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Optimal Antenna Configurations for Digital Oilfield Implementations

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Abstract. Antennas play a very pivotal role in the development and advancement of digital oil fields. They provide the last mile communication link to the field locations and thus must be properly sized to ensure the link availability and reliability. There are different types of antennas currently being deployed with each having different impacts on the communication link performance. This paper discusses typical antenna configurations for implementing last mile communications to the field in digital oilfield applications. It analyzes the characteristic of each configuration, the impact these different configurations have on data security, deployment speed and communication range and presents an optimal configuration that improves data security, deployment speed and communication range.

Introduction

Digital oil field technology is a combination of IT and automation & instrumentation technologies, as an improvement of the existing technologies in the oil & gas industry. This integrated operations technology makes the analysis faster and easier with software involved in efficient data management, provides more realistic image of the reservoir and the availability of resources, helps to optimize process required for production, and renders much safer operations with the inclusion of remote surveillance and collaborated environments. Digital oil field technology includes segments of IT such as outsourcing, software services, and equipment based expenditure. Automation & instrumentation is another segment of digital oil field market, which includes key networking processes and communication technologies such as SCADA, PLC, smart well, safety systems, and wireless systems. [1]

Digital Oilfield deployments entail the use of real time data collection instruments including sensors, process automation and control devices to acquire process and production data from the field location (reservoir and wellheads) and the transmission of these data to the office domain where data integration, mining and visualization activities are performed and business/ operational decisions are taken to optimize the production process[2][3][4].This technology has led to an increase in field performances, a reduction in CAPEX and OPEX and an improvement in reservoir management [6].

The deployments utilize wired and wireless sensors connected to Remote Terminal Units which collate the data from the field and transmits these data wirelessly to a central processing station [7]. Antennas play a very pivotal role in this communication networks as they provide the last mile communication link to the field locations and thus must be properly sized to ensure the link availability and reliability. There are different types of antennas currently being deployed with each having different impacts on the communication link performance. The most popular antenna currently being used by manufacturers for the wireless sensors and RTUs are the Omni directional antennas [7] and this is due to the ease of installation and resistance to the problems of a loss of alignment.

Implementation of wireless technology offers many advantages over wired, some of these include: low installation cost, mobility, remote location coverage, rapid installation, etc. However, each technology has certain challenges. The key challenges with wireless transmission range from

interference, low capacity, low quality of service and increased security vulnerability with the security vulnerability being the most critical. Wireless networks are usually more vulnerable to various security threats as the unguided transmission medium is more susceptible to security attacks than those of the guided transmission medium. Wireless technologies operating in unlicensed frequency spectrum are more susceptible to interference/noise effects while the wireless technologies with licensed spectrum has less interference, but they are costly due to the licensing requirements. [8].
Typical attacks experienced by wireless networks range from denial of service, attacks on information in transit, eavesdropping attack etc. The popular encryption-decryption techniques for protecting transmitted data devised for the traditional wired networks are not feasible to be applied directly for the wireless networks and in particular for wireless sensor networks. This is because applying the security mechanisms such as encryption could also increase delay, jitter and packet loss in wireless sensor networks [9] [10].

Several strategies have been developed to secure wireless transmissions with the most popular approach being the use of frequency hopping. A dynamic combination of the parameters like hopping set (available frequencies for hopping), dwell time (time interval per hop) and hopping pattern (the sequence in which the frequencies from the available hopping set is used) could be used with a little expense of memory, processing and energy resources. Important points in achieving this security feature includes the efficient design of the hopping scheme so that the hopping sequence is modified in less time than is required to discover it and also for both the sender and receiver to maintain a synchronized clock [9][11]

Digital Oilfield Communication Link Requirements
Communication links are very critical systems in Digital oilfields. These links must be designed to be 100% available regardless of the external environmental conditions. The must be available all through the life of the field to ensure that production date is streamed continuously from the field locations to the gateway. A typical digital oilfield communication architecture is shown in Figure 1

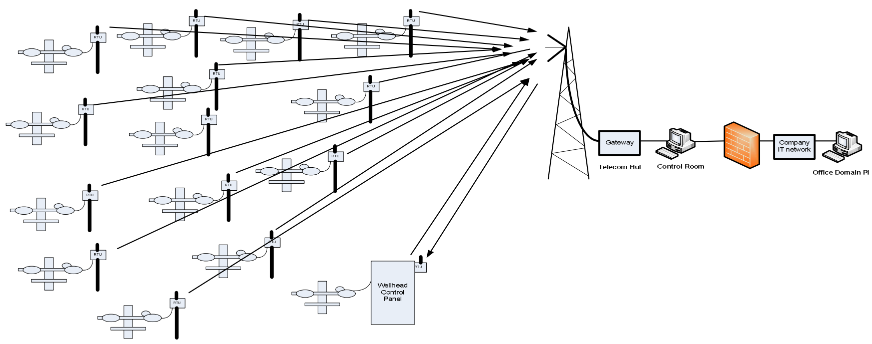

Figure 1: Typical Digital Oilfield communication architecture.

From Figure 1, the data from the wellheads are all transmitted to the field control room and integrated to the company IT network. The focus of this work is on the link between the wellhead and the gateway in the field control room. The requirements for the communication links for digital oilfield implementation comprises of the following

1. Data reliability
2. Data security
3. Very low latency
4. High resistance to interference from other transmitters
5. High resistance to vandalization
6. Communication reliability regardless of vegetation height since the installation should last for as long as the well is producing

Antenna Types (and the radiation patterns)

Antennas can be classified either as Omni directional in which case the radiate or receive transmission from all directions around the antenna while the directional antennas receive or transmit energy in one direction. Other types of antenna classes have been developed to maximize the use of these antennas leading to smart antennas, beam forming antennas etc.The most popular antenna types available for deployment of digital oilfields include

(i) Omni directional antennas
(ii) Yagi antenna
(iii) Parabolic dish antenna

Key parameters for consideration in the selection of antennas include the following: [12]

(i) The radiation pattern of antenna*:* This is a representation (pictorial or mathematical) of the distribution of the power out-flowing (radiated) from the antenna (in the case of transmitting antenna), or inflowing (received) to the antenna (in the case of receiving antenna) as a function of directional angles from the antenna.
(ii) The radiation intensity, directivity and gain are measures of the ability of an antenna to concentrate power in a particular direction.

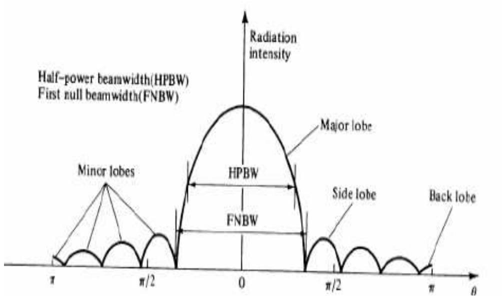

Figure 2 Antenna lobes and Radiation intensity

Figure 2 shows the antenna lobes and radiation intensity distribution. It consists of the major lobe, the side lobe. The direction of transmission is in the direction of the major lobe.
Typical beam width specifications for the antennas are shown in Table 1.

Table 1. Typical Antenna beamwidth

Antenna Type	Horizontal Beam width	Vertical Beam width
Omni	360°	7° to 80°
Patch/Panel	30° to 180°	6° to 90°
Yagi	30° to 78°	14° to 64°
Parabolic Dish	4° to 25°	4° to 21°

From Table 1, the Omni antenna radiates or receives transmission from all locations around the antenna while the parabolic dish antenna has the narrowest beam spread.

Typical Installation Configurations for Wellhead to FLB Communication Links

Option 1: High gain high directivity antenna: This configuration utilizes a high gain/highly directional antenna at the wellhead location. This antenna requires a mast and has the ability of a long range of transmission. The diagram is shown in figure 3.

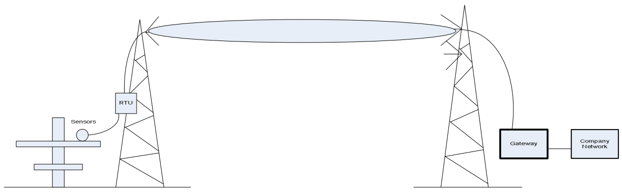

Figure 3: Communication link with high gain/ high directivity antenna

The features of this architecture are listed below.

1. Very Precise Installation.
2. Longer distance coverage possible.
3. More prone to signal loss due to miss alignment due to wind or other factors.
4. Antennas are more expensive.
5. Tower required in the event of tall vegetation between the wellhead and the Field Logistics Base (FLB).
6. More secure as the transmission is point to point and radiation is directed at the intended antenna.
7. Can only be used for point to point transmission.
8. More detailed installation design required.
9. Antenna installation has to be very firm so as not to shift in the event of wind or other factors.
10. Best suited for installation at wellheads located very far away from the FLB where range is of high priority.

Option 2: Directional Antenna: This configuration utilizes a parabolic dish antenna at the wellhead location. This antenna requires a mast and has the ability of a long range of transmission. The diagram is shown in figure 4.

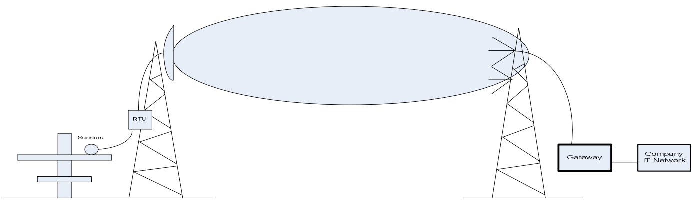

Figure 4: Communication link with directional/ parabolic dish antenna

The features of this architecture include

1. Requirement of precise installation
2. Long distance
3. Prone to signal loss due to antenna misalignment from the effect of wind or other factors
4. Antennas expensive
5. Tower required in the event of tall vegetation between the wellhead and the FLB
6. More secure as the transmission is point to point and radiation is directed at the intended antenna
7. Can only be used for point to point transmission
8. Best suited for installation at wellheads located very far away from the FLB (distance is of high priority

Option 3: Omni directional Antenna: This configuration utilizes an Omni antenna at the well head location. This antenna requires a shorter mast and has the ability of a shorter range of transmission. The diagram is shown in figure 5.

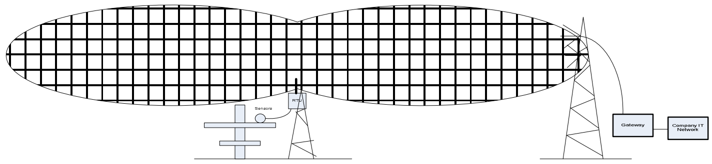

Figure 5: Communication link with Omni directional antenna at the wellhead

The features of this architecture include the following.

1. Installation does not require a high level of precision
2. Covers a shorter distance due to lower gain of Omni antenna
3. Not prone to signal loss due to antenna misalignment from the effect of wind or other factors
4. Antennas are least expensive
5. Antenna can be installed at wellhead level with a high possibility of transmission overcoming the effect of vegetation between the wellhead and the FLB
6. Transmission is least secure if the antenna is used at the Wellhead as the signal will be transmitted to areas around the wellhead which may not be the desired destination of the transmission
7. The Omni antenna is best suited for installation at the FLB so that multiple wellheads can send data to the FLB
8. It is best for multi-point to point transmission (Wide area coverage)

Observations and Discussions

Antennas required for setting up communication links in digital oilfield applications are required to be able to withstand the effect of weather and sustain the data transmission regardless of the environmental conditions without losing alignment. The links are to have sufficient fade margins built into the link budget to ensure signal fidelity all year round.

Table 2: Selection Matrix

Priority	Parameter	Directional	Parabolic	Omni	comments
1	Security of transmission	Highest	Higher	High	The Directional antenna configuration has the highest security because its signals are beamed in the direction of the intended receiver
2	Range	Highest	Higher	High	The Directional antenna configuration has the highest range because its signals are beamed in the direction of the intended receiver
3	Resistance to loss of Alignment	High	Higher	Highest	The Omni Directional antenna configuration has the highest resistance to loss of alignment due to the nature of the physical construction of the antenna
4	Installation Ease	High	Higher	Highest	The Omni Directional antenna configuration has the easiest installation as it can be screwed on as is implemented by most of the manufacturers [Y]
5	Installation data requirement	High	Highest	Highest	The Omni antenna requires only the antenna height while the directional and the parabolic antennas require the height and the Azimuth and Elevation angles

The critical nature of Oil and gas installations requires that the transmissions are secure and able to resist unauthorized access.

From the matrix in Table 1, the security of the data and the network is of the highest priority and as such the directional antenna configuration is the most suitable. The susceptibility to loss of alignment due to the effect of strong winds and the complexity of installation can be mitigated by the use of secure mounting kits and suitable installation kits.

Conclusion

The typical antenna configuration utilized in digital oilfield implementations is determined by the specifics of the field and this can be determined by a network plan. The use of Omni directional antenna provides the easiest deployment approach but has the greatest security vulnerabilities. It also has the lowest gain and as such has the shortest range thus it will require higher transmit power output to achieve the same range as the other antenna types The directional antenna requires a mast at the wellhead and has a higher resistance to interference, and security vulnerabilities. It has higher directivity and also requires the smallest amount of transmit power. The security of the data and the network is of the highest priority and as such the directional antenna configuration is the most suitable. The susceptibility to loss of alignment due to the effect of strong winds and the complexity of installation can be mitigated by the use of secure mounting kits and suitable installation kits. A reduction in transmit power, proper antenna selection and radiation pattern and frequency hopping will ultimately improve the transmission performance and security in digital oilfield implementations.

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