

normal bone structure in individuals with osteoporosis.

Figure 30 is a block schematic showing a method for maintaining normal bone structure in normal individuals during weightlessness.

Figure 31 is a block schematic showing a method for detecting benign or malignant tissue types using resonant acoustic and/or acousto-EM energy.

Figure 32 is a block schematic showing a method for stimulating and/or disrupting proteoglycans adhesive units between cells using resonant acoustic and/or acousto-EM energy.

Figure 33 is a block schematic showing a method for augmenting, identifying, detecting, and/or disrupting structures of multicellular organisms using resonant acoustic and/or acousto-EM energy.

Figure 34 is a block schematic showing a method for augmenting the growth rate of multicellular organisms using resonant acoustic and/or acousto-EM energy.

Figures 35 A & B are block diagrams showing a method and system for determining acoustic and/or acousto-EM frequencies of inorganic material or structure.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The methods of the present invention comprise delivering acoustic energy at resonant frequencies to an inorganic or biologic structure as shown in Figure 1. Using methods known to those skilled in the art, any device capable of generating and transmitting acoustic energy through any medium can be used to generate the resonant acoustic frequencies utilized by the invention. This includes, but is not limited to, devices that produce acoustic energy using traditional EM stimulation of piezoelectric transducers, (man-made or naturally occurring), purely mechanical devices (such as high frequency air whistles), and laser devices. Individual components for acoustic energy systems are commercially available from a wide variety of manufacturers, which can be configured to particular applications and frequency ranges. (See Thomas Directory of American Manufacturers, Photonics Buyer's Guide, 1996, Microwave and RF, and Electronic Engineer's Master Catalogue).

Any oscillator, also called signal generator or function generator, that produces a signal with predetermined characteristics such as frequency, mode, pulse duration, shape, and

repetition rate may be utilized to generate the resonant acoustic frequencies utilized by the invention. Various oscillators or signal generators can be commercially purchased for frequencies ranging from Hertz to Gigahertz, such as the MicroLambda LMOS series (500 MHz-18 GHz), the BK Precision 2005A (100 KHZ-450 MHz) (B&K Precision, Chicago, IL), the Tektronix SMEO2 (5 KHZ-5 GHz), and the Tektronix 25 SME 4040 (0.5 Hz -20 MHz) (Tektronic, Inc., Beaverton, OR), and the Matec 700 series (1-1100 MHz) and the like.

The frequency at which resonance occurs depends on the size, shape, and composition of a structure. For instance, the resonant frequency of a sphere is the frequency at which the acoustic wavelength is equal to the sphere diameter. A more complex structure - a cylinder - has two resonant frequencies based on two axes of orientation, with one of the resonant frequency wavelengths being equal to 1.5 times the length. The more complex the shape of the structure, the more complex the resonant acoustic frequency pattern, however, the wavelength at which acoustic resonance occurs is roughly equivalent to the size of the structure.

The frequency which matches a particular acoustic wavelength depends on the composition of the structure, according to the equation:

$$\text{velocity} = \text{frequency} \times \text{wavelength} \quad (1)$$

where velocity refers to the speed of the acoustic wave propagation (the speed of sound) in the medium composing the structure. Although the speed of sound varies among various biological tissues, it is roughly equivalent to the speed of sound in water (1,500 m/s), because most biologic organisms are composed chiefly of water. Using the speed of sound in water as the velocity of the acoustic wave, and using the structure size as the rough equivalent of the wavelength, the approximate range of resonant acoustic frequencies in organic or biologic structures, is given by:

$$\text{Frequency} = \frac{\text{Velocity}}{\text{Wavelength}} = \frac{\text{Velocity}}{\text{Size}} = \frac{1,500 \text{ m/s}}{\text{Size}} \quad (2)$$

(See the chart that follows.)

Other known speeds of sound in biologic tissues vary and include:

(1) liver (1550 m/s); (2) muscle (1580 m/s); (3) fat (1459 m/s); (4) brain (1560 m/s); (5)

kidney(1560 m/s); (6) spleen (1570 m/s); (7) blood (1575 m/s); (8) bone (4080 m/s); (9) lung (650 m/s);(10) lens of eye (1620 m/s); (11) aqueous humor (1500 m/s); and (12) vitreous humor (1520 m/s). Resonant acoustic frequency ranges for targeted organic or biologic structures comprised of tissues with acoustic velocities different from the speed of sound in water, are derived using the same equation (velocity/wavelength) and correlate to the charted ranges listed below, plus or minus, depending on the speed of sound in the targeted tissue.

Although velocity of acoustic energy in a particular medium is for the most part constant, there is a slight dependence of velocity on frequency - an effect called dispersion. For example, over the frequency range of 1 to 20 MHz, the acoustic velocity changes by 1%. Thus, in the present invention the resonant frequency(s) or at least the range of frequencies within which the resonant frequency can be found for a targeted structure depend on its size, shape, and composition, and the specific frequency range under examination. Some approximate acoustic resonant frequencies for biologic structures are included in the following Table 1.

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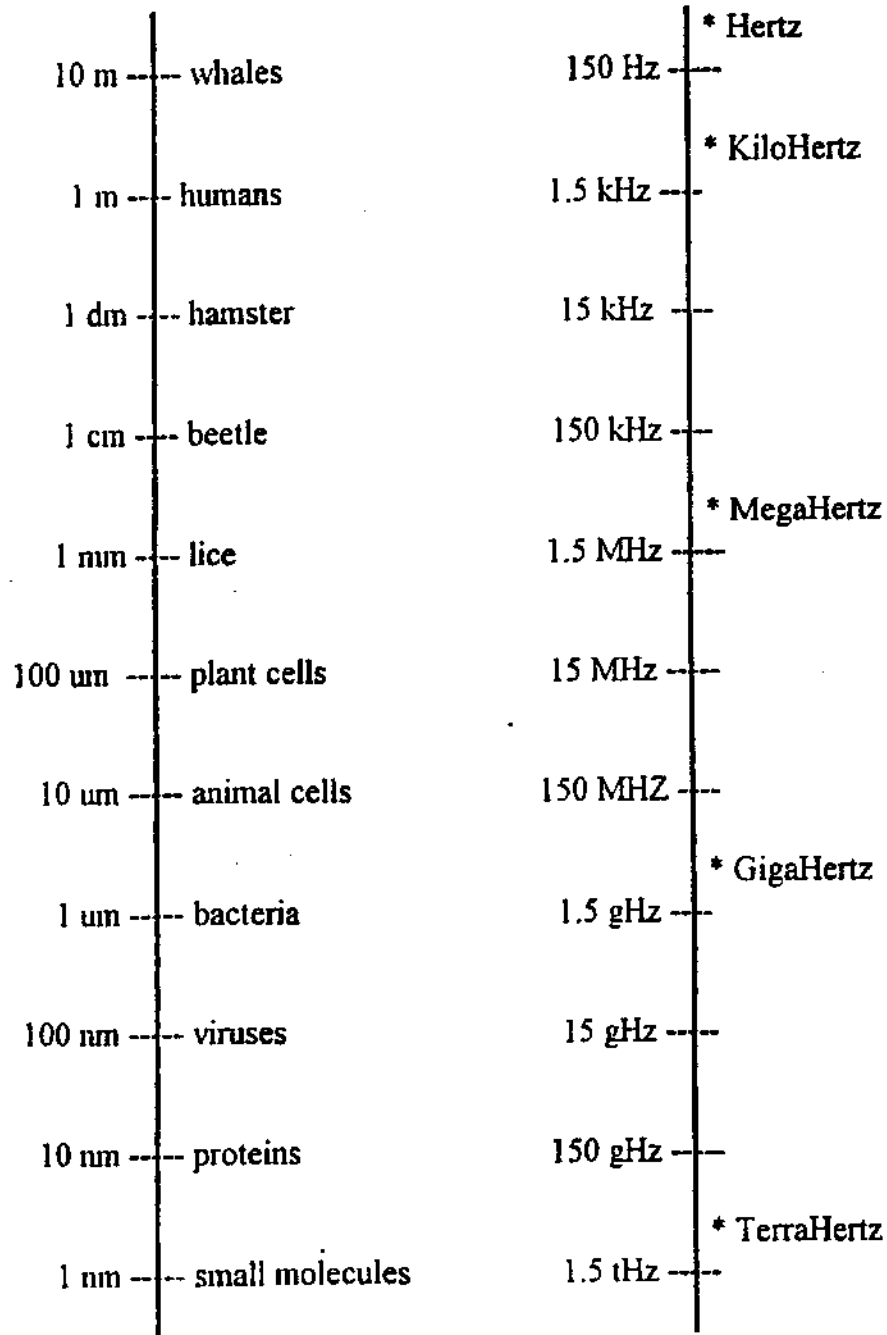
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TABLE 1

Approximate Acoustic Resonant Frequency Ranges for Biologic Structures

(Speed of sound = 1,500 m/s)



To obtain the maximum transfer of acoustical energy from one medium to another, the characteristic acoustical impedance of each should be as nearly equal to the other as possible. This problem of impedance matching, as it is termed, occurs in many branches of physics, and is employed in acoustical techniques, as a means of matching two media of different acoustical impedances R_1 and R_2 respectively. The matching medium is sandwiched between the other two and should be the appropriate thickness relative to the wavelength of the sound transmitted, and its acoustical impedance R should be nearly equal to $\sqrt{R_1 R_2}$. An impedance matching device that is commercially available and which can be utilized in this invention includes Model 60, manufactured by Matec Instruments, Inc.

Acoustic energy can be produced by a transducer that converts received electromagnetic energy into rapid, physical vibrations, and thus acoustic energy. The first acoustic transducers used the piezoelectric properties of naturally occurring quartz to produce acoustic energy waves.

EM energy → piezoelectric transducer → acoustic energy waves

New transducers use materials such as ferroelectric ceramics (barium titanate, lead titanate, or lead zirconate) and zinc oxide. Recent advances in materials engineering have also produced piezoelectric polymers which can be shaped into sheets and cords, allowing a multiplicity of applications.

Transducers are also commercially available from a wide variety of manufacturers, in a wide variety of designs which can be configured to particular applications and frequencies. Examples of acoustic transducers that may be utilized in the present invention and which can be commercially purchased for frequencies ranging from Hertz to Gigahertz include Matec broadband immersion transducers MIA series (10-196 MHz), Matec broadband MIBO series (5-10 MHz), Matec broadband MICO (3.5 MHz), Matec broadband MIDO (2.25 MHz), Matec broadband MwO series (50 KHZ-1 MHz), Matec GPUT series (500 KHz-20 MHz), Matec intravascular blood flow VP-A50 series (5-30 MHz), the Teledyne Electronic Technologies In-phase or Out-of phase broadband MHz/GHz (up to 17.5 GHz) array transducer of zinc oxide on sapphire and optional anti-reflective coating, and Channel Industries Kilohertz transducers. In the ultrahigh acoustic frequencies (upper GHz and THz) maser and laser systems may be utilized.

The transducers can produce an acoustic wave within a range of frequencies