Comparison of Current Wireless Downhole Telemetry

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The following article looks at the three primary wireless communication methods in downhole oil and gas applications. It gives a brief overview of each, and discusses their pros and cons in the context of appropriate applications. The article does not go into detail regarding the science and technology behind each method, rather focusing on their key challenges and opportunities.

Completions are becoming ever more complex, and there is a growing need to both monitor and control production at the reservoir interface. As such, the current widespread use of control line systems has been placed under scrutiny, highlighting significant operational cost and risk. Control line based systems require additional operation time as well as increasing the number of pressure feedthroughs in the system. For example, a typical hydraulic valve system has three lines, plus an additional line per extra device, once above a single node. Control line systems also rely on surface infrastructure to provide either hydraulic or electrical power.

Devices can be categorised in two states, 'Gauge' (P,T etc.) and 'Control' (ICV, Sleeve etc.). Downhole Gauges are a mature product and have many 1000s of installations. These provide a high data rate and have lifetimes from 5years up to 15years and beyond. The main barriers to adoption are the long control lines, the inherent cost, and impact on other completion equipment.

Downhole control valves are typically hydraulic actuated, although several electric systems have emerged in recent years. These are un-intelligent devices, in that they are essentially actuators, remote from the topside control and intelligence. Wireless devices can also be used to operate autonomously, making value-based decisions on measured reservoir parameters.

In a move away from these traditional systems, the use of wireless technology is growing. Wireless systems remove the feedthrough pressure barrier risk as well as allowing devices to be placed where control lines cannot. i.e. in complex multi-lateral junctions or exceptional distances below surface. They can also be installed after the completion as a retrofit system, to either gain data from un-monitored wells, or to replace existing failed equipment.

The following examines and compares three key varieties of these wireless systems.

Acoustic

Acoustic telemetry is probably the most mature and widely used in downhole environments. To date, devices are able to deliver pressure and temperature data to the surface, with a high data rate of up to 1 point per second. Acoustic telemetry is typically deployed using the tubing string as the main communication conduit, with a receiver at the wellhead.

One of the main disadvantages of acoustic is the need for regular repeaters as the transmission distance is limited.

As with all wireless technology, battery consumption and longevity due to temperature discharge is a key factor. Acoustic systems trade-off between power consumption and transmission distance. The typical distance between repeaters is 500m/1500ft.

Recent developments have seen the addition of downhole control to the acoustic area. This technology is not yet mature, and while valuable, it currently suffers from the same power versus distance issues. Thus far, acoustic gauges have typically been used for shorter term applications e.g. wide use in Drill Stem Testing applications, but some case studies have shown up to 6years operation at moderate temperatures. However, acoustic systems do require a surface setup to receive and transmit data, which can be a barrier to adoption.

EM/RF

Electromagnetic or Radio Frequency style communication is the most widely used wireless communication method, from the WiFi we use in daily life, to the rise of the Internet of Things (IoT). Utilised in downhole applications this technology provides very high data rates and wide bandwidths, making it highly suitable for digital oilfield operation. However, the signal is readily attenuated within downhole fluids, especially at high data rates.

At low data rates the length of transmission does increase, but as with acoustic systems, not to a sufficient enough length to eliminate the need for repeaters. EM/RF is also very power hungry, the trade-off between power and distance remains a factor. Thus, the technology is best suited to short hop, device to device communication, where short bursts of high rate data are needed. EM also has the key disadvantage that signal strength, and therefore transmission distance, significantly drop off as water in the formation increases. As with acoustic systems, EM/RF also requires a surface setup to receive and transmit the data, again acting as a barrier to adoption.

Pressure/Flow

A number of emerging technologies rely on the fluid column in the well to be the transmission conduit. By affecting the normally steady state of the flow, these changes can be intelligently decoded. So far two primary methods have been commercialised and observed in use. One method operates by creating a specified pressure change at the surface, repeating at set intervals to trigger a downhole action, such as valve or latch movement. This first method facilitates one way communication only, aimed at instructing downhole devices, and is best suited to short-term operations. Ultimately it removes the need for an additional intervention run to adjust a downhole device.

The second method uses a series of pulses to communicate. Being semi-duplex, in that communication can be either surface to device or device to surface, this method allows both Gauge and Control functionality. The system intelligently measures the gaps between pulses and decodes the signal to access the data or instruction being delivered. The size and duration of the pulse are irrelevant to the data accuracy, and this allows for changes in well performance to occur without compromising communication. The downhole device achieves this by using built-in intelligence to modify the pulses created, ensuring good signal quality.

As with other wireless options, both pressure and flow methods rely on battery powered systems, and a trade-off between data frequency and longevity exists. However, no repeaters are needed, allowing a single device to communicate to surface however far that distance is. Furthermore, pressure and flow systems do not require any additional surface equipment. They intuitively use the existing wellhead choke to create pressure changes at the surface, and the existing well head pressure sensor to monitor pulses from downhole.

Conclusion

As has been shown above, the various communication methods all have a place and purpose, each well suited to particular applications. The common issues in all systems is the current state of battery technology, however as this develops the increase in wireless device longevity will lead to greater market uptake. At this time however, fully intelligent devices can be made to operate autonomously, removing the need to transmit data to surface for a decision, and thus significantly reducing the power required. For example, a downhole valve may detect a surface shut in and close or choke back to prevent cross flow, or could be programmed to choke a zone to prevent hydrate production.

The following table summarises the key points:

Method	Data Rate	Requires Tubing	Length between repeaters/ transmission length	Lifetime at 100C (at max data rate)	Primary Advantage	Primary Disadvantage	Secondary Disadvantage	Typical Application
Acoustic	High	Yes	500-1500m	1-2yr	High Data Rate	Repeaters	Surface Equipment	Well Tests
EM/RF	High	No	Varies due to water content information	1-2yr	High Data Rate	Repeaters	Surface Equipment	Well Tests
Pressure /Flow	Low	No	No repeaters/ no limits	5+yr	No repeaters, longevity	Data Rate	-	Permanent monitoring and control