Introduction to Digital Microwave Radio Technology

1. Introduction to DMR

Point-to-point digital microwave radio (DMR), as the name implies, is a digital transmission technology that provides a wireless radio link operating at microwave frequencies between two points. A terminal at one end of the link communicates exclusively with a complementary terminal at the other end of the link. Each terminal is fitted to a parabolic dish antenna and communication is by line-of-sight beams between the dishes.

DMR is very flexible and does not depend on other elements such as satellite, cable, or optical fibre). Communication distances can be as short as a few meters (eg across the street between buildings in the city) or very long (up to 80km) in the country. To achieve line-of-sight, antennas and at least a portion of the terminal are typically mounted on rooftops, on hills or on towers. Links can also be daisy-chained to avoid major obstructions or to cover virtually endless communications distances.

DMR links can be used to carry a wide variety of traffic. In the telecommunications industry, they are used to carry data, voice, fax while in the broadcast industry they carry video and audio signals. In the wireless data communications market, DMR links carry Ethernet traffic between Local Area Network (LAN) sites. Other applications include security, telemetry, monitor and control and many other applications requiring transport of digitised information.

Radio spectrum usage and data transmission standards are subject to regulatory frameworks throughout the world, in the interests of efficient spectrum usage and interoperability. The European Telecommunications Standards Institute (ETSI) incorporates International Telecommunications Union (ITU) recommendations into the European regulatory framework, and these are followed in much of the rest of the world. The Federal Communications Commission (FCC) oversees radio spectrum usage in the US, where American National Standards Institute (ANSI) data standards are typically used.

For telecommunications, the traffic usually carried by DMR is structured in a hierarchy of data rates and formats known collectively as Plesiochronous Digital Hierarchy (PDH) according to standards set by the ITU and ANSI.

The microwave operating frequencies and the structure of the actual frequencies and bandwidths used are standardised by the ITU and FCC into operating bands. The frequency chosen for a particular link will depend upon many factors including the region (higher frequencies are attenuated by rain and cannot be used in tropical environments) and the service (there are more frequency allocations available at higher frequencies and they are used in areas of higher traffic density, such as cities).

The products offered by Codan have operating frequencies ranging from 7GHz to 38GHz with data interfaces allowing flexible combinations of PDH data streams and Ethernet traffic. The maximum aggregate data rate that can be carried is 52Mbs, depending on the data standards and spectrum licencing arrangements in the country of use.

A substantial driver for the development of the DMR industry in recent times has been deregulation of the telecommunications industry in many countries. Today, fixed and mobile network operators and even private users can establish their own networks throughout the world, with the right to provide the transmission infrastructure independently of the dominant carriers. DMR allows private voice and data networks and cellular networks to be established very quickly, efficiently and at substantially lower cost than cable systems.

As more countries deregulate their telecommunications infrastructure, as communications services are extended to more regions of the world, and as the demand for ever higher data rate capacities expands, the market for communications by digital microwave radio is expected to expand rapidly.

Let us now focus on the applications of digital microwave radio and its main users, while also trying to explain the reasons for an explosive growth in demand for such products.

What is DMR used for?

1.1. Cellular Applications

The greatest growth area for the use of digital microwave radio is currently associated with the emergence of new cellular mobile operators as part of a liberalized telecommunications environment. It is normal for newly licensed operators to be granted the rights to self-provide the transmission infrastructure.

It is also the trend that the terms of such competitive licenses commit the operators to challenging operational obligations, i.e. to provide service throughout a certain percentage of the country within an ambitious time frame. Furthermore, operators need to provide service at the earliest opportunity to realize revenues in line with their business plans.

Faced with this scenario, mobile operators are very conscious of the advantages of digital microwave radio. The speed of installation and flexibility to upgrade in line with network requirements has meant that almost all mobile operators who are independent from the PTT organizations and have the right to self-provide have chosen digital microwave radio as the interconnect solution for base stations.

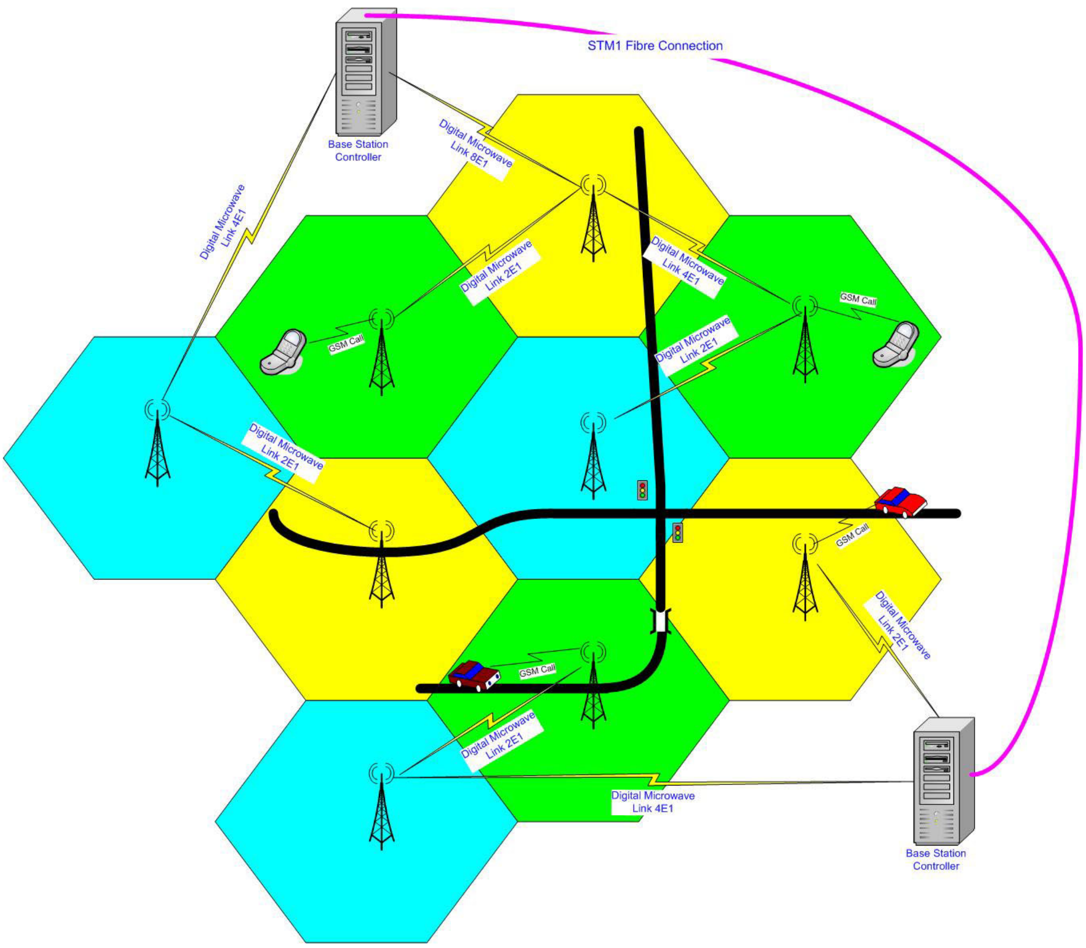

Figure 1 – GSM Application

1.2. PTT fixed network applications

Newly licensed competitive operators are not the only users of microwave radio, and a number of factors are leading to a growing demand from incumbent fixed network operators. With the growing liberalization in telecommunications, PTT's are now finding themselves operating in a more competitive environment. As a result, users are being offered greater quality of service and learning that they can demand more from service operators. Time scale for provision of service is a major differentiator for a PTT operator wishing to offer competitive services.

Because of the flexibility of microwave radio and the ease and speed of installation, these products are increasingly finding their way into PTT access or back-haul networks. Elsewhere, in many developing markets, operators who wish to provide international telephone and data services to customers are utilizing microwave direct from exchanges to the customer premises in order to bypass local networks that are often inadequate.

Utilizing microwave radio as an access medium direct to a customer's premises has been common for a number of years. However, a number of factors are leading to an increase in this application. New operators are being licensed who, unlike the entrenched PTT's, do not have established cable networks but do have a need to connect customers quickly. Likewise, microwave radio is commonly used within these networks in back-haul applications, i.e. connecting from a strategic distribution point within the network (such as a business park) back into the switched network. **Figure 2** illustrates a few of these applications.

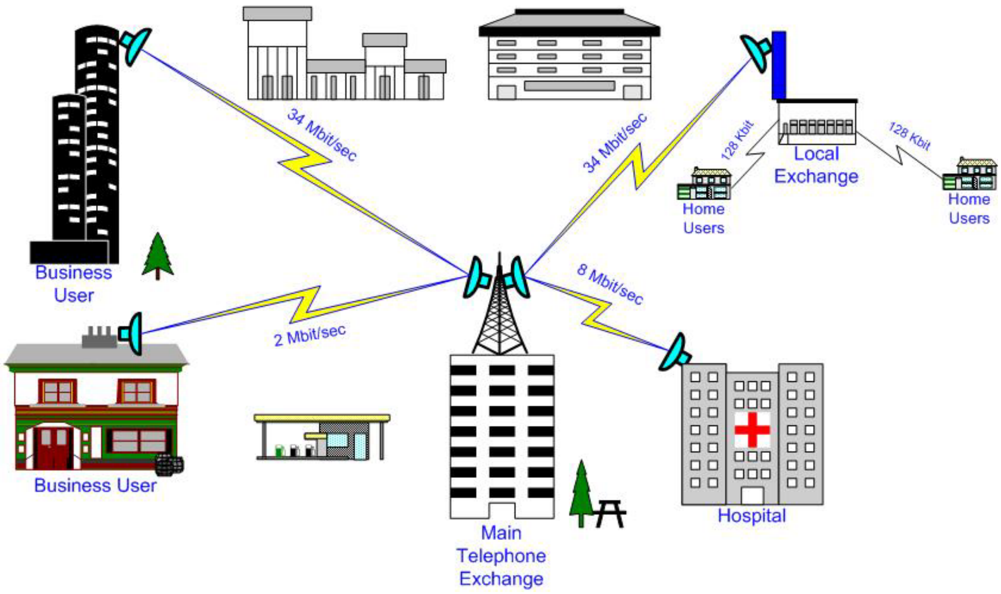

Figure 2 – PTT Fixed Network

1.3. Private network applications

In certain parts of the world, utility and government organizations have long had discretionary rights to build their own networks, and have historically been users of microwave radio. With growing liberalization, many other private users are recognizing the benefits of digital microwave radio. The applications in this arena are quite varied, ranging from the users who wish to interconnect a network of PBXs in multiple locations throughout a region, to the smaller users who simply wish to interconnect two LANs in two different buildings within a single site.

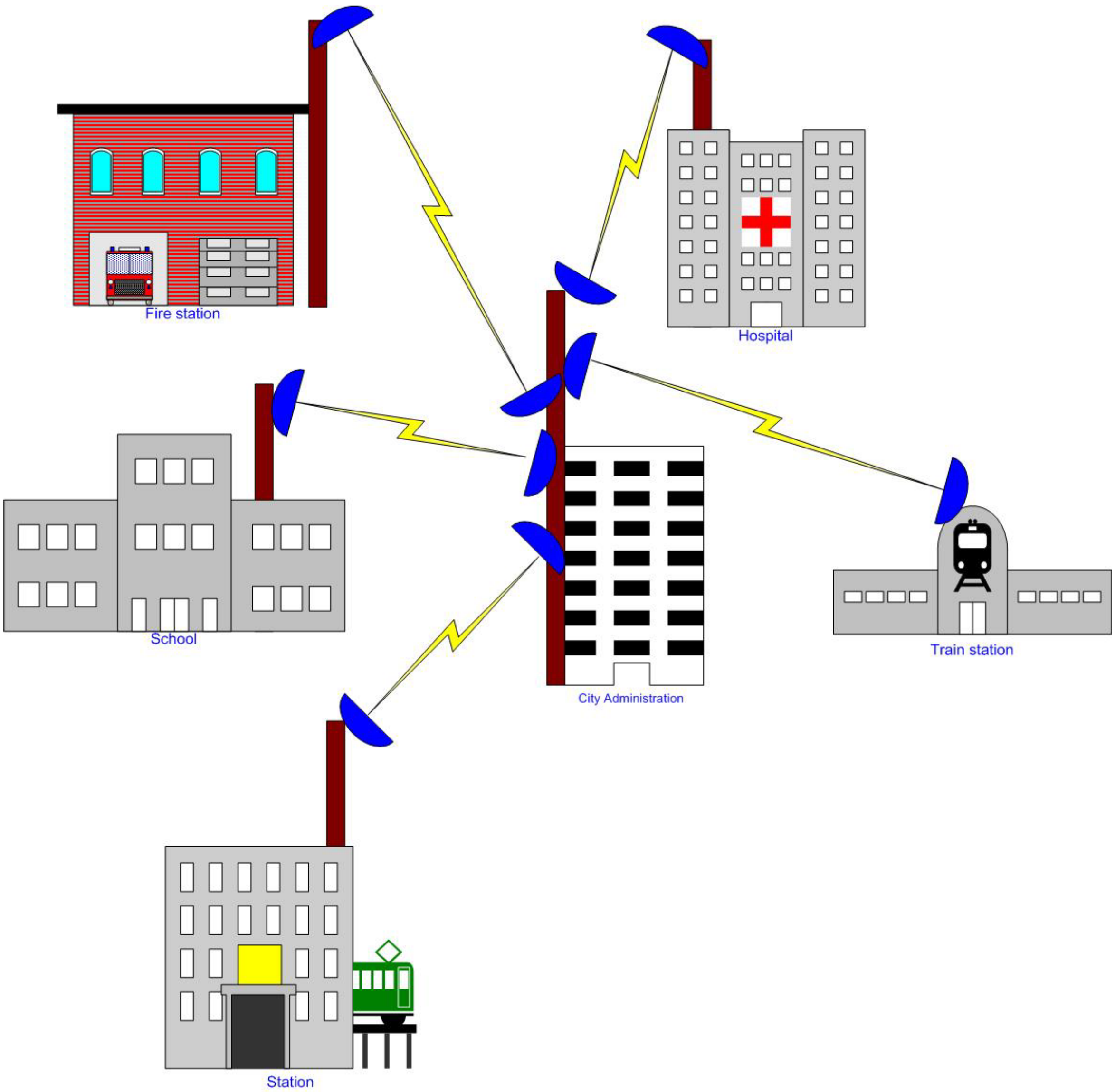

Figure 3 – City Administration Private Network

2. Benefits to Fixed Wire, GSM, CDMA, WLL and PTT operators

The above network applications have mentioned many reasons why a network operator, given the right to self-provide transmission infrastructure, should choose microwave radio as opposed to utilizing leased lines or implementing their own cable based systems. In summary, the advantages of microwave radio systems are as follows.

- **Economical compared to fibre or leased lines** - Significant whole-life cost savings can be achieved by building self-provided networks as opposed to leasing services from the local PTT
- **Ownership** - A self-provided transmission network remains under the control and ownership of the end user, which removes a dependency upon the incumbent PTT (often a competitor) and provides operational benefits
- **Flexibility** - Modern microwave radio architecture has been designed to provide a high degree of flexibility in terms of distance and traffic capacity, enabling links to be designed to precisely fit operator requirements and local conditions. Link capacities can also be field upgraded to cater to a network's growing traffic requirements as subscriber numbers increase
- **Reliability** - Self-provided networks can be planned to provide a higher quality of service than often guaranteed by the PTT. Radio based solutions can be engineered to provide availability at least equivalent to cable based systems when viewed over many years, during which it is possible that a cable will be dug up or severed several times.
- **Right of way not required** - Laying cable requires time-consuming and potentially costly rights of way to cross third-party property. Microwave radio avoids this problem by utilizing the air that is a free resource.
- **Speed of Installation** - A microwave link can, in the majority of circumstances, be installed and commissioned in a much shorter period of time than cable based alternatives, because a microwave link does not require the same degree of civil works associated with laying cables
- **Ability for re-deployment** - Microwave radio links can be easily removed and re-deployed to another geographical area, without leaving valuable assets in the ground
- **Availability** - Microwave radio is commercially available and can be supplied in extremely short time scales
- **Gives a competitive edge** - Finally, microwave radio gives a new operator the ability to minimize time to market, hence maximizing revenue.

Microwave radio provides a clear, cost-effective and feasible solution against leased lines or self-provided cable-based alternatives.

3. Microwave radio configurations

Microwave radio systems can be found in various configuration types, including:

- **Indoor rack mounted**. In this configuration, the radio terminal consists of an indoor-mounted baseband shelf and RF transceiver, with a parabolic antenna connected to the indoor equipment via wave-guide.
  This configuration provides the advantages of:
  - Lightening protection – no electronic equipment on the tower
  - Ease of maintenance – no need to climb the tower

  The main disadvantage is that you need to use expensive waveguide to connect the RF equipment to the antenna. These configurations are often deployed in extremely cold areas where ice forming on the tower prevents maintenance access. Installations in corrosive atmosphere situations like certain mining sites where outdoor mounted equipment may be damaged by the highly acidic emissions also use indoor mounted equipment.
- **Split mount**. In this configuration, the radio terminal consists of an indoor-mounted baseband shelf, an outdoor-mounted RF transceiver, and a parabolic antenna. The indoor unit provides the interfaces to other equipment, and is separated from the RF transceiver via standard coaxial cable by typically up to 300 meters.

  This is by far the most common type of configuration for PDH microwave link installations. The main advantage of this type of configuration is the ease and cost of the installation through the use of a single coaxial cable to connect the indoor and outdoor equipment.

The RF transceiver, when mounted outdoors, can be mounted directly behind the parabolic antenna, or the RF unit can be mounted remotely from the antenna. Systems are available in either non-protected (1+0) or protected (1+1) configurations.

A protected terminal provides full duplication of active elements in a terminal (i.e. both the RF transceiver and the baseband components), in a "hot standby" mode to protect the user against equipment failure. Automatic switching to the standby system during periods of equipment failure allow the operator to deliver the required service to their customers without any down time.

Space diversity (2 antenna) is a variation on the hot standby configuration that provide protection against reflections from the ground and other similar propagation anomalies. The theory behind this type of configuration is that when the microwave path causes a problem with one antenna, statistically speaking, the other one is able to operate without being affected by the problem. The advanced space diversity switching algorithm used in the Codan 8800 series optomises link performance under difficult conditions by selecting the best path on a frame-by-frame basis.

4. Equipment considerations

When selecting appropriate radio equipment for deployment within a Telecommunication Network, the following characteristics/ specifications are among those that should be considered:

- **Radio performance** - A modern radio design will incorporate one or more facilities to counter the adverse effects of the radio wave propagation through the atmosphere, generally seen as fading, or reduction, of the received signal. Fading countermeasures include interference rejection capability, forward error correction (FEC), and Automatic Transmit Power Control (ATPC) and space diversity arrangements.

  All these features are supported by the Codan 8800 series. Additionally, the Codan 8800 uses Continuous Phase Modulation (CPM), which is inherently robust in the presence of propagation impairments.

- **High spectral efficiency** - An efficient modulation scheme to minimize channel bandwidth is a great benefit when planning the radio network, and is some times a prerequisite of the regulatory authority.

  The Codan 8800 series uses 4-state CPM, which provides the spectral efficiency required in most countries.

- **High system gain** - This is a function of the radio output power and received signal threshold.

  The Codan 8800 series compares favourably with most competing products.

- **Low background BER** - This is a measure of the performance (bit error rate) of the radio equipment in the absence of interference induced by propagation anomalies, and should ideally be less than 10^{-12}.

  The Codan 8800 is specified as to perform with a Background BER of 10^{-15}.

- **High environmental specification** - Essential for reliable operation in harsh environments when equipment is located externally. Equipment must have a minimum operational temperature range of –30 °C to +55 °C for outdoor equipment. Other important factors are ingress protection against water and dust or sand, and corrosion resistance.

  The Codan 8800 is specified from –33 °C to +55 °C.

- **Equipment reliability and maintainability** - Important in ensuring a low life-cycle cost is the ability of the equipment to operate for long periods without failure (high mean time between failures, or MTBF). Equally, when failures occur they must be easily and rapidly repaired (low mean time to repair, or MTTR). This will be facilitated by spares commonality across a range of capacities and frequency ranges. An operator must also determine which links require protection, based upon the criticality of each link and the existence of alternative traffic routing in the case of failure.

  The Codan 8800 series MTBF is expected to be in excess of 30 years. The mean time to repair a Codan 8800 series link by a trained field service engineer is less than 1 hour.

5. Network design process

To reach the stage where a microwave radio link can be deployed and brought into service, several steps must be successfully completed, often in an iterative process, leading to a final link design. These steps are briefly:

- Determine design objectives, that is:
  - Availability target for network
  - Availability target for radio path
  - Required capacity (current and future)
  - Maintainability, i.e. protected or non- protected
- Determine and produce network design. A network design is required to establish all of the nodes within the network that require transmission links between them. This can then be developed to become the main reference document for network planning and implementation
- Determine local frequency availability and regulatory restrictions.
- Select and survey sites
- Establish existence of line-of-sight
- Detailed network design - frequency planning.

5.1. Network Topologies

Figure 4, **Figure 5** and **Figure 6** depict three common configurations that are adopted for the transmission system of a GSM Network.

5.1.1. Star network

A star network topology will contain one or more hub sites at strategic locations that serve spurs or chains of subordinate sites from the centralized hub. A star network can be multilayered in that some of the nodes in a spur may be hub sites for further subordinate spurs.

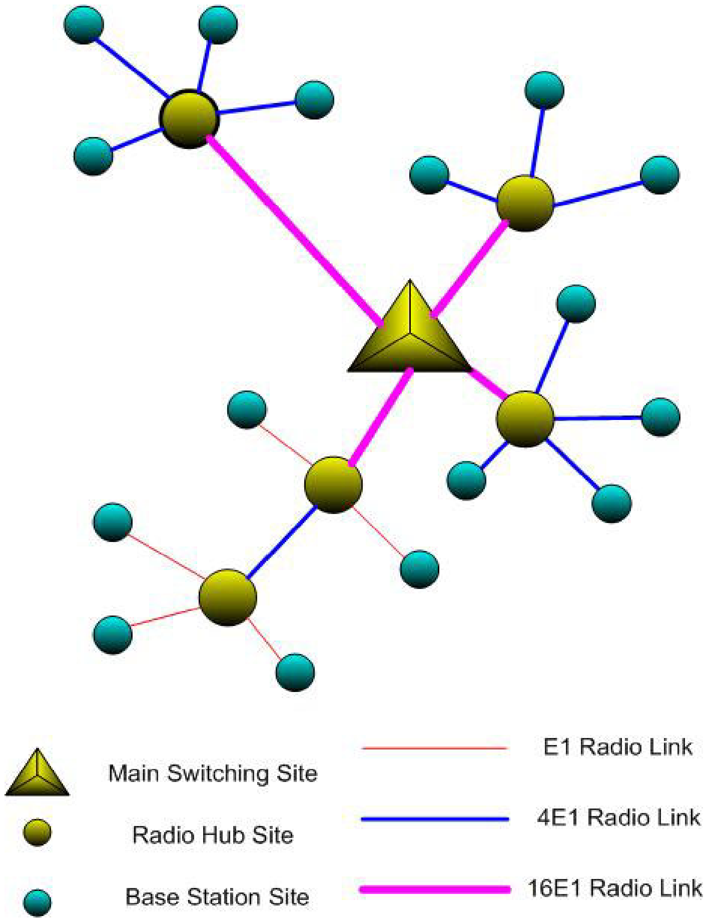

Figure 4 – Star Network

Star networks have one major disadvantage in that outages on a single transmission link may affect many sites and have a significant effect on overall network availability. This can be reduced or alleviated by protecting some or all of the links with Hot Standby installations.

5.1.2. *Ring network*

Ring structures can be successfully achieved in PDH networks if the necessary routing and grooming intelligence exists at all appropriate equipment that is connected to the DMR links in the network.

The capacity of all of the links in a ring has to be sufficient to support all sites in the loop, so that some links have increased capacity over the equivalent star structure.

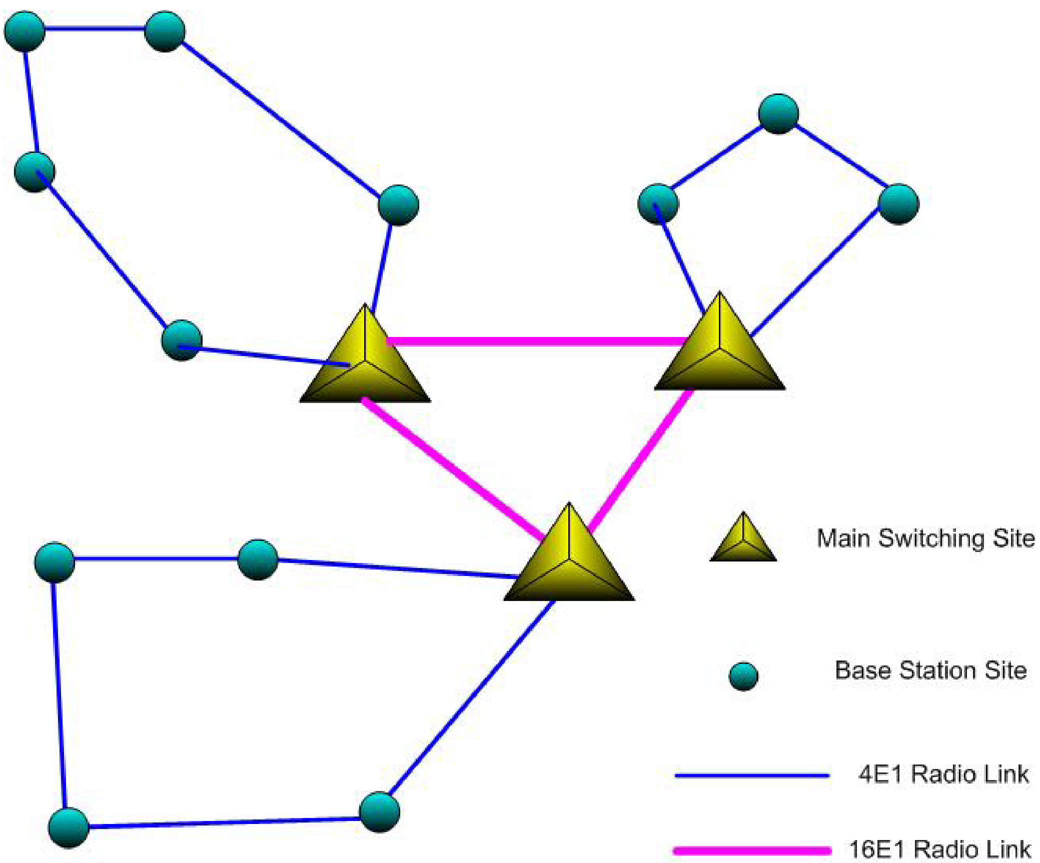

Figure 5 – Ring Network

The advantage provided by this topology is that the rings can be used to provide path diversity and integrity to the network, and can remove the need for duplication (i.e. protection) of single links.

6. Regulatory Considerations

Frequency spectrum is a valuable resource and is generally subject to appropriate planning and management to prevent misuse and interference between the many and varied applications. National administrations will allocate some or all these bands for fixed microwave radio use in line with local requirements. Before network planning commences, an operator must determine available frequency bands and channel plans specific to that country. Often, and preferably, an operator may be able to obtain a number of frequency allocations as a block for nation wide use thus enabling him to perform his own network planning in advance without risk of interference from other users.

Most regulatory authorities also operate a local link length policy, where the length of a particular path will determine what frequency bands are available for the operator to choose from. Typically, the shorter the path the higher the frequency required.

The local requirement for equipment type approval will also vary from country to country, ranging from a simple paperwork exercise to a full product test program to local standards. Type approval is generally the responsibility of the radio supplier, but an operator should ensure that all requirements are satisfied before links are deployed.

Other limitations imposed by authorities can also have an impact upon microwave radio deployment - for example, tower height restrictions or limitations upon antenna size. These factors can restrict effective radio lengths at the planning stage and should be ascertained in advance of the detailed link design stage.

6.1. Site selection and survey

Selection of a suitable microwave radio site must encompass a number of issues. There are economical and engineering benefits to be gained by maximizing the sharing of infrastructure and sites between the various types of elements in the network, particularly regarding expensive civil infrastructure such as towers and equipment housings. It is becoming more common for competing operators to share the expensive and common portion of site construction like towers, shelters and mains power connection.

The location of good microwave sight, particularly in relation to hub sites, will be relatively high points to provide the maximum line of site availability. This information should be fed back into the network plan as it can affect both routing and path planning.

Attention should be given to future growth requirements in all areas, especially if the site is likely to develop into a future hub. It is always wise to inform the landowner of any potential future growth to prevent problems at a later date.

Attention should be paid to any local authority planning restrictions and approvals for structures or antenna installations planned. Such restrictions could be found to eliminate a site at a very late stage of the process and cause much wasted effort.

An operator should aim to perform only one site survey to minimize costs. Equipment installation requirements must be confirmed considering amongst other things, power, accommodation, and environmental conditions. The ease of service access for maintenance personnel, particularly tower mounted equipment can have significant impact on costs and repair time. Required loading needs to be calculated if new tower installations are proposed, and these must take into account the antenna wind and ice loading.

New terminals being added to an existing tower require calculations that ensure incremental loading can be accommodated. Cable and/or waveguide routing should be checked, including length and securing.

6.2. Frequency bands

The International Telecommunication Union (ITU) ITU-R organization defines a number of specific frequency bands that are allocated to fixed services - i.e. for microwave point-to-point links. **Table 1** shows the ITU-R bands covered the Codan 8800 series, and outlines the usage for digital telecommunications purposes.

Table 1: Common Fixed Microwave Link Frequency Bands

Band GHz	Range GHz	Distances*	Comments
7/8	7.1-8.5	50 km	Med. to High capacity
10.5	10.5-10.68	45 km	Low capacity, efficient modulation
13	12.75-13.25	40 km	Low to medium capacity
15	14.4-15.35	40 km	Low to medium capacity
18	17.7-19.7	25 km	Low to medium capacity
23	21.2-23.6	14 km	Low to medium capacity
38	37-39.5	8 km	Low to medium capacity
* Depending on antenna size, terrain, and rainfall, distances shown are typically the maximum for the given frequency.			

Different frequency bands are subject to differing propagation criteria, which results in attenuation in the link received signal. As a general rule, the higher the frequency band, the shorter the usable distance of the link.

In the extreme case, use of frequency bands above 20 GHz in tropical areas will limit path length to just a few kilometres.

Frequency management organizations will also make most effective use of frequency spectrum by imposing a link length policy; i.e. shorter links will be licensed only in the higher frequency bands and vice-versa.

6.3. Confirmation of line of sight

A clear transmission path must exist between the two link nodes of any microwave radio link. Furthermore, as the radio wave disperses as it moves away from the source, there must exist additional clearance over any obstructions to prevent attenuation of the transmitted signal. This additional clearance, known as the Fresnel zone, differs for the frequency band of the radio path, where higher frequency translates into a smaller clearance requirement.

See **Figure 7** below.

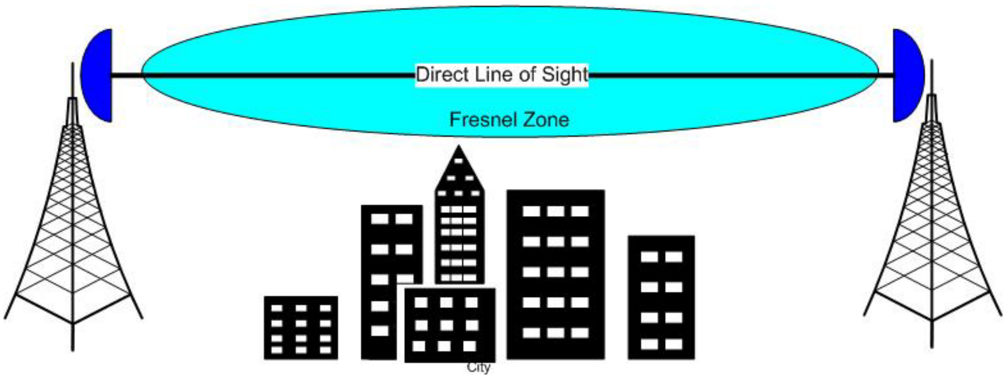

Figure 7 – Line of Sight

Line of sight between two sites can be confirmed by either map-based studies or direct visual survey. In either event, the surveyor must allow for future obstructions that may impinge the radio path. These can be due to various causes, such as new buildings, tree growth, cranes, etc.

6.4. Frequency planning

Frequency planning is the coordination of link frequencies to minimize any interference between links within the network and those operated by other users. In some instances, the local regulatory authority undertakes frequency planning. However, if a block allocation has been obtained, then planning will be the responsibility of the operator. Several factors must be considered that will affect the calculations of interference that will determine the optimum channel frequency for each radio link.

There are a number of equipment performance parameters that become relevant when considering interference within a microwave network. These include:

- Path availability target considerations, since higher availabilities will require higher levels of protection from interference and hence increase planning difficulties. The level of availability must be considered in conjunction with the network plan and the physical position of the link. Availability targets can be relaxed for the lower capacity outer links where short outages may not cause disruption to subscriber services, due to overlapping coverage from adjacent cells, or the availability of diverse routing
- Radiated transmit power (EIRP)
- Link operating frequencies
- The channel plan
- The Carrier to Interference (C/I) performance of the equipment which determines how well the radio equipment can discriminate the wanted signal in the presence of interference
- Antenna characteristics, such as radiation pattern envelope (RPE), gain and front-to- back ratio.

7. Summary

There are numerous economic and operational benefits in utilizing digital microwave radio in a transmission network. Radio presents an attractive alternative to both PTT-provided leased lines or self-provided cable based systems, and major operational advantages accrue from the fact that, being a wireless technology, microwave radio can be installed, commissioned and re-deployed easily and quickly.

For a new telecommunications operator in an existing or emerging competitive environment, these advantages can provide the crucial edge for success, and enable the operator to establish an operational network in a matter of months, thereby providing early revenue for re- investment and return to shareholders and other investors.

Many operators are now recognizing these benefits, and we are seeing significant growth in demand emerging, specifically from newly licensed cellular operators, as well as competitively licensed fixed network operators and even the incumbent PTT’s who have to operate in the new competitive environment.

PDH digital microwave radio's place as a key network element is well established and has a bright future.