SCADA Uses Radio to Bridge the Gap

Bill Greeves

The concept of radio telemetry is bringing about cost and efficiency benefits in the water supply industry – enabling effective monitoring and communications from a wide variety of points and increasing the capabilities of SCADA and DCS.

Essentially, radio telemetry is a means of communication without the existence of a physical connection between the transmitter and the receiver. It can, for example, be used as a replacement for a physical link where difficult terrain or natural obstacles militate against such a link, or where the transmitting or receiving end is in motion and the attachment of a physical link is impossible.

Radio telemetry is ideal for industries such as water supply and treatment, where multi-locational sites requiring a sophisticated communications network are commonplace. Radio's high integrity and the possibility to incorporate shutdown systems provide an ideal solution, and it is relatively cost-effective when compared with other physical links.

Although ideally a radio link should be "transparent" – that is to say, act as if it were not present and impose no constraints on the data speed or content – this is rarely possible owing to the physical problems encountered and the specifications under which these systems must work. The main limiting factor in the use of radio telemetry is distance – and the distance to be covered defines the type of radio telemetry system applied and the frequency used.

The Behaviour of Radio

Radio waves are electromagnetic waves consisting of an electric field and a magnetic field at right angles which will propagate in a vacuum. All electromagnetic waves travel at almost three million metres per second; their frequency and wavelength are inter-related and represented by $V = F \times W$, where F = the frequency, W = the wavelength and V = the speed of light (3×10^8 metres/second). All that distinguishes one type of wave from another is the frequency. As the frequency changes, so do the properties and behaviour of the wave and, due to the range of frequencies in the electromagnetic spectrum, there are large differences in this behaviour – it can, to a large extent, be defined by the way in which electromagnetic radiation interacts with solid matter. The differences in the way that radiation of various frequencies penetrates or reflects at the surfaces of different materials is an example.

The two important allocations for low-power radio telemetry are at 173MHz (VHF) and 458MHz (UHF), corresponding to the wavelengths of 1.70 and 0.66 metres respectively. These unlicensed bands were allocated in 1987 following DTI deregulation. Radio telemetry using the VHF band, at 1mW (or 10mW with licence) effective radiated power (ERP), is applicable to about 1 kilometre and in line-of-sight conditions. The UHF band, at up to 500mW of power ERP, will cover distances of about 10-15 kilometres, dependent on the terrain.

The two bands are far enough away from each other to exhibit some differences in behaviour. In general, the lower the frequency, the less the wave will attenuate or weaken when travelling over ground. This effect is even more pronounced when travelling through foliage with the lower frequency wave attenuating much more slowly with distance.

Reflection and refraction also affect the behaviour of radio waves when transmitting above 500 metres;

Bristol Babcock's Spacenet 3000 control and command station with Enterprise workstation and products from Bristol Babcock's Network 3000 process control range

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Bristol Babcock's Spacenet 3000 control and command station with Enterprise workstation and products from Bristol Babcock's Network 3000 process control range reflection occurs from solid objects such as buildings, and refraction can occur over hill tops, for example. It is unusual for only one wave to be received from a transmitter: usually there is a direct wave and a number of others arriving slightly later after having been reflected (this is known as multipath transmission). A pronounced form of this effect takes place over water, for example, between two hills or across a lake. The effect is to produce a dead zone where there is phase cancellation between the incoming signals. If the various waves arriving at the antenna are more or less equal in amplitude then summation or subtraction can occur. Moving an antenna only a small distance at these frequencies can shift it from a null to a peak, i.e. from a position where arriving waves cancel to one where they add. Owing to the shorter wavelength, this effect is more pronounced at UHF than at VHF, and the nulls and peaks are much closer to each other.

High power radio telemetry at distances greater than 20 or so kilometres can also be affected by atmospheric fading and the effect of earth curvature.

Frequency Modulation

A plane radio wave carries no information – all that it can indicate is its presence or otherwise. With low power telemetry, frequency modulation (FM) is used to impress information onto the "carrier" radio wave. The frequency of the carrier is varied in proportion to the amplitude of the data. At the receiver end, the original signal is detected or "demodulated".

All data transmitted in radio telemetry is digital – all analogue inputs are converted into a digital form before transmission. Therefore the process of modulation is used to impress two states on the carrier. With FM, the modulated carrier will be moved (deviated) between two frequencies, each corresponding to a logic state.

Transmitting and Receiving

All radio waves have a specific frequency and wavelength, and most antenna designs and dimensions for UHF and VHF depend entirely on the wavelength at which the antenna – either omni-directional or directional – is to operate. The antenna building blocks consist of "elements" which are quarter- and half-wave long and are dimensioned to be resonant at the frequency in use. (A resonant antenna literally "rings" at the frequency for which it has been made.) Where an omni-directional antenna is required – such as a base station with a number of "slave" stations around it – a single vertical element could be used or a vertical co-linear. The "slave" stations, which only need to communicate with the base, would use directional antennas.

At resonance, the antenna will present a predictable impedance at its feed point, an important factor on the transfer of energy in either direction. This "input impedance" is not measurable by normal instruments as it only exists at the design frequency of the antenna. Any connection made, must, therefore, be at the same resistance level.

Where very short ranges are required, small plug-in-antennae can be mounted directly on the case of transmitters or receivers. The connection of transmitters or receivers to antennae is via a coaxial feeder cable designed to its "characteristic impedance", and where such a cable is connected to an antenna of the same impedance, there will be maximum power on transmission and maximum sensitivity on reception (for example, a 50 ohms antenna and a 50 ohms cable).

Generally speaking, for the best possible results, antennae should be mounted as high as possible and with as clear a field of view in the direction which it is pointed as is practical. Raising antenna height can produce an improvement in signal strength out of all proportion to the amount of increase in height. It should also be remembered that the beam widths of antennae used are quite wide – for example, a metal tower well off to one side of a transmission path may create a potent secondary path signal. The possibility of this effect will be increased with omni-directional antennae.

Radio Equipment

Radio equipment for low power radio telemetry in the UK has to meet specifications developed under DTI auspices. Transmission on the two prescribed low power bands does not require a licence.

MPT 1328, the specification covering the VHF band from 173.200MHz to 173.350MHz, allows for five channels of 25kHz or 11 channels of 12.5kHz. 173.225MHz is reserved for alarm purposes and should not be used for telemetry. The transmit output power is limited to 1mW, but in special circumstances this may be raised to 10mW if a licence is obtained. This band enables low power radio telemetry up to 1 km line of sight, and is generally used in plant monitoring.

MPT 1329 is the specification covering the UHF band from 458.500 to 458.800MHz affording 11 channels at 25kHz or 23 channels at 12.5kHz. The maximum transmit power is 500mW, giving a considerable increase in range – up to 10-15km.

High power radio telemetry is achievable under the MPT 1411 specification, covering the frequency range 457.5 to 458.5 and 463.0 to 464.0MHz, although licences always have to be obtained for these frequencies and are issued on a site-by-site basis with a power limit decided by the DTI.

Radio telemetry applications in countries other than the UK are subject to the regulations pertaining to each individual country.

Low Power Radio Telemetry in Process Control Applications

Radio telemetry interfaces with process control systems such as supervisory control and data acquisition (SCADA) and distributed control systems (DCS), and can greatly increase their power and efficiency. Its benefits over physical links include higher integrity and incorruptibility (a radio link cannot be dug up or drilled through, for example), ease of set-up and operation and greater cost-effectiveness.

Each location within a radio telemetry system will be given its own "identity" and be identified by a unique number. In process control terms, the simplest radio telemetry system is a "one-way" system, where a group of outstations are equipped with radio transmitters. At random intervals, each will transmit its data to a master station equipped only with a receiver. Each data package consists of the information to be transmitted plus the identity of the outstation. The possibility of transmission clash, i.e. where two or more outstations transmit at the same time, can be avoided by making the intervals between each transmitter's transmissions different. In practical terms, no more than about eight outstations should be included in a one-way system.

More commonplace are two-way systems, where individual outstations are "polled" in turn by the master station. The master station will issue a request which contains the identity of the station to be interrogated and only

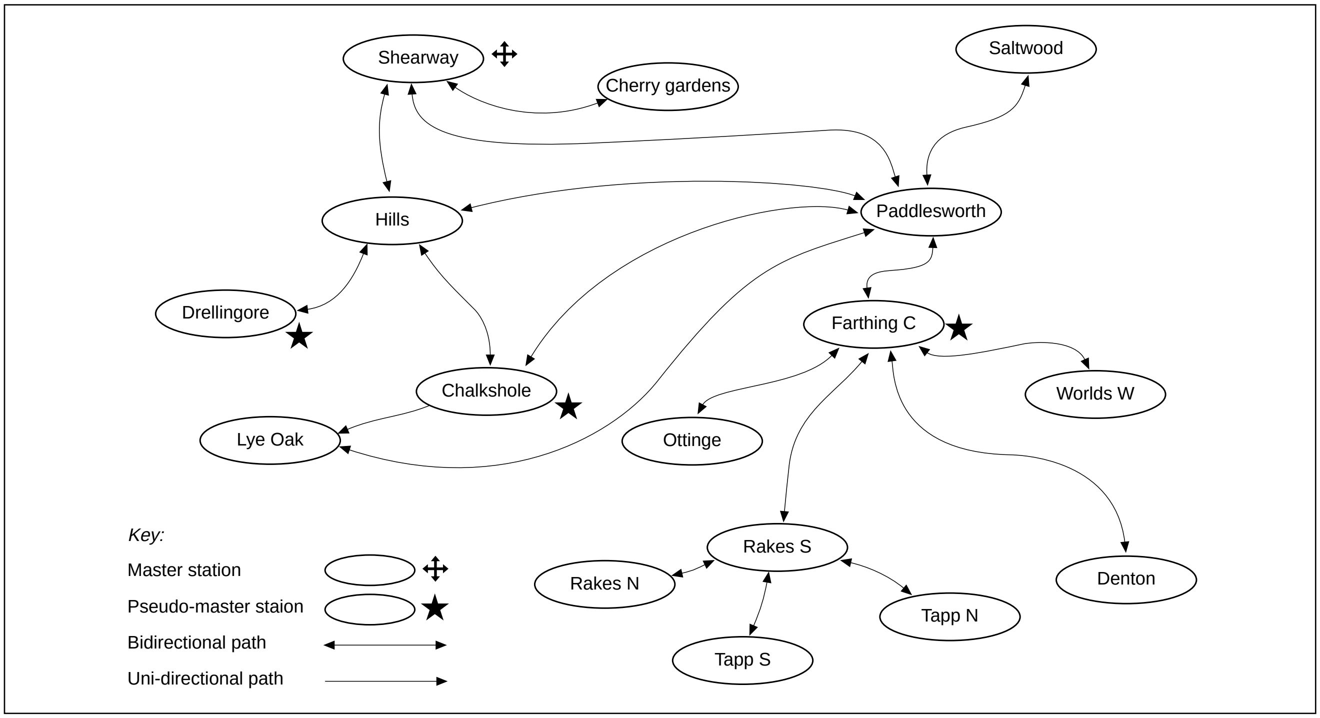

Figure 1. Communications Strategy: Schematic for Folkestone and Dover Water Services Radio Telemetry Installation

that one will respond. With this type of system, the flow of data can be two-way and thus the master station can be used to control events at the outstations. It can also be arranged that one outstation can communicate with another via the master.

RS232 cable links can also be replaced with a radio link operating in half duplex mode (i.e. only transmitting or receiving at any one time). The RS232 cables can be replaced with two radio modules, one at each end, with no software configuration necessary on the main system. These modules communicate with each other and, as all necessary communication protocols are managed by the microprocessors in the units, the operation is transparent to the host system.

Large scale and sophisticated SCADA systems – such as those in the water services industry – can incorporate complete regional telemetry schemes, controlling a number of sites over distances of many kilometres. A central control station could be linked by land lines to “intelligent clusters”, each comprising a “gateway” station linked by radio to a number of outstations. All information can be viewed at the central control station which communicates with the “gateway” station, which in turn communicates with the outstations in a distributed monitoring system. An alarm at, for example, a reservoir outstation, will alert the “gateway” station which in turn will alert the central control. In such a system, radio telemetry is the main form of communication.

A major benefit of radio telemetry is the ability to provide a “shutdown” facility. A “dual redundant” radio system will comprise two radio links; if one fails, the system will automatically switch over to the other radio link.

Bristol Babcock Ltd, part of the FKI group of companies, is a market leader in the provision of radio telemetry systems within the water industry and has its own in-house radio telemetry expertise. The company was chosen to supply a radio telemetry system for Folkestone and Dover Water Services after a pilot area of 6km^2 – comprising a master station and 22 wells – was tested, resulting in an estimated cost ratio of 3:1 in favour of radio telemetry against cabling and fibre optics. Folkestone and Dover Water Services then ran the system for two years to verify cost savings, expectation and monitor system reliability; and decided to introduce low power radio telemetry systems throughout its central area for data collection and control links.

The telemetry equipment had to interface with existing Square D PLCs and used Spacenet 232 radios – designed to replace RS232 cable links but which can, with a special interface, also replace RS422 links. The system used UHF radio links conforming to MPT 1329. The PLCs on the Folkestone and Dover Water central area relay data to and from the master station located at Shearway, provide local control at each outstation and act as data collection points for onward transmission. Twenty-three stations are covered and the telemetry links have a required range of 12km in all directions. The area is split into zones, each of which has a pseudo master station to control the zone. Configured in this manner, the network can perform data exchange at five levels from the furthest station to the master.

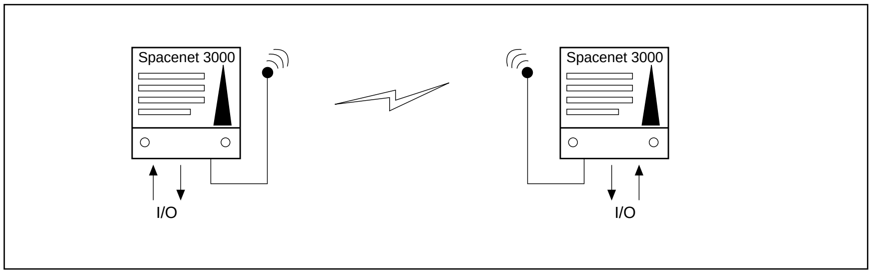

Figure 2. Point to Point Network using Spacenet 3000

The transmitted data provides information on reservoir levels, flows, pressures, treatment parameters and general plant status. Control activity is concerned principally with pumping plant, with level controls from reservoirs being incorporated in the near future.

Versatility of Radio Telemetry

The development of radio telemetry in process control applications has been closely linked to the water supply and treatment industries, but the technology is applicable to a number of areas. Burgeoning environmental regulations on the chemicals industry, for example, highlight the use of radio telemetry in the monitoring of effluent output at a number of distant locations. The power generation industry is finding radio telemetry increasingly effective, particularly in hydroelectric installations.

Overseas, Bristol Babcock has been contracted to install a radio telemetry system for the Vietsovpetro Project, a joint Russian and Vietnamese venture comprising seven oil platforms in the "White Tiger" field, 120 miles off the Vietnamese coast. The system transmits voice and data communication between the master platform and its six satellite platforms, and transmits over two different frequencies (UHF and VHF bands) to overcome the problem of signal fading owing to the varying level of the sea. The aerials are also mounted at different heights for space diversity, and both data frequencies operate concurrently to overcome any start-up delay owing to one frequency fading.

As control systems become more complex and sophisticated, the role of radio telemetry is set to grow. Its cost-effectiveness – especially in the UK where a low power radio telemetry network needs no licence to set up – together with its benefits of high operational integrity and installation expertise, mean that the technology can help to expand and improve communications in an increasing number of industries.

Further information from Helen Hyams, Bristol Babcock Ltd, Vale Industrial Estate, Stourport Road, Kidderminster, Worcs, DY11 7QP. Tel: 0562 820001; Fax: 0562 515722.

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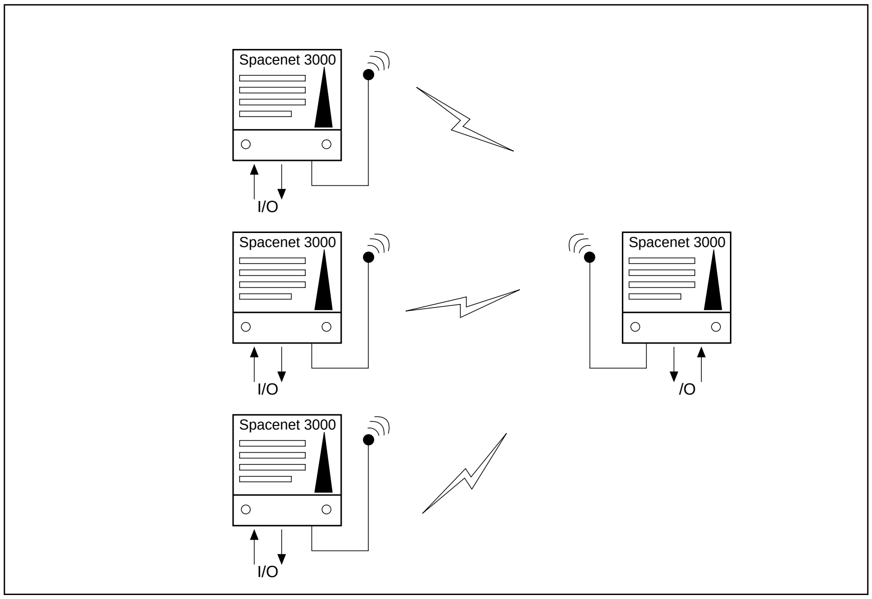

Figure 3. Point to Point with Multiple Slave Nodes

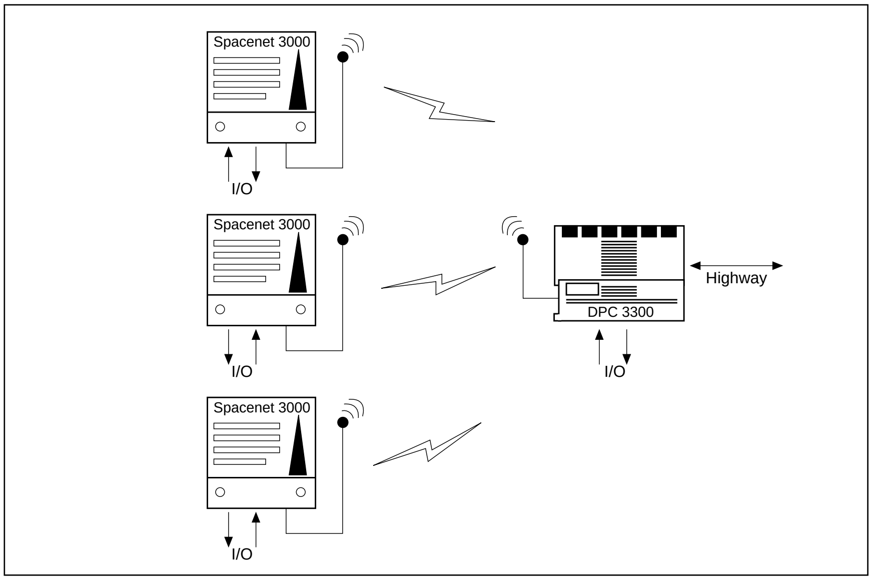

Figure 4. Single or Multiple Slave Nodes with a Bristol Babcock Network 3000 Master

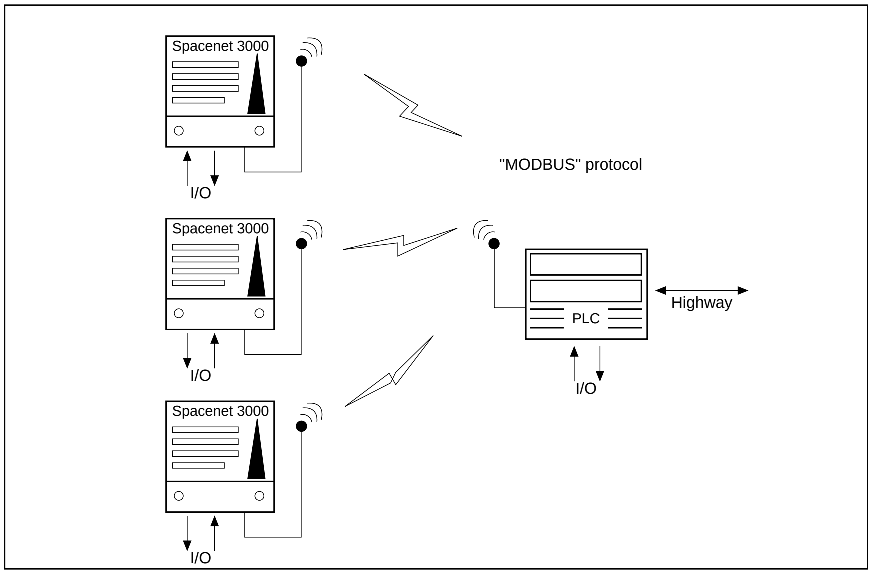

Figure 5. Single or Multiple Slave Nodes with a Third Party PLC or DCS Controller