SONIC ENHANCED OIL RECOVERY SYSTEM AND METHOD

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Filed: Aug. 18, 2011

Abstract

To increase oil recovery from an oil reservoir, an acoustic transmitter is disposed in a source well and an acoustic receiver is disposed in a producing well. A portion of the oil reservoir is disposed between the source well and the producing well. An acoustic signal is transmitted from the acoustic transmitter at frequencies of 30 Hz and greater. The transmitted acoustic signal is received by the acoustic receiver and a resonant frequency of the portion of the oil reservoir is determined based on attenuation of the transmitted signal. The acoustic signal is transmitted from the acoustic transmitter at the determined resonant frequency to reduce a boundary layer effect between oil in the oil reservoir and a surface of a substrate in the oil reservoir and between the oil and a brine interface in the oil reservoir.
FIG. 6

Frequency (Hz)

Magnitude (dB)
FIG. 7

Layered Reservoir at Water Flood Break Through

Permeability, md

Change in Relative Permeability

Darcy Flow

Sonic Flow

Change in Absolute Permeability

Recovery Factor

0.8

0.6

0.4

0.2

0

1000

100

10

1
FIG. 8

Intermediate Wet – Brea Sandstone

Recovery Factor

Pore Volumes Injected

Water Flood

Water Flood Plus Sonic Stimulation

Water Flood Plus Sonic Stimulation Plus Surfactant
Effect of Carbon Dioxide Injection

FIG. 13
SONIC ENHANCED OIL RECOVERY SYSTEM AND METHOD

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to U.S. Provisional Application Ser. No. 61/377,713, filed on Aug. 27, 2010, titled “SONIC ENHANCED OIL RECOVERY METHOD,” the disclosure of which is incorporated herein by reference in its entirety.

FIELD OF THE INVENTION

[0002] The present invention generally pertains to the recovery of oil from a subsurface oil reservoir.

BACKGROUND OF THE INVENTION

[0003] The production of crude oil from a formation is initially supported by the expansion of fluids in the pore system and then, as the reservoir pressure falls below the bubble point of the oil, the expansion of solution gas provides pressure support. This phase of the reservoir life is called primary recovery. Some reservoirs are connected to a aquifer and the flow of water from the aquifer provides pressure support to displace the crude oil to the producing wells.

[0004] As the production rate of crude oil declines under primary recovery mechanisms, secondary oil recovery techniques are used to provide pressure support for the oil reservoir. The most popular technique is water injection into the oil zone and is called waterflooding. For high viscous oils, steam flooding is used to provide pressure support, reduce the thermal viscosity and increase the mobility of the oil. For lighter oils, gas injection can be used to induce gravity drainage of the oil toward the structurally lower production wells and this method is call gas assisted gravity drainage; however, if steam is the injected gas, it is called steam assisted gravity drainage.

[0005] In order to improve the ability to recover oil above that normally possible with secondary recovery techniques, tertiary oil recovery techniques are used. A tertiary method commonly used in zones being water flooded includes the use of diversion agents such as polymers to increase water viscosity and plug off swept zones to improve vertical and horizontal sweep efficiencies. To mobilize residual oil in the areas already swept by water, surfactants and caustic agents are mixed with the injected water to reduce surface tension, but absorption of the expensive surfactants on clay particles limits the application to cleaner formations. This type of flood is called an alkaline, surfactant and polymer flood (ASP flood).

[0006] Unfortunately, these prior art procedures are tedious, time consuming, expensive, and/or fail to recover much of the oil present in oil formations. Accordingly, it is desirable to provide a method and apparatus capable of overcoming the disadvantages described herein at least to some extent.

SUMMARY OF THE INVENTION

[0007] The foregoing needs are met, at least to a great extent, by the present invention, wherein in one respect an apparatus and method is provided that in some embodiments improves the recovery of oil from oil formations.

[0008] An embodiment of the present invention pertains to a method of increasing oil recovery from an oil reservoir. In this method an acoustic transmitter is disposed in a source well and an acoustic receiver is disposed in a producing well. A portion of the oil reservoir is disposed between the source well and the producing well. An acoustic signal is transmitted from the acoustic transmitter at frequencies of 30 Hz and greater. The transmitted acoustic signal is received by the acoustic receiver and a resonant frequency of the portion of the oil reservoir is determined based on attenuation of the transmitted signal. The acoustic signal is transmitted from the acoustic transmitter at the determined resonant frequency to reduce a boundary layer effect between oil in the oil reservoir and a surface of a substrate in the oil reservoir and between the oil and a brine interface in the oil reservoir.

[0009] Another embodiment of the present invention relates to an apparatus for increasing oil recovery from an oil reservoir. The apparatus includes an acoustic transmitter, an acoustic receiver, and a means for determining a resonant frequency. The acoustic transmitter is disposed in a source well and is configured to transmit an acoustic signal at frequencies of 30 Hz and greater. The acoustic receiver is disposed in a producing well and is configured to receive the transmitted acoustic signal. A portion of the oil reservoir is disposed between the source well and the producing well. The resonant frequency of the portion of the oil reservoir is calculated by the means for determining the resonant frequency based on attenuation of the transmitted signal. The acoustic transmitter is configured to transmit the acoustic signal at the determined resonant frequency to reduce a boundary layer effect between oil in the oil reservoir and a surface of a substrate in the oil reservoir and between the oil and a brine interface in the oil reservoir.

[0010] There has thus been outlined, rather broadly, certain embodiments of the invention in order that the detailed description thereof herein may be better understood, and in order that the present invention may be better appreciated. There are, of course, additional embodiments of the invention that will be described below and which will form the subject matter of the claims appended hereto.

[0011] In this respect, before explaining at least one embodiment of the invention in detail, it is to be understood that the invention is not limited in its application to the details of construction and to the arrangement of the components set forth in the following description or illustrated in the drawings. The invention is capable of embodied in addition to those described and of being practiced and carried out in various ways. Also, it is to be understood that the phraseology and terminology employed herein, as well as the abstract, are for the purpose of description and should not be regarded as limiting.

[0012] As such, those skilled in the art will appreciate that the invention upon which this disclosure is based may readily be utilized as a basis for the designing of other structures, methods and systems for carrying out the several purposes of the present invention. It is important, therefore, that the claim be regarded as including such equivalent constructions insofar as they do not depart from the spirit and scope of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] FIG. 1 is a cross-sectional view showing a sonic stimulation tool across from the formation.

[0014] FIG. 2A is a graph of a raw cross well bore tomography image with common receiver plotted against depth and time.

[0015] FIG. 2B is a graph of a single trace plotted against amplitude and time.
FIG. 3 is a graph of an averaged Fourier Transform of all traces in a single layer.

FIG. 4 is a graph of a typical attenuation curve shape for a single layer with a Q-factor of 28.

FIG. 5 is a graph of a typical attenuation curve shape for a single layer with a Q-factor of 4.5.

FIG. 6 is a graph of a Fourier Transform for a single trace of a guided slow compression wave or tube wave in a thick sand layer at a central frequency of 517 Hz.

FIG. 7 is a graph showing the effect of acoustic stimulation on oil recovery factor at water flood break through on the highest permeability layer of an exemplary layered reservoir.

FIG. 8 is a graph showing recovery factors following core flooding, acoustic stimulation of water flood after break through, and flooding with water and surfactant with acoustic stimulation in an exemplary Berea sandstone reservoir.

FIG. 9 is a graph of a Fourier Transform for a few traces of a guided slow compression wave or tube wave in a packet in a sand-shale layer sequence having three central frequencies of 409, 503, and 578 Hz.

FIG. 10 is a cross sectional view of a heavy oil production well with a sonic tool placed across the formation.

FIG. 11 is an aerial view of a 9-spot pattern under water, steam, surfactant or carbon dioxide flood.

FIG. 12 is an aerial view of a natural water drive reservoir against a fault.

FIG. 13 is a graph of an average velocity ratio of first arrival shear wave versus first arrival slow compression wave of a zero offset cross well bore tomography image of a carbon dioxide flood.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The present invention provides for a method to physically determine the resonant frequency band needed to stimulate a natural water drive, water flooded, steam flooded, or CO₂ flooded oil reservoir with fluid coupled acoustic frequencies. The resonant frequency band of the slow compression wave is a strong function of reservoir thickness, reservoir matrix, shale layering and gas saturation. The travel time of the slow compression wave is a function of fluid compressibility, reservoir depth and rock matrix type.

Field data indicate that the effective resonant frequency band is bounded by 30-2000 Hz and is about 80 to 120 Hz wide for most formations. The lower bound of 50 Hz is determined by the thickness and fluid compressibility of the formation. Lower frequencies such as 10 Hz cannot be reflected off of the interface between the shale and formation because the wavelength greatly exceeds the thickness of the formation. The upper bound of 600 Hz is determined by the attenuation of the acoustic energy in the horizontal direction between wells. For example, a low permeability limestone with 10% porosity will transmit acoustic energy with high frequencies.

The primary method used to determine the resonant frequency band of a reservoir is to conduct cross well bore tomography (cross well seismic) between source and receiver well bores. The resonant frequency band is specific to the area between the source and receiver well bores; however, depending on formation thickness and matrix properties the resonant frequency band should range from 30-2000 Hz. The cross well bore tomography should generate a fluid coupled compression wave in the reservoir interval to maximize Stoneley and Tube wave generation across the target oil formation. Clamped casing sources will maximize the shear wave propagation of the cross well bore tomography but this method minimizes the generation of Stoneley and Tube waves that are used to find the resonant frequency of the formation.

A second method of determining the resonant frequency of the formation is to calculate it from monopole or dipole sonic logs that show compression, shear and Stoneley wave arrival times. This is only an estimate and does not account for coupling between sand and shale layers or saturation, matrix and thickness changes in the reservoir.

To determine the effective coverage and the sweep efficiency in the area surrounding the sonic stimulation source, hydrophones can be installed in offset wells to monitor the acoustic wavelet arrival for frequency shift and velocity change. The source frequency is swept for an approximate 100 Hz bandwidth above and below the current resonating frequency to verify that the sonic source well is broadcasting the correct resonant frequency to each offset well location. When comparing subsequent cross well tomography surveys to original surveys in the same source and receiver wells, frequency shifts and changes in P and S wave velocities reveal changes in reservoir saturations between the source and receiver wells.

In cases where both sonic stimulation and water injection are utilized, a catonic, anionic or nonionic surfactant can be added to the injected water to reduce the surface tension. Core tests show that sonic stimulation by itself can lower residual saturations below 25% and that the addition of surfactant to water can lower residual saturation below 25%, but both acting together can reduce residual oil to below 10% for most sandstone cores.

In general, the method presented in the present application is the near resonant frequency band for the target formation is measured between at least 2 wellbores and that frequency band is transmitted with a liquid coupled acoustic source into the formation to reduce the residual oil saturation by disrupting the surface tension between the oil and brine phase and disrupting the interfacial tension between the oil and the solid pore face. The resonant frequency band is measured occasionally and the transmission is changed to match changes in saturation and in reservoir pressure.

It is an advantage of one or more embodiments of the invention that, the resonant frequency band of a producing oil reservoir is determined or estimated. A sonic stimulation device is disposed into a well directly across from the producing reservoir and generate the determined resonant frequency band in the stimulation well. The sonic stimulation causes more oil to be mobilized and the offset producing oil wells recovers additional oil. After the device is in operation, sound data in the offset wells are recorded and the output frequency band is fine tuned to match the resonant frequency bands of the offset wells based on the recorded sound data from the stimulation device. In this manner, the stimulation process is optimized.

The main purpose of the invention is to use sonic stimulation to reduce the boundary layer effects between oil and water in the pore and between oil and solid surface of the pore. On a microscopic scale, during sonic stimulation, one mode is that the fluid moves in-phase with the rock matrix and the other mode is that the fluid moves out of phase with the rock matrix for maximum fluid shear against the pore surface. For high viscosity, heavy crude oils, the in-phase mode is
prominent due to the viscous drag force exceeding the force required to accelerate the oil droplet. For low viscosity fluids such as water or gas, the out of phase mode is prominent. For solid tars or bitumen in the rock matrix, there is no second fluid compression wave mode.

On a core size rock sample, sonic stimulation can reduce surface tension between oil and the core matrix and reduce interfacial tension between oil and water with the overall effect seen as a change in wettability of the core (more water wet) and a reduction in residual oil. So, as the water or gas saturation increases in the rock matrix, the shear effect from sonic stimulation increases and helps emulsify the oil droplets in the displacing water phase, thus reducing residual oil saturation.

On a sand layer thickness scale, sonic stimulation can increase water injectivity by reducing scale damage and increasing relative permeability by reducing residual oil in the near wellbore volume. Sonic stimulation can also increase oil productivity by reducing fines damage around the producing well bore and mobilizing residual oil within the drainage radius. Heat generated from electrical losses and gas bubble compression will heat the oil in and near the well bore volume and reduce oil viscosity.

FIG. 1 is a cross-sectional view showing a sonic stimulation tool across from the formation. A Stonely or tube wave is generated in the well bore and is mode converted into a slow compression wave in the target oil formation. The well is an injection, production or sonic source well. For the high acoustic contrast case, shale bounds the oil sand or limestone layer.

As shown in FIG. 1 the acoustic energy produced from the sonic source can be contained in the target formation if the frequency band is chosen to resonate within the target formation or internally reflect off the bounding shale layers. For fluid coupled acoustic tools, the Stonely or tube wave generation with the target formation will improve the slow compression wave mode conversion or coupling. The fluid coupling between the sonic source and the target formation can be improved by increasing perforation density or size, hydraulically fracturing the formation, or completing in open hole with or without under reaming.

FIG. 2A is a graph of a raw cross well bore tomography image with common receiver plotted against depth and time. FIG. 2B is a graph of a single trace plotted against amplitude and time. To acquire accurate measurements of frequencies and velocities in the target formation and surrounding strata, cross well bore tomography is shot between wells in the section of the oil field of interest. FIGS. 2A and B show a common receiver gather for depths ranging from 4800 ft to 5300 ft and a single trace at 4932 ft. The three wave forms highlighted are the compression wave, the shear wave and the guided/tube wave. The fastest acoustic wave arrival is the compression wave that has a velocity of the rock matrix. The shear wave is the next arrival along with reflections from layer boundaries. The noise in the cross well bore image surrounding the compression and shear wave arrivals is generated from previous acoustic pulses and down hole equipment from other wells in the field.

The guided, slow compression and tube waves usually arrive at 2 to 4 time intervals after the shear wave arrival time. These sets of waves are coupled to the fluid in the pore space and have velocities equal to or slower than the fluid velocity. The sonic source is swept through the lower frequencies to find the guided wave modes in the formation. The best guided wave mode for residual oil production is where the acoustic energy traveling in the fluid is out of phase to the acoustic energy traveling in the rock matrix.

This out of phase movement between the rock and fluid creates a shear force on the boundary layer of fluid next to the pore surface. With acoustic strain rates exceeding 10-6 seconds, the shear force exceeds the surface tension or interfacial tension force between the oil and water. With the acoustic energy canceling the surface tension force, the oil droplet can move between pores based on the pressure gradient created by the production wells draining the reservoir.

FIG. 3 is a graph of an averaged Fourier Transform of all traces in a single layer. Noise (relative amplitudes below -25 db) has been removed for clarity. Note: compression wave center frequency is 1230 Hz, shear wave center frequency is 820 Hz and the guided/tube wave center frequency is 385 Hz. FIG. 3 shows the Fourier transform of a single arrival time trace averaged over all the traces for a single reservoir layer. The compression wave (P-Wave) arrivals show an amplitude peak at 1230 Hz, but there is significant acoustic energy that mode converted to a tube wave before it was recorded at the hydrophone in the receiving well. The shear wave (S-Wave) arrivals have a peak amplitude around 820 Hz. Reflected shear waves from other layers have altered their frequency band as they traveled across this layer.

The guided, slow compression and tube waves show an amplitude peak at 385 Hz. The frequencies above 600 Hz in the contour plot around the peak are probably other shear wave reflections while the frequencies below 100 Hz are probably Stoneley waves generated in the well bore of the receiving well. There is a low signal to noise ratio at these long record times due to multiple reflections in the reservoir and tube wave reflections in the well bore.

FIG. 4 is a graph of a typical attenuation curve shape for a single layer with a Q-factor of 28. Notice the negative attenuation for frequencies between 30 and 790 Hz where higher frequency acoustic energy is transformed to lower frequency energy. FIG. 4 shows the guided wave and slow compression wave attenuation curve for a layer with a Q-factor of 28. The negative values on the attenuation curve from 30 to 790 Hz show the layer is trapping higher frequency (1-3 kHz) acoustic energy and attenuating it into the lower frequency band. The two small dips at 80 Hz and 190 Hz show the first out of phase and first in-phase guide wave modes. The 80 Hz out of phase guided wave mode would be best for a production well because the acoustic pulse tends to pump fluid towards the source. The actual acoustic source should be swept from 70 to 90 Hz. The 190 Hz in-phase guided wave mode would be best for an injection well because the acoustic pulse tends to pump fluid away from the source. The actual source could be swept from 170 to 210 Hz.

FIG. 5 is a graph of a typical attenuation curve shape for a single layer with a Q-factor of 4.5. Notice the attenuation remains positive (acoustic energy leaking to bounding layers) and only approaches zero for a single frequency. FIG. 5 shows the guided wave and slow compression wave attenuation curve for a layer with a Q-factor of 4.5. This low Q-factor layer would represent a high permeability, high porosity sandstone bounded by a low-permeability siltstone in a transgressive or regressive marine strata sequence. Notice the slow compression wave resonance at 52 Hz and the ‘leaky’ guided wave resonance at 490 Hz. Stimulation of this reservoir would be more effective with multiple sources due to the leakage of acoustic energy into the bounding layers.
FIG. 6 is a graph of a Fourier Transform for a single trace of a guided slow compression wave or tube wave in a thick sand layer at a central frequency of 317 Hz. For thick sandstones bounded by thick shale layers, the guided wave frequency band is very sharp due to negative attenuation concentrating acoustic energy into the central guided wave frequency as shown in FIG. 6. The central guided wave frequency for this cross well bore tomography example is 317 Hz. There are a number of sharp troughs in the frequency curve from 80 Hz to 390 Hz and these troughs can be resolved with layer modeling of the cross well bore tomography data. The acoustic source should sweep between 300 to 340 Hz to stimulate the oil zone in FIG. 6.

FIG. 7 is a graph showing the effect of acoustic stimulation on oil recovery factor at water flood breakthrough on the highest permeability layer of an exemplary layered reservoir. As shown in FIG. 7, the increase in recovery factor of oil for high permeability layers is due to changes in relative permeability. Thick sandstone reservoirs that are intermediate or oil wet can greatly benefit from acoustic stimulation. The increase recovery factor of oil for low permeability zones is due to increase in absolute permeability of the zone. The vertical sweep in a water injection well would greatly benefit from acoustic stimulation because all the layers would have a more uniform injection profile. Another added benefit is that the scale build up in the well bore is continuously cleaned during sonic stimulation.

FIG. 8 is a graph showing recovery factors following core flooding, acoustic stimulation of water flood after breakthrough, and flooding with water and surfactant with acoustic stimulation in an exemplary Berea sandstone reservoir. FIG. 8, shows a typical water flood core test for an intermediate wet rock. The ultimate recovery factor for a water flood is about 59% at 10 pore volumes injected. At 99.8% water cut, the core was stimulated with an acoustic sweep of 100 to 120 Hz. The recovery factor increased to 71% at 99% water cut with 3 incremental pore volumes injected. Then, the water surface tension was reduced with a surfactant and flooded to 99% water cut and the recovery factor was increased to 81% for 6 incremental pore volumes injected. Core tests were repeated with 10 pore volumes injected for a water flood followed by surfactant only and the ultimate recovery was 69% at 16 total pore volumes injected. Intermediate core tests show that sonic stimulation increases recovery by an average of 11% of original oil in place over a typical water flood with 3 incremental pore volumes injected. Oil-wet core tests show that sonic stimulation increases recovery by an average of 25% of original oil in place over a typical water flood with 3 incremental pore volumes injected.

FIG. 9 is a graph of a Fourier Transform for a few traces of a guided slow compression wave or tube wave in a packet in a sand-shale layer sequence having three central frequencies of 409, 503, and 578 Hz. For sequences of thin sandstone, silstone, shale and/or limestone layers, there are multiple guided wave frequencies measured at the receiving well as shown in FIG. 9. Notice there are only three major troughs at 65 Hz, 270 Hz and 710 Hz which means a significant amount of acoustic energy is leaking from one layer to another and traveling to the receiver well. For the example in FIG. 9, the acoustic source will need to sweep from 350 to 600 Hz to cover the entire resonate frequency band. To overcome the acoustic energy loss to bounding layers, sonic stimulation sources can be installed in closer than normal proximity to each other.

FIG. 10 is a cross sectional view of a heavy oil production well with a sonic tool placed across the formation. Worm holes created from sand production are used to sustain oil production rates during the primary depletion phase of the reservoir. A Stonely or Tube wave is generated in the well bore to resonate in the formation and in the wormhole to help suspend the sand in the oil during production. Fluid filled worm holes help augment the fluid coupling between the well bore and the formation.

FIG. 10 shows a production well with a sonic source stimulating a heavy oil production zone. Large perforations and a progressive cavity pump are used to produce the heavy oil to the surface along with the entrained sand. The sand production creates worm holes in the formation which in turn provide channels to drain the heavy oil to the production well. Stonely waves generated in the well bore will create resonant tube waves in the worm holes. The resonant tube wave will fluidize the sand in the channel and keep the wormhole growing into the formation. The resonant tube wave will also reduce the heavy oil viscosity by a factor of 2 to 2.5 in the channel, thus reducing pressure loss around the near wellbore area.

FIG. 11 is an aerial view of a 9-spot pattern under water, steam, surfactant or carbon dioxide flood. The sonic source well can be an injector, producer, or dedicated source well. The guided wave source can stimulate multiple patterns depending on the attenuation in the oil formation.

FIG. 11 demonstrates a typical 9-spot water injection pattern using the water injector in the middle of the pattern as a sonic source well. However, a production, an injection or a dedicated well could all serve as sonic source wells. The source spacing will depend on the guided or slow compression wave attenuation in the oil reservoir determined from cross well bore tomography or calculation from sonic logs. The solid dots represent production wells while the open triangles represent water injection wells. To augment the oil recovery achieved with sonic stimulation, the surface tension of the water can be reduced by removing hardness or adding surfactant.

FIG. 12 is an aerial view of a natural water drive reservoir against a fault. The sonic source well is located between the oil-water contact and the fault. The sonic source well can be a water injection well, a production well or a dedicated source well.

FIG. 12 is an illustration of a field where a sonic stimulation pilot test was actually performed. This is a natural water drive field with layers dipping away from the fault and the fault itself splitting a gentle anticline. The oil accumulated at the top of the gentle anticline. The field was developed with the natural water drive and produced to 99% water cut or 1% oil cut. A sonic stimulation tool was installed in a production well and the oil cut increased from 1% to 8% in a producing well near the sonic source and farther away the oil cut increased to 4%. Wells more than 1200 ft away showed no increase in oil cut. The central frequency of the tool was 350 Hz based on cross well bore tomography analysis of the guided waves and the tool was swept between 300 and 400 Hz.

FIG. 13 is a graph of an average velocity ratio of first arrival shear wave versus first arrival slow compression wave of a zero offset cross well bore tomography image of a carbon dioxide flood. Notice the carbon dioxide has gravity segregated to the top of the oil reservoir creating a near top-down gravity drainage displacement. As the carbon dioxide satura-
tion increases, the slow compression wave velocity decreases which in turn decreases the resonant frequency of the formation.

FIG. 13 shows the effect of carbon dioxide on the slow compression wave velocity. As carbon dioxide swells the oil and makes a second liquid phase, the compressibility of the liquid increases and the viscosity of the liquid decreases. Both of the effects slow the compression wave velocity below the velocity of water in the reservoir. Sonic stimulation will increase gravity segregation between the carbon dioxide phase and the oil phase and enhance top-down carbon dioxide flooding in patterns with thick productive zones.

The many features and advantages of the invention are apparent from the detailed specification, and thus, it is intended by the appended claims to cover all such features and advantages of the invention which fall within the true spirit and scope of the invention. Further, since numerous modifications and variations will readily occur to those skilled in the art, it is not desired to limit the invention to the exact construction and operation illustrated and described, and accordingly, all suitable modifications and equivalents may be resorted to, falling within the scope of the invention.

What is claimed is:

1. A method of increasing oil recovery from an oil reservoir, the method comprising:
   - disposing an acoustic transmitter in a source well;
   - disposing an acoustic receiver in a producing well, wherein a portion of the oil reservoir is disposed between the source well and the producing well;
   - transmitting an acoustic signal from the acoustic transmitter at frequencies of 30 Hz and greater;
   - receiving the transmitted acoustic signal;
   - determining a resonant frequency of the portion of the oil reservoir based on attenuation of the transmitted signal; and
   - transmitting the acoustic signal from the acoustic transmitter at the determined resonant frequency to reduce a boundary layer effect between oil in the oil reservoir and a surface of a substrate in the oil reservoir and between the oil and a brine interface in the oil reservoir.

2. The method according to claim 1, further comprising:
   - conducting cross well bore tomography between the source well and the producing well to determine the resonant frequency.

3. The method according to claim 1, further comprising:
   - determining effective coverage and sweep efficiency of the acoustic signal by modulating the acoustic signal from about 100 Hz above the determined resonant frequency to about 100 Hz below the determined resonant frequency and monitoring an acoustic wavelet generated by the acoustic signal.

4. The method according to claim 1, wherein the acoustic signal is transmitted at a frequency band of about 80 Hz to about 120 Hz wide.

5. The method according to claim 1, further comprising:
   - injecting water into the source well.

6. The method according to claim 5, wherein the injected water includes a cationic surfactant.

7. The method according to claim 5, wherein the injected water includes an anionic surfactant.

8. The method according to claim 5, wherein the injected water includes a nonionic surfactant.

9. The method according to claim 1, further comprising:
   - re-measuring the resonant frequency of the oil reservoir and modifying the acoustic signal in response to changes in the resonant frequency of the oil reservoir due to saturation and reservoir pressure.

10. An apparatus for increasing oil recovery from an oil reservoir, the apparatus comprising:
    - an acoustic transmitter disposed in a source well, the acoustic transmitter being configured to transmit an acoustic signal at frequencies of 30 Hz and greater;
    - an acoustic receiver disposed in a producing well, wherein a portion of the oil reservoir is disposed between the source well and the producing well, the acoustic receiver being configured to receive the transmitted acoustic signal; and
    - means for determining a resonant frequency of the portion of the oil reservoir based on attenuation of the transmitted signal, wherein the acoustic transmitter being configured to transmit the acoustic signal at the determined resonant frequency to reduce a boundary layer effect between oil in the oil reservoir and a surface of a substrate in the oil reservoir and between the oil and a brine interface in the oil reservoir.

11. The apparatus according to claim 10, further comprising:
    - means for conducting cross well bore tomography between the source well and the producing well to determine the resonant frequency.

12. The apparatus according to claim 10, further comprising:
    - means for determining effective coverage and sweep efficiency of the acoustic signal by modulating the acoustic signal from about 100 Hz above the determined resonant frequency to about 100 Hz below the determined resonant frequency and monitoring an acoustic wavelet generated by the acoustic signal.

13. The apparatus according to claim 10, wherein the acoustic transmitter is configured to transmit the acoustic signal at a frequency band of about 80 Hz to about 120 Hz wide.

14. The apparatus according to claim 10, further comprising:
    - means for injecting water into the source well.

15. The apparatus according to claim 14, wherein the injected water includes a cationic surfactant.

16. The apparatus according to claim 14, wherein the injected water includes an anionic surfactant.

17. The apparatus according to claim 14, wherein the injected water includes a nonionic surfactant.

18. The apparatus according to claim 10, further comprising:
    - means for re-measuring the resonant frequency of the oil reservoir and modifying the acoustic signal in response to changes in the resonant frequency of the oil reservoir due to saturation and reservoir pressure; and
    - means for measuring saturation changes in the oil reservoir due to changes in the resonant frequency.