assembly and the receiver array to optimize system performance according to required application, and in particular the radial depth of investigation.

[0023] In accordance with an aspect of the invention, the system in paragraph 21 and 22 records data to be processed with imaging algorithms to generate 2D images of properties of the formation and other materials surrounding along the borehole axis for every azimuth direction similar to 2D reflection surface seismology. The system can further provide a scan of the 2D images for 360 degree azimuth direction. The set of scanned azimuth 2D images can subsequently stacked and/or processed with advanced imaging algorithms to provide a full 3D image of properties of the formation and other materials surrounding along the borehole axis.

[0024] The system may further include optimizing the processing algorithms and display of the resulting images such that the information that they contain about the properties around the well bore is readily evident to the user of the data.

[0025] In accordance with some aspects of the disclosure, wireline or pipe conveyed logging tool positionable within a well bore is disclosed. The tool includes (a) an ultrasonic transducer constructed and arranged to be placed in a borehole, the transducer configured to be excited by two simultaneous but not identical transient electrical signals of duration between 20-200 microseconds, with a first signal at a first frequency between 250 kHz and 1.5 MHz and a second signal at a second frequency between 300 kHz and 1.5 MHz, that produce first and second acoustic waves at the first frequency and the second frequency, respectively; (b) an acoustically nonlinear material having a length between ~~3 and 12 inches~~7 cm and 33 cm arranged along a transmission path of the transducer that allows nonlinear mixing of the two acoustic waves generated by the transducer to produce a transient acoustic beam of the same duration as the original excitation signals with a frequency corresponding to the difference in instantaneous frequencies between the first frequency and the second frequency, the acoustic beam having a frequency between 15 and 120 kHz.

[0026] The tool can be configured such that the electrical signals are encoded by introducing a time-varying component including one or more of frequency chirping or frequency sweeps to one or both of the signals. Moreover, the tool can be configured such that the acoustic beam has the frequency between 15 and 120 kHz. Further, the tool can be configured such that the tool is arranged to maintain a level of collimation of the acoustic beam that depends on a mixing length in the nonlinear material and produce the acoustic beam such that the

can then refracted by the second acoustic lens 1630 and directed outside the borehole 1605. The first and the second acoustic lens 1610 and 1630 can be a Fresnel lens made of Plexiglass or other suitable materials having a low sound attenuation and the appropriate acoustic impedance and that when appropriately shaped modifies the beam by either converging or diverging the beam depending on the particular arrangement of the lens.

[0089] The acoustic reflector or acoustic mirror 1625 and the second acoustic lens 1630 can be rotated about a longitudinal axis of the borehole 1605 to generate one or more circumferential images of the formations outside the borehole. Additionally, the inclination of the mirror with respect to the borehole axis can be controlled to alter the angle of incidence of the beam at the borehole wall.

[0090] The external dimensions of logging tools determine the range of hole sizes in which they can operate. A device with an operating frequency range of 20 to 120 kHz, using FC43 as the non-linear material, could be built with a diameter of about ~~four inches~~10 cm, making it usable in borehole diameters of ~~six inches~~15 cm and above. Larger devices generating more powerful collimated beams, and operating at lower frequencies could be used in larger diameter boreholes. A scaled down device operating at higher frequencies could be lowered through production tubing for service in completed wells.

[0091] Acoustic impedance contrasts due to local inhomogeneity, planar fractures etc. outside the borehole cause reflection or scattering of the acoustic beam, some of which will return to the borehole. In a cased hole, energy is reflected from the inner wall of the casing, the outer wall of the casing that may or may not be attached to cement, any voids in the cement, the cement or fluid interface to the formation, and any additional concentric casing strings. In an open hole application, energy is reflected from impedance boundaries due (for example) to drilling induced formation mechanical alteration, fluid invasion, natural fractures, nodules of secondary minerals and bed boundaries.

[0092] A system using the source device described above and receivers to detect scattering energy from outside the borehole for 3D borehole reflection seismology to create a 3D dimensional image of the earth surrounding the borehole is shown in Figures 19a, 19b and 20. The system comprises the acoustic source with rotatable mirrors, such as reflector 1625, and lenses, such as lenses 1610 and/or 1630, that are rotatable through one or more actuators/motors 1635 and which can be mounted within the logging tool and a receiver array 1640, which are mounted along the tool placed in the borehole to detect the reflection signal.

scattered sources along the beam path. Thus, the borehole imaging with a beam source may present a simplification and reduction in uncertainty of the final time image in contrast to conventional (not beam) sources which require an accurate detailed velocity model for computation of the 3D image. Furthermore, because the beam is focused and steerable, in azimuth and inclination with respect to the borehole, the imaging would tend to have higher resolution than obtained with a conventional (not beam) source. The method allows for detailed imaging of features including invaded zones, cement bonding with casing, damaged zones, fractured zones, stratigraphic layering particularly at high apparent dip (the angle between the plane of the bedding and the plane perpendicular to the tool axis). The broad band difference beam frequency for the invention ranges from 1 kHz to 100 kHz. The low end of this frequency range, also used by some conventional sonic logging tools, achieves a depth of penetration up to ~~one hundred feet~~30.5 meters. It is important to note that, because the beam is broadband and can be encoded, the signal to noise ratio of the detected signal may be considerably enhanced after processing and decoding. Because of the broadband beam characteristics with generally greater depth of penetration and higher signal to noise ratio due to encoding, the method also may allow for detailed imaging and/or characterization of nonlinear properties of rock formation and its fluid contents surrounding the borehole.

[0099] The various acoustic beam sources described in detail above can be used in many applications derived from imaging around the borehole. For example, the above-described acoustic beam sources can be used for various evaluation of natural fractures, mapping of vugs, nodules or other inhomogeneities, evaluation of the presence and properties of the cement sheath between one or more casing strings and the formation around a cased well, mapping fluid invasion from the borehole and assessment of the mechanical integrity of the formation around the wellbore, in particular any alteration caused by the near wellbore stress concentration. There are additional applications for the compact source in fields such as nondestructive testing.

[00100] The various configurations described in detail above are for the purposes of illustration only. Modifications to the configurations can be made for other applications without departing from the invention. For example, in the Logging While Drilling (LWD) and pipe conveyed configurations, using technology that allows the tool to pass through the bottom of the drill string, the compact acoustic beam generation device will enable efficient look ahead of the bit resulting in the detection of over-pressured zones or significant changes in the rheology of the formation before they are reached by the drill-bit. Steering of the beam