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WHITE PAPER

Comparison of MIRRORED BITS® Communications and Ethernet IEC 61850 GOOSE for Teleprotection Using Spread-Spectrum Radio

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INTRODUCTION

Teleprotection systems improve the overall operating times for relay systems on transmission and subtransmission lines. Many communications methods are suitable for application, and many different protection schemes can be used. Proper engineering of the overall protection system requires choosing a combination of schemes, communications, and signals that will provide the best operating time, best reliability, and best security against false operations. This paper shows that the specific considerations of using ISM band spread-spectrum radio impact the protection scheme and give MIRRORED BITS® communications a significant advantage over IEC 61850 GOOSE messages.

SPREAD-SPECTRUM RADIO

The basic operating principle of spread-spectrum radio is to perform frequency hopping at rapid intervals. This avoids prolonged interference from fixed frequency sources. Spread-spectrum radios generally operate in unlicensed spectrum bands, so they are convenient to install [1]. As a communications system for sending a teleprotection signal from one substation to another, spread-spectrum radio offers significant advantages from a cost and convenience standpoint, provided the physical limitations are met. These limitations include a reasonable line of sight between stations and a maximum range of over twenty miles, depending on the antenna type (Figure 1).

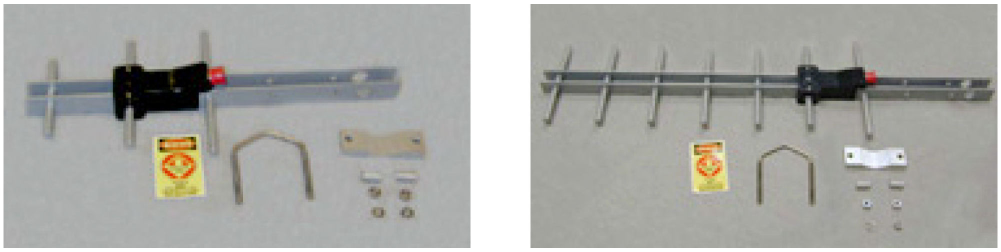

Figure 1 (a) 6 dB Directional (Yagi) Antenna, Up to 6 Mile Range

(b) 12 dB Directional (Yagi) Antenna, Up to 25 Mile Range

Because spread spectrum is unlicensed, some consideration must also be given to congested areas where large numbers of other radios will be operating in the same band and geography. Generally, this is only a factor in metropolitan areas. Repeaters have been successfully used to extend the range and reduce interference from line-of-sight obstacles, but their use is beyond the scope of this paper. Consider the amount of data sent during each frequency “hop” (Figure 2) when selecting the signal to be transmitted. If a hop occurs in the middle of a digital data packet, data can be lost, with the possibility of a false or delayed trip.

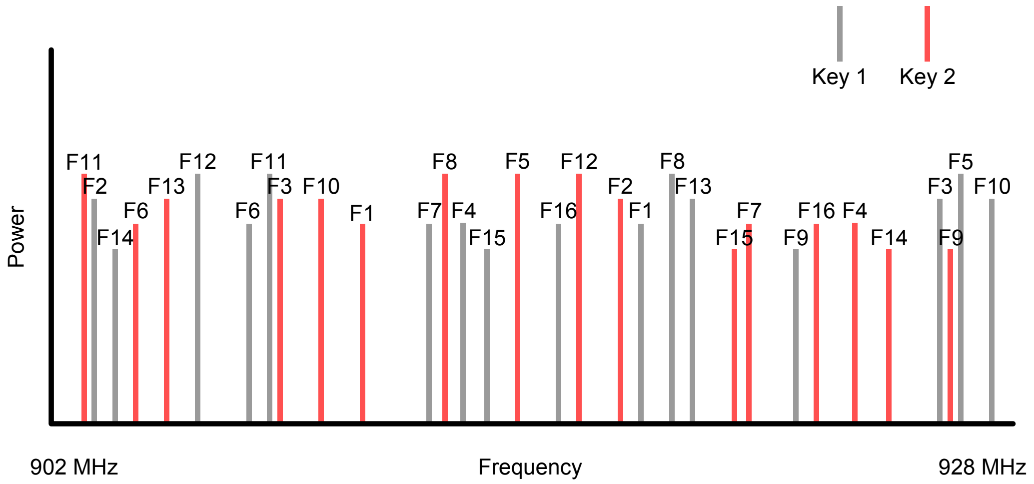

Figure 2 Frequency Hopping Avoids Interference (Other Bands Include 2.4 and 5 GHz)

TELEPROTECTION SCHEME

Adding communications-assisted tripping (teleprotection) to a protection scheme reduces the overall tripping time for the combination of both ends of the line. Information from forward or reverse elements (Figure 3) is transmitted from one terminal to another to accelerate operation.

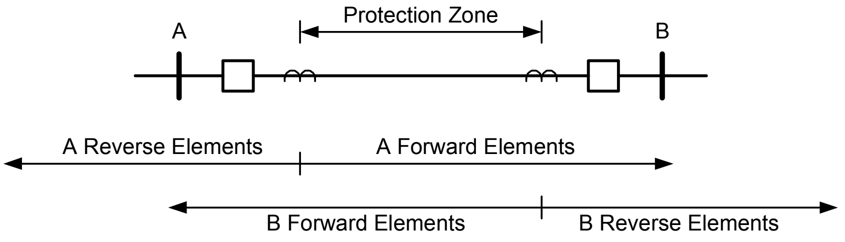

Figure 3 Both Forward and Reverse Elements Can Be Used in Teleprotection Schemes

Traditional teleprotection schemes were developed to take into account the limitations and strengths of the communications medium [2]. For example, a blocking scheme was often used when the fault itself could cause a signal to be lost, such as with power line carrier. Where this was not the case, such as with frequency shift audio tone over microwave, permissive (POTT) schemes were developed to provide faster tripping and take advantage of continuous monitoring.

POTT schemes send a signal from each terminal that sees a fault. Receipt of a permissive signal, combined with seeing a fault in the forward direction, initiates tripping.

To initiate tripping, Directional Comparison Blocking (DCB) schemes combine the lack of a reverse fault at the remote end of the line with the detection of a forward fault. A coordinating time delay allows the remote relay to see a reverse fault and send a blocking signal before local tripping occurs. Any event or protocol that slows down the transmission speed from the remote terminal makes it less suitable to apply a blocking scheme. Because high speed and dependability are so critical to a DCB scheme, an Ethernet-based system is a poor choice in this application.

A digital signal sent between stations over spread-spectrum radio is not affected by faults on the protected line, so a POTT scheme is generally superior to a DCB scheme. In addition, a digital signal can be continuously monitored. SEL MIRRORED BITS communications provides a high-speed, monitored signal that uses error checking for security. Because multiple signals can be sent over a single data channel, it is possible to combine schemes for improved performance [2].

Blocking schemes, combined with a weak infeed logic for echo repeating, will increase coverage for high-resistance faults without sacrificing speed for more severe faults.

While an Ethernet-based signal (IEC 61850 GOOSE) can be sent over spread-spectrum radio, the overhead and the probabilistic nature of the protocol increase time and complications. These complications include added difficulty in performing signal monitoring, varying time delays based on network traffic, and increased coordinating time delays.

The performance of protection schemes using MIRRORED BITS and Ethernet communications was recently highlighted in two technical papers [3] [4]. Table 1 shows a summary of the scheme performance over spread-spectrum radio.

Table 1 Protection Scheme Operating Times

	SEL-311 MIRRORED BITS POTT Scheme [3]	**SEL-421 MIRRORED BITS POTT Scheme Test**	**GE Lab Tested Ethernet GOOSE POTT Scheme [4]**	**GE Lab Tested Ethernet GOOSE Blocking Scheme [4]**
Channel Latency	4 ms	4 ms	10–40 ms (10–15 ms Typical)	10–40 ms (10–15 ms Typical)
Average Scheme (Both Ends) Operating Time	28 ms	22 ms	30–35 ms	64 ms

It is easy to see that MIRRORED BITS communications is superior to Ethernet IEC 61850 GOOSE in a POTT scheme.

MULTITERMINAL LINES

The extension of a POTT scheme to three-terminal lines is very straightforward and does not cause additional delays. Adding additional point-to-point channels, as shown in Figure 4, is a low-cost way to simply provide high-speed three-terminal protection. No additional delays are added, and other than the radio channels, no extra equipment is needed.

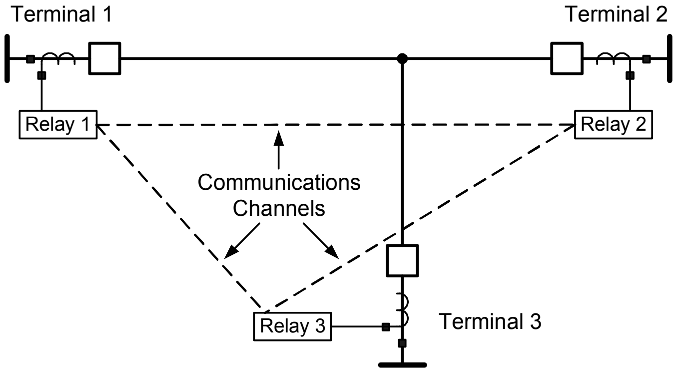

Figure 4 Three-Terminal Line Protected With Three Point-to-Point Links

A logic processor simplifies the application of directional comparison protection to multiterminal lines. Figure 5 shows the directional comparison scheme for a line with three or more terminals. The logic processor, installed at Terminal 3 in this example, communicates with relays at Terminal 1 and Terminal 2. The processor also communicates locally with the Terminal 3 relay. If a fault anywhere on the line can be seen from all terminals, a MIRRORED BITS communications

POTT scheme over spread-spectrum radio will provide high-speed operation. If the effect of infeed from one of the terminals, or a low fault contribution from one terminal, makes it impossible to ensure that the protection relays at each terminal see all possible faults on the line, it may be best to apply a DCB scheme. This will be inherently slower than a POTT scheme, but it will improve tripping times for faults at terminals with strong infeed.

As shown in Table 1, MIRRORED BITS communications in a blocking scheme is about 2 cycles faster than Ethernet GOOSE.

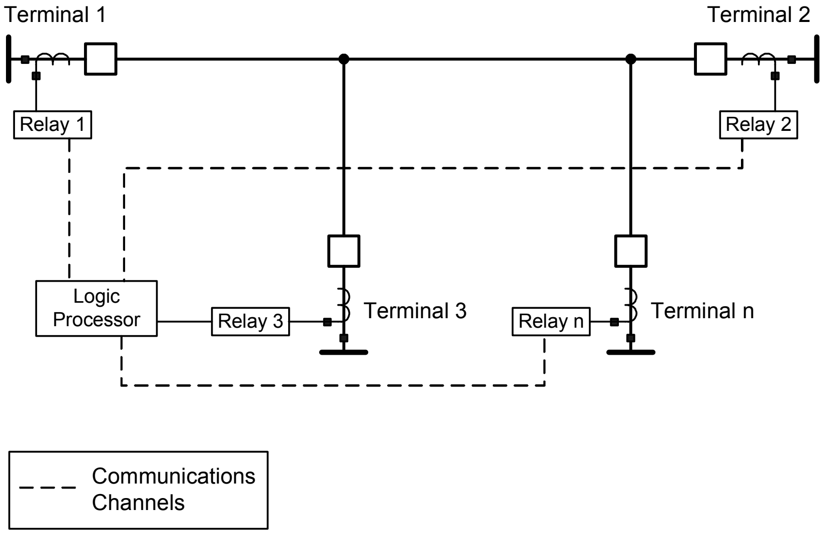

Figure 5 Three (or More) Terminal Line Protected Using a Logic Processor

CONCLUSIONS

1. For any voltage system, high-speed protection is preferred to minimize equipment damage and reduce the risk of system problems, such as voltage collapse or overtripping.
2. Because radio signals are independent of power line conditions, a POTT scheme is the best choice for high-speed fault clearing from both ends of the line.
3. SEL relays with MIRRORED BITS communications provide an optimal package of reliability, security, and high speed over radio. Performance of MIRRORED BITS communications over spread-spectrum radio is superior to Ethernet GOOSE messages.
4. A logic processor using MIRRORED BITS communications makes it easy to apply blocking or permissive schemes to multiterminal lines with minimal added time delay.

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[4] R. Hunt, M. Adamiak, A. King, and S. McCreery, “Application of Digital Radio for Distribution Pilot Protection and Other Applications,” Proceedings of the 34th Annual Western Protective Relay Conference, Spokane, WA, October 2007.

BIOGRAPHY

Roy Moxley has a B.S. in electrical engineering from the University of Colorado. He joined Schweitzer Engineering Laboratories, Inc. (SEL) in 2000 as market manager for transmission system products. He is now a senior product manager. Prior to joining SEL, he was with General Electric Company as a relay application engineer, transmission and distribution (T&D) field application engineer, and T&D account manager. He is a registered professional engineer in the state of Pennsylvania.

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