One aspect relates to a method of installing a transmission system in a hydrocarbon production well. The transmission system is operable for transmitting power and/or control signals down the well or for transmitting data signals back up the well. The well comprises a main well bore, a production tubing inside the main well bore and a branch off the production tubing. The branch comprises a side track tubing. The method includes: providing a sensor and/or load assembly in the branch; installing a first inductive coupler of an induced current transmission arrangement around the production tubing in the main well bore, and connecting the sensor/load assembly to the first inductive coupler via a communication link. Another aspect relates to a hydrocarbon production well installation.
SIGNAL AND POWER TRANSMISSION IN HYDROCARBON WELLS

Field of the Invention
The present invention relates to the transmission of power and signals in hydrocarbon wells, and more particularly, but not exclusively, to transmission in through-tubing radial branches.

Background
A variety of technologies have been developed for transmitting power and or signals (such as data signals from sensors or control signals for controlling devices) to/from deep underground in hydrocarbon production wells. One such technology involves the use of current transformers to induce a current onto the tubing and pick it up again from the tubing. An example of this technology is described in WO2007/004891. Current transformers (as referred to herein) essentially consist of a closed loop of inductive material enclosing the tubing.

Other technologies include using inductive coupling in the use of coupled loop antennas. As referred to hereafter, the term "inductive coupler" refers to any form of construction where a current or magnetic field is induced, and unless indicated otherwise includes current transformers as well as other types of inductive coupling devices. There have also been quite a few attempts at making down-hole wet mate cable connectors, both for electrical and optical connections, but generally so far the results are at best questionable.

Through Tubing Rotary Drilling (TTRD) has become established as a cost-effective method of increasing access to hydrocarbon reserves. Using existing wells in mature reservoirs, additional reserves are accessed through the existing well completion tubing by drilling new sidetracks branching off the existing production tubing. However, well branches such as TTRD branches present considerable problems, particularly for installing signal and power transmission systems. The cables in cable systems are especially vulnerable to damage. Also, the existing current transformer or inductive coupling technologies have a major problem if there is a short circuit between the inside of the tubing and the annulus fluid between the production tubing and the well bore along a long length of transmission. The annulus fluid could typically be a brine...
containing corrosion inhibitors, but could be diesel or other non-conductive and non-
corrosive fluid.

Accordingly, there is a need for an improved way of making a connection to an
induced-current (or similar) system for power and/or data signal transmissions in a well
branch, where the new completion is not brought back to the surface but is hung off in
the production tubing. The same principles may be used both for TTRD branches and
in many other well branch constructions.

Summary

According to a first aspect of the invention there is provided a method of installing a
transmission system in a hydrocarbon production well. The transmission system is
operable for transmitting power and/or control signals down the well or for transmitting
data signals back up the well. The well comprises a main well bore, a production tubing
inside the main well bore and a branch off the production tubing. The branch comprises
a side track tubing. The method includes: providing a sensor and/or load assembly in
the branch; installing a first inductive coupler of an induced current transmission
arrangement around the production tubing in the main well bore, and connecting the
sensor/load assembly to the first inductive coupler via a communication link.

In one embodiment, the communication link comprises a cable, and connecting the
cable between the sensor assembly and the first inductive coupling comprises joining
two sections of cable in a side pocket on the production tubing. The cable may be fed
from the sensor/load assembly to the side pocket inside the side track tubing.
Alternatively, the cable may be fed from the sensor/load assembly to the side pocket
outside the side track tubing.

In another embodiment, the communication link comprises an induced current signal
transmission arrangement and the method further comprises installing a second
inductive coupler of the signal transmission arrangement around the side track tubing
in the branch. The first inductive coupler may be installed in the main well bore at a
position selected to minimise any current induced in the production tubing when an
alternating current is applied to the first inductive coupler. The method may further
comprise connecting a cable between the first inductive coupler and a node at a
location higher up the main well bore for relaying data signals and/or for supplying power and/or control signals. Alternatively, the method may further comprise installing an induced current signal transmission arrangement for relaying data signals from the first inductive coupler to a node at a location higher up the well and/or for supplying power and/or control signals to the first inductive coupler.

The method may further comprise installing a third inductive coupler around the production tubing in the main well bore such that the branch exits the production tubing between the first and third inductive coils. The method may also further comprise providing a second sensor and/or load assembly in the main well bore below the branch to provide sensor data signals to and/or receive power and/or control signals from the third inductive coil.

One or more of the inductive couplers may have an impedance matched to that of another coupler to optimise power and/or signal transfer.

The method may further comprise providing electrical insulation to at least a portion of the production tubing and/or the side track tubing for reducing losses due to parasitic conductance from the tubing.

According to a second aspect of the present invention there is provided a hydrocarbon production well installation comprising: a main well bore; a production tubing inside the main well bore; and a branch off the production tubing, the branch comprising a side track tubing. A sensor and/or load assembly in the branch provides sensor data signals and/or receives power and/or receives control signals. A communication link relays the sensor data signals to and/or power/control signals from a first inductive coupler of an induced current transmission arrangement, the first inductive coupler being disposed around the production tubing in the main well bore.

The branch may be a TTRD branch wherein the side track tubing extends from inside the production tubing into the TTRD branch.

The communication link may comprise a cable. The cable may extend from the sensor assembly to a side pocket on the production tubing.
Alternatively, the communication link may comprise a second inductive coupler of the signal transmission arrangement, the second inductive coupler being disposed around the side track tubing. Preferably the first inductive coupler is disposed in the main well bore at a position selected to minimise any current induced in the production tubing when an alternating current is applied to the first inductive coupler. The first inductive coupler may comprise a coil around the sidetrack tubing and inside the production tubing. The communication link may further comprise an induced current signal transmission arrangement in the TTRD branch between the sensor/load assembly and the second inductive coupler. The installation may further comprise an electrical signal conditioning device disposed in the TTRD branch between the sensor/load assembly and the second inductive coupler.

The installation may further comprise a cable connected to the first inductive coupler for relaying data signals to a node at a location higher up the well and/or for supplying power and/or control signals.

Alternatively, the installation may further comprise an induced current signal transmission arrangement for relaying data signals from the first inductive coupler to a node at a location higher up the well and/or for supplying power and/or control signals to the first inductive coupler. The induced current signal transmission arrangement may comprise a third inductive coupler, the first and third inductive couplers being implemented as one device.

The induced current signal transmission arrangement in the main well bore may further comprise a third inductive coupler disposed around the production tubing, wherein the TTRD branch exits the production tubing between the first and third inductive coils. The installation may further comprise a second sensor and/or load assembly disposed in the main well bore providing sensor data signals to and/or receiving power and/or control signals from the third inductive coil. The production tubing between the first and third inductive coils may comprise an electrical insulation material or coating. An electrical connection may be provided between the insulated section of the production tubing and a side stack tubing of the TTRD branch via slips or other mechanical contacts.

The first/second/third inductive couplers may be current transformers.
One or more of the inductive couplers may have an impedance matched to that of another coupler to optimise power and/or signal transfer.

At least a portion of the production tubing and/or the side track tubing may comprise electrical insulation for reducing losses due to parasitic conductance from the tubing. The insulation may comprise one or more of: a coating on the tubing; a non-conductive annulus fluid; non-conducting tubing centralizers; in-cemented sections of tubing comprising cement or other curing substances, such as polymers, with low electrical conductivity; and parts of the tubing formed of a material having a low electrical conductivity.

Brief description of the Drawings

Figure 1 illustrates an embodiment of a connection for transmitting power and/or signals to/from a location in a well branch.

Figure 2 illustrates an alternative to the embodiment shown in Figure 1 of a connection for transmitting power and/or signals to/from a location in a well branch.

Figure 3 illustrates another embodiment of a connection for transmitting power and/or signals to/from a location in a well branch.

Figure 4 illustrates an alternative to the embodiment shown in Figure 3 of a connection for transmitting power and/or signals to/from a location in a well branch.

Figure 5 illustrates an embodiment of a connection for transmitting power and/or signals to/from a location in a well below a branch.

Figure 6 illustrates an embodiment of a connection for transmitting power and/or signals to/from a location in a well branch as well as transmitting power and/or signals to/from a location in the well below the branch.

Figure 7 illustrates another embodiment of a connection for transmitting power and/or signals to/from a location in a well branch.

The embodiments show four principle ways that an induced current arrangement can be used for transmitting power and/or signals in a well having a TTRD branch. Referring to figure 1, a hydrocarbon production well 10 has a main well bore 12. Well bore 12 would typically be a bore drilled through a "formation" - i.e. layers of rock, sand, clay or combinations of these as might occur either in a well drilled or land or sub-sea under the sea bed. In many wells the bore is lined with a casing or liner, but in
some wells the bore is left un-lined. Inside the well bore 12 is a production liner or tubing 14. An annular space 16 separates the production tubing 14 from the formation around the well bore 12. The annular space 16 may be filled with cement, which both fixes the tubing 14 in place and, at least where the formation is hydrocarbon-bearing, is porous to act as a filter for hydrocarbons that are extracted from the well. Alternatively, in other parts of the well, the tubing may be surrounded by an annulus fluid such as a heavy completion fluid like the brine containing corrosion inhibitors referred to above. The annulus fluid could also comprise hydrocarbon fluids, which could be the diesel referred to above or a production fluid or a low density fluid, typically dry gas used to help lifting the well fluids.

A TTRD branch 18 comprises tubing that branches off the production tubing 14 to form a sidetrack assembly through the formation. The sidetrack assembly includes side track tubing 20 inside the branch 18 and surrounded by an annular space 22. Depending on the production requirements the annular space 22 may also be filled with cement. The side track tubing 20 is of smaller diameter than the production tubing 14 in the main well bore 12. The side track tubing 20 has a top open end 24, and extends into the branch 18 as shown. The top open end 24 is held concentrically in position by hangers, which in this case are in the form of packers 26, but could also be permeable constructions in the production tubing 14. The side track might typically extend for a large distance (e.g. many kilometres).

A sensor/load assembly 28 is located on the side track tubing 20 in the branch 18. This might comprise sensors such as pressure gauges, or powered devices such as actuators for moving components situated in the branch/sidetrack. The sensor/load assembly 28 therefore requires a power supply as well as a communication link for receiving control signals controlling the powered devices and sending sensor data back to the surface or, in principle, to any upper node position higher in the well. In this embodiment power is delivered from an upper node position and data signals transmitted back to the same or another upper node position using an induced current/current transformer system, one end of which is shown in the form of an inductive coupler 30. The inductive coupler 30 is energised by a magnetic field or current induced in the production tubing 14 in a known manner (as described, for example, in WO2007/004891). The connection from the inductive coupler 30 to the sensor/load in the branch 18 is provided from via a first cable 32 from the inductive coupler 30 to a side pocket 34 on the outside of the production tubing 14 and in the
annular space 16. A cable connector is located in the side pocket 34, which connects the first cable 32 to a second cable 38 that is fed through the wall of the production tubing 14 to inside the side track tubing 20.

Figure 2 shows a similar arrangement to Figure 1, where equivalent features have the same reference numerals, with features that have modified locations indicated with a "prime" marker '. In this case the inductive coupler 30' and the side pocket 34' are located on the production tubing 14 below the top end 24 of the side track tubing 20, and the cable 38' is fed through to the sensor/load assembly 28 in the sidetrack outside the side track tubing 20.

As shown in Figures 1 and 2, the cable 38, 38” is connected directly to the sensor/load 28. However, particularly where the side track extends for a long distance from the main well bore, the cable could be connected to a further inductive coupler for relaying the power/signals along the side track by a further induced current/current transformer arrangement.

The arrangement shown in Figure 1 has the advantage that the cable is protected inside the tubing during the installation or 'running in' in the well. Assembly of the connection in the side pocket can be done with a tool in a separate operation after the TTRD branch completion is in place. Alternatively, the complete assembly of the sensor/load assembly 28, connection 36 and cable 38 could be retrofitted in the well using a wire-line. The arrangement shown in Figure 2 is more compatible with normal cabled completions, with the cable clamped to the outside of the side track tubing 20. However, in this case the connection in the side pocket 34” would have to be made when the side track tubing 20 is landed (i.e. prior to installation). Also, having the cable 38” on the outside of the tubing 20 makes it less protected and more susceptible to damage while running in.

The connection 36, 36” in the side pocket 34 could be any regular wet mate connector, or it could be a dedicated inductive coupler.

As shown in Figures 1 and 2, the production tubing 14 up to the inductive couplers 30, 30” is insulated with an outer layer or coating of insulation 40. This is provided to reduce losses due to parasitic conductance. This is particularly important for the
transmission of power to reduce losses, although not so important for data signals
transmission where the signal content can usually be regenerated even if more than
99% of the current strength is lost. Although shown in the form of a coating, the
electrical insulation of the tubing can be achieved in a variety of ways, examples of
which include:

- a coating on the tubing
- a non conductive annulus fluid (and non conducting centralizers)
- in-cemented sections of tubing using cement or other curing substances
  (e.g. polymers) with low electrical conductivity
- introducing parts in the tubing, for example near the branch exit window or
  other critical locations, having a low electrical conductivity (e.g. ceramic
  parts or coatings).

In some cases, where the production tubing is encased in cement (as described
above), the cement itself may have sufficient insulating properties to keep power losses
to an acceptable level.

Figure 3 illustrates another embodiment illustrating a second of the principle ways that
an induced current arrangement can be used for transmitting power and/or signals in a
well having a TTRD branch. Again equivalent features to those shown in Figure 1 have
the same reference numerals. In this embodiment the relaying of power/signals into
the TTRD branch is by way of an induced current/current transformer arrangement. A
first inductive coupler or current transformer 42 is located in the main well, while a
second inductive coupler or current transformer 44 is located around the side track
tubing 20 in the branch. The first inductive coupler 42 is preinstalled on the production
tubing 14, but preferably without any metal core in which to induce a current. This first
inductive coupler 42 is located between the open end 24 of the side track tubing 20 in
the main well and the exit position of the TTRD branch. The second inductive coupler
44 has a connection 46 to the sensor/load assembly 28. After installation of the TTRD
branch completion, a current can be induced on the side track tubing 20 at the first
inductive coupler 42 for transmitting power to the side track, while a current signal
induced in the side track tubing at the second inductive coupler 44 will be picked up at
the first inductive coupler 42. The first inductive coupler 42 has a connection, which in
this embodiment is shown in the form of a cable 48, for power/signal transmission
from/to the upper node location (which might be at or near the surface).
The first inductive coupler 42 is shown positioned around both the production tubing 14 and the side track tubing 20, which is inside the production tubing 14. However, to avoid unacceptably high power loss the position of first inductive coupler 42 is selected to minimise any current induced in the production tubing 14 below the hanger/packer 26. For example, the first inductive coupler 42 may comprise coils and/or a magnetic core that are wrapped around the side track tubing 20 in the annular space between the side track tubing 20 and the production tubing 14. As long as the coils of the first inductive coupler 42 are on the inside of the production tubing 14 no (or very limited) current will be induced in the production tubing (although some of the return current may flow in the production tubing if this is the path of the least resistance). Note, however, that the packer 26 acts as the grounding for the current induced in the first inductive coupler 42. Hence there needs to be current flow in some parts of the tubing 14, but ideally this can be confined to a region close to the packer 26. For short distances losses from the tubing may be acceptable, but to minimise losses over longer distances the longitudinal current going down the well from the inductive coupler 42 needs to be minimised by some means. One possibility is to eliminate conductive material in the tubing 14 within the inductive coupler 42, for example by having a length of the tubing 14 formed of a non-conductive material. Alternatively the conductive path in the tubing 14 could be broken by adding a non conducting pup joint just below the inductive coupler 42.

In Figure 3, the side track tubing 20 between the first and second inductive couplers 42, 44 is shown insulated with an outer layer or coating of insulation 50. Any suitable means for insulating the tubing may be used, including those described above in relation to Figures 1 and 2. This insulation is provided to reduce losses due to parasitic conductance, which may be significantly higher at the TTRD branch location where the side track tubing 20 passes through the TTRD branch junction.

Figure 4 illustrates an alternative arrangement to that of Figure 3, in which the power/signal transmission above the first inductive coupler 42 is provided by an additional induced current/current transformer arrangement. Again equivalent features to those shown in Figures 1 to 3 have the same reference numerals. In this case a third inductive coupler 52 is located on the production tubing 14 just above, and with a connection (not shown) to the first inductive coupler 42. The outside of the production tubing 14 above the third inductive coupler 52 has insulation 54. The third inductive
coupler 52 is at the bottom end of an upper conductive loop which needs to be
grounded to the formation while the power going to the branch is split off and
transferred to the first inductive coupler 42. The first and third inductive couplers 42
and 52 could be implemented as one device. Provided the circular tangential
component of the magnetic field can be transferred from outside of the production
tubing 14 to the inside and the electrical current is allowed to flow in the original
production tubing. For example, this might be achieved using a section of non-
magnetic metal tubing on top a magnetic inner core with electrical insulation in-

Figure 5 illustrates an embodiment of a connection for transmitting power and/or
signals to/from a location in a well below a branch. Again equivalent features to those
shown in Figure 1 have the same reference numerals. An induced current/current
transformer arrangement is used to bridge the region of the main well where the TTRD
branch occurs. This means that transmission of power/signals to/from the lower part of
the main well bore can be established, or maintained if previously established. As
shown in Figure 5, an upper inductive coupler 60 is located around the production
tubing 14 just above the location where the TTRD branch 18 is taken off the production
tubing 14. A lower inductive coupler 62 is located below the TTRD branch 18. A
communication link 64 is provided for transmitting power/signals between the surface
and the upper inductive coupler 60. This could, for example, be a cable or other
transmission means of choice.

Thus power/signals can be transmitted to/from the main well bore below the TTRD
branch by inducing a current in the production tubing at the upper or lower inductive
coupler on one side of the TTRD branch and picking up the induced current at the
other inductive coupler.

In order for this to work, the contact resistance between the exit window and the casing
(or the formation) should be of the same order of magnitude as the electrical resistance
of the production tubing between the upper and lower inductive couplers 60, 62.
Although in an idealised situation there would be no physical contact, and so a very
high contact resistance, in reality it is almost impossible to avoid some contact. It is
also possible to utilize the frequency in the reactive part of the impedance to reduce
losses at the exit point relative to the energy transfer to the lower inductive coupler.
Particularly with the transmission of power, this will generally only be at one frequency, and so the frequency can be tuned for optimum transfer of power between the two inductive couplers 60, 62. Both the resistive parts of the impedances and the reactive part of the leakage impedance, if significant, need also to be considered as well as the source impedance for power matching.

The induced current will be divided between the transmission to the next inductive coupler and losses to the formation in proportion to the conductance of each path. As stated above for signal transmission large losses can be tolerated, but not for power transmission. However, the distance between the upper and lower inductive couplers 60, 62 is relatively short and the conductance in the production tubing 14 between the couplers will be relatively high (compared with typical lengths of production tubing in well bores that can extend for kilometres). To control the resistance metal to metal contact between production tubing 14 and the well bore casing (which is very effectively coupled to the formation/ground) should be avoided. One way to control this is to coat the production tubing with an insulation material (as indicated by insulation 66 in Figure 5) between the upper and lower couplers at locations where it might contact the casing. Other, additional or alternative methods include use of centralizers, polishing the exit window, lining the exit window with a non conductive material and cementing the tubing in place with a cement having a modest electrical conductivity.

Figure 6 illustrates an embodiment of a connection for transmitting power and/or signals to/from a location in a well branch as well as transmitting power and/or signals to/from a location in the well below the branch (as in Figure 5). Equivalent features to those shown in Figures 1 and 5 have the same reference numerals. The arrangement is similar to that shown in Figure 5, except that an upper inductive coupler 70 is located above the open end 24 of the side track tubing 20 to induce current in the production tubing 14. A second inductive coupler 72 is located below the TTRD branch 18 (as with the inductive coupler 62 of Figure 5). A further inductive coupler 74 is located on the side track tubing 20 in the branch 18. Conductive contacts 76 provide a conductive bridge between the production tubing 14 in the main well bore and the side track tubing 20 inside the production tubing. These contacts 76 may be "slips" or other contacts that maintain electrical connection and may be mounted in the packers 26. The slips in a normal packer or hanger assembly will normally achieve this, having metal teeth that are expanded into the original tubing.
For power transmission down the well, the current path from the upper inductive coupler 70 will be divided between the production tubing 14 in the main well bore where it will be picked up by the lower inductive coupler 72, and the side track tubing 20 where it will be picked up by the further inductive coupler 74 in the branch 18. To minimise parasitic losses it is preferable for the further inductive coupler 74 to be located as close to the junction between the main well bore and the TTRD branch as possible. To reduce losses, as well as insulation 78 being provided on the production tubing 14 between the upper and lower inductive couplers 70, 72, a layer or coating of insulation 80 is provided on the side track tubing 20 at least as far as the further inductive coupler 74. As previously explained, in some cases the insulation provided by cement or a fluid in the annular spaces 16, 22 may be sufficient.

Figure 7 illustrates another embodiment for transmitting power and/or signals to/from a location in a well branch. Equivalent features to those shown in Figures 1 to 6 have the same reference numerals. In this case a sensor/load assembly 82 is at a location some considerable distance away from the TTRD branch junction with main well. The power/signals are transmitted via two induced current/current transformer sections. An upper section 84 is provided for transmission through the TTRD branch 18, while a lower section 86 is provided along the side track tubing 20 in the branch. The upper section has an upper inductive coupler 88 in the main well bore and a lower inductive coupler 90 on the side track tubing 20 in the branch. This upper section is essentially similar to the embodiment of Figure 3. The lower section has an upper inductive coupler 92 and a lower inductive coupler 94, both of which are located on the side track tubing 20. The lower inductive coupler 94 is connected to the sensor/load assembly 82. A connection is made between the lower inductive coupler 90 of the upper section 84 and the upper inductive coupler 92 of the lower section 86, further details of which are described below.

Thus power is transmitted down the well to the sensor/load assembly 82 via the upper section 84 (as described above for the embodiment of Figure 3) and then via the lower section 86 by inducing a current in the side track tubing 20 at the upper inductive coupler 92, and picking this up at the lower inductive coupler 94.
Although any suitable form of connection may be used to connect between the lower inductive coupler 90 of the upper section 84 and the upper inductive coupler 92 of the lower section 86, Figure 7 illustrates a short length of cable 96 fed through a packer in the annular space 22 surrounding the side track tubing 20. Also shown is an optional electronic signal conditioning unit 98 disposed between the two sections. This may include, for example, a transformer and/or a frequency converter. Frequency conversion can be used to manipulate the reactive impedance matching for the separate sections independently.

The embodiments described above incorporate many of the advantages in using the induced current/current transformer technology to extend the transmission capabilities into a well branch. This can be done with a reduced need for accurate positioning of the branch exit window (for example relative to a cable connection). This allows greater flexibility in positioning the branch exits and not requiring the same precision in landing the TTRD branch completion.
CLAIMS:

1. A method of installing a transmission system in a hydrocarbon production well, wherein the transmission system is operable for transmitting power and/or control signals down the well or for transmitting data signals back up the well, and wherein the well comprises a main well bore, a production tubing inside the main well bore and a branch of the production tubing, the branch comprising a side track tubing, the method comprising:
   providing a sensor and/or load assembly in the branch,
   installing a first inductive coupler of an induced current transmission arrangement around the production tubing in the main well bore, and
   connecting the sensor/load assembly to the first inductive coupler via a communication link.

2. The method of claim 1 wherein the communication link comprises a cable, and connecting the cable between the sensor assembly and the first inductive coupling comprises joining two sections of cable in a side pocket on the production tubing.

3. The method of claim 2 wherein the cable is fed from the sensor/load assembly to the side pocket inside the side track tubing.

4. The method of claim 2 wherein the cable is fed from the sensor/load assembly to the side pocket outside the side track tubing.

5. The method of claim 1 wherein the communication link comprises an induced current signal transmission arrangement and the method further comprises installing a second inductive coupler of the signal transmission arrangement around the side track tubing in the branch.

6. The method of claim 5 wherein the first inductive coupler is installed in the main well bore at a position selected to minimise any current induced in the production tubing when an alternating current is applied to the first inductive coupler.
7. The method of claim 5 or claim 6, further comprising connecting a cable between the first inductive coupler and a node at a location higher up the main well bore for relaying data signals and/or for supplying power and/or control signals.

8. The method of claim 5 or claim 6, further comprising installing an induced current signal transmission arrangement for relaying data signals from the first inductive coupler to a node at a location higher up the well and/or for supplying power and/or control signals to the first inductive coupler.

9. The method of any preceding claim further comprising installing a third inductive coupler around the production tubing in the main well bore such that the branch exits the production tubing between the first and third inductive coils.

10. The method of claim 9 further comprising providing a second sensor and/or load assembly in the main well bore below the branch to provide sensor data signals to and/or receive power and/or control signals from the third inductive coil.

11. The method of any preceding claim wherein one or more of the inductive couplers has an impedance matched to that of another coupler to optimise power and/or signal transfer.

12. The method of any preceding claim further comprising providing electrical insulation to at least a portion of the production tubing and/or the side track tubing for reducing losses due to parasitic conductance from the tubing.

13. A hydrocarbon production well installation comprising:
    a main well bore;
    a production tubing inside the main well bore;
    a branch off the production tubing, the branch comprising a side track tubing;
    a sensor and/or load assembly in the branch providing sensor data signals and/or receiving power and/or receiving control signals, and
    a communication link relaying the sensor data signals to and/or power/control signals from a first inductive coupler of an induced current transmission arrangement, the first inductive coupler disposed around the production tubing in the main well bore.
14. The installation of claim 13, wherein the branch is a through-tube rotary drilled, TTRD, branch wherein the side track tubing extends from inside the production tubing into the TTRD branch.

15. The installation of claim 13 or claim 14 wherein the communication link comprises a cable.

16. The installation of claim 15 wherein the cable extends from the sensor assembly to a side pocket on the production tubing.

17. The installation of claim 13 or claim 14 wherein the communication link comprises a second inductive coupler of the signal transmission arrangement, the second inductive coupler being disposed around the side track tubing.

18. The installation of claim 17 wherein the first inductive coupler is disposed in the main well bore at a position selected to minimise any current induced in the production tubing when an alternating current is applied to the first inductive coupler.

19. The installation of claim 18 wherein the first inductive coupler comprises a coil around the sidetrack tubing and inside the production tubing.

20. The installation of claim 18 or claim 19 wherein the communication link further comprises an induced current signal transmission arrangement in the TTRD branch between the sensor/load assembly and the second inductive coupler.

21. The installation of claim 20 further comprising an electrical signal conditioning device disposed in the TTRD branch between the sensor/load assembly and the second inductive coupler.

22. The installation of any of claims 17 to 21, further comprising a cable connected to the first inductive coupler for relaying data signals to a node at a location higher up the well and/or for supplying power and/or control signals.

23. The installation of any of claims 17 to 21, further comprising an induced current signal transmission arrangement for relaying data signals from the first inductive
coupler to a node at a location higher up the well and/or for supplying power and/or control signals to the first inductive coupler.

24. The installation of claim 23 wherein the induced current signal transmission arrangement for relaying data signals and/or for supplying power and/or control signals from/to the first inductive coupler comprises a third inductive coupler, the first and third inductive couplers being implemented as one device.

25. The installation of any of claims 13 to 24 wherein the induced current signal transmission arrangement in the main well bore further comprises a third inductive coupler disposed around the production tubing, wherein the TTRD branch exits the production tubing between the first and third inductive coils.

26. The installation of claim 25 further comprising a second sensor and/or load assembly disposed in the main well bore providing sensor data signals to and/or receiving power and/or control signals from the third inductive coil.

27. The installation of claim 25 or claim 26 wherein the production tubing between the first and third inductive coils comprises an electrical insulation material or coating.

28. The installation of claim 27 wherein an electrical connection is provided between the insulated section of the production tubing and a side stack tubing of the TTRD branch via slips or other mechanical contacts.

29. The installation of any of claims 13 to 28 wherein the first/second/third inductive coupler is a current transformer.

30. The installation of any of claims 13 to 29 wherein one or more of the inductive couplers has an impedance matched to that of another coupler to optimise power and/or signal transfer.

31. The installation of any of claims 13 to 30 wherein at least a portion of the production tubing and/or the side track tubing comprises electrical insulation for reducing losses due to parasitic conductance from the tubing.
The installation of claim 31 wherein the insulation comprises one or more of:

- a coating on the tubing;
- a non-conductive annulus fluid;
- non-conducting tubing centralizers;
- in-cemented sections of tubing comprising cement or other curing substances, such as polymers, with low electrical conductivity; and
- parts of the tubing formed of a material having a low electrical conductivity.
### A. CLASSIFICATION OF SUBJECT MATTER

INV. E21B47/12 G01V3/00 E21B17/00 E21B41/00

ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

### B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

E21B G01V

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

### C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
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<td>EP 0 964 134 A2 (SCHLUMBERGER TECHNOLOGY BV [NL]; SCHLUMBERGER SERVICES PETROL [FR]; SC) 15 December 1999 (1999-12-15) paragraph [0048] - paragraph [0053]; figures 8,9</td>
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Date of the actual completion of the international search: 19 September 2011

Date of mailing of the international search report: 30/09/2011

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