DATA-LINC GROUP

Technical Paper: Discrete/Analog Multiplexer

Wireless Communication System for Stray Current Interference Testing

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Abstract - This paper examines the applications and technologies associated with the use of wireless communications for stray current interference testing. The adoption of wireless testing is expected to deliver improvements in safety, versatility, and scalability.

The system comprises of discrete/analog multiplexer, combined with signal isolator, which performs to the demanding requirements. Immediate response to fluctuating voltages, increased operating distance before loss of transmission and acceptable levels of accuracy were delivered with this system. This compact system improves safety, versatility and scalability without sacrificing the quality of service.

This paper demonstrates the enhanced method of interference testing, along with the capability to accommodate future developments.

Keywords: wireless system, stray current, interference testing, corrosion

1.0 Introduction

Corrosion is the spontaneous degradation a metal undergoes when exposed to an environment, such as air, water, or soil. (1) The nature of environment and stray currents are two major sources of corrosion on underground metal structures.

Cathodic protection (CP) and railway drainage bonds (RDB) applied on buried structures can prevent corrosion. However, these systems can cause stray current corrosion on adjacent foreign structures.

Stray currents are those that have deviated from their intended path. They deviate because the resistance of the unintended path is lower than that of the intended path.

Interference testing is carried out on CP and RDBs to determine if they cause stray current affects on adjacent foreign structures. The present method of interference testing on railway drainage bonds and cathodic protection systems requires the use of cables for connection between structure reference points and a test vehicle.

The set up for the present method of interference testing requires:

- Risk assessment of the site: finding a safe location to position team and test vehicle, on or adjacent to main roads.
- Cable length limitations often determine the parked location of the test vehicle.
- Cabling across the road could only be laid when there was no traffic flow
- Extending the cables over footpath poses potential slips, trips and falls for pedestrians.

The primary reason for favouring the use of wireless system is to overcome the issues related to public and worker safety. Licensed radios have been used previously for interference testing. This system was abandoned because of poor accuracy of results and high cost of annuallicence.

The proposed wireless system will provide seamless communication and will make the set up and monitoring process less hazardous.

The master unit will be placed in the test vehicle. This unit will receive data from the structure under test.

- Test vehicle can be parked away from main roads. This avoids the need to interrupt traffic flow and pedestrian thoroughfares
- Avoids the need to extend the wiring across main roads
- Increases the ability to reach distant test structures.

This wireless system can also be applied to any cathodic protection system to transfer data from the structure under test to the receiver that is placed in the test vehicle. The transmitter can be moved to the various test points whilst the test vehicle remains stationary.

The proposed wireless system provides a simpler and less time consuming set-up.

Section 2 will describe the wireless system model. It details the components and their operation. Section 3 of this report will provide an introduction to the test methods and discuss the results obtained. The results will determine the conclusion, whereby the success of the wireless system is decided.

2.0 System Model

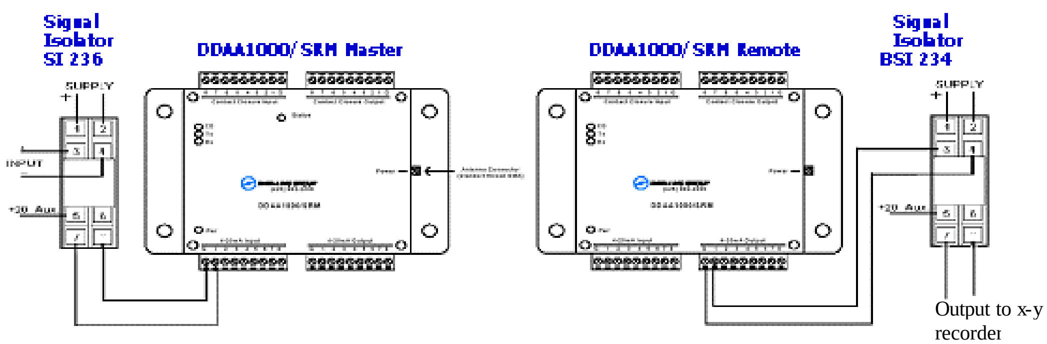

Figure I: Proposed wireless system for interference testing

Signal isolator: The Signal Isolator is an isolating converter providing true 3-way galvanic isolation up to 2kV r.m.s. The isolators come in three, coding plug selectable models to accept either: Process, mV or Bipolar input signals.

The nature of interference testing and the system design requires isolators with bipolar input and output.

> SI 236: This isolator is connected to the structure and transmitting multiplexer. It produces an isolated unipolar output signal (i.e. 4-20mA) from bipolar input signal (Voltage).
>
> BSI234: This isolator is connected to the receiving multiplexer and is located in the test vehicle. It produces an isolated bipolar output voltage from an input signal (i.e. 4-20mA).

DDAA1000/SRM Master/Remote: The DDAA1000/SRM is Discrete/Analog wireless multiplexer. It provides applications the ability to transmit analogue or discrete signals without the cost and inconvenience of adding wires or additional devices. Each multiplexer has eight discrete inputs and eight outputs, as well as eight analog (4-20mA) inputs and outputs.

The industrial grade multiplexers incorporate the license-free 902-928 MHz ISM (industrial/scientific/medical) band technology of radio modems. The frequency hopping is achieved in the 902-928MHz band by dividing the RF band into 112 operating channels and hopping through the channels one at a time, in a pseudo-random pattern. [(2)]

Frequency Hopping takes the incoming data and breaks it down to individual packets that are sent in different frequencies. Each packet is error checked. Once the packets have been transmitted, the data is recompiled in its original format. If a packet cannot be successfully sent on a given frequency, it is re-sent on another.

Antenna: A six inch unity gain whip antenna is supplied with each multiplexer. To utilise wireless technology and increase the scalability of the system, two different types of external antennas are used with this system model.

1. A 6.5 dBi cellular antenna is used for fringe areas and country applications where there is great distance between test points.
2. A multi band quadrant antenna is used for areas with high external interference such as buildings.

End-to-End System Operation

The signal isolator connected to the transmitting multiplexer will convert the bipolar input voltage to 4-20mA output. This output signal of 4-20mA becomes the input signal to the multiplexer. The multiplexer modulates the signal using Gaussian Frequency Shift Keying (GFSK). Signal is transmitted using frequency hopping spread spectrum.

The signal is then recompiled by the receiving multiplexer. The recompiled, demodulated signal becomes a 4-20mA output from the multiplexer. The signal isolator connected to the receiving multiplexer, then converts the 4-20mA signal to bipolar voltage output. The bipolar output voltage can be connected to a data logger or x-y recorder to analyse interference patterns.

3.0 Test Methods

The requirements of the system model are:

1. Deliver accurate readings for both Cathodic Protection (CP) and Drainage Bonds (RDB)
2. Immediate response to fluctuating voltages
3. Provide increased distance of wireless communication as to utilise wireless technology.

3.1 CP system testing

Measurement for interference is initially made using a voltmeter and, if levels of measured interference are significant, then the interference is recorded using a suitable 2-pen chart recorder, half-cell and shunts.

A time switch is placed in series with the impressed current circuit to allow switching of the system during testing. Testing is carried out in the following switching sequence: 5 SECONDS ON & 15 SECONDS OFF. The "ON/OFF" foreign structure potential and the system current are recorded on the same chart, with at least 5 "ON" and 5 "OFF" cycles.

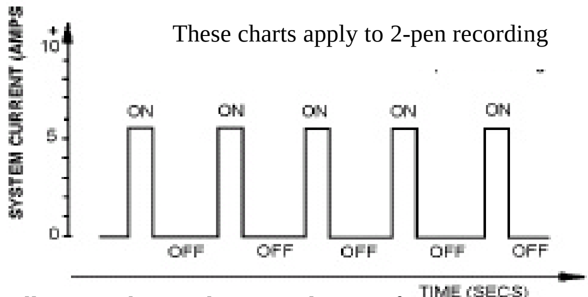

Figure IIa: Illustrates the simultaneous plotting of primary system current with foreign structure

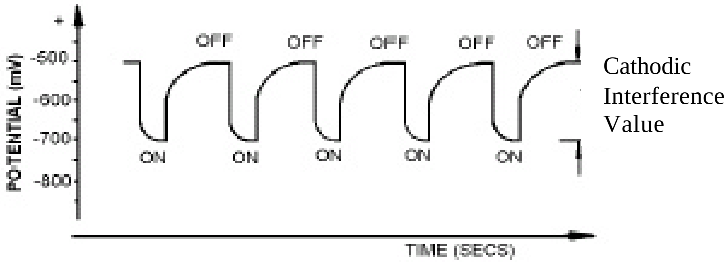

Figure IIb: Illustration of foreign structure cathodic interference measuring chart [3]

3.1.1 Field Test Results of CP system

To determine the success of the wireless system, recording includes hard-wired measurements. The nature of CP testing will indicate the ability of the wireless system to respond to time switching.

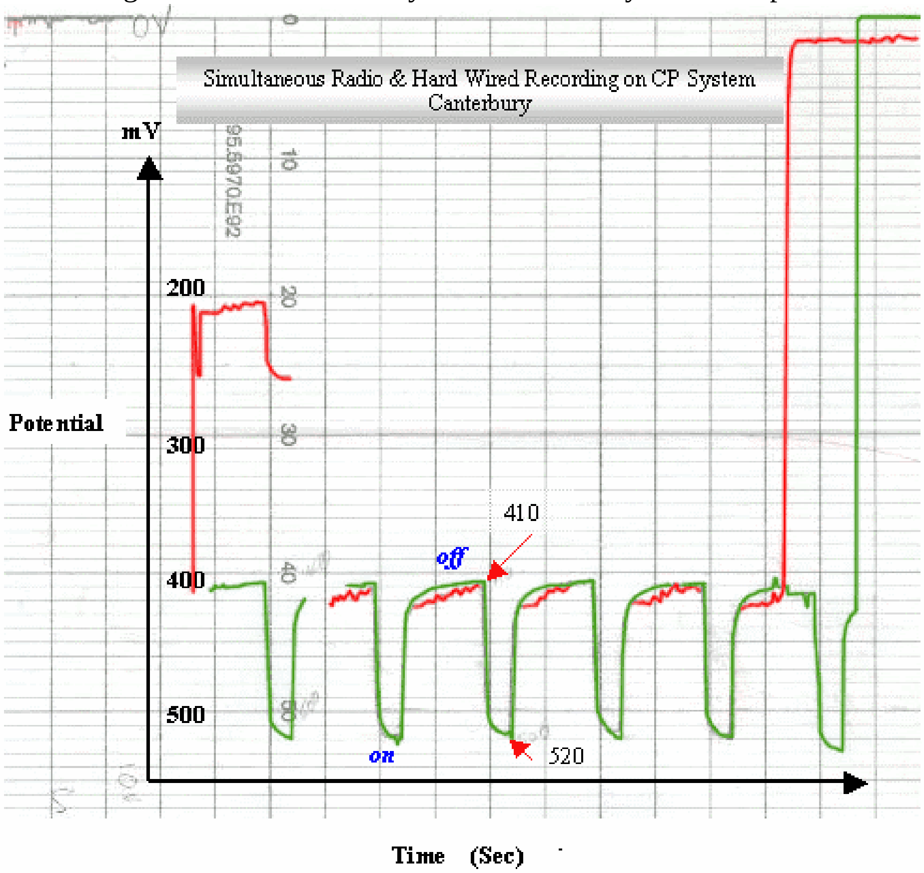

Figure III: Structure potential chart, Canterbury 13/5/04

Red Measurement recorded using wireless system

Green CP system was directly connected to the recorder.

Figure III indicates the response of wireless system is instantaneous. It shows no delay between the two signals while switching.

The numerical recording of wireless system is consistent with that of hard-wired system – both systems indicating peak (410 mV) and trough (520 mV) at the same potential values.

The ripple present on the wireless system recording is due to internal noise. We examined the effects of using filters by adding capacitors of varying magnitudes. As the capacitor magnitude increased the fluctuations increased. The best results were obtained in the absence of filters.

Although a ripple is present, it can be said that wireless system is accurate, as the final readings are not compromised. The system also responds to fluctuations without delay.

The wireless system was tested on many CP sites. Recordings have indicated instantaneous response to switching. The accuracy of the system has been at most $\pm$ 5mV compared to hard-wired recordings. It should be noted that human error in analysing the result is compounded as system accuracy.

The wireless system is successful in meeting the requirements for CP interference testing, and is recommended as an alternative to hard-wired system.

3.2 Railway Drainage Bond (RDB) testing

A railway drainage (RD) system will "drain" or conduct stray railway current from underground structures back to the rail via a metallic path. The cable connection includes a resistor and diode to limit the magnitude and direction of the stray current. Returning stray current through a metallic path reduces current flow through the ground and thus minimises corrosion. (3)

Foreign structure correlation recordings are made on an X-Y recorder. The system is switched "ON" and "OFF" at various Foreign structure to Rail (FS-RR) voltages. Recordings are taken over sufficient range of FS-RR voltages to indicate system characteristics. The "ON/OFF" switching is controlled from the Test Vehicle using a DC relay in series with the drainage circuit.

The correlation chart consists of a graph of foreign structure to half-cell potential plotted against foreign structure to railway potential. The change in the relationship that occurs on switching the drainage system "ON" and "OFF" is a measure of interference. If there is no change in the relationship, then there is no interference (3).

Figure IV is an illustration of correlation chart based on typical data for a steel structure using a copper/copper sulphate half-cell to measure potentials to earth (3)

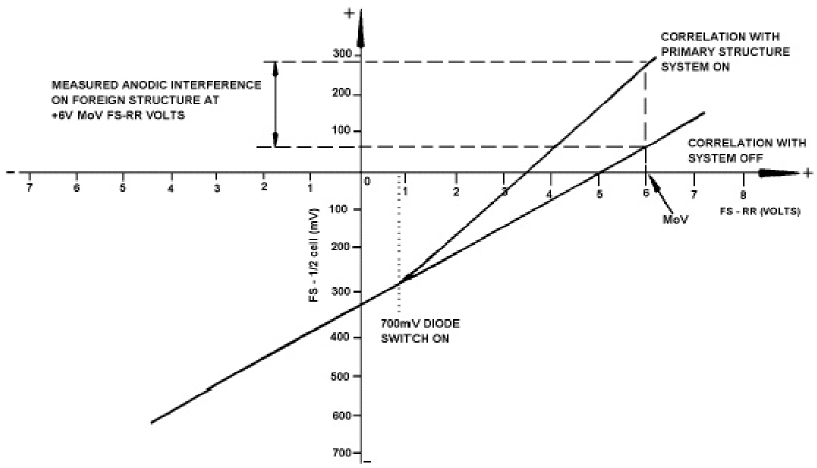

Figure IV: Illustration of anodic interference correlation for foreign structure (3)

3.2.1 Field Test results of Railway Drainage bond

To assess the reliability of the wireless system for RDB interference testing, results were obtained as both wireless and hard-wired system connected simultaneously.

Figures V & VI show the primary structure to rail correlation for hard-wired and wireless system at Villawood.

Telstra communication cable was used as the primary structure for this correlation.
Readings from the correlations are:

At 7 V	Hard-wire (mV)	Wireless System
On	-660	-3.3V/5 = - 660 mV
Off	-560	-2.825V/5 = -565 mV

Table I: Primary structure to rail correlation readings from Figure V & VI

Input signal isolator converts 4V (±2 V) to 16mA (4-20mA), where as the output isolator converts 16 mA (4-20mA) to voltage range of 20V (±10V). This limitation of the isolator requires the conversion of the final output signal. Input: Output signal ratio becomes 1:5. Hence, the wireless system output readings have to be divided by 5 to compare with input readings.

Interference is measured at the average point of primary structure to rail volts. For this correlation the average structure to rail volts is 7V.

Therefore the interference is

Hard-wired	-660 - (-560) = -100 mV
Wireless	-660 - (-565) = -95 mV

Table II: Comparison of hard-wired and wireless system interference as calculated from Figure V & VI

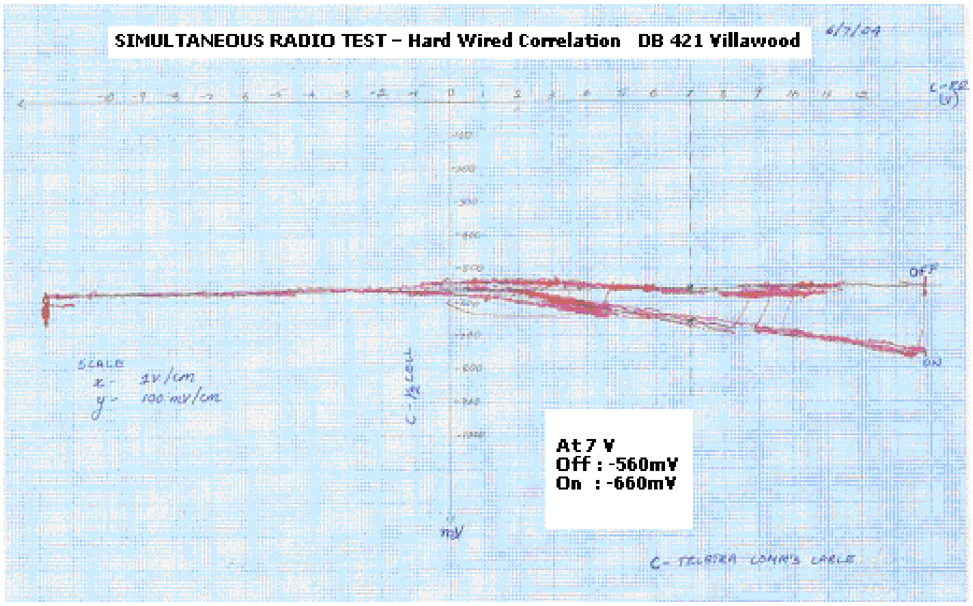

Figure V: Bond correlation at Villawood for hard-wired system

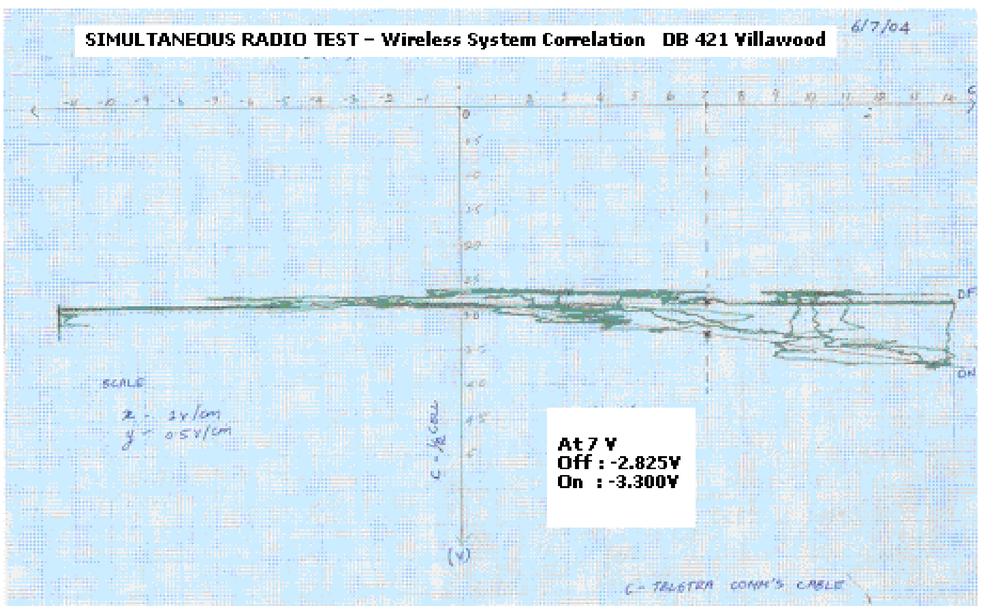

Figure VI: Bond correlation at Villawood for wireless system

Wireless system results indicate a discrepancy of 5mV compared to hard-wired system result. This discrepancy arises due to human error and selection of output isolator.

It is vital to choose the line of best fit. The variation in gradient of the “ON” and “OFF” will alter the interference measurement. The error is further exaggerated because of the input: output isolator ratio of 1:5.

Output isolator’s are designed to give ± 1V, ± 5V, and ± 10V. For input signal range of ± 2V, using isolator of ± 5V output will half the error as compared to ± 10V.

The wireless system response shows slight delay. This is due to the two different types of X-Y recorders used to record the graph. Recorders having different inductance will have different reaction times.

Wireless system results are accurate and respond accordingly to fluctuating voltage.

Conclusion

This innovative wireless technology designed by Sydney Water Corporation has improved safety while interference testing, without affecting accuracy. It replaces over 30 years of hard-wired testing. The wireless system was designed according to the requirements of both CP and DB interference testing. The wireless system was tested for its key requirements: accuracy, response and distance before loss of transmission. Tests were conducted on both CP and DB systems with supplied antenna and external 6dB antenna.

Results have been accurate and the worst case has been ± 5mV away from the hard-wired reading for CP & DB systems. Response of the wireless system has been instantaneous for the CP systems and negligible delay for RDB interference testing. The external antennas provide reliable transmission for our requirement of 1km. It is capable of transmitting beyond 1km.

The use of the wireless equipment will make a safer work environment. It will eliminate the need to extend cables across main roads and will not interfere with pedestrian thoroughfare. This will greatly reduce the risk of injury or accident associated with interference testing for both employees and public. The wireless system will also improve efficiency as it eliminates the time-consuming cable set-up. Mobility of wireless system will increase the ability to reach distant structures.

This wireless system can be improved further. This can be achieved by replacing the X-Y recorder with a laptop. An analogue measurement unit can be used to acquire the data. This in turn will connect to the laptop via the USB port where the results can be viewed with the development of specialised software.

Acknowledgment

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Reference

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