CHAPTER II

Review of Literature

2.1 Introduction

In 1935 Wente [13] was the first to give attention to the frequency response of rooms. A number of papers were devoted to this topic. A certain part of these investigations was discovered in 1954 by Schroeder Kuttruff and Thiele [6] who were able to show both theoretically and experimentally that the frequency response curves for all rooms are similar and depend largely on reverberation time. In 1964 the improvement of the stability by frequency shifting method was suggested by M.R. Schroeder. [5]

2.2 Properties of Feedback Stability of The Audio System with Frequency Shifter [5]

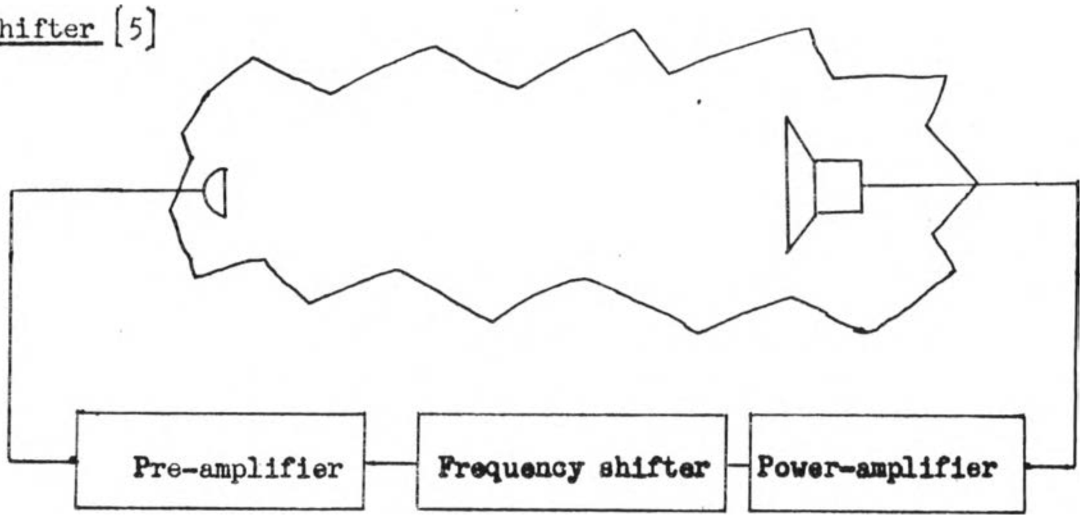

Fig. 2.1 Audio System with Frequency Shifter

The block diagram in Fig. 2.1 represents a simple audio system with a frequency shifter that shifts all frequency component of its input signal by a constant amount Δf. It is assumed that the frequency shifter has a unity gain where as other audio components have a flat frequency response in the audio frequency band.

A sinusoidal signal of frequency f_1 applied to any point in the feedback loop will have its frequency shifted to $f_1 + \Delta f$ and its power increases or decreases by a factor of $|g(f_1)|^2$. After n trips around the feedback loop, the signal power is multiplied by

$$M_n = \left\{ |g(f_1)|^2 \times |g(f_1 + \Delta f)|^2 \times |g(f_1 + 2\Delta f)|^2 \times \ldots\ldots \ldots\ldots \times |g(f_1 + (n-1)\Delta f|^2 \right\} \qquad (2.1)$$

where M_n = Open-loop signal power gain in the system after n trips

$g(f)$ = Complex open loop voltage gain

Expressing the open-loop power gain in decibels

$$l(f) = 10 \log |g(f)|^2$$

then

$$10 \log M_n = \left\{ l(f_1) + l(f_1 + \Delta f) + l(f_1 + 2\Delta f) \ldots\ldots + l\left[f_1 + (n-1)\Delta f\right] \right\} \qquad (2.2)$$

For large n, one may write in good approximation

$$10 \log M_n = n.\ \bar{l} \qquad (2.3)$$

where $\bar{l}$ is the average open-loop power gain in decibels

From equation (2.3) the stability is obtained if

$$\bar{l} < 0 \qquad (2.4)$$

While instability occurs for $\bar{l} \geq 0$

If the squared modulus of the transmission function between two points in a room is exponentially distribution, then

$$P(|g|^2) = G^{-1} \exp(-G^{-1} |g|^2) \quad \text{.................(2.5)}$$

where P ( ) is probability distributed function

G **is** the average power gain around the feedback loop.

From equation (2.5), one obtains the distribution of the power gain in decibels, **by a simple transformation of the variable :**

$$P(l) = bG^{-1} \exp\left[- G^{-1} \exp(bl) + bl\right] \quad \text{..........(2.6)}$$

where $b = (10 \log e)^{-1}$

$= 0.2303$

The mean of this distribution [5] is

$$\bar{l} = 10 \log G - 2.5 \text{ dB} \quad \text{......................(2.7)}$$

By combining equation (2.7) and the stability criterion (2.4), one can obtain the following critical value of power gain of the audio system:

$$10 \log G_o = 2.5 \text{ dB} \quad \text{..................................(2.8)}$$

where G_o **is** the critical power gain around the feedback loop - **- with frequency shifting.**

Equation (2.8) states that the system with frequency shifter will be stable if the average power gain around the feedback loop is less than 2.5 dB.

2.3 Properties of Feedback Stability of An Audio System without Frequency Shifter. [5]

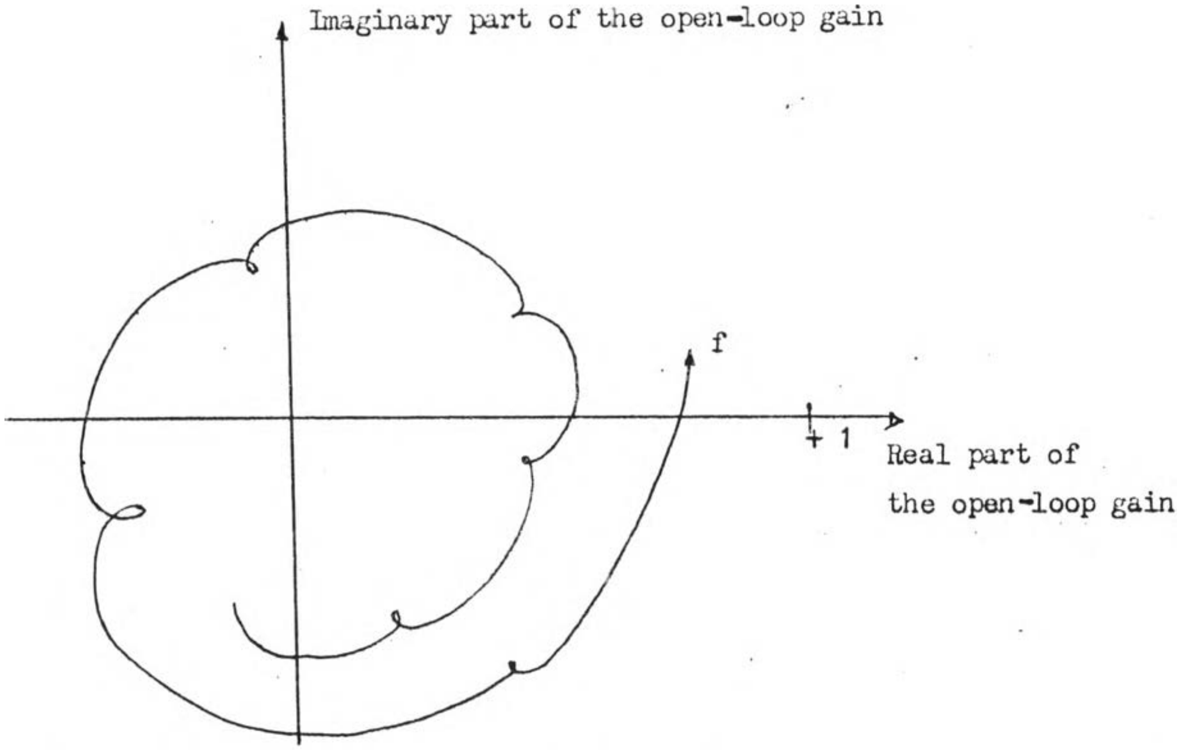

Fig. 2.2 Complex Open-Loop Gain of A System

Fig. (2.2) is a typical section of the complex open-loop gain g (f) of an audio system in a room. In 1964 Schroeder used the probability calculation [5] to express the condition of stability that is the point + 1 on the real axis must not be encircled by the locus of the complex open-loop gain. The result [5] showed that the critical power in decibel is

$$10 \log G_m = -10 \log \left[\log \frac{WT_{60}}{22} \right] - 3.8 \text{ dB} \quad \text{..........(2.9)}$$

where G_m is the critical power gain around the feedback loop without frequency shifting

W is the bandwidth of the system

and T_{60} is the reverberation time, see Appendix B .

From equation (2.8) $10 \log G_o = 2.5$ dB, the additional stable gain decibels due to frequency shifting will be

$$\Delta 1 = 10 \log G_o - 10 \log G_m = 2.5 + 3.8 \text{ dB} + 10 \log (\log \frac{WT_{60}}{22})$$

$$= 6.3 \text{ dB} + 10 \log (\log \frac{WT_{60}}{22}) \quad \text{......(2.10)}$$

The typical value of T_{60} is 1 second, then for a bandwidth $W = 5000$ Hz, the additional stable gain $\Delta 1$ calculated from equation (2.10) will be 10 dB. This is the theoretical improvement on the output power of the stable system expected from the frequency shifting method.