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Analogue v Digital

When real time, broadcast quality video is required with no latency, analogue transmission is often the ideal solution. Digital can provide high quality video but time is required to undertake the compression and decompression processing. The delays introduced by our digital equipment are as low as possible at less than 50 mS, but nevertheless it is not true real time. Similarly although digital DVB-T provides high quality images, far higher than that possible with IP based systems, some of the video is nevertheless discarded, thus inevitably some of the detail will be lost.

The conclusion from this is that analogue transmission is generally particularly applicable to safety critical monitoring systems in railway applications where no significant delays or loss of quality can be accepted. They are also applicable to long-range camera systems where loss of clarity or resolution would be unacceptable because it would necessitate even longer focal length lenses, or to city centre systems where real time operation is essential for the efficient tracking of targets.

The major disadvantage of analogue is that it has a very limited non-line of sight capability. Thus if there is no line of sight between the camera and the Control Centre, it will be necessary to install repeaters or relays. Digital links on the other hand, if they use the lower frequency bands, have a non-line of sight capability albeit at 10% of their line of sight range, and therefore are ideal for mobile and transportable applications.

The other disadvantage of analogue is that the bandwidths are generally higher than those required for compressed digital transmission, although in practice within the frequency bands used by our equipment, several hundred cameras can be installed in a medium sized town without any limitations or interference

Thus in general, the digital links are preferred in mobile or transportable systems where lines of sight cannot be guaranteed or if there are many hundreds of cameras located within a few square kilometres of one another.

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DVB-T v Internet Protocol

In digital systems, when image quality is of prime importance the use of Digital Video Broadcast – Terrestrial (DVB-T) is essential. The standard was developed by broadcasters and provides a good image quality despite the compression processing.

Our DVB-T based equipment is therefore suitable for the vast majority of surveillance applications providing latency is not an issue and providing the very highest video quality is not a requirement.

The disadvantage of the DVB-T system is that although it requires less bandwidth than full quality analogue, it nevertheless uses higher data rates that IP based systems. For example, it is possible to transmit up to 20 IP videos in a single Ethernet channel on one of our equipments, whereas only 5 DVB-T channels can be transmitted or just one analogue channel.

Thus if low or moderate quality video is acceptable for any specific application, for example in general surveillance where the prime requirement is to monitor the overall activity and detect unusual occurrences, the use of IP could well be the right solution. This may be true in commercial premises, car parks and supermarkets, where positive identification is of secondary importance to that of reacting to events.

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Frequency Selection

If there are no other constraints, the higher frequency bands are preferred because more spectrum is available, which in turn means that there is more capacity. In addition there are fewer other equipments operating in those bands and the antennas tend to be directional, which means that the possibility of interference is remote. This together, with effective co-ordination allows us to unconditionally guarantee interference free operation.

The other feature of high frequency transmission that is especially important in military systems is that the technology is very advanced, which means that equipment is not freely available. This together with the use of narrow bean antennas means that they are far less vulnerable to unauthorised reception or deliberate jamming.

These are the major benefits in using the 31 GHz and 58 GHz bands. Against this, the higher frequency bands and especially those above 10 GHz are more susceptible to signal loss due to rain fade; the higher the frequency, the greater the loss. In some parts of the Middle East this is not a major problem, but elsewhere, especially the tropics, the range of the high frequency links can be very limited.

It should be noted that all our equipments are set up to provide a specified availability under all weather conditions. No links are supplied with less than 99.95% availability, i.e. a loss of signal due to heavy rainfall for up to 5 hours a year, but we can supply equipment with availabilities of 99.99% or even higher.

Typically the range of a 31 GHz link is up to 10 km in Europe, 15 km in the Middle East but as low as 5 km in the tropics where 100 mm/hr of rainfall can frequently occur. The range of the 58 GHz equipment is even shorter because as well as rainfall, oxygen absorbs the microwave signal. Typically 94% of the signal is lost every kilometre due to this effect alone. The overall result is that 58 GHz links are only suitable for short ranges of 1 km or less.

Thus, if very long ranges are required, it is necessary to use lower frequencies. The ideal is the 4.5 to 5 GHz band because it is substantially unaffected by weather. In most countries, it is also protected by licensing in that it is not a public or licence exempt band and therefore has improved immunity against interference. The ranges of the 5 GHz links can be as long as 100 km for single channel equipment or 80 km for multichannels.

Clearly there are other frequencies in which transmissions could be made, most notably the licence exempt bands around 2.4 and 5.8 GHz. Although we manufacture equipment in these bands and there are many advantages in using them, the major disadvantage is that they can be used by anyone and there are generally fairly lax controls on the characteristics of equipment at these frequencies.

This means that interference is a serious problem in cities and towns, and becoming increasingly so as more and more domestic items including laptops and other equipment use these frequencies. The issue is discussed in more detail in another download but in summary, we only recommend the use of these bands for very short range links in cities or for ranges of up to 2 km in the countryside. Even so, no-one can guarantee interference immunity.

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Licenced v Public Band

There are three advantages in using the public bands at 2.4 and 5.8 GHz. The first is that there is no licence fee to pay, and in most countries the regulations and controls associated with equipment in those bands are relatively lax. This means that it is easy to set up a system and to operate it to its maximum capability without any undue regulatory involvement.

The second benefit is that because the frequencies are low, there is relatively little fade due to rain and other weather effects. In addition the lower frequencies allow the signals to penetrate walls and foliage or to be reflected from the local terrain, walls and other structures, which in turn means that it allows non line of sight transmissions to be achieved without too much difficulty.

The third advantage is that the equipment is cheap. Most equipments are based on Wi-Fi or other similar technologies, the chips for which are included in laptops and other devices and are therefore available from several suppliers at very low prices.

The major disadvantage is an inevitable consequence of the advantages. Because there is no licence, the bands can be used, and are used, by everyone. All the wireless laptops in the world use these frequencies. This is in addition to other wireless systems, every microwave oven and any of number of ISM systems. Interference is therefore inevitable.

This is not a serious problem in domestic applications where the ranges are very short at a few tens of metres. It is also not a major limitation in local area broadband wireless systems that provide access to the internet because these systems are packet switched, such that if there is interference on one packet it is simply re-transmitted. The overall effect is that the transmission rates are slowed.

In CCTV on the other hand, the effects are much more noticeable because the video is required to be transmitted continuously in as close to real time as possible. Any interference will cause the picture to freeze or perhaps become corrupted, which will then cause problems for operators if they need to use the system to follow an incident or perhaps to track a target.

Technologies have been developed that claim to reduce interference. Spread spectrum is one where the power is spread over the full band. In theory and at low data rates, it is very effective, but in practice at the moderate or high data rates used in CCTV, the benefits are negligible. Similarly, the use of adaptive antenna arrays to null out the interference has been proposed. These systems provide some advantage but only at the Control Centre, not at the camera, and the benefits rapidly dwindle in the real world where there could be many sources of interference.

Interference becomes more serious as the ranges increase. The use of multiple channels alleviates the problem to some extent but nevertheless it is inevitable that interference will occur if the technology is used in a citywide CCTV system. At present the rule of thumb is that the system can be employed in a retail park a few hundred metres square because there is a reasonable level of confidence that there will be no interference. In the future however, with the increasing use of Wi-Fi and Wi-Max, there can be no certainty that this will continue.

On the other hand in a town centre system, it is almost certain that there will be interference sooner or later. In some cases, this can be avoided by switching channels or by re-locating units. In other cases, nothing can be done and the system will inevitably be degraded.

Licenced bands by comparison require regulatory approval, which can sometimes be difficult to obtain. In the UK, some other European countries and in many parts of the Middle East there are no serious problems in obtaining licences. Elsewhere however, the bureaucratic problems can be immense and it is virtually impossible to obtain a licence, in which case there is no option but to use a licence exempt band.

The major benefit of using a licenced band is that interference free operation can be unconditionally guaranteed. The other benefit for military systems, is that the use of the high technology at 31 and 58 GHz together with the narrow antenna beamwiths makes unauthorised reception or deliberate jamming virtually impossible.

In addition, since considerable spectrum is available in the higher licenced bands, 600 MHz at 31 GHz and 1,000 MHz at 58 GHz, no compromises have to be made on the video quality by reducing the data rates and the bandwidths. The same is not true in the licence exempt bands where the bandwidths are very limited and compromises have to be made if there are more than a few cameras in the system.

The two disadvantages in using the licence bands are the cost of the equipment, which is higher than the unlicenced because it is specialised professional equipment rather than being based on consumer products. Also, in general the only licenced frequencies are high and therefore it is impossible to use them for non line of sight systems because the signals do not penetrate walls and foliage or reflect efficiently from buildings.

The conclusion from this, and our recommendations are that if the equipment is to be used for a safety critical application or as part of a high priority security system, the use of public, licence exempt should be avoided. It should not even be considered. Such systems have to use licenced bands.

Similarly when high quality video and interference free operation is essential a licence band should be used. In these applications the licence exempt bands should only be used if it is impossible to obtain a licence.

Licence exempt frequencies could also be considered in CCTV systems for commercial areas or in small housing complexes. However if this is done, the customer has to be advised of the interference risk. They should not however be used in a large or significant citywide systems because interference is almost inevitable. Indeed many systems that use public bands have been switched off simply because the interference problems are now becoming intractable.

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Line of Site v Non Line of Site

A non line of sight capability is essential for mobile systems. It is also useful in fixed systems because it can in principle avoid the need for collecting points or relays. If the conditions are right, it may in certain circumstances be possible to transmit directly from the camera to the Control Centre.

There are however serious limitations. All non line of sight systems, including our own, require the signals to be transmitted through walls or foliage, or to be reflected off buildings. If this is not possible then clearly no signal will be received at the other end of the link. It is difficult to be precise about the loss of signal when reflections occur but generally there is a 20 dB loss, which corresponds to a 10:1 reduction is range. Thus if a system has a line of sight range of 30 km like our vehicle mounted Mobile-T, it will only have a non line of sight range of 3 km. The effect when the signal has to penetrate through walls is more variable. Sometimes the loss can be 20 dB, but on occasions it can be considerably higher.

In general, the best rule of thumb is that a 10:1 reduction in range is the best that can reliably be achieved providing there is only one obstruction or only one reflection is required. If two are necessary to complete the transmission path, the loss could be double this, i.e. a 30 km system could have a range as low as 300 metres. This effect is universally true and is irrespective of the modulation.

For example, the DVB-T system we supply uses a 2,000 carrier OFDM modulation scheme whereas the best Wi-Fi option, including that used on our Ethernet equipment has only 64 carriers. This means that the DVB-T solution is far more resilient to the errors introduced by reflections, but despite this it does nothing to improve the range under non line of sight conditions.

The other serious limitation in relying on non line of sight paths is that the characteristics of the paths can well change, which means that one day there may be good communications between the cameras and the Control Centre, whereas on another day the path could become marginal or even lost. This is a typical problem with Wi-Fi and Wi-Max equipment and whilst not too serious if it is merely providing internet connectivity in domestic applications, it could be serious for professional CCTV systems where it is unrealistic to move the equipment.

An example of this is that in a separate business area we manufacture a broadband wireless system that requires a line of sight. We supply it to ISPs who use it to provide business services. The same ISPs also provide some of their domestic subscribers with internet connectivity using other non line of sight systems. However since the availability of such systems is variable and uncontrolled, the ISPs do not consider using the non line of sight system for their business customers simply because the transmission cannot be guaranteed.

In summary therefore mobile systems have to use non line of sight systems. In fixed systems however there is a choice and our recommendation is always to use a line of sight system if reasonable ranges and a high availability are required. Alternatively if these requirements are not particularly important, it may be possible to use a non line of sight system. A possible variation is to use non line of sight systems for short range applications to communicate to a collecting point and then to use a long range line of sight system to complete the communications to the Control Centre.

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Point-to-Point v Point-to-Multipoint

Point-to-Point systems are the norm for most professional CCTV systems. The major benefit is that it allows frequencies to be reused on the links to different cameras because the antennas provide discrimination between the signals. It therefore has a higher capacity than a Point to Multipoint system that has to employ a different frequency channel for each camera within the beam at the Control Centre. Typically, all other things being equal, the capacity of a Point-to-Point system is three to five times greater than a Point to Multipoint.

The second benefit of a Point-to-Point system is that the equipment need only be purchased when it is required, whereas in a Point to Multipoint, a relatively complex Base Station is necessary at the Control Centre, even if there are just a few cameras in the network. Thus depending on the features, it could be a more expensive option for a few cameras, but considerably cheaper if there are many. In this case however it is important to recognise that the available bandwidth will have to be shared between all the cameras and inevitably compromises will have to be made on data rates, which will impact on the picture quality.

In practice Point to Multipoint systems are only used in IP based systems. Many companies supply such equipment in the licence exempt bands, whereas we supply equipment in the 10.5 GHz licenced band.

An important exception to the above is our Multichannel link in a collecting point configuration. Here, single channel links transmit from the cameras to the collecting point, and a Multichannel link transmits from the collecting point to the Control Centre. In this case, when an additional camera is required, a new single channel link has to be fitted, but additional modules only are required in the Multichannel link to carry the video back to the Control Centre.

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Broadband Wireless CCTV Transmission

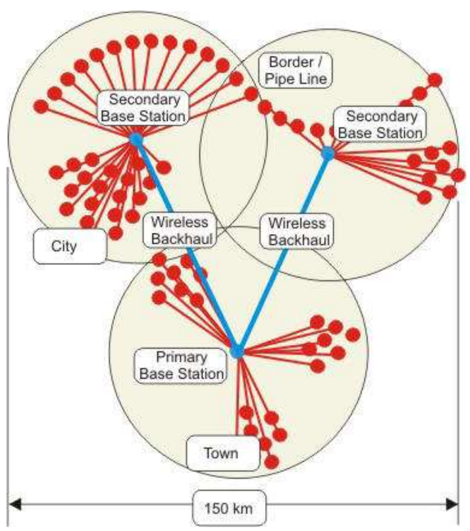
Ogier Electronics

1 Summary

This paper describes the advanced broadband wireless system that is capable of transmitting video and data over ranges of 40 km from many hundreds of CCTV cameras to a common Base Station.

The primary application is for CCTV cameras when they are installed over a wide area, such as in a town or city, but where they are not necessarily required to be viewed continuously, and the video quality requirements are lower than those for city centre CCTV networks. Such applications are for commercial premises such as banks, supermarkets and industrial sites when CCTV is generally only required in the event of a security problem.

A network of base stations using the wireless itself for the backhaul can provide the communications over very large areas of up to 20,000 square km. These applications include oil fields, pipe lines and large military bases.



Coverage with wireless backhaul

The core of the system is the high technology 10 GHz point to multipoint wireless equipment developed by Ogier Electronics; a system that is in commercial service in several countries around the world.

It complies with DOCSIS - the world standard for cable internet systems and uses the latest generation of hardware from Cisco Systems and other major manufacturers. A minimum of infrastructure is needed. This makes it easy to install and allows cameras to be commissioned and operational in hours.

The system incorporates a number of features that are essential for high security applications. High frequency directional antennas make the transmissions more difficult to detect or jam than low frequency, public band, wireless. The system encodes the video and data to ensure that only authorised users can interpret the information. It is also appreciably more resilient to attack than optical fibre or cable where complete networks can be disabled by cutting the fibre or cable in unprotected areas.

Because of this, the system is ideally suited to areas where on-going security operations demand an efficient, robust and easily installed CCTV transmission network.

2 Description

The system comprises four major elements:

- The cameras and compression
- The wireless units
- The base station hardware
- The system controller

Each of these elements is described below.

2.1 Cameras and Compression

Ogier CCTV transmission as used in Sharjah

The equipment comprises the camera and lens, the pan and tilt mount and the video compression unit.

The wireless system can transmit video from almost any camera, ranging from simple fixed internet units to professional low light devices with pan, tilt and zoom controls. Video can also be transmitted from IR or other night vision cameras.

This flexibility means that different types of camera can be used in a mix and match arrangement to suit the requirements at each location in the network.

The camera outputs are connected either to MPEG2/4, H261 or motion MJPEG video compression modules which are available from many manufacturers.

MPEG provides higher video quality than Motion JPEG for the same data rate, but has a longer latency of 50 to 200 mS. With fixed cameras this is clearly not a problem. Similarly it is not usually too serious a concern if the PTZ controls are merely required to pan to different areas rather than to track moving targets. Unless the absolute minimum latency is essential, the higher resolution MPEG solution is recommended.

Indigovision MPEG4 Compression

2.2 Wireless Units

The standard equipment comprises a wireless access module, a power supply and a cable modem. All the units are connected by a single low loss coax cable.

The dimensions of the wireless access module are only 22 x 21 x 5 cm. It is designed for all-weather operation on simple wall or pole installations. It requires a line of sight and alignment to the base station, but because the beam is relatively wide the alignment can be performed by eye in all but the most critical cases.

The wireless module provides access out to ranges of 10 km with availabilities of 99.99%. Standard 60 cm parabolic antennas can be used for longer ranges out to 40 km.

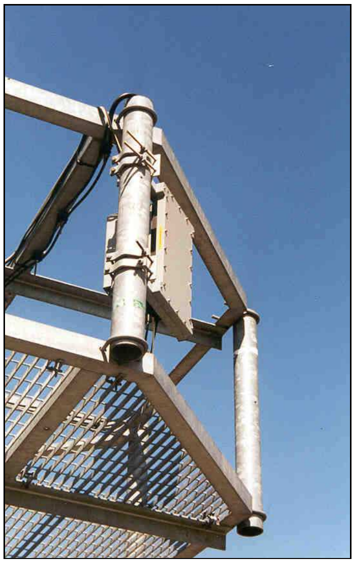
Camera Wireless Unit

2.3 Base Station Hardware

The base station requires only two types of unit

A Router and Upconverter
A Transceiver, Antenna & Power Supply

A Transceiver is usually required for each azimuth sector. However, in low density applications, a single Transceiver can feed two back-to-back 90 degree sectors. In this way, only two Transceivers are required for 360 degree coverage, but additional units can be added at any time should the capacity requirements increase.



Base Station Transceiver

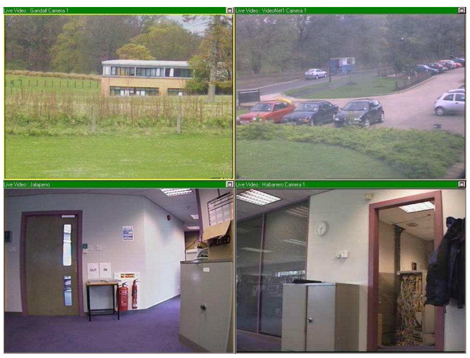
The Transceivers are interfaced to the Router through an Upconverter in the downstream direction. The connections are direct in the upstream direction.

A powerful router like the Cisco Systems uBR7246VXR has a modular design that enables it to be expanded in service by adding cards to provide the data processing for up to 8 Transceivers.

At the opposite end of the spectrum, low cost "pizza box" solutions may be more appropriate for smaller systems.

2.4 System Controller

The system can display each video in any number of ways from full screen, to quad or 16 videos per screen, using analogue or digital monitors.



Typical quad format

In most systems quad formats of the type shown above are used for general surveillance with full screen displays of any operator selected video. Map overlays and touch screen controls can be incorporated.

Video motion detectors are recommended in high capacity systems with hundreds of cameras, especially if many are located in sparsely populated areas. In this way, the videos need only be viewed when the pictures change. The motion detection can be local to the cameras, or at the control centre.

Recording can also be local or central. The fact that the system is entirely digital from the camera onwards, means that there is considerable flexibility in where these functions are implemented.

3 Capacity

The simplest base station provides a usable data rate of 32 Mbps in both the downstream and the upstream directions. This is sufficient to operate 32 cameras, all transmitting simultaneously at 1 Mbps. In practice only 1 in 5 cameras usually operate at the full rate at any time, with the others using much lower rates. This means that 100 cameras can be supported in a typical small system.

The capacity can be increased by the addition of modules and units. Plug in cards can be fitted in the Routers and additional Transceivers can increase the angular coverage or the capacity in any sector.

The system uses up to 90 MHz in each direction. It employs spectrally efficient modulation to achieve a useable data rate of almost 150 Mbps in each sector - 600 Mbps from a single station. This corresponds to 600 cameras all transmitting simultaneously, or more than 2,000 in a real multiplexed system. In practice the capacity is even greater because several base stations can be co-located within the coverage area.

4 Options

The configuration of the system is particularly flexible. Cameras can be added at any time. To activate a new camera, the operator simply allocates it an address and a channel number.

The capacity can be increased and the coverage can be extended by the use of repeaters or by adding Base Stations. Other services and remote monitoring can also be provided.

4.1 Repeaters

The range of the system can be extended and blind sectors “filled in” by Repeaters which relay the signals between the Base Station and the cameras.

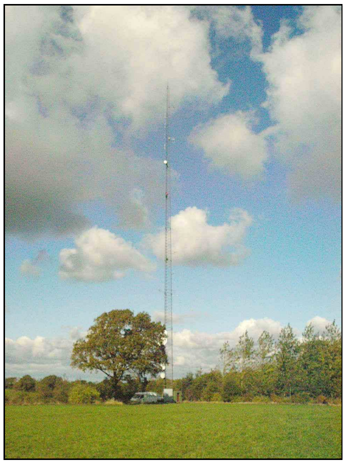
Simple Repeater

The most sophisticated Repeater comprises a unit that provides the communication to the Base Station, and has one or more Transceivers to provide coverage to the local cameras.

At the other extreme, very compact Relays as shown in the photograph can be used to cover localised blind spots.

4.2 Secondary Base Stations

The complexity of the backhaul to the outside world can be reduced by aggregating the data requirements of several base stations using the wireless network itself to provide the communications between the stations.



Secondary Base Station

The secondary Base Stations can be located up to 30 km from the master without the need for any additional equipment. However if a dedicated directional antenna is used at the master, the separation to the Secondary stations can be up to 80 km.

4.3 Data and Voice transmission

In addition to video, the equipment can transmit voice, or data at rates of 4 kbps, both upstream and downstream, to any user. The interface is 10baseT Ethernet.

A performance equivalent to dedicated leased lines can be made available, but it tends to be wasteful in spectrum. To overcome this the transmission system uses the DOCSIS protocol, which is the world standard for cable networks. It is a packet switched protocol that enables many users to share the available capacity in the most efficient way possible. Typical contention ratios up to 20:1 are used

4.4 Internet Connectivity

The system operates in a stand alone mode as a totally self contained network. However, it can also be connected to the internet so that the video and the data can be made available to authorised users anywhere in the world. In these circumstances the system becomes a virtual private network.

The Cisco Systems Routers are specifically designed for internet compatibility and form the basis of the majority of the world's cable modem networks.

No changes or modifications to any of the elements of the network are required to enable internet connectivity. The interface can be Ethernet, ATM or virtually any international protocol. The physical connection can be either cable, fibre or satellite VSAT.

5 Specifications

The top-level outline specifications are provided below. More details on any part of the system can be provided if required.

Camera interface	PAL or NTSC
Camera control	Fixed or proportional PTZ
Digital compression	MPEG2/4, H261 or JPEG
Data rate per camera	0.5 to 2 Mbps
Camera capacity	2,000 per base station
Video quality	Equivalent to VHS
Transmission Frequency	10.2 GHz downstream 10.5 GHz Upstream
Bandwidth	30 to 90 MHz
Transmission protocol	DOCSIS
Camera to base station	10 km as standard 40 km with 60 cm ants
Base station capacity	24 to 600 Mbps
Base station separation	Up to 80 km
Videos per display	Full screen, quad or 16

6 Case Study

6.1 Requirement

There is a requirement in a city in the Arabian Gulf for a broadband wireless CCTV system to supplement the roadside cameras planned for the city. A broadcast quality analogue system will be used for the roadside cameras because the highest possible video quality is required with no latency.

However the quality requirements of the broadband wireless network are less demanding. Their application is for shops and other commercial premises. In the event of a security problem or emergency, the police controllers will use the system to assess the situation, to make an initial appraisal of the resources needed and to monitor the effectiveness of the response.

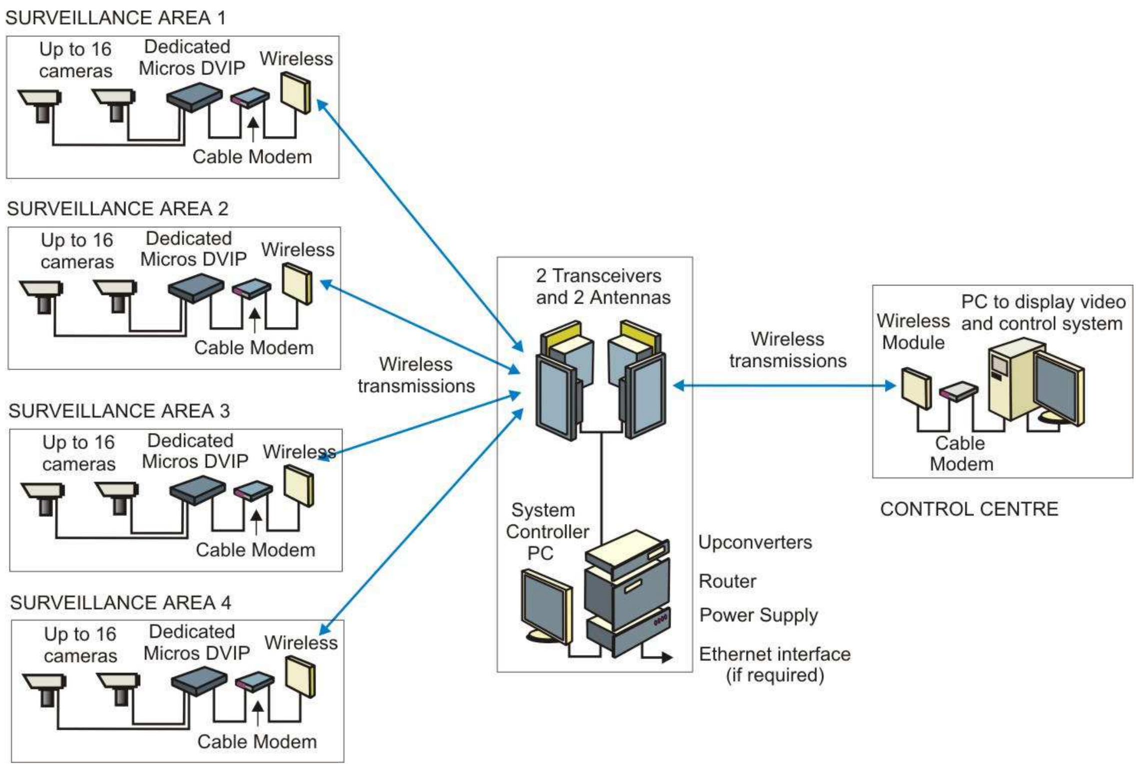
The use of the public, licence exempt bands was not acceptable because of fears regarding interference, whereas the broadband wireless system operating in the licensed 10 GHz band provided an ideal solution.

6.2 Installation

A mast in the centre of the city was identified as the ideal location for the Base Station. The control centre, located at the Police Headquarters is 5 km from the mast and the shops at which the cameras are to be installed are at ranges of up to 10 km.

The diagram below shows the general configuration of the system which is based on the use of Dedicated Micros DVIP units. There are several DVIP units in the network, one for each surveillance area. Up to 16 analogue cameras in each area (commercial building or terrace of shops) are hardwired to a DVIP unit which in turn is connected to a wireless transceiver through a standard cable modem.

The wireless units communicate with the Base Station and then to the Police Headquarters. In the simple illustration shown below, a single work station allows an operator to call up any camera in the network or any combination of cameras in the selected surveillance area using a split screen or montage form of presentation.



6.3 Configuration

The actual configuration of the system is illustrated in the diagram below. Sixteen DVIP units are used, each with up to 16 cameras. This gives an initial capacity of 256 cameras.

In addition, 10 PC terminals will be used throughout the city, each with 4 Mbps of data in the downstream and upstream directions. The initial assessment is that they will require access with a 10:1 contention ratio. Four work stations will be provided at the Police Headquarters.

6.4 Data Rates

The system is scalable. The basic configuration has just one line card in the Cisco router, leaving 3 blanks for future growth.

The capacity of this configuration is 40 Mbps in the downstream direction and 32 Mbps in the upstream. These are the usable rates (some 70% of the total) and exclude that used for error correction and other overheads.

The data rates actually required are indicated on the diagram. From this it can be seen that the network uses only 40% of the system capacity in the downstream and 44% in the upstream.

6.5 Growth Potential

If three additional line cards are inserted in the Router and the number of Transceivers is increased to match, then the capacity of the system can be quadrupled. In addition, further Transceivers can be installed together with another router to re-use the frequencies transmitted and received in opposite directions.

Taken together, this gives a total capacity of 320 Mbps in the downstream and 256 Mbps in the upstream.

Translating this into hardware, the capacity with the 4 work stations at the Police Headquarters is more than 20 times greater than that shown in the diagram, i.e. 40 DVIPs, each with 16 cameras and simultaneously, 200 other PC users at a 10:1 contention.

In reality the total capacity is even higher. Only 30 MHz of spectrum is necessary to run the system with 640 cameras and 200 PCs. In practice there is at least 3 to 5 times this spectrum available in the 10 GHz band, which means a capacity of 2,000 to 3,000 cameras.

Even this is not the limit because several base stations can be installed within a city. In London for example NTL, the largest cable company in the UK, installed 6 Base Stations over a 500 sq km area.