BRIEF SURVEY ON RESONANCE PHENOMENON

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Abstract. *Resonance as the fundamental property of every sistem, play an important role in its behavior. It represents the knife with two sides, one that has plenty of applications in medicine, biology, chemistry, art, etc. and another one with destructive effects. This article presents a detailed survey about the phenomenon of resonance in our everyday life, its understanding, its role in electric circuits, acoustics and medicine approach in Magnetic Resonance Imaging, Nuclear Magnetic Resonance and Magnetic Resonance Fingerprinting.*

Keywords: *Resonance phenomenon, Galileo Galilei, Magnetic Resonance Imaging, Nuclear Magnetic Resonance, Forced mechanical resonance*

Introduction

In our life take place a range of amazing and sometimes incomprehensible phenomena. Their behavior is simple explained by the laws of physics. For example, the swinging on a cradle, children's favourite pastime. That activity seems to be a simple one if children easily can manage it. But have you ever wondered why, if you act correctly on the swing, then its range will become bigger and bigger? The idea is that you need to act strictly at certain points of time and in a certain direction, otherwise the result of the action may not be a swing, but a complete stop of the swing.

Consequently, the external action (force) needs to be repetitive, with a period that depends on the sliding period [1]. In other words, it is necessary to have an external influence with the frequency that coincides with the oscillation frequency of the swings themselves, in which case the swing range will increase. This phenomenon is called resonance.

An understanding of phenomenon

In everyday life, we can observe the resonance phenomenon in various devices that use radio waves, such as televisions, radios, mobile phones, etc. Every transmitting station broadcast a specific signal (i.e. electromagnetic waves with a particular frequency). The receiving antenna picks up the radio signals of many stations. An important element of each radio receiver is the resonant circuit (also called tuned circuit), that select from all the frequencies, induced in antenna, only the desired one. To do this, you need to tune the natural frequency of the receiver (tuned circuit), to the frequency of the transmitting station. If the frequencies coincide, a resonance will occur, and only one signal will pass through the circuit.

One type of magnetic resonance, electron paramagnetic resonance [2], discovered in 1944 by the Russian physicist E.K. Zavoyski, is used in the study of the crystal structure of elements, the chemistry of living cells, chemical bonds in substances, etc. [3].

Besides its well known applications, resonance can have negative consequences as disasters. Earthquakes or seismic waves, as well as the operation of highly vibrating technical devices, can cause destruction of buildings, bridges and other structures. In addition, earthquakes can lead to the formation of huge resonant waves - tsunamis with a very large destructive force.

An example is the well-known destruction of the Tacoma bridge [4]. On November 7, 1940, an accident occurred at a wind speed of about 65 km / h, which led to the destruction of the central span of the bridge. The cause of the catastrophe was the phenomenon of forced mechanical resonance, in which the external frequency of the change in the wind flow coincides with the natural (internal) vibration frequency of the bridge structures. The accident of the bridge left a significant mark in the history of science and technology and contributed to the research of the resonance phenomenon.

Acoustic Resonance

Leonardo da Vinci (1452-1519), whom belongs many inventions in the field of practical mechanics, who was also an excellent musician and designed linguistic instruments, clearly understood the oscillatory nature of sound. *Like a stone thrown into water*, he wrote, *it becomes the center and cause of various circles, the sound generated in the air also spreads in circles* [5]. Such a motion of water seemed to him an interesting example of oscillatory motion. In this way, Leonardo da Vinci described the sound.

The name Galileo Galilei (1564-1642) is associated to *The beginning of the theory of oscillations as a science*. Studying the oscillations of the pendulum, he came to the fundamental discovery of the isochronism of small oscillations, made by observation swings of the chandelier of the *Pisa Cathedral*. Galileo considered the question of mechanical vibrations in close connection with acoustic problems (string vibrations, resonance theory).

Galileo Galilei in his book *Conversations* outlined all the fundamental issues known at that time in the field of musical acoustics [6], where, also, is present the resonance phenomenon. These discoveries put the base for the latter research of resonance and application of it in life.

Helmholtz Resonator

An important type of resonator with very different acoustic characteristics is the Helmholtz resonator [7], named after the German physicist Hermann von Helmholtz. A hollow sphere with a short, small-diameter neck, a Helmholtz resonator has a single isolated resonant frequency and no other resonances below about 10 times that frequency. The resonant frequency (*f*) of a classical Helmholtz resonator, shown at fig. 1. is determined by its volume (V) and by the length (L) and area (A) of its neck, where S is the speed of sound in air.

$$f = \frac{S}{2\pi}\sqrt{\frac{A}{LV}} \qquad (1)$$

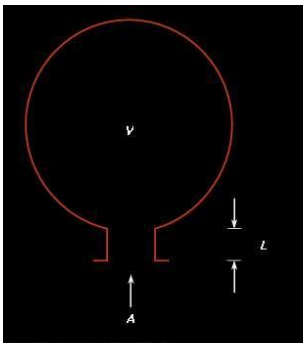

Figure 2. Helmholtz resonator

The isolated resonance of a Helmholtz resonator [8] made it useful for the study of musical tones in the mid-19th century, before electronic analyzers had been invented. When a resonator is held near the source of a sound, the air in it will begin to resonate if the tone being analyzed has a spectral component at the frequency (*f*) of the resonator. By listening carefully to the tone of a musical instrument with such a resonator, it is possible to identify the spectral components of a complex sound wave such as those generated by musical instruments.

Resonance in Electric Circuits

In electrical circuits containing inductors and capacitors, resonance occurs at a certain frequency when the inductive and capacitive components of the reaction of the system are balanced, i.e. when the reactance is zero.

The working principle of an oscillating circuit can be explained as: the variation of magnetic field of the inductance generates an electric current charging the capacitor, and the discharge of the capacitor creates a magnetic field in the inductance - a process that is repeated periodically, allowing energy to circulate between the magnetic field of the inductive element and the electric field of the capacitor. By analogy with a mechanical pendulum, in this case oscillates the electric field in circuit [9].

The phenomenon of electrical resonance plays a useful role in tuning the radio to the desired radio station by changing the inductance and capacitance, one changes the the natural frequency of the oscillating circuit (f_0). If the frequency of electromagnetic waves, emitted by a radio station (f) coincide with the natural frequency (f_0), the ocillating circuit will resonate just like the Helmoltz resonator in acoustic waves. This leads to tuning the radio to the desired station.

Another feature of electrical resonance is the possibility of using it in engines with active permanent magnets. Since the control electromagnet periodically changes polarity, powered by alternating current, electromagnets can be included in the composition of the oscillatory circuit with a capacitance.

The connection of electromagnets can be in series, parallel or combined, and the capacitance is selected by resonance at the operating frequency of the motor, while the average value of the current through the electromagnets will be large, and the external current feed will compensate mainly for active losses.

Applications of Resonance in Atomic Systems

a) Nuclear Magnetic Resonance. The phenomenon of nuclear magnetic resonance was discovered in 1938 by Isidore Rabi in molecular beams [10]. In the 1930's, Rabi and his team were attempting to measure the magnetic properties of various nuclei including hydrogen, deuterium, and lithium. Rabi described how nuclei could be induced to flip their principal magnetic orientation by an oscillating magnetic field. Rabi's method involved using an electromagnet producing an oscillatory electromagnetic radio frequency field. The oscillations were maintained at constant frequency and the main magnetic field was varied by changing the current. He then passed a "molecular beam" of lithium chloride (LiCl) molecules through a vacuum chamber and subsequently into the magnetic device. In 1938 he and his team reported energy absorption/resonance peaks for both Li and Cl as predicted. Rabi named this phenomenon *Nuclear Magnetic Resonance*.

b) Magnetic Resonance Imaging. Another application of resonance is MRI (Magnetic Resonance Imaging) which is a medical imaging technique used in radiology to form pictures of the anatomy and the physiological processes of the body [11]. It was originally called NMRI (*nuclear magnetic resonance imaging*), but "nuclear" was dropped to avoid negative associations. MRI scanners use strong magnetic fields, magnetic field gradients, and radio waves and does not involve X-rays or the use of ionizing radiation, to generate images of the organs in the body. MRI provides accurate anatomical brain images without the use of ionizing radiation, allowing longitudinal studies of brain morphometry during adolescent development.

c) Magnetic Resonance Fingerprinting. Magnetic Resonance Fingerprinting [12] (MRF) uses quantitative information to generate a more precise understanding of a patient's condition. Quantitative MRF offers enormous potential to improve tissue differentiation and enable less invasive diagnostics. Based on reliable, absolute numbers, MRF data could increase objective comparisons in follow-up studies. Ultimately, aided by artificial intelligence (AI), quantitative measurements will lead to more personalized treatments. MR Fingerprinting is at the frontier of a new dimension in quantitative imaging.

Conclusion:

Resonance has a major influence in our lives, due to its characteristics. For the first view it does not present a big deal, because it depends on the well-known laws of physics, however on a larger scale we can observe its huge and devastating power. Moreover, resonance has a range of applications that contributes to the development of new technologies used vague in medicine, art, physics, biology and gives new opportunities in changing our everyday life.

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