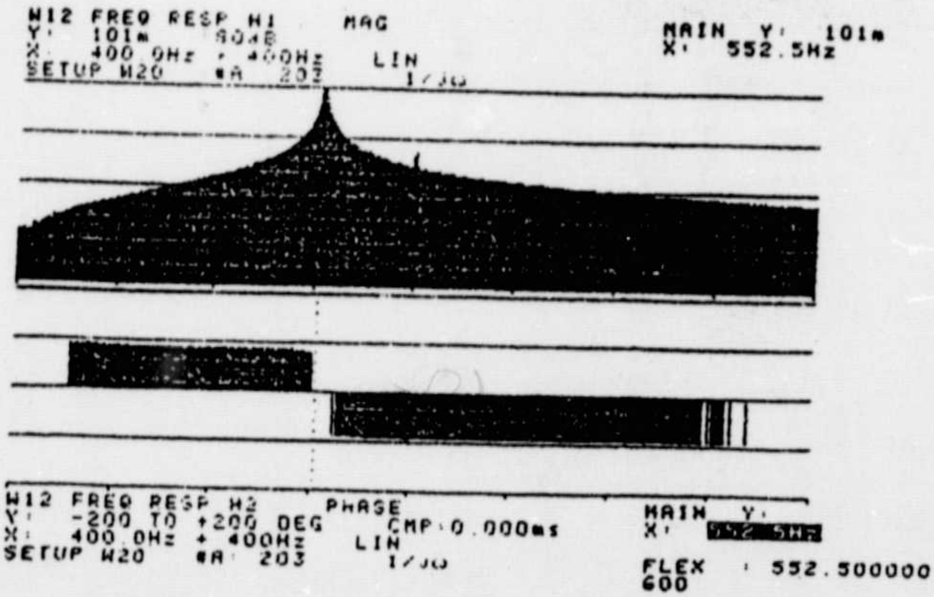

Fig. 1b. Frequency Response curve for Free-Free Tube with half ring. (Random input signal)

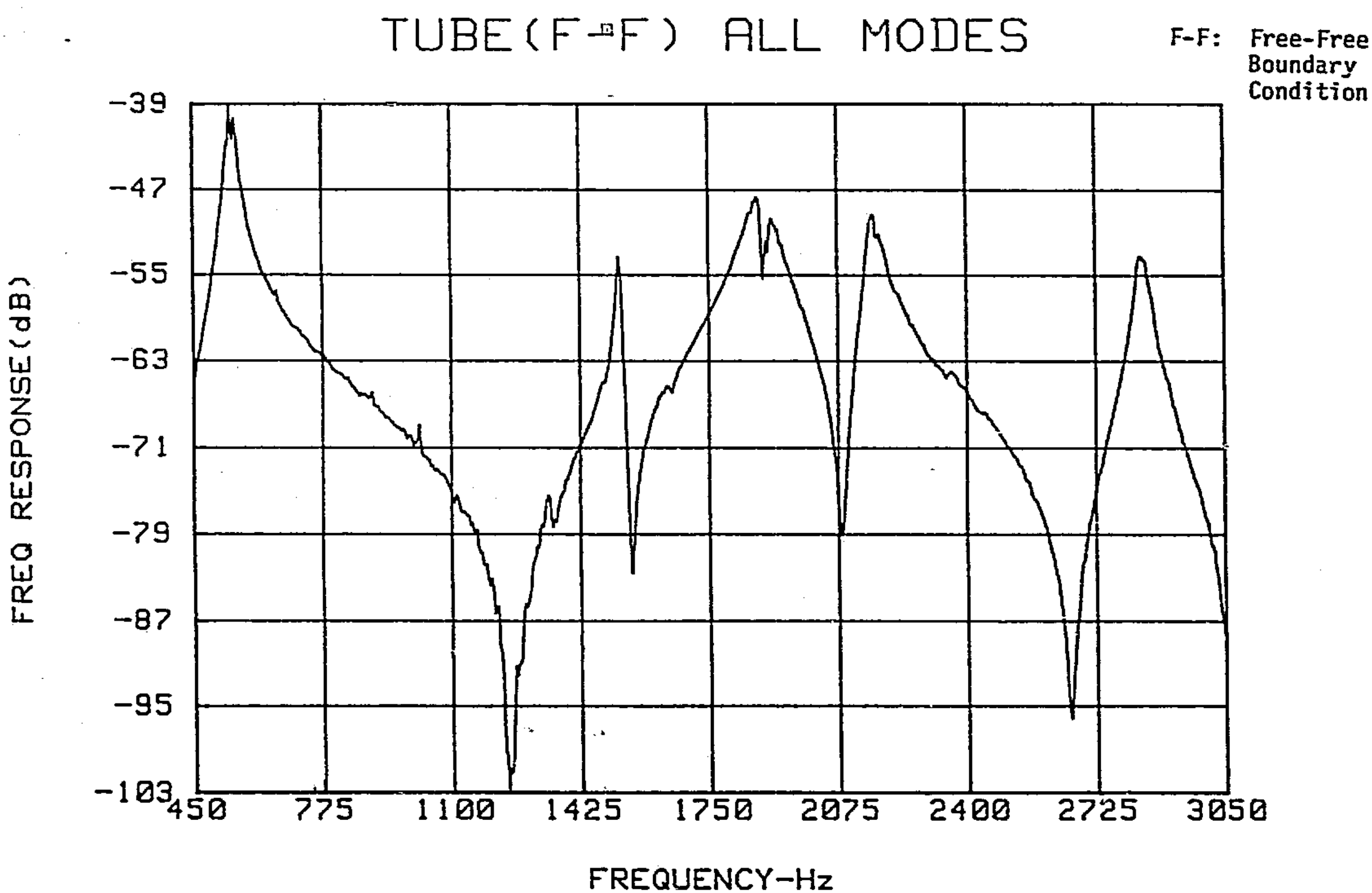

Figure 2. Forced Vibration Response for the tube specimen (Frequency Range 450-3050 Hz) (Random input signal)

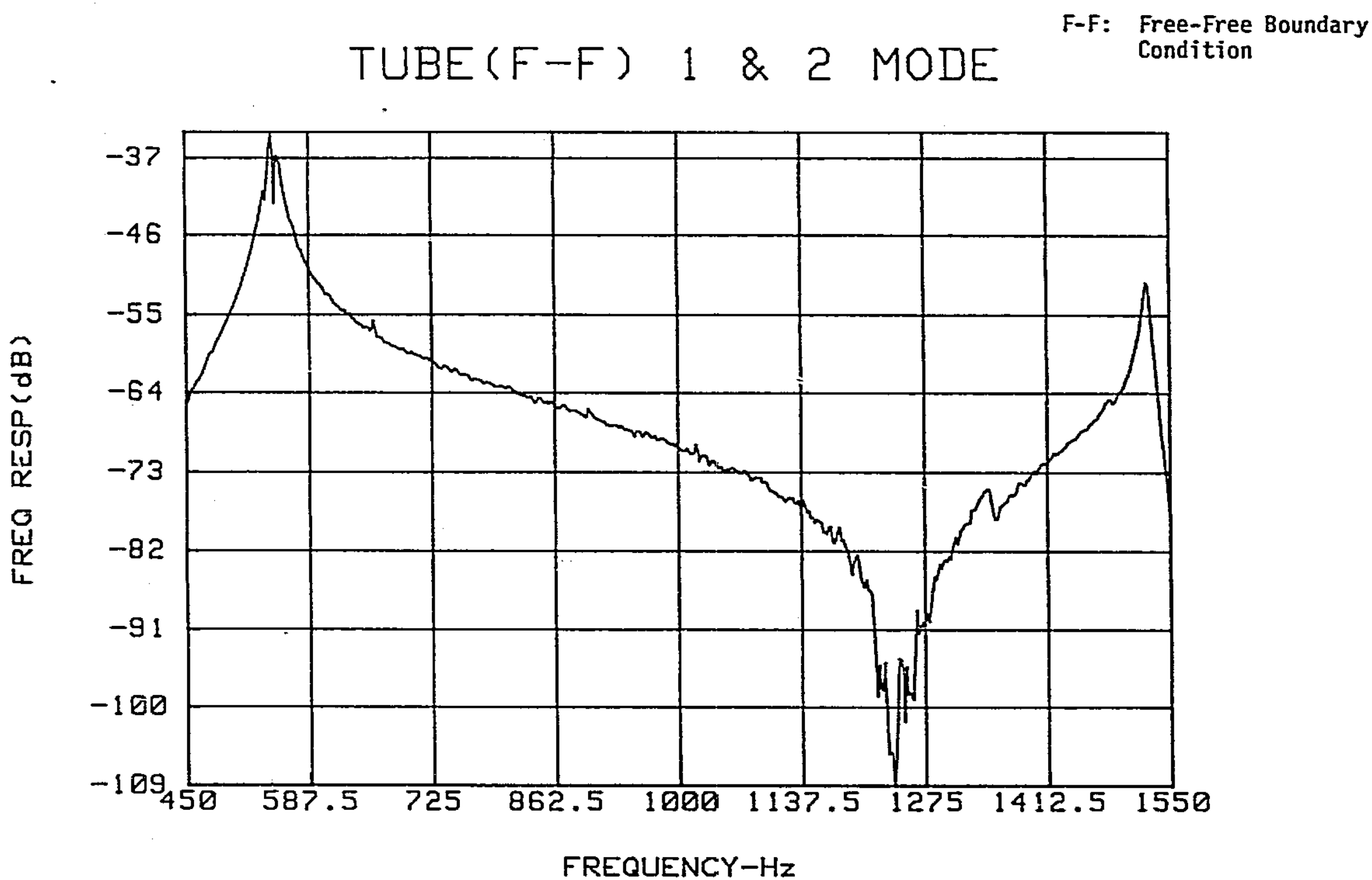

Figure 3. Forced Vibration Response for tube specimen (Frequency Range: 450-1550 Hz)
(Random input signal)

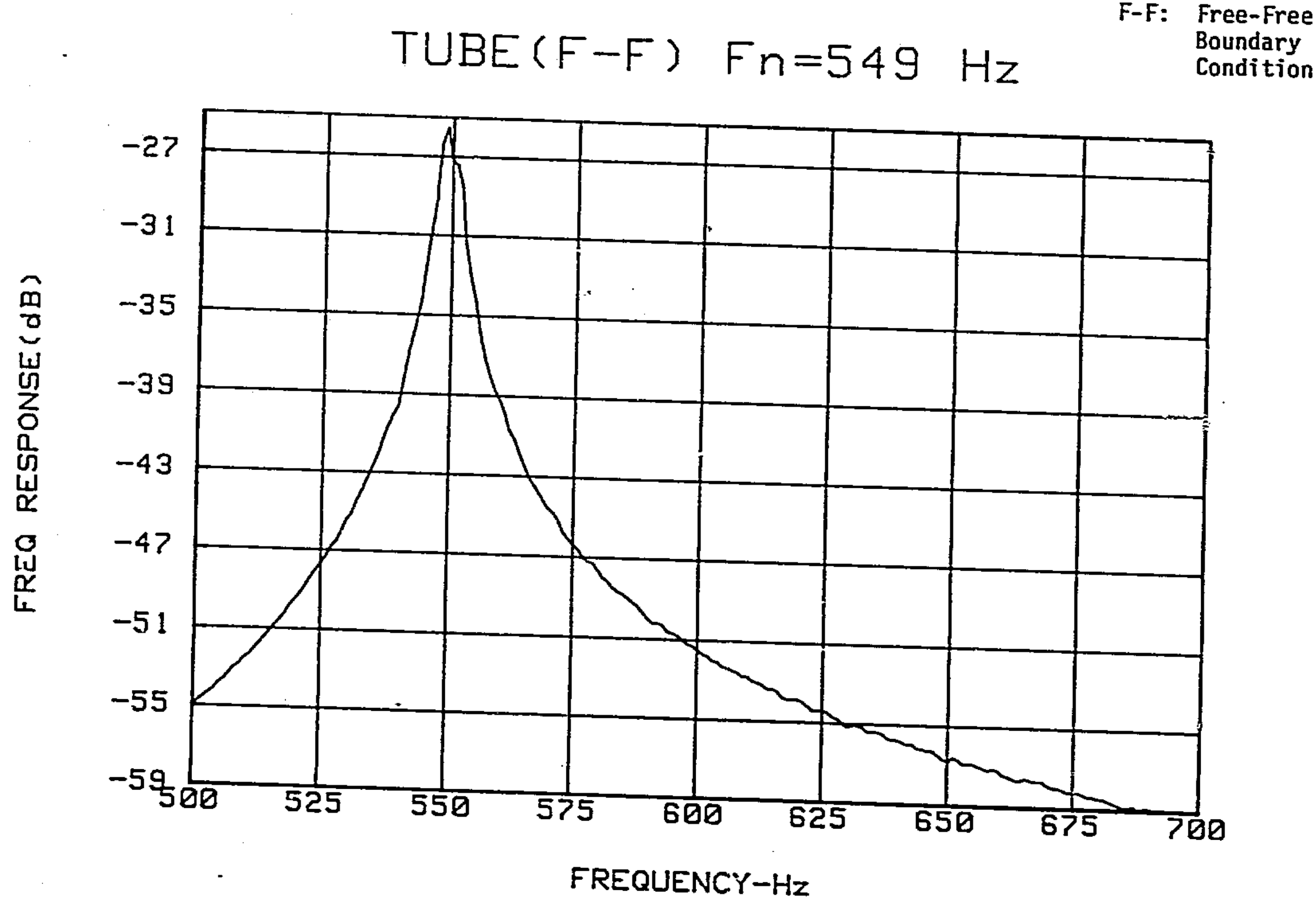

Figure 4. Forced Vibration Response for the tube specimen (Frequency Range 500-700 Hz) (Random input signal)

F-F: Free-Free Boundary Condition

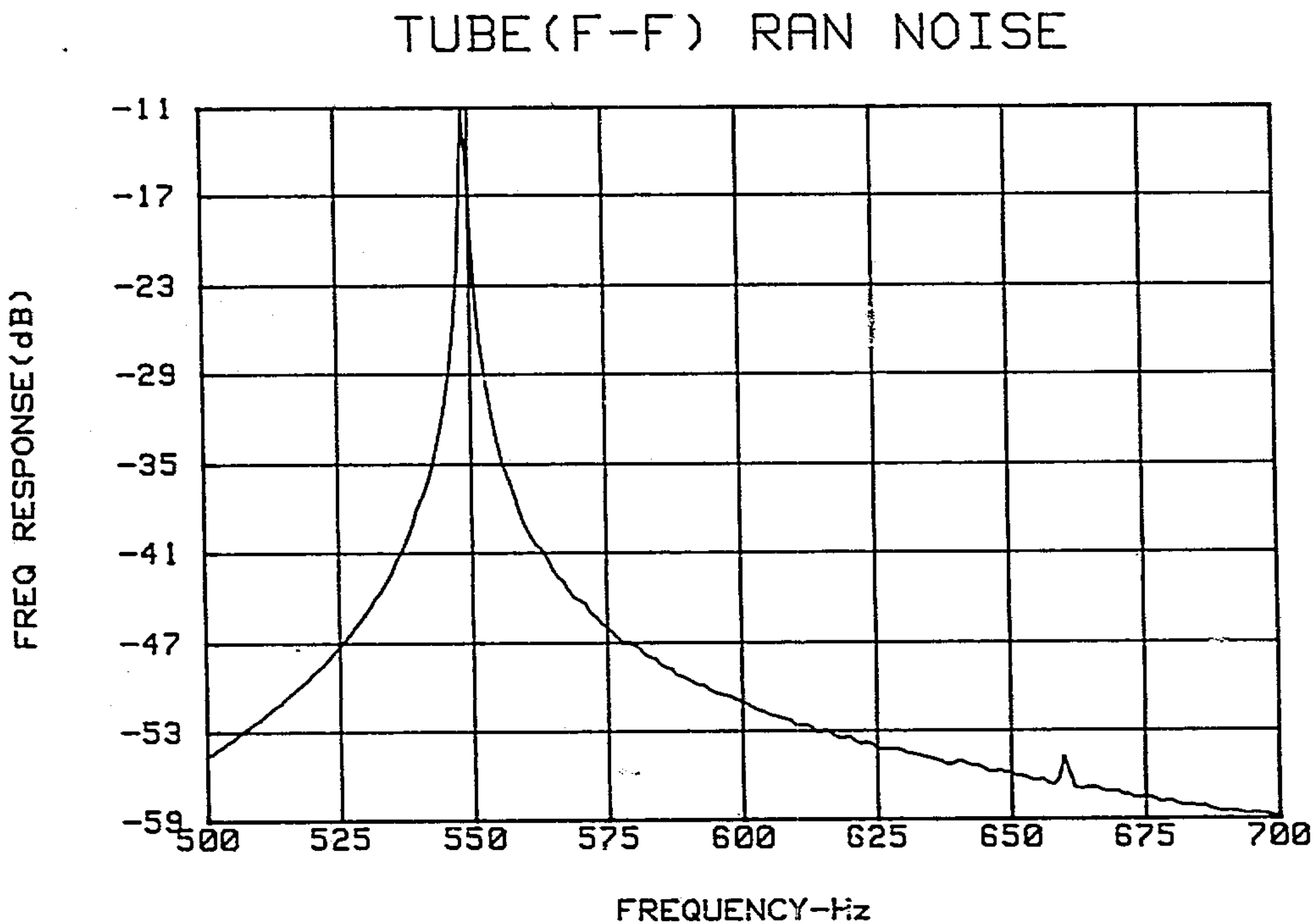

Figure 5. Comparison of Frequency Response due to different input signals

Case a. Random Input Signal

F-F: Free-Free Boundary Condition

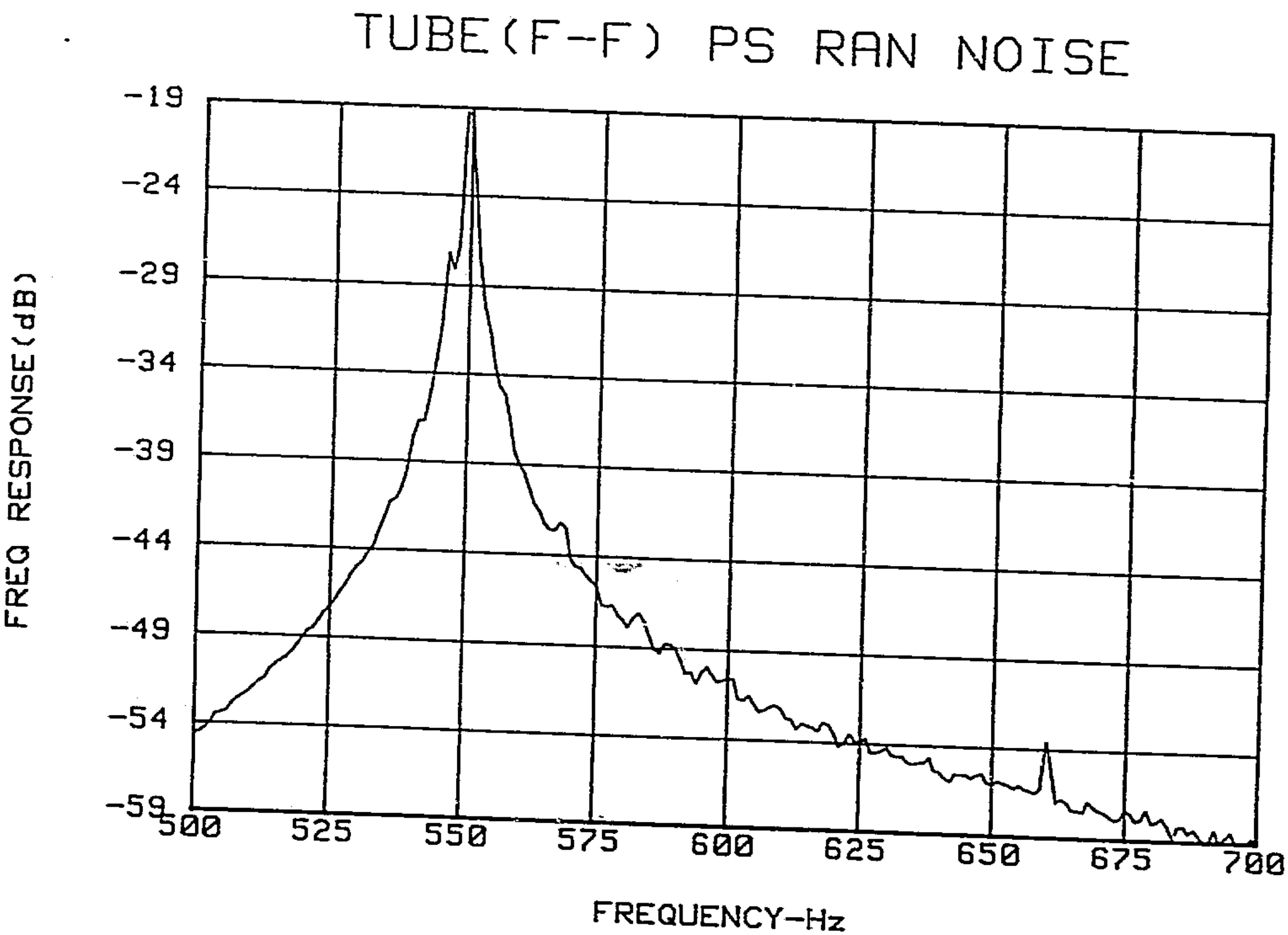

Figure 6. Comparison of Frequency Response due to different input signals

case b. pseudo-random input signal

F-F: Free-Free Boundary Condition

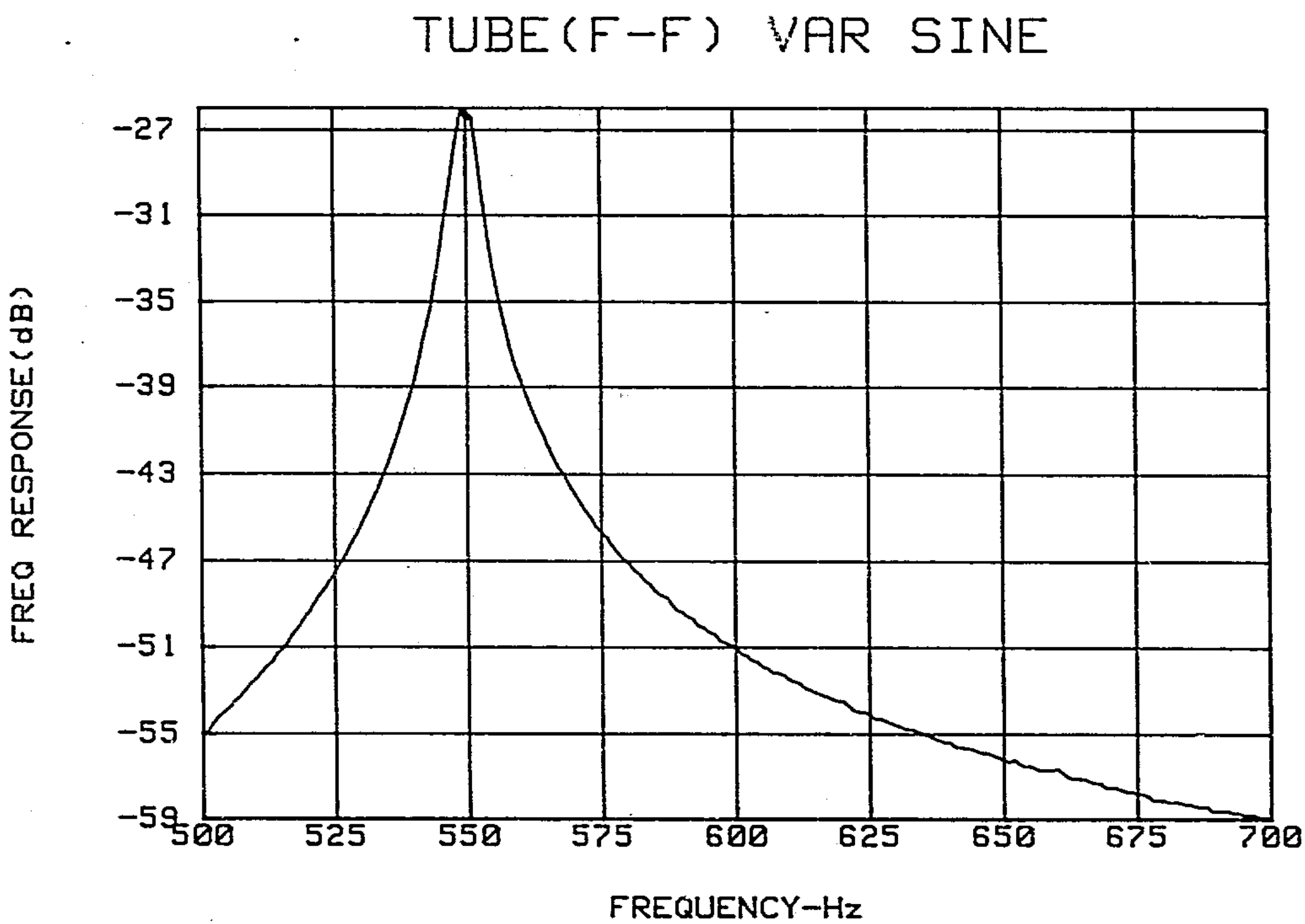

Figure 7. Comparison of Frequency Response due to different input signals

case c. Swept sine input signal

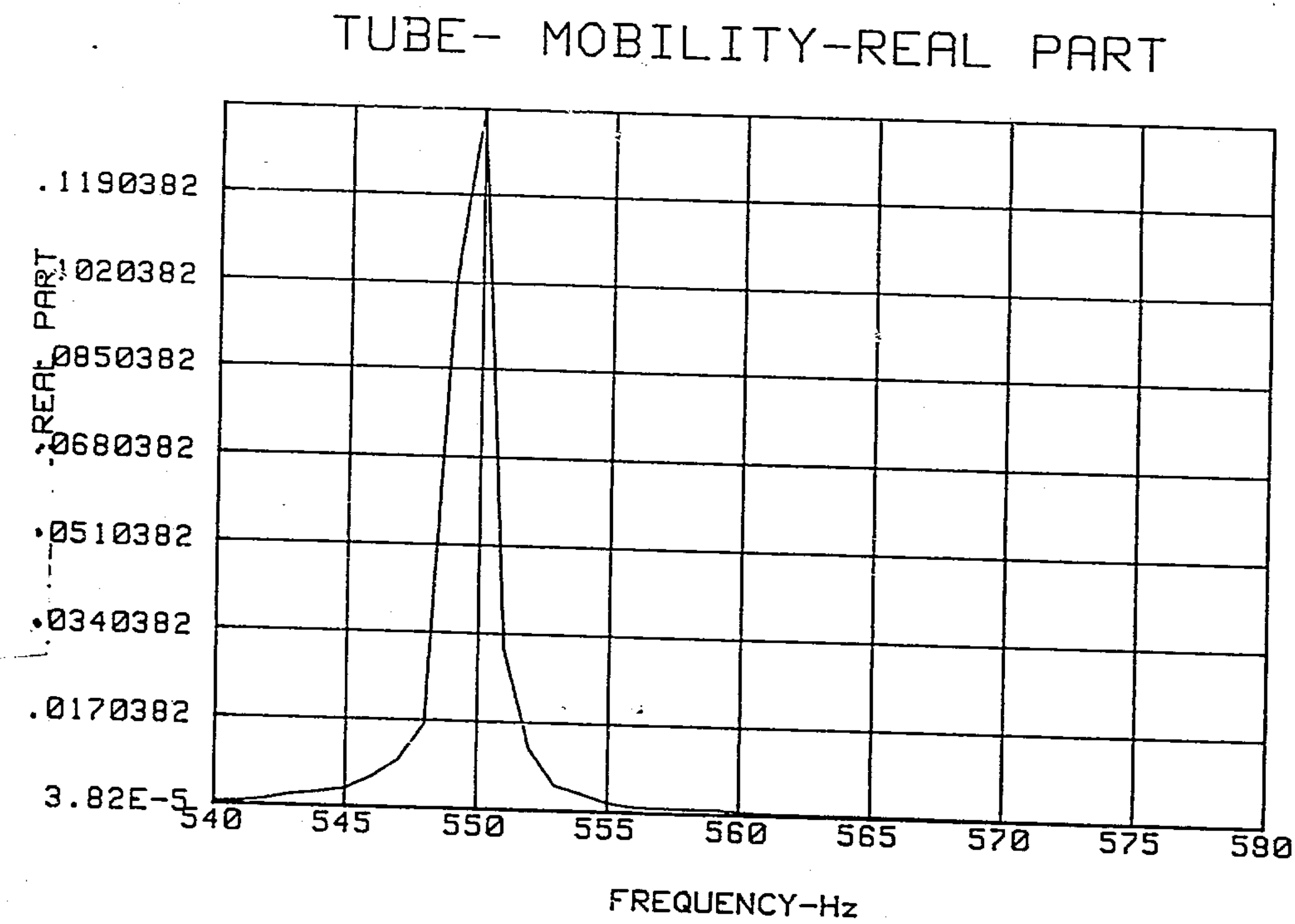

Figure 8. Mobility function: Real part (Random input signal)

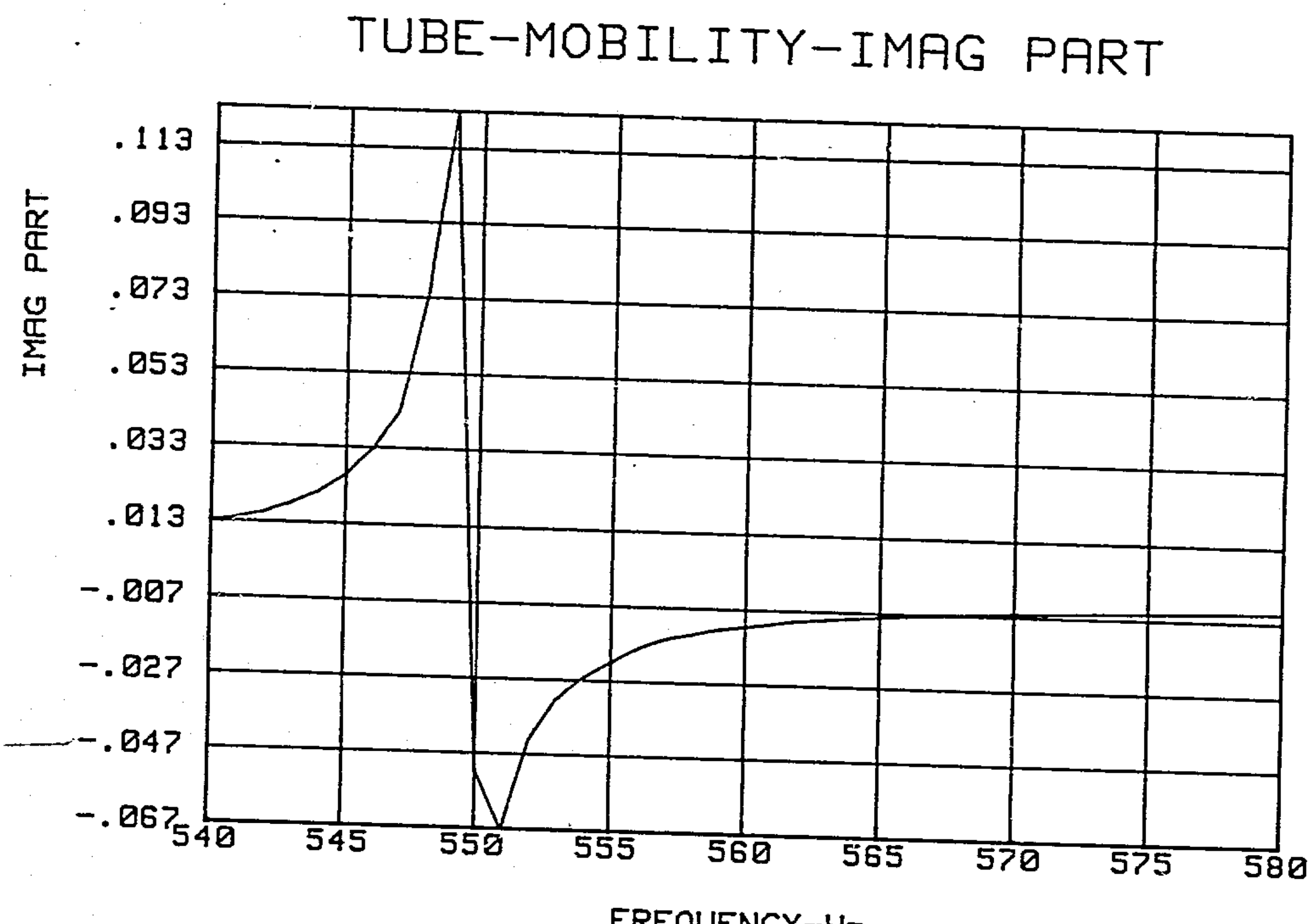

Figure 9. Mobility function: Imaginary part (Random input signal)