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Resonance*

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Summary

In this contribution, the theme of resonance is dealt with. Considering the fundamental role of resonance and its universality over different topics, a guided route about resonance is discussed. Moreover, the universal concept of resonance is stressed and enlarged to a system generalization, both in social sciences and arts.

Keywords: *Resonance, mirror neurons, social resonance, universality.*

Riassunto

Risonanza

Questo articolo propone una guida ragionata per affrontare il tema della risonanza, considerando il suo ruolo fondamentale e la sua universalità in molteplici ambiti di ricerca. Inoltre, il concetto universale di risonanza è approcciato al fine di generalizzarlo negli ambiti delle scienza sociali e delle arti.

Parole chiave: *Risonanza, neuroni specchio, risonanza sociale, universalità.*

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1 Introduction

There are universal concepts and principles that have been and still are the cornerstones of the knowledge. We will meet them in designing devices, in making projects, in analyzing signals and phenomena. Feedback and resonance are two of them. Indeed the previous two principles are, in some senses, related each other. The aim of this contribution is to give focus to the various aspects of resonance. In his life, each researcher meets some subjects that he considers as his friends during his life. Resonance appeared during my undergraduate studies and it does appear suddenly during our research activity. Therefore, inspired by this fact a route about resonance will be discussed in this note.

In the literature, a lot of items, papers and details about resonance had been approached. In this note, the concept of resonance will be discussed making a very long travel since when I was a student until my recent results regarding the resonance subject.

The key phenomenon that allows electrical communication and that is the basic principle of each communication device is the resonance effect (Van Valkenburg, 2001). Therefore the hardware keystone of the modern telecommunication systems is the resonant device. Synchronization and clocks are widely related to the resonance effects. In this note, we will remark the old concept of resonance introducing a generalized concept of resonance, that is fundamental in terms of social and human communications. The generalized concept of resonance that will be emphasized is related both to the theory of mirror neurons (Rizzolatti and Sinigaglia, 2008), that are the core of the interrelation communication among people, and to the axes of resonance (Rosa, 2019), that represent a new item suggesting a way to improve social communications and to achieve a better quality of the human life.

Mirror neurons establish the idea that a synchronization between world observations and actions is present. In the human mind this type of synchronization allows the knowledge of other people and, therefore, learning by imitation. The mirror neurons system permits also the emulation of the observed actions and therefore to reinforce the people knowledge. Moreover the mirror neurons establish the basics of language. This means that the network of mirror neurons allows the communications among people. In order to achieve a resonance effect among each other, the mirror neurons networks in the brain of two persons must be synchronized. Damages of such a type of brain network, in fact, lead to serious diseases.

The concept of axes of resonance has been introduced by the sociologist Hartmut Rosa to explain the social relationships. It is aimed at promoting the social conditions in order to get successful relationships. Indeed Rosa, analyzing the modernity, remarks that it induces a terrible acceleration leading to the decrease of the quality of life. Moreover, establishing the so-called axes of resonance in the social interrelationships, the quality of the life can be increased, in spite of the modernity acceleration.

The discussion will give focus to the communication problem that involves the generalized concept of resonance in a global view of a world where the communication systems, the internet and the telecommunication platforms have become the core of a new lifestyle, especially in the actual time of viral pandemic diseases.

The paper is organized as follows. In Sec. 2 some classical historical references on resonance will be given, while in Sec. 3 a gallery of resonant phenomena approached during several years is presented. In Sec. 4, the link between mirror neurons and resonance is explored, and in Sec. 5 that one with sociology. Finally, a brief remark on the places of resonance and some concluding remarks are reported in Sec. 6.

2 Classical Resonance and some historical references

It is now reported the definition of resonance given in the classical Encyclopedia Britannica, Ed. 1964 (The Editors of Encyclopaedia, 1964).

RESONANCE, a term used in physics and related fields originally denoting a prolongation or increase of sound because of sympathetic vibration of some body capable of moving in the proper period. An example is the oscillation induced in a violin or piano string of a given pitch when a musical note of the same pitch is sung or played nearby [...]. *The term has been extended by analogy to the familiar selective mechanical resonance of a spring board or bridge to certain frequencies of jumping or walking; and to the selective electrical resonance*, allowing the natural magnification of the phenomena, *of a tuned radio circuit to the radio frequency transmitted by a single radio station. At the high frequency used in microwaves and radar, the tuned circuit is actually constructed most easily in the form of a small cavity resonator not unlike the cavity of an acoustical resonator such as an open-mouthed bottle.*

The term resonance derives from the Latin term *Resonantia* with the meaning of echo rumbles. The following list regards famous sentences in which term associated with resonance and having resonance as root, are reported to stress the impressive meaning that Latin culture gave to this term.

- *Resonant avibus virgulta canoris*: Shrubs resonate with bird songs (Virgil);
- *Ubi non resonent imagines*: where no echoes resound (Cato);
- *Qui ad nervos resonant incantibus*: the horns echo the notes of the songs accompanying the string instruments (Cicero);
- *Formosam resonare doces Amaryllida silvas*: Teach the woods to resonance the name of the beautiful Amarylis (Virgil).

It appears that, from a technical point of view, had been Vitruvius, an architect around the 80 b.C., to emphasize the concept of the resonance and to propose the introduction of systems based on the resonance principle in order to increase the acoustical performance of a theater:

To get the voice of the actors to reach the spectators, enhanced in volume and clarity, it is necessary to build half the height of the acoustic chambers in which bronze vases built according mathematical calculations and musical rules must be placed: in the two extreme chambers are placed the vases that resonate to a given note and, always in pairs, you go towards the center, varying the notes. When the actors voice agrees with the sound produced by the vases it will reach the ears of the spectator louder and clearer

The Vitruvius resonators had been realized in the Beit She'an Theater, located 30 kilometers from Gerusalem in a north region near the Tiberiade lake, placing bronze vases around the auditorium of the theater. *Let the bronze vases be made proportional to the size of the theater* and *let them be so fashioned that, when touched, they may produce with another the notes of the fourth, the fifth and son on up to the double octave* (Vitruvius, 1960).

Indeed, the resonance phenomenon has been focused in the history related to music more than 5000 years ago. We can conjecture therefore that the first experiments of resonators had been performed in that period, especially in Egypt.

Moreover, it is interesting to give focus to the following connection among music and resonance that Guido D'Arezzo (XI century b.C.) derived from the Paolo Diacono (Christian monk) liturgical hymn of vespers on the solemnity of Saint John the Baptist to introduce musical notes:

UT queant laxis	So that they can sing
REsonare fibris	with free voices
MIra gestorum	the wonderful of your deeds
FAmuli tuorum	your servants
SOLve polluti	erase sin
LAbii reatum	from their impure lip
Sancte Iohannes	Saint John

An incomplete list of resonance related devices and phenomena includes:

harmonic oscillators	resonant converters
mechanical resonators	evolutive resonance
acoustic resonators	Helmholtz resonators
aeroelastic resonators	electromechanical resonators
electrical oscillators	quartz
stochastic resonance	plasmonic resonators
hydraulic resonance	resonant membranes
piezoelectric materials	mediatic resonance
mirror neurons	empathy
resonance axes	nonlinear resonance
jump resonance	magnetic resonance
water hammer	resonant drop
self-oscillations	cloister soundboards
resonant robots	orbital resonance
resonant membranes	critical speeds
multiple resonance	

In the following gallery of resonant systems and phenomena, the following physical quantities with the related symbols and dimensional units are used.

physical quantity	symbol	dimensional unit
frequency	f_0	Hertz [Hz]
angular speed	ω	$[\frac{rad}{s}]$
force	F	Newton [N]
displacement and size	δ,x	meter [m], millimeter [mm]
mass	M	$[\frac{Ns^2}{m}]$
inductance	L	Henry [H]
capacitance	C	Farad [F]
resistance	R	Ohm [Ω]
damping	B	$[\frac{Ns}{m}]$
elastic constant	k	$[\frac{N}{m}]$
gravitational acceleration	g	$[\frac{m}{s^2}]$
Young modulus	E	$[\frac{N}{mm^2}]$
pressure	P_a	Pascal [Pa]
density	ρ	$[\frac{Kg}{m^3}]$

3 A Gallery of Resonance

In this Section, a set of classical resonant devices and resonance scenario will be presented.

3.1 Helmholtz Resonators

In Fig. 1 the set of Helmholtz resonators with the corresponding resonance frequency are reported (Perucca, 1956).

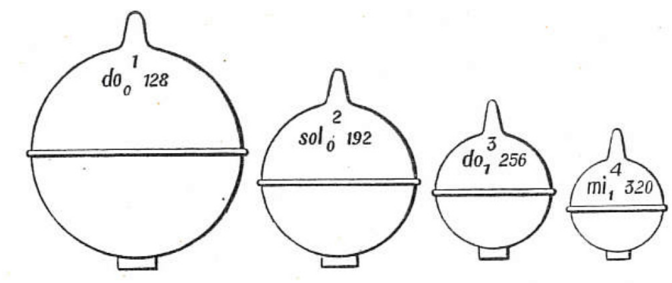


Figure 1: Helmoltz resonators.

The diameter of the resonator determines the acoustic characteristic frequency of the device for which the intensity of the sound is enlarged.

3.2 Spring-mass system

The resonance frequency of the spring-mass system shown in Fig. 2 is given by $f_o = \frac{\sqrt{\frac{k}{M}}}{2\pi}$, where k is the elastic constant of the spring measured in $\frac{N}{m}$, while M is the mass measured in N (Purcell, 1971).

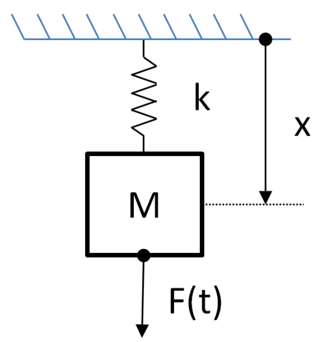


Figure 2: Sketch of a spring-mass system.

For the forcing sinusoidal signal with frequency f_0, the amplitude of x is ideally infinite.

3.3 LC circuit

In Fig. 3 the classical LC electrical circuit is shown (Purcell, 1972). The frequency resonance is given by $f_0 = \frac{1}{2\pi}\frac{1}{\sqrt{LC}}$, where L is the inductance measured in Henry and C the capacitance measured in Farad. At this frequency the current will be infinite, if a small resistance is inserted in series anyway the current at that frequency achieves a peak of amplitude. The corresponding phenomenon does occur in mechanical devices like that mentioned in Subs.2 where the maximum displacement is achieved.

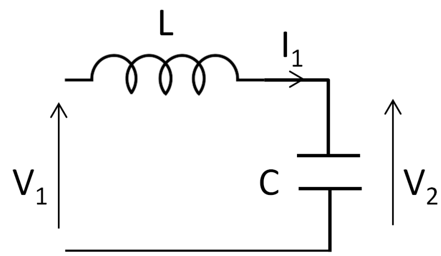


Figure 3: Sketch of an inductor-capacitor circuit.

For sinusoidal signals with frequency f_0, the current amplitude I_1 tends to infinite.

In Fig. 4 is reported the family of classical resonance curves for a second-order dissipative system, either spring-mass-damper systems (Fig. 4(b)) or LCR circuits (Fig. 4(c)).

3.4 Galileo's pendulum

The frequency of the Galileo's pendulum is given by $f_0 = \frac{1}{2\pi}\sqrt{\frac{g}{L}}$, where g is the gravitational acceleration, measured in $\frac{m}{s^2}$ and L is the pendulum length, expressed in m.

The classical resonant mathematical model (Purcell, 1971) is given by $M\ddot{x} + B\dot{x} + kx = F(t)$, where x is the displacement, M is the mass, B is the damping, k is the elastic constant and $F(t)$ is the external force.

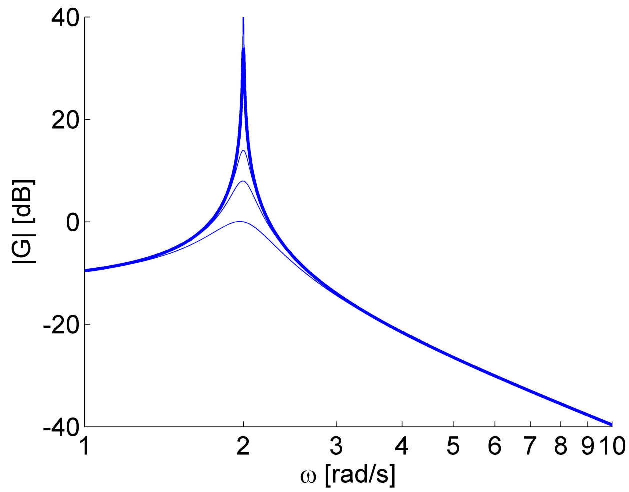
3.5 Resonant bridges

The classical example of destructive resonance is referred to the catastrophes of the bridge collapse in more cases. It is reported in Fig. 5 the Angers bridge collapse. Moreover, the most common example is the Tacoma Narrows Bridge, whose oscillations were filmed (see a snapshot in Fig. 6), where the complex phenomenon of resonance referred to is given by the mathematical expression $M_{s,a}(\dot{\bar{x}}, \bar{x}, t)\ddot{\bar{x}} + B_{s,a}(\dot{\bar{x}}, \bar{x}, t)\dot{\bar{x}} + K_{s,a}(\dot{\bar{x}}, \bar{x}, t)\bar{x} = \bar{F}(t)$ that includes also nonlinear terms and where M, B and K are not constant but mathematical operators (Robison, 1994). This phenomenon takes the name of aeroelastic flutter.

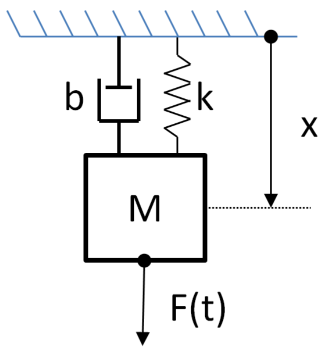
3.6 Vacuum tube resonant circuits

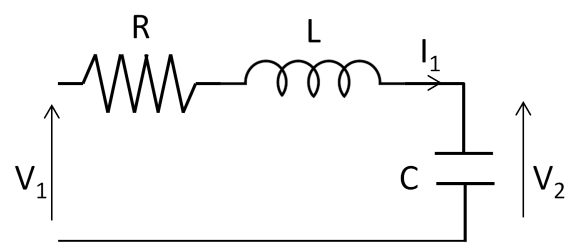
In the Fig. 7 it is reported the classical scheme of a vacuum tube-based oscillator (Terman, 1955).

It is a Colpitts-like oscillator with resonance frequency defined by the LC tank oscillator. With the inductor $L = 5\mu$H and variable capacitor in the range



(a)





(b) (c)

Figure 4: Second order dissipative resonant systems: (a) family of frequency responses for different values of the damping; (b) inductor-capacitor-resistor circuit; (c) spring-mass-damper system.

of $C = 80\text{pF}$, the resonance frequency is in the order of $f_o = 8\text{MHz}$. The circuit with vacuum tube in operation mode is reported in Fig. 8.

3.7 Quartz resonant circuits

A quartz scheme and the corresponding high-frequency stability oscillator is reported in Fig. 9.

It does oscillate at the mechanical resonance frequency of the quartz device. In the considered application, it works at the frequency f_s.

3.8 Resonant inverters

A resonant DC-DC inverter is reported in Fig. 10. It is normally used to back illumination of monitors and LCD panels (Mohan *et al.*, 2003).

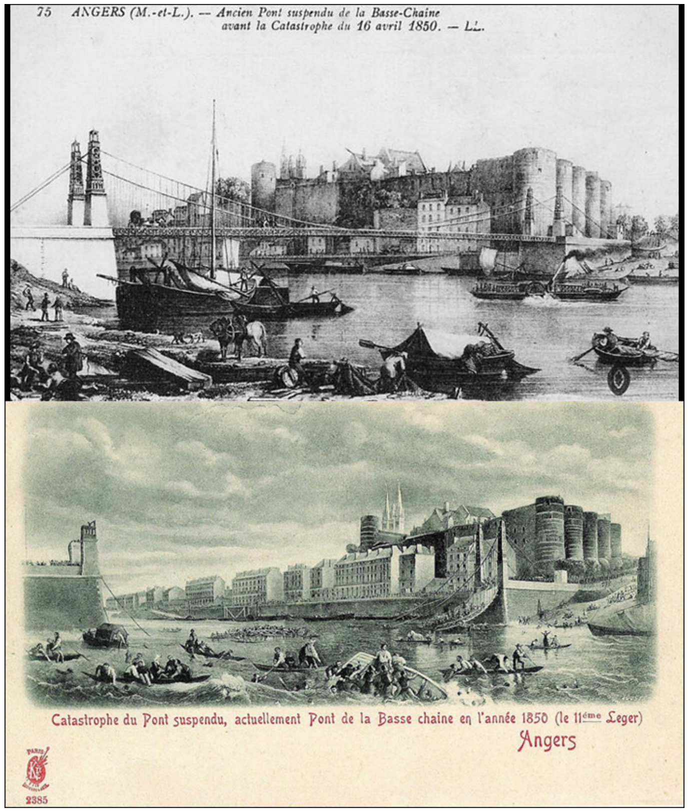


Figure 5: Angers bridge collapse.

This circuit, thanks to resonance, allows to get an high output voltage from a low supply voltage.

3.9 Critical speed of flywheel generator at JET

The critical speed of the axis of the flywheel generator built for the nuclear fusion machine at the Joint European Torus (Wesson and Campbell, 2011) is given by $\omega = \sqrt{\frac{g}{\delta}}$ where δ is the displacement at the center of the axis, as reported in Fig. 11, and g is the gravitational acceleration. In the Fig. 12 it is shown the plasma environment, while in the Fig. 13 are reported pictures of the flywheel generator. From experimental evaluations, the deformation is $\delta = 0.002$m, hence the critical speed is $\omega = \sqrt{\frac{g}{\delta}} = \sqrt{\frac{9.8}{0.002}} \approx 70$rad/s. Therefore, it is $N = \frac{70}{2\pi}60 = 668$ turns per minute. Due to the fact that the normal working conditions of the flywheel generator at the JET correspond to a speed of 225 turns per minute, which is below the critical value, the safe operations of the system are ensured.

3.10 Resonant hydraulic penstoke

Let us consider the hydroelectric dam shown in Fig. 14. Some dynamical effects of the penstock can induce a resonance effect which may destroy the structure,

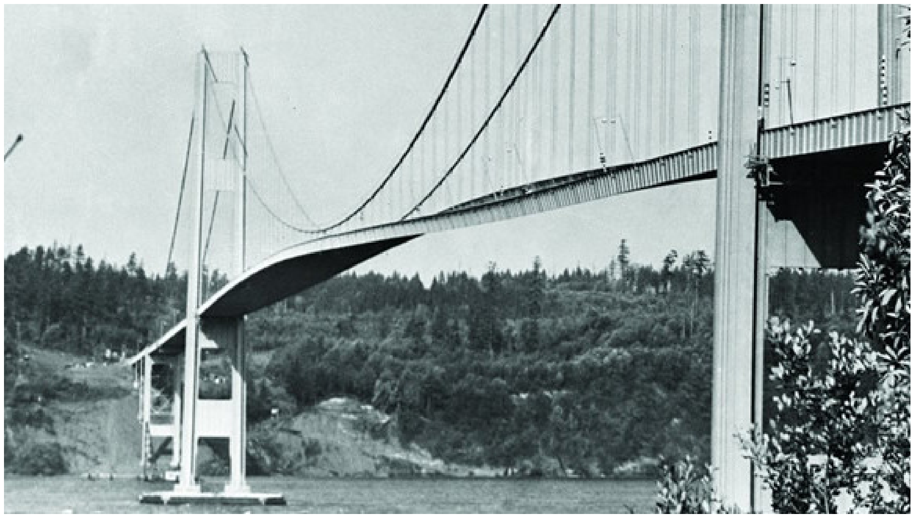


Figure 6: Resonant oscillations of the Tacoma Narrows bridge.

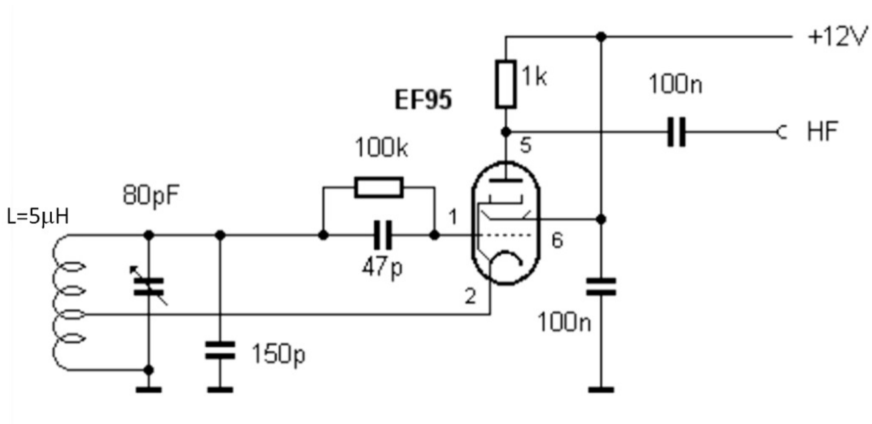


Figure 7: Scheme of a resonant circuit including a vacuum tube.

as shown in Fig. 15. The resonance frequency of a penstoke (Dörfler *et al.*, 2012) can computed as $f_0 = \frac{1}{2\pi}\sqrt{\frac{k}{M}}$, where $k = \frac{ESL}{R}$, being E the Young modulus of the material of the penstoke, S, L and R are the section, the length and the radius of the pipe, respectively, and $M = \pi R^2 L\rho$, where ρ is the density of the water. Considering a pipe with $R = 1$, $L = 260$m and $S = 10$mm, made of cast iron, whose Young modulus is $E = 78000\frac{N}{mm^2}$, leads to a resonance frequency $f_0 \approx 25$Hz, for which a catastrophe does occur (as in Fig. 15).

3.11 Resonant water drop

Also the water drop is resonant. In Fig. 16 the sequence of displacements of a single drop of water falling onto a water layer is shown. The sound generated is linked to a resonance phenomenon. The resonance frequency is given by the expression $f_0 = \frac{1}{2\pi}\sqrt{\frac{k}{M}}$, where $k = P_a 4\pi R$, being P_a the atmospheric pressure and R the radius of the drop, and $M = \frac{4}{3}\pi R^3 \frac{\rho}{\alpha}$, being ρ the water density and

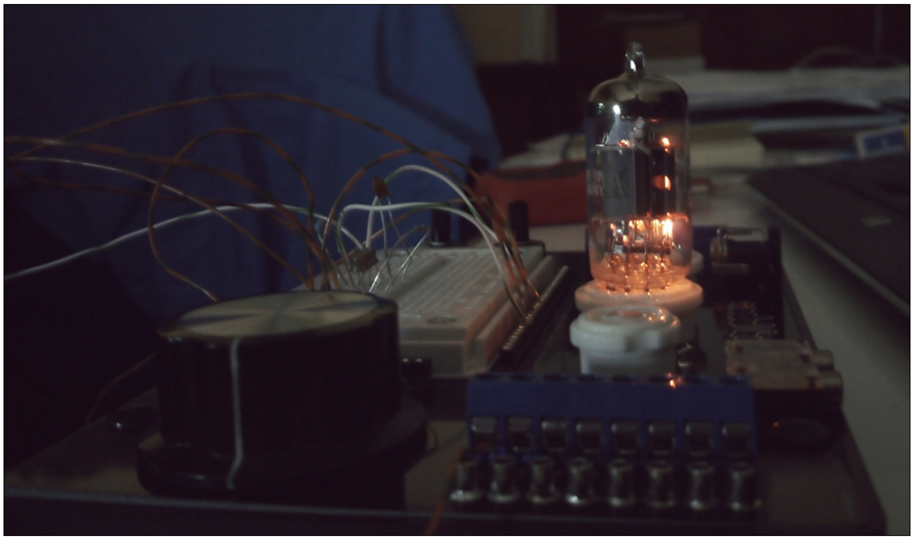


Figure 8: Operating resonant circuit with enlighten vacuum tube.

α an adimensional coefficient accounting for drop shape, usually between 1 and 2. Considering $P_a = 101$hPa, $R = 0.355$mm, $\rho = 1000\frac{kg}{m^3}$ and $\alpha = 1.2$, it results $f_0 = \frac{1}{2\pi}\sqrt{\frac{k}{M}} \approx 8.3$kHz.

3.12 Resonant microrobots

In the Fig. 17 a resonant robot is shown. The robot has been designed with piezoelectric legs that are excited by their resonance frequency in order to achieve the maximum speed for the device. The resonance depends on the characteristics of the piezoelectric resonator. For the considered microrobot, the resonance frequency is around 80Hz (Buscarino *et al.*, 2007).

3.13 Jump resonance

Jump resonance is a phenomenon typically occurring in nonlinear systems driven by a sinusoidal input that determines a multi-valued frequency response with an associated hysteretic behavior with respect to increasing/decreasing frequency of the input.

The peculiarity of jump resonance is that there exists a range of frequencies for which the system frequency response is a multi-valued function that, therefore, leads to an hysteretic behavior. The occurrence of this behavior depends on both the linear and nonlinear part of the system and the span of the hysteresis window is influenced also by the amplitude of the forcing signal. The presence of a frequency multi-valued function leads to a response in which abrupt jumps down/up in the magnitude of the output signal are retrieved, as long as the frequency of the driving signal is increased or decreased, thus generating an hysteretic behavior in the sense that the value of the output amplitude switches at two different frequency thresholds, depending on the way in which the in-

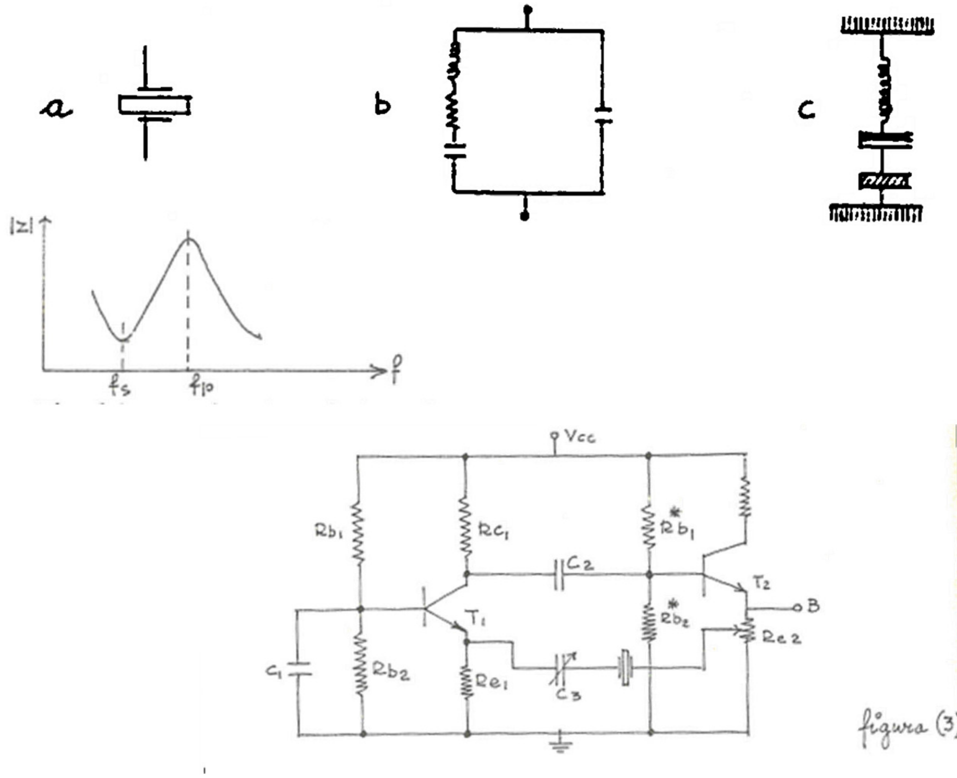


Figure 9: Quartz oscillators with noise frequency robustness (Fortuna, 1977).

put frequency has been varied (decreasing it or increasing it). An example of frequency response with jump resonance is shown in Fig. 18.

A question for future researchers: could be the aeroelastic flutter of bridges classified as a nonlinear jump resonance phenomenon?

Moreover, recently the phenomenon of jump resonance has been actively used for frequency drifts detection (Buscarino *et al.*, 2020). The electronic circuit realized following the schematic in Fig. 19, and the experimental results are shown in Fig. 20.

3.14 Discussion

The reported examples show how resonance, at various levels, is present in our life. In some cases, we design systems in order to achieve resonance phenomena. In other engineering system, the resonance phenomena must be avoided performing a correct design and taking into account all the external inputs that could lead to work in resonance conditions.

The impressive consideration is that even in complex systems, like the flywheel generator or the penstoke, the resonance can be really approximated with that of the mass-spring resonance, or in any electrical circuits can be approximated to the resonance of the LC circuit.

Indeed, resonance is present from nano/micro scales to macro scales, from atoms to the universe.

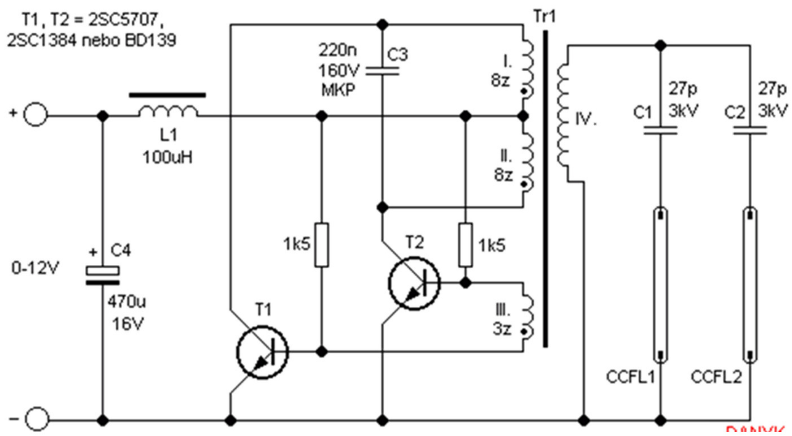


Figure 10: Schematic of a DC-DC resonant inverter.

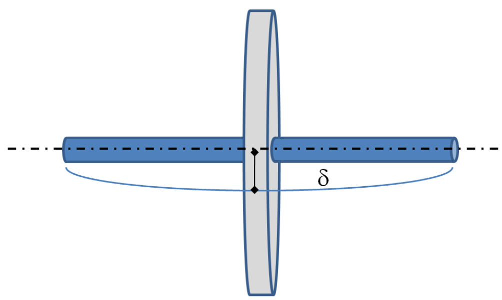


Figure 11: Schematic representation of the flywheel deformation in static conditions, due to its weight.

4 Resonance and Mirror Neurons

The term that often is used to define the empathy between two persons or more people, that means to understand and share the feeling of each others, is known and characterized by the common language as to achieve an emotional resonance. The word resonance is used with the meaning of emotion amplification. For a leader, creating resonance means setting in motion a series of positive feelings in the group of people he directs. Emotional intelligence is the ability to create ideal relationships with oneself and with others. The emotional intelligence is activated by the mirror neurons. In fact, mirror neurons are activated not only when a subject performs an action, but also when he sees an action being performed. It is as if each of us are equipped with an internal simulator that allows ourselves to feel what a fellow man does, perceiving his feelings, emotions and intentions. These neurons, forming neurophysiological structures of the emotional brain (limbic systems and amygdale) (Hudspeth *et al.*, 2013), probably form the basics of empathy (Gallese and Goldman, 1998), a competence possessed by human beings to feel in real time what the other is feeling.

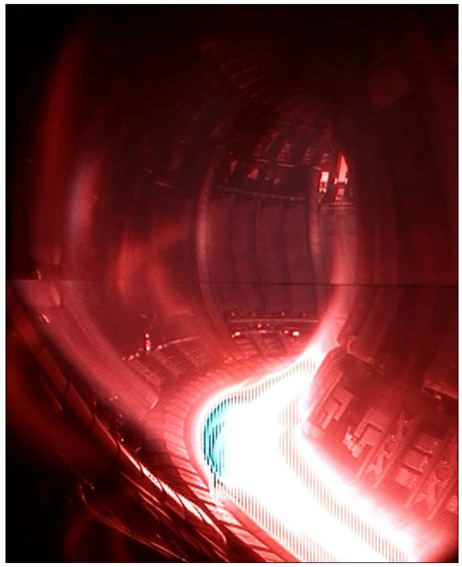


Figure 12: Nuclear fusion experiment at the Joint European Torus.

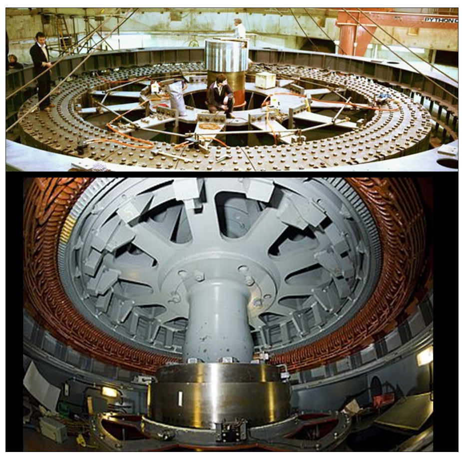


Figure 13: Pictures of the flywheel generator during its realization at JET.

This leads to an amplification and, therefore to an effect of resonance, in the human being. The fantastic thing is that children also possess this competence, probably as early as the fourth month of life: it is said that *children have antennae.* As it is evident, the classical concepts of communications are related to neurophysiological novel principles.

Mirror neurons are neural structures also involved in the process of imitation and behavior understanding (Iacoboni *et al.*, 2007) and are now considered key structures in the brain, assuming in neurophysiology and neuroscience an importance like that of the DNA discovery has in biology. Mirror neurons are active cells initially found in the macaque brain and located in the ventral premotor area (AREA F5) in the brain (Hudspeth *et al.*, 2013). The study of these neurons revealed that they have both motor and visual properties and that are cells emitting information either when the monkey performs a specific action or when the monkey observes someone else performing similar actions. The discovery

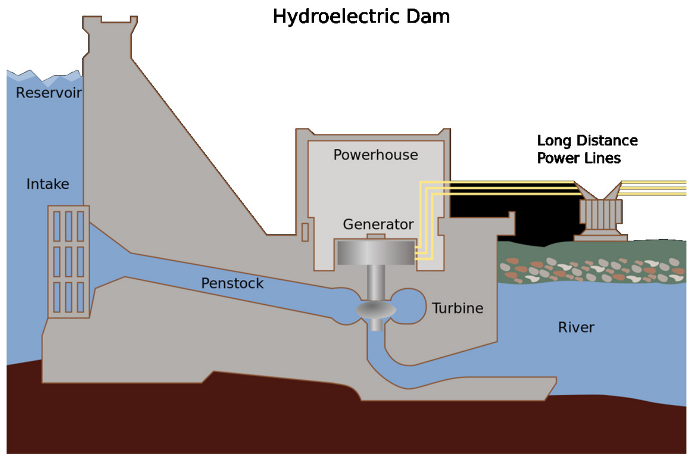


Figure 14: Schematic representation of an hydroelectric dam.

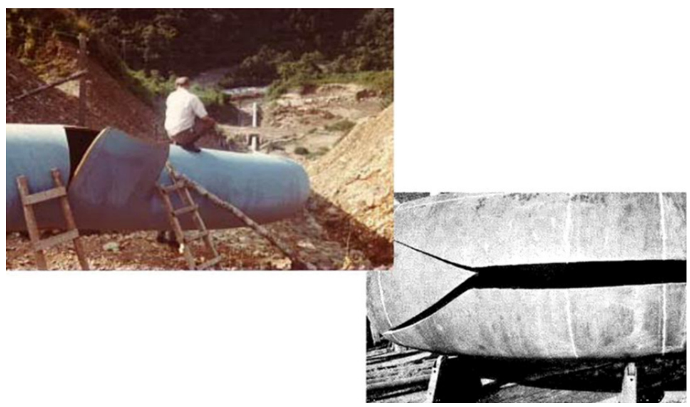


Figure 15: Broken penstoke due to the catastrophic resonance effect linked with the dynamical interaction with water.

of mirror neurons in monkeys has been defined as one of the most important discoveries in the last decades in all neuroscience. Mirror neurons represent the key element in understanding phenomena like imitation, evolution of language, autism and knowledge of the behavior of others. The synchronization between two persons behavior is due to the mirror neurons action that permits the amplification of the emotion and then the effect of emphatic resonance. The studies on mirror neurons revealed that the area F5 of the macaque brain has a direct projection to the upper cervical segments of the spinal cord and the stimulation of this area evokes, in the motor cortex, mouth and hand movements and also actions such as grasping, manipulating and holding (Gallese *et al.*, 1996). Unlike canonical, visual mirror neurons are also activated when the monkey observes another one performing an action. This mechanism in the brain of monkeys is able to show the congruence between the observed and executed actions. Mirror neurons have several applications of interactions between human and robots in order to establish a *cold* resonance between human and machines (Buscarino *et al.*, 2010).

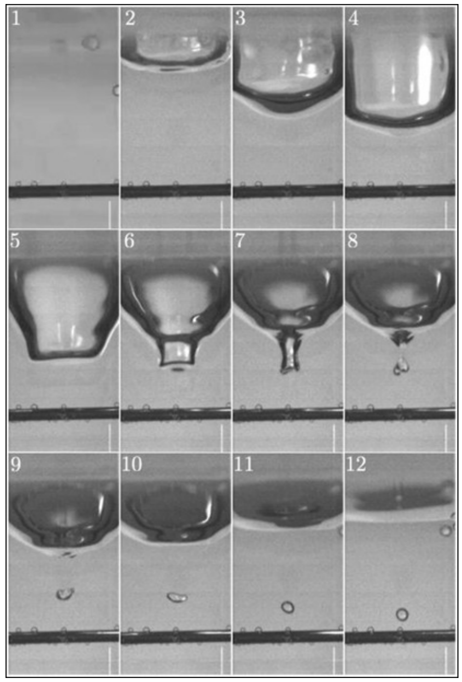


Figure 16: Sequences of pictures taken during the formation and falling of a water drop (Phillips *et al.*, 2018).

5 Resonance and the sociology of our relationship with the world

A wider form of resonance at high hierarchical level is the theme of the last researches of Harmut Rosa. In our mind, we can find the effects of resonance, starting from its original meaning. In fact resonance leads to an amplification of some phenomena that in general are searched in order to improve communication or that allow some phenomena to be better perceived. Resonance is therefore a condition in which dynamical systems can be. The effect of resonance could be local or distributed in more dimensions. Its generalized point of view has been just considered in the case of mirror neurons and in the case of empathy that characterizes the behavior and the feeling of the people.

In the case of sociology, resonance has been considered by Harmut Rosa as the way that must be achieved in order to establish our relationship with the world in a wide sense. This means, to be concrete, *from the art of breathing to the adoption of culturally distinct world views*. The great crisis of modern society, that is driven by acceleration leading to a distorted relationship to the world, is characterized by the broken relationship to the world around us. This means that modernity could be approached positively seeking out for the resonance. Distorted relationship to the world both to the individual and at a collective level are the causes of the crisis of the modern society. This are referred to the environmental crisis, democracy crisis, psychological crisis. Lackness of *Resonance* leads to the broken relationship and leads to the communication failure. The key of approaching the modernity is listening and responding. The general concept of Resonance that Hartmut Rosa gives is that it is related to the

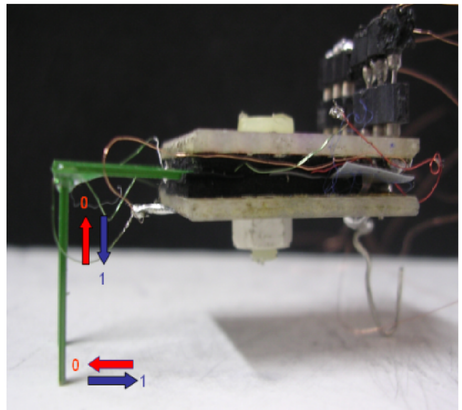


Figure 17: Resonant piezoelectric microrobot.

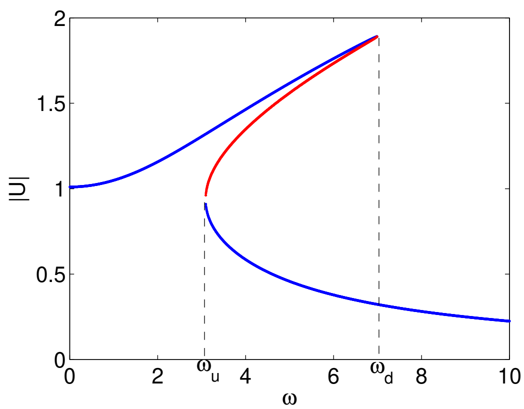


Figure 18: Example of jump resonance. Stable branches are indicated in blue, while the unstable one in red.

relationships between us and the world in term of *come to relate each other*. The term *world* is intended generalized: this includes people, artifacts and natural objects. The world does includes also nature, universe, history, God, life. Moreover it includes body and emotions. At this point the social theory of resonance is strictly related to the empathy and the neurophysiology concepts outlined in the previous section and represents a key to understand the sociological theory in Rosa. His studies are related to the definition of three different kinds of resonant relationships:

1. Horizontal relationships;
2. Diagonal relationships;
3. Vertical Relationships.

These are the basic resonance axes. The problem is related to a multi-resonance environment. The approach allows us to revise the modernity concept where the resonance axes will be activated or not. Therefore the anti-resonance effect characterize the alienation inside the accelerated modernity (Rosa, 2013,

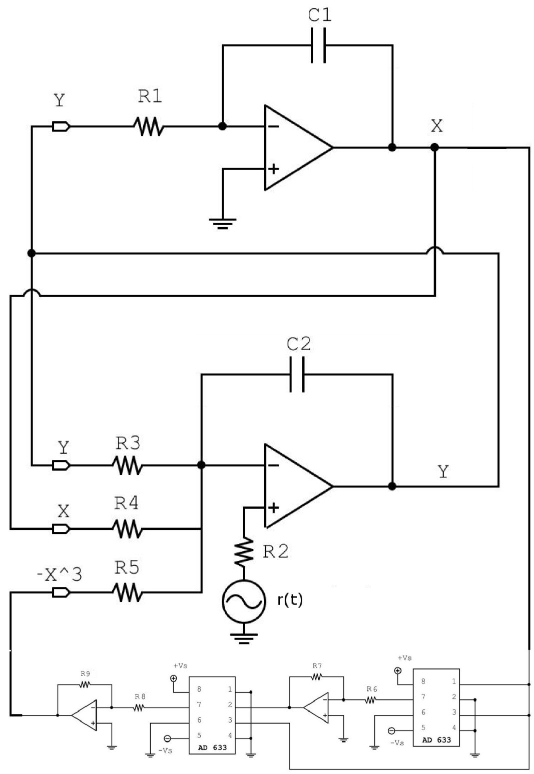


Figure 19: Implementation of the frequency drifts detector. Component values: $R_1 = R_2 = R_4 = 1k\Omega$, $R_3 = 50k\Omega$, $R_5 = 100k\Omega$, $C_1 = C_2 = 8.2\mu$F, $Vs = \pm 18V$. $R_6 = R_8 = 10k\Omega$, $R_7 = R_9 = 100k\Omega$, $TL084$ OP-AMPs and $AD633$ analog multipliers have been used.

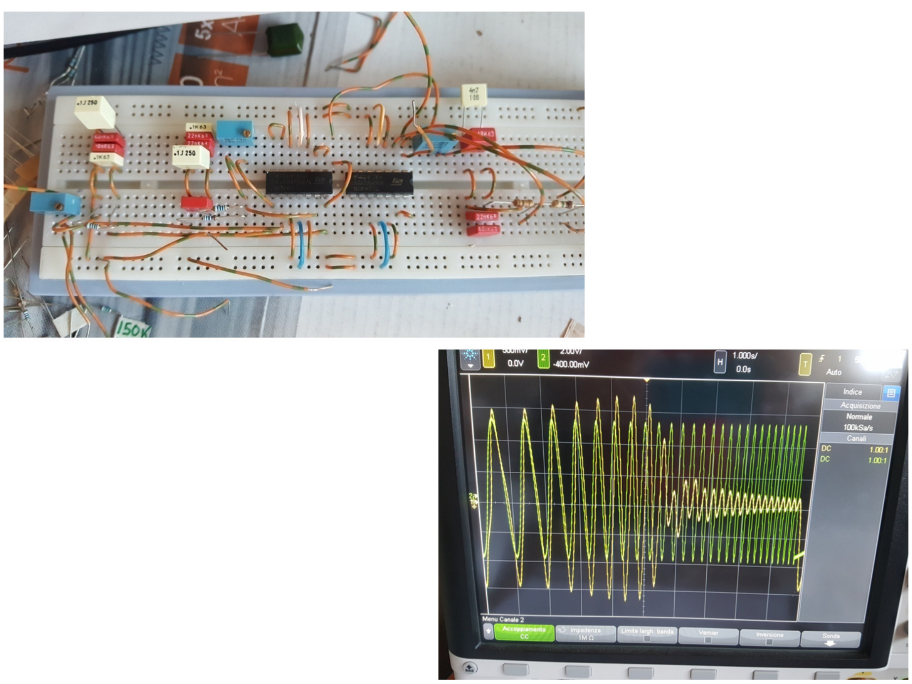


Figure 20: Jump resonance circuit for detecting frequency drifts.

2014). Let us consider the Horizontal resonance axis, it includes the social relationships like friendships, the family and even the political relationships.

The Diagonal axis of resonance is related to achieve resonance in the things. This is related for example to the schools, to the sports and so on. Indeed diagonal resonance axis is referred to the relationships regarding materialities in the sense of *living thing*.

The Vertical axis of resonance is referred to the concepts that are related to a dimension outside ourself. The universe, the nature, the power of art and the religious things belong to the vertical axis that is considered by Rosa.

In the chapter 5 of his book Rosa considers the fundamental components of the recent neurobiology, the cognitive science, the evolutionary biology, the actual psychological studies related to the communication actions. In particular, his attention is devoted to the phenomenological theory of resonance related to the synchronized oscillations that in some sense indicates *the resonance of the brain*. These important remarks allow us the real possibilities that our brain could achieve the target of multiple resonance axes. Therefore the basics of the social impact of resonance is related to join culture and nature: all the scientific elements exist in order to actuate the Hartmut Rosa Resonance approach for a better life quality. Moments of resonance and experience of alienation represent the two opposite poles and the antagonist forces in the world. The resonances are the results and the expressions of the specific kind of intersections among more levels of relationship to the world.

The conclusion of Rosa is that a better world is achievable if it is possible to establish a strong resonances among the three axes. Global resonance could save the modernity (Rosa, 2007).

6 The place of resonance: conclusive remarks

The Greek theaters are in our opinion the resonant place for excellence and are and have been, therefore, the real experiments of the global resonance (Argan, 1966). The theater was conceived in a place near the town, near to soft mountains and where the sea can be seen, with a precise location that could guarantee an optimal sunset. The nature must play a dominant effect on the theater. Birds sounds, natural flower smells characterize some of the Greek theater environment. In Fig. 21, the Syracuse Greek Theater is shown.

The project of the theater and its realization were optimized in order to achieve the best performance, both as regards actors acoustic and people acoustic. To achieve this performance experiments were performed in a systematic conception. Moreover the Greek conception of the drama had been based on a culture that emphasized a complete empathy among people, actors and environment. The coupling of the drama place, the actors, the people represented the essential elements to establish a global resonance.

Let us reconsider the Rosa resonance theory: in the Greek theater representations all the three axes were activated. Moreover the Greek theaters induced

Figure 21: Syracuse Greek Theater.

some perceptual phenomena in which stimulation of one sensory or cognitive main grain center could induce different pathway. This is the Synesthesia effect that involves a generalized perception of the union of the senses in a resonance generalized pathway (Hubbard and Ramachandran, 2005).

In this brief note about resonance, we have considered the term resonance at large.

Resonance is the fundamental element for the communication, remarking the universal theory of communication as in the Shannon idea (Shannon, 1948). This aspect has been widely discussed and emphasized.

Moreover, some final remarks. Global communication and networks does work in the same universe. We intend network communication or brain communication networks both are related to resonance. Both are related to oscillating devices. Mirror neuron networks are made by neurons, that do work thanks to resonance (Hindmarsh *et al.*, 1984). Axes of resonance are related to the activation of mechanisms that allow to achieve a correct communication among the people and the world in order to live better. Greek theaters had been conceived in order to achieve this task, moreover Greek people did not know mirror neurons, resonance axis, but perceive the resonance effects.

People search today for universal concepts related to the Invariance Principles, that means to reach objective truths as Robert Nozick explains in his book (Nozick, 2001). This contribution is guided by a continuous impulse towards proving universal the concept of resonance.

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