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BIFURCATION AND CHAOS OF DIRECT RADIATION LOUDSPEAKER

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The bifurcation and chaos of an 8" cone loudspeaker from its radiation in axial direction have been investigated by adopting an experimental setup quite similar to that of measuring frequency response in an anechois room. Experiments show that lower order and more fractional subharmonics of the fed-in signal begin to appear with increasing input voltage and eventually a chaotic state is reached.

The existence of subharmonics in ordinary electrodynamic cone loudspeakers has been observed and analyzed since the middle of 1930s[1-5], but so far no experimental findings concerning lower subharmonics (less than 1/4 of the driving frequency) have been reported nor in most cases the measuring procedures clearly described. The present paper furnishes an example of such forced vibration systems that can manifest a number of fractional harmonics or bifurcations and the final chaotic state. The thresholds are found to vary from one speaker to the other in size and driving frequency, and to be dependent on the manufacturers; however, we believe the phenomena are universal.

What we are going to report is an 8" cone loudspeaker with an impedance of 8 ohms and a rated power of 10 watts. The experiment is conducted in an anechoic chamber with the set-up shown schematically in fig.1. The microphone (BK4145) is 40cm apart in axial and front directions from the baffled loudspeaker. The linearity of the apparatus producing the electrical signals (audio frequency generator BK2010 and power amplifier DK100) as well as that of the receiving system (preamplifier BK2627 and FFT SD340) must be ensured before the acoustical experiment. We do this by connecting the input voltage up to 27V across an 8 ohm carbon resister, instead of the loudspeaker, and then to preamplifier and directly to FFT, the screen of which will show a line spectrum of the fundamental only at a frequency within the range of 2000 to 4000Hz (fig.2). The dynamic range of such a microphone is much in excess of the maximum sound pressure level to be received (110dB), where the finite amplitude effect of the sound waves in the frequency range 2-4kHz at a distance of 40cm is of neglegible amount (1.5%) as compared with the nonlinear distortion of the loudspeaker. A bandpass filter

(BK2120) is introduced to suppress the fundamental between the preamplifier and the FFT so that the ultraharmonics and especially the subharmonics can be observed more clearly and the linearity of FFT is further guaranteed.

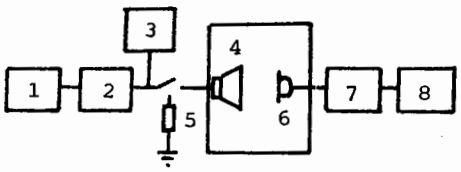

Fig.1
1. Generator (Type: BK2010)
2. Power amplifier (Type DK100)
3. Voltmeter (Type GB-9)
4. Loudspeaker (8Ω, 10W)
5. Resistance (8Ω, 50W)
6. Microphone (Type BK4145)
7. Bandstop (Type BK2120)
8. FFT Analyze (Type SD-340)

Figure 3 shows 1/2 subharmonics at an input voltage of 8 V and an exciting frequency around 2.2kHz. It is about 26dB below the fundamental or about the same order of magnitude as the first and second ultraharmonics, but driving at a frequency of 2.4kHz.

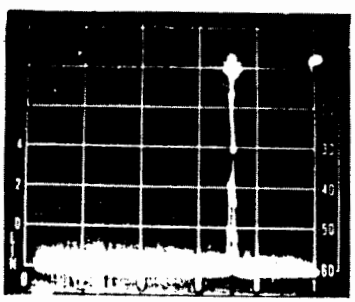

Fig.2

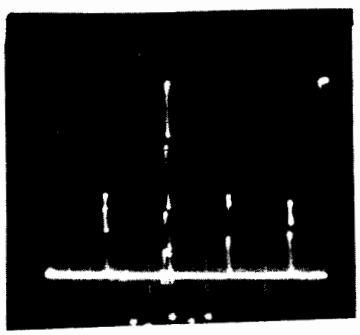

Fig.3

The bandstop filter is employed in order to find out deeper subharmonic of integer order only. The third subharmonics is found at an 8V driving voltage and a frequency 3.56kHz (fig.5); the 4th subharmonics at 27V, 3.76kHz (fig.6); the 8th subharmonics at 18V, 3.62kHz (fig.7),and the tenth at 27V, 3.94kHz (fig.8); and again 27V, 3.5kHz (fig.9) for the 20th subharmonics. In addition, we have also found a number of other phenomena of bifurcations and chaos. The situation remains so even when the loudspeaker is driven within its rated power (fig.4). Finally from fig.10 or better from fig.11 we can see that the chaotic state is reached at a driving voltage 18V and a frequency of 2506Hz.

One important remark we have to make is that, since our experiment was conducted in a certain period of time, the environmental temperature and humidity may affect somewhat our experimental results, but what is shown in the present paper is typical and reproducible.

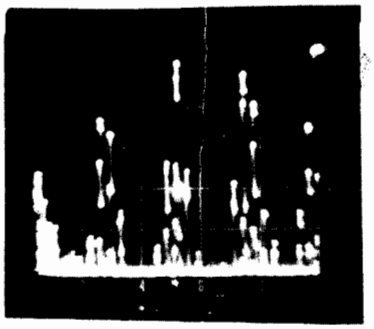

Fig.4

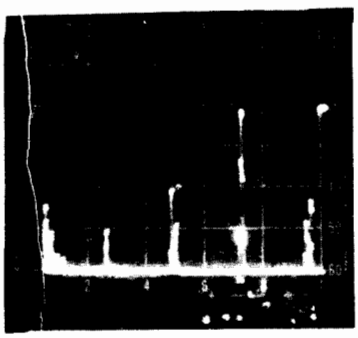

Fig.5

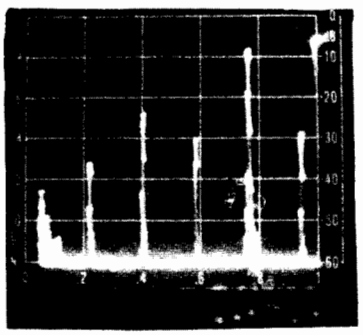

Fig.6

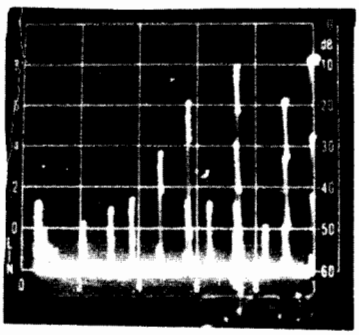

Fig.7

Fig.8

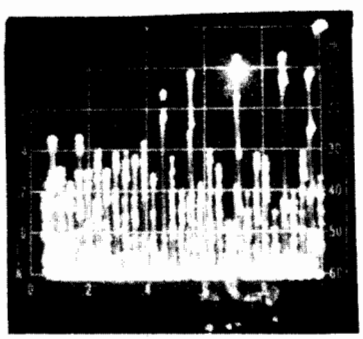

Fig.9

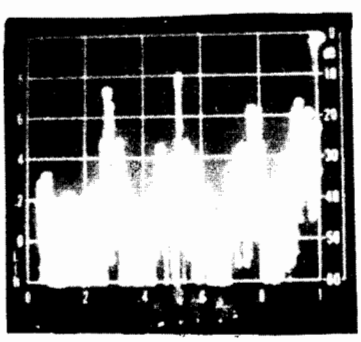

Fig.10

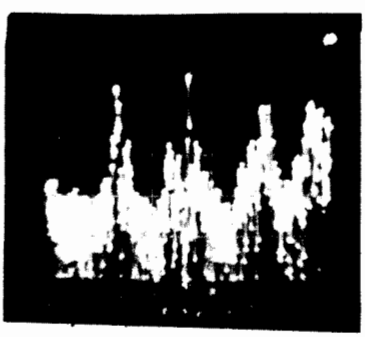

Fig.11

The direct radiation loudspeaker, though simple in construction, is a nonlinear vibrating system, generated both by the suspension of voice coil etc., and by that of the paper cone even driven at a voltage within its rated wattage. The term "nonlinear distortion" often refers only to the generation of higher harmonics by some people working in electroacoustics, but the problem of subharmonics has already been brought to attention[2] more than forty years ago. The generation of the extraneous frequencies would certainly result in unpleasant sound quality of reproduction system. The theory concerned with this is usually based on Mathieu equation or Duffing equation, which shows fractional harmonics[6] bifurcation and chaos[7,8] and will be discussed later in another article.

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