Next Generation COFDM Microwave Links for Military Surveillance

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**Foreword**

EVERY NOW and then a technology comes along that can honestly be described as a ‘game-changer’. COFDM (Coded Orthogonal Frequency Division Multiplexing) is such a technology. By quite simple but ingenious means, it overcomes most of the hazards of wireless communication in difficult terrains, whether a city or mountainous landscape.

This Special Report opens with an article that looks at Enterprise Control Systems Limited, an award winning leader in the field of military surveillance, which supplies a number of key surveillance users with enhanced capabilities, taking advantage of COFDM microwave links. COFDM is a spread spectrum radio transmission technique which splits the data stream over multiple carriers with much slower symbol rate than a single carrier transmission. This gives resilience to multipath fading. The article goes on to describe EVENLODE, a lightweight data terminal specifically designed to meet the demands of Unmanned Aerial Vehicles (UAV), but which is equally well suited and employed for other airborne, ground and maritime data applications. The article ends by describing various operational advantages of the EVENLODE link.

The report goes on to examine COFDM, what it is and why does it work. It’s quite a technical section but we’ve managed to find some layman’s explanations to complement the technology rich ones. We also consider what the technology’s characteristics mean for users. We then look at the main purpose for which, in the context of this paper, COFDM is deployed – surveillance. What forces need to know may not have changed much but the speed and accuracy with which they need to know it has. Knowledge, as the article says, is power: so getting it and using it is critical to success. We then look at the variety of applications to which COFDM had been put. In particular, we look at the disruptive effect that a technology that can communicate around corners and past mountains brings to the whole communication scene. And we consider how the military are using the opportunities of COFDM. Last but not least, we ask ‘who needs COFDM?’ It’s great to have new toys in the box but we also need to know who can use them and for what purpose. We look across a range of civilian, quasi-military and military users of the technology.

From the definition of its acronym to the technical descriptions of how it works, this is never going to be easy reading. Let us hope that the efforts of the authors have allowed readers to understand a little more of what COFDM is and what it can do.

John Hancock
Editor

**COFDM Delivers Combined Military Surveillance and IP Data Links**

Enterprise Control Systems Limited

**Military Surveillance** demands high capacity, secure and robust data links to deliver the multiple, high definition real time images available from the sensors of modern surveillance platforms. Range requirements vary from tactical assets needing only 4-5 km through to long-range patrol surveillance systems demanding capability at least to the radio horizon.

Traditional VHF/UHF systems have provided low data rates for voice and highly compressed imagery. Satellite communications provide Beyond Line of Sight (BLoS) capabilities, but are severely capacity limited by virtue of both their cost and availability. Traditional military and commercial microwave Line of Sight (LoS) data links can be infrastructure independent and have been suitable for tactical ranges and for urban surveillance if utilising suitable waveforms. A typical application of standard microwave LoS data links has been to transmit surveillance video from air platforms to the ground.

The latest COFDM data links used for surveillance applications have now evolved to include an IP link to the platform combined with the high integrity, high capacity, military grade security and extended range of the latest generation of COFDM microwave links. The ‘uplink’ data path may be used to remote control sensors and/or control unmanned systems in the most demanding environments. As surveillance sensors, their platforms and capability have advanced they are now being matched by the capability and flexibility of the latest generation of COFDM microwave links that combine, to best effect, many of the attributes of legacy military data links with the performance of the latest imagery transmission systems. As surveillance sensor platforms become smaller and more pervasive in the battle space, COFDM microwave links are being adopted by those needing to realise the true capability of their sensors that are currently constrained by legacy military communications systems. Enterprise Control Systems (ECS), as an award winning leader in this field, is already supplying a number of key surveillance users with these advanced capabilities.
COFDM microwave links

Enterprise Control Systems Ltd (ECS) has since 2003 optimised the DVB-T standard for surveillance use, tuning the implementation to achieve the highest levels of integrity and availability, security and range performance that are essential to the military surveillance task. This advanced ‘militarised’ implementation of the highly capable COFDM scheme has been delivered to specialist customers since 2004. The robust nature of this link, the intuitive user interfaces provided and the aircraft certification/hype approval for all standard systems are the reasons why over 200 airborne ECS systems are now used for operationally-critical missions in over 40 countries. Continuing advances in techniques and technology coupled with the development of operational concepts and battle space surveillance solutions have now taken these capabilities to another level.

The ECS EVENLODE Data Terminal

EVENLODE is the lightweight data terminal specifically designed to meet the demands of Unmanned Aerial Vehicles (UAV) and equably well suited and employed for other airborne, ground and maritime data applications. A pair of EVENLODE data terminals behaves like an Ethernet cable between networks at either end of the link whilst simultaneously providing 2 High Definition (HD) video streams from the sensor(s). With advanced, flexible and even dynamic configuration control EVENLODE provides an innovative solution for the most demanding information exchange requirements in surveillance systems. The standard system provides 10 W Radio Frequency (RF) output and has been proven to provide links of up to 200 Nautical Miles (NM) range and, up to 21 Mbps data exchange rate. The system is available in L, S and C radio bands and is DO160 approved for airborne installation.

The even air, equipment, at 3 kg for the standard 10 W system has been designed for UAV and is modular. The standard EVENLODE air data terminal comprises of Transceiver, Power Regulation & Supply, Heat Exchange and, Linear Power Amplifier modules. The modules may be distributed for load balance, or be provided to meet bespoke operational requirements. A separate Video Encoder Module capable of encoding up to two video signals and two audio signals is supplied for direct video and audio input. The Video Encoder Module has 4 High Definition (HD) and 2 Standard Definition (SD) inputs. Any video input may be selected and switched, including during a mission, as an input to the two video encoders with the configuration and control of the Advanced Video Codec (AVC/H.264/MPEG4 P10) compression parameters also dynamically selectable. As such the Video Encoder Module is offered as a front-end video management system.

The data from the Air Video Encoder Module is presented to the transceiver as an Asynchronous Serial Interface (ASI) (Reverse ProPAGATIoN FORMS) along with the Internet Protocol (IP) data and multiplexed onto the Transport Stream. The Transport Stream data is then modulated using a COFDM technique and transmitted. An Internet Protocol (IP) data buffer is incorporated as part of the transceiver module to manage IP data fluctuations that may momentarily exceed the link capacity. Such that data is not lost, IP data is buffered at the transmitter section of the transceiver and released as soon as the link is capable of sending the buffer content. IP communication is point-to-point. Critically, for a surveillance asset, the ASI information (in most cases the sensor output) is transmitted omni-directionally to any number of receivers within range, each of which decodes the signal to view it. In this way the EVENLODE system is predominantly agnostic to the sensor platform orientation or motion and provides a secure data link from the sensor to multiple receive sites simultaneously, coupled with an IP link to the platform to deliver any available IP based functionality required.

To manage the trade-off between the available data rate and the link range, an EVENLODE system is provided with the ability to adjust the radio link parameters and optimise them for the surveillance task. The way in which this control is implemented is bespoke to customer, sensor and platform requirements. This control may be based on the assessment of the link range with Global Positioning System (GPS) data sent between the two link data terminals, by user control, by automatic sensing of the required data rate for the information requested to be sent or, by automatic link monitoring between the two data terminals.

EVENLODE ground data terminals may be provided specific to operational requirements with options for mobile, portable and static systems. A majority network voting system may be used to link any number of ground data terminals onto an IP network backbone. The Network Voting System automatically selects the Code (AVC/H.264/MPEG4 P10) compression parameters: the best receive signal available in the network and transmitting the same signal from every ground data terminal or, selectively by knowledge of the position of the platform.

The EVENLODE system is extremely flexible and can be configured to meet the demands of highly capable surveillance sensor systems. With close human factors analysis of customers requirements ECS is able to provide intuitive interfaces to EVENLODE systems and provide pre-set profiles for specific operational tasks, or even tighter configuration into mission systems. Fully embedded security is always provided, carefully integrated into these advanced systems so as to work in seamlessly with the complex demands of full motion video communication. Systems are supplied with either integrated Advanced Encryption Standard (AES) (subject to export license) or Substitution Cipher encryption.

Benefits of the Next Generation of COFDM Systems

Internet Protocol (IP) is fast becoming a ubiquitous interconnection standard within all platforms from the individual soldier system, through specialist battlefield vehicles, to ships, to aircraft and unmanned systems. For example Avionics Full Duplex Switched Ethernet (AFDX / ARINC 664 Part 7) is a standard that is replacing bus systems such as ARINC 429 for data exchange requirements on air platforms. It is therefore essential to integrate with these IP data bus systems.

Extending the platform IP data bus with an IP communications link that is already embedded within the encrypted COFDM data link from the sensor platform delivers a significant capability gain. The user gets a smaller, lighter, more efficient and substantially less complex system. These performance and capability improvements can be coupled with reduced size, weight and power consumption are most apparent on the surveillance platform itself, with a lower box/equipment count. However, the system improvement continues to roll out through the receive networks across the large number of potential consumers of the surveillance product, all of whom benefit from the simplicity, the tighter system integration and the increased performance available.
The EVENLODE System is extremely flexible and can be configured to meet the demands of today’s highly capable surveillance sensor systems.

The leading manufacturers of platform Electro Optical (EO) camera turrets continue with the Standard Digital Interface video outputs as their output of choice. These SDI outputs can be encoded and inserted on an MPEG2 P1 Transport Stream and sent as a Constant Bit Rate (CBR) datalink payload. The Transport Stream may be encapsulated with IP and presented onto an IP network using one-directional protocols such as Unidirectional Datagram Protocol (UDP) or the SDI may be encoded and presented to the IP network without indexing on a Transport Stream using Real Time Protocol (RTP) and a jitter buffer at the receiver. Control of platform sensors is increasingly IP-based. Therefore systems such as EVENLODE provide the ability to control platform sensors remotely over the COFDM link with the ability to send both SDI video via the Video Encoder Module, or any IP based information.

EVENLODE provides a remote IP network link which gives all manner of operational advantages. The EVENLODE link may be used to provide a remote terminal access on the sensor platform into a database or server system. The platform then has access to the server system information such as mapping, operational tasking and intelligence with remote access into this information over the COFDM EVENLODE link. In this way, the storage of sensitive information on the sensor platform is minimized and can be denied should the platform be compromised. The IP link may be used for messaging, transferring files, Video over IP and, to provide ‘internet-on-the-platform’. As an example, in the case of manned air surveillance platforms, it is now feasible to relocate the air surveillance sensor from the platform, to the controlling, or controlling, or providing the operator from the platform, to the controlling, or controlling, or the controlling.

As the surveillance ‘eyes’ of the battle space play an increasingly critical role in the execution of operations, it makes sense that everyone across multiple domains is able to exploit to best effect what these ‘eyes’ can see. Today’s sensor platforms are increasingly becoming ‘un-tethered’ from their single points of control and single points of product ingest into the battle space. The dissemination of surveillance product direct from the sensor platform to the widest number of potential users, without adding the burden of complex user to user transport has been happening as a quiet revolution for some time. The continued deployment of advanced COFDM techniques optimized for the military surveillance domain and their combination with platform and networked C2 is adding yet another step-change improvement in the delivery of this vital commodity.
COFDM: What Is It And Why Does It Work?

Peter Dunwell, Correspondent

COFDM is a modulation scheme that divides a single digital signal across 1,000 or more signal carriers simultaneously. The signals are sent at right angles to each other (hence, orthogonal) so they do not interfere with each other.

COFDM sends its message using multiple transmitters all on the same frequency (frequency division multiplexing) which are transmitted at right angles to each other. This has the effect of enabling the signal to cope with terrain related disruption better than if only one transmitter is used and the whole signal goes in the same direction, and that makes it very good for surveillance systems.

This is quite a technical area so that, inevitably, explanations tend towards the technical, such as Tektronix. “Coded” means that the data to be modulated has error control. Orthogonally means that the spectra of the individual carriers do not influence each other. A single-frequency network is used for the actual transmission. This is a modulation scheme used for digital transmission that is employed by the European DVB system. It uses a very large number of carriers (hundreds or thousands), each carrying data at a very low rate. It is, therefore, particularly suited for mobile reception and for single-frequency networks.

What It Means for Users

Perhaps a less technical but more accessible explanation comes from TechTarget on SearchNetworking: “COFDM is a modulation scheme that divides a single digital signal across 1,000 or more signal carriers simultaneously. The signals are sent at right angles to each other (hence, orthogonal) so they do not interfere with each other.” The articles can also be mined to explain that towards the technical, such as Tektronix: “Coded” means that the data to be modulated has error control. Orthogonally means that the spectra of the individual carriers do not influence each other. A single-frequency network is used for the actual transmission. This is a modulation scheme used for digital transmission that is employed by the European DVB system. It uses a very large number of carriers (hundreds or thousands), each carrying data at a very low rate. It is, therefore, particularly suited for mobile reception and for single-frequency networks.

What COFDM Can Manage

What may be of more interest to users is that COFDM enables signals to cope with terrain and infrastructure that might have blocked older transmission systems because its multiplicity of transmitters and variability of direction mean that, where there is an obstruction, different transmissions will ‘approach’ it at different angles ensuring that some will get past. It has been described as allowing signals to ‘flow’ around obstructions.

Interestingly, OFDM/COFDM has seen a lot of development in connection with digital television and audio broadcasting. The reasons for this are that, being less vulnerable to disruption, it is better able to maintain the quality and integrity of terrestrial high definition television (HDTV) and digital audio broadcasting (DAB) where it not only copes with terrain and environment related disruption but also can deal with changes experienced by a moving receiver, such as in a car. COFDM has made DAB car radio possible. While this has no particular surveillance relevance, it illustrates the capabilities of OFDM/COFDM links.

The concept actually grew out of Multi Carrier Modulation (MCM) developed for military high frequency (HF) radios in the late 1950s which divided streams [messages] into several parallel streams used to modulate several carriers. And it is still military applications where a lot of the progress is being made with the development of COFDM links to improve surveillance prospects by combining a number of COFDM radio together over a wide area so that whichever one is able to get the best surveillance, the whole mesh can be used.
Surveillance is Not an Academic Matter
The armed services might regard the quality of surveillance in terms of the difference between knowing the enemy’s plans, positions and routes or being caught out by a surprise assault... the difference between life and death. But, not everything in warfare has changed so much. One of the critical tasks of surveillance, even as we move from the industrial age to the information age, is to discover and understand the enemy’s positions and, from a distance, to use modern surveillance technologies to gather intelligence. Surveillance has long been the prerequisite to success in battle. Of course the calibre of the people and the quality of the equipment with which they fight are massive factors but, as guerrillas from the Vietcong to the Taliban insurgents in Afghanistan have shown, knowing the terrain on which you are fighting, knowing your enemy’s dispositions and strength, and being able to deny the enemy that knowledge of your force can enable militarily weaker fighters to inflict deadly and damaging damage to a larger, better equipped force.

New Technologies Delivering Established Principles
These days, the range of questions for which surveillance is the answer is larger than ever and in which soldiers still lose their lives. Battlefield protection and troop protection remain key priorities in any action and it will usually be surveillance that will enable troops on the ground to call in and provide targets for support forces and/or air strikes.

Some Things Have Changed...
The asymmetric type of war that armed forces feel they often have to fight today is against an enemy who is less predictable, less likely to be organised in obvious formations and more likely to choose the general population rather than a clear target. Therefore, even with the latest technology and equipment, the success of any military campaign is only as good as the quality of information that can be delivered to processors. If it is accurate, it is possible to mount an attack and deter. If it is not, the attack will fail.

Businesses that rely on knowledge delivered to a processor to inform decision-making understand that there is no substitute for good intelligence when operating in the modern world, where the enemy is less predictable, less likely to be organised in obvious formations and more likely to choose the general population rather than a clear target. Therefore, even with the latest technology and equipment, the success of any military campaign is only as good as the quality of information that can be delivered to processors. If it is accurate, it is possible to mount an attack and deter. If it is not, the attack will fail.

... Others Remain the Same
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A Variety of Applications

Francis Slade, Staff Writer

**COFDM is making its mark in both the civil and military worlds but for very similar and transferable purposes**

**Convergence and Disruption Create a New Paradigm**

Two of the most potent terms in technology today, are ‘convergence’ and ‘disruption’. Convergence is easy enough to explain; it’s where two or more technologies come together to create a device with multiple capabilities such as mobile phones with web capability, music players and cameras. Disruption almost suggests a negative effect whereas it really means the creation of a new paradigm, such as the same mobile phone’s impact on the retail music market and the rise of people’s journalism.

These effects can also be found in the realms of communication links where the technology of COFDM is, as its acronymic nature results from the convergence of several other technologies (explained elsewhere in this paper). It has also made possible a number of applications that might previously have been problematic. Some of these are in the civil realm and, while this is a defence inclined paper, there is something to be learned from civilian applications of shared technologies.

**At the 20th International Television Symposium in 1997, JJ Stott of the BBC explained:** “Coded Orthogonal Frequency Division Multiplexing (COFDM) has been specified for Digital Broadcasting systems for both audio – Digital Audio Broadcasting (DAB) – and (terrestrial) television – Digital Video Broadcasting (DVB-T). COFDM is particularly well matched to these applications, since it is very tolerant of the effects of multipath (provided a suitable guard interval is used).” However, rather more involved than simply adding coding – the ‘C’ – to an uncoded OFDM system. The coding and decoding is integrated in a way which is specially tailored to frequency-dependent channels and brings much better performance than might be thought based on a casual inspection.

It is COFDM’s ability to cope with the potentially disruptive effects of urban structures that makes it particularly suitable for terrestrial digital broadcasting.

**Capability Transfer**

This ability of capability can then be transferred to a more militaristic purpose, surveillance. These days and to an increasing degree, governments and public authorities use surveillance as one tool in their efforts to maintain safe streets and manage the areas for which they are responsible. But, in an urban environment, surveillance, like any broadcast system, can be subject to disruption from the effects of the urban infrastructure. COFDM can be applicable here. "An entire city can be covered by COFDM video and IP solutions, enabling government and law enforcement authorities to protect citizens, keep transport infrastructure running smoothly and combat major crime, terrorism and drug trafficking. With high powered receivers mounted at strategic elevated positions, video and audio information can be transmitted to local and central monitoring points... (And) if first responders, such as the ambulance service, utilise body worn cameras at the scene of an accident, they can send pictures via strategically placed receivers directly to the nearest hospital, enabling accident and emergency personnel to prepare for incoming patients. Once mobile in the ambulance, all the patient’s vital signs can be shared with the doctors and they can, in turn, offer additional advice to paramedics if needed."10

**Technology Transfer**

But, of course, as much as a military force wishes to preserve the quality of surveillance and information, an enemy, especially a technically advanced enemy, will wish to disrupt both the gathering and communication of data. To that end, the British Army has developed a number of digital communications systems to function in, “An extremely complex environment where increasingly large amounts of information must flow without interruption, whilst being protected from exploitation or disruption by a technically advanced enemy.”11

**Land, Sea and Air**

This issue has become even more pertinent with the advent of unmanned ground vehicles (UGV) in the surveillance role. As Armed Forces International puts it11: ‘‘While the shape & size of these unmanned vehicles will continue to evolve, one requirement will remain constant – the communications link between personnel and UGV’s must be as reliable as the information being gathered. Video, audio, data must be brought back in real-time, clearly, and flawlessly. With robust communications equipment essential to transmitting high bandwidth traffic over terrestrial or satellite networks, high quality digital microwave and COFDM technology provide the ideal solution.’’

**The PA Consultancy Group’s report, Defence Demand for Spectrum 2008-2027 acknowledged the part that COFDM could contribute for the MoD in getting the best return for the communications spectrum available to it12.**

Given the range of tasks to which armed forces are now applied, surveillance does not always occur in battle conditions but might as likely occur at sea where forces are deployed to deal with piracy or drug smuggling. As on land, a COFDM digital video transmitter with integral cameras and GPS will provide a vital and secure situational awareness system for sea based law enforcement operations. The same will also apply for air to ground communication requirements where aircraft (often unmanned) are used for theatre surveillance or to track individual threats. The information will need to be sent to the operational bases very quickly and accurately to allow a proper course of action to be determined.

**Disruptive Technology**

COFDM does not only enhance the quality and speed of communications, it makes possible new types of warfare such as we are increasingly seeing in areas where nobody wishes to risk boots on the ground ‘but where intelligence and action are necessary – truly disruptive technology in every sense.’
Who Needs COFDM?

Peter Dunwell, Correspondent

It’s surprising how many great applications there are for a technology that revolutionises communications links

The system copes well when line of sight is not always available because the way it constructs transmissions allows signals to go around obstacles without causing interference at the receiving end.

Enabling Technology

COFDM is the enabling technology behind a revolution in broadcasting and electronic communications. In his paper, ‘The how and why of COFDM’, JH Stott explains; ‘DAB (unlike its AM and FM predecessors) was especially designed to cope with the figures of reception in moving cars – especially the problem of multipath reception which, in this case, is time-varying. For DMB-T, a higher capacity than DAB was essential, mobile reception was not a priority, but multi-path tolerance was still important because of the widespread use of set-top TV antennas. A new form of modulation – COFDM – was chosen for both systems, albeit with differences in detail, and with appropriate changes of parameters, to suit the different requirements of DAB and DMB-T. Both systems include a degree of flexibility."

Other Uses

That ‘all-terrain’ ability to function without line of sight is also useful in other contexts. News organisations that need to be able to survey a cityscape for local programming find that COFDM allows them far more scope in where they go and from where they can broadcast. COFDM offers a number of advantages over conventional microwave for which either a line of sight or a devised pathway is necessary in order to get food communication. Also conventional microwaves can be distorted. COFDM does not require line of sight or a devised pathway nor will it be degraded or distorted by outside influences.

The system copes well when line of sight is not always available because the way it constructs transmissions allows signals to go around obstacles without causing interference at the receiving end (see elsewhere in this paper for technical explanations). Microwave Communications described the capability as, “benefitting greatly from the inherent multipath advantages that COFDM provides; if a few carriers are lost to multipath, the lost data can be easily recovered by error coding.” COFDM can cope better than other systems with echoes and reflections.

Police and Civil Applications

Police forces certainly understand the value. For instance, for the Beijing Olympics, Beijing Police used two helicopters, vehicles and a base network fitted with COFDM technology from a British firm to enhance their ability to manage the Olympic park, its environs and the wider city during the event. The equipment enabled the police to upload pictures from vehicles so that the picture could then be re-broadcast simultaneously along with an image from the gyro stabilised camera mounted on the helicopter. This ability to achieve real-time surveillance data use gave the police instant situational awareness which was described as a force multiplier, i.e. it allowed the police to do more and to do it more effectively.

In other applications, COFDM is a valued part of the ‘protection’ toolkit for those assigned to protect VIPs. “The mobility of the VIPs determines the technology that has been employed as well as its flexibility and portability. The mobility of the operations as well as the targets needs to be covered with appropriate surveillance systems. Surveillance requires that information be consolidated, stored and ultimately processed in real-time in order for the management to be able to control on the spot decisions inside the headquarters. The systems should be such that there is no gap between the on-site operation and the centralised information management... With increased insecurities among the royalties, celebrities and various government dignitaries, there is a high demand for RF jamming capabilities from the security personnel. The UK came up with the first digital COFDM Microwave links late in the 1990s for video surveillance.

The UK came up with the first digital COFDM Microwave links late in the 1990s for video surveillance.

These should be provided alongside military surveillance as well as police control systems.

Military Service

In military service, “COFDM digital microwave provides clear advantages over alternative radio technologies in the delivery of video, audio, and data. These advantages are easily demonstrated over long distances and in unforgiving environments where significant multipath interference occurs.” COFDM based technologies can support specific operations such as the sea and air surveillance of a particular area. They can also be used to communicate with an individual unit to detect threats and where they are coming from in order to inform their own actions or to call in external force such as air strikes. And a whole surveillance system to serve national security and defence can use COFDM technology in linking units on land, at sea and in the air with the main command centre and mission management centre.
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