VERY HIGH-SPEED DRILL STRING COMMUNICATIONS NETWORK

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TOPICAL REPORT

Testing at Rocky Mountain Oilfield Testing Center, Casper, WY
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ABSTRACT

Testing of a high-speed digital data transmission system for drill pipe in a 4500 ft well at the Rocky Mountain Oilfield Testing Center in Casper, Wyoming is described. Passive transmission of digital data through a series of four segments of telemetry drill pipe of approximately 1000 ft each has been successfully achieved. Data rates of 2 Mbit/sec have been tested through the 4500 ft system with very low occurrence of data errors.

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GRANT DE-FC26-01NT41229

BACKGROUND

The present work relates to the development of a high data rate communications system for the down-hole drilling environment. Applications for the communications system include asset characterization and optimization, wellbore stability monitoring, and real time assessment and control of the drilling process.

During 3-10 February of 2003, Novatek and drill pipe manufacturer Grant Prideco participated in a field test of a prototype telemetry transmission drill pipe system (IntelliPipe®) in a previously drilled 6000 ft well. This testing took place at the Rocky Mountain Oilfield Testing Center (RMOTC) located at Naval Petroleum Reserve No. 3 near Casper, Wyoming. This test was the first test to deploy over 1000 ft of IntelliPipe® in a single well, and is the first known test of a high-speed downhole drilling network.

Figure 1. Naval Petroleum Reserve No. 3 (Teapot Dome) near Casper WY.

Over 4300 ft of prototype 5-7/8 drill pipe was delivered to the test site, including normal weight and heavy weight drill pipe (HWDP).

TEST OBJECTIVES

The objectives of the testing at RMOTC were to:

a) Demonstrate the functionality of a simple high data rate downhole network, including a downhole data source and at least three IntelliLink™ subs. The downhole data source and the IntelliLinks™ should be accessible from the surface by commands sent through the network.

b) Demonstrate passive data transmission of a downhole digital signal over at least a 1000-ft interval from the data source sub to the surface. At minimum, the 1000 ft goal should be accomplished at a transmission speed of 1 Mbit/sec and an acceptable bit error rate for future modem installations. Most preferably, a transmission speed of over the 1000 ft passive data interval is 2 Mbit/sec. Additional emphasis may be placed to also accomplish a >1,000 ft goal at either transmission speed.

c) Demonstrate the system's durability by drilling at least 1,000 ft of new 8-3/4" hole size. Receive uninterrupted data transmission throughout the drilling phase. Further demonstrate the durability of the system through performing other operations such as reaming to bottom and rotating off bottom. Demonstrate data transmission capability with and without mudflow during these operations.

EXPERIMENTAL

Test site selection and preparation. The present test was designed to verify operation of a high speed drilling network in an intermediate depth well. Previously, all developmental testing of the high data rate communications system had taken place in relatively shallow wells: a 1,000 ft cased well in Provo, UT and a 1,600 ft well in Catoosa, OK. Since the tested device includes the drill pipe itself, proper design verification required a well wherein a substantial amount of pipe could be deployed. Well 61-2-TPX-15 at RMOTC offered a cased section with nominal 9" ID casing to 3050 ft and an open borehole of at least 8-1/2" diameter to 6000 ft. This well was deemed suitable for the 7" diameter tool joints of the XT57 drill pipe size used in the test, based on fishing requirements. A second alternative, where a new grass roots 10-3/4" well would be drilled was considered but rejected based on costs.

The largest onsite rig (DOE #2) was selected for the test. This rig was able to provide pull back capacity for no more than approximately 4500 ft of the 5-7/8 drill pipe used in the IntelliPipe® product (safety factors applied). This depth was judged to be sufficient to satisfy the objectives of the test.

In order to provide for objective c) above, it was determined to set a 300 ft cement kick-off plug in well 61-2-TPX-15 from approximately 3300 to 3600 ft. This plug was constructed of high compressive strength cement to increase the likelihood of a successful kick-off into the surrounding formation. Two other plugs were set at the same time for well abandonment. An advance team from Grant Prideco visited the test site prior to the testing to assist in these preparations.

Figure 2. DOE #2 Rig

Drill string design. Several drill string design options were considered, with a primary goal of achieving a successful kick-off into new formation. A bottom hole assembly (BHA) was chosen that provided increased flexibility of the drill string directly above the bit.

Standard 6-3/4 rental drill collars were used in the string. Drillstring hydraulics was modeled using commercially available software. None of the drill collars were wired for data transmission; however ten joints of XT57 heavyweight drill pipe were provided with wiring. The first available data link was therefore placed between the last drill collar and the first IntelliHeavyweight™ joint. Since DOE rig 2 is a kelly rig, a new product, a wired kelly (IntelliKelly™) was manufactured.

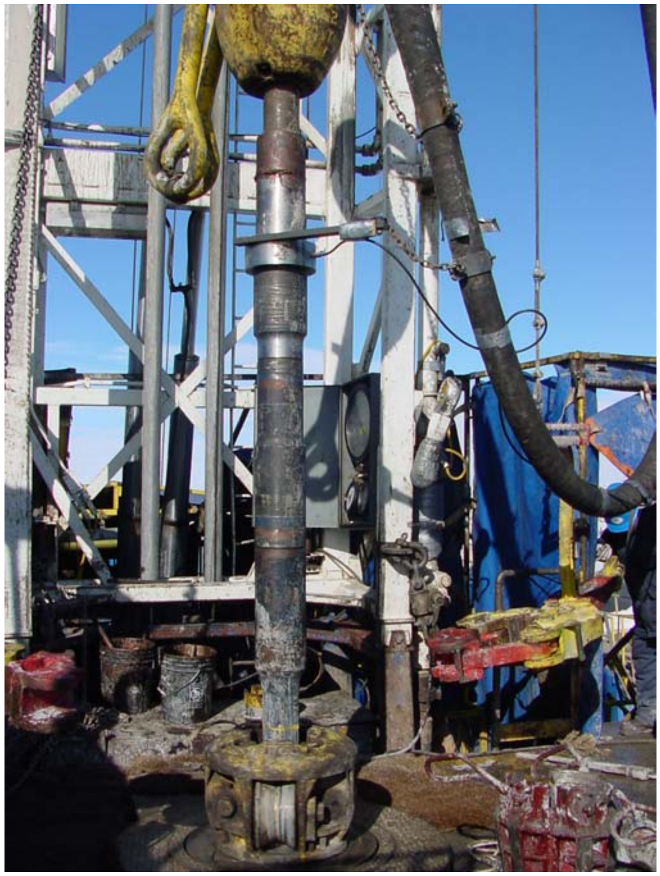

Figure 3. IntelliKelly™ and Data Link slip ring assembly

Setup of top-hole data transmission system. Above the kelly, a data swivel assembly was used to transmit data from the rotating drill string to the stationary world. A laptop computer was used for a user interface with the server and data storage.

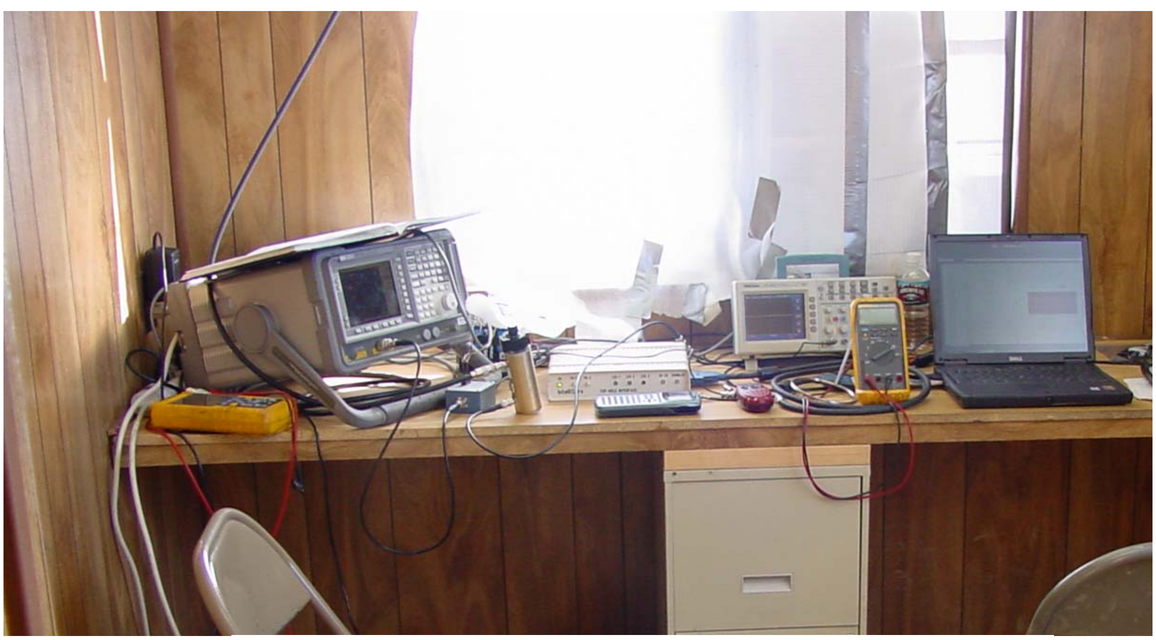

Figure 4. Top-hole Data Server and Test Equipment

Overall test procedure. The testing proceeded as follows. The BHA was tripped in the well followed by a crossover sub IntelliLink™. The IntelliLink™ was then polled continuously for live digital information (battery voltage and temperature) and diagnostics were compiled regarding any digital errors detected by the system.

Following this initial system characterization, a joint of Intelli-Heavyweight™ was added to the system, and the IntelliLink™ was polled again. Following this, the remaining nine joints of Intelli-Heavyweight™ were added to the string. Next, the wired drill pipe or IntelliPipe® was run into the well. The system was polled for live digital information as above at several points in the tripping-in process. This process continued until enough pipe was tripped in the well to tag the first cement plug (approximately 3300 ft), at which point kickoff was attempted and drilling proceeded. As the open hole section of the well was reached (>3050 ft), the kelly was picked up as needed for establishing circulation, reaming, or drilling new formation. Whenever the kelly was made up to the string, data was taken through the IntelliKelly™ and Data Swivel assembly.

Pipe handling procedures. Special pipe handling procedures were required because the DOE #2 rig was not equipped with the same handling equipment that is typical to offshore and larger onshore rigs, where this pipe is typically run. The principal procedures included use of a standard XT57 stabbing guide, engaging the threads by hand for 3 full rotations to ensure proper thread start, and use of a cat line to straighten pipe alignment as needed during spin-up. Best-O-Life brand premium blend Copper grease was applied to all connections, per manufacturer's instructions.

In addition to these procedures, the temperatures encountered during the test (often sub-zero degrees F) required warming up (and at times de-icing) threads prior to making up. The high viscosity of the chosen grease at the temperatures encountered made it extremely difficult to remove thread protectors from the pipes on the rig floor and furthermore left some question as to whether the make-up torque was properly achieved. To avoid these concerns, the joints were warmed by filling the rig's mouse hole with warm water prior to insertion of the joint into the mouse hole.

RESULTS & DISCUSSION

Summary of overall system test results. A drill string comprising 121 joints of IntelliPipe®, Intelli-Links™, and IntelliHeavyweight™ (3827 ft) was successfully run in the well, and was able to establish communication along the entire string for the duration of the testing. A data rate of 2 Mbit/second was established through the system for all tests. Total string length including the BHA was 4531 ft. In this string, five IntelliLinks™ were used as network nodes and data collection sites. Each network node (IntelliLink™) was able to respond to commands sent from the top-hole data server unit, and return live temperature, battery voltage, and drillstring vibration data upon request. Two-way communication was established along the drill string while flowing, rotating, drilling, reaming, tripping in and out of the well, and while hanging in the slips.

General handling of IntelliPipe®. In terms of handling, the IntelliPipe® joints did not behave any differently than standard XT57 drill pipe. Certainly, this size of pipe stretched the capacity of the DOE #2 drill rig – for example, the tongs used were much heavier than those typically used on the rig, due to the higher torque requirement for the XT57 connection. This required modification to the counterweights on the rig. Modifications to the kelly/swivel assembly, namely, the additional wiring required by the system, were out of the way and did not affect rig floor operations.

The implications of cold weather testing conditions were not understood and planned for prior to the test. Special handling procedures developed during the testing to compensate for thread dope viscosity issues mentioned above can be eliminated by selection of lower temperature grease blends. Future testing in cold climates will require simple changes to eliminate the need for special cold weather handling procedures.

Ruggedness of IntelliPipe®. The IntelliPipe® joints used in the testing were subjected to varied drilling conditions including drilling approximately 400 ft, reaming approximately 600 ft, tripping and racking, and typical rig handling (use and abuse). The maximum recorded standpipe pressure was 1200 psi. Rig abuse included occasional high impact striking of the pin nose, which contains the IntelliPipe® electrical coupling, on the primary shoulder of its mating pipe. In addition to this, the system was subjected to at least 3 firings of the jar while tripping in the well. Under all of these conditions, the electronics modules and wired drill pipes appear to have survived undamaged.

CONCLUSIONS

In accordance with the objectives of the test, a simple high data rate downhole network, including a downhole data source and four IntelliLink™ subs has been functionally demonstrated in a 4500 ft well. Specific conclusions derived from this test include the following:

1) Passive data transmission of live digital data is demonstrable over a 1000 ft interval with the present version of the network. A transmission speed of 2 Mbit/sec is possible over this interval at low bit error rate. This data may be transmitted while drilling with standpipe pressures of 1200 psi and rotary speeds up to 80 rpm. Passive transmission distance may be improved substantially by improved electronics modules.

2) The IntelliPipe® transmission line and IntelliLink™ electronics modules have successfully withstood anticipated loadings as well as unanticipated loadings that include multiple jar firings and subzero temperatures. Further and more extensive robustness testing is desirable.

Though the objective to drill 1000 ft of new formation was not achieved, approximately 400 ft of cement plug and new formation was drilled. Another approximate 600 ft of the well was reamed, which offered additional robustness testing.

REFERENCES

None.