

# Tactical Data Links - 22Mbs over 5Mi Using Copper Cables 'WD-1/TT' As Its Transmission Medium

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**This paper presents an innovative approach for tactical data links – developed in close collaboration with the Australian Army Signal Corps RASC, with the objective of overcoming the problem of fibre-optic cables' propensity to damage in the field.**

**The result of this successful collaboration has led to the development of a field deployable communications product that uses copper cables (WD-1/TT type) as its communications medium and is capable of extending data over 5 miles at bandwidth of up to 22Mbs – an effective soldier friendly alternative to the fibre-optic cable based systems, especially on a brigade level and below.**

**The paper reviews the rationale behind the selection of an 'off the shelf' transmission technology and its adaptations to make it highly suitable for the military field deployed environment. Technical and logistical advantages of using copper wires in modern data applications are presented, including the Australian Army's report of the early field trial.**

**This collaboration and the resulting product won the AFCEA 'Golden Link Award' as well as a number of other prestigious industry awards for its outstanding innovation.**

*Keywords: WD1-TT, hsdsl, transmission, bandwidth, data links*

## I. INTRODUCTION

Rapidly deployed, simple to use, effective and reliable communications are vital in modern military operations. The area of data tactical links and the so called 'ad hoc' networks requires equipment providing high bandwidth for expedient data transfer while being simple to install, operate and repair. Invariably this equipment needs to be capable of a wide range of applications.

The commonly adopted standard in tactical LANs is fibre-optic cables (FOC) offering secure signal propagation and high bandwidth. However, fibre-optic cables have a propensity to damage especially when used in areas of high troop and machinery movement. This is particularly relevant to the 'rear echelon' or Troop Support Elements where FOC damage is a regular occurrence due to it being bent or torn. Inherent in FOC is its difficulty and often impracticality to repair in the field.

Compounding the problem is the fact that logistics troops need to relocate every few days.

Another practical problem with FOC is that they are often impossible to roll-out in difficult terrain e.g. in earthquake recovery operations, mountainous terrain, tunnels and similar harsh environment. Wireless technologies are often difficult to use due in these locations due to signal reach (i.e. lack of direct line of sight) and sometimes due to security constraints.

With these concerns as its background brief, the Australian Army started to research alternative technologies that could alleviate FOC field deployable problems. One technology that stood out was 'DSL' - transmission signal modulation specially designed for copper cables for delivery of internet and other data services by telecom carriers. What this technology promised to allow was the use of common 'field wire' or WD-1/TT type steel reinforced copper wire in place of FOC in specific environments and on a brigade or below levels.

The rationale for using copper cables (or 'DON10' as it is known in Australia) was that the technology promised relatively high bandwidth over distance, but more importantly, copper cables offered a 'soldier friendly' transmission medium that even when damaged could easily and quickly be repaired by soldiers.

## II. ADAPTING DSL TECHNOLOGY FOR MILITARY APPLICATIONS

The key characteristic of an 'off the shelf' public telecom DSL technology is that it is specified in two main variants: exchange (or switch) based modems and customer premises based modems. Effectively, this corresponds to two types of equipment with different power and infrastructure requirements and thus restricts its use in portable deployable applications. In addition, chipsets that provide signal (data) modulation and are different at each end of the transmission line which further restricts equipment configuration and more importantly, its bandwidth flow.

The first challenge therefore in adapting an off the shelf 'dsl' based equipment is redesigning its exchange and customer premises delineation *i.e. a programmable line interface or*

*Master/Slave configuration is the first step that opens dsl to be used in portable field deployable communications products.*

The second, relatively simple design challenge is selection of the most suitable modulation technique of the two defined by CCITT (public telecommunications standards governing body). The DMT (or Dual Multi-Tone) modulation was determined to be well suited for the field deployable environment due to its noise immunity whereby the signal (and the effective bandwidth) is modulated in multiple frequency carriers (up to 300) with each carrier being tested and then monitored for bit-error-rates, signal-to-noise ration and other electrical parameters.

Once transmission issues were clearly defined, the remaining design concerns were similar to any other portable field deployable device: battery back up power, rugged carry case, dust and moisture proofing.

Within a relatively short period of six months a number of functioning prototypes were built for trials by the Australian Army. The trials were a resounding success and proved conclusively the effectiveness of DSL technology and as a result, established grounds for actual product development.

### III. P3 – REDEFINING A STANDARD IN TACTICAL DATA LINK

#### A. WHY GO BACK TO COPPER?

The general scepticism towards using copper cables for modern data communications is historical. Copper cable and its military variant or ‘Field Wire’ has been used as a basic means of Morse code communications and general ‘Signal Wire’ since before the First World War. Although a well proven comms medium its use in modern communications is perceived as archaic. Of course, Field Wire (or WD1/TT) is still used today in both military and industrial applications, but its use is limited to basic telephony or as ‘signal’ wire.

Transmission technologies used in today’s armed forces for voice and data links are predominantly fibre-optic cable and satellite based. However, when transmission systems are used in a tactical environment two important disadvantages of using fibre-optic cables (FOC) are overlooked:

- FOC tendency to damage due to heavy machinery operating and night time troop movements
- FOC inherent difficulty to be repaired in the field

DSL transmission technology allows copper cable to be used as a modern and relatively high bandwidth communications infrastructure and Australian Army have lead the way in this technology adaptation for its requirements. The three important factors in considering this alternative by the Army were:

- a significant cost reduction (a factor of x20) in using copper compared to FOC
- the ease of copper cable roll-out and retrieval and

- the ease with which copper cable can be repaired: “as easy as tying shoelaces”
- copper cable: bandwidth over distance performance: see ‘*Transmission Performance Measurements*’ for further details

*In summary: copper cable offers a simple and effective alternative to fibre-optics in field deployed scenarios where rapid set up is needed – typically on a brigade level and below. Its predominant advantage when coupled with P3/P4 transmission systems is that it is significantly easier to roll out, retrieve and repair.*

#### B. EARLY TRIALS SUCCESS:

The first functioning prototypes of a tactical data modems using Rate Adaptive DSL technology were trialled in a field deployed logistics environment during ‘Crocodile West’ Army exercise (see also Army Field Trial Report [pg-6](#)). The equipment viability was proven within the first two days of the exercise when FOC links were inadvertently damaged and the main data link between the two logistical depots continued to operate over copper cable.

The way was now open to the new product development that would provide a viable alternative to the FOC systems. Its configuration and features were determined in close consultation with the Army Signallers thus ensuring that the product did precisely what was expected of it.

Figure 1. P3 early field trials & first production version



The number of transmission channels was determined to be three: for both diverse paths connectivity and redundancy. Basic analogue telephony and VoIP functionality was also integrated as a complementary feature.

To make the new product (named ‘P3’ *Portable 3 transmission channels*) field deployable, its electronics were integrated into a rugged case; with battery back up and a variety of external power sources operating it.

Particular effort went into the design of a user interface where P3’s set up and management is simple and kept to an absolute minimum.

In early 2003 the P3s were distributed across Army Signal Units for operational use.

#### IV. SECURE TRANSMISSION OVER COPPER

P3, with its rate adaptive DMT modulation technology represents highly secure transmission of voice and data over copper in the tactical environment.

##### A. DSL Initialisation Process & Data Scrambling

Digital signal modulation encrypts (or scrambles) the data transmission across 300 frequency carriers – that effectively represents max possible bandwidth. At the time of initialization each of the 300 frequency carriers is tested for its signal-to-noise ratio and bit-error-rate. The length and physical condition of the copper cable will have impact on these parameters. Once the process is complete, only those carriers that passed the initialization test will be activated. At this time, data packets are scrambled across active carriers. From the transmission perspective the scrambling minimizes interference between each frequency carrier. From the data security perspective, the effective result can be compared to a ‘one time pad’ – a unique transmission condition, as data scrambling parameters exist only between any two directly connected P3s.

The greater the number of users or data packets sent across any given data link, the greater the scrambling effect.

##### B. Electronic signature

The transmission energy of dsl is low - approx 3W per transmission channel. It is driven directly into the copper making its electronic signature extremely small.

Signal leakage or energy that is not driven directly in to the copper cable is eliminated by the fact that during the initialization each frequency carrier that did not pass the bit-error-test will be deactivated. Furthermore, it is impossible to ‘listen’ to the transmission as any transmission parameters variation will cause the link to shut down. Similarly, if the copper cable is cut, the transmission stops.

##### C. Transmission Security Summary

These features are inherent in the DSL technology itself and although very effective in terms of transmission security, do not represent any government level of data security. In order to establish that, military grade encryption systems are used – deployed prior to the point where data (Ethernet) is connected to a P3. This in effect makes P3s a transparent data transmission device.

#### V. COST OF COPPER CABLE VERSUS FIBRE

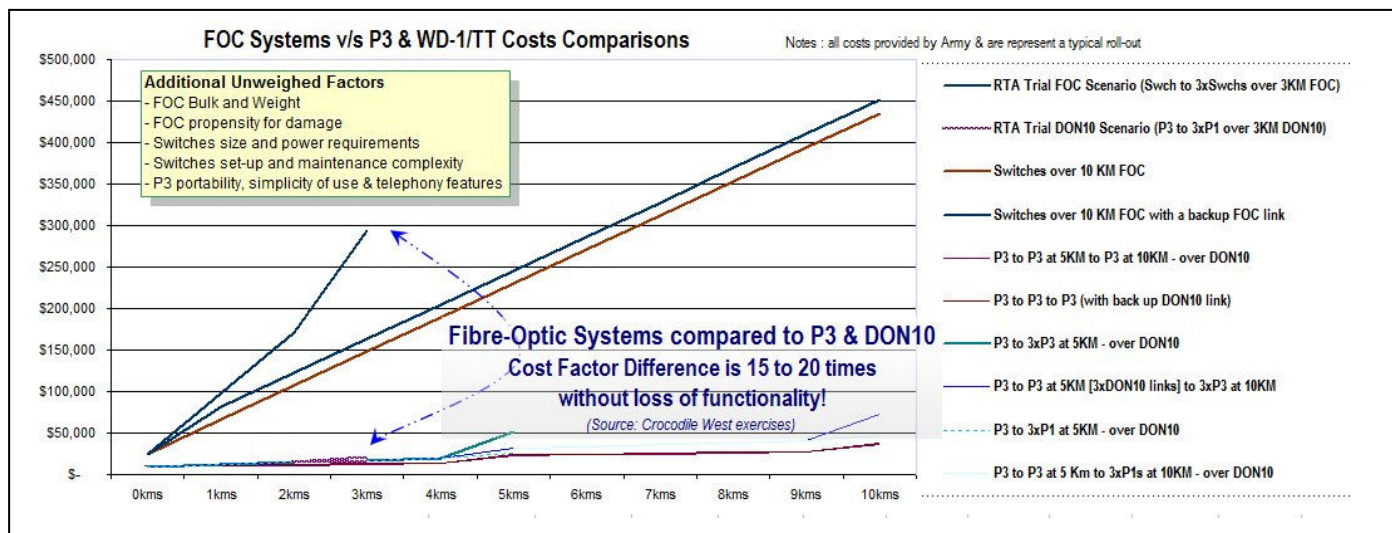
Following early equipment trials, Australian Army conducted an assessment of the cost differential between using copper cable based transmission and an equivalent fibre optic cable based system. This was based on the cost of infrastructure and did not take into account costs of damage and replacement of cables, commonly experienced with fibre optic.

Using a variety of scenarios, FOC costs show linear increase, largely attributable to the cost of fibre cable over distance. When compared to the equivalent set up using copper cable (WD-1/TT) the cost is consistently lower by a factor of 20 – again this is predominantly attributable to the cost of copper cable over distance.

The starkest example of cost escalation in the Army trials was duplication (back up) of either comms medium. Extending duplicate copper links produces a marginal cost increase where as, fibre optic duplication produces a dramatic cost rise (a factor of x40).

Additional factors for consideration are the bulk and weight of FOC, the size of switches and power requirements and complexity of maintenance compared with P3’s portability, simplicity of use and inbuilt telephony features.

Figure 2. Costs Comparison of Fibre-Optic versus WD-1/TT



## VI. TRANSMISSION PERFORMANCE MEASUREMENTS

Of specific interest to this paper's topic are actual transmission performance measurements over copper cable.

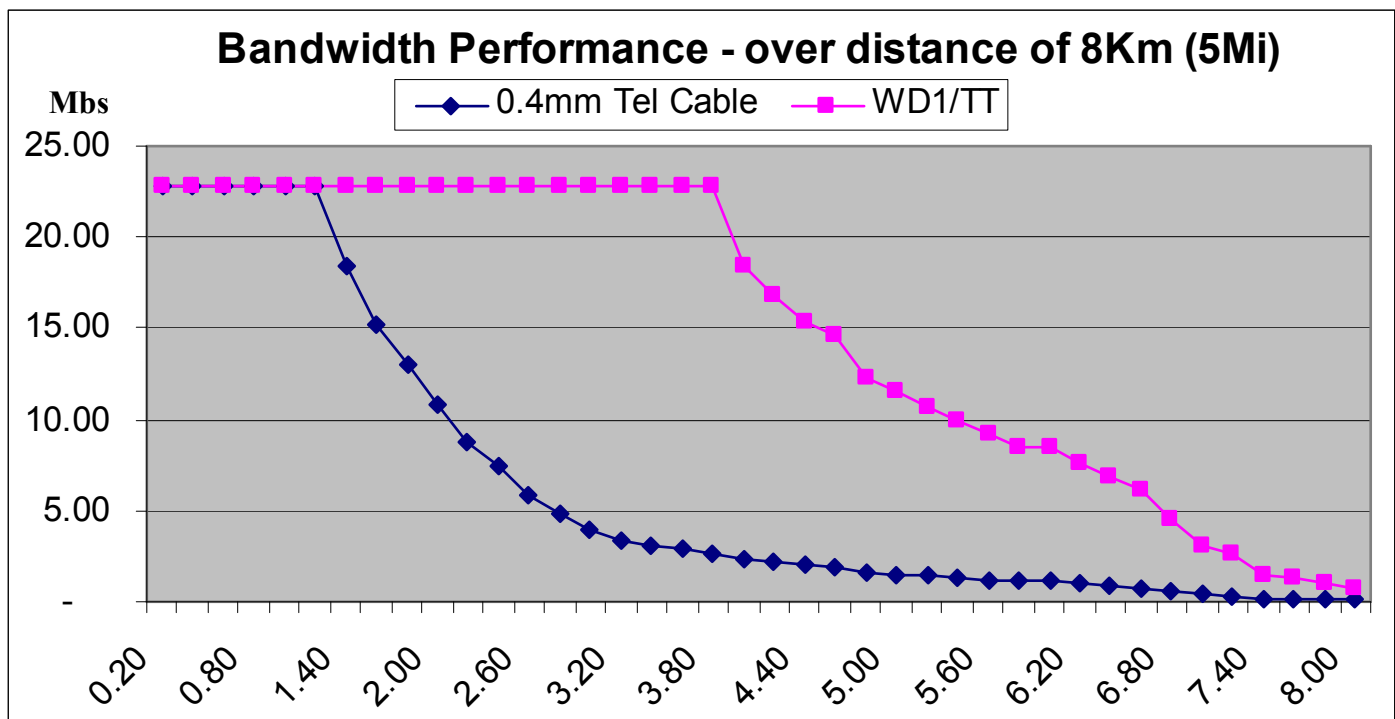
The key factor making the transmission over distance possible is the copper content in the WD1/TT wire. In fact, the construction of the cable (*steel strands for strength, interlaced with copper strands*) makes the cable far more suitable for long range links than telephone wire. Specifically, WD1/TT cable consists of two isolated conductors, each comprising 4 strands of tinned copper and three strands of steel. Combined copper strands provide an equivalent 1.12mm gauge – compared to the standard telephone wire of 0.4mm or 0.9mm (highest gauge available). The three steel strands, used primarily for strength provide additional favorable transmission characteristics to the cable.

In simple attenuation terms, the effective transmission characteristic of the WD1/TT is some 3 times better than the standard telecom wire of 0.4mm gauge and approx 50% better than the high grade telecom wire of 0.9mm gauge.

Another factor that adversely affects long distance transmission links is crosstalk noise between pairs of copper cable. WD1/TT wire, in practical terms, does not have this problem as its conductors tend to have large physical separation when compared to telephone cables.

Figure-3 depicts typical performance results using the new Hybrid Symmetrical DSL modulation system 'P4' with four transmission channels system operating over 8km (5miles) WD1/TT cable. The two curves indicates performance comparison of WD1/TT and standard telephone wire – with a linear bandwidth decrease over distance (due to signal attenuation over distance).

Figure 3. Bandwidth over distance performance data



## VII. AREAS OF APPLICATION

Australian Defence had identified the need for a solution that allowed its Land Local Area Network (LAN) Communications to be extended to its field deployed logistics units. The in barracks logistics system, the Standard Defence Supply System (SDSS) was to be extended to provide support for its logistics business, whilst being deployed operationally in the field. The resulting deployment of SDSS supported by a stand-alone version of SDSS called FLMS (Field Logistics Management System) provides seamless 'in and out of barracks' communications.

The extension of the LAN communications was largely made possible with the use of P3 and is now part of Army's new standard for field deployed communications.

Another important issue addressed by ADF was the need to provide redundant links (backup) for downed fibre optic networks – a regular occurrence in the field. Signallers can easily and cheaply repair copper cable, resulting in significant cost savings with no loss of capability.

### A. Specific P3 Application Examples

The British Army, in seeking to improve its out of barracks logistics and supply support, (UNICOM OOB) successfully trialled P3 in 2003. P3 is now in service with the British providing remote access and enhancing the capability of the existing UNICOM system.

The Canadian Army has also trialled the product for an innovative 'Fire Control' application where the device provides data as well as voice command extensions from a ballistics computer to individual gun positions. Again, the use of copper as the main communications medium is not only significantly cheaper but enhances functionality by providing seamless back up links using the spare P3 transmission channels.

Inter-coalition data links can be established with ease and extremely cost effectively by simply rolling out copper cable between two or more HQs within an area of operation. Subject to bandwidth requirement this may not always be practical but when the bandwidth demand is within P3 capability, this is a very effective C3 option.



Figure 4. British Army 'UNICOM' P3 Deployments

### B. CIVIL DEFENCE & EMERGENCY

Communications are of paramount importance in the management of emergency situations. In crises such as fire, flood or explosions, existing communications infrastructures (typically fibre optic networks) are often damaged or destroyed, and an immediate task for emergency response teams will be to enable communications to and from the damage site. There is a further demand for interoperability of equipment between civil emergency response teams and the military.

It is commonly thought that wireless communications will provide an immediate and all encompassing solution. However, in a typical disaster area where no power and other infrastructure may be available it takes considerable time and resources to deliver and setup for wireless. As well, this technology has limitations in propagating in difficult terrain.

In such disaster situations, P3s have a proven functionality. A portable device that is weather proof and independent of power or other infrastructures can be deployed on site instantly. Multiple P3s may be interconnected expediently with field wire (reinforced copper wire) thus creating an independent data and voice network to allow affected communities to exchange video, email, voice and other data sensory information.

An issue which arises at the site of major disasters is the sheer number of personnel needing to communicate with each other. The presence of multiple government agencies and NGOs often results in their duplicating each others efforts and, more frequently, being unable to provide aid and relief due to unavailability of one or the other infrastructure. The P3 system, being compatible with industry data and voice networks as well as with each other, means an agency or NGO can tap in to the P3 communications, from initial through the ongoing stages of operation. The ease with which links are extended between

relief camps and actual disaster area of operation, makes it extremely effective to "reach" personnel via voice, data or video, provide full telemedicine capabilities and to offer affected groups communication with the outside world.

### VIII. FUTURE OF THE COPPER BASED TRANSMISSION

A number of technological developments in copper based transmission ensure a future path for tactical data modems that use copper cables.

There is always the predominant factor of its low cost and ease of use and repair when compared to fibre-optic based system. However, advances in new modulation technologies are offering considerably higher data rates as well as bandwidth aggregation.

One specific technology variant that was selected as a basis for P3 replacement was SHDSL or Symmetric Hybrid modulation – allowing up to 6Mbps of symmetric bandwidth on a single pair of copper cable. A number of leading chipset manufacturers are integrating 4 SHDSL circuits in one chip; increasing the bandwidth to up to 22Mbps over comparable distance – see actual performance measurements over 8Km (5Mi) distance in [Figure-3](#).

Defence Communication Industry is already trialling these new products with the Australian Army with the new product available in the 3Q2010.

### IX. CONCLUSION

Over the period of 5+ years of substantial product use in the field by ADF and other customers, it has been determined that a considerable market in both defence and industrial markets exists for this type of product. The decisive factors for this are the dramatic savings in cost, setup and maintenance. Copper continues to be a soldier friendly medium and P3 resurrects its role in meeting today's communications needs.

While fibre optic will retain its role as the communications backbone, P3s provide an effective alternative to tactical data links on the brigade level and below. Its small size and stand-alone operation make it a versatile means of extending data links especially in harsh terrain where laying of FOC is difficult. This scenario is especially pertinent in areas where there is no clear line-of-sight, making radio based systems inoperable e.g. mountainous terrain or urban disaster recovery operations.

In short there is still life left in the old copper cable and in the words of one Australian Army Signaler, "P3 is a DON10 (sic WD-1/TT) resurrector".

### X. AUSTRALIAN ARMY FIELD TRIALS REPORT: "NEW TECHNOLOGY - WDD A/TT (DON-10) NETWORK"

Army uses fibre-optic cable to provide a communications infrastructure for logistic support. The fibre optic cable, kevlar-

armoured especially for Defence, is an expensive medium and suffers breakages from being caught up in the track link of tanks or broken by forklifts. These accidents, actual events during Exercise Phoenix, normally occur during night under blackout conditions. Although the fibre can be repaired, such repair requires return to base and expensive facilities.

Army traditionally uses Don-10 copper wire strands reinforced with strands of stainless steel wire to carry voice in the field. This cable, capable of withstanding heavy stress, still gets broken but is easily repaired by users. Wire cable deployment is also considerably easier to achieve than laying fibre optic cable. P4 xDSL was employed during Operation Phoenix and Crocodile West to prove an ability to replace fibre optic cable segments with Don-10 on selected long runs.

The following are some first hand impressions and feedback from Army users of the Don-10 technology on Operation Phoenix; "Soldiers understand this and they can fix it" (meaning wire and breaks that occur as opposed to fibre optic cable); "Can I get some more; "This is great"; and "Hey, it works".

Portable xDSL systems provide data rates over copper or steel cables that are acceptable with significantly reduced capital costs. P4 primary application during Operation Phoenix was to enable a transparent LAN extension within a large logistic area, located in the bush near Tindall.

A number of specific future requirements have been discussed. One such special development is a simple back-to-back xDSL modem, providing the Army with rapid deployment multimedia infrastructure over copper cable. It greatly reduces the cost-per-line factor due to the elimination of the more cumbersome subrack assembly of a standard system. This technology successfully provided the logistic LAN backbone on Operation Crocodile West, 150 km SW of Tennant Creek, when fibre optic breakages and distance limitations proved difficult to overcome.

The WDD A/TT (Don-10) LAN extensions are robust, cost-effective and well-accepted by soldiers. Tempest-rated within the restricted environment, the solution is now a Defence Infrastructure standard within the strategic environment however it is not yet formally accepted in the tactical arena.

*end of report*

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Support Office) for integrating P3s in to their portfolio and subsequent product management.

*This paper is dedicated to all Signalers that helped and guided the product development and have been a constant source of inspiration.*

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#### AUTHORS BIOGRAPHIES

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Alec began his career in 1981 in the telecommunications industry, with the then Telecom Australia (currently Telstra) in the area of Switching. Alec holds degrees in Digital Electronics and Communications and Advanced Microprocessor Design & Techniques.

Joining Philips (Public Telecommunications Systems) in 1986 Alec worked on introduction of fibre-optic transmission to major carriers with postings in Australia, Germany and UK.

Returning to Australia in early 2000 and having obtained further diplomas in small business management and as a healthy contrast, in contemporary music performance, Alec formed own company, Defence Communications Industry - specializing in design, development and marketing of communications products for defence and industrial markets.

Alec plays guitar, enjoys travelling and is an active AFCEA member.

##### **William Winter – VP Operations, Associated Industries**

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